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

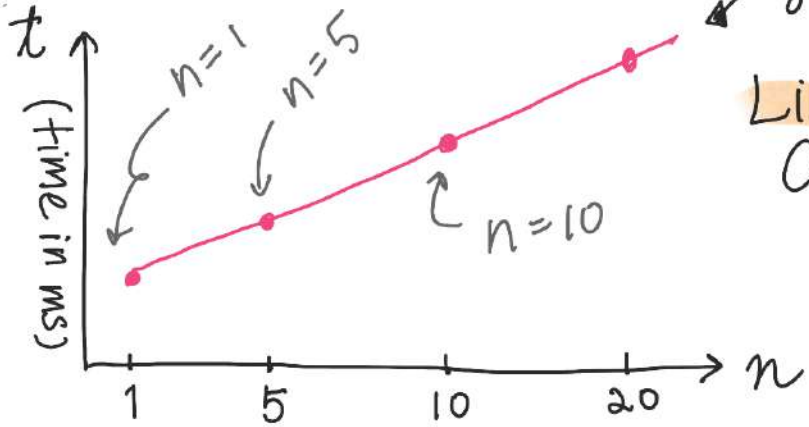
Let's see if there is a needle in the haystack!

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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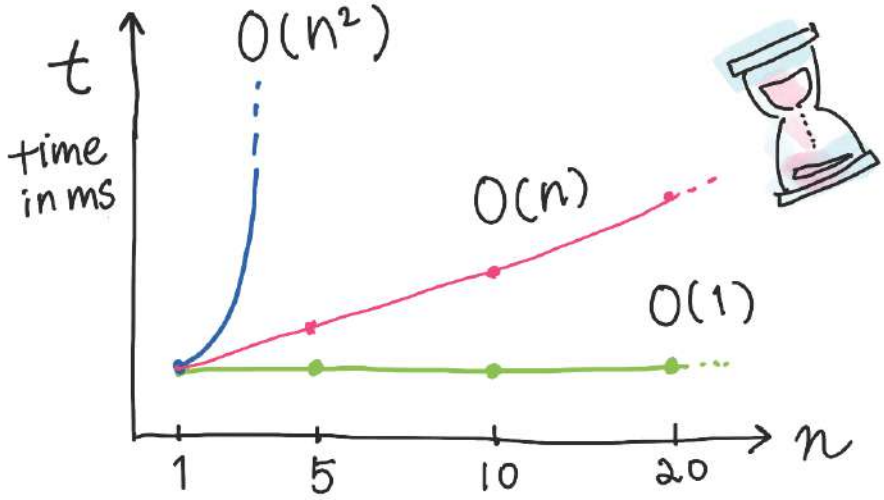
Big O Notation

