Big O Notation

Time complexity of an algorithm

"How much time it takes to run a function as the size of the input grows."

{ Runtime

```
Const array1 = [ , , , , ]
```

array

number of elements n = 5

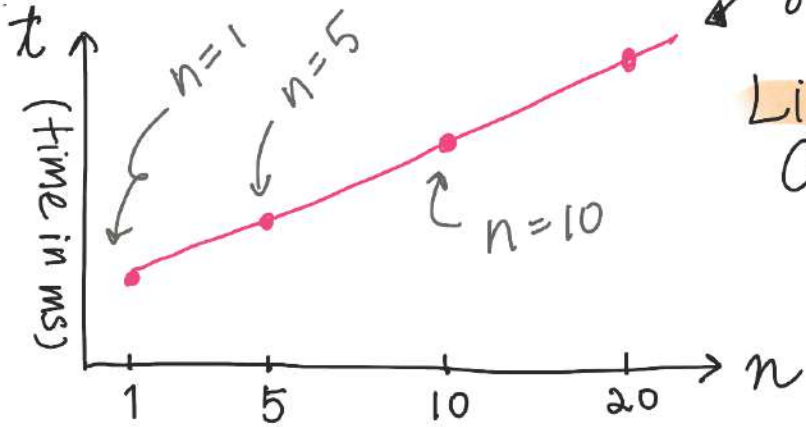
Let's see if there is a needle in the haystack!

JS

```
Const numNeedles = (haystack, needle) => {
  let count = 0
  for (let i = 0; haystack.length ; i++) {
    if (haystack[i] === needle) count += 1;
  }
  return count;
}
```

How long does it take to execute when the number of elements (n) is:

- execution time grows linearly as array size increases!



this is Linear time Complexity

||

O(n)

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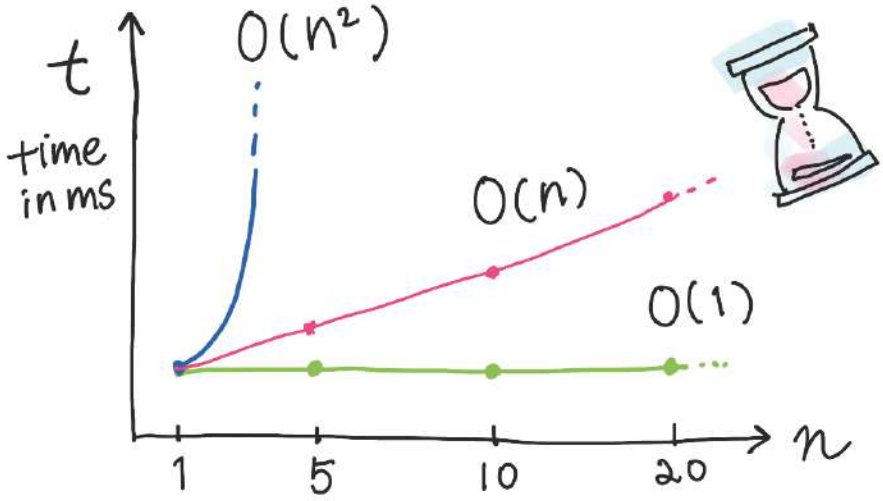
Big O Notation

Let's see if we have some function that doesn't actually loop the array:

```
const alwaysTrueNoMatterWhat = (haystack) => {
  return true;
```

n=5
n=10
n=20
⋮

Array size has no effect on the runtime



☆ Constant time
=
O(1)

☆ Quadratic time = $O(n^2)$

n=5, however the runtime is proportional to n^2

Const array2 = [🐱, 🌸, 💩, 💩, 🥕];

```
Const hasDuplicates = (arr) => {
  for (let i = 0; i < arr.length; i++) {
    let item = arr[i];
    if(arr.slice(i+1).indexOf(item) !== -1) {
      return true;
    }
  }
  return false;
}
```

