22nd Sept 2020

Recess Week Remedial

CS1101S AY20/21 SEM 1

Studio 03A

Chen Xihao
Year 2 Computer Science

chenxihao@u.nus.edu
@BooleanValue

Recess Week Remedial :')

Agenda

- Searching
- Sorting
- Binary Search Trees
- Data Structures
- Review:
    - Studio 5 in-class sheet
    - Studio 6 in-class sheet

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Searching

Searching

Overview

- Integral part of modern algorithms
- Sometimes we choose to sort the list once so that operations later can run faster, improving overall runtime
    - "Pre-processing": just some insights into CS2040S

Searching

Linear Search

- Intuitively:
  - If we want to search for the element x in a list
  - Go through every element in the list
  - Check if it matches
- But what if the item we want is the last one?
  - Then it’s a waste of resources to go thru every element before that

Searching

Binary Search

- Remove redundant stuff
- Analogy:
    - I have a 500 page book, I want to find something around page 300
    - I can discard the first half of the book (pages 1 - 250)
    - I can then discard pages 376 - 500 (leaving me with 251 - 375
    - … continue discarding until we reach around page 300

Searching

Binary Search

- Notice that page numbers are in ascending order
- Criteria for binary search:
  - Items in the list must be ordered (ascending, descending)

Searching

Put on the Thinking Cap

- In a list of distinct numbers in ascending order, find the smallest index such that the item at that index is equal to the index itself.
    - `list_ref(xs, index) === index`
    - How do we go about finding this?
    - Answer
    - Google interview question

Sorting

Sorting

Insertion Sort

- Take an element, insert it into the right place in a new list
- Continue with the rest of the elements
- Note: we need to keep track of a new list that’s built from nothing

Sorting

Insertion Sort

- Complexity:
  - time: O(n^2)
  - space: O(n)

Sorting

Selection Sort

- Select the smallest element (or largest)
- Place it at the front of the list (or end)
- Repeat for rest of the list
- A lot of wishful thinking

Sorting

Selection Sort

- Complexity:
  - Time: O(n^2)
  - Space: O(n)

Sorting

Quick Sort

- Take a pivot
- Partition into to sublists
- Sort the two sublists
- Join the left sublist + pivot + right sublist
- And a lot of wishful thinking
    - Divide and conquer algorithm

Sorting

Quick Sort

- Complexity:
  - Time: depends!
    - If we select good “enough” pivots: O(n logn)
    - If we select bad pivots: O(n^2)
  - Space: O(n)

