
Never send a human
to do a machine's job.

Performance, Algorithms, and Data Structures

Performance

Linear Search

- Brute force, linear search
- Start at the first element
- compare subsequent elements until the desired value if found, or there are no more.

Linear Search

```
def search(ary, n)
  ary.each do |e|
    return true if e == n
  end
  false
end
```

Linear Search

```
def search(ary, n)
  ary.each do |e|
    return true if e == n
  end
  false
end
```

'Fancy algorithms are slow when n is small, and n is usually small.'

-- Rob Pike

O() Notation

- We need a way to measure and compare the efficiency of algorithms

- Big O notation is a order of magnitude measure of the amount of work required in the worst case for a given algorithm (or class of algorithms)

- This measure is typically in terms of the size of the input data set.

O(1)

```
def a(ary)
  ary[0].nil?
end
```

- The size of `ary` has no impact of how much work this code does.
- So *O(1)*

O(n)

```
def search(ary, n)
  ary.each do |e|
    return true if e == n
  end
  false
end
```

- As the size of ary increases, the amount of work in the worst case (when n is not in ary) increases linearly.
- So $O(n)$

$O(n^2)$

```
def contains_duplicates(ary)
  (0..ary.count).each do |i|
    (0..ary.count).each do |j|
      if i != j
        return true if ary[i] == ary[j]
      end
    end
  end
  false
end
```

- For each element, ary is scanned looking for duplicates that match it.
- If there are no duplicates, ary is fully walked for each element, other than where $(i == j)$.
- Hence the comparison is done $(n^2 - n)$ times, so $O(n^2)$

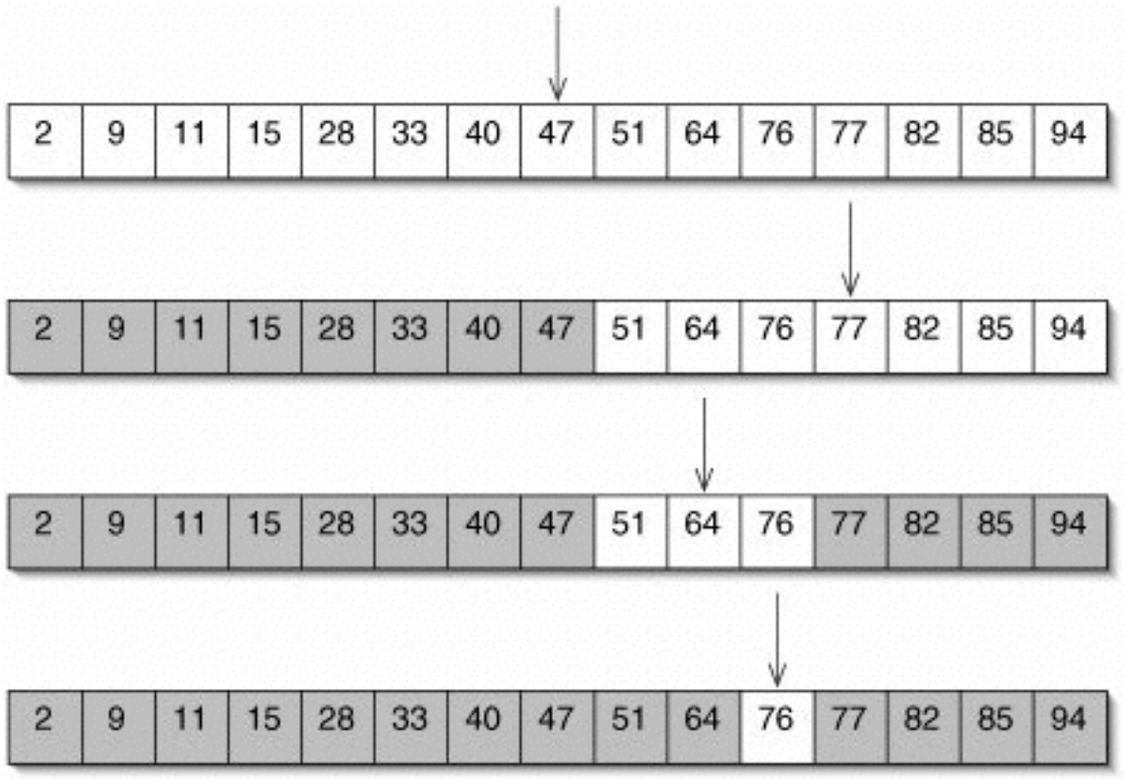
Linear Search

- Our linear search algorithm has to compare the value being searched for with every element before knowing it isn't there.
- So it is $O(n)$
- How can we do better?
- What about if we sort the array?
- How can we take advantage of that?

Binary search

- If it's sorted, then we could look at the middle element.
- if it's what we want, we're done
- if what we're looking for is less, we can ignore the second half of the array
- if it's greater, we can ignore the first half.
- Do this repeatedly until found or you're down to a single element without being found

Binary search



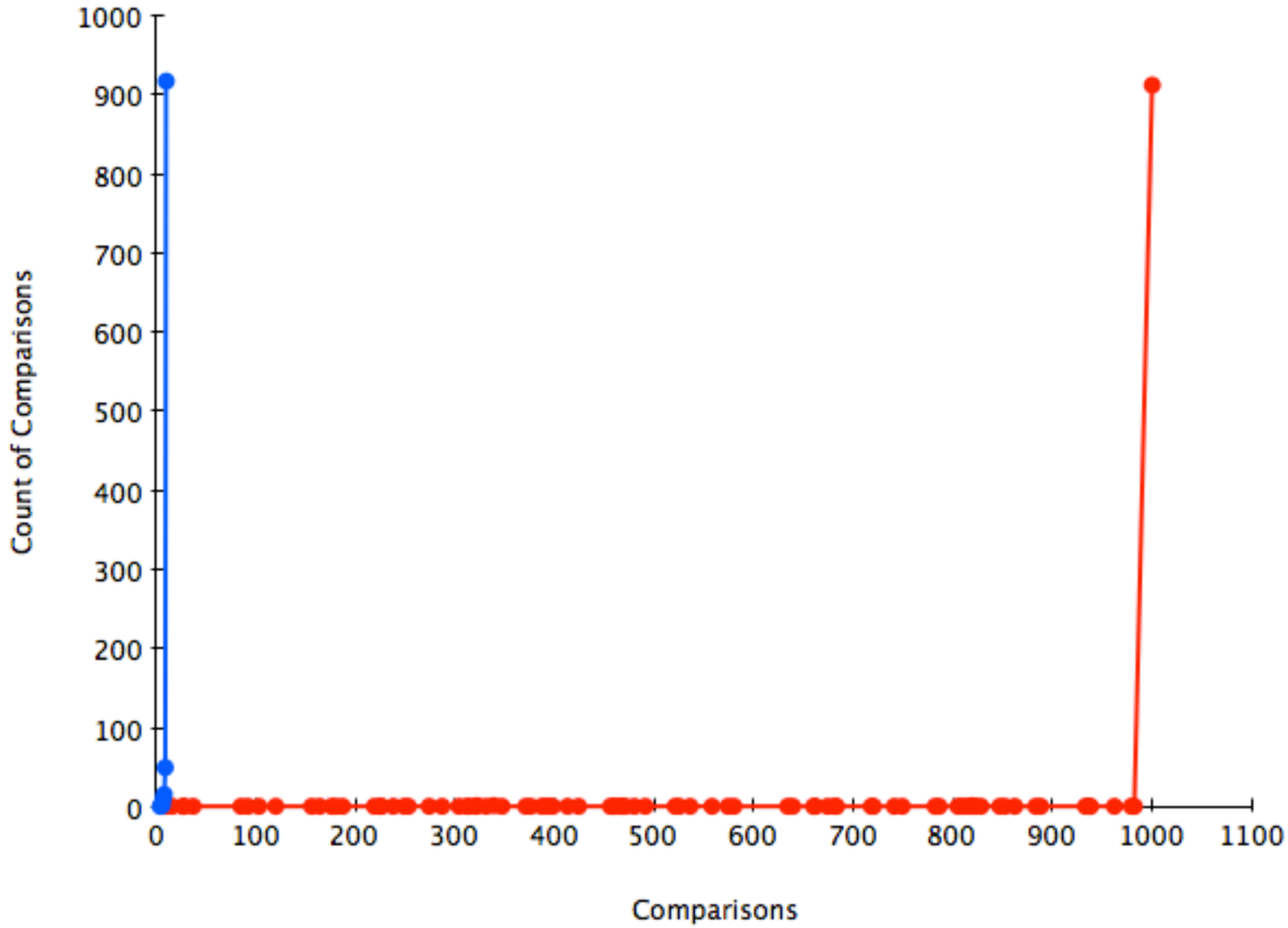
Binary search code

```
def binary_search(ary, n)
  l = 0
  h = ary.count
  while l <= h
    m = ((l + h) / 2).floor
    if n < ary[m]
      h = m - 1
    elsif n > ary[m]
      l = m + 1
    else
      return true
    end
  end
  false
end
```

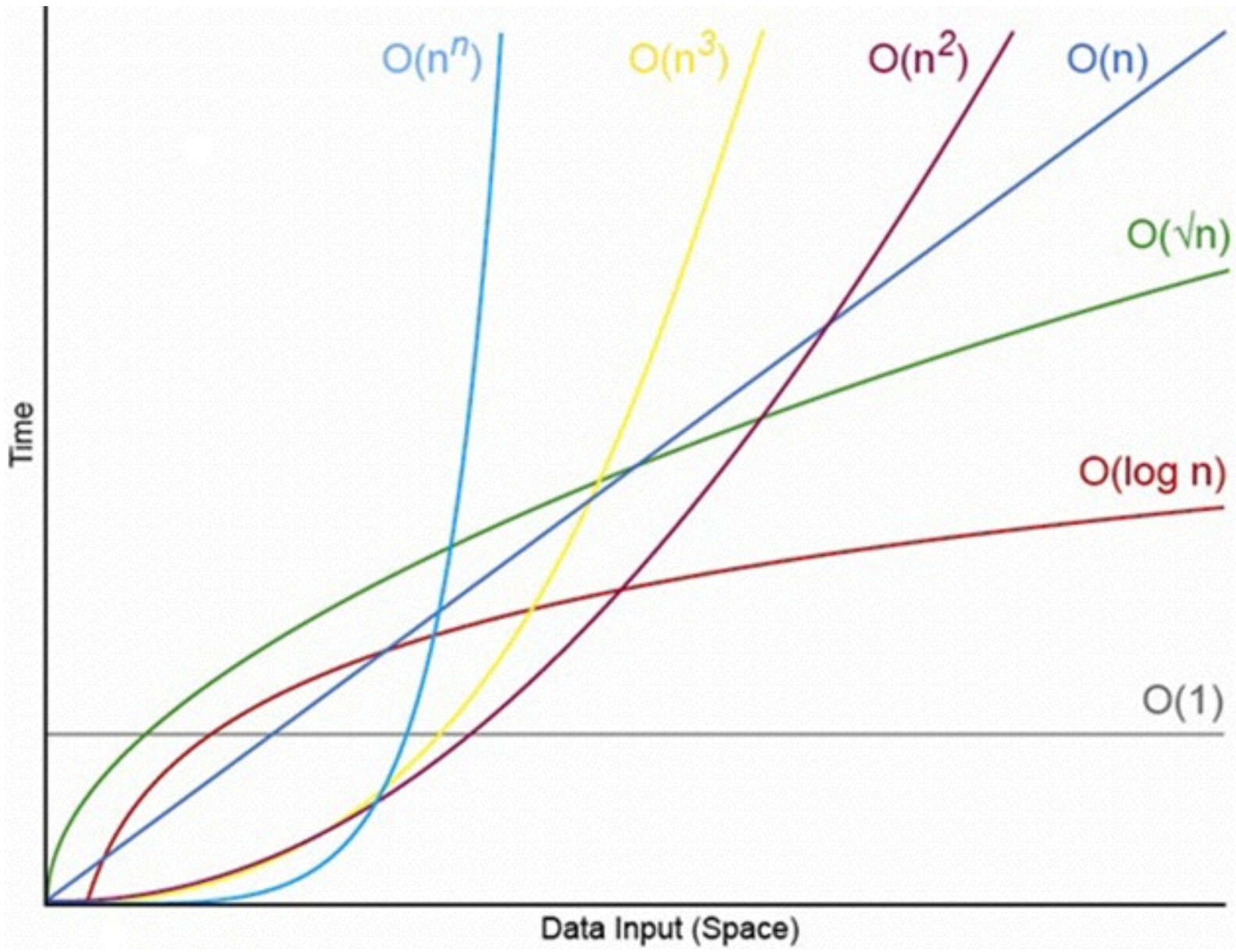
O(log(n))

- Actually, $O(log_2(n))$
- This is pretty ideal.
- Depends on treating the problem as a balanced binary search tree (which is easy with a sorted array)

Comparison


Count of Comparisons
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000
1100
Comparisons

Big O comparison

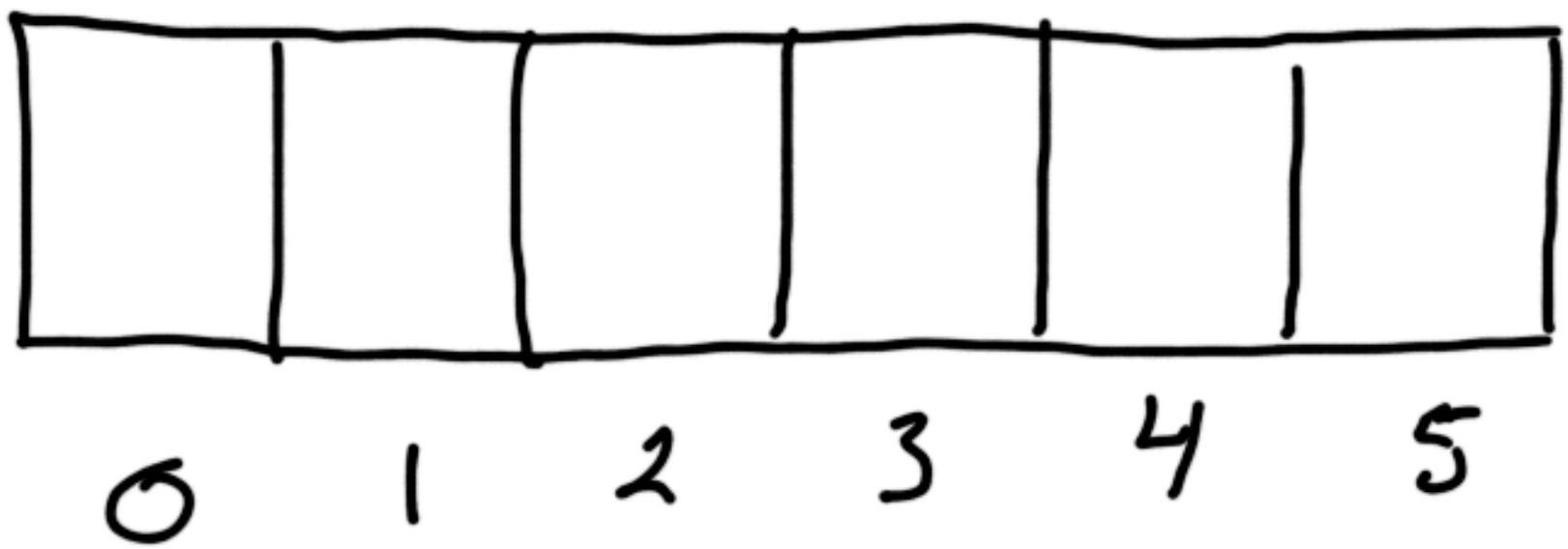


Array

Structure

- A collection of values, indexed by integer.
- Indices are typically contiguous, but sparse arrays are at times useful. Unless otherwise stated, you can assume indices starting at 0 (sometimes 1) and increase contiguously.
- Random access

Structure



Operations

- empty?
- size
- append
- access
- update
- insert
- remove

Exercise

- Implement DbcArray
  - https://github.com/dastels/dbc-deep-dives.git
  - Algo directory
  - delete the contents of the lib dir, and put dbc_array.rb there
  - You can build on top of Ruby's array
  - Use rspec spec/array_spec.rb to guide you

Applications

- When you need a collection of things and need random access

Stack

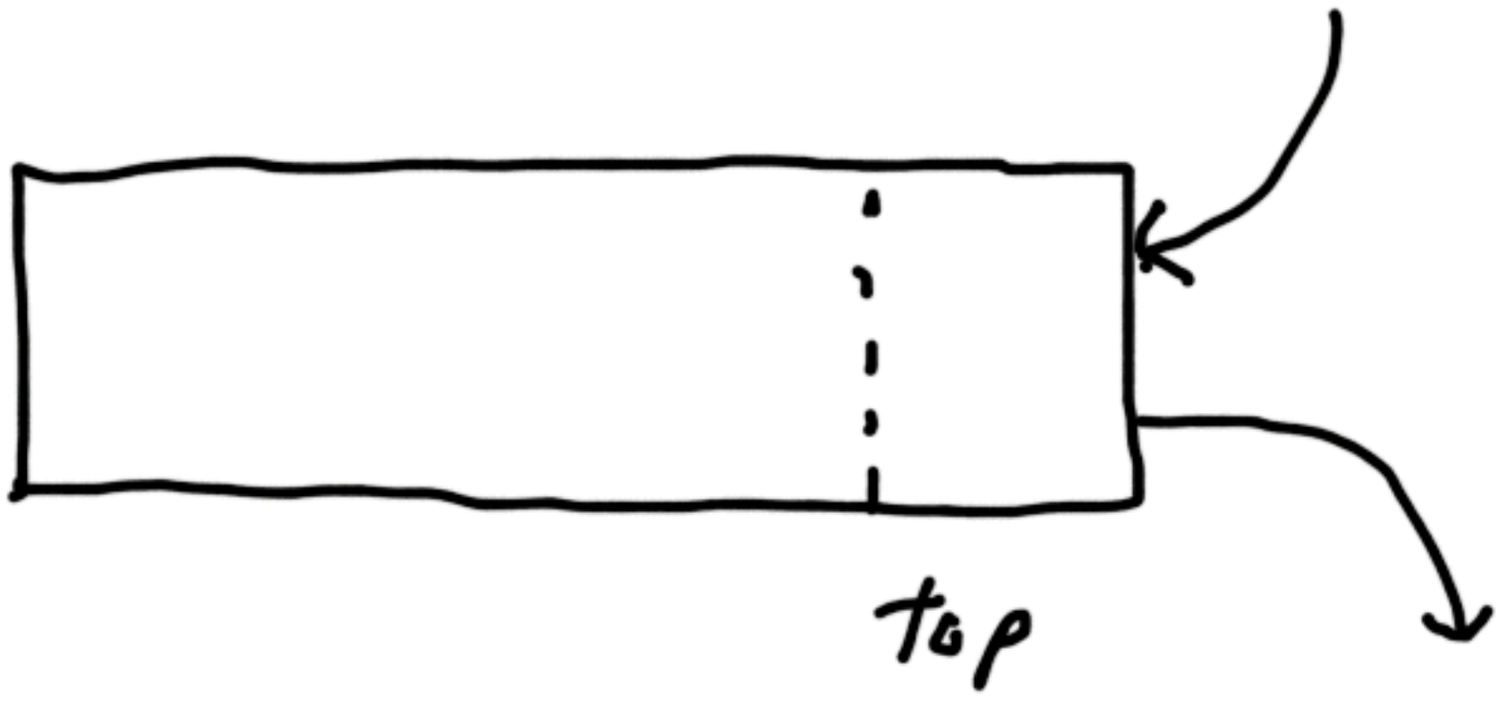
Structure

- A linear collection of values, with can be added and removed.

- Access only by the peeking or popping

- Access is last-in, first-out

Structure



Operations

- empty?
- push
- pop
- peek
- full? Might be useful if we limit the size of the stack
- do we need to know the size?

Exercise

- Implement DbcStack
  - https://github.com/dastels/dbc-deep-dives.git
  - Algo directory
  - delete the contents of the lib dir, and put dbc_stack.rb there
  - You can build on top of Ruby's array
  - Use rspec spec/stack_spec.rb to guide you

Applications

- When you need to keep track of things for later, and revisit them as you backtrack.

- Example: check for balanced parens & brackets:
  - the empty string is balanced
  - if S is balanced, then (S) is
  - if S is balanced then [S] is
  - if S and T are balanced, then ST is

Queue

Structure

- A linear collection of values, with can be added and removed.

- Add to one end (rear), remove from the other (front)

- Access only by dequeuing

- Access is first-in, first-out

Structure

Operations

- empty?
- enqueue
- dequeue
- full? Might be useful if we limit the size of the queue
- do we need to know the size?