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

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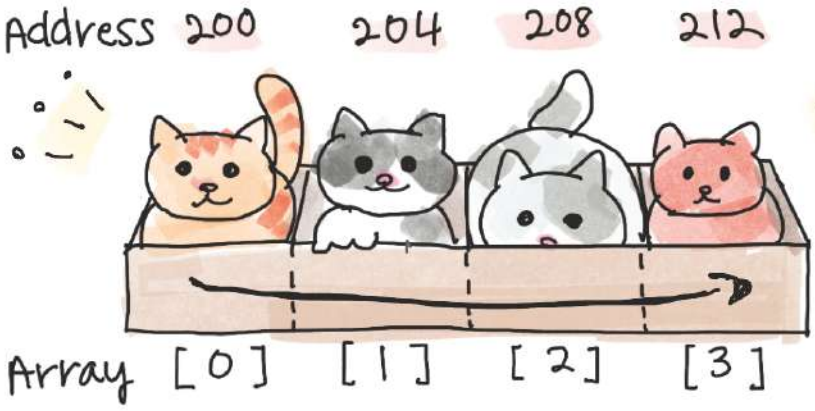
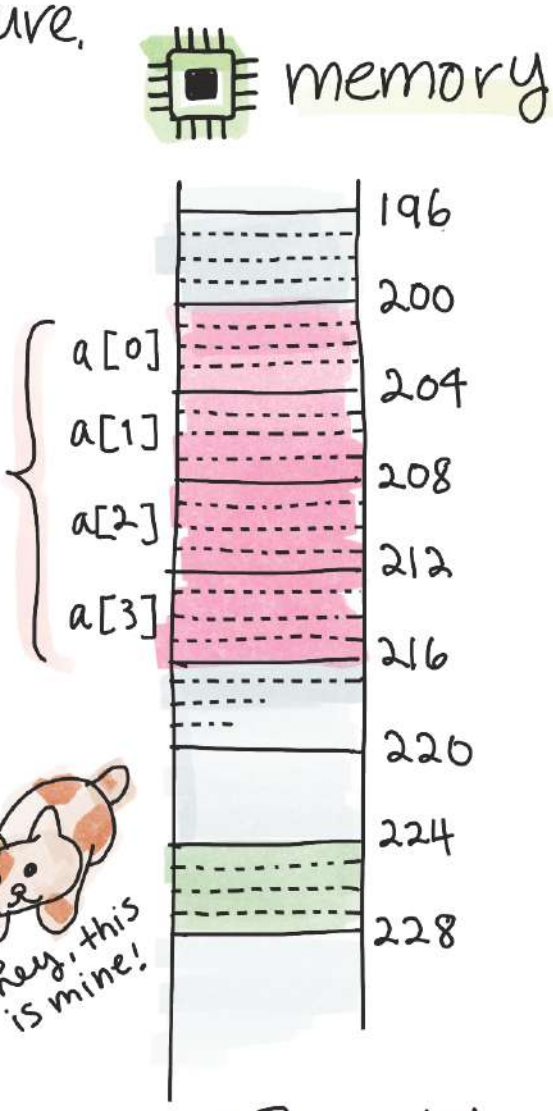
Data Structures

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.