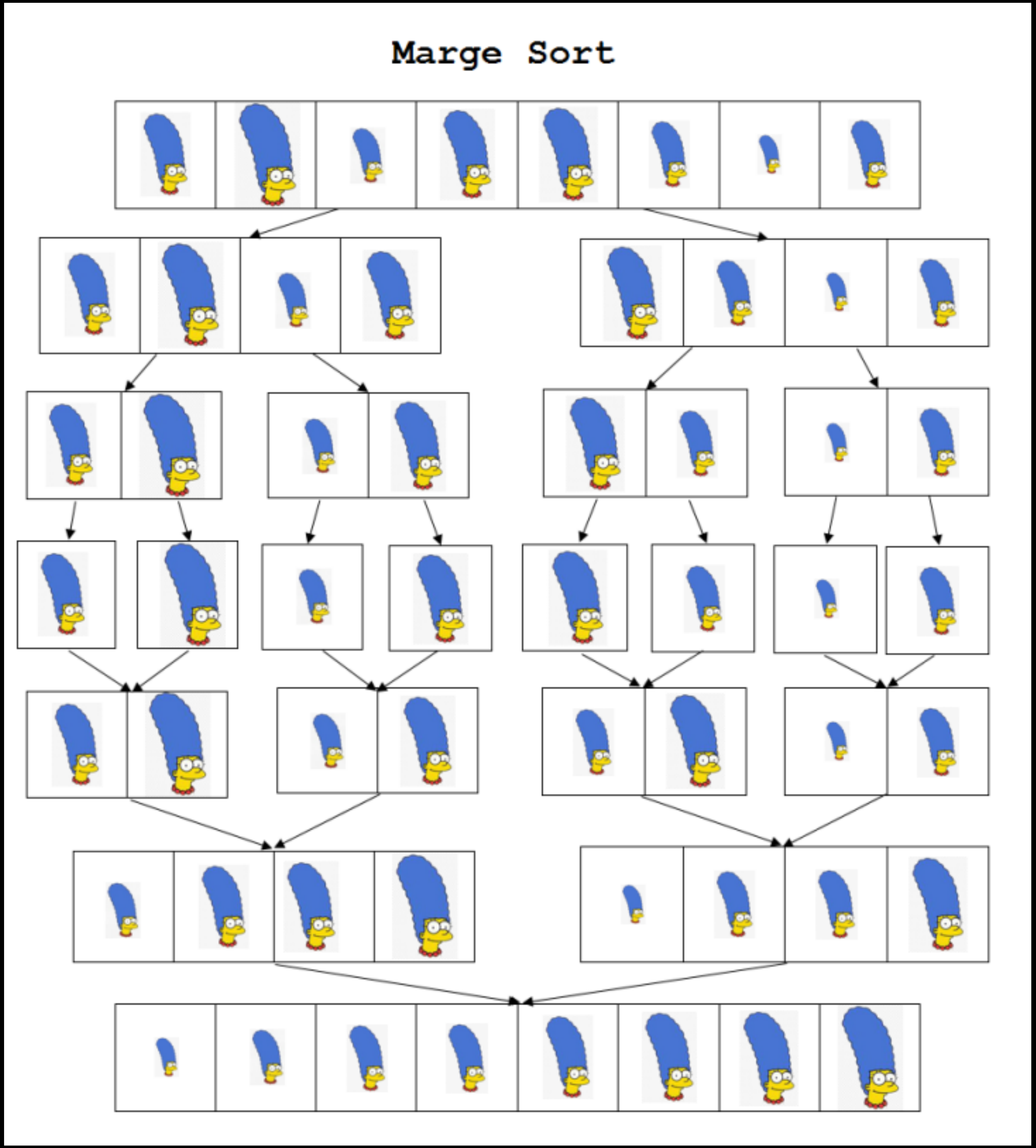
Sorting

Quick Sort

- Exercise: what are bad pivots?
    - Good pivots: roughly equal number of elements in each partition
    - Bad pivots: every element belongs to one partition
        - One partition of n elements, the other has no elements
        - Then this is just insertion sort!

Sorting

Merge Sort



Sorting

Merge Sort

- Split the list into two
- Sort the two lists separately
- Merge the two lists
- More wishful thinking!

Sorting

Sorting Complexities

- Best we can do for the above mentioned: O(n log n)
- Can we do better?

mathew ✅

@mathew@mastodon.social

I came up with a single pass O(n) sort algorithm I call StalinSort. You iterate down the list of elements checking if they're in order. Any element which is out of order is eliminated. At the end you have a sorted list.

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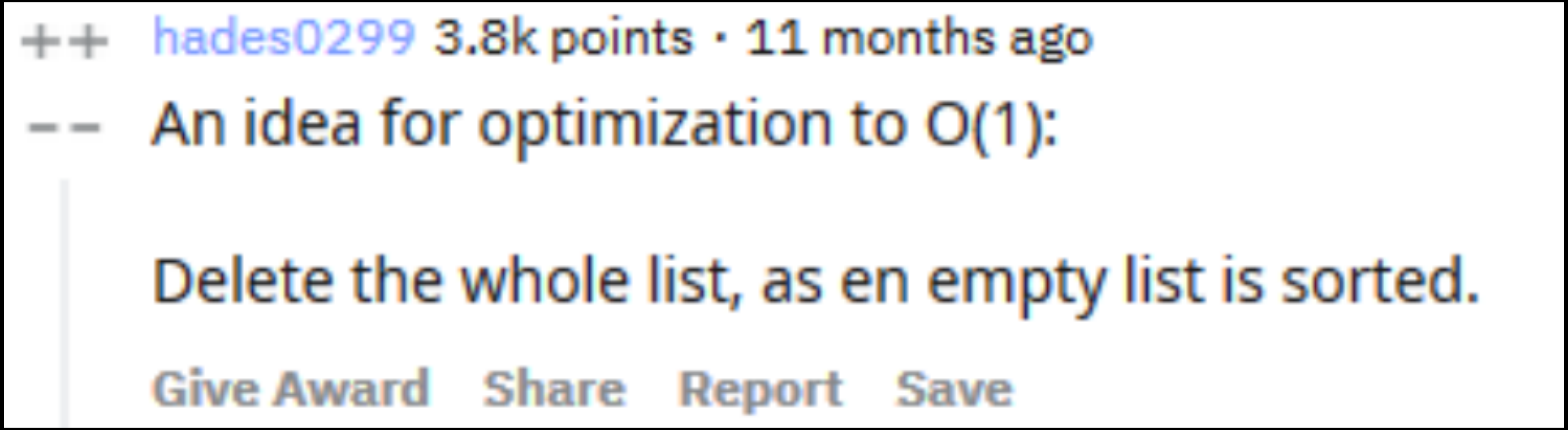


hades0299 3.8k points · 11 months ago

An idea for optimization to O(1):

Delete the whole list, as en empty list is sorted.

credits: Reddit

Sorting

Sorting Complexities

- Best we can do: O(n log n)
- Can we do better?
  - All comparison based sorting algorithms have a lower bound of Ω(n log n)
    - aka at least log(n) comparisons are made
  - There are sorting algorithms that can do better
    - Counting sort: trades space for faster runtimes