Exercise

- Implement DbcQueue
  - https://github.com/dastels/dbc-deep-dives.git
  - Algo directory
  - delete the contents of the lib dir, and put dbc_queue.rb there
  - You can build on top of Ruby's array
  - Use rspec spec/queue_spec.rb to guide you

Applications

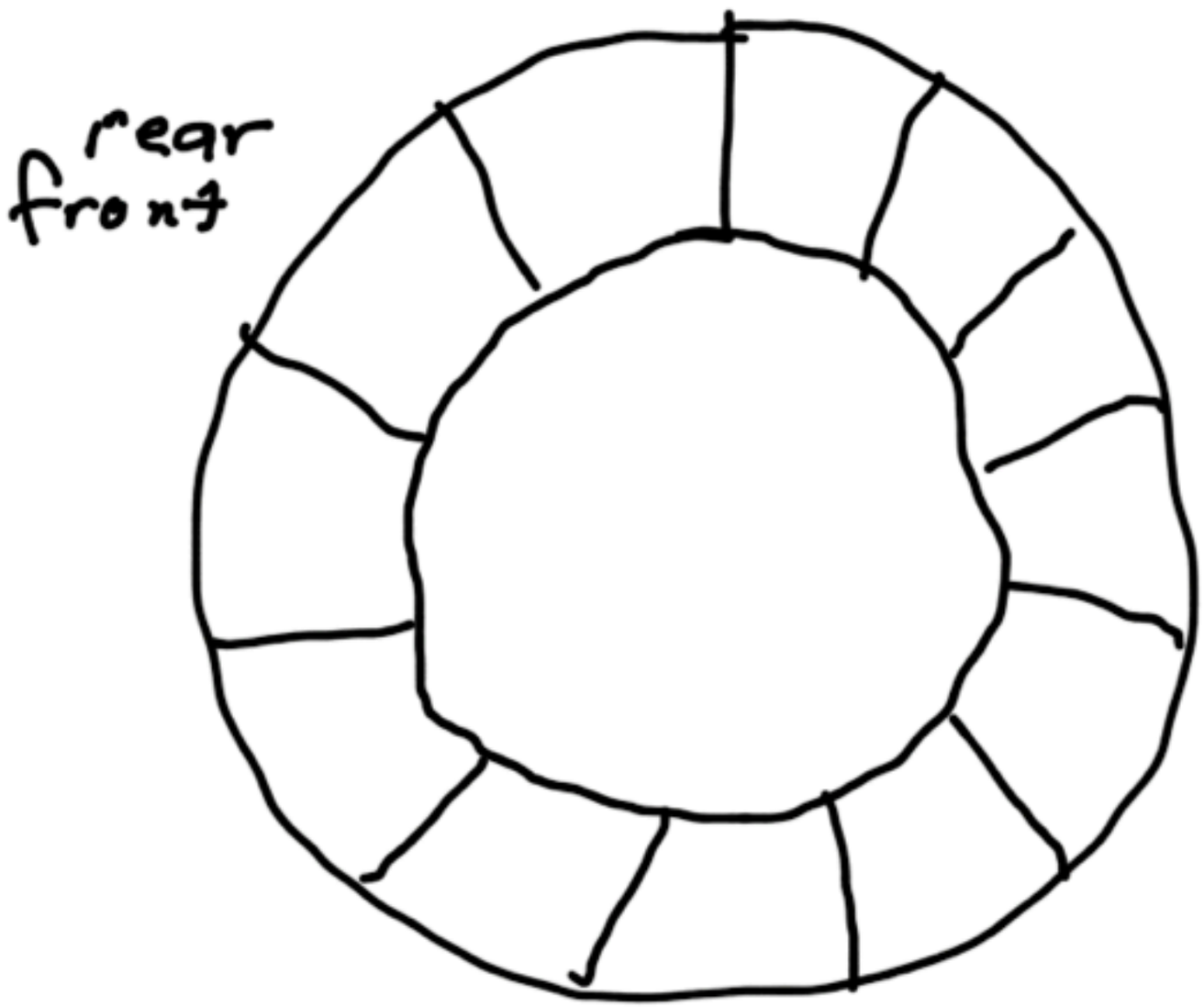
- Job queues

Circular Queue

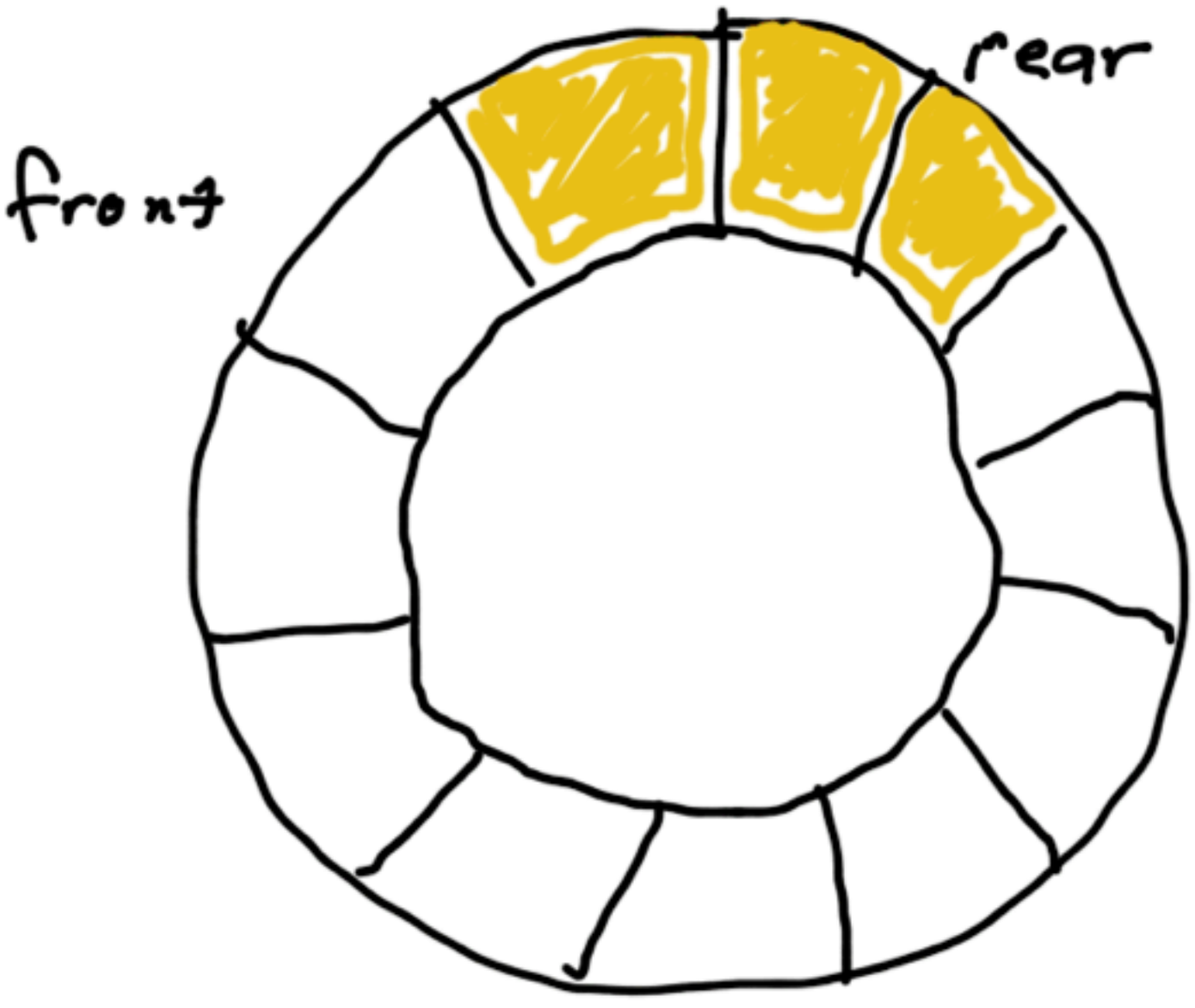
Structure

- Same as a queue, except:
- Size is limited whereas a plain queue can grow arbitrarily
- Typically implemented with a ring buffer built on an array

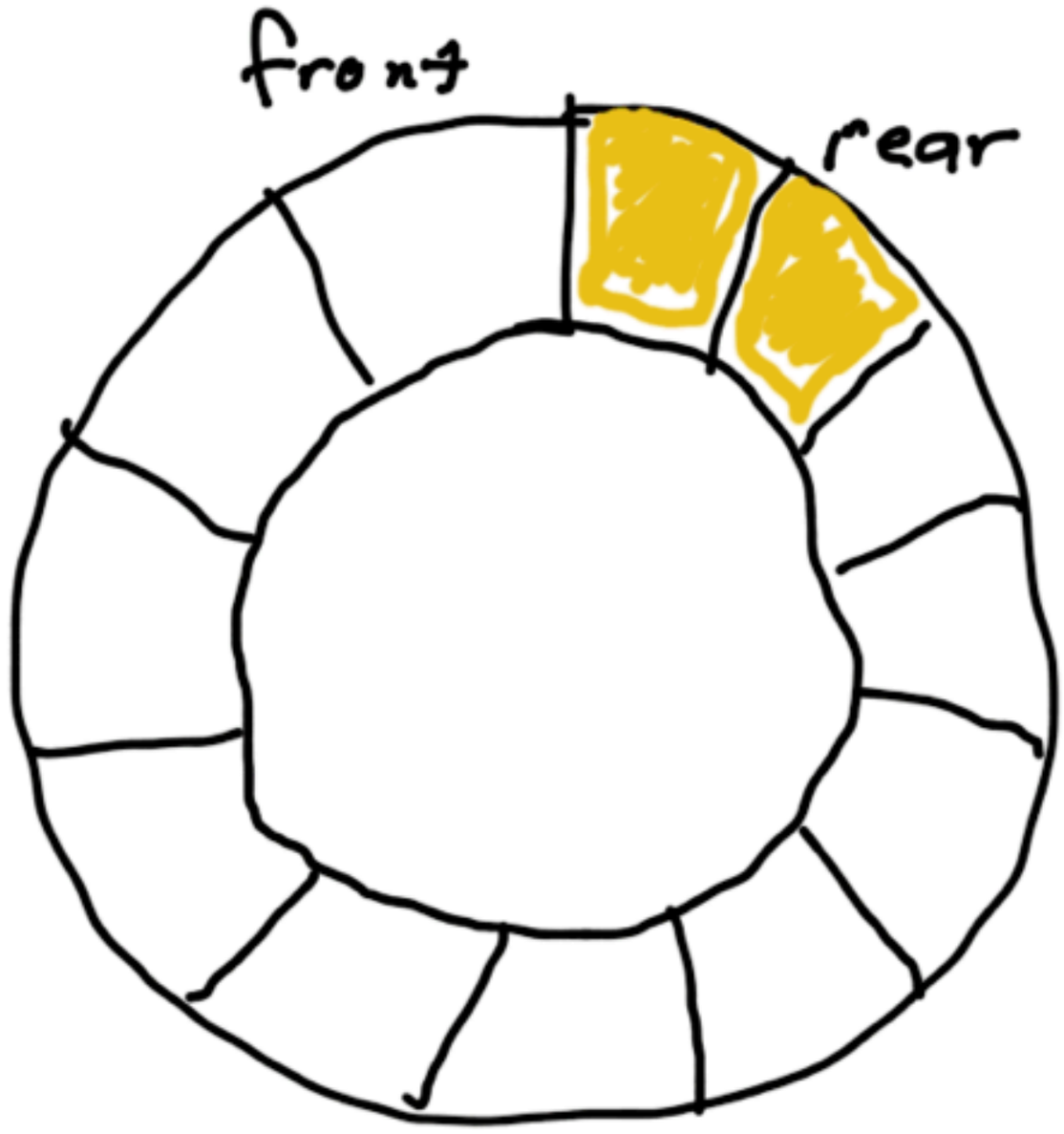
Empty



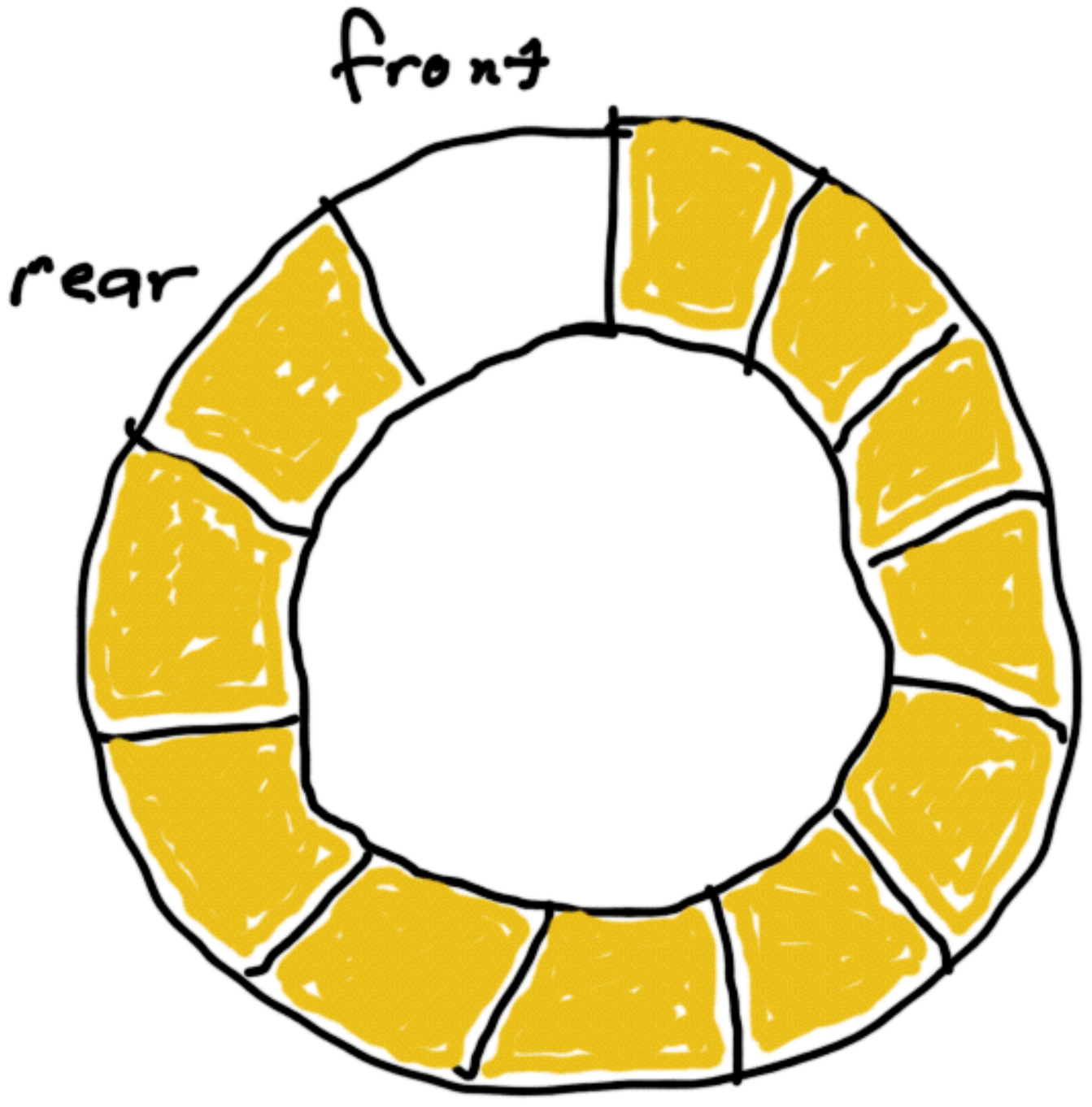
Add a few



Remove one



Full



Operations

- empty?
- full?
- enqueue
- dequeue
- do we need to know the size?

Exercise

- Implement DbcCircularQueue
  - https://github.com/dastels/dbc-deep-dives.git
  - Algo directory
  - delete the contents of the lib dir, and put dbc_circular_queue.rb there
  - You can build on top of Ruby's array
  - Use rspec spec/circular_queue_spec.rb to guide you

Applications

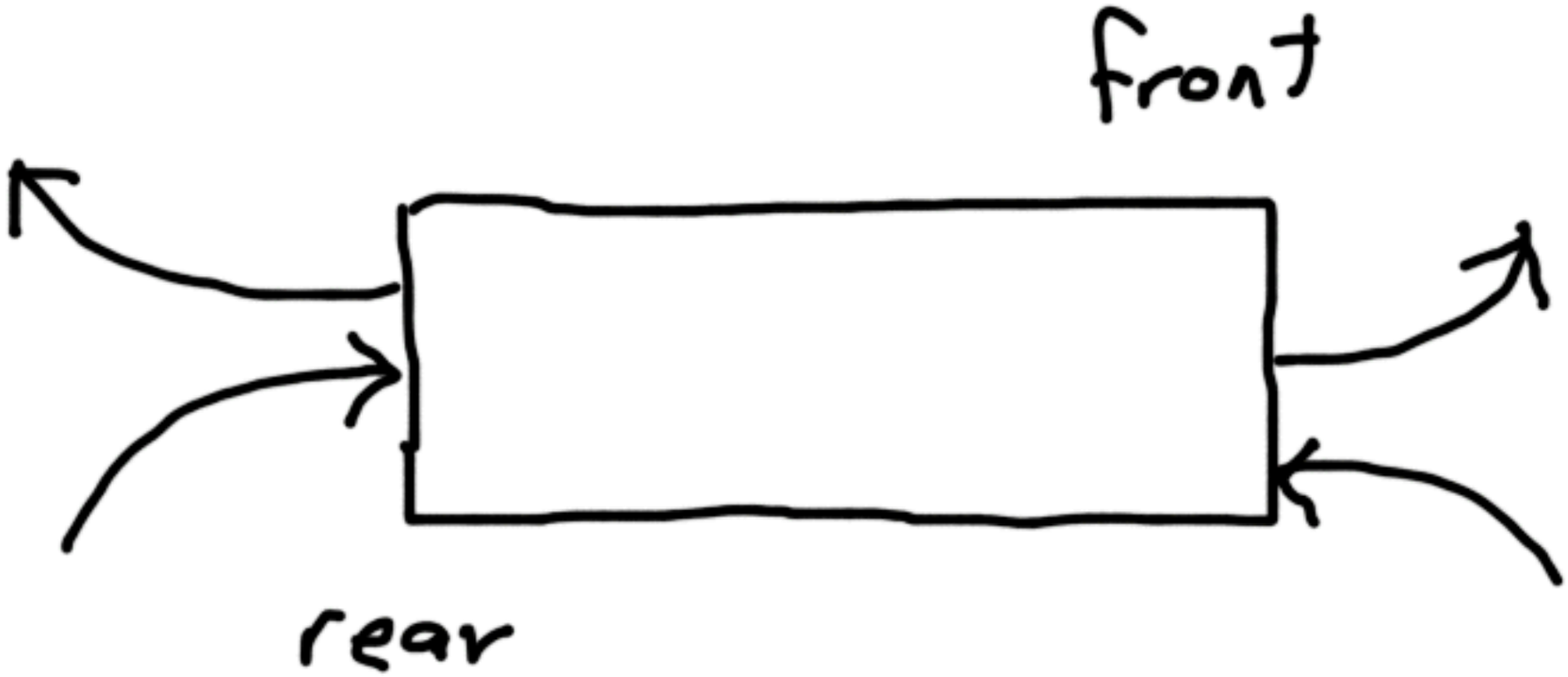
- Anywhere you would use a queue, but want to constrain it’s size, with fixed memory allocation.

Double Ended Queue

Structure

- Like a queue, but you and enqueue and dequeue on both ends.

Structure



Operations

- empty?
- full?
- enqueue_front
- enqueue_rear
- dequeue_front
- dequeue_rear
- do we need to know the size?

Exercise

- Implement DbcDoubleEndedQueue
  - https://github.com/dastels/dbc-deep-dives.git
  - Algo directory
    - delete the contents of the lib dir, and put dbc_double_ended_queue.rb there
    - You can build on top of Ruby's array
    - Use rspec spec/double_ended_queue_spec.rb to guide you

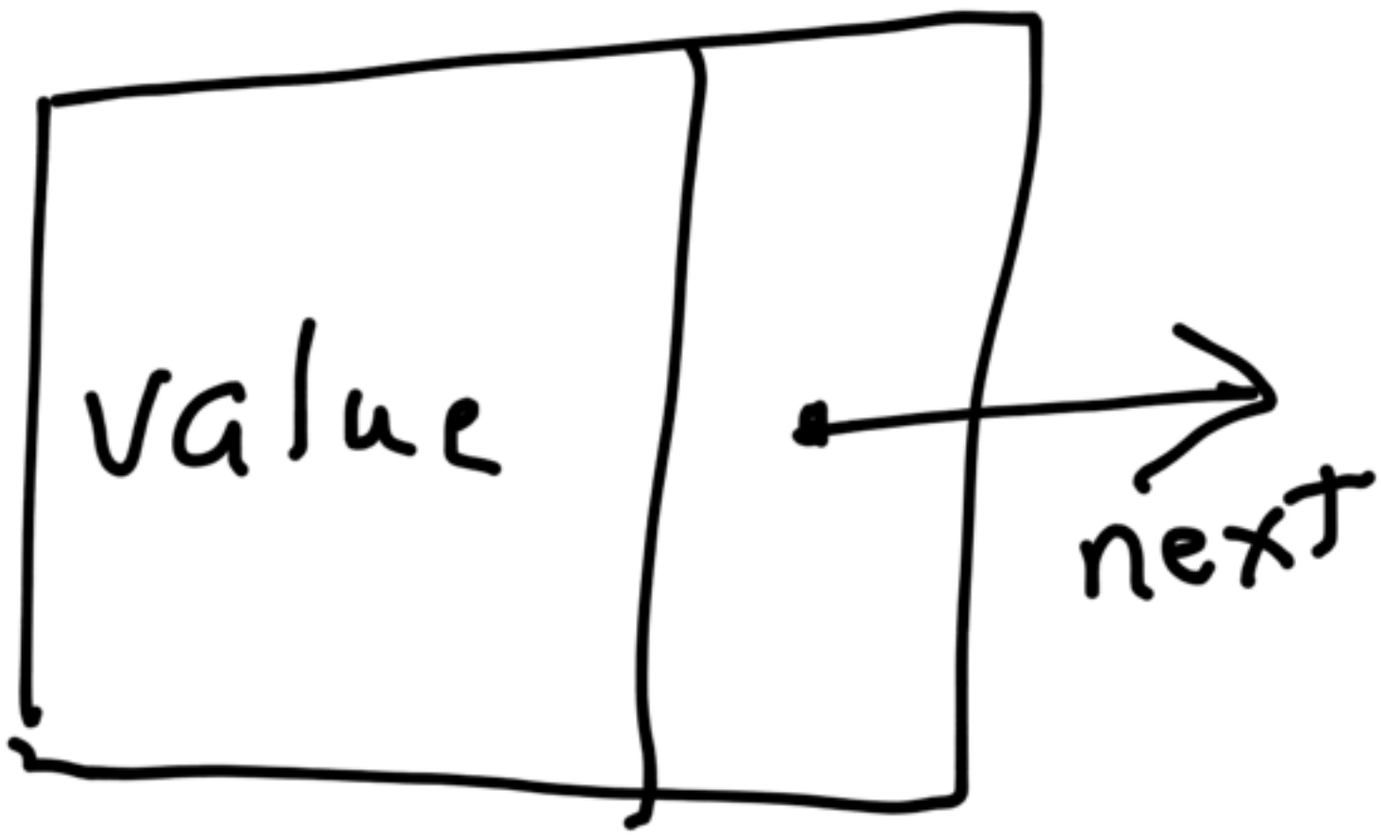
Applications

Singly Linked List

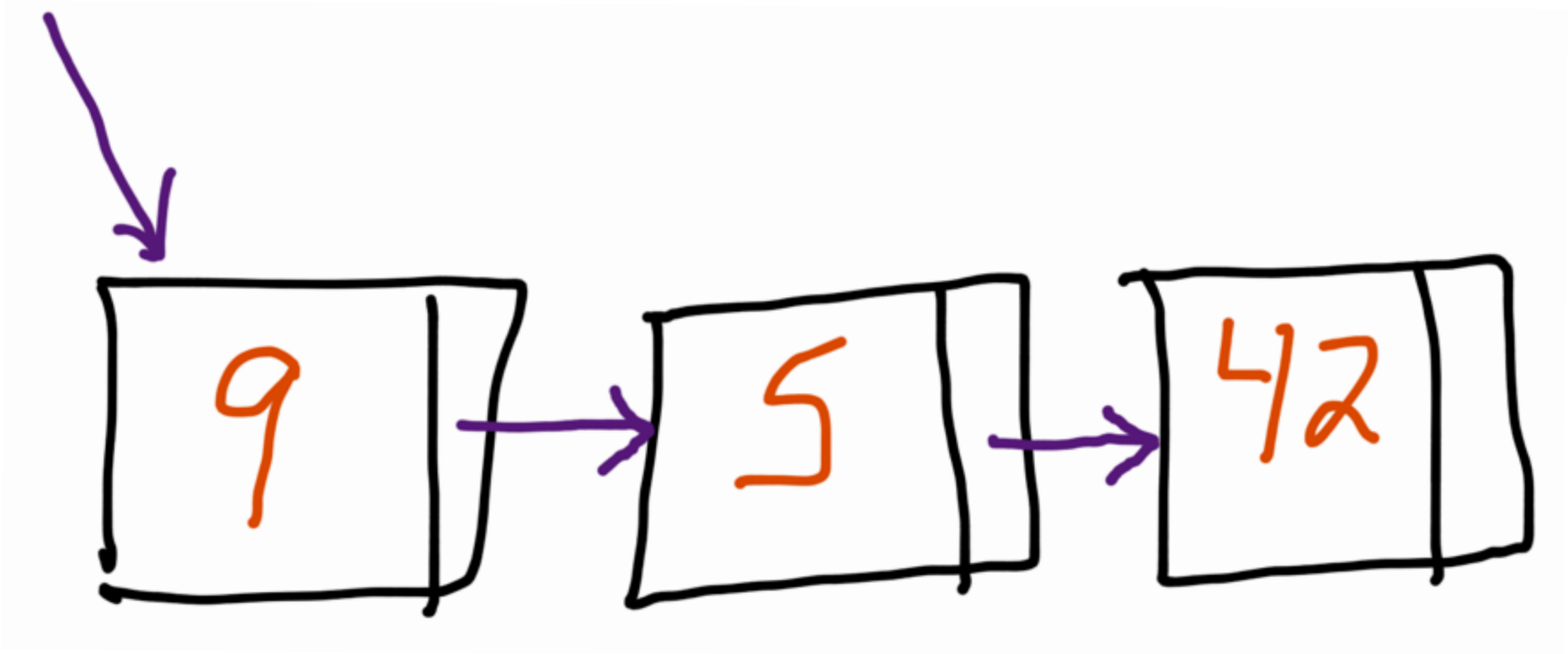
Structure

- A list of nodes, each with a value and a reference to the next node in the list.