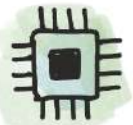
Data Structures

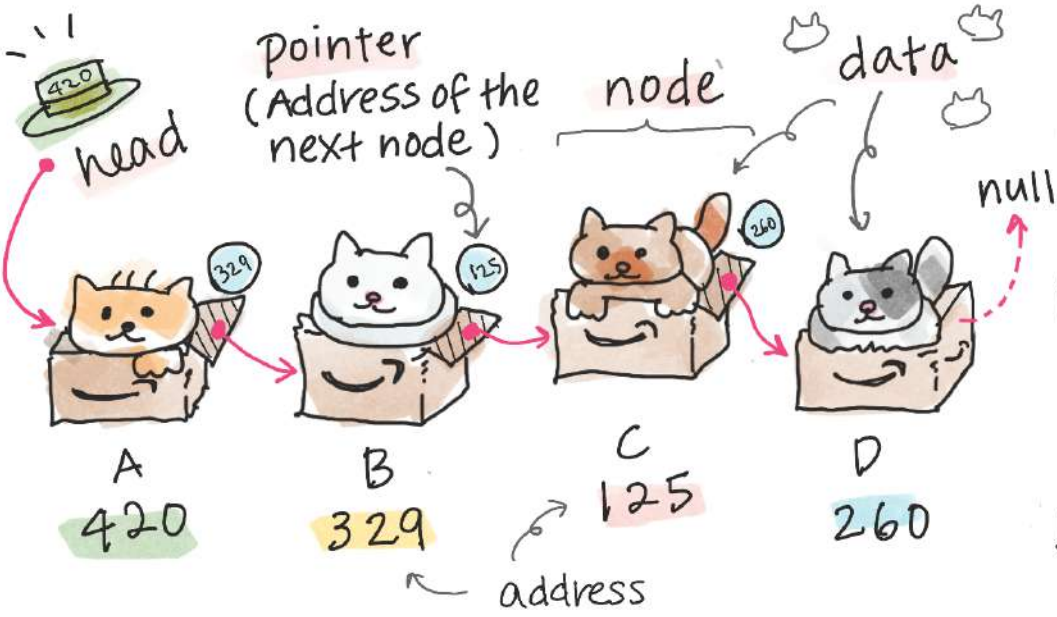
Linked list

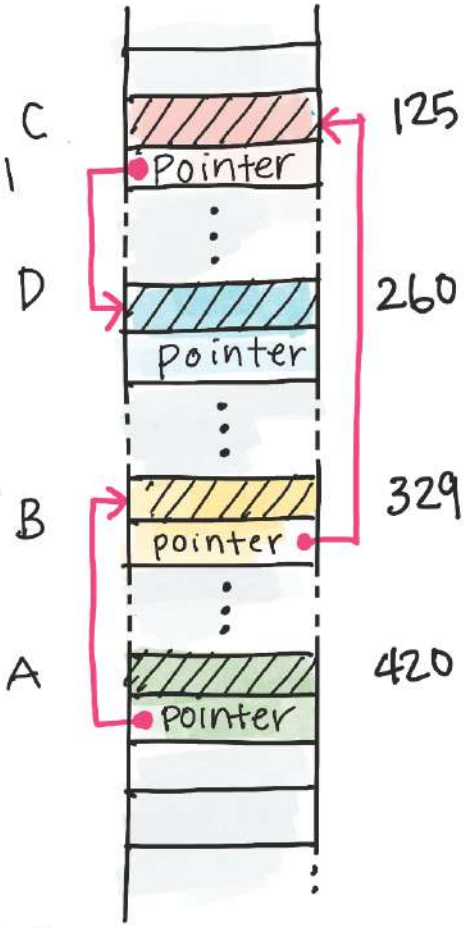
Array & Linked List

: ★ a linear data structure

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







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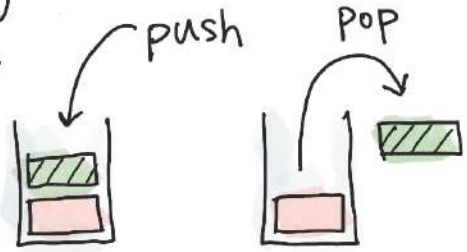
A stack is a LIFO (Last-in-First-out) data structure, where an element added last (=push) gets removed first (=pop)



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.push('mint choc');      // stack is: ['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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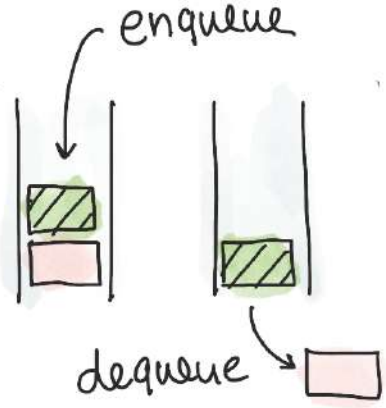
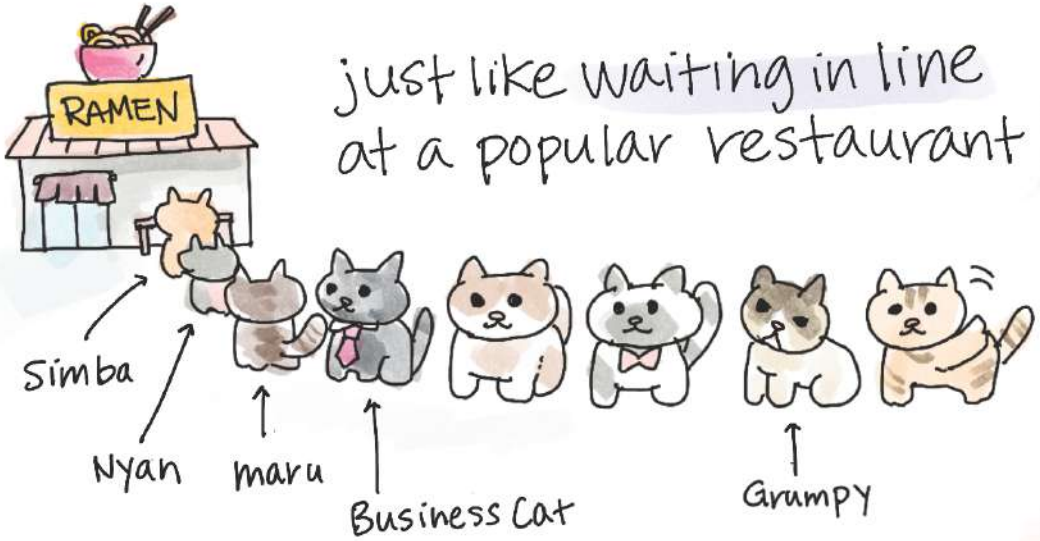
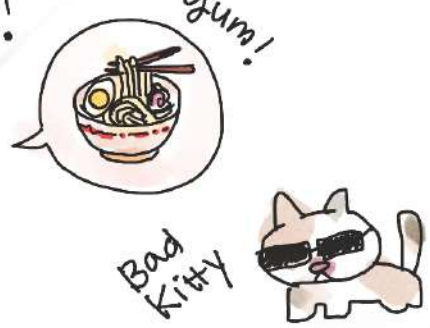
A queue is a FIFO (First-in-First-out) data structure, where an element added first (= enqueue) gets removed first (= dequeue)







