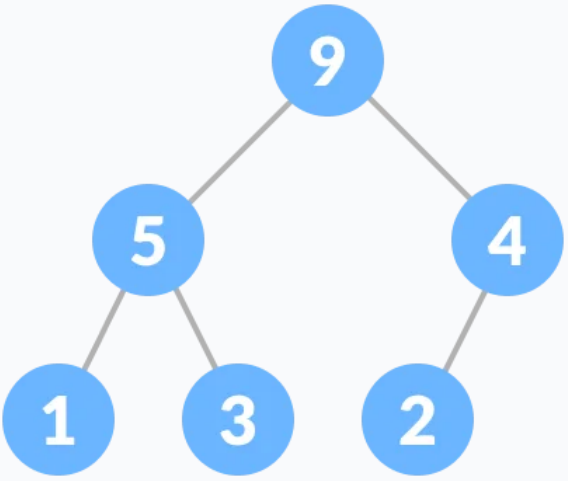
Heap Data Structure

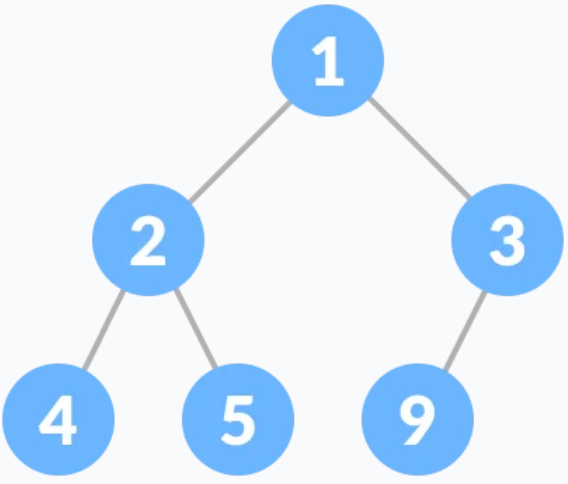
In this tutorial, you will learn what heap data structure is. Also, you will find working examples of heap operations in C, C++, Java Python.

Heap data structure is a complete binary tree that satisfies **the heap property**, where any given node is

- always greater than its child node/s and the key of the root node is the largest among all other nodes. This property is also called **max heap property**.
- always smaller than the child node/s and the key of the root node is the smallest among all other nodes. This property is also called **min heap property**.



Max-heap



Min-heap

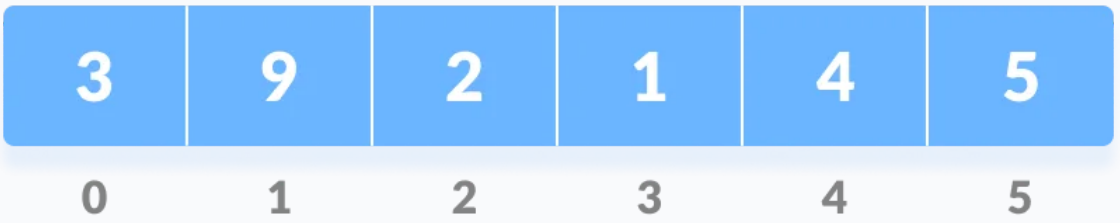
This type of data structure is also called a **binary heap**.

Some of the important operations performed on a heap are described below along with their algorithms.

Heapify

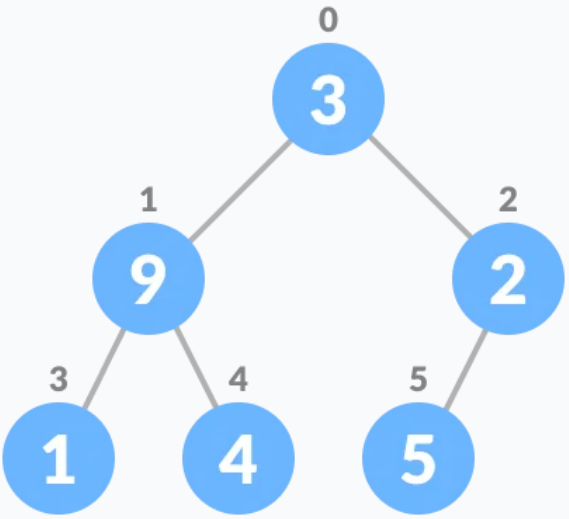
Heapify is the process of creating a heap data structure from a binary tree. It is used to create a Min-Heap or a Max-Heap.