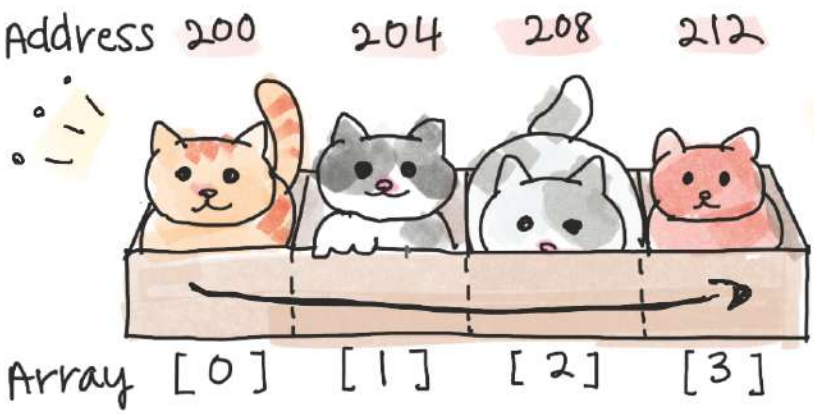
① Loop thru the array

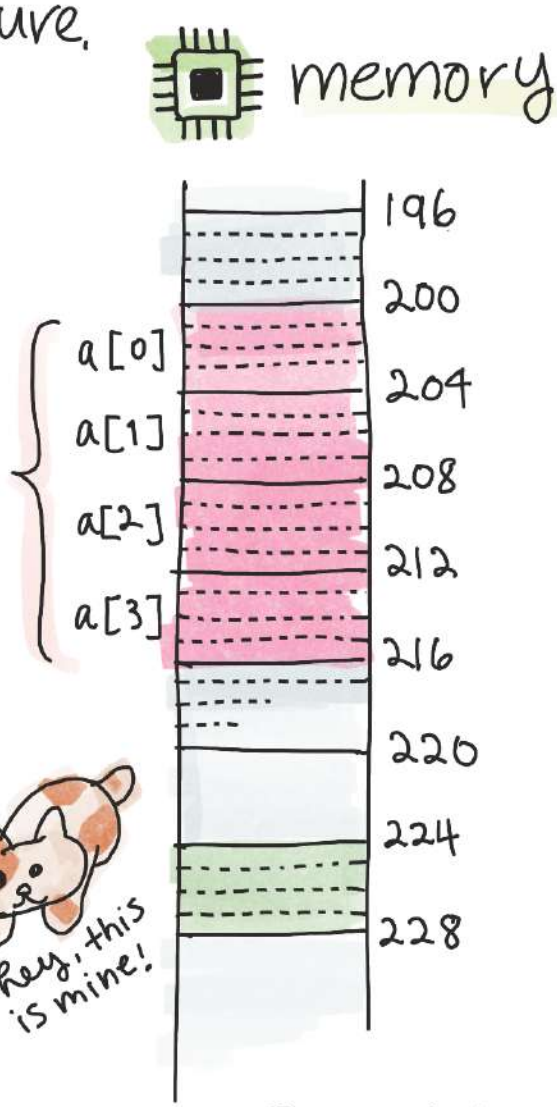
② Another array lookup w/ indexOf method

Data Structures

Array & Linked List

Array a linear data structure, stored in contiguous memory locations.





- Assume each 🐱 is an integer = requires 4 bytes space
- The array of 🐱 must be allocated contiguously!
  → address 200 — 216

yay!

- can randomly access w/ index
  a[2] → 
- contiguous = no extra memory allocated = no memory overflow

meh!

- fixed size. Large space may not be avail for big array
  = 🐱 took the space! =
- Insert + delete elements are costly.
  → may need to create a new copy of the array + allocate at a new adress.