Stack as an array in JS

Wrong! 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 is:
queue.push('Nyan');   // ['simba', 'nyan']
queue.push('maru');   // ['simba', 'nyan', 'maru']
let eater = queue.shift(); // eater is 'Simba'
                           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 lookup. O(1) on average
  - ↳ Faster than brute-force linear search

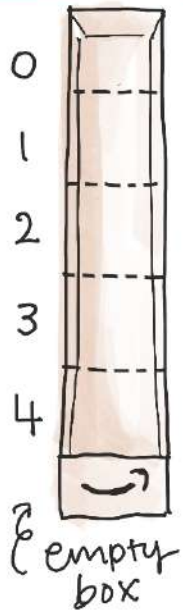
① Let's create an array of size 5.

We're going to add data.

key = "Tabby"

value = "pizza"

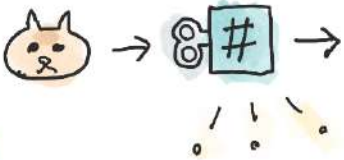
some data
Let's say, favorite food!



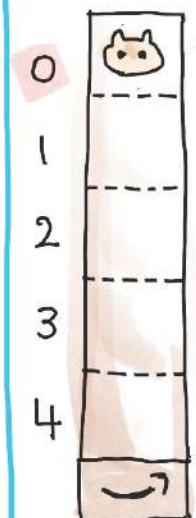
② Calculate the hash value by using the key. "Tabby".

e.g. ASCII code, MD5, SHA1

③ Use modulo to pick a position in the array!



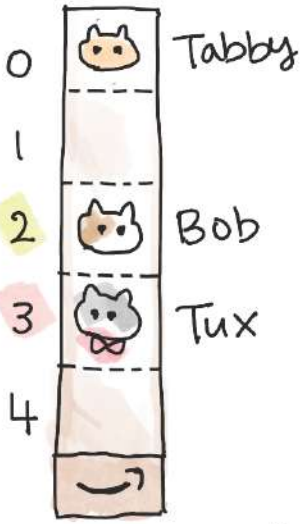
[0]