Sorting

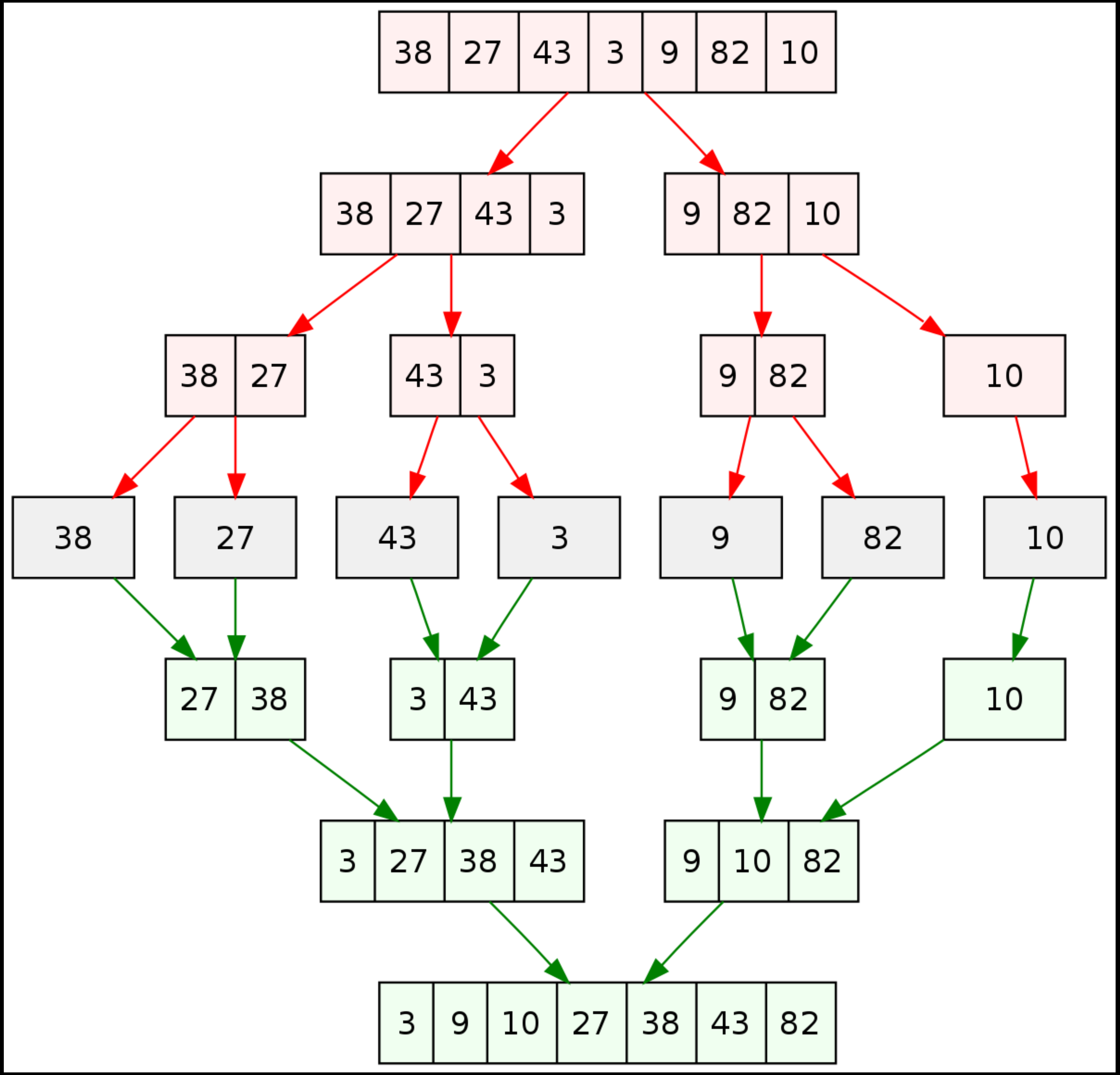
Common Mistake

- During divide and conquer (merge sort, quick sort)
    - Visually we think of both partitions / lists being sorted simultaneously
    - Actually:
        - Computers are sequential machines
        - One partition is fully processed first before going on to the other

Sorting

Common Mistake

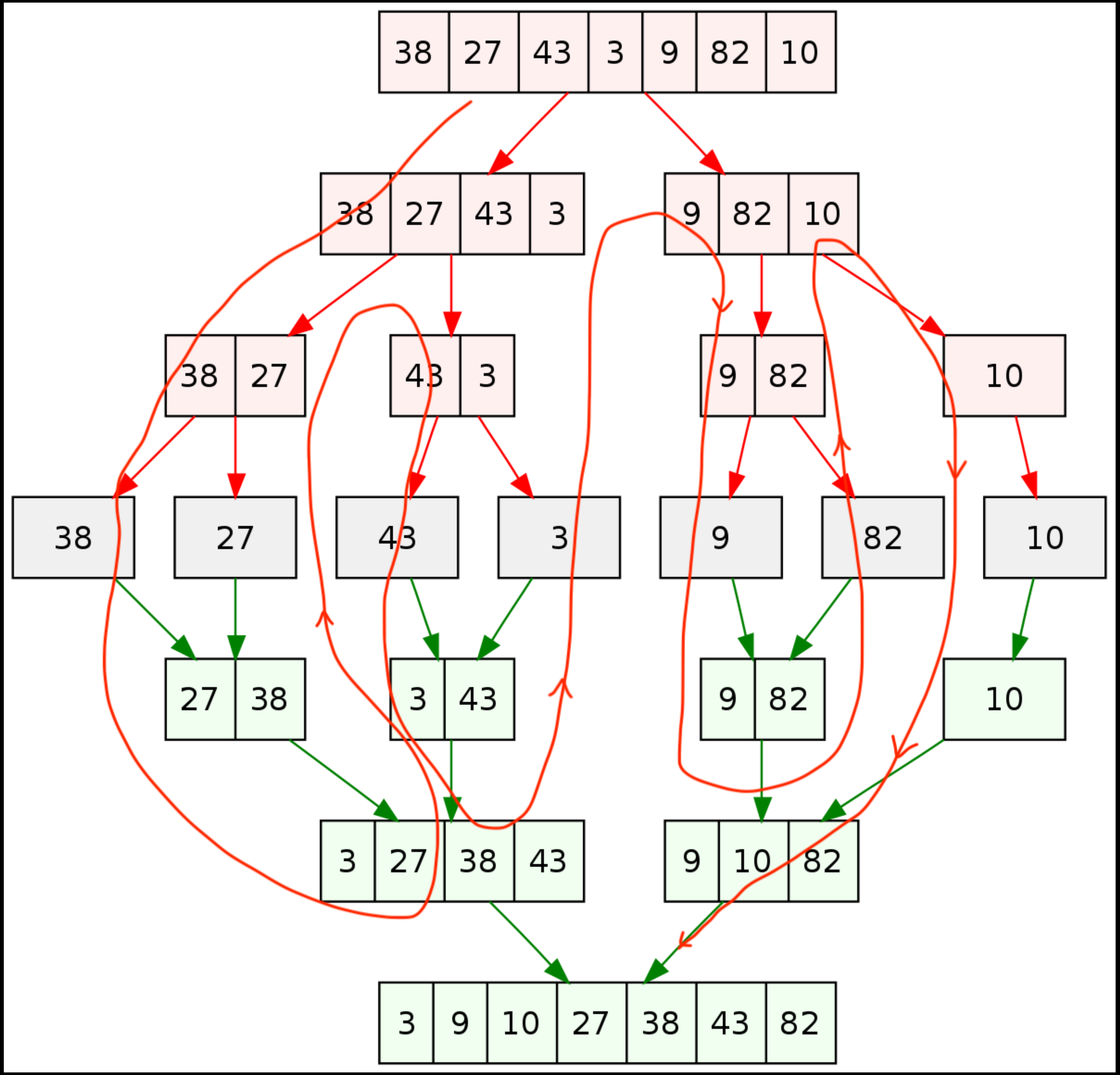
- “Simultaneously”