Data Structures

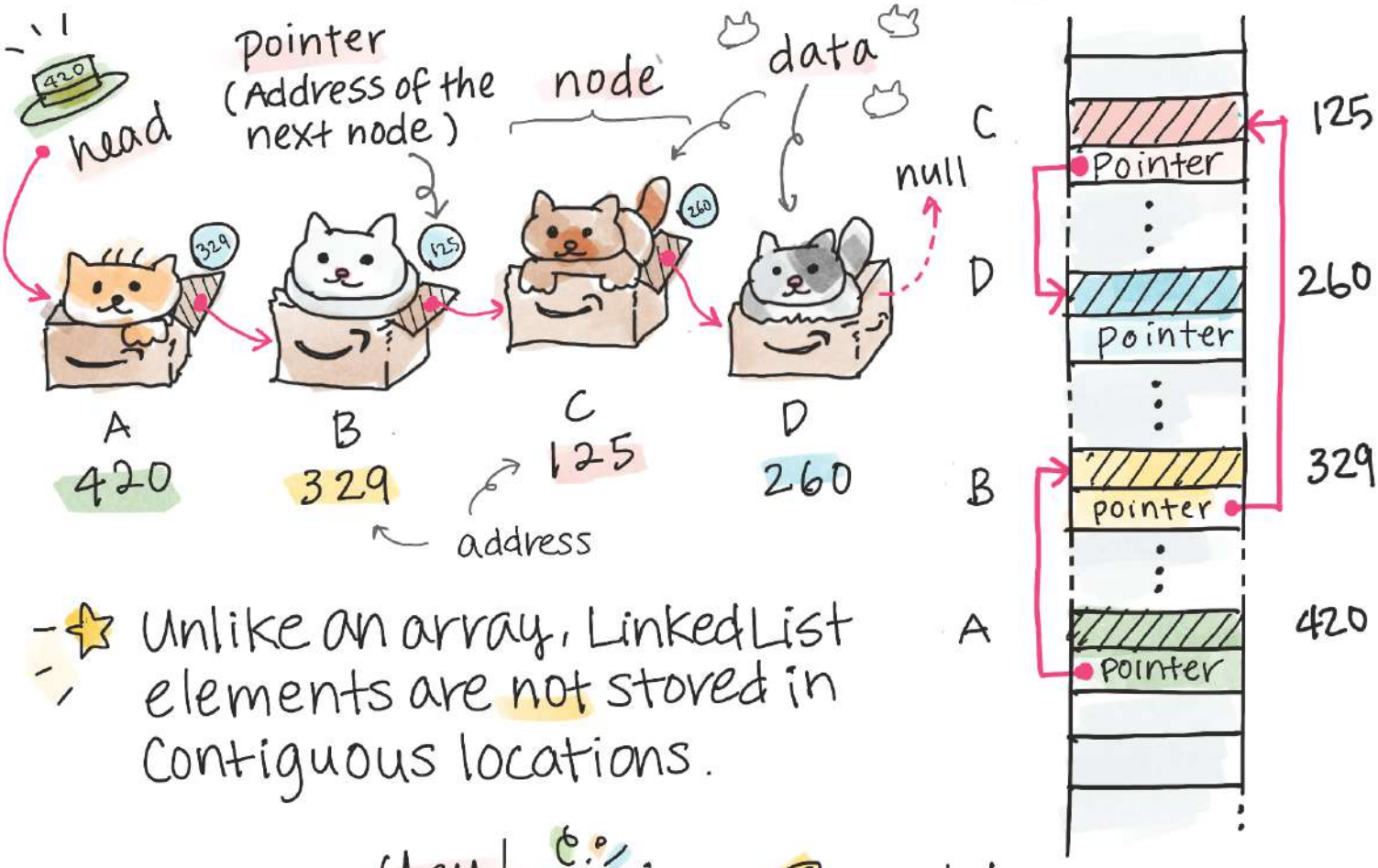
Linked list

Array & Linked List

: ★ a linear data structure

: ★ each element is a separated object & elements are linked w/ pointers

memory



- ★ Unlike an array, LinkedList elements are not stored in contiguous locations.

yay!

- ♥ Dynamic data
  = size can grow or shrink
- ♥ Insert & delete element are flexible.
  → no need to shift nodes like array insertion
- ♥ memory is allocated at runtime

meh!

- ☠ No random access memory.
  → Need to traverse n times
  → time complexity is O(n). array is O(1)
- ☠ Reverse traverse is hard

Data Structures

Stack & Queue

LIFO

FIFO

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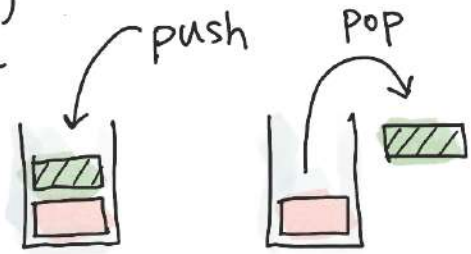
A stack is a LIFO (Last-in-First-out) data structure, where an element added last (=push) gets removed first (=pop)



just like a stack of ice cream scoops!

omg, the bottom one is always melting !!

Stack as an array in JS

arrays in JavaScript are dynamic!

```
let stack = [ ];                          stack is:
stack.push('mint choc');                  // ['mint choc']
stack.push('vanilla');                    // ['mint choc', 'vanilla']
stack.push('strawberry');                 // ['mint choc', 'vanilla',
                                                'strawberry']
let eaten = stack.pop();                  // eaten is
                                                'strawberry'
                                          ['mint choc', 'vanilla']
```

Time complexity is O(1) for both pop + push.

