

# CS350: Data Structures

## Heap Sort

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# Heapsort

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- **The priority queue can be used to sort N items as follows**
  - Insert N elements to be sorted into heap
  - Heapify the heap to put it into heap-order (minHeap)
  - Call deleteMin N times and the elements will get removed from the heap in ascending order

This same procedure can be used with a maxHeap and deleteMax to produce output in descending order

# Heapsort

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- **Build the heap so that you extract the values in the opposite order that you want them sorted**
  - Build a minHeap if descending sort order is desired
  - Build a maxHeap if ascending sort order is desired

# Heapsort

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- **Run time of heap sort is broken down into each step**
  - Initially inserting  $N$  elements into the heap takes  $O(N)$
  - The heapify step runs in  $O(N)$  time
  - The sorting step runs in  $O(N \log N)$  time
    - Each deleteMin takes  $O(\log N)$  time
    - Must call deleteMin  $N$  times
  - Total time complexity =  $O(N) + O(N) + O(N \log N) = O(N \log N)$

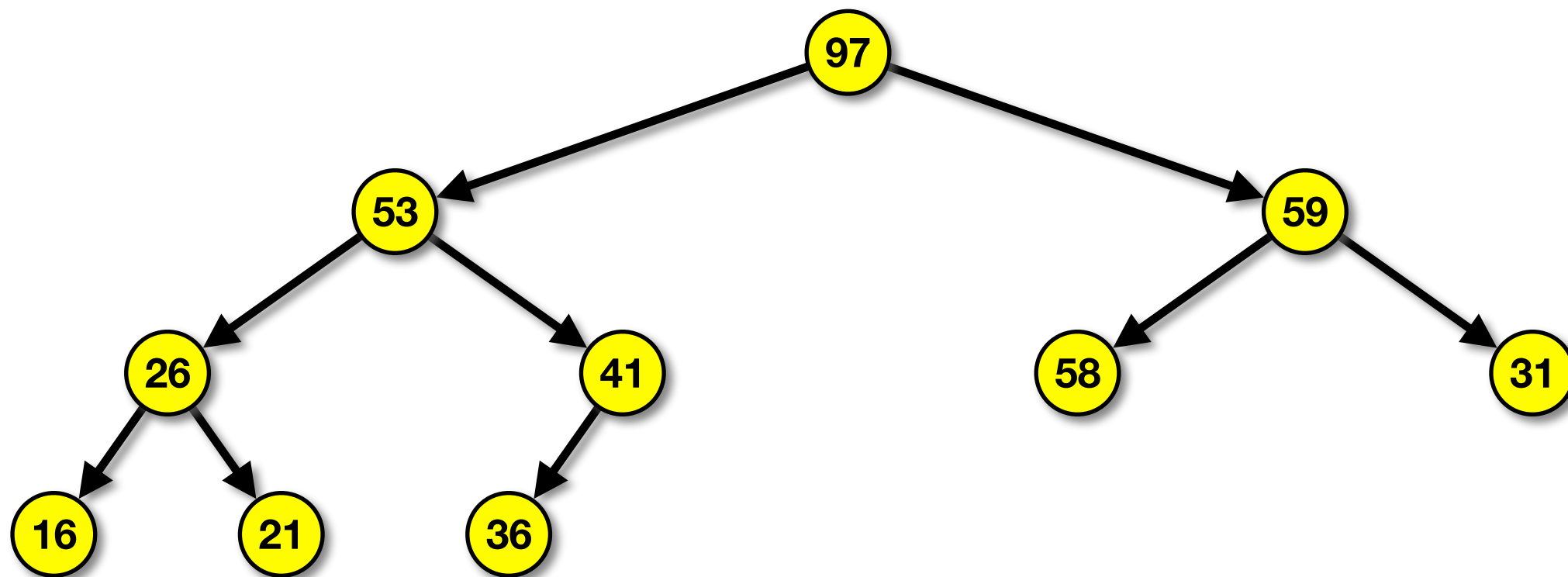
# Heapsort

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- **When calling deleteMin or deleteMax on the heap, the sorted values must be stored somewhere**
  - One option is to create a second array that stores the sorted values
    - Doubles the memory requirements for the sort
  - Another option is to reuse heap space in a clever manner so as not to need a secondary array
    - As heap shrinks, store sorted values in array positions that are no longer part of the heap

# Heapsort Example

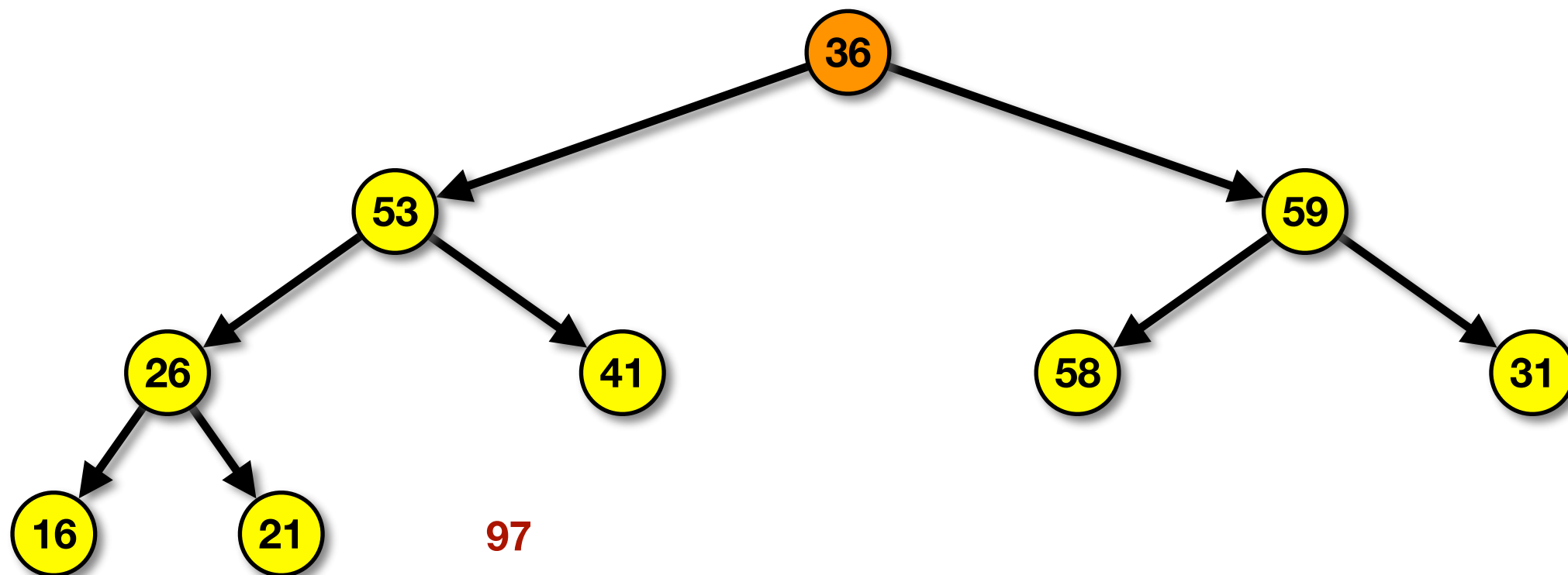
- ▶ Start with a maxHeap
- ▶ Repeatedly call deleteMax and place the max element in the newly open array position at the end of the heap