Sorting

Common Mistake

- In reality:
  - follow red arrow



Binary Search Trees

Binary Search Tree

Definition

- A binary search tree is an abstraction of binary search
  - Can see the similarity?
  - Removes redundant stuff
- A binary search tree is the empty tree, or it has an entry, a left branch and a right branch (both also binary search trees).
- All entries in the left branch are smaller than the entry, and all entries in the right branch are larger than the entry.
  - By definition: <u>no duplicates!</u>

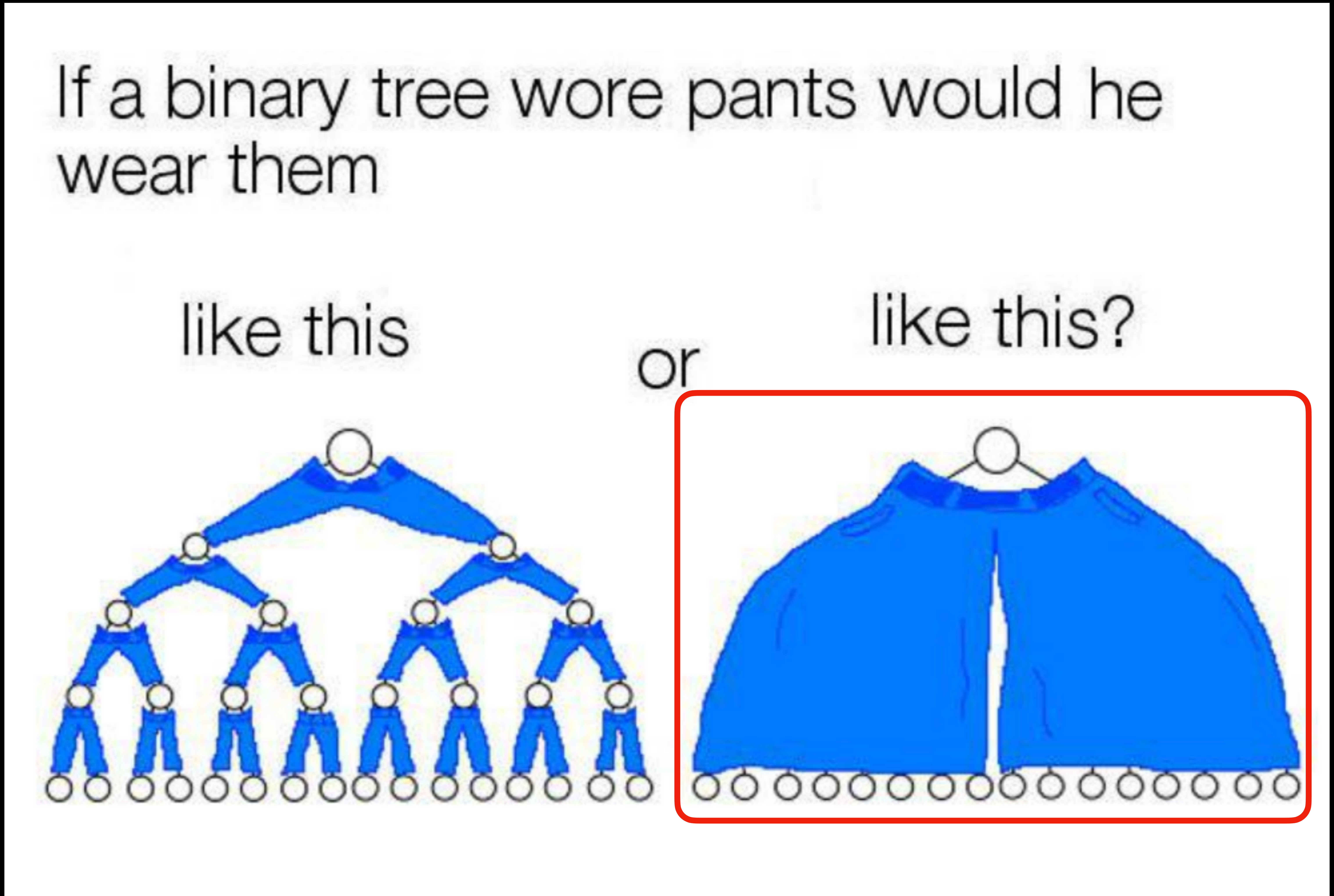
Binary Search Tree

Definition

- Common mistake:
  - Some only compare the values with the immediate children
- Correct:
  - Need to compare with the ENTIRE left and right sub-tree
  - Root should be larger than all the elements in the left sub-tree
  - Root should be smaller than all the elements in the right sub-tree