Data Structures

Stack & Queue

LIFO

FIFO

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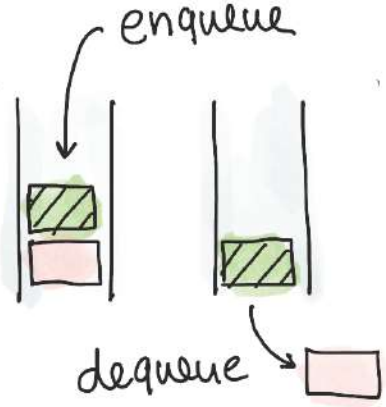
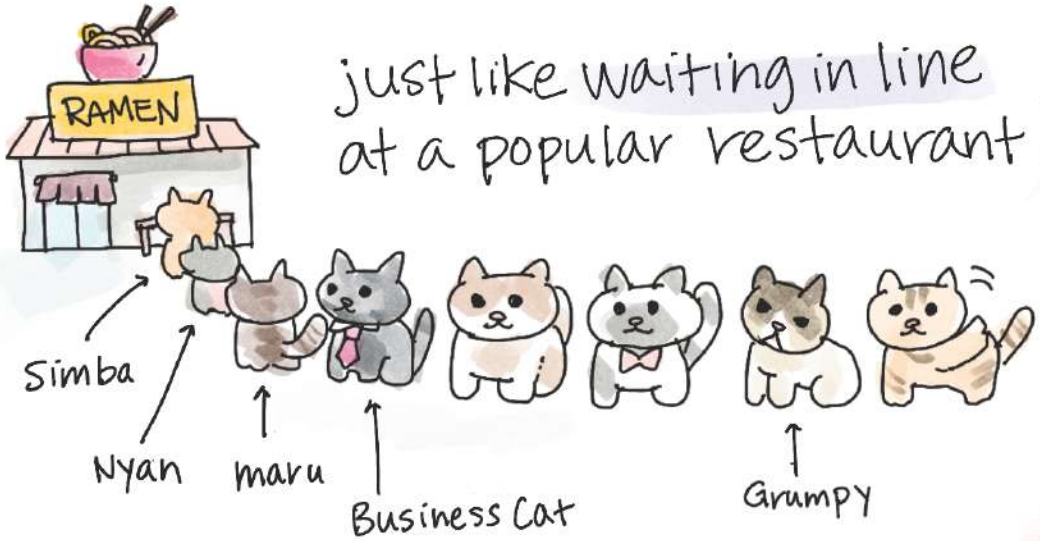
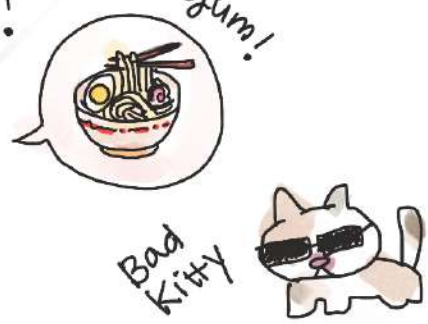
A queue is a FIFO (First-in-First-out) data structure, where an element added first (= enqueue) gets removed first (= dequeue)







Stack as an array in JS

if you queue.unshift ('bad kitty'), instead of push(), then the cat cuts in to the front of line!

```
let queue = [ ];
queue.push('Simba');  // ['simba']
queue.push('Nyan');   // ['simba', 'nyan']
queue.push('maru');   // ['simba', 'nyan', 'maru']
let eater = queue.shift(); // eater is 'Simba'
```

queue is:

queue is ['nyan', 'maru']

Time complexity should be O(1) for both enqueue & dequeue but JS shift() is slower!

Data Structures # Hash Table

- A hash table is used to index large amount of data
- Quick key-value look up. O(1) on average
  - ↳ Faster than brute-force linear search

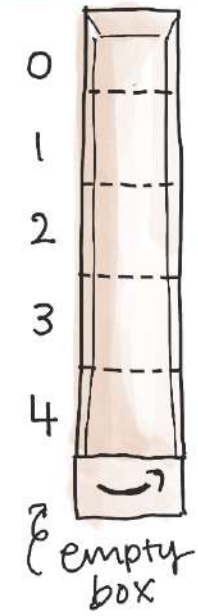
① Let's create an array of size 5.

We're going to add  data.

key = "Tabby"

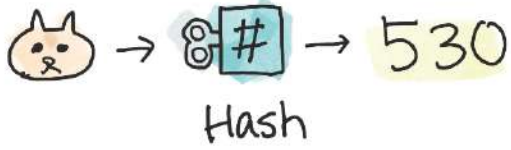
value = "pizza"

↑ some data
Let's say, favorite food!

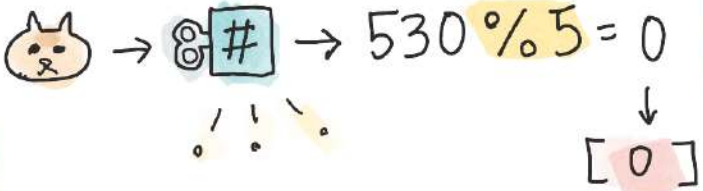


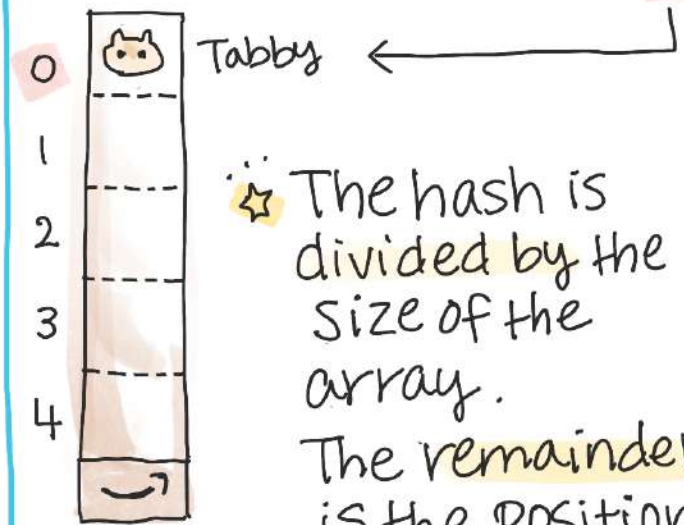
② Calculate the hash value by using the key, "Tabby".