	97	53	59	26	41	58	31	16	21	36					
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

# Heapsort Example

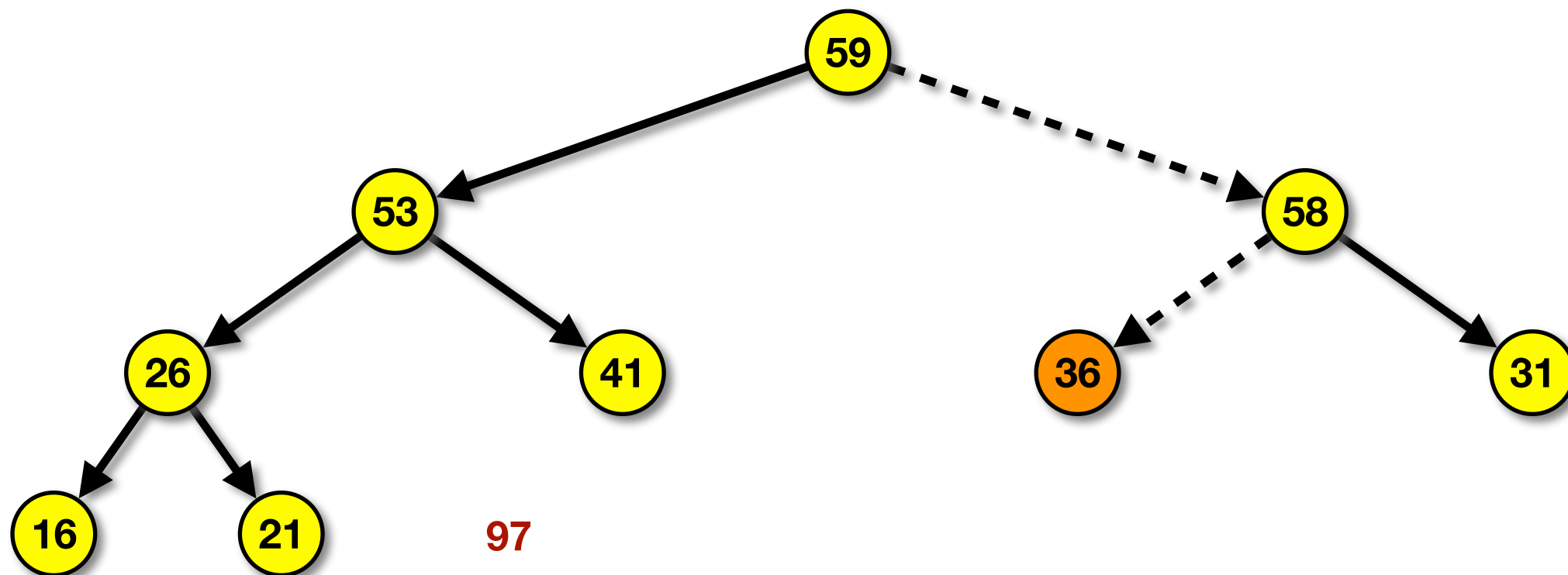
- ▶ Call deleteMax method
- ▶ Swap node 36 with node 97 and shrink the size of the heap



	36	53	59	26	41	58	31	16	21	97					
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

# Heapsort Example

- Call `percolateDown` on node 36

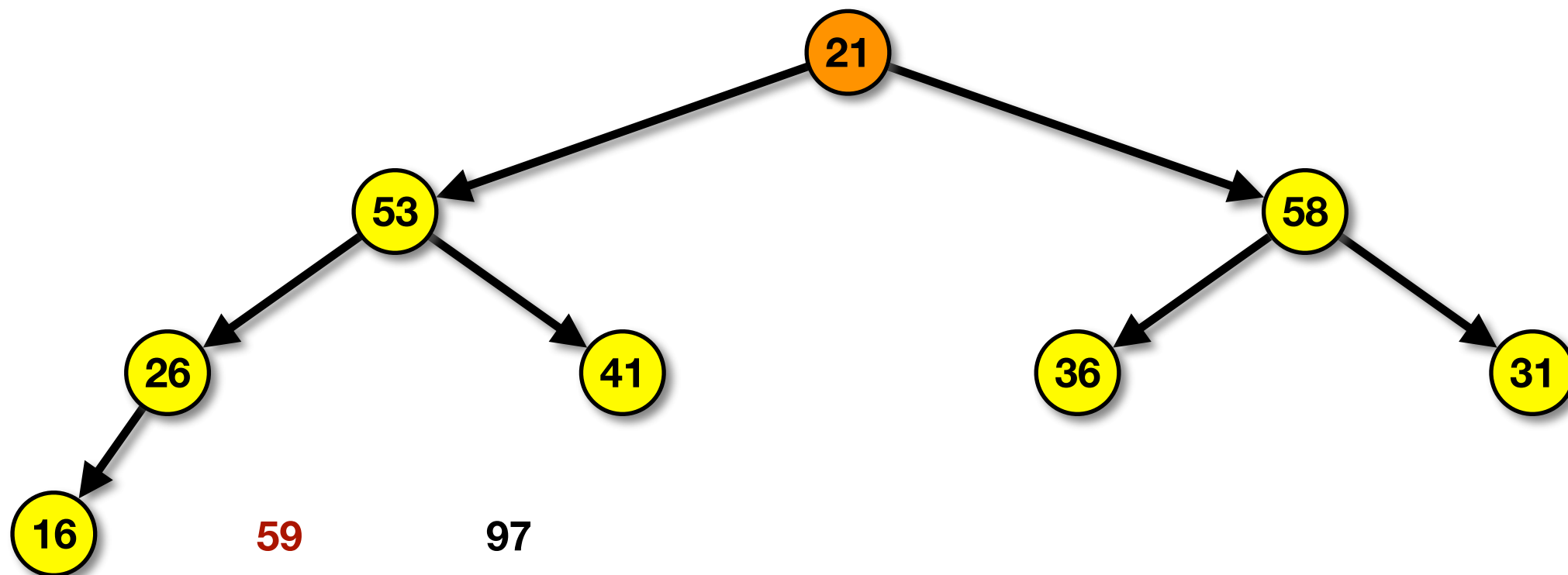


	59	53	58	26	41	36	31	16	21	97					
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15