☆ 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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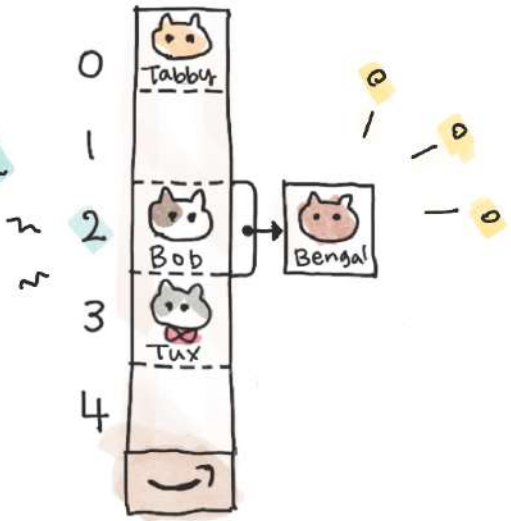
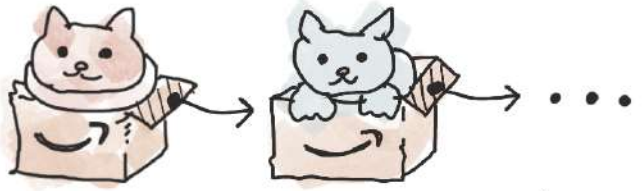
Collision!

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



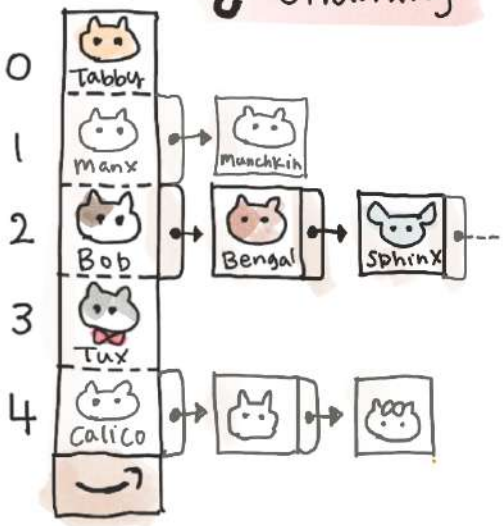


key: "Bengal"
value: "Dosa"

"Sphinx"
"Fish & Chips"

keep adding data

chaining



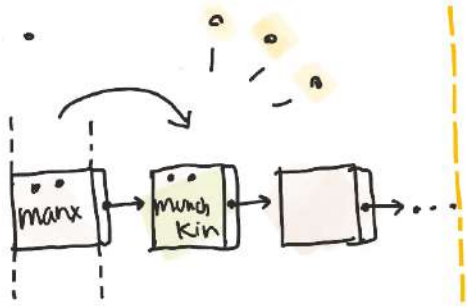
searching for data

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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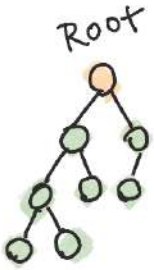
Data Structures Binary Heap



Binary tree

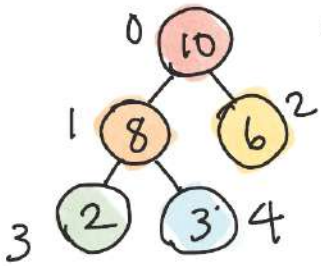
- tree data structure
- each node has at most 2 children

→ Binary search tree

→ Binary heap

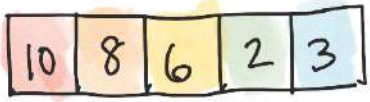
- Complete tree
- Min heap or max heap
- used for priority queue heap sort etc.

☆ Max heap

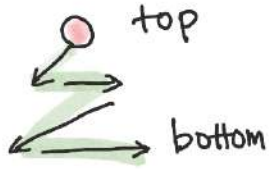


← the root has the largest (min heap is the opposite!)