e.g. ASCII code, MD5, SHA1



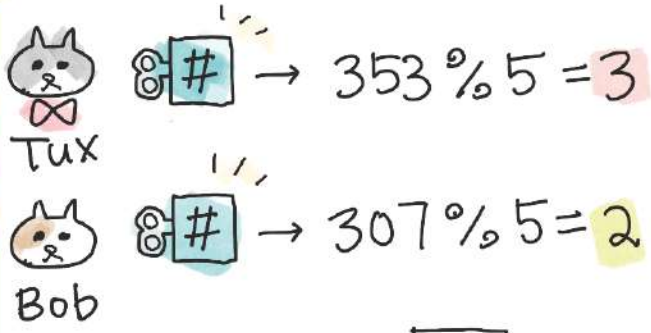
③ Use modulo to pick a position in the array!



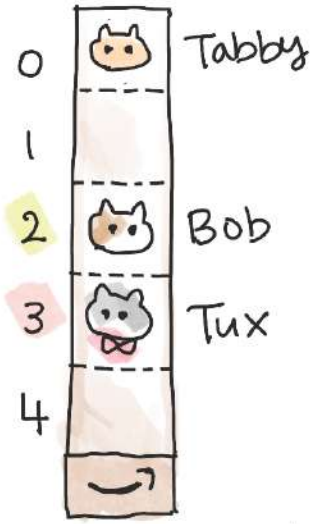


☆ The hash is divided by the size of the array. The remainder is the position!

④ Let's add more data.



Use the same method to add more 



Hash Table

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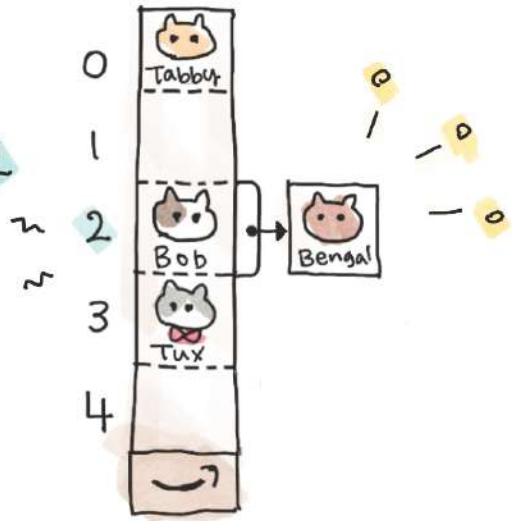
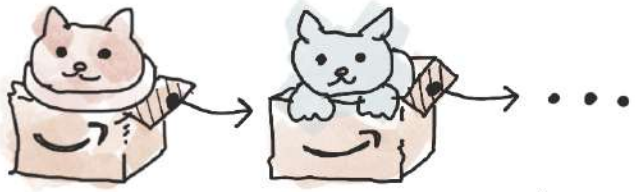
Collision!

Now we want to add more data.
Let's add "Bengal".

"Bengal" → # → 617 % 5 = 2

But [2] slot has been taken by "Bob" already! = collision!
so let's chain Bengal next to Bob! = chaining



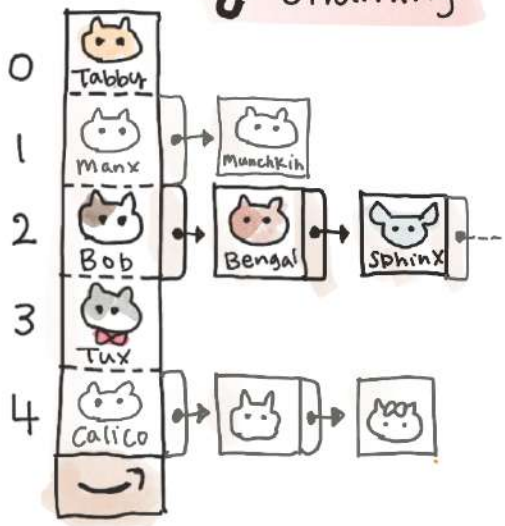


key: "Bengal"
value: "Dosa"

"Sphinx"
"Fish + Chips"

keep adding data

chaining



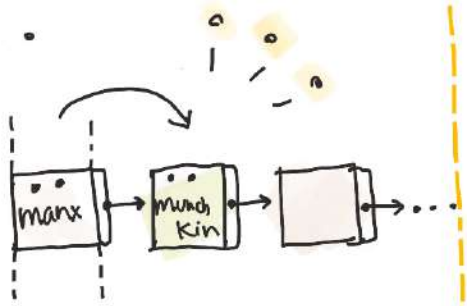
searching for data

Let's look up the value for "Bob"

① Get the hash → 307 ← O(1)
② Get the index → 307 % 5 = 2
③ Look up Array [2] → found!