# Heapsort Example

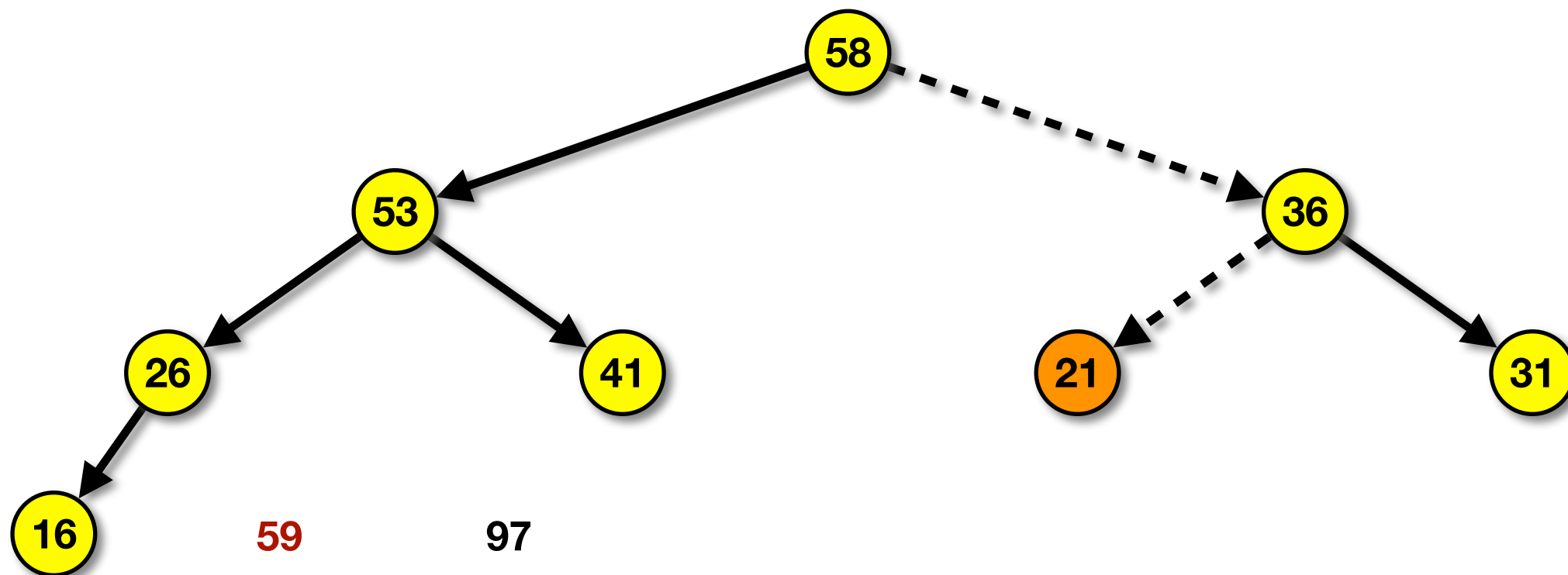
- ▶ Call deleteMax method
- ▶ Swap node 21 with node 59 and shrink the size of the heap



	21	53	58	26	41	36	31	16	59	97					
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

# Heapsort Example

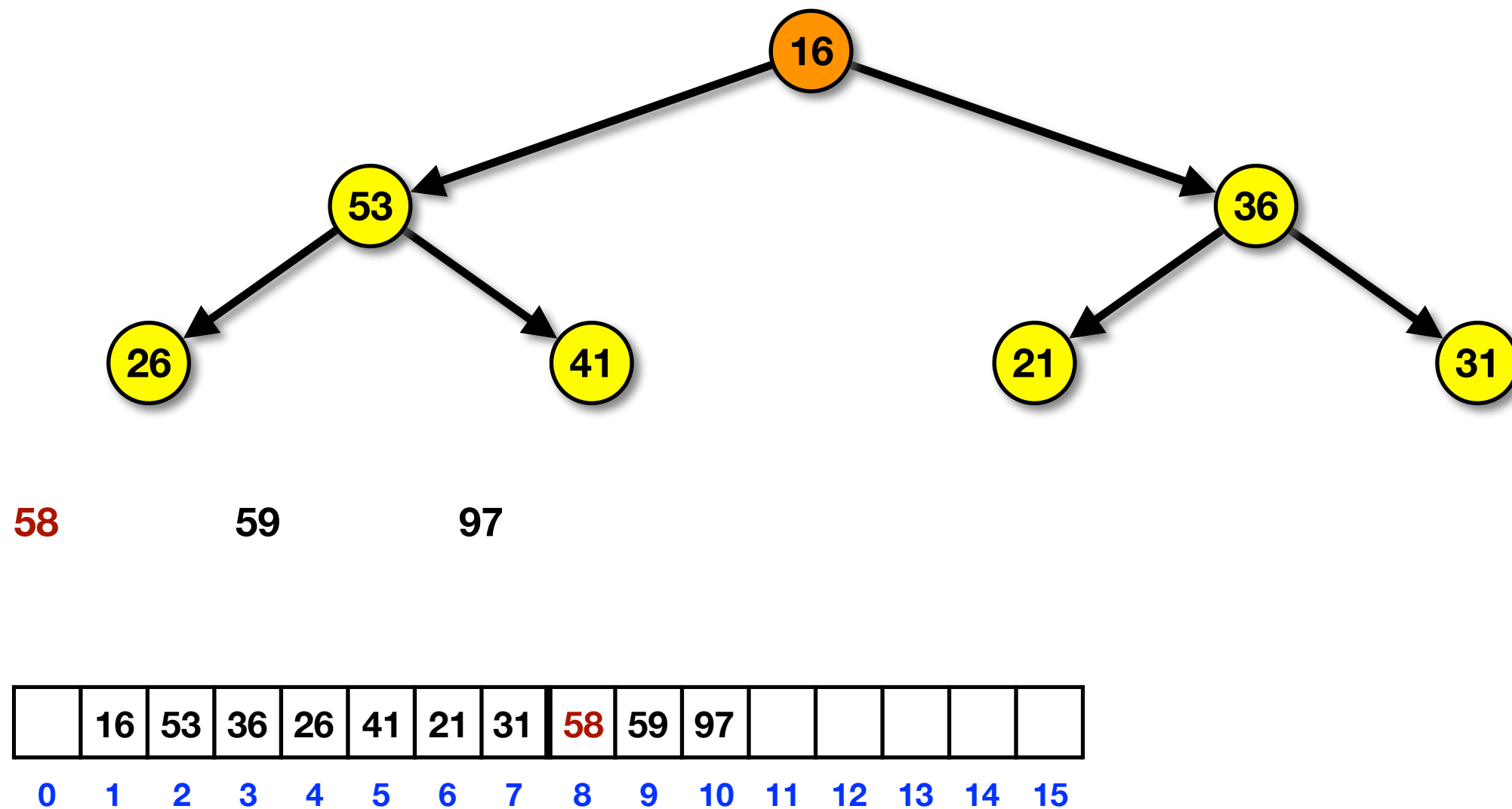
- Call `percolateDown` on node 21



	58	53	36	26	41	21	31	16	59	97					
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