1. Let the input array be



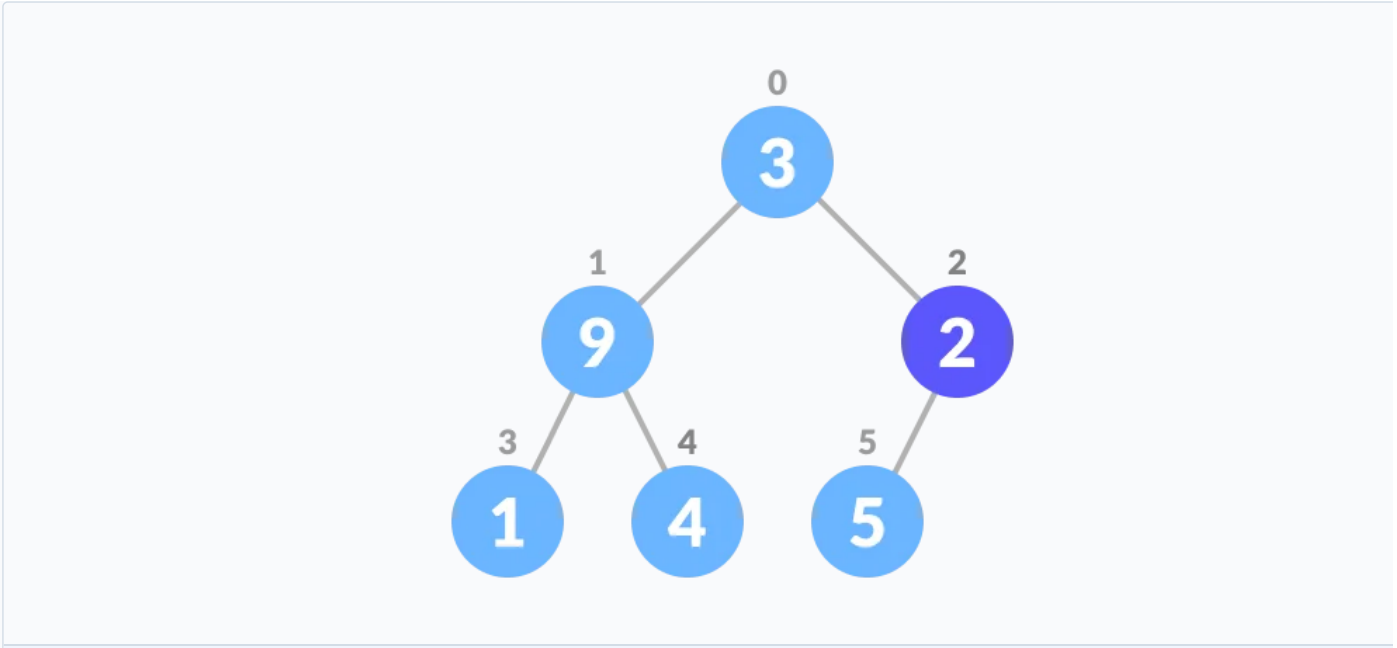
Initial Array

2. Create a complete binary tree from the array



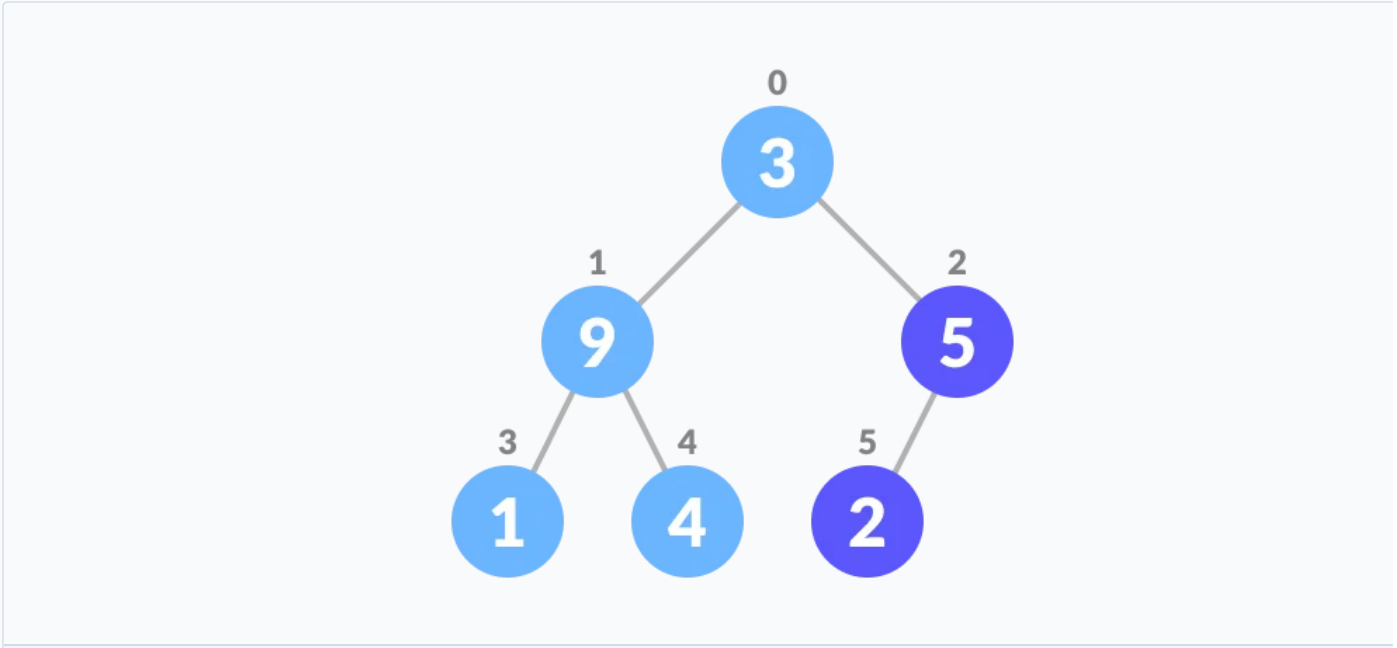
Complete binary tree

3. Start from the first index of non-leaf node whose index is given by `n/2 - 1`.



Start from the first on leaf node

4. Set current element `i` as `largest`.
5. The index of left child is given by `2i + 1` and the right child is given by `2i + 2`.
   If `leftChild` is greater than `currentElement` (i.e. element at `ith` index), set `leftChildIndex` as largest.
   If `rightChild` is greater than element in `largest`, set `rightChildIndex` as `largest`.
6. Swap `largest` with `currentElement`



Swap if necessary

7. Repeat steps 3-7 until the subtrees are also heapified.

Algorithm

```
Heapify(array, size, i)
  set i as largest
  leftChild = 2i + 1
  rightChild = 2i + 2

  if leftChild > array[largest]
    set leftChildIndex as largest
  if rightChild > array[largest]
    set rightChildIndex as largest

  swap array[i] and array[largest]
```

To create a Max-Heap:

```
MaxHeap(array, size)
  loop from the first index of non-leaf node down to zero
    call heapify
```