Let's look up "munchkin"

① Hash → 861
② Index → 861 % 5 = 1
③ Array [1] → "manx"
④ Operate a linear-search to find "munchkin"
↳ Average O(n)



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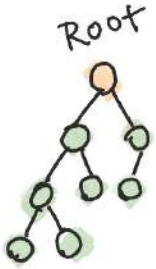
Data Structures Binary Heap



Binary tree

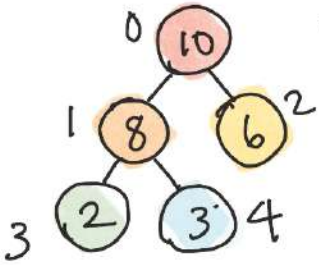
- tree data structure
- each node has at most 2 children

→ Binary search tree

→ Binary heap

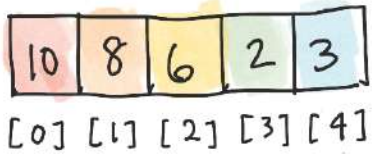
- Complete tree
- Min heap or max heap
- used for priority queue heap sort etc.

☆ Max heap

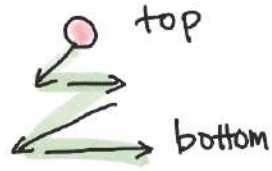


← the root has the largest (min heap is the opposite!)

in array →

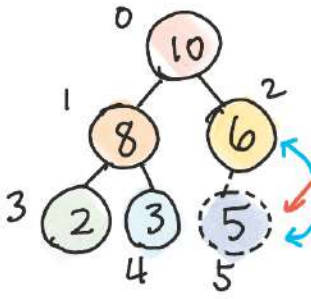


- each node has 0 – 2 children
- always fill top → bottom, left → right



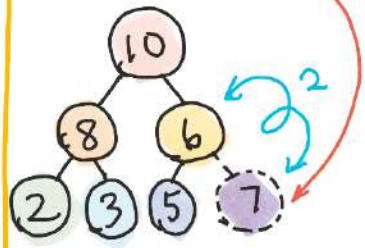
☆ Insertion

Let's add 5 to the heap!



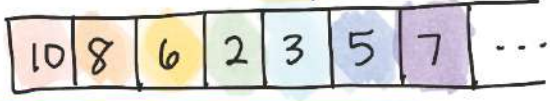
1. add to the next node.
2. Compare w/ its parent
3. the parent is greater. Cool, it's done! Let's add more!

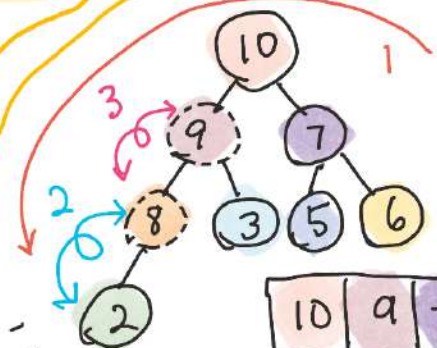
Add 7



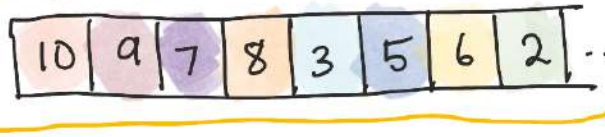
1. Add to the next node
2. Compare w/ parent.

Oh, no! the parent is smaller than its child! Swap them!!!





Add to the next node & repeat the process!



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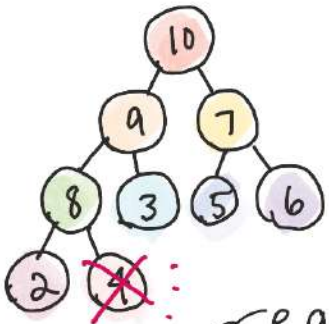
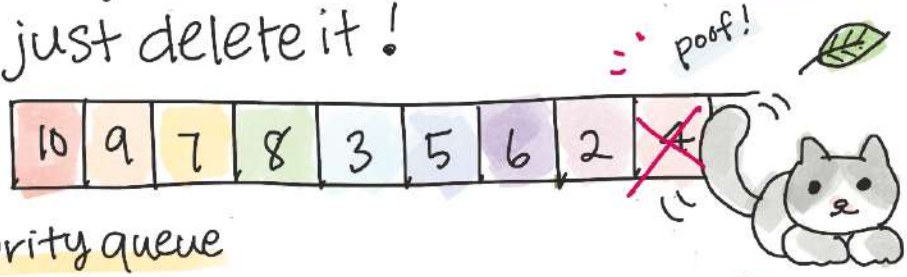
Data Structures Binary Heap