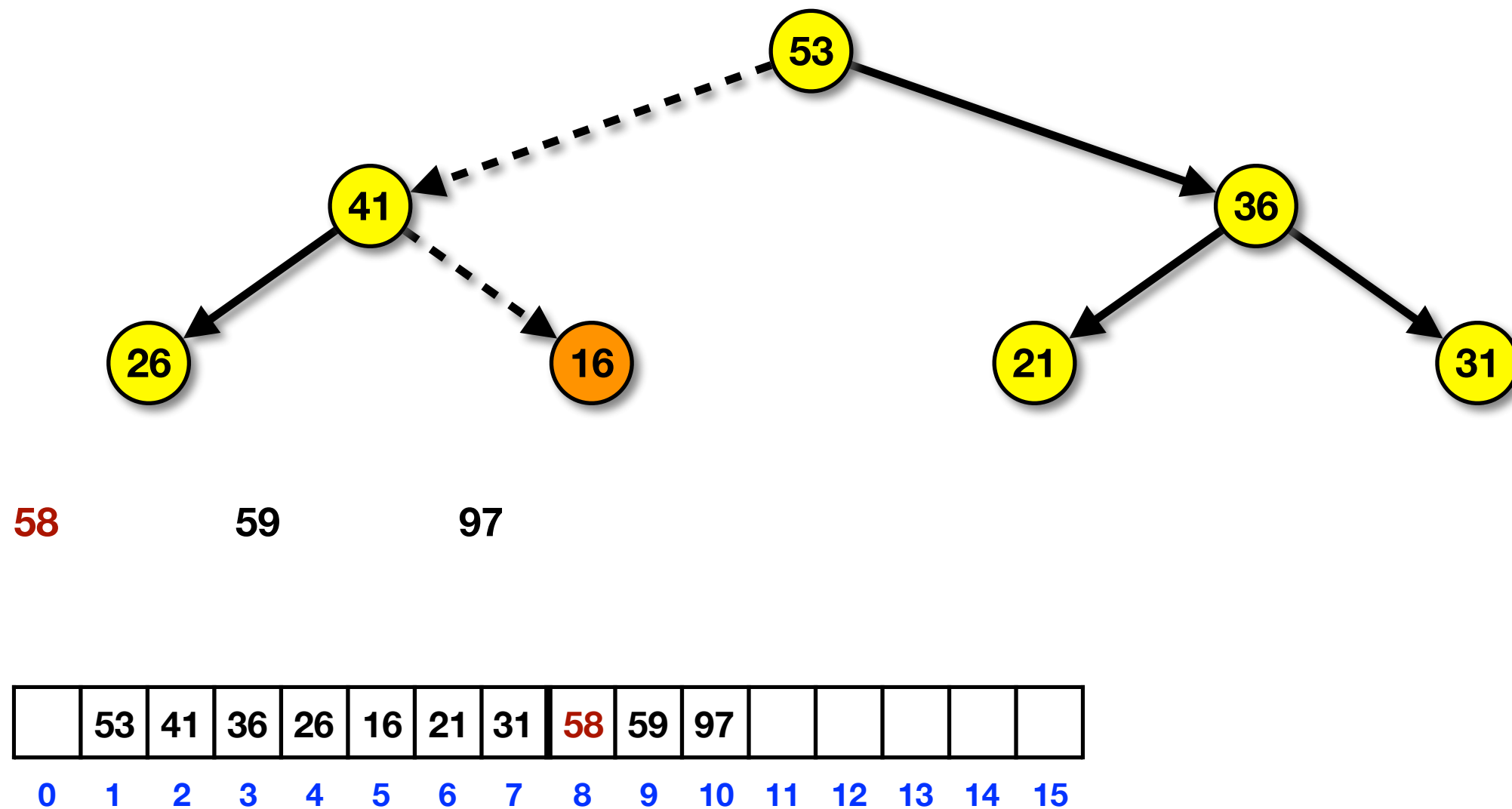
# Heapsort Example

- ▶ Call deleteMax method
- ▶ Swap node 16 with node 58 and shrink the size of the heap