Binary Search Tree

Definition



Binary Search Tree

Quiz

- Is this a BST?
    - Yes

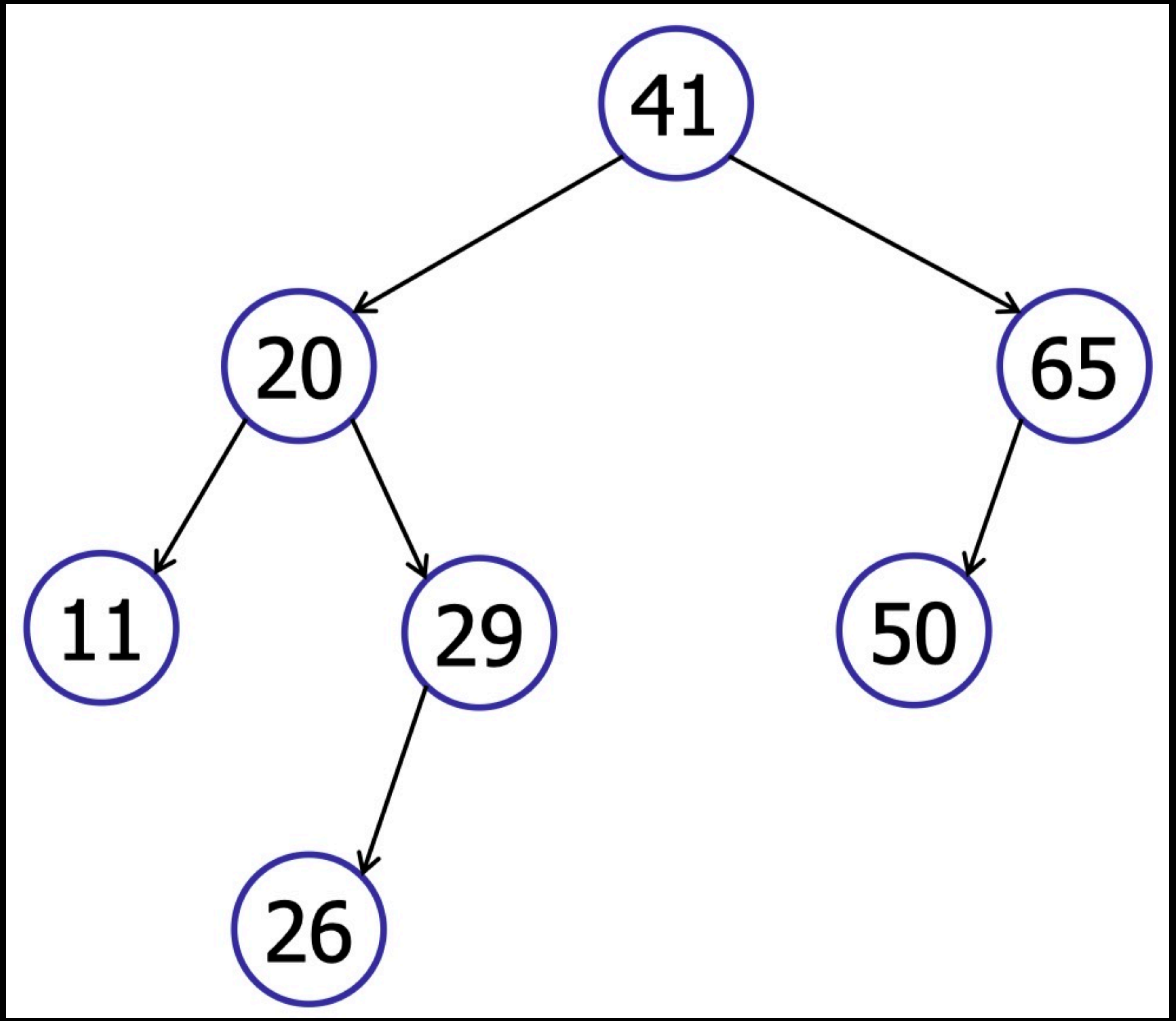


diagram from CS2040S