in array →

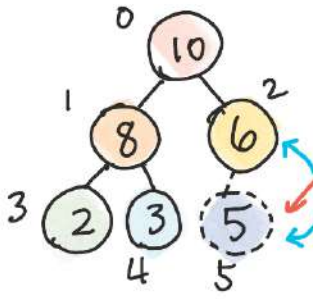


- each node has 0 – 2 children
- always fill top → bottom, left → right

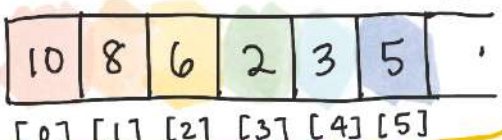


☆ Insertion

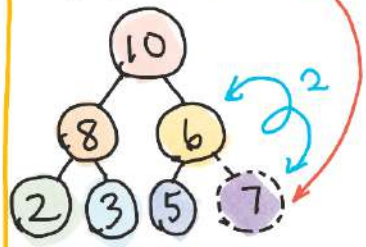
Let's add 5 to the heap!



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

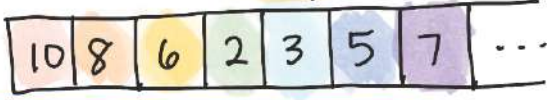


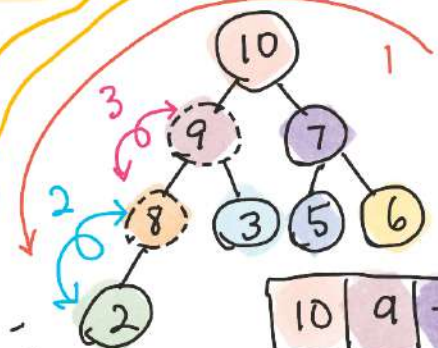
Add 7



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!

Data Structures

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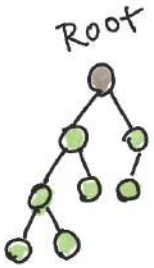
BST

Binary Search Tree

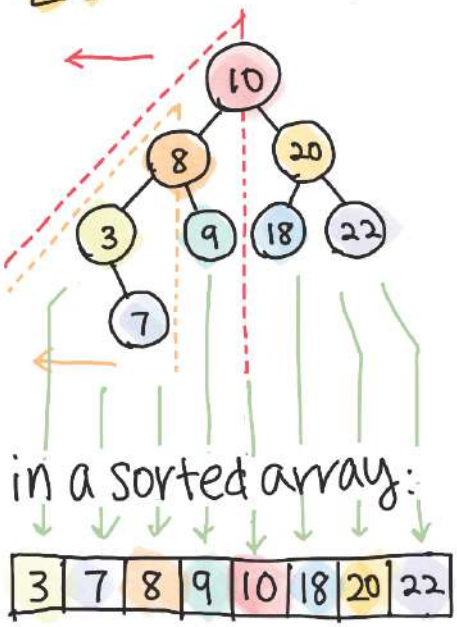


Binary tree → Binary heap

→ Binary Search Tree

- tree data structure
- each node has at most 2 children
- a.k.a. ordered or sorted binary tree
- fast look up
  e.g. phone number lookup table by name

Rule of thumb



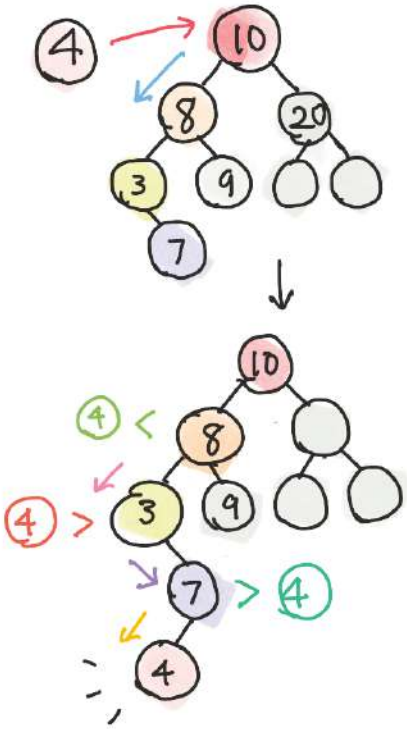
★ each value of all nodes in the left subtrees is lesser

- (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)