Heap Deletion

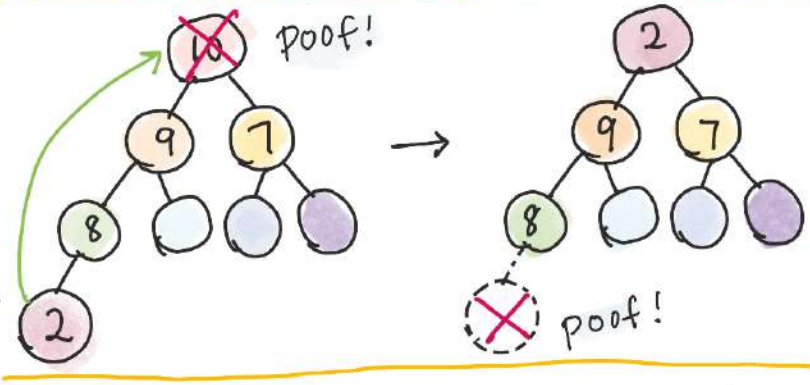


If you want to delete the last leaf, just delete it!

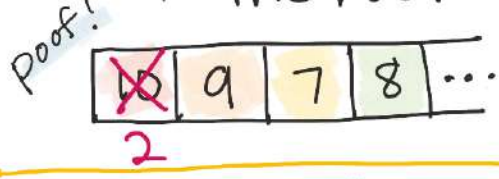


e.g. priority queue

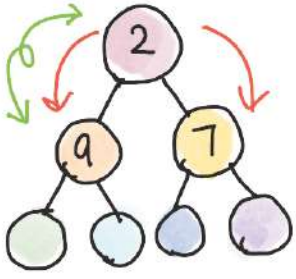
But typically, you would delete root + heapify!

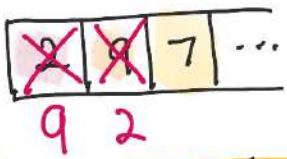


1. Remove the root
2. Move the last leaf to the root

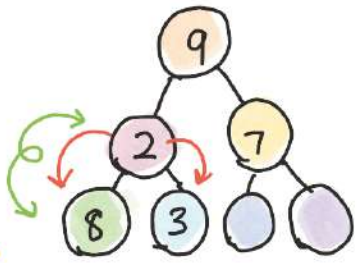


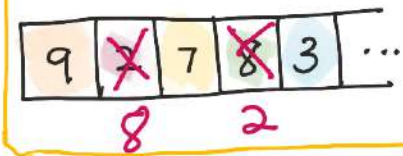
Now, let's place them in the correct order!



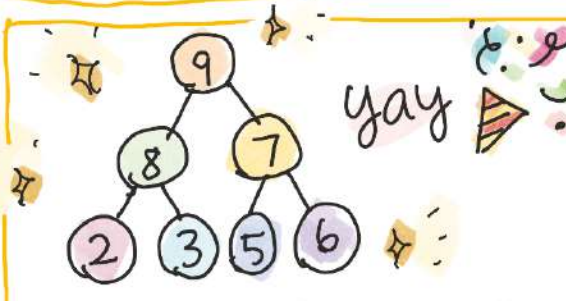


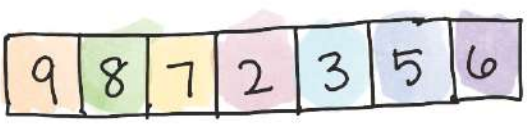
If either child is larger than the root, swap it with the larger child.





Repeat. Compare w/ the children + swap w/ the larger child





Time Complexity

	Average	Worst
• Insert	O(1)	O(log n)
• Delete	O(log n)	O(log n)

Data Structures

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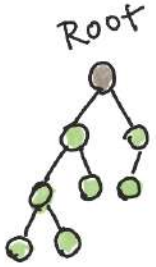
BST

Binary Search Tree



Binary tree

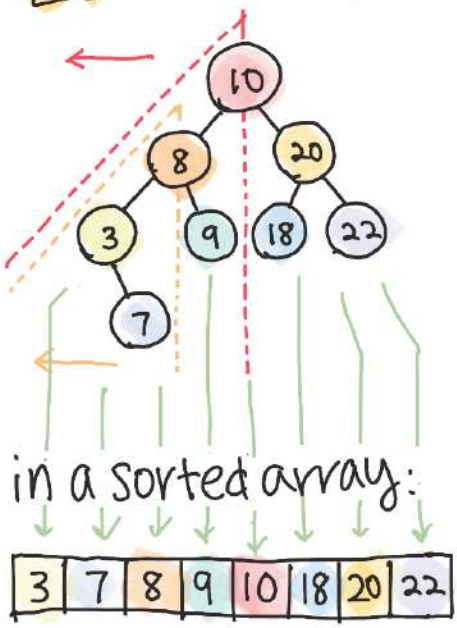
- tree data structure
- each node has at most 2 children