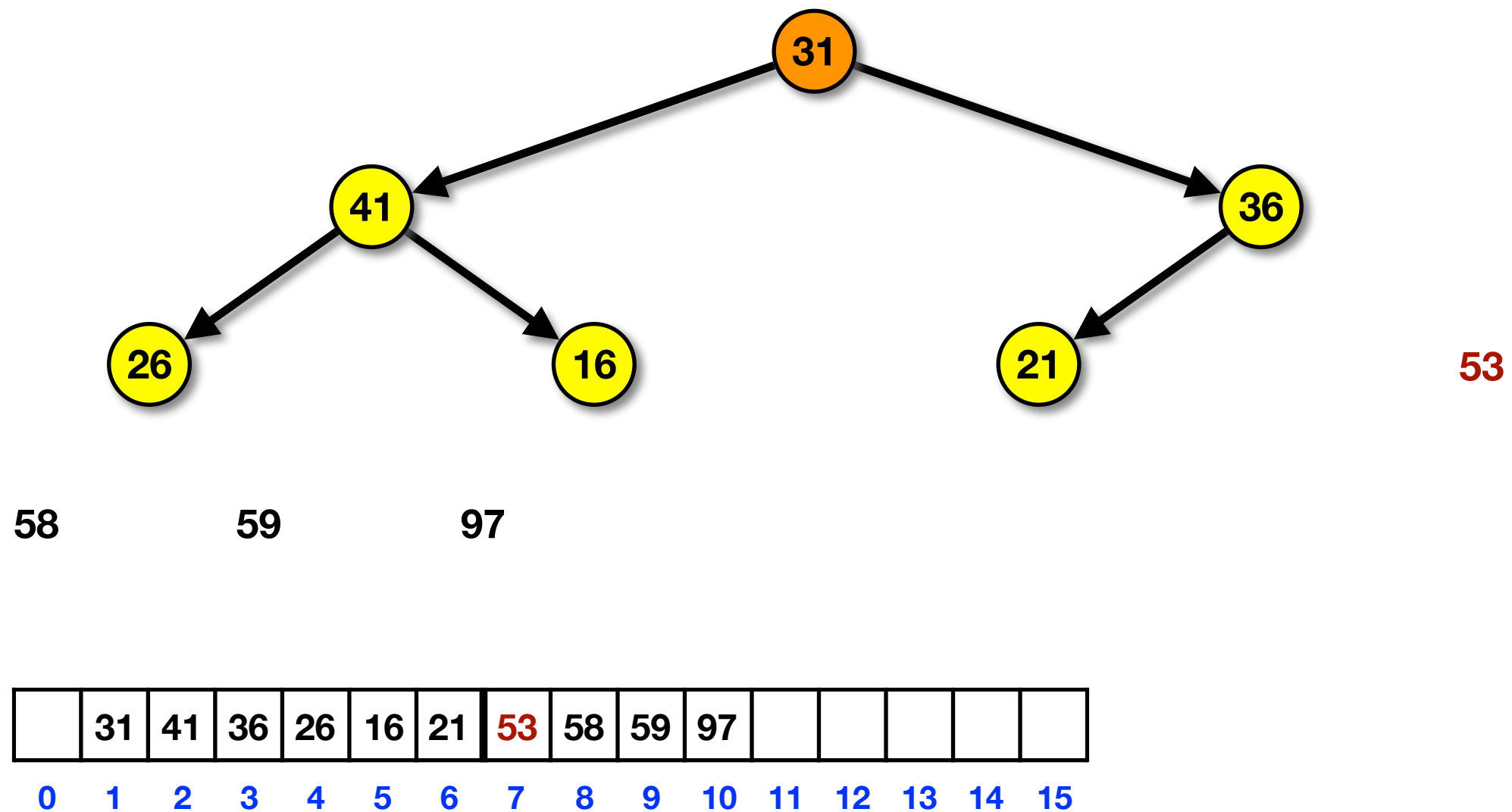
# Heapsort Example

- Call `percolateDown` on node 16



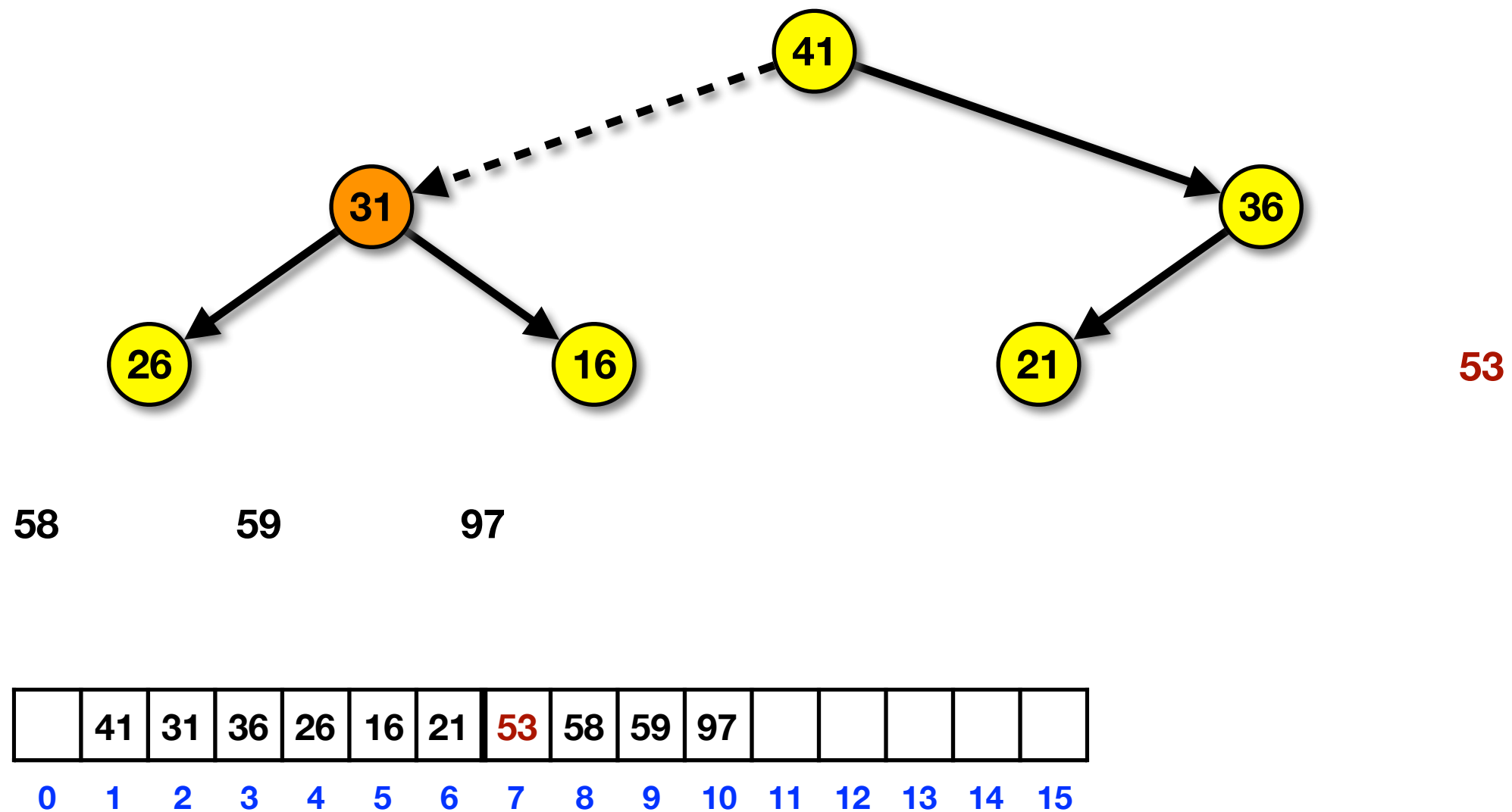
# Heapsort Example

- ▶ Call deleteMax method
- ▶ Swap node 31 with node 53 and shrink the size of the heap