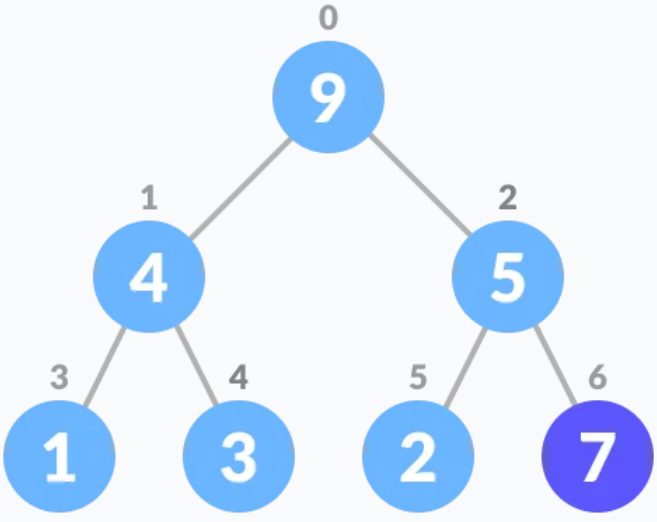
For Min-Heap, both `leftChild` and `rightChild` must be larger than the parent for all nodes.

Insert Element into Heap

Algorithm for insertion in Max Heap

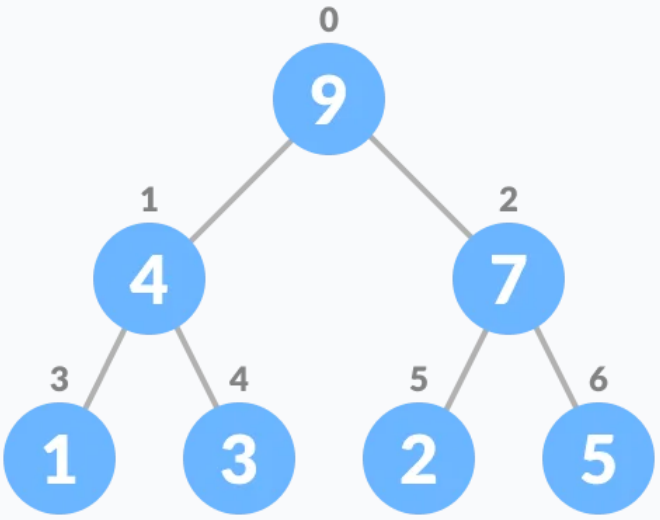
```
If there is no node,
  create a newNode.
else (a node is already present)
  insert the newNode at the end (last node from left to right.)

heapify the array
```

1. Insert the new element at the end of the tree.



Insert at the end

2. Heapify the tree.



Heapify the array

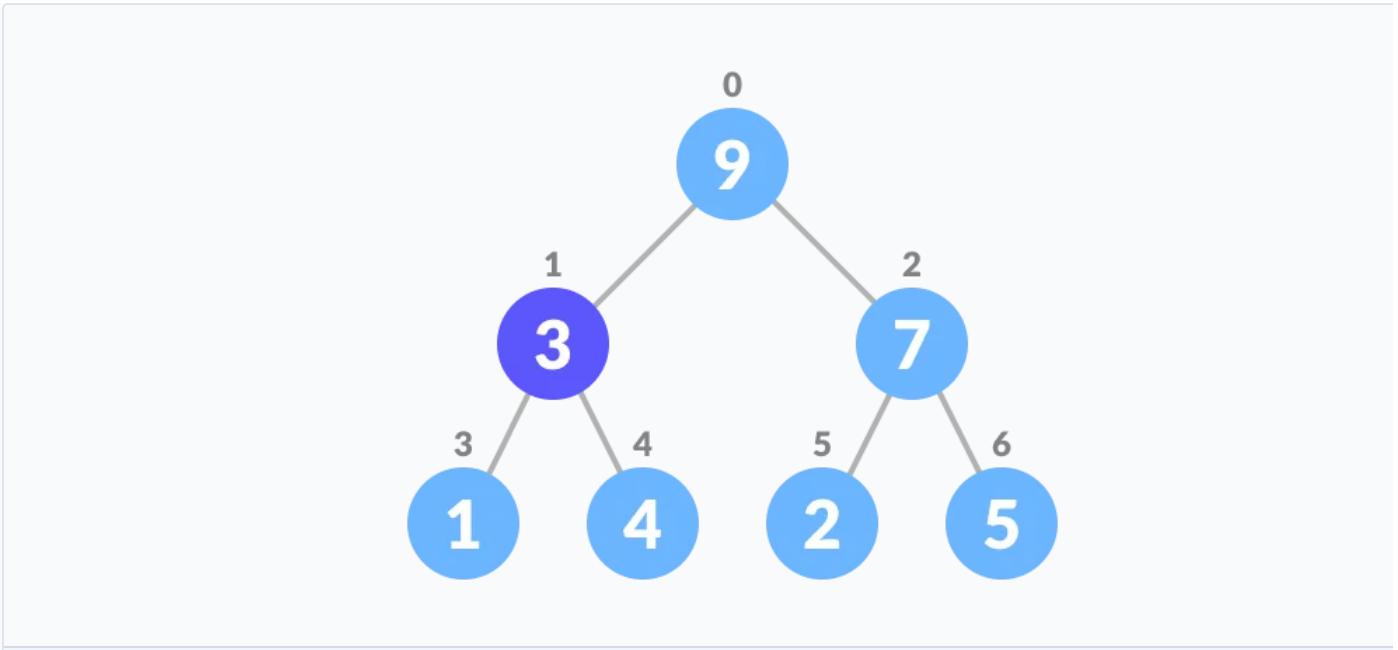
For Min Heap, the above algorithm is modified so that `parentNode` is always smaller than `newNode`.