→ Binary heap

→ Binary Search Tree

- a.k.a. ordered or sorted binary tree
- fast look up
  e.g. phone number lookup table by name

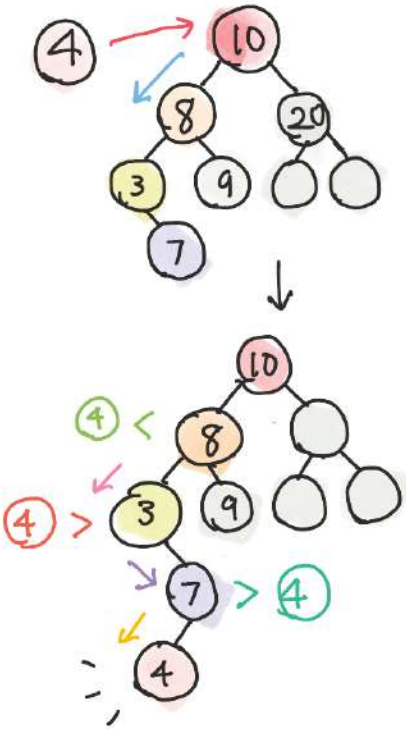
Rule of thumb



in a sorted array:

- ★ each value of all nodes in the left subtrees is lesser
  - △ (10)'s left subtrees : 8, 3, 9, 7
  - △ (8) : 3, 7 ← smaller than parent
- ★ each value of all nodes in the right subtrees is larger
- ★ no duplicate values

Insertion → Always add to the lowest spot to be a leaf 🍃 No rearrange!



Let's add (4)

1. Compare w/ the root first.
2. (4) < (10) so go left.
3. then compare w/ the next, (8)
4. (4) < (8) so go left
5. Compare w/ the (3)
6. (4) > (3) so go right.
7. Compare w/ the (7)
8. (4) < (7), so add to the left! Done.

Complexity:
Ave. O(log n)
Worst. O(n)

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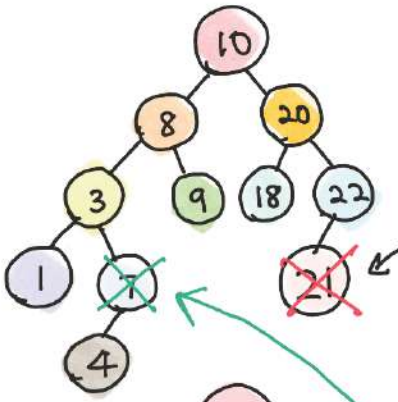
Data Structures BST

Binary Search Tree!

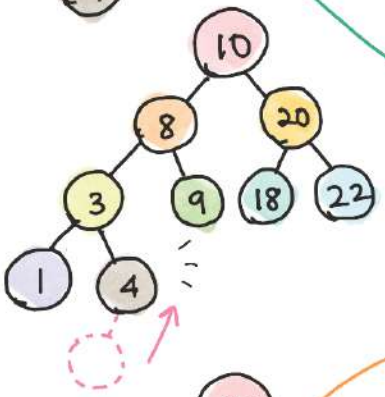
Deletion

Case 1: the to-be-deleted node has no child
Case 2: the node has 1 child
Case 3: the node has 2 children

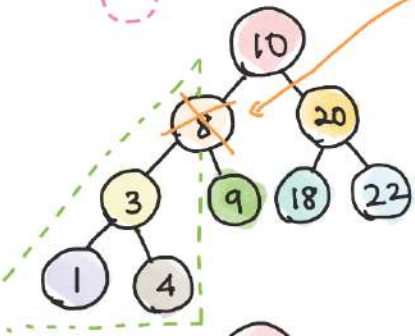


Let's remove (21) ← Case 1.
It has no child. So just remove it from the node. Done! Easy

peachy!

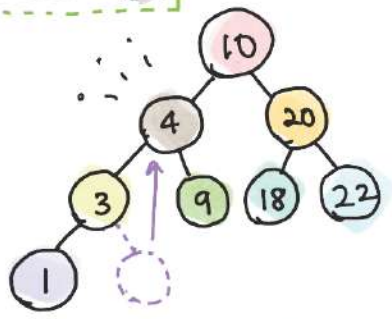


Now, let's delete (7) ← Case 2
1. just remove it
2. then move the child, (4) to the spot!



Now, let's delete (8) ← Case 3!
1. Remove it from the spot
2. Then look for the largest node from the left subtree
3. The largest is (4)!
move the node to the removed spot!
(Alternatively, look for the smallest from the right subtree.)

Done!



(4) originally had no child. but if it has children?
→ Repeat the process!
↳ Find the largest from left subtree. Move it
↳ Find the largest from left subtree...

Recursive

Complexity:
Ave. O(log n)
Worst. O(n)