Binary Search Tree

Quiz

- Is this a BST?
  - No

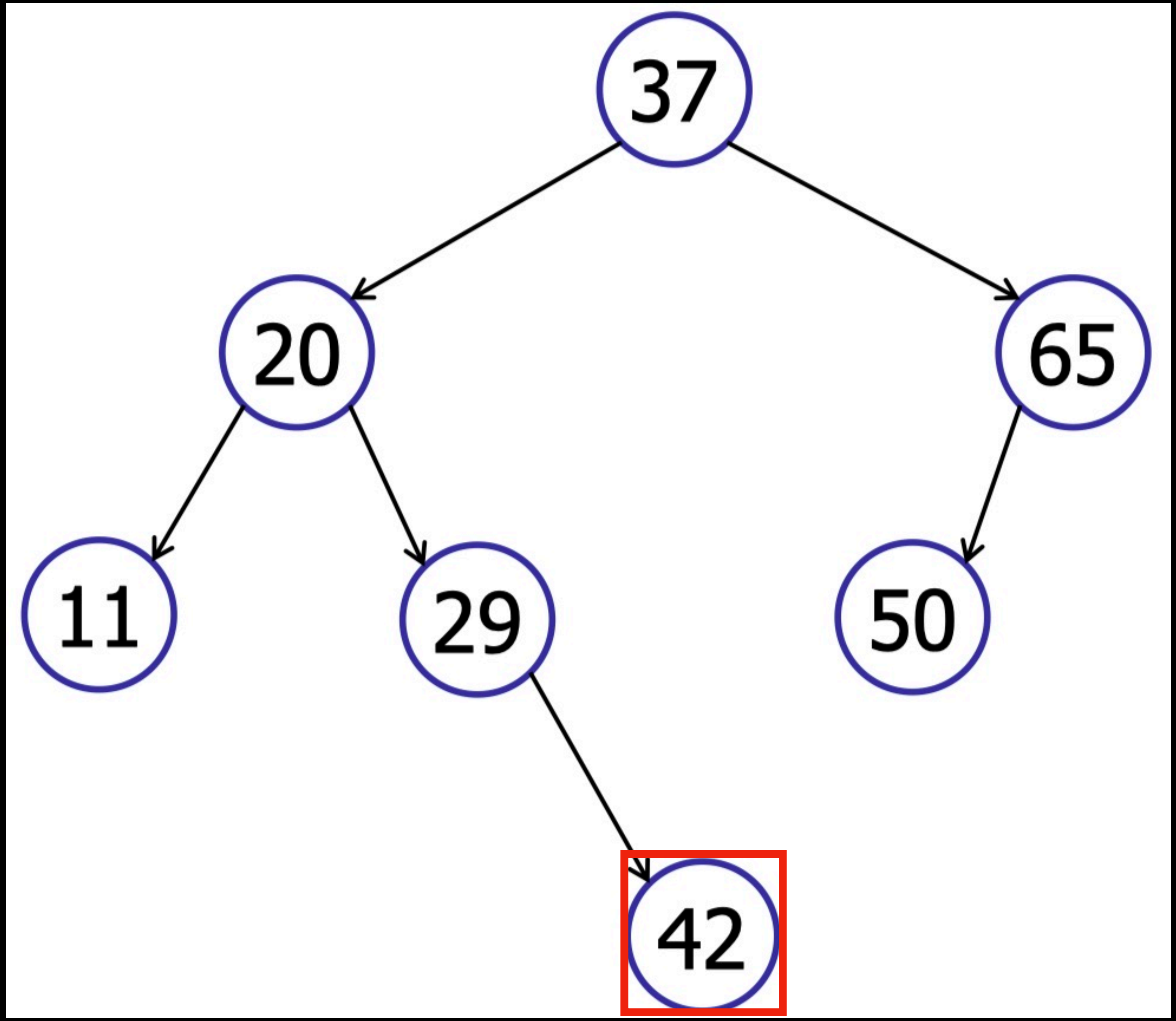
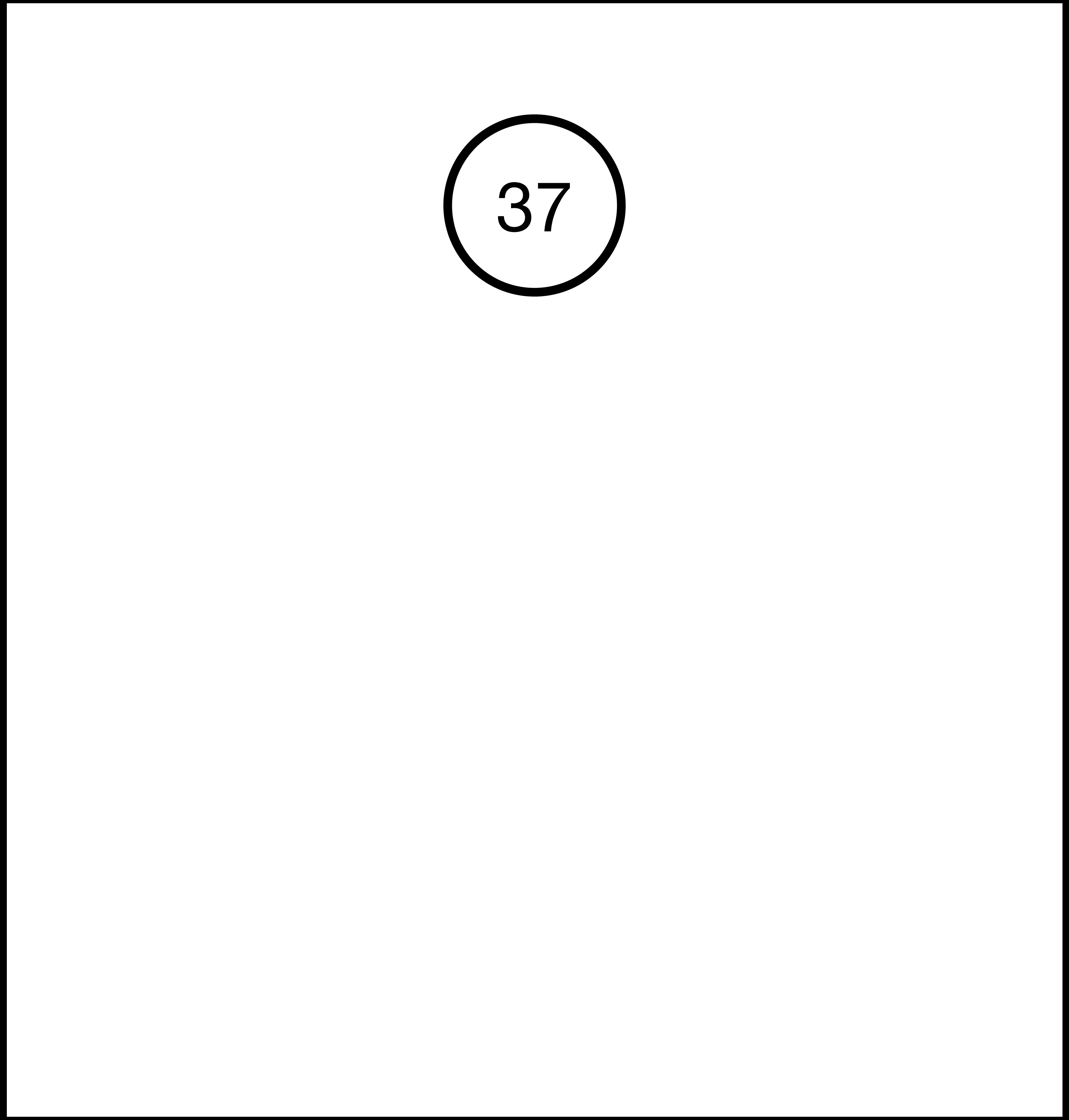