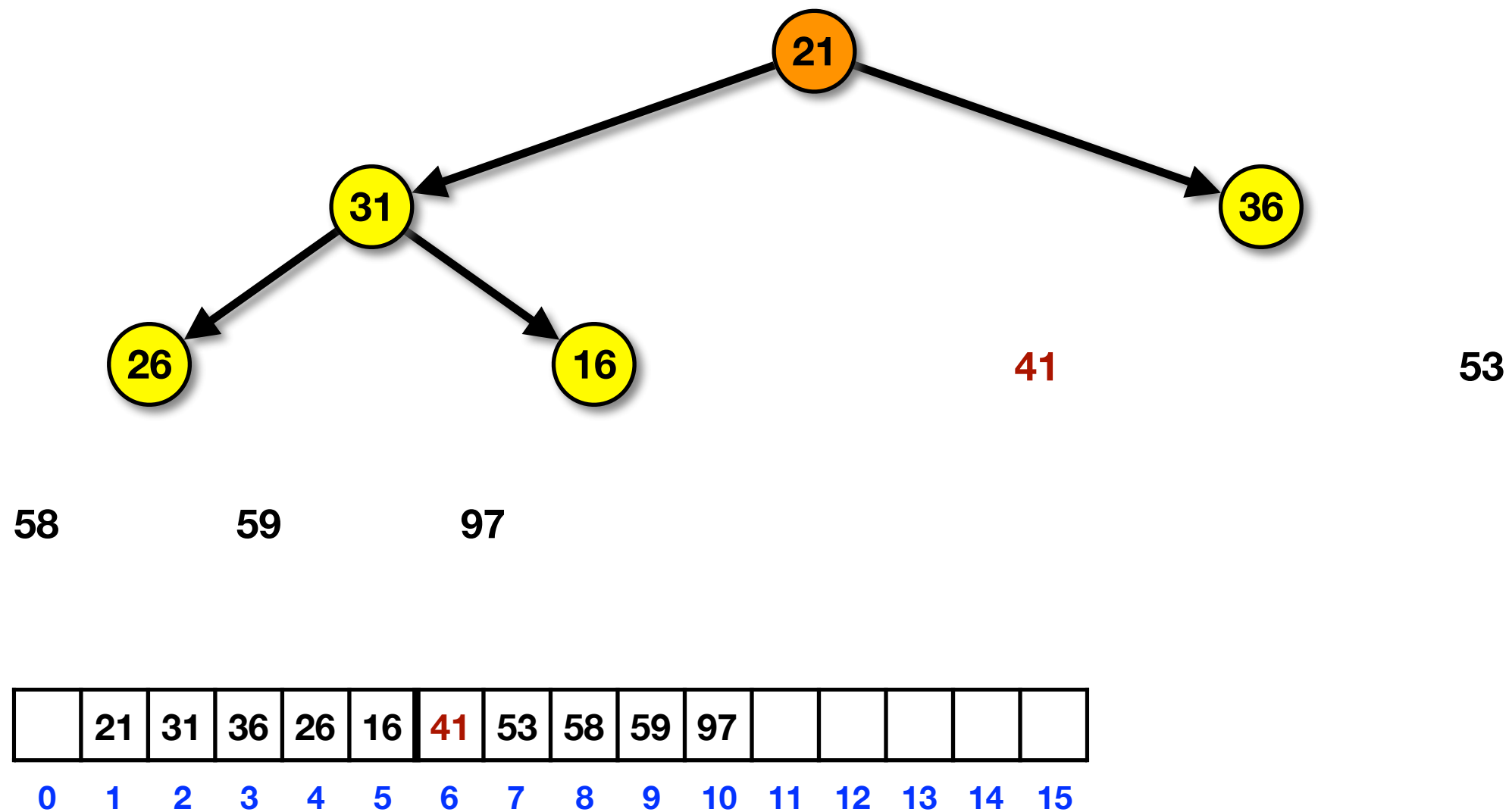
# Heapsort Example

- Call `percolateDown` on node 31



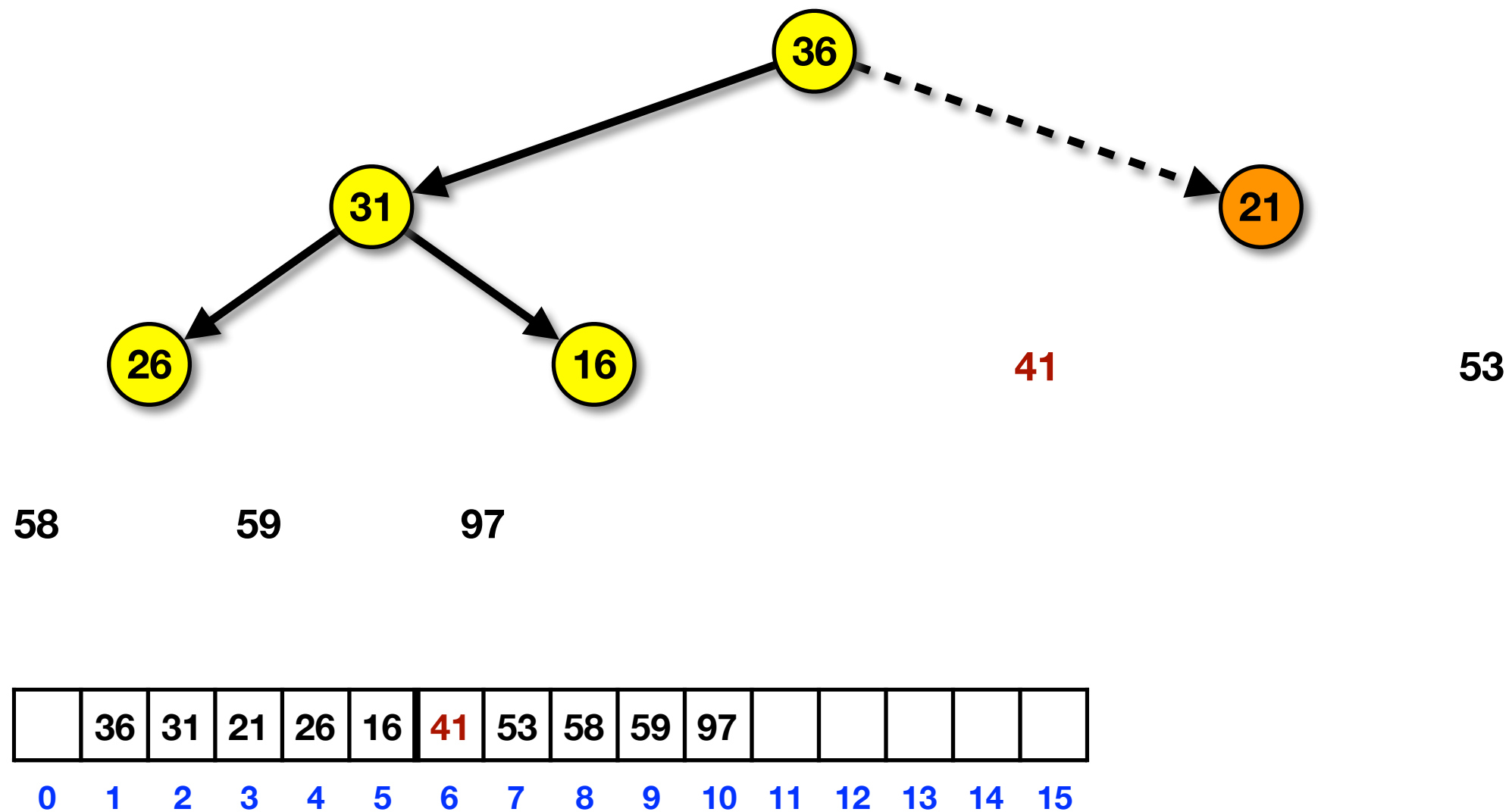
# Heapsort Example

- ▶ Call deleteMax method
- ▶ Swap node 21 with node 41 and shrink the size of the heap



# Heapsort Example

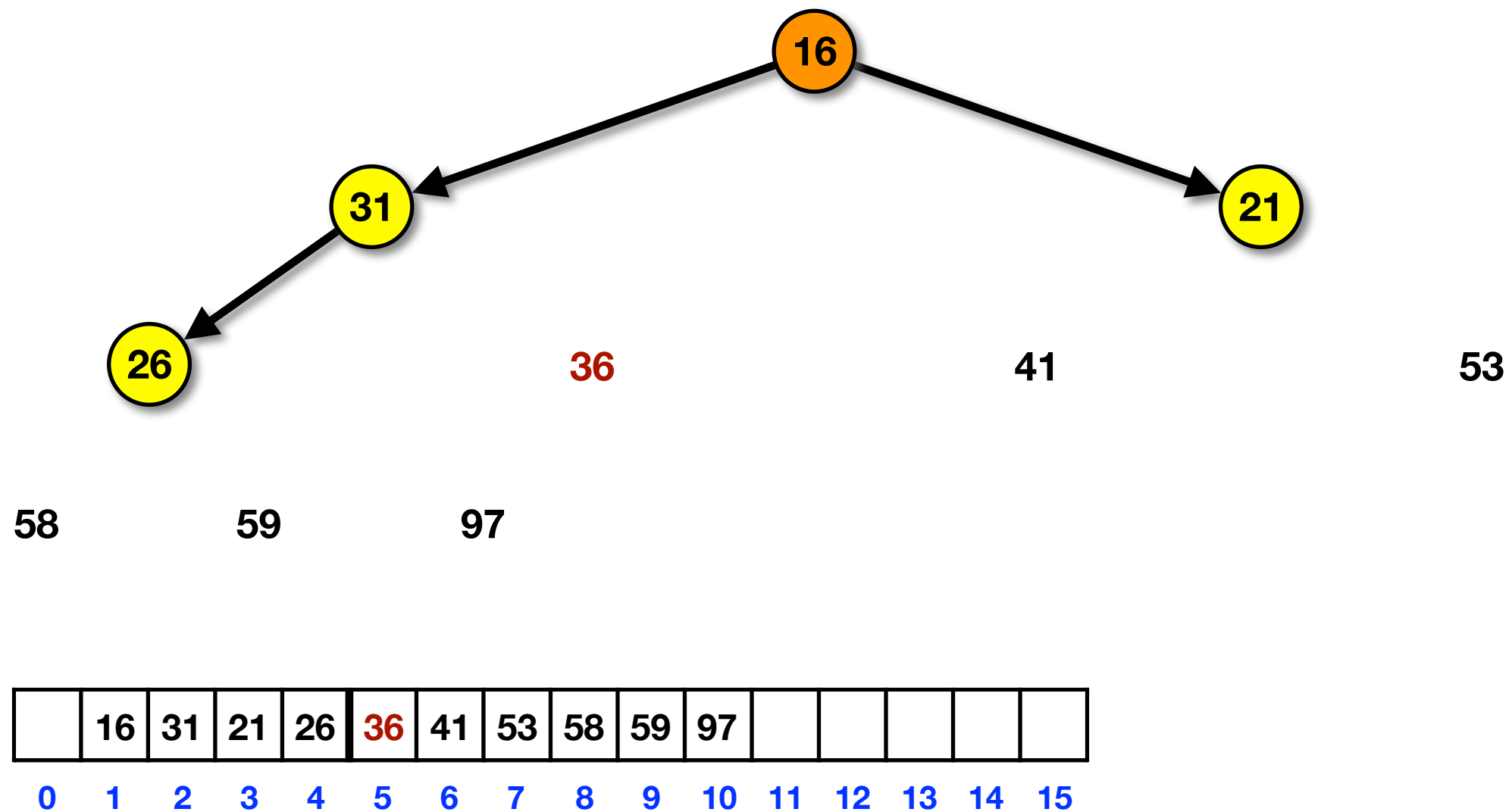
- ▶ Call `percolateDown` on node 21





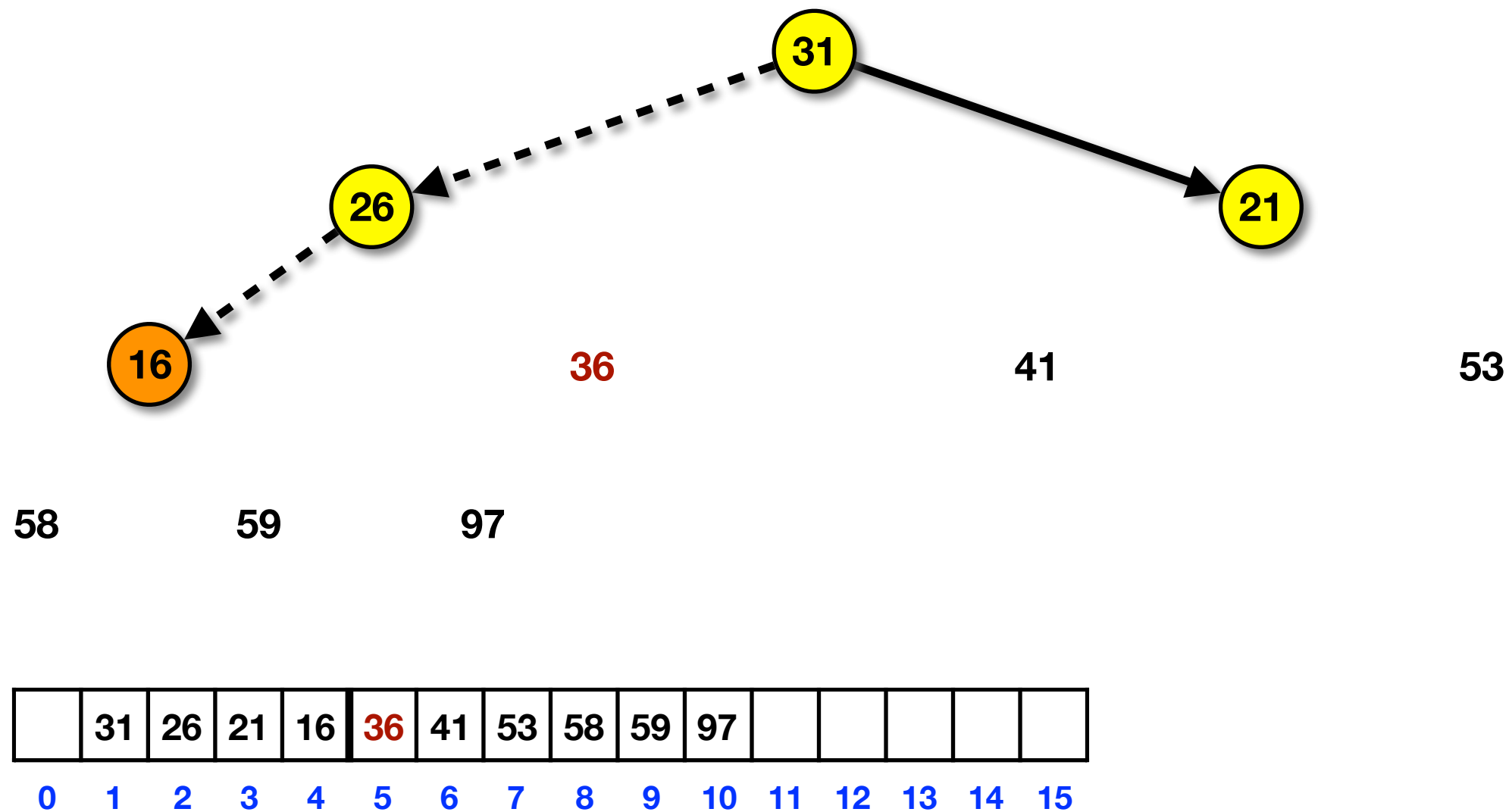
# Heapsort Example

- ▶ Call deleteMax method
- ▶ Swap node 16 with node 36 and shrink the size of the heap



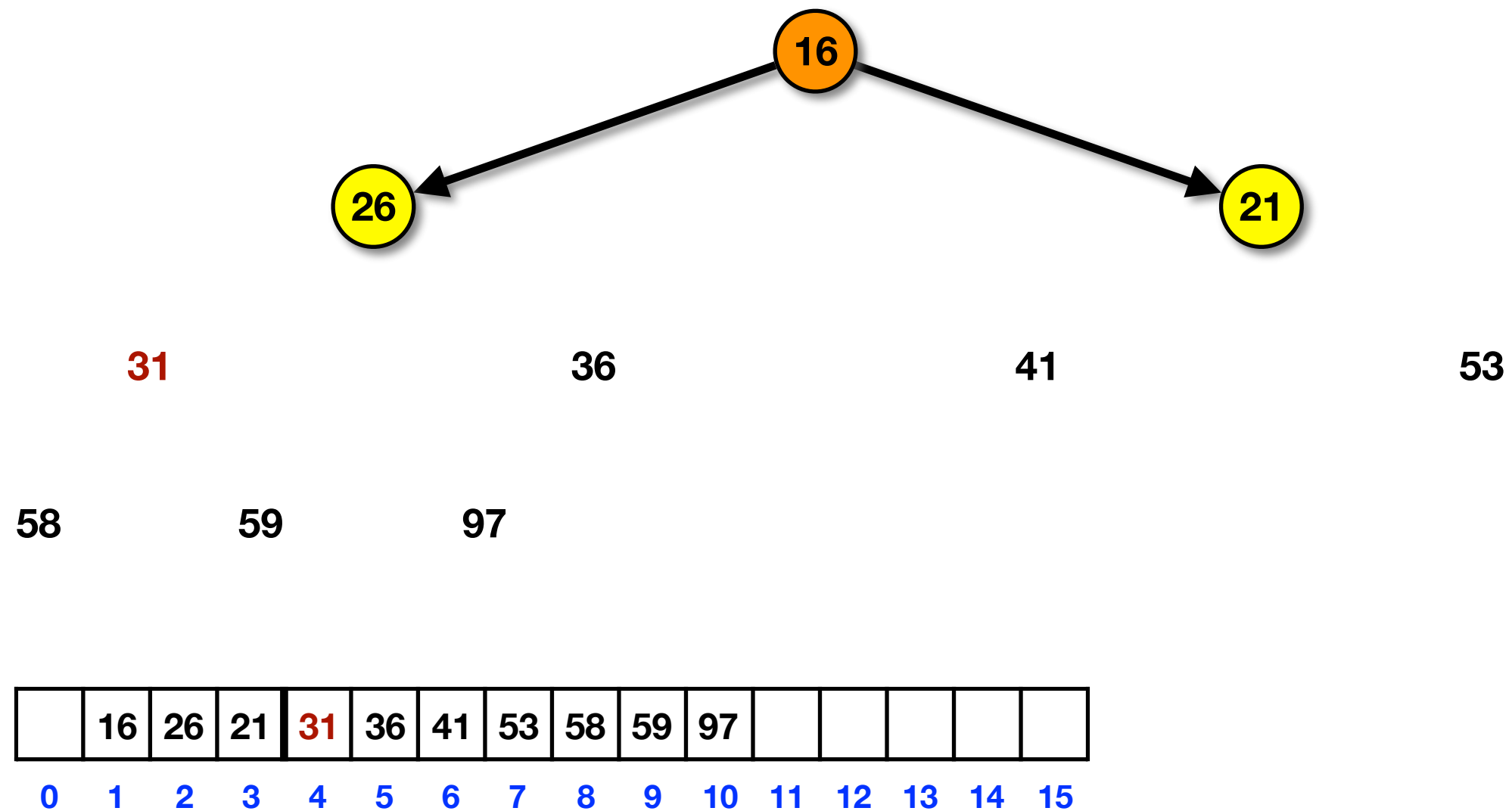
# Heapsort Example

- ▶ Call `percolateDown` on node 16