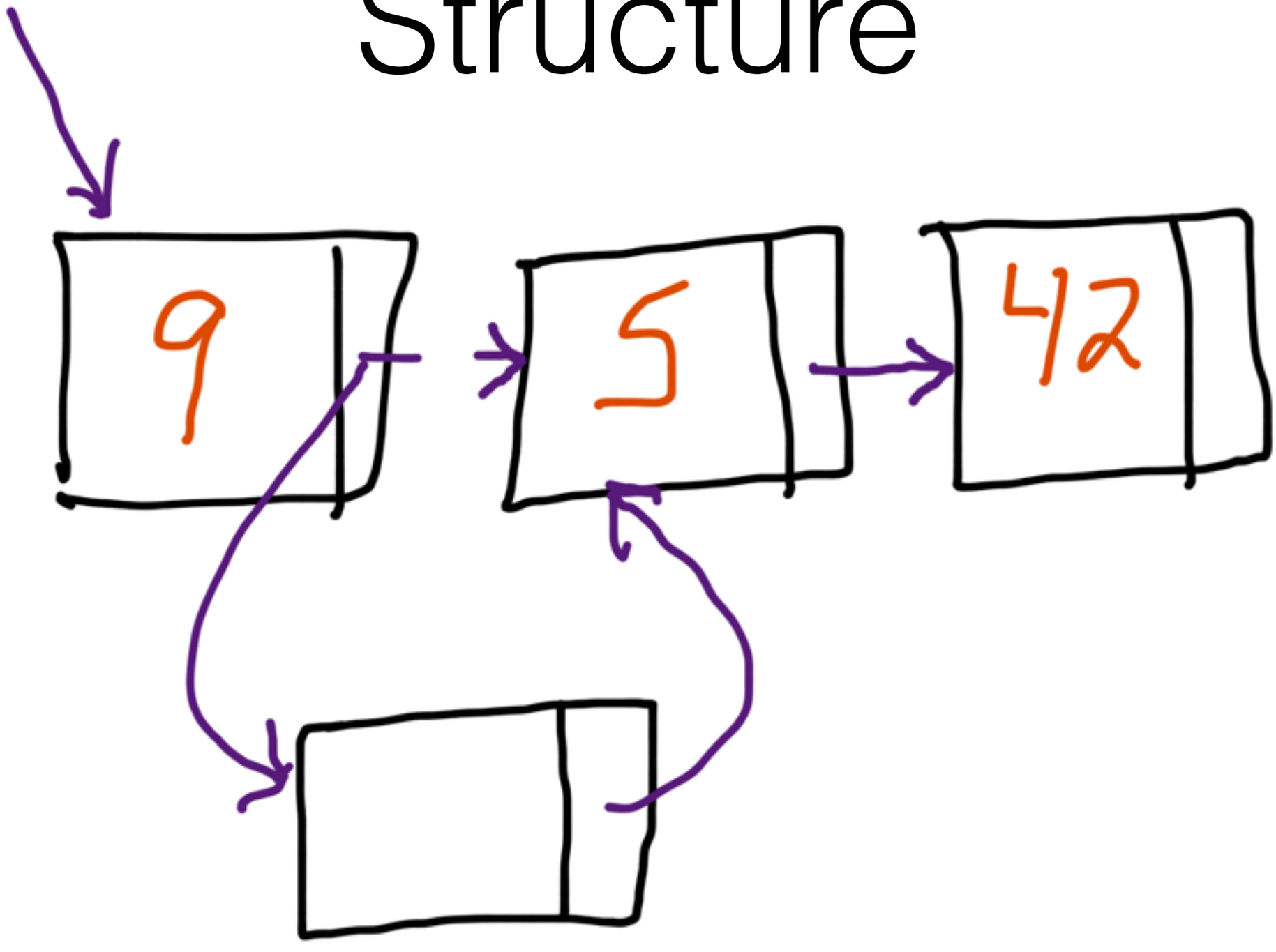
Structure



Structure



Structure



Operations

- empty?
- size
- insert
- delete
- append
- prepend
- find
- map
- reduce

Exercise

- Implement DbcLinkedList
  - https://github.com/dastels/dbc-deep-dives.git
    - DataStructures directory
    - delete the contents of the lib dir, and put dbc_linked_list.rb there
    - Use rspec spec/linked_list_spec.rb to guide you

Exercise

- Try to make recursive solutions.

- Let's walk through implementing size together.

Applications

Doubly Linked List

Tree

Structure

- An arrangement of nodes, each of which can reference some number of other nodes, and can only be referenced by a single node.
- A linked list is like a degenerate tree where each node refers to at most one other node.

Binary Search Tree

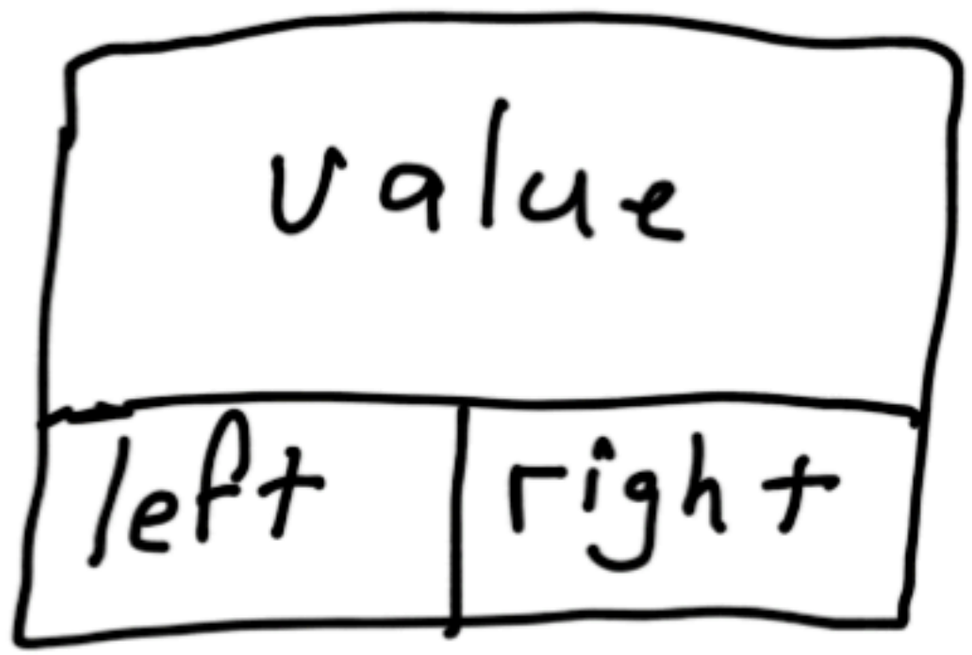
Structure

- An arrangement of nodes, each of which can reference at most **two** other nodes, and can only be referenced by a single node.

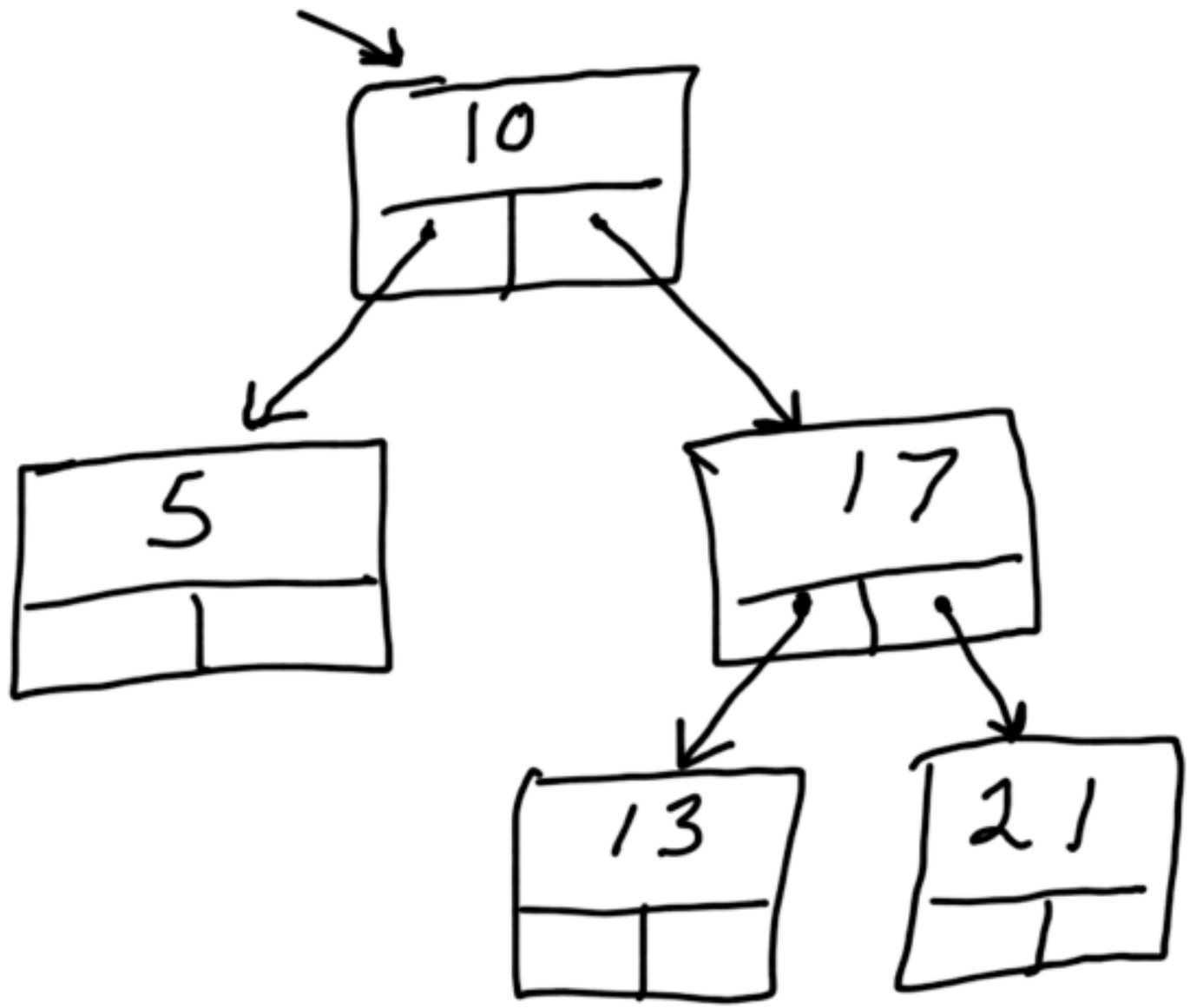
- Acyclic

- Directed

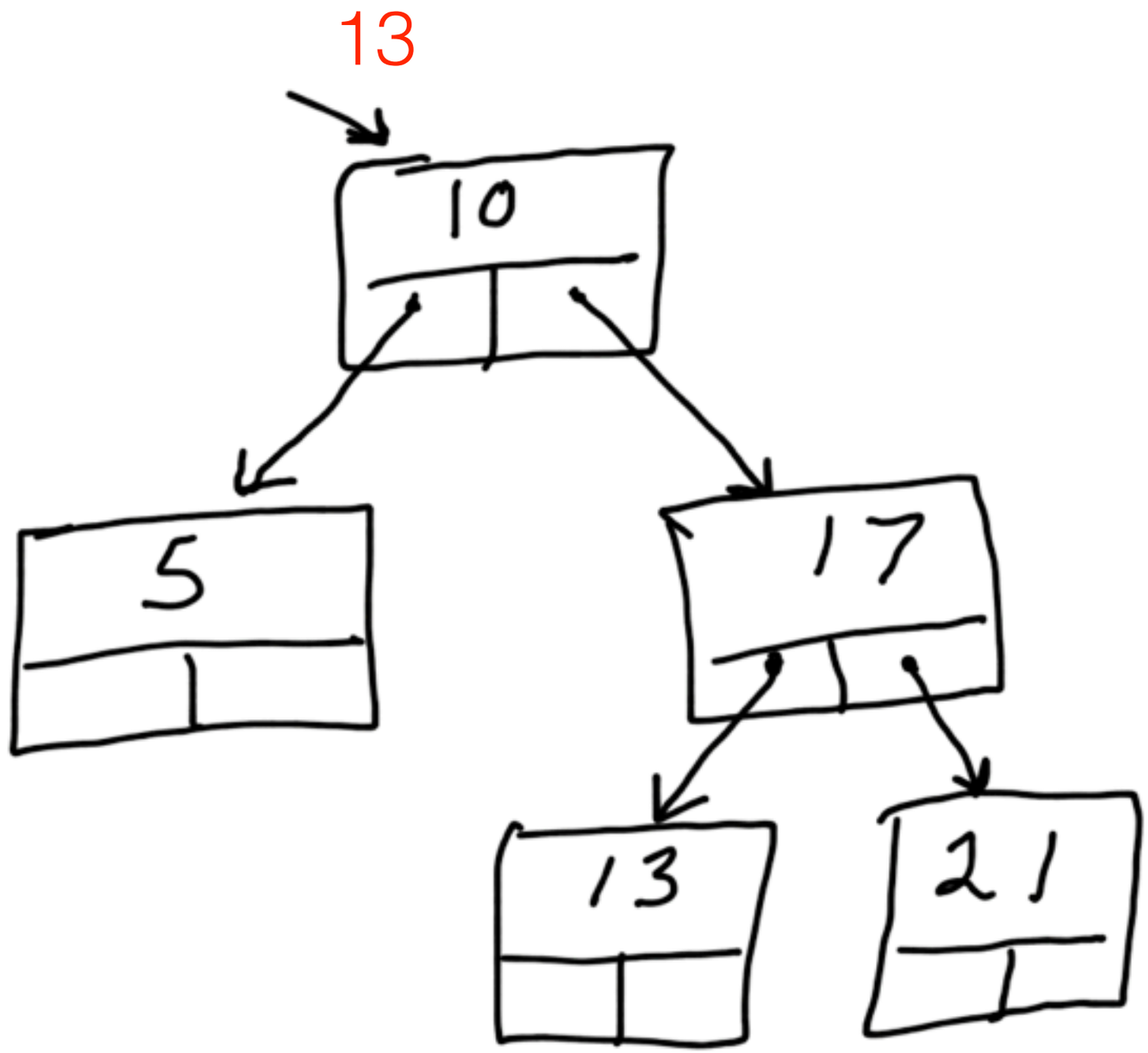
Structure



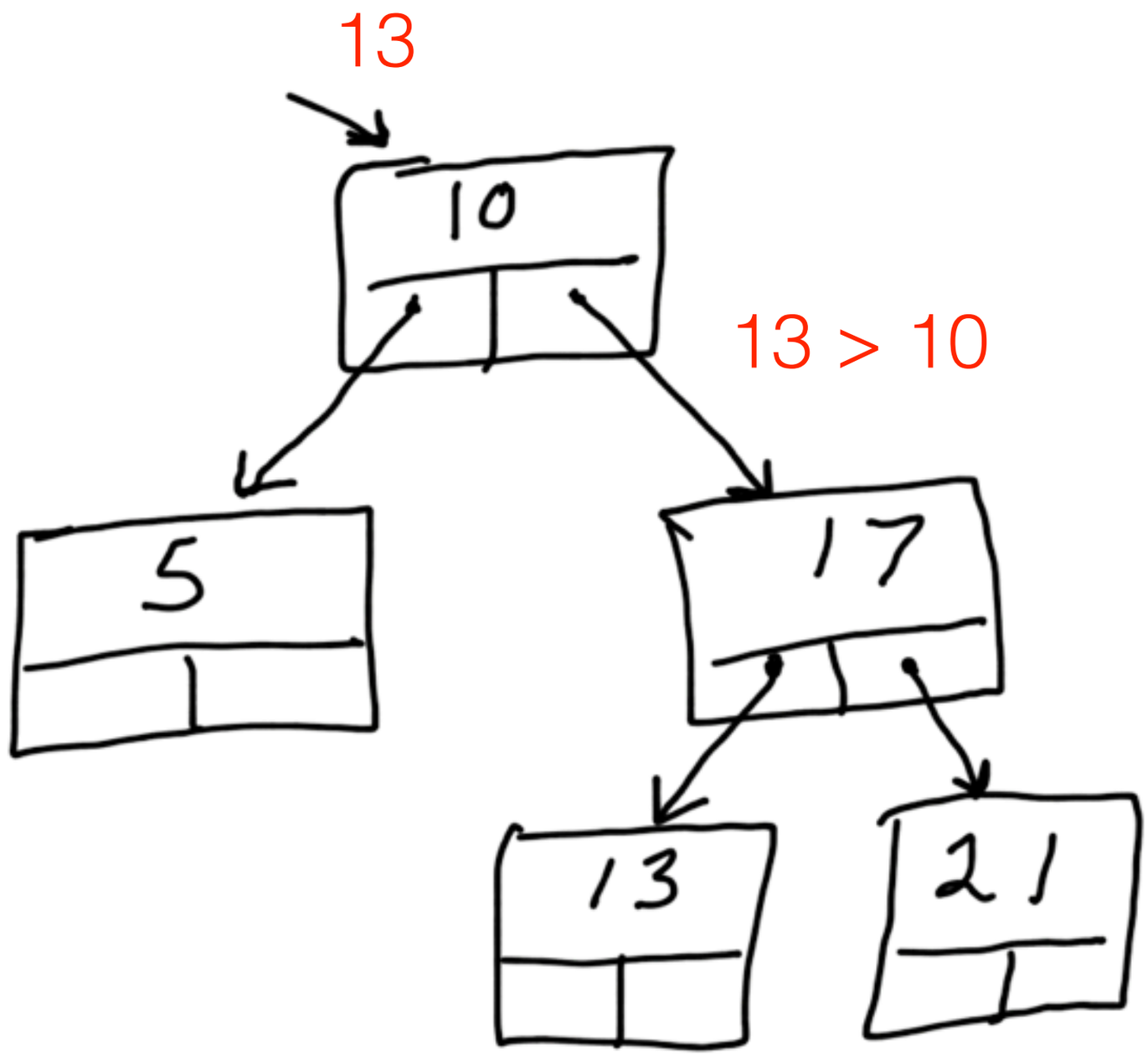
Searching



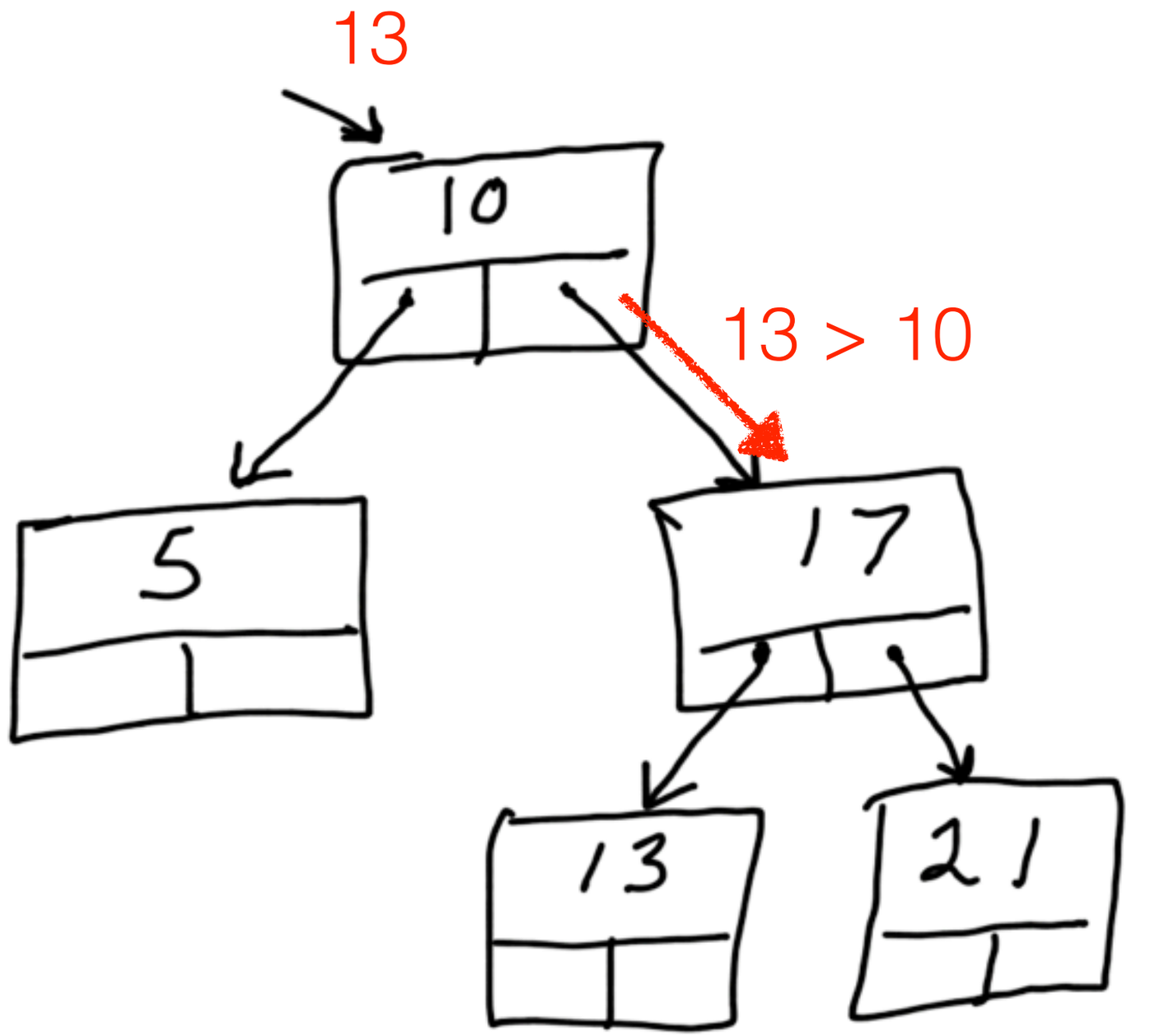
Searching



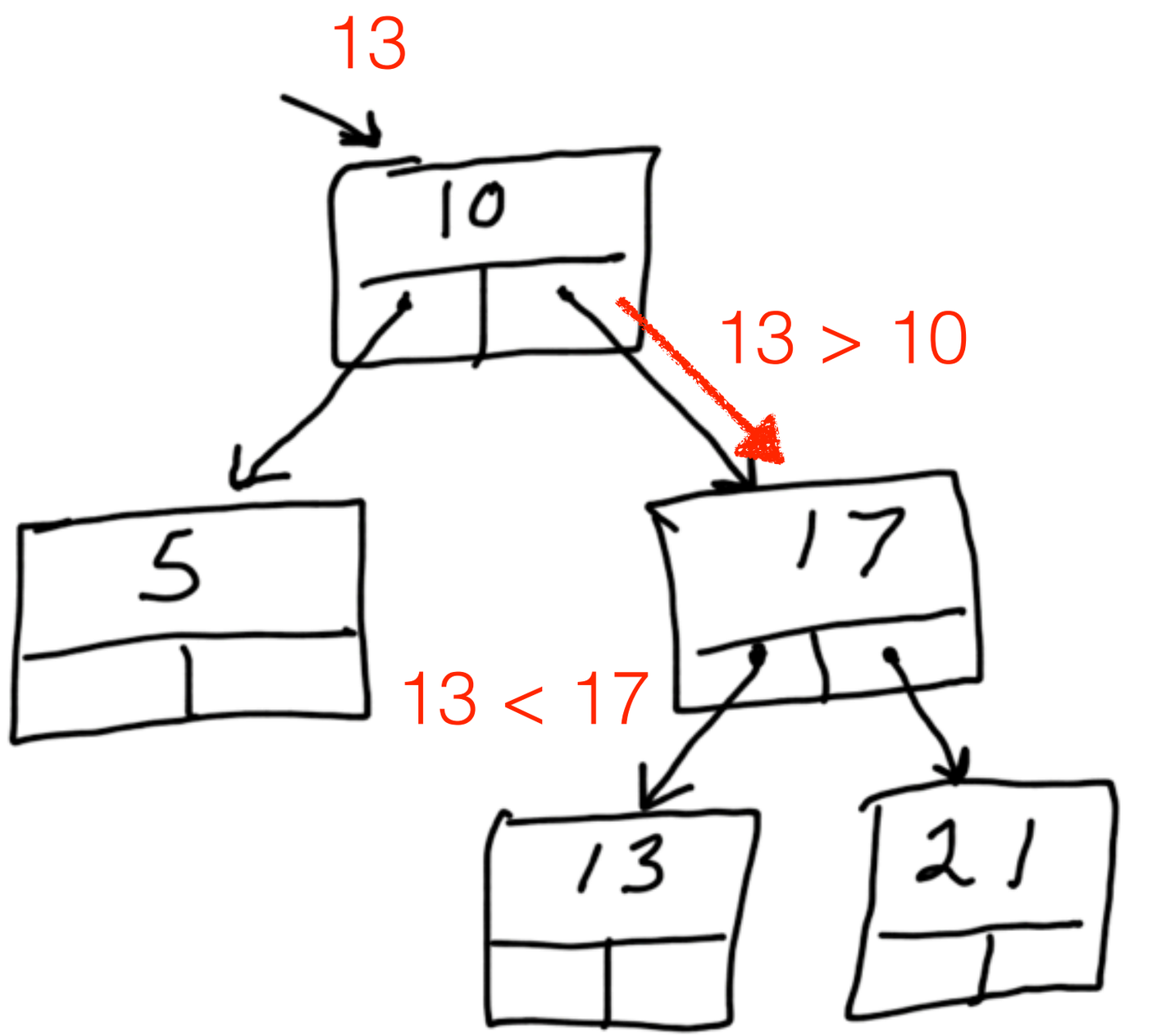
Searching



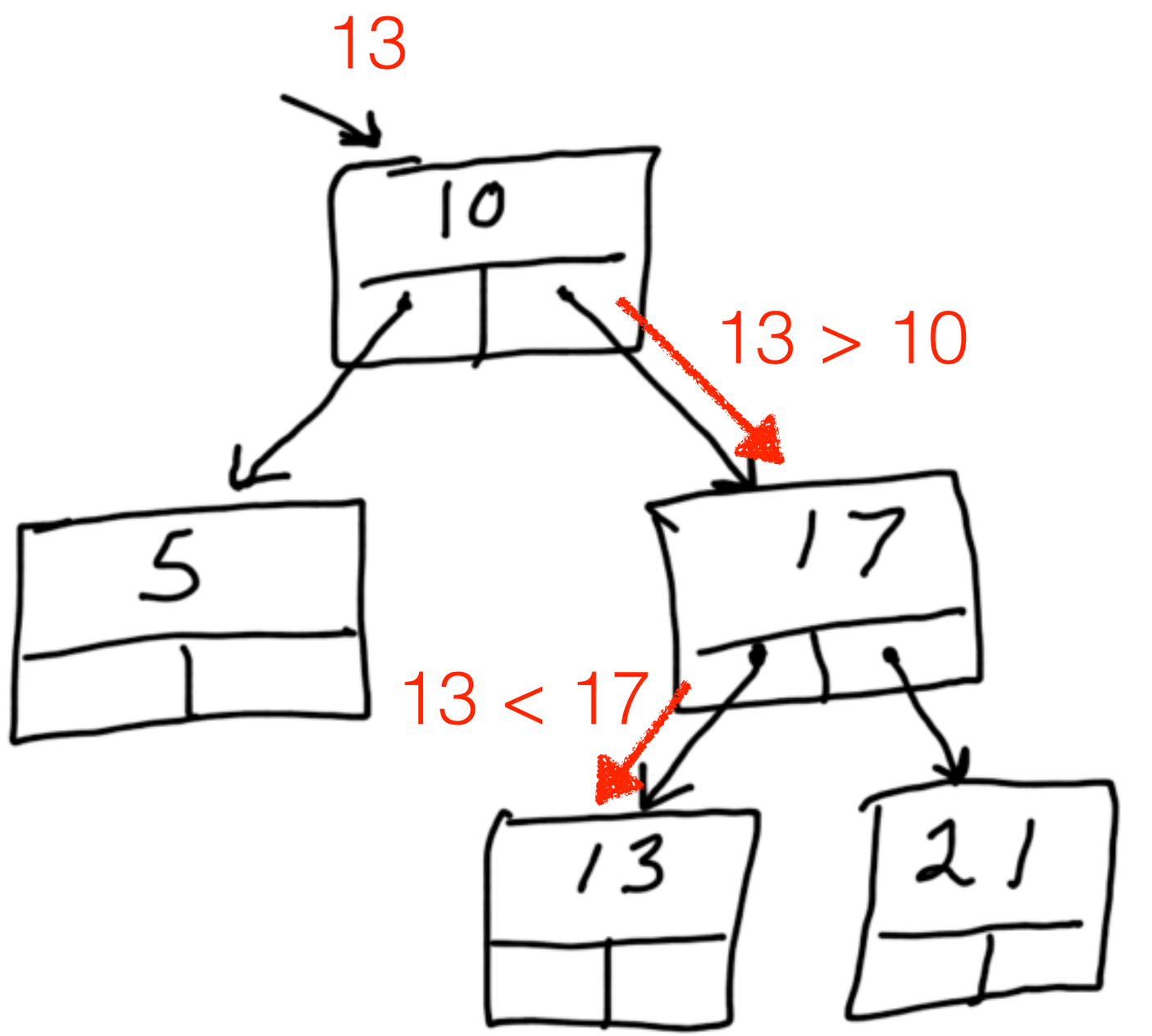
Searching



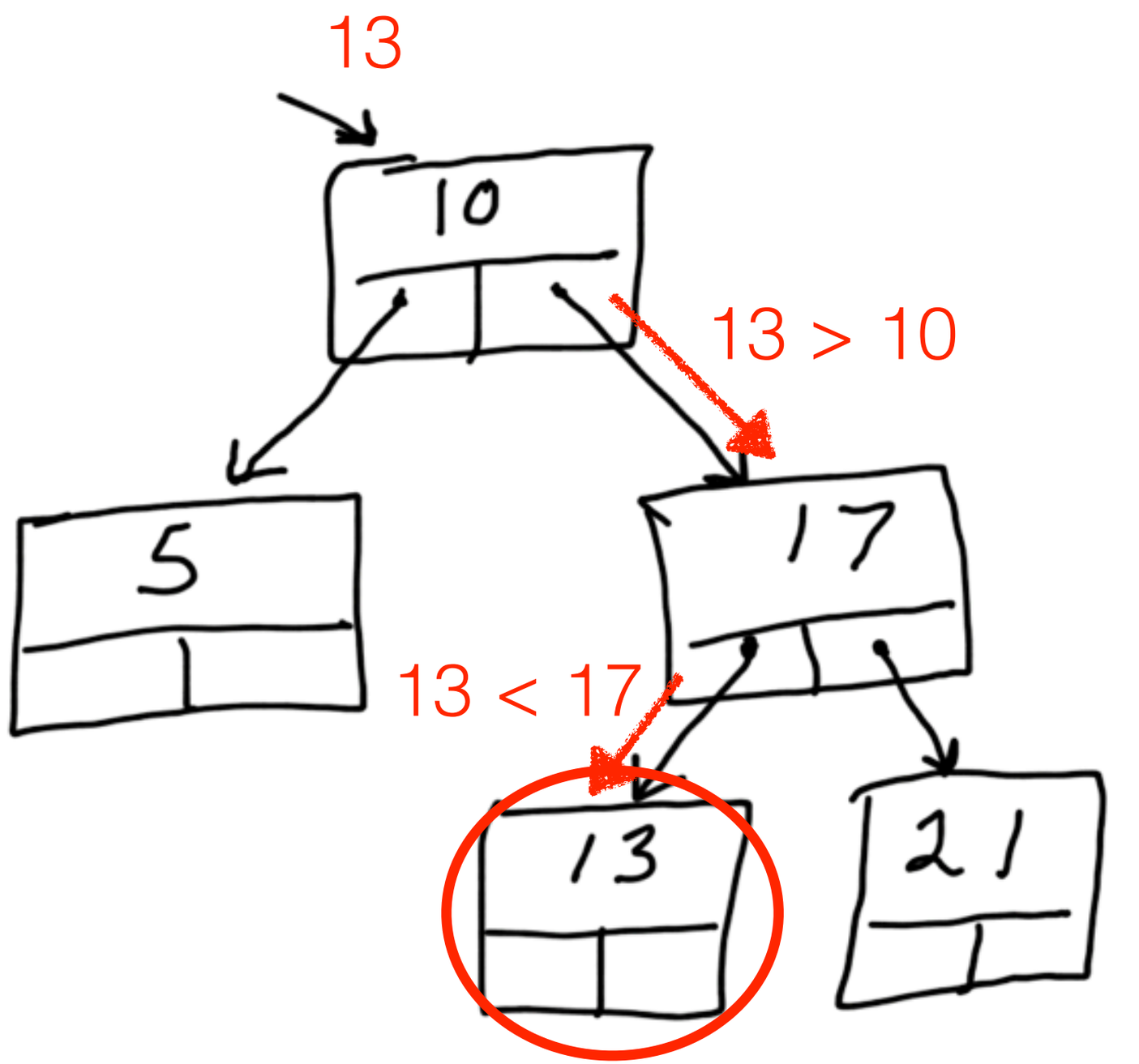
Searching



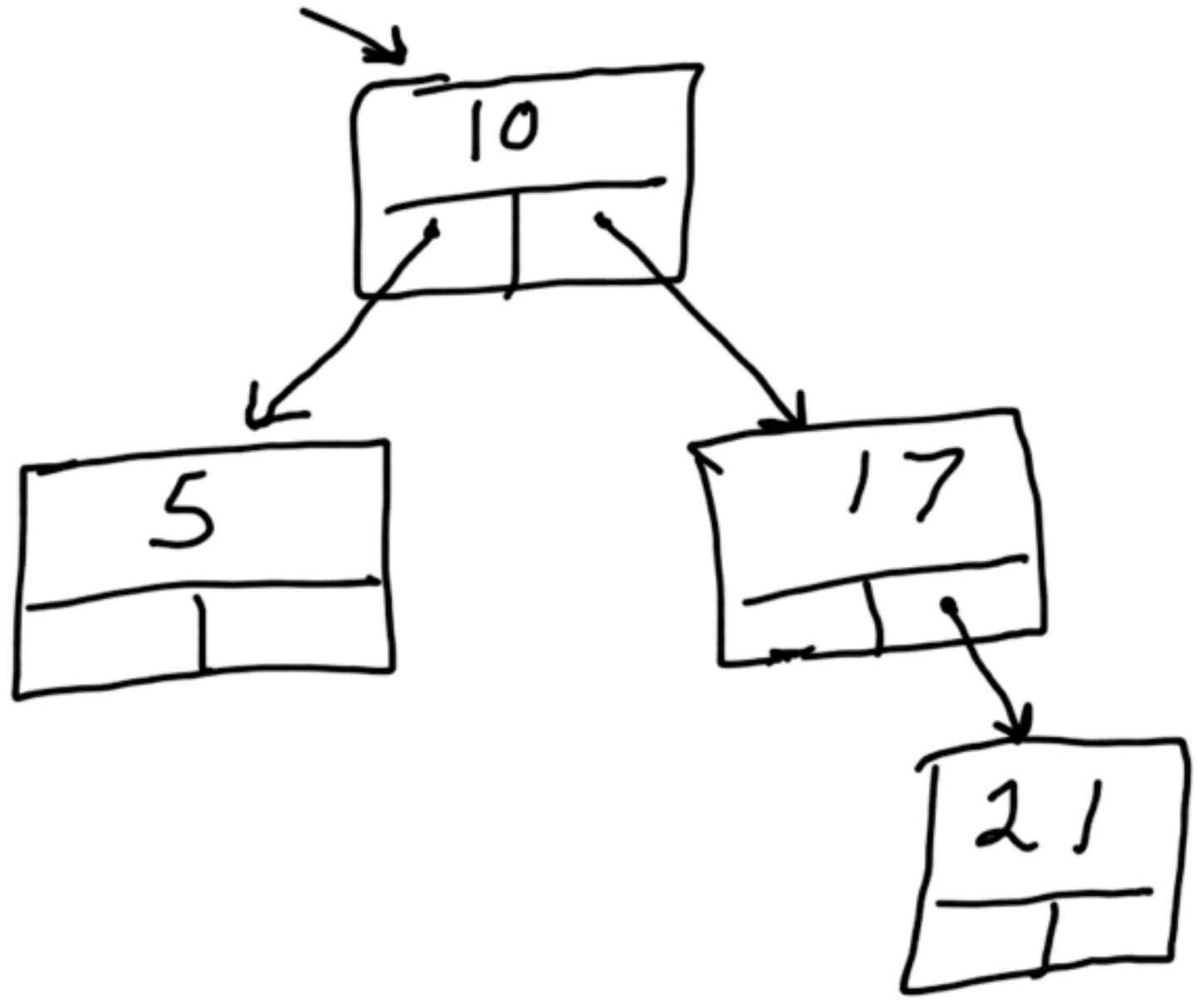
Searching



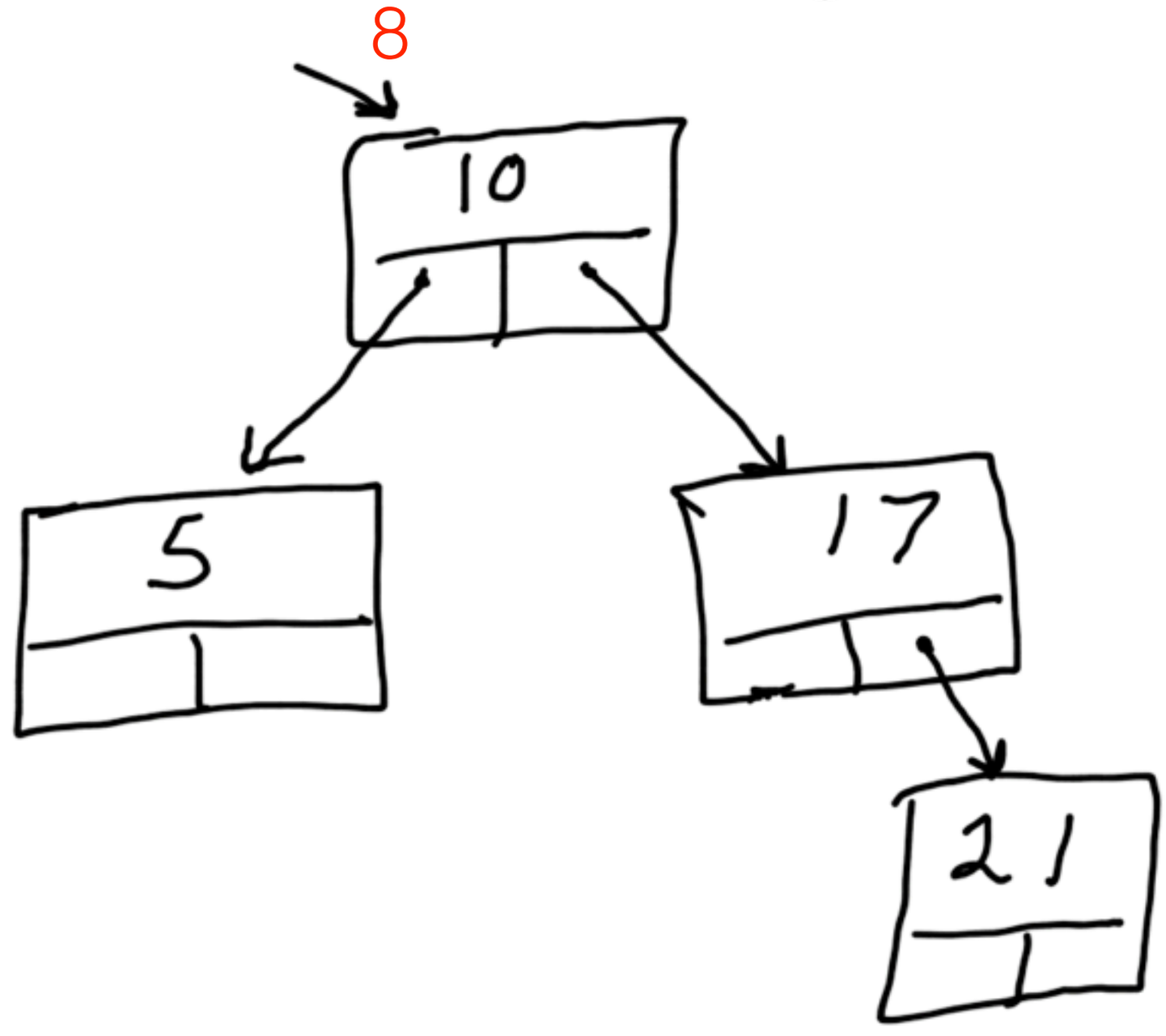
Searching



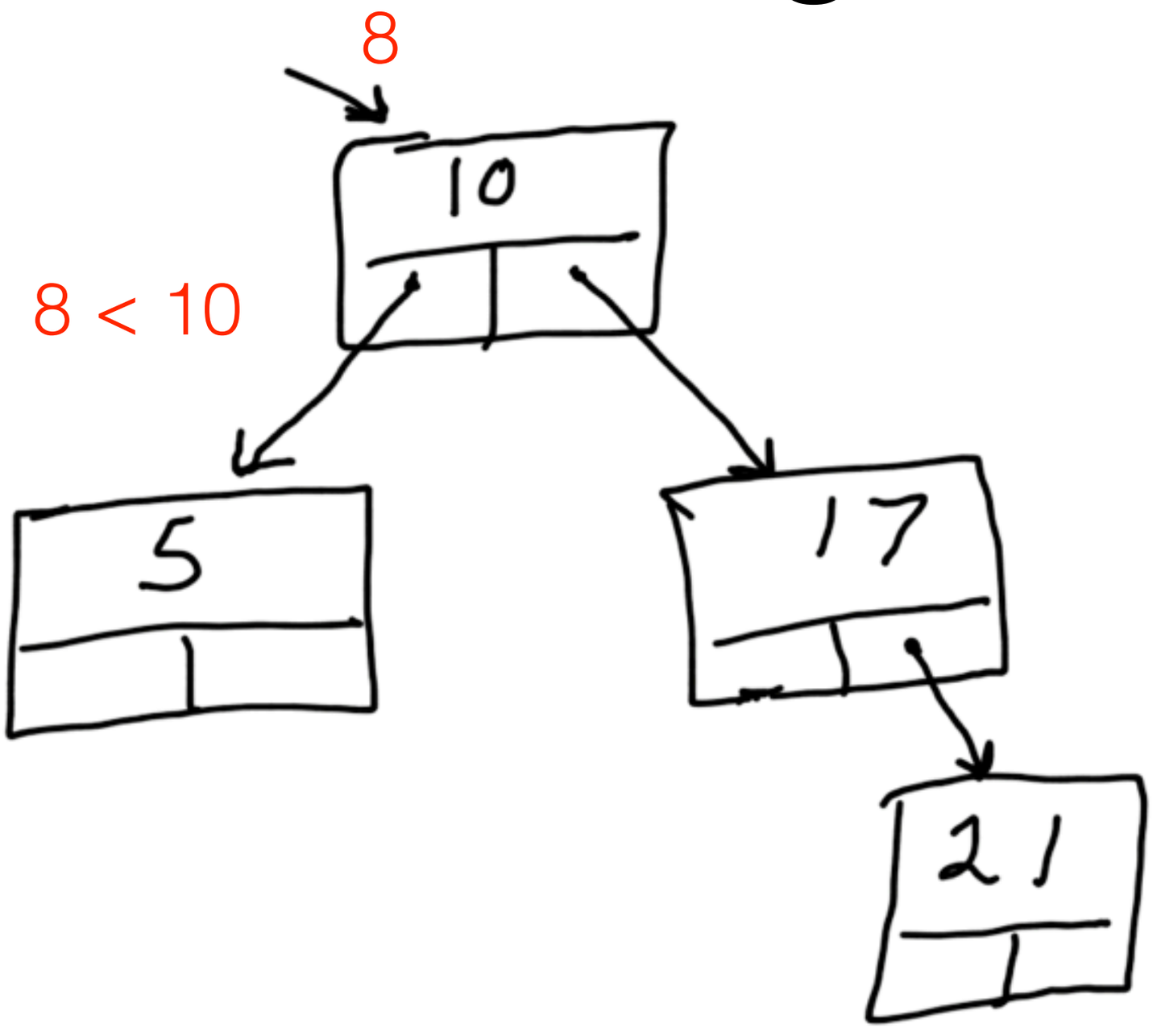
Inserting



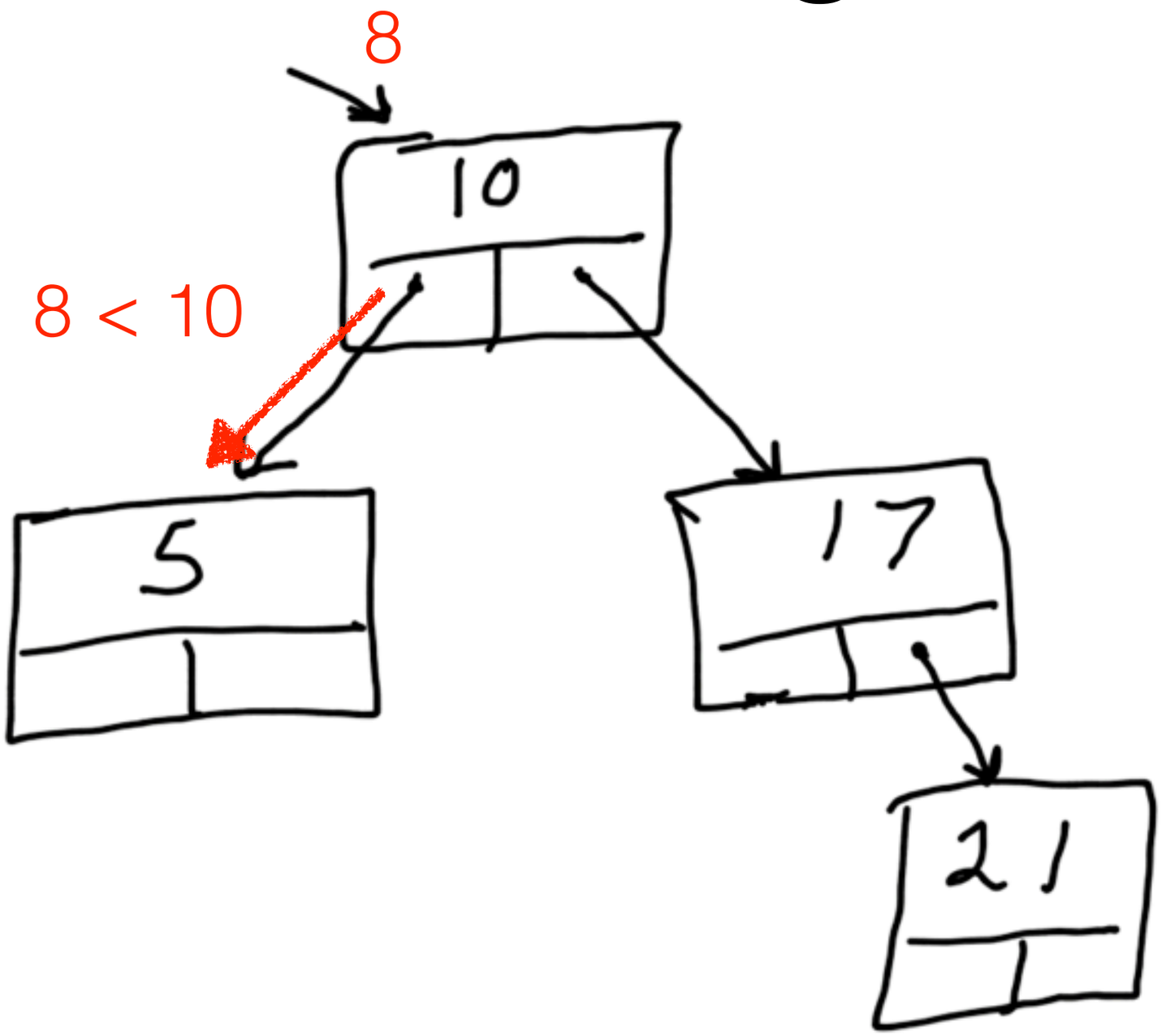
Inserting



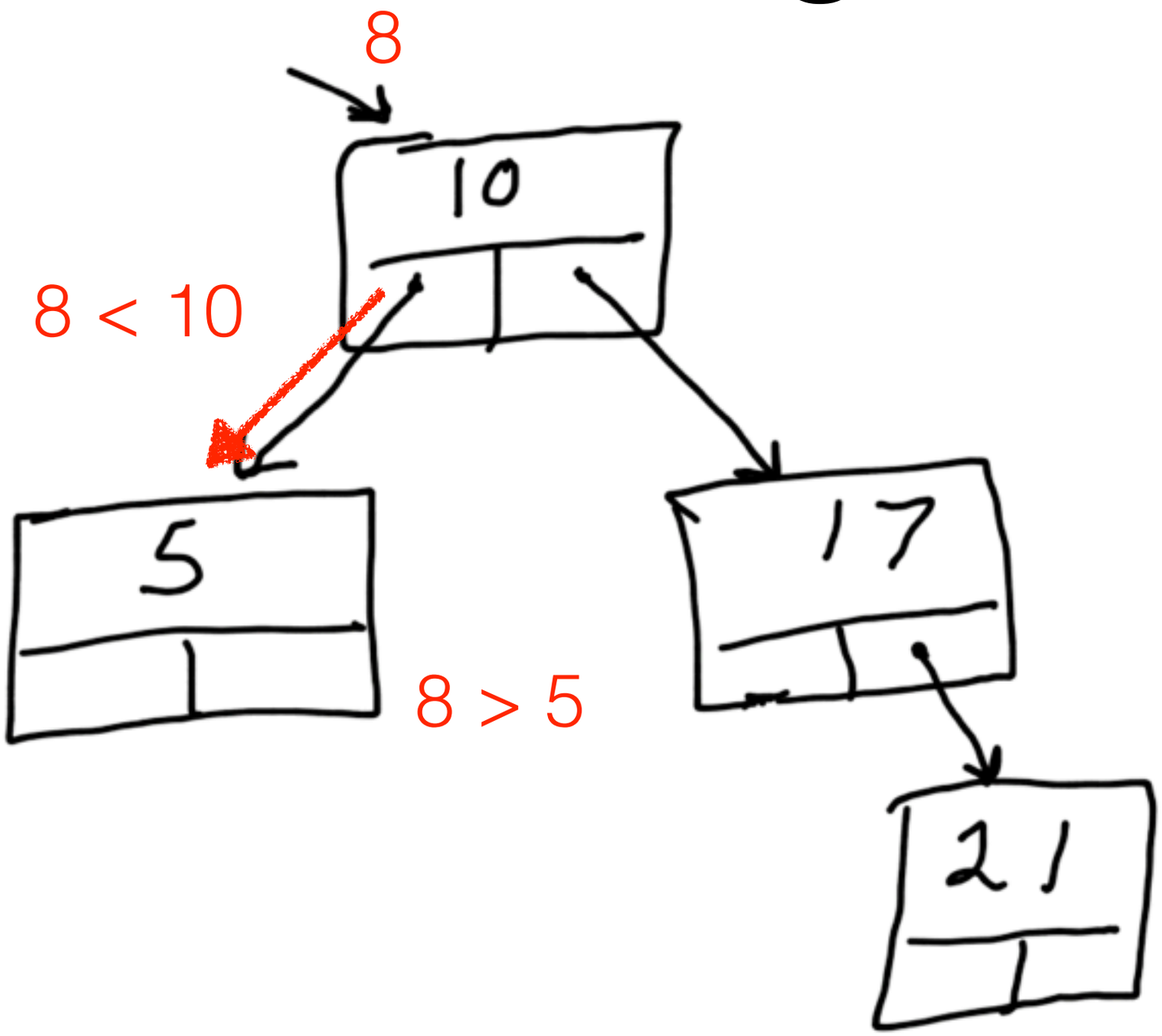
Inserting



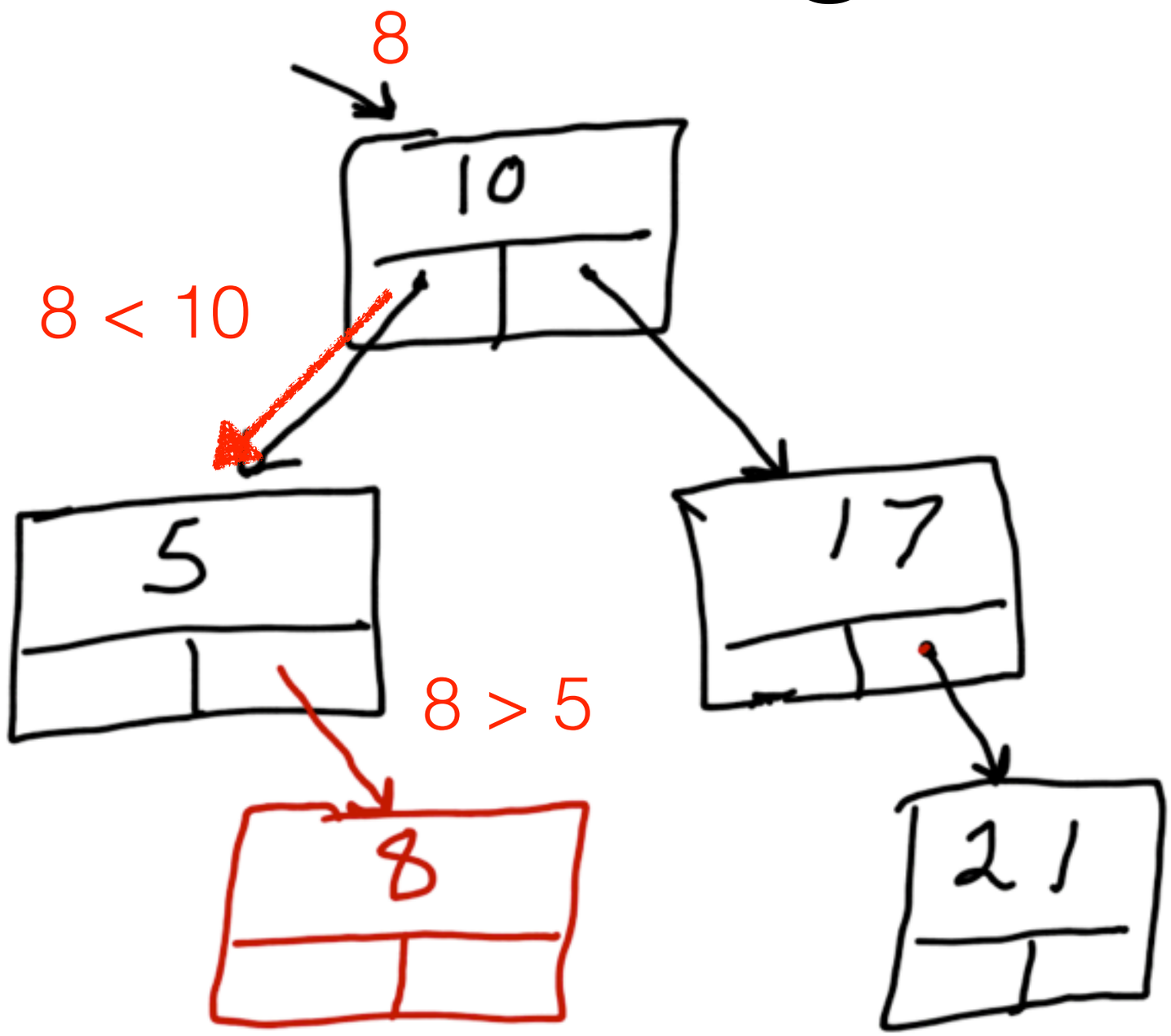
Inserting



Inserting



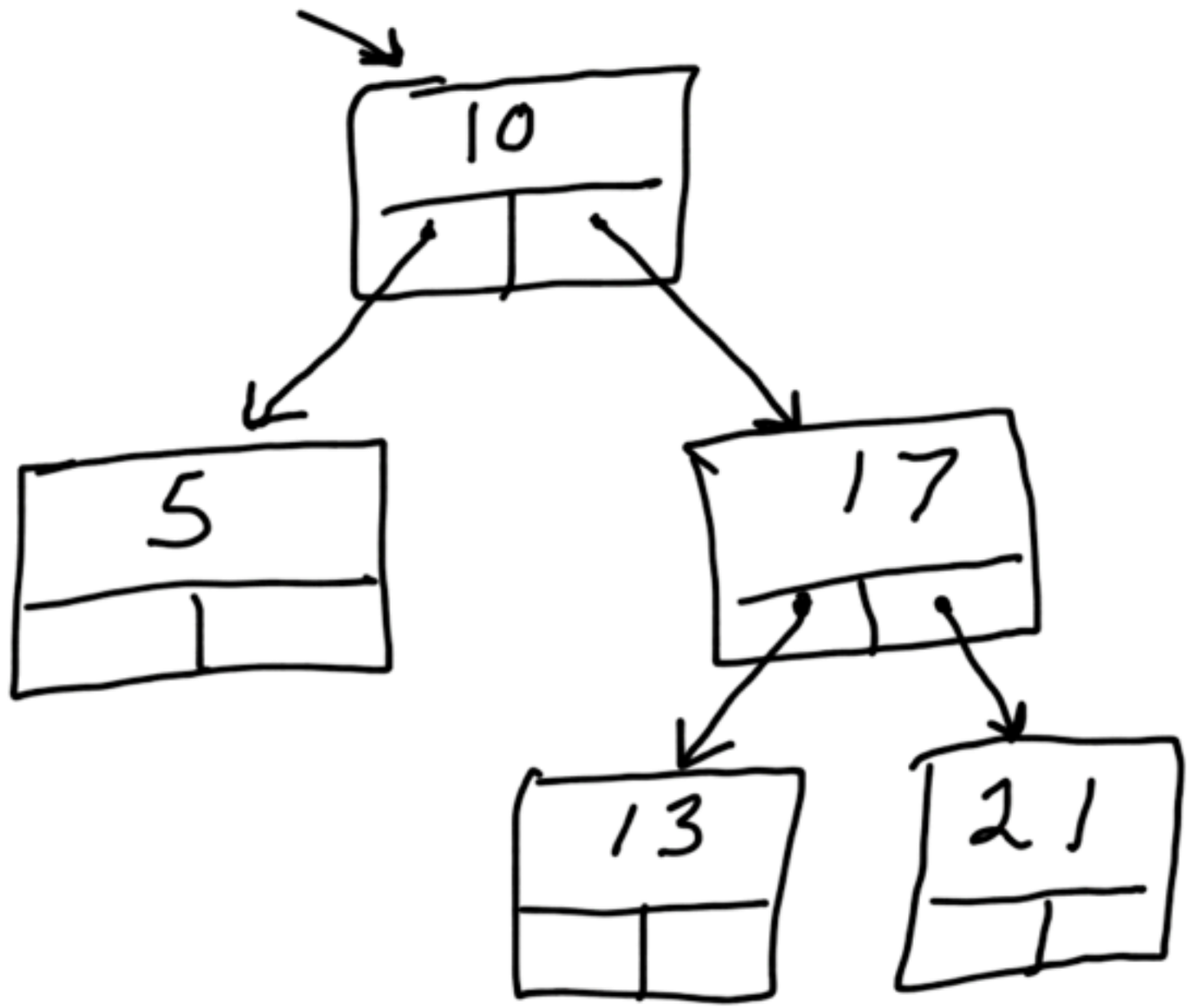
Inserting



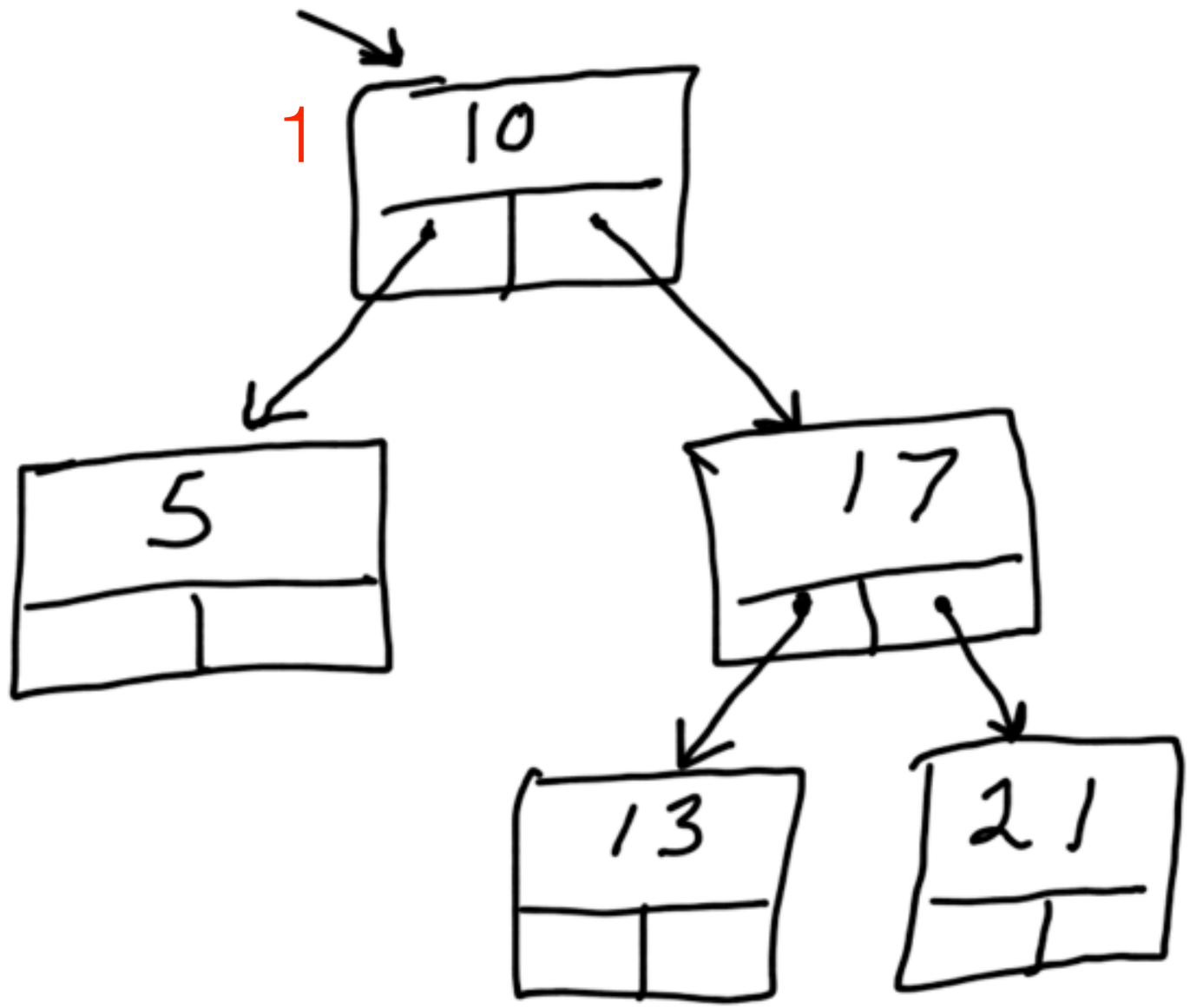
Operations

- size
- depth
- insert
- find
- preorder traversal
- inorder traversal
- postorder traversal
- Bonus: map
- Bonus*: delete

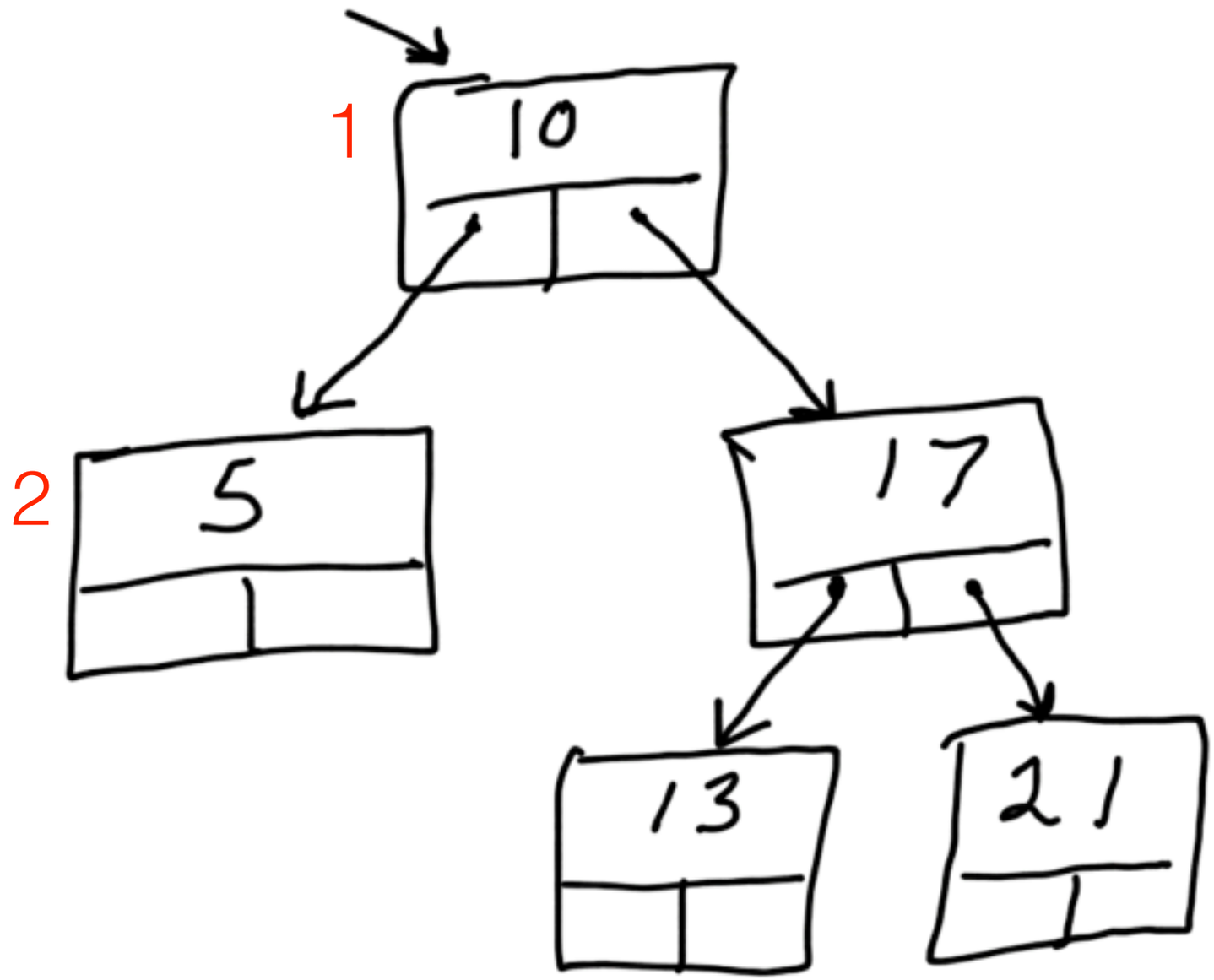
Preorder



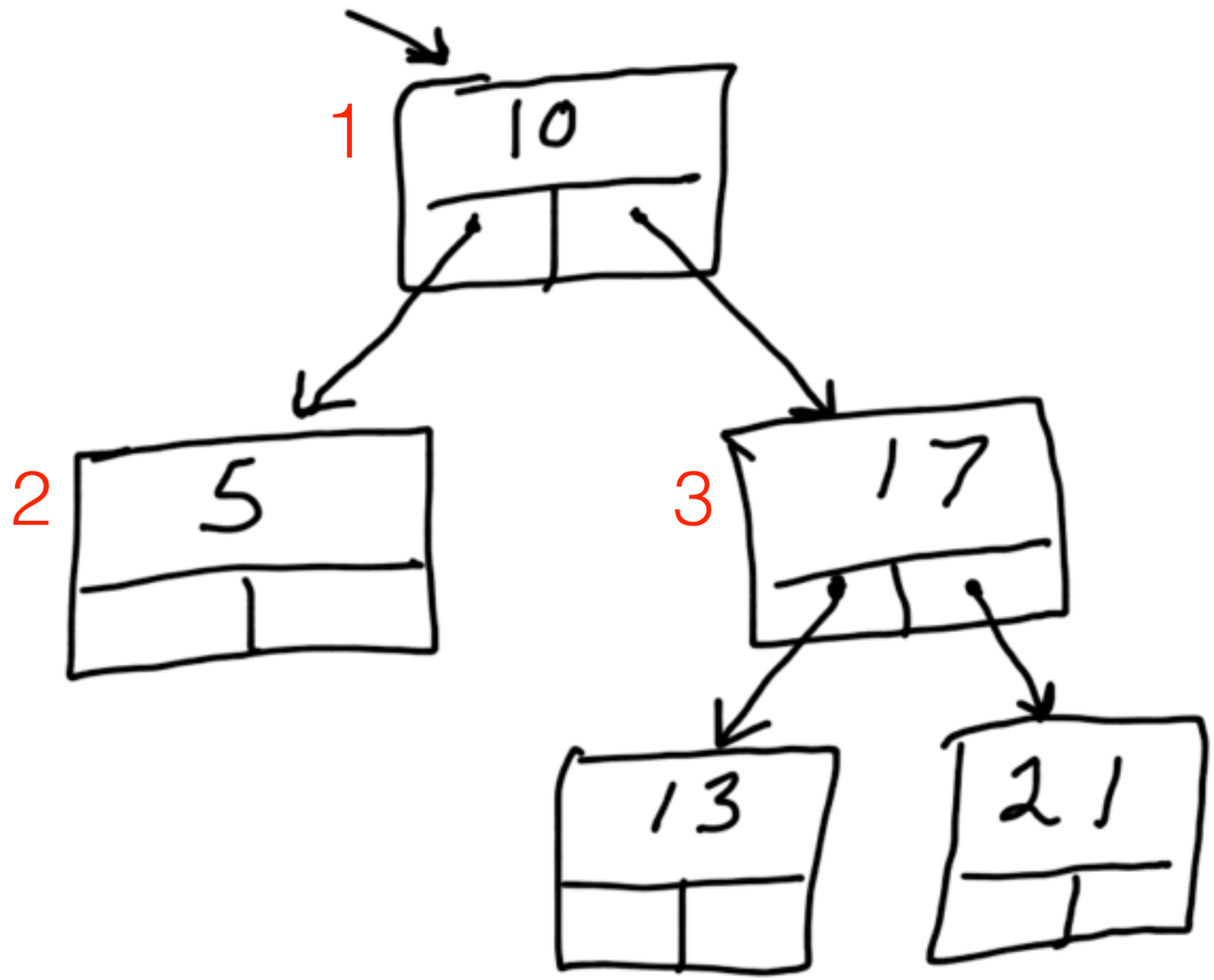
Preorder



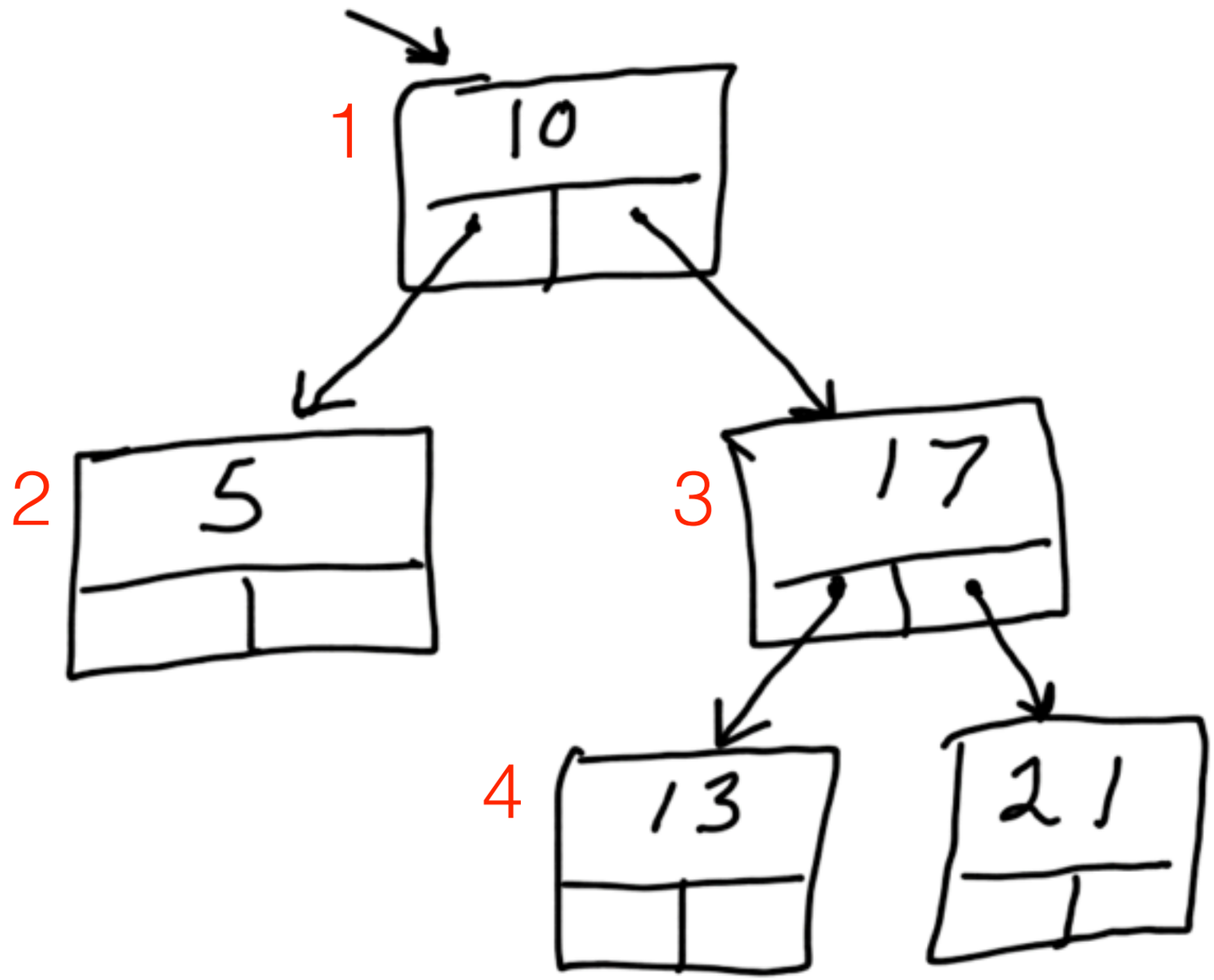
Preorder



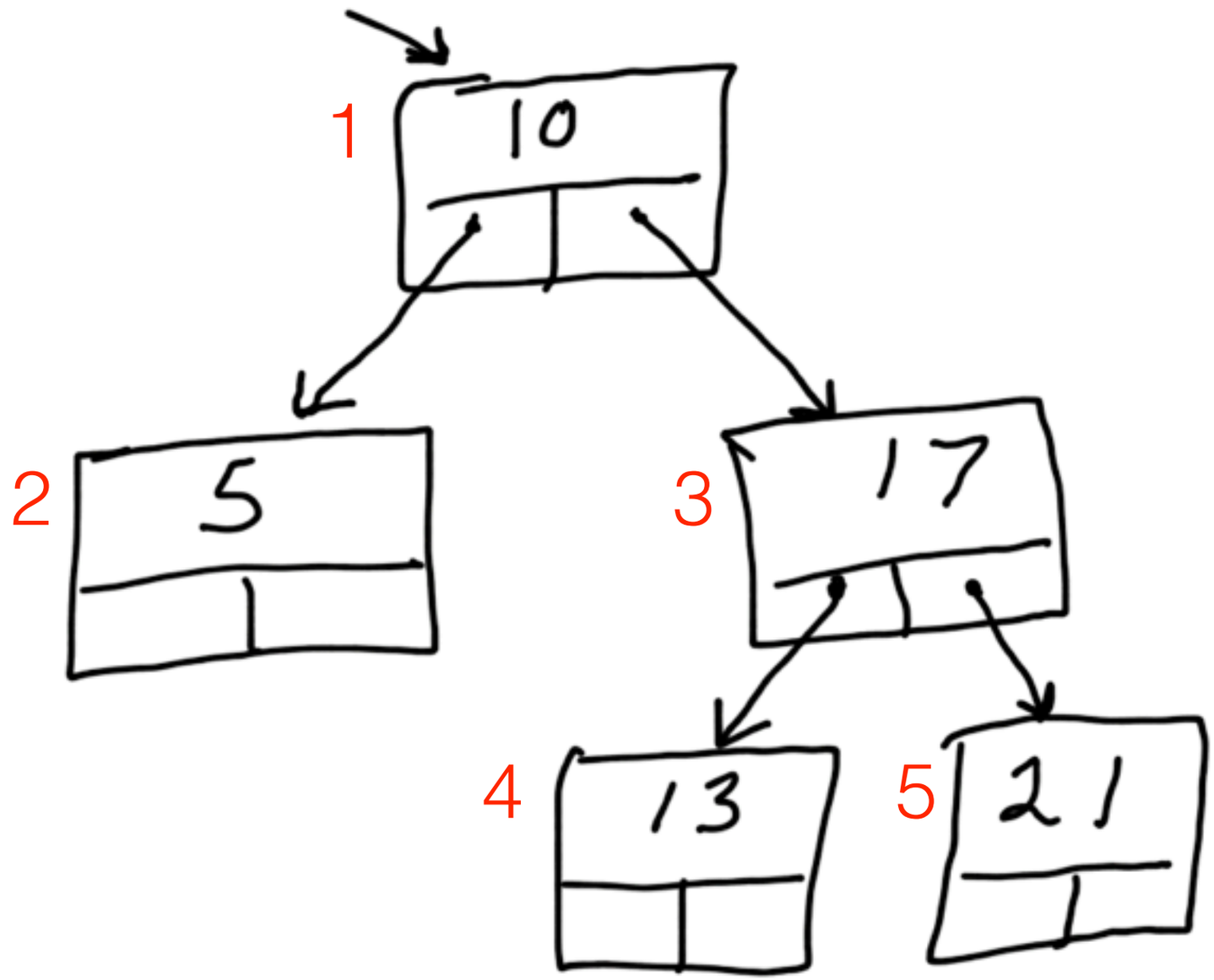
Preorder



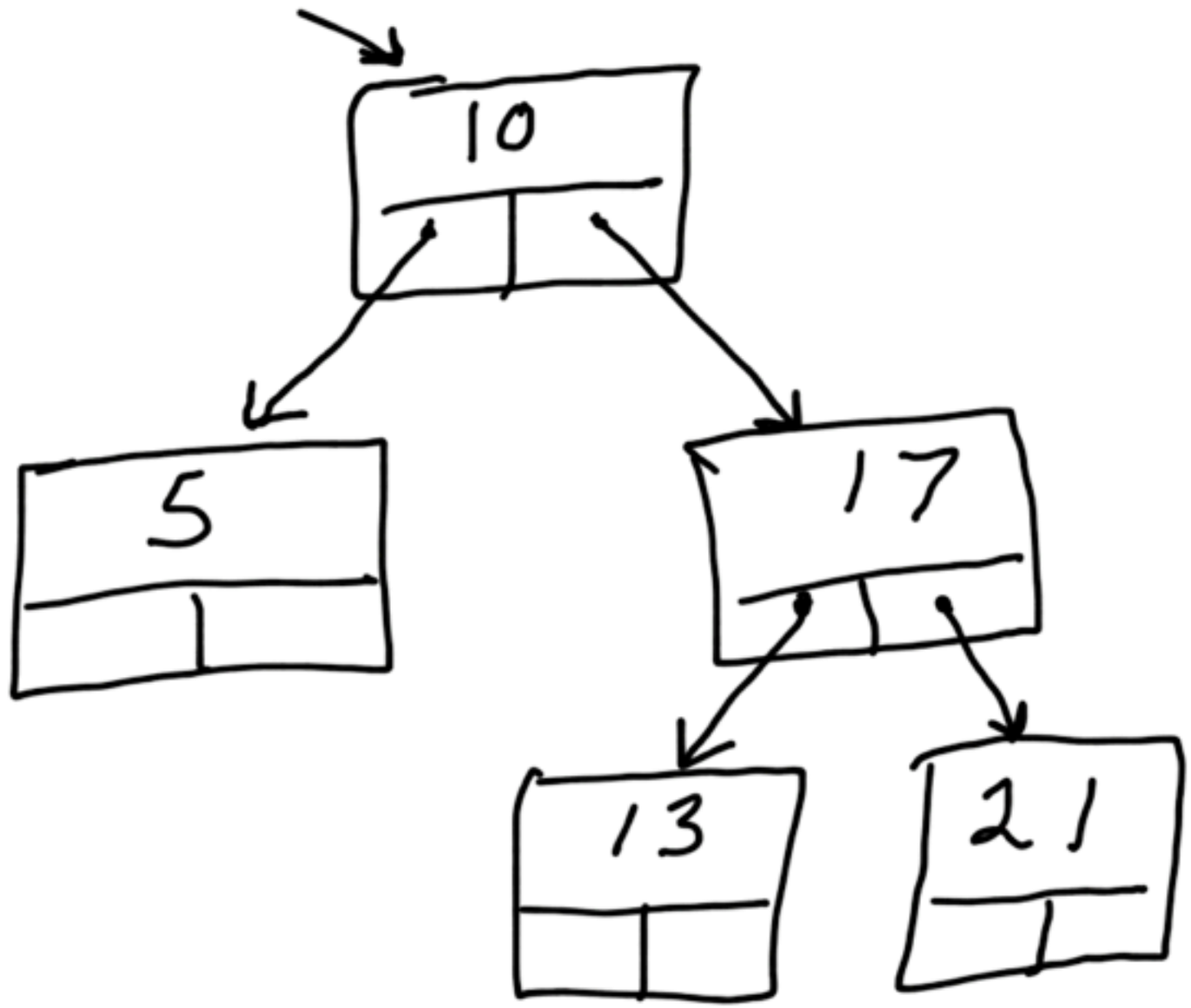
Preorder



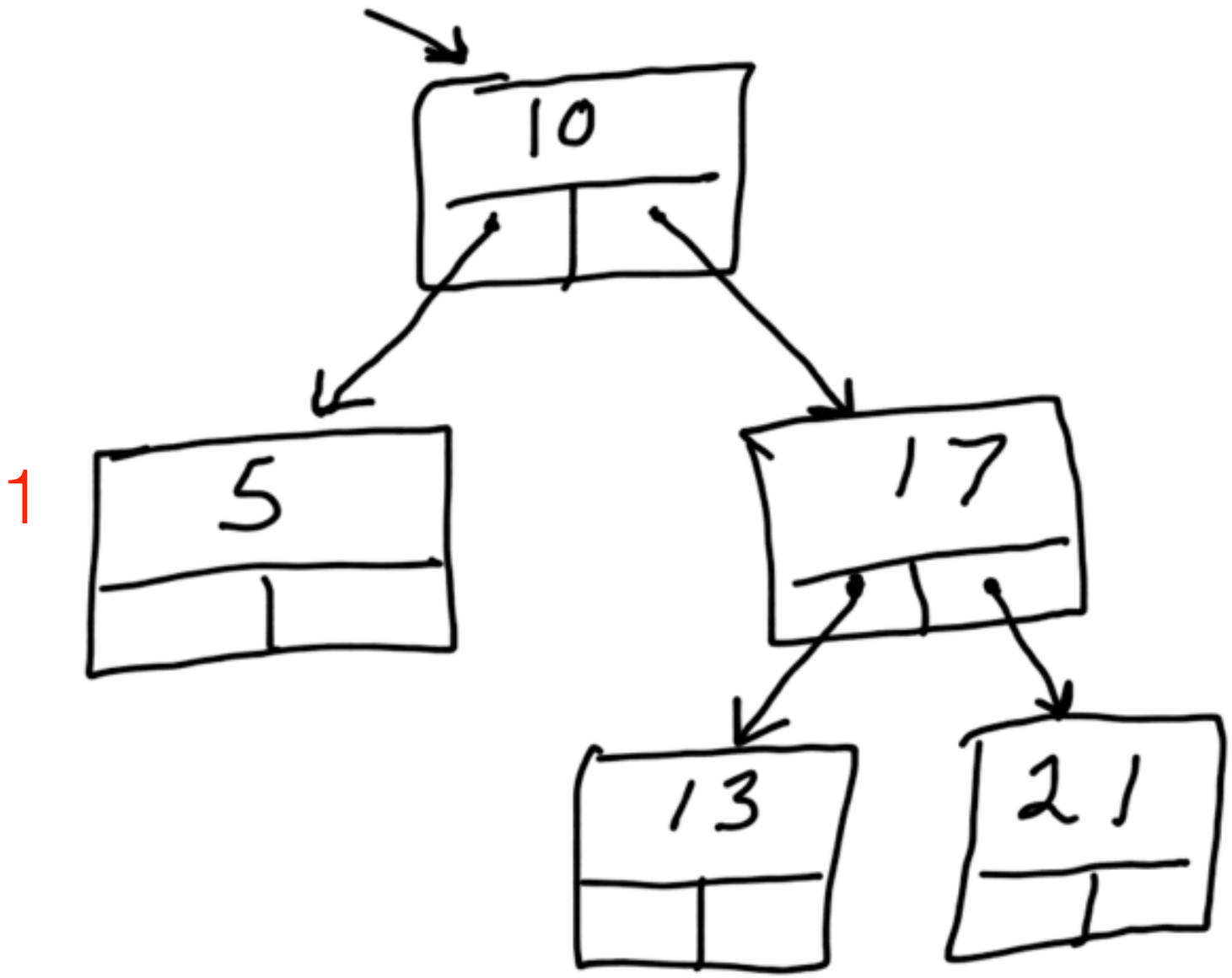
Preorder



Inorder

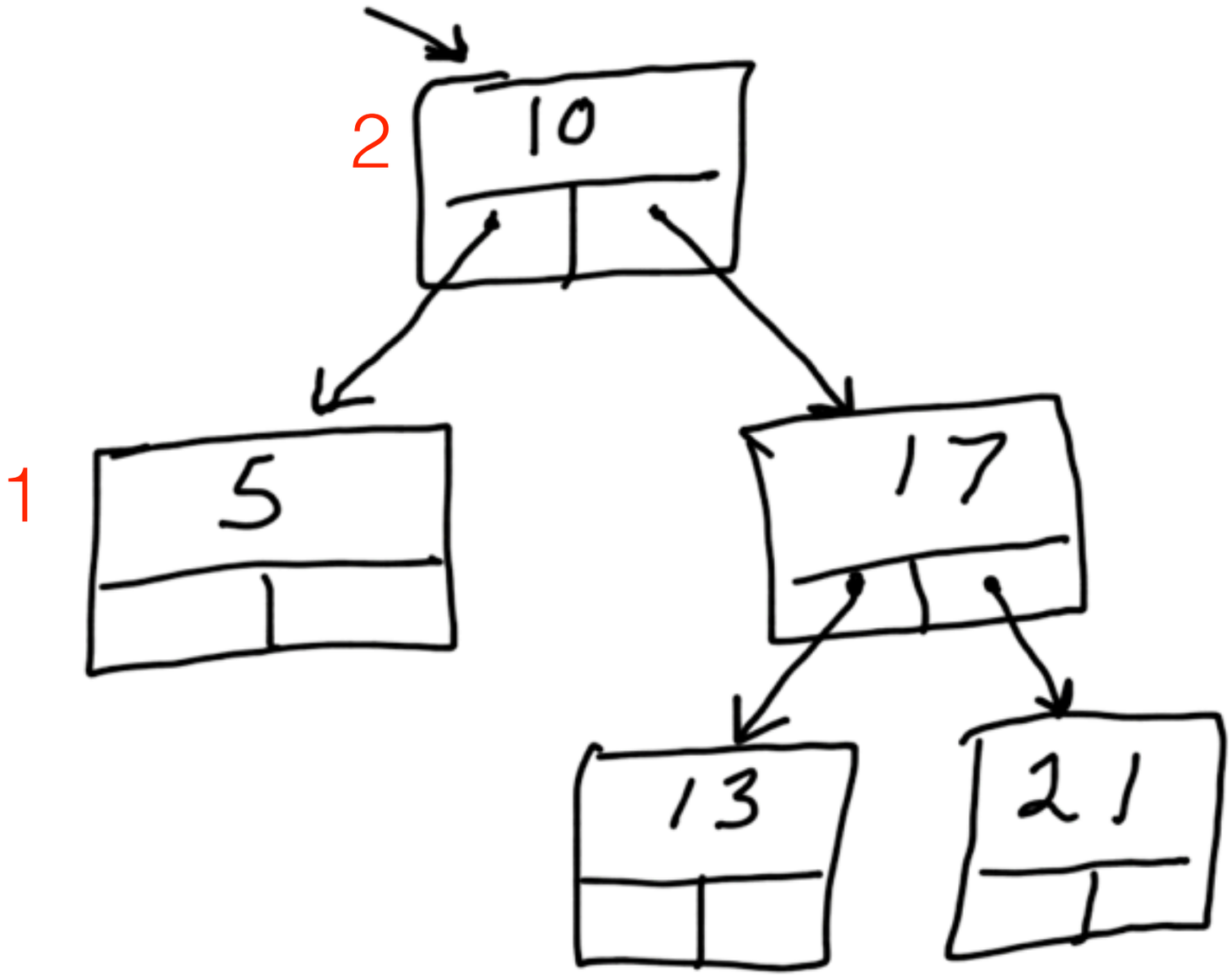


Inorder

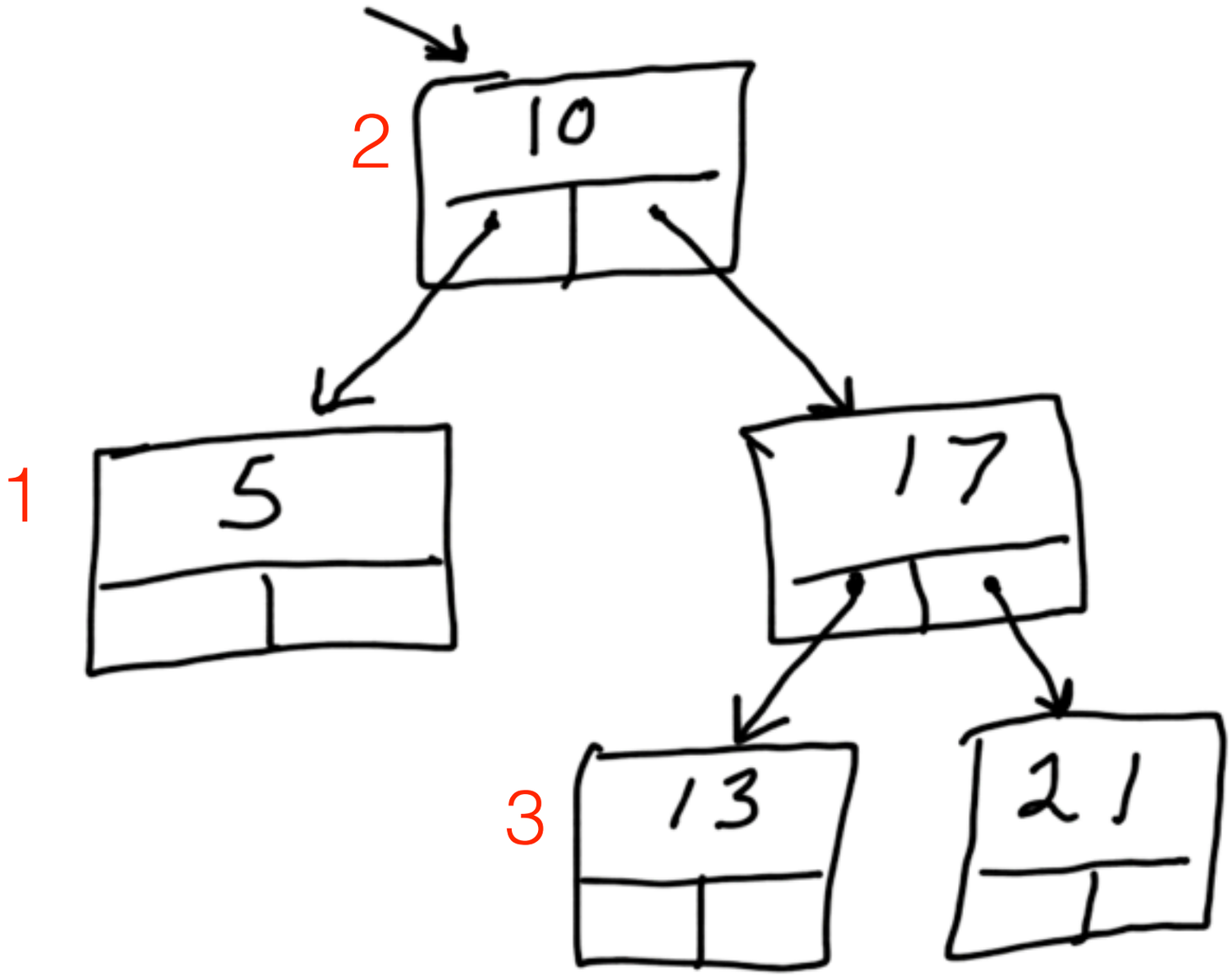


1

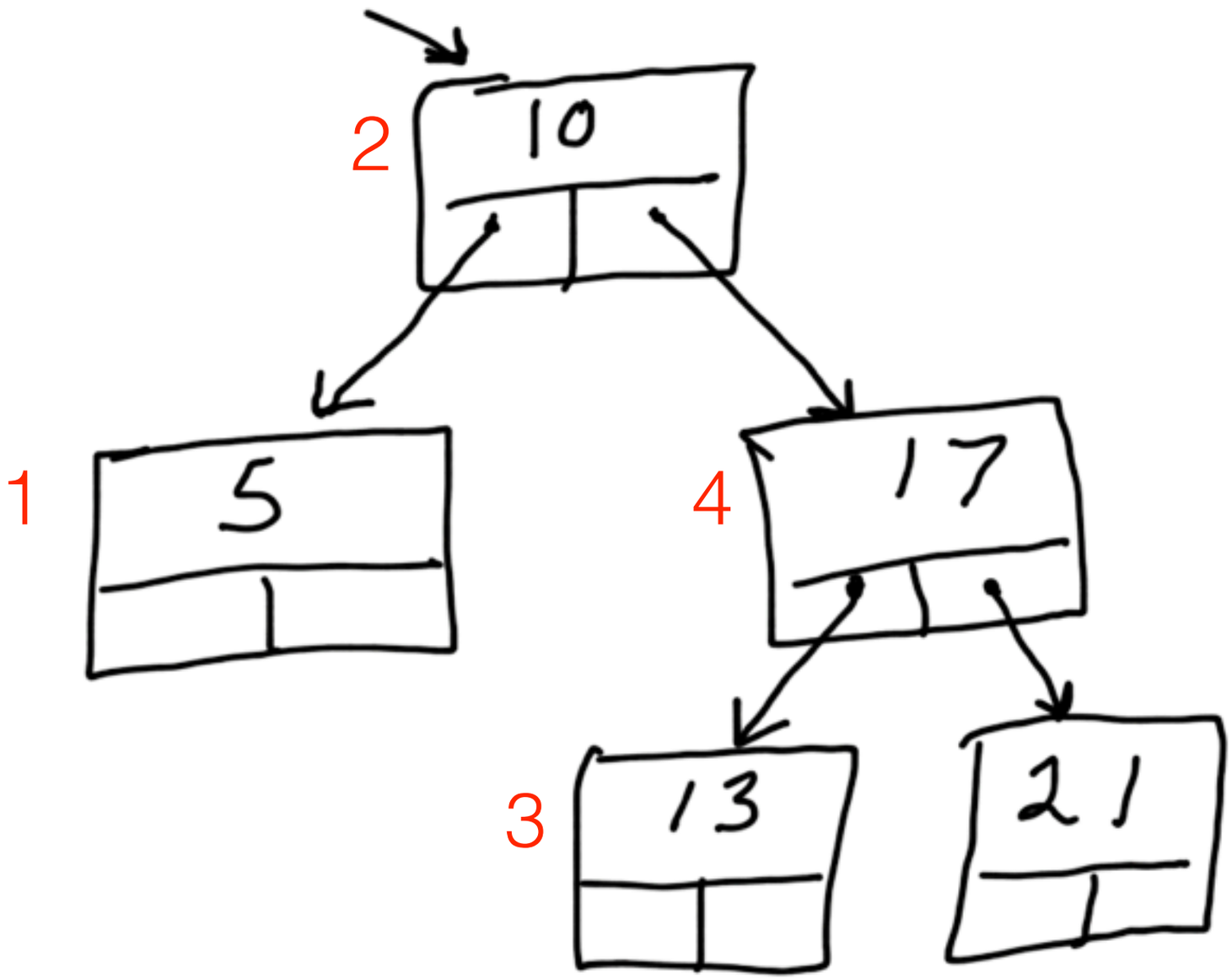
Inorder



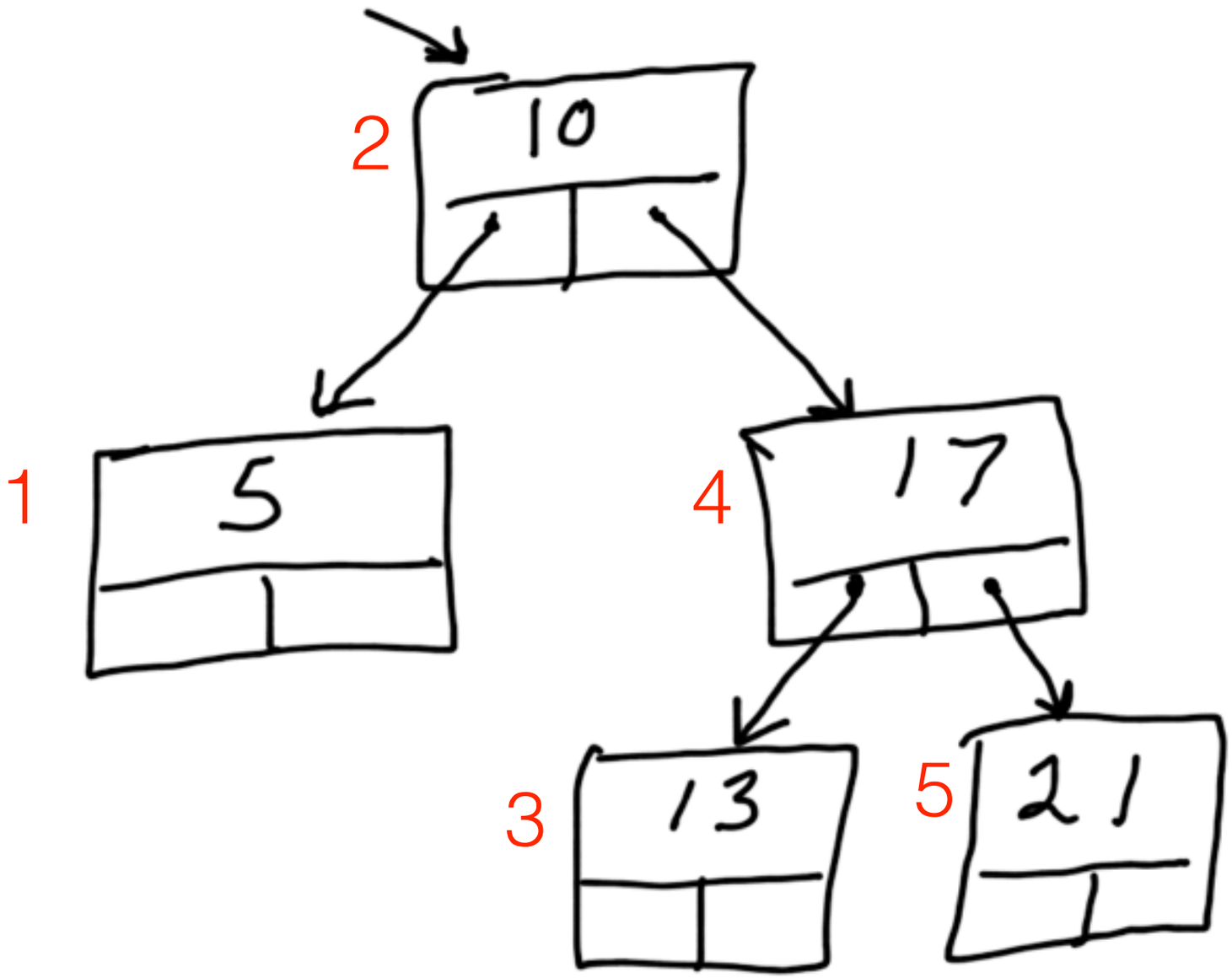
Inorder



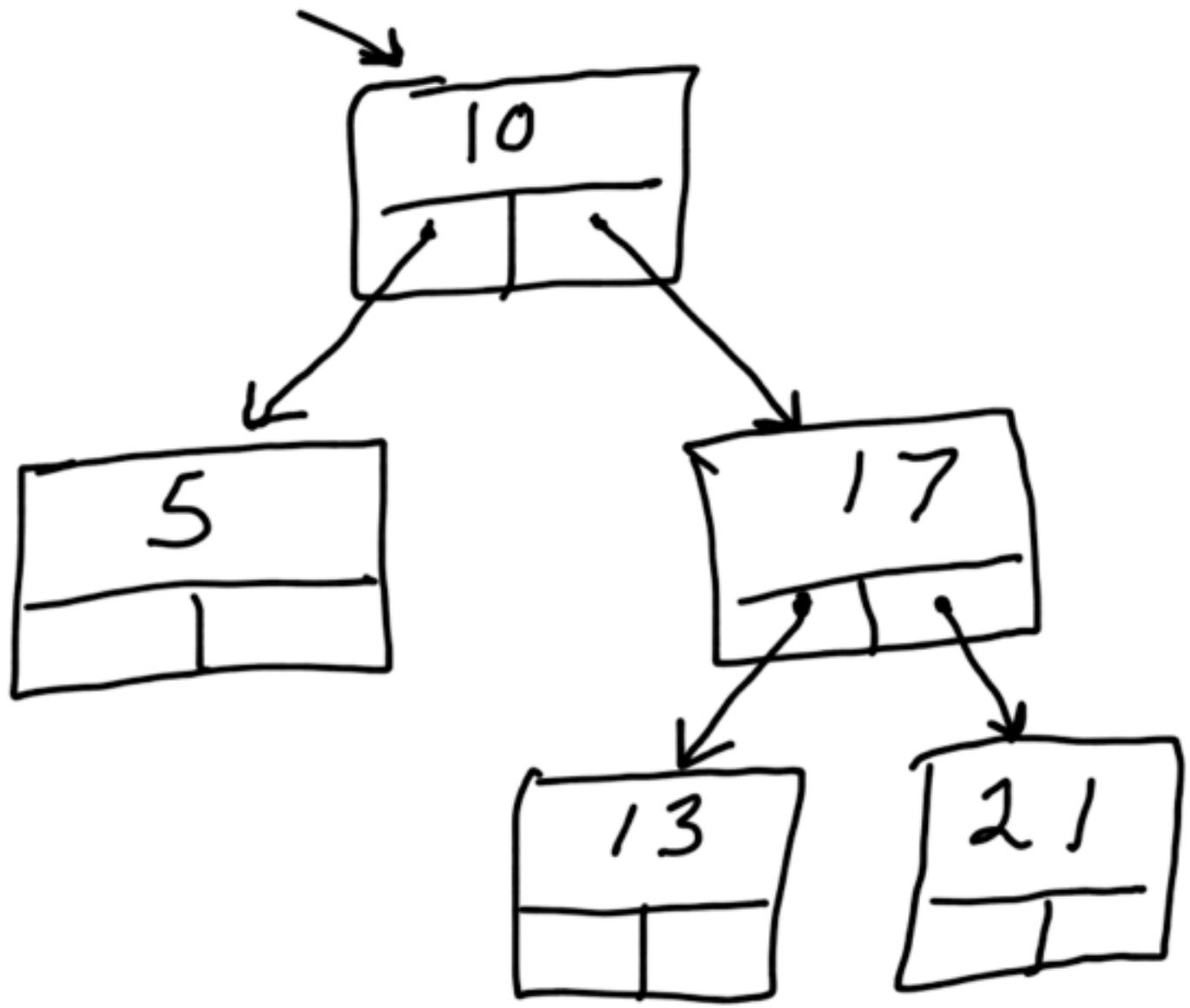
Inorder



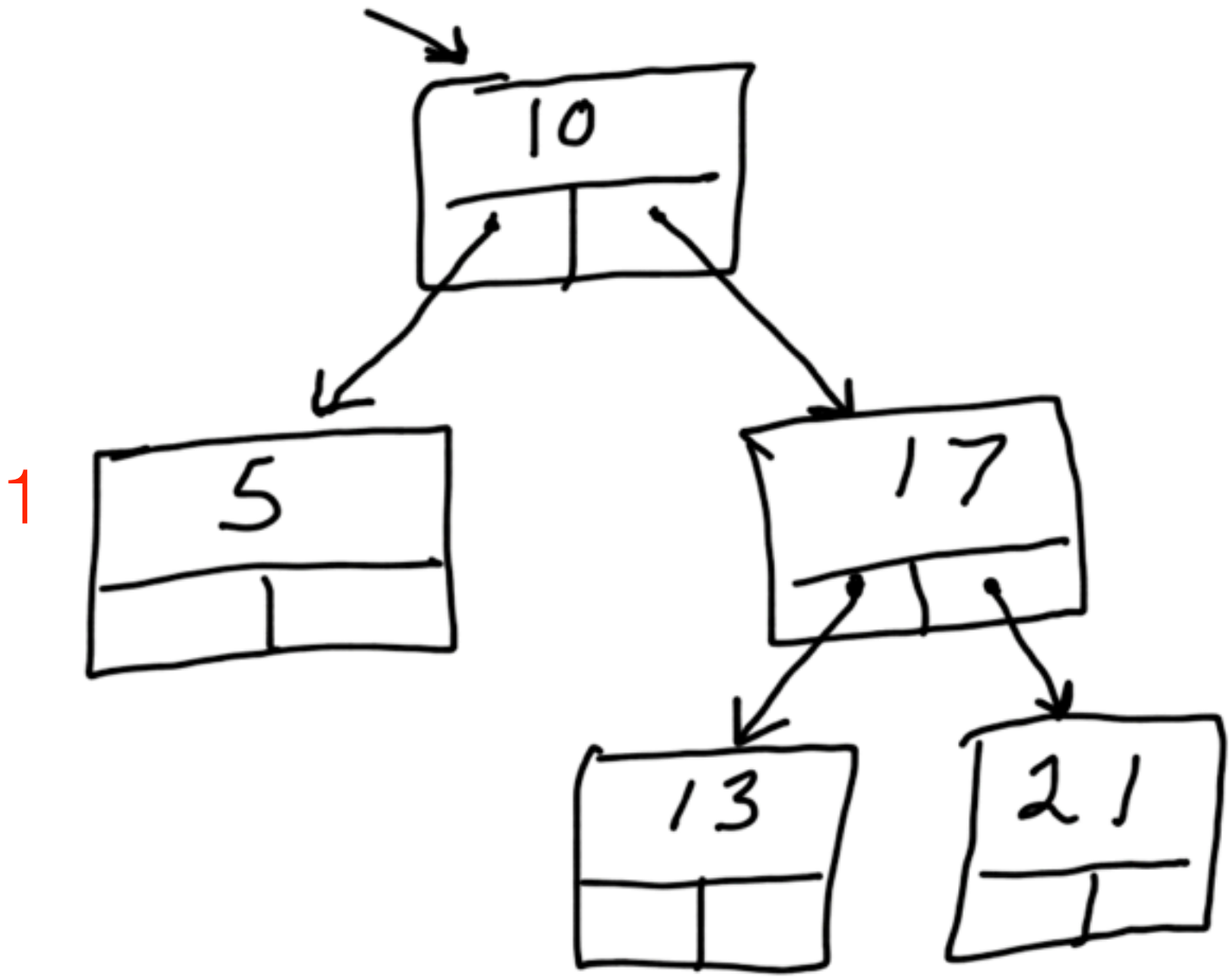
Inorder



Postorder

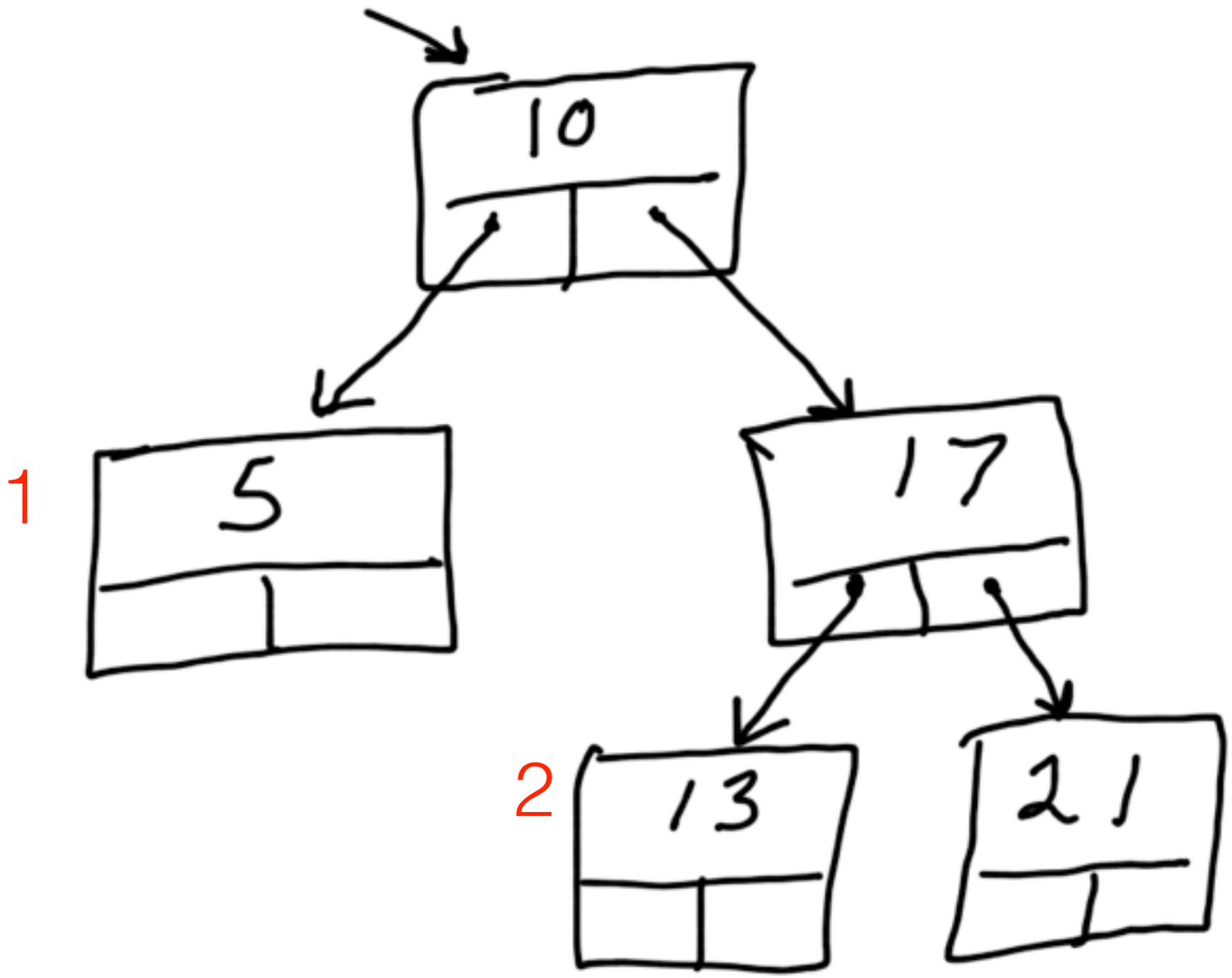


Postorder

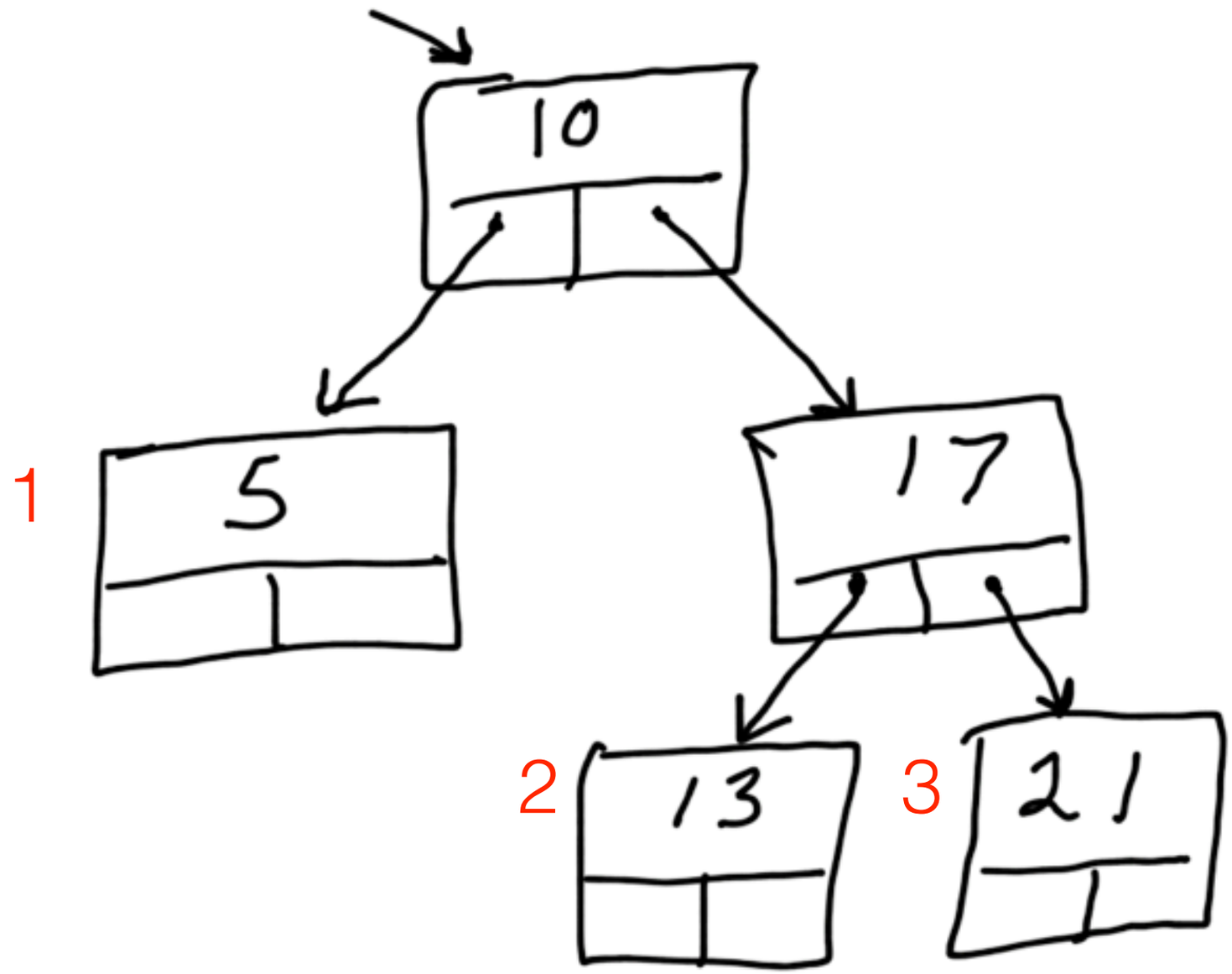


1

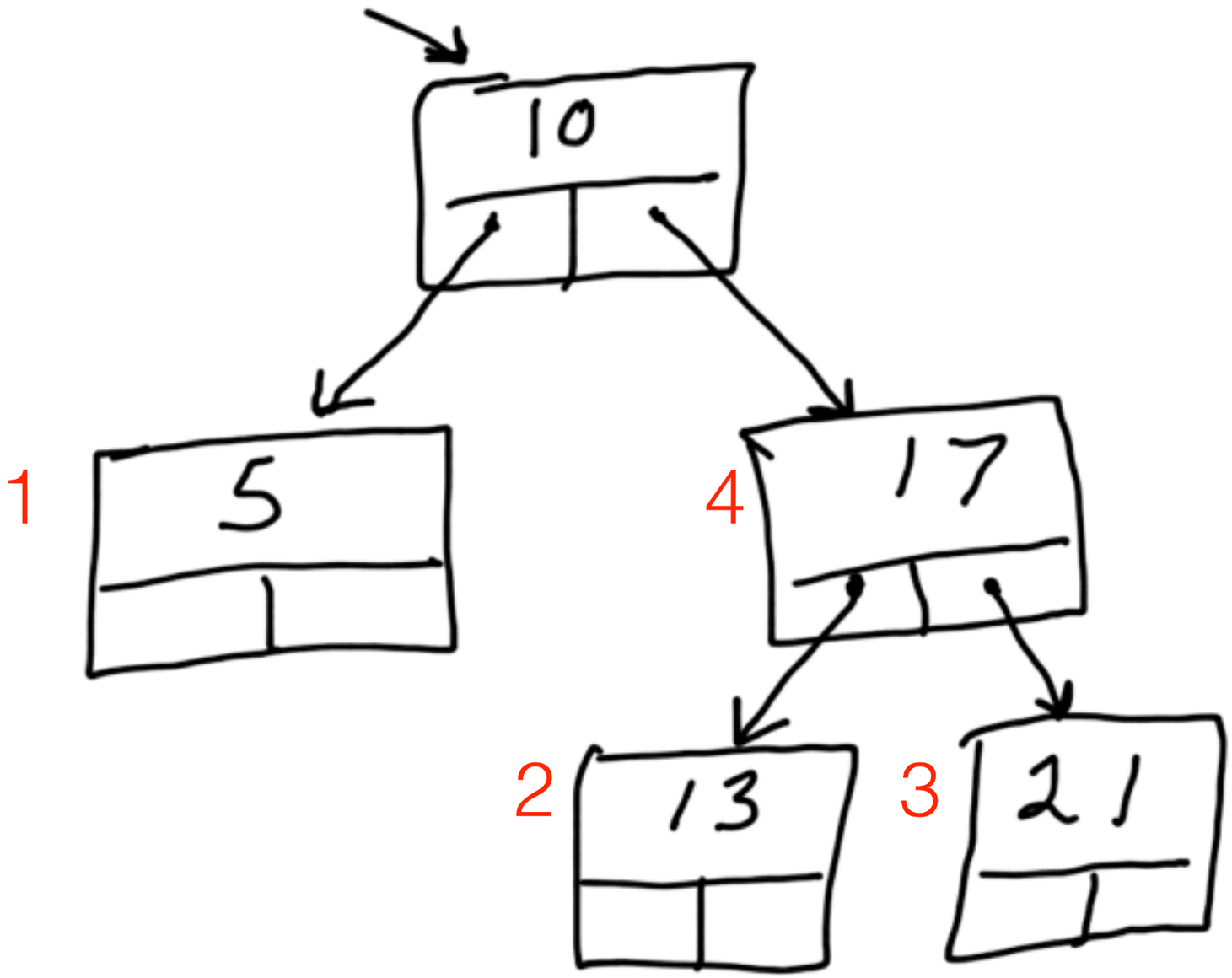
Postorder



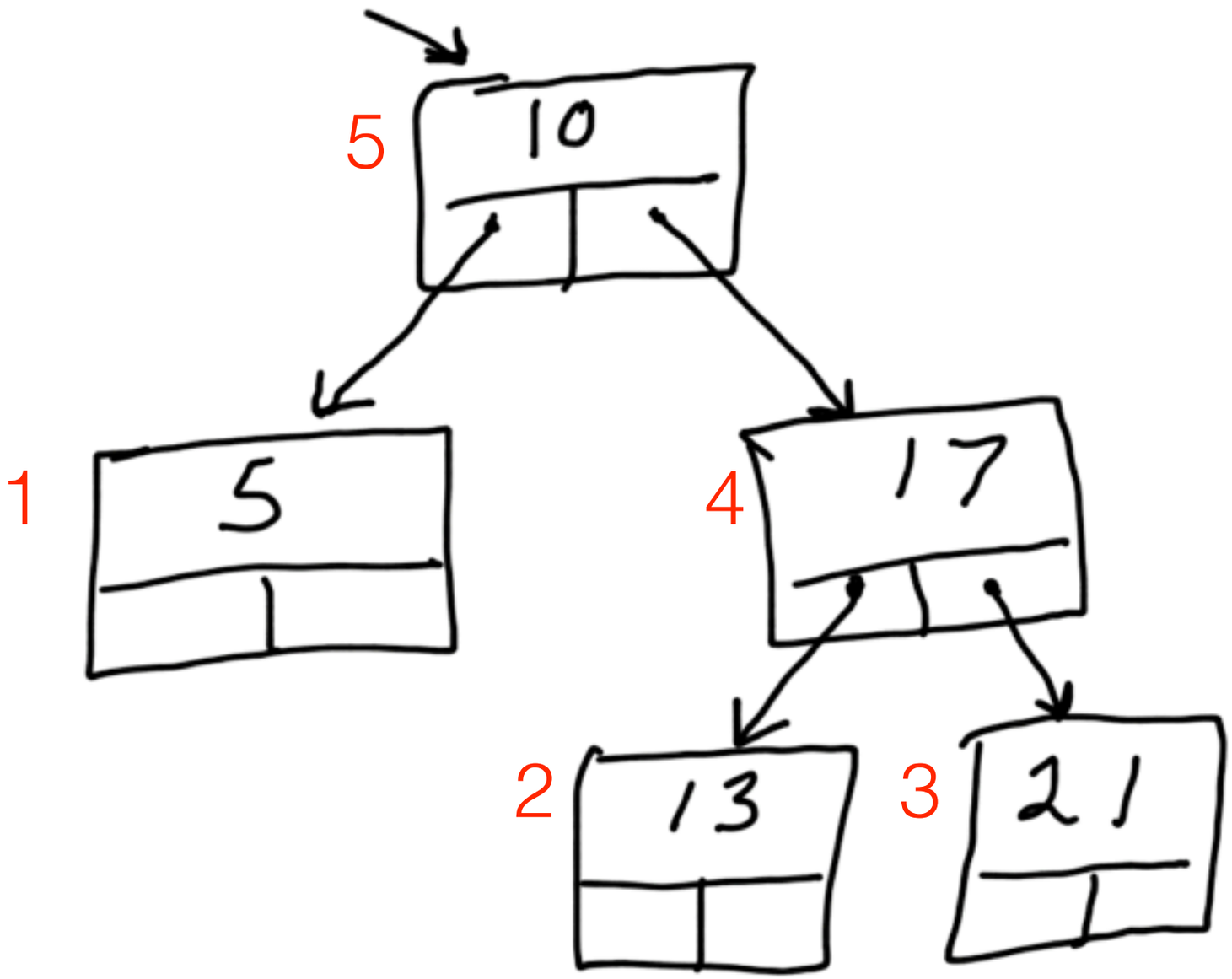
Postorder



Postorder



Postorder



Exercise

- Implement DbcBinaryTree
  - https://github.com/dastels/dbc-deep-dives.git
    - DataStructures directory
    - delete the contents of the lib dir, and put dbc_binary_tree.rb there
    - Use rspec spec/binary_tree_spec.rb to guide you

Exercise

- Make recursive solutions.

- Let's walk through implementing size together.

AVL Tree

But First

- Lots of nil checks are messy

- Use a nil node object instead

What

- A binary search tree that is maintained in a balanced state

- The depths of the left & right subtrees at any node differ by at most 1

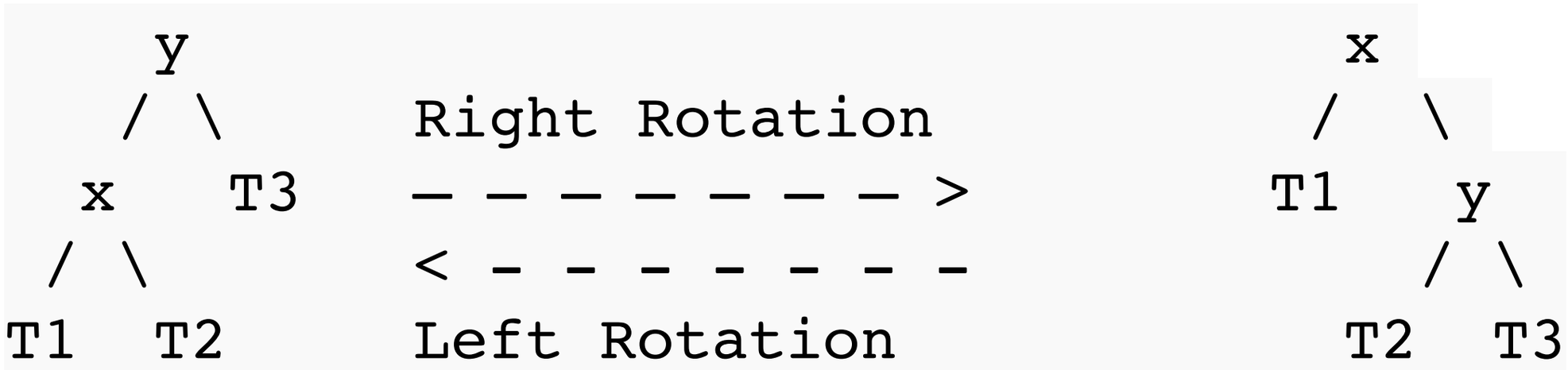
Why

- Keeping a binary search tree balanced maintains O*ln*(n) performance

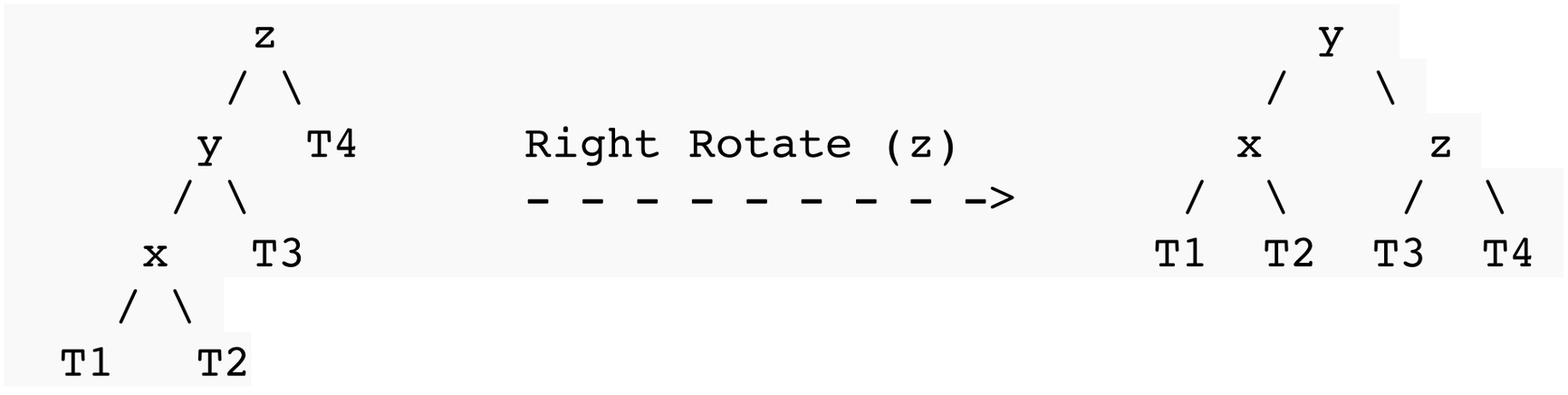
How

- After each insertion into a node, the balance of that node is checked. If the node is unbalanced, it needs to be rebalanced via rotation.

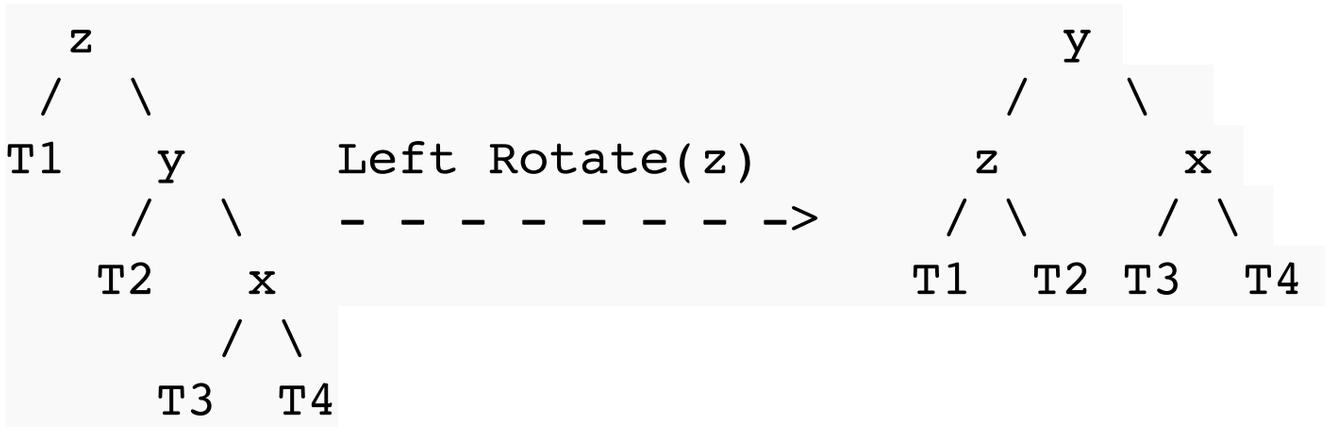
Left & Right Rotation



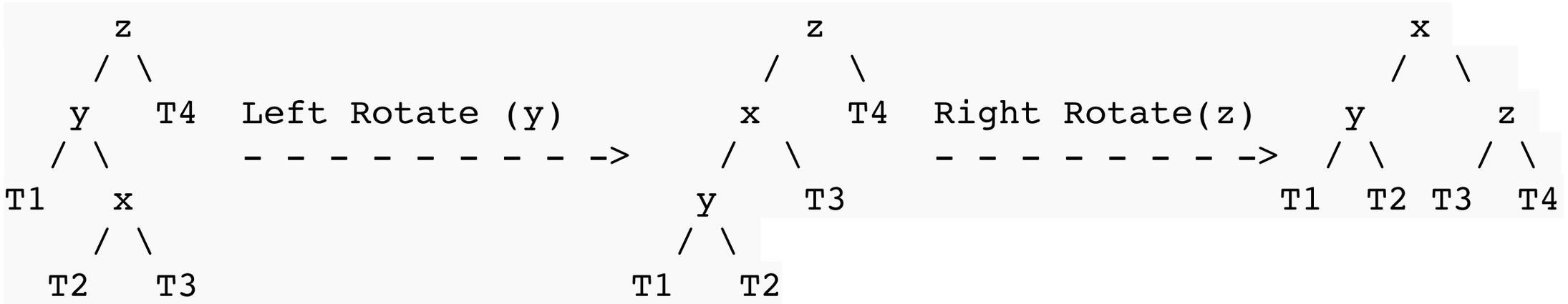
Left Left Case



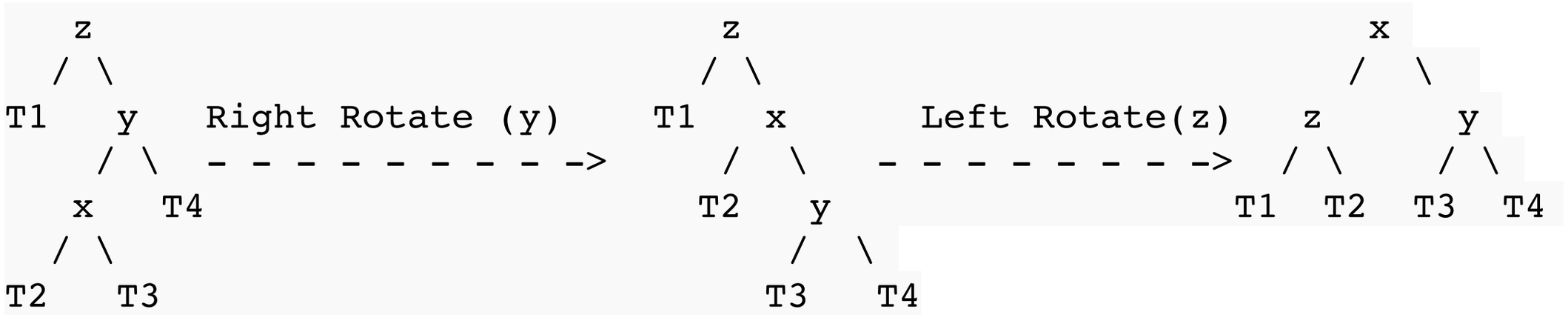
Right Right Case



Left Right Case



Right Left Case



Rotating Left

```
def left_rotate
  AVLTreeNode.new(@right.value,
                  AVLTreeNode.new(@value,
                                  @left,
                                  @right.left),
                  @right.right)

end
```

Rotating Left

```
def right_rotate
  AVLTreeNode.new(@left.value,
                  @left.left,
                  AVLTreeNode.new(@value,
                                  @left.right,
                                  @right))
end
```

B-Tree

Graph

Hashtable

Set

Bag

MultiSet

Sorting

Bubble Sort

Insertion Sort

Quiksort

Contact

dastels@icloud.com

@dastels

Bubble Sort

Insertion Sort

Quiksort