diagram from CS2040S

Binary Search Tree

Quiz

- Is this a BST?
  - Yes



Binary Search Tree

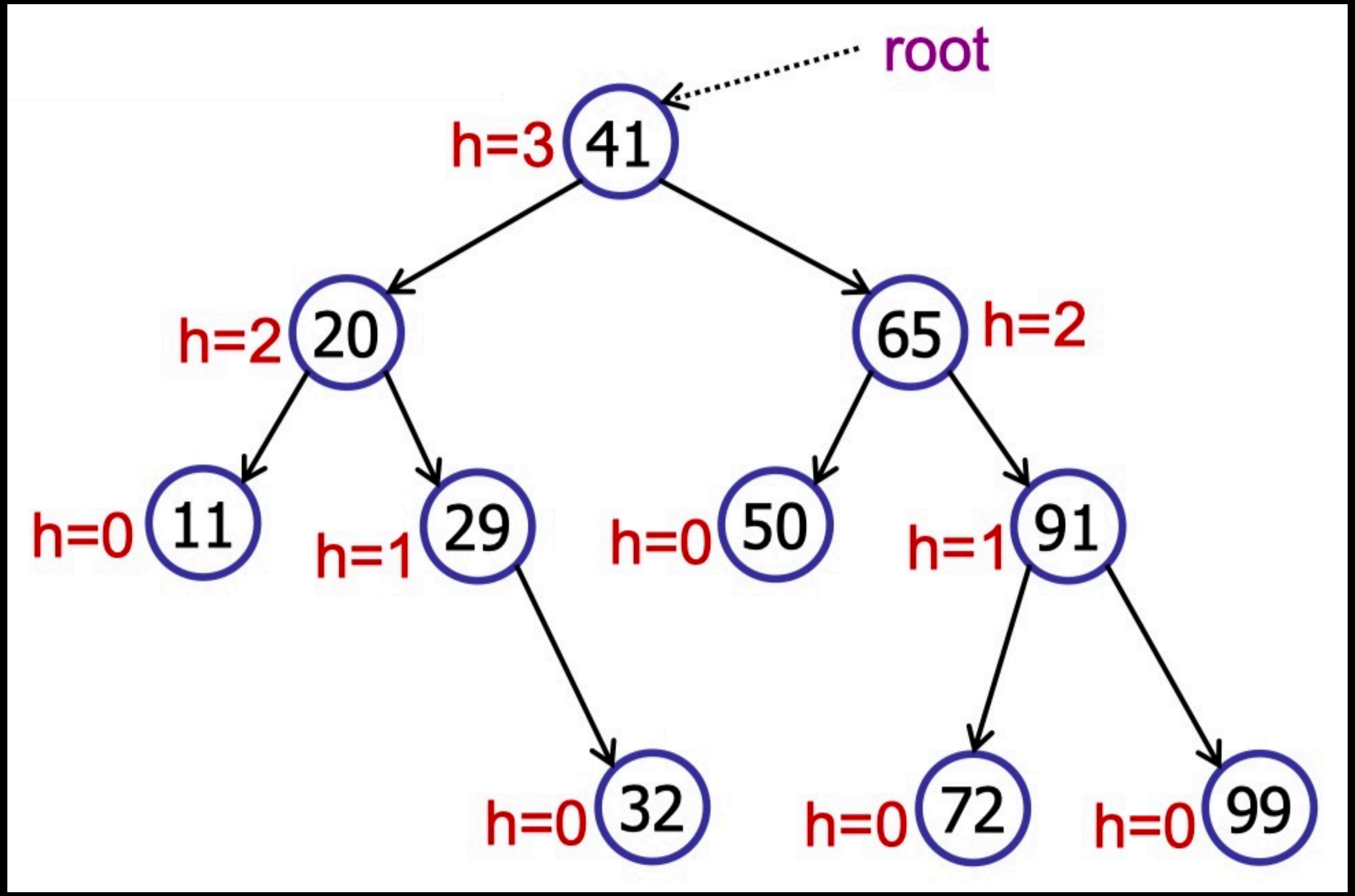
Definition

- Hack:
  - If you “flatten” a tree to get a sequence of numbers
  - If the sequence is in ascending order, then it is a BST
  - Else, it’s not

Binary Search Tree

Height

- Height of a tree
  - Number of edges (pointers) on the longest path from root to leaf



Binary Search Tree

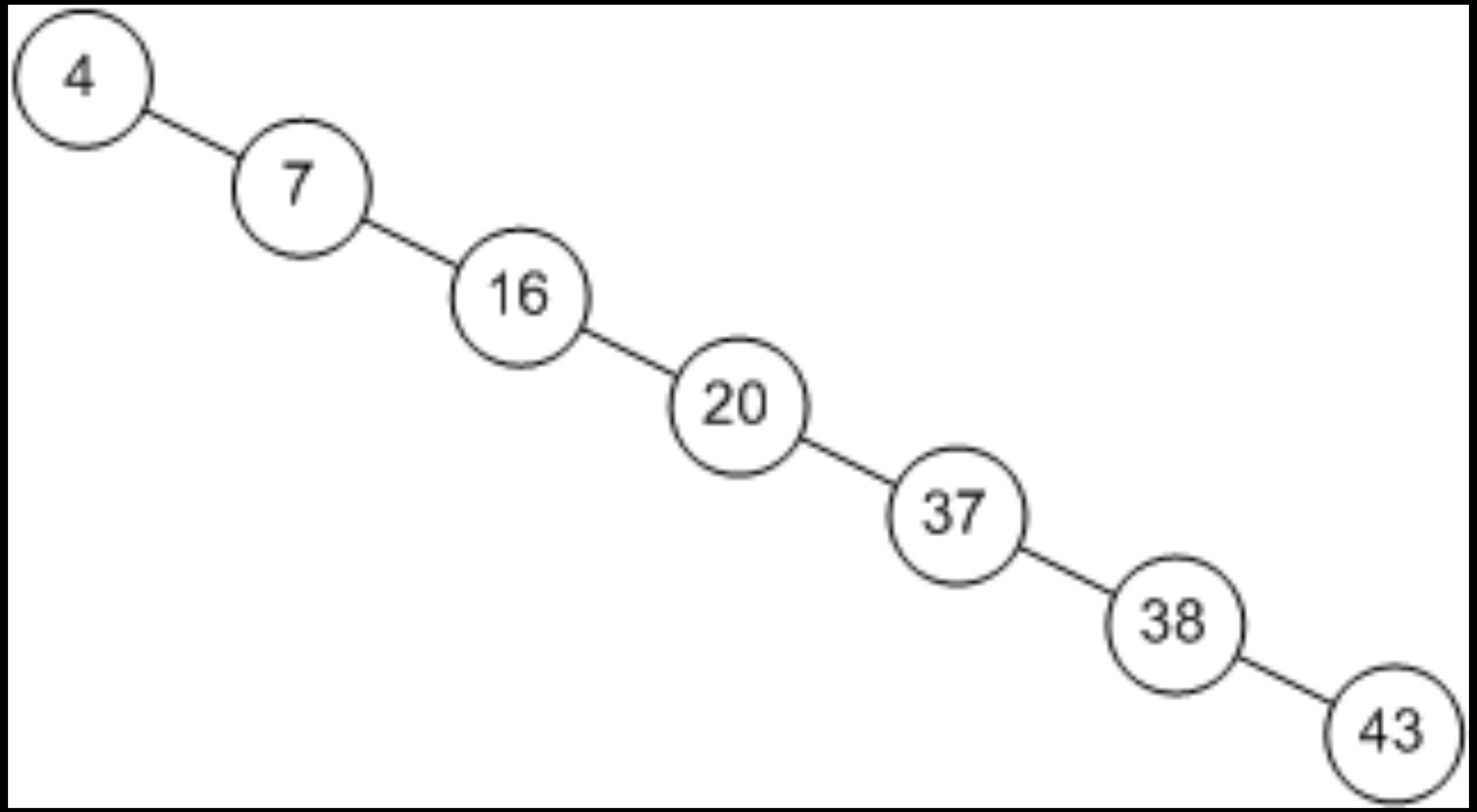
Purpose

- Linear search runs in O(n) time
- If we have a binary tree:
    - We can search for the item in O(log n) time
    - Why? Recall binary search and relationship to BSTs
- Best case: O(log n)
- Worse case: O(n)
    - How?

Binary Search Tree

Purpose

- Worst case O(n):
  - Imagine if we only add to the right sub-tree
  - It's just a list…



Binary Search Tree

Traversal

- Pre-order
- In-order
- Post-order

Binary Search Tree

Traversal

- Pre-order:
  - Visit root
  - Visit left sub-tree recursively
  - Visit right sub-tree recursively

Binary Search Tree

Traversal

- In-order:
    - Visit left sub-tree recursively
    - Visit root
    - Visit right sub-tree recursively

Binary Search Tree

Traversal

- Cool fact about in-order traversal:
    - Visits items in sorted order
    - Refer to Mission Search and Rescue

Binary Search Tree

Traversal

- Post-order:
  - Visit left sub-tree recursively
  - Visit right sub-tree recursively
  - Visit root

Data Structures

Data Structures

A Recap

- `const a = list(1, 2, 3);`
- `a === insertion_sort(a)  // ?`

- Answer: false

```
function insert(x, xs) {
    return is_null(xs) ? list(x) : x <= head(xs)
            ? pair(x,xs)
            : pair(head(xs), insert(x, tail(xs)));
}
function insertion_sort(xs) {
    return is_null(xs)
        ? xs
        : insert(head(xs), insertion_sort(tail(xs)));
}
```

Binary Search Tree

A Recap

```
function insert(x, xs) {
  return is_null(xs) ? list(x) : x <= head(xs)
      ? pair(x,xs)
      : pair(head(xs), insert(x, tail(xs)));
}
```

- Why?
  - When we call `insert`, we created new pairs
  - New list created
- Not sorted “in-place”

Any questions?