Delete Element from Heap

Algorithm for deletion in Max Heap

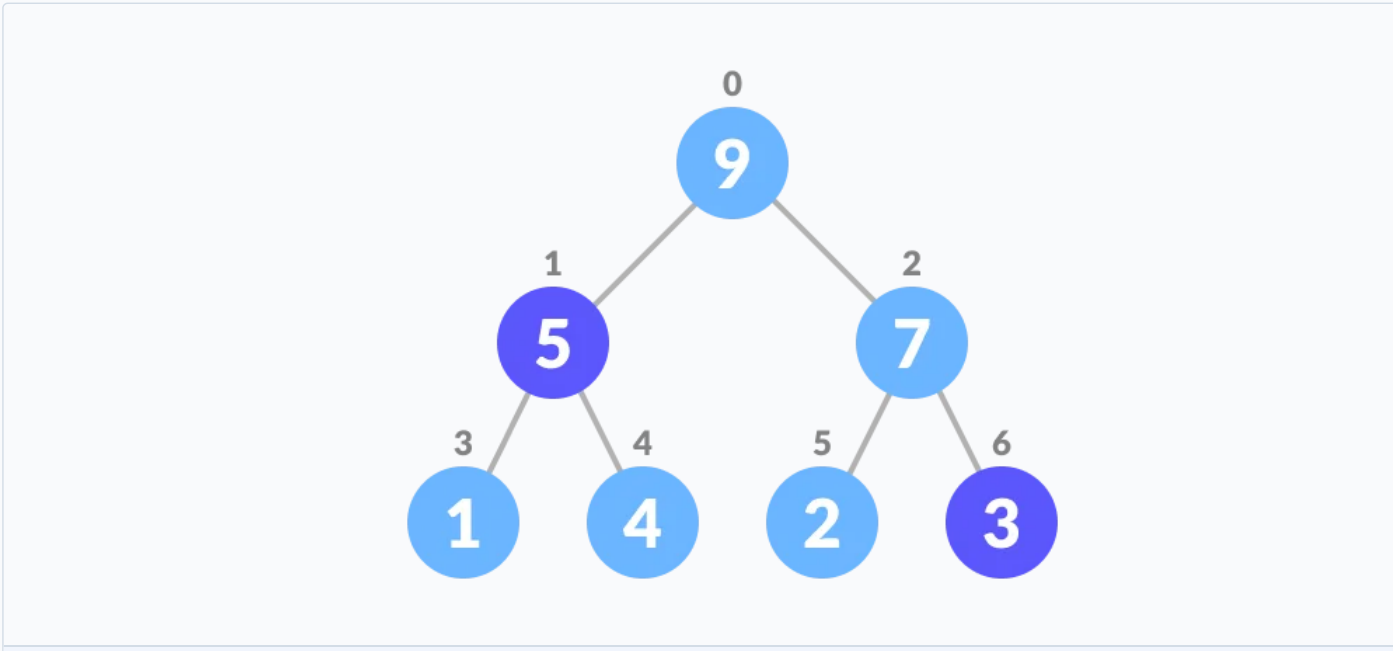
```
If nodeToBeDeleted is the leafNode
  remove the node
Else swap nodeToBeDeleted with the lastLeafNode
  remove noteToBeDeleted

heapify the array
```

1. Select the element to be deleted.



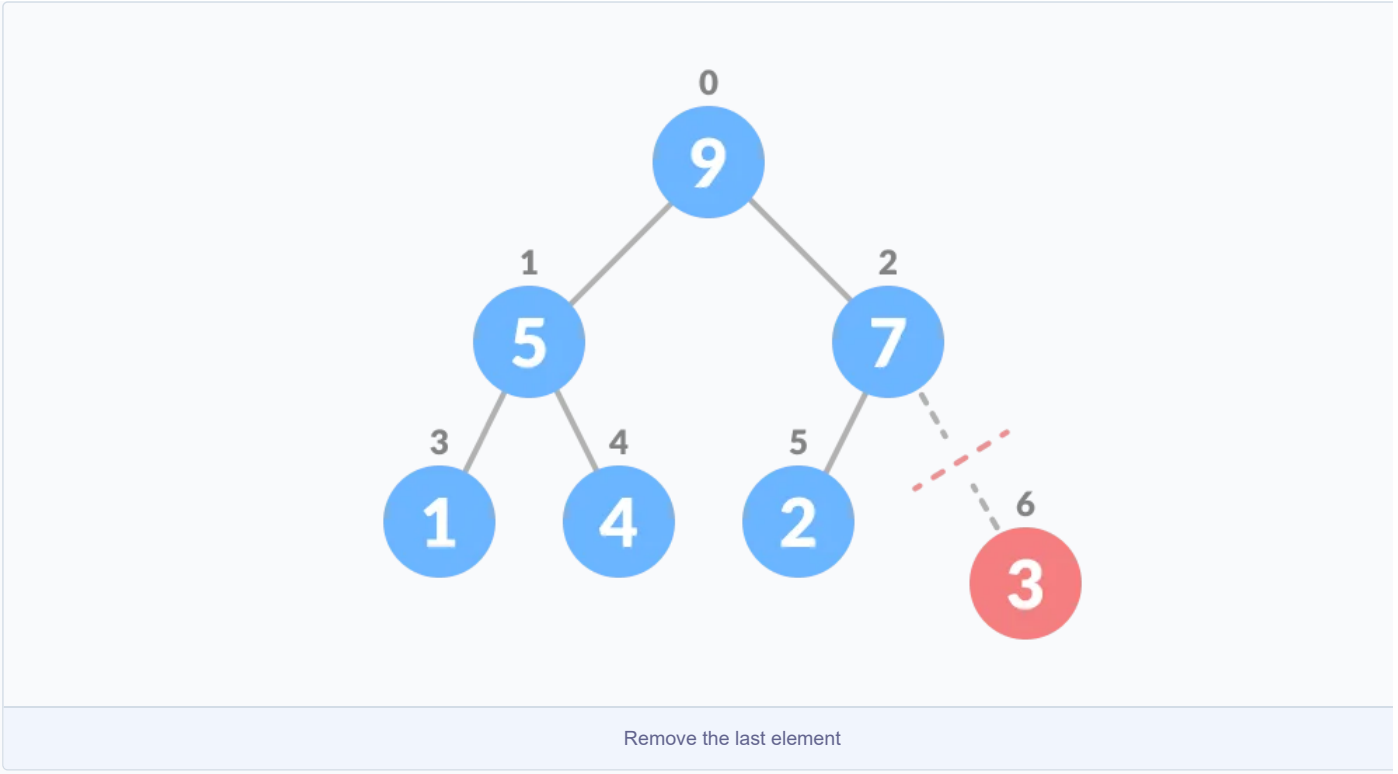
Select the element to be deleted

2. Swap it with the last element.



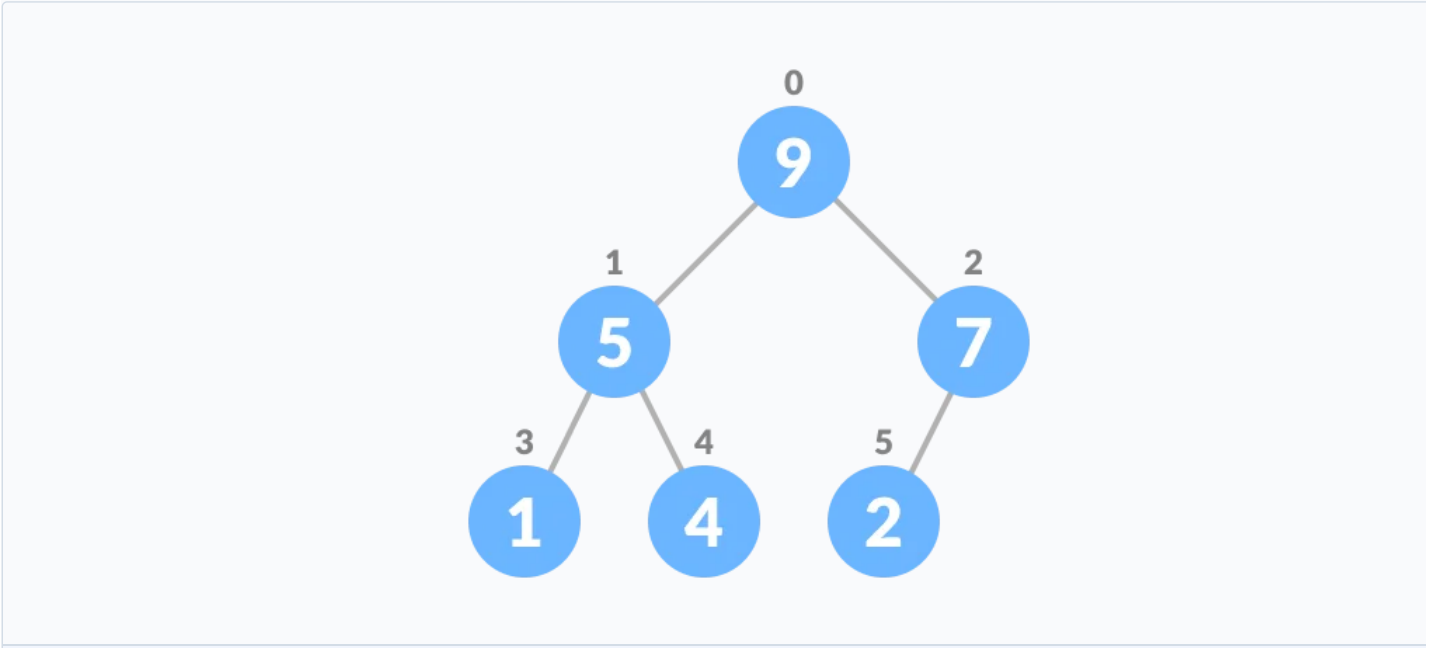
Swap with the last element

3. Remove the last element.



Remove the last element

4. Heapify the tree.



Heapify the array

For Min Heap, above algorithm is modified so that both `childNodes` are greater smaller than `currentNode`.

Peek (Find max/min)

Peek operation returns the maximum element from Max Heap or minimum element from Min Heap without deleting the node.

For both Max heap and Min Heap

```
return rootNode
```

Extract-Max/Min

Extract-Max returns the node with maximum value after removing it from a Max Heap whereas Extract-Min returns the node with minimum after removing it from Min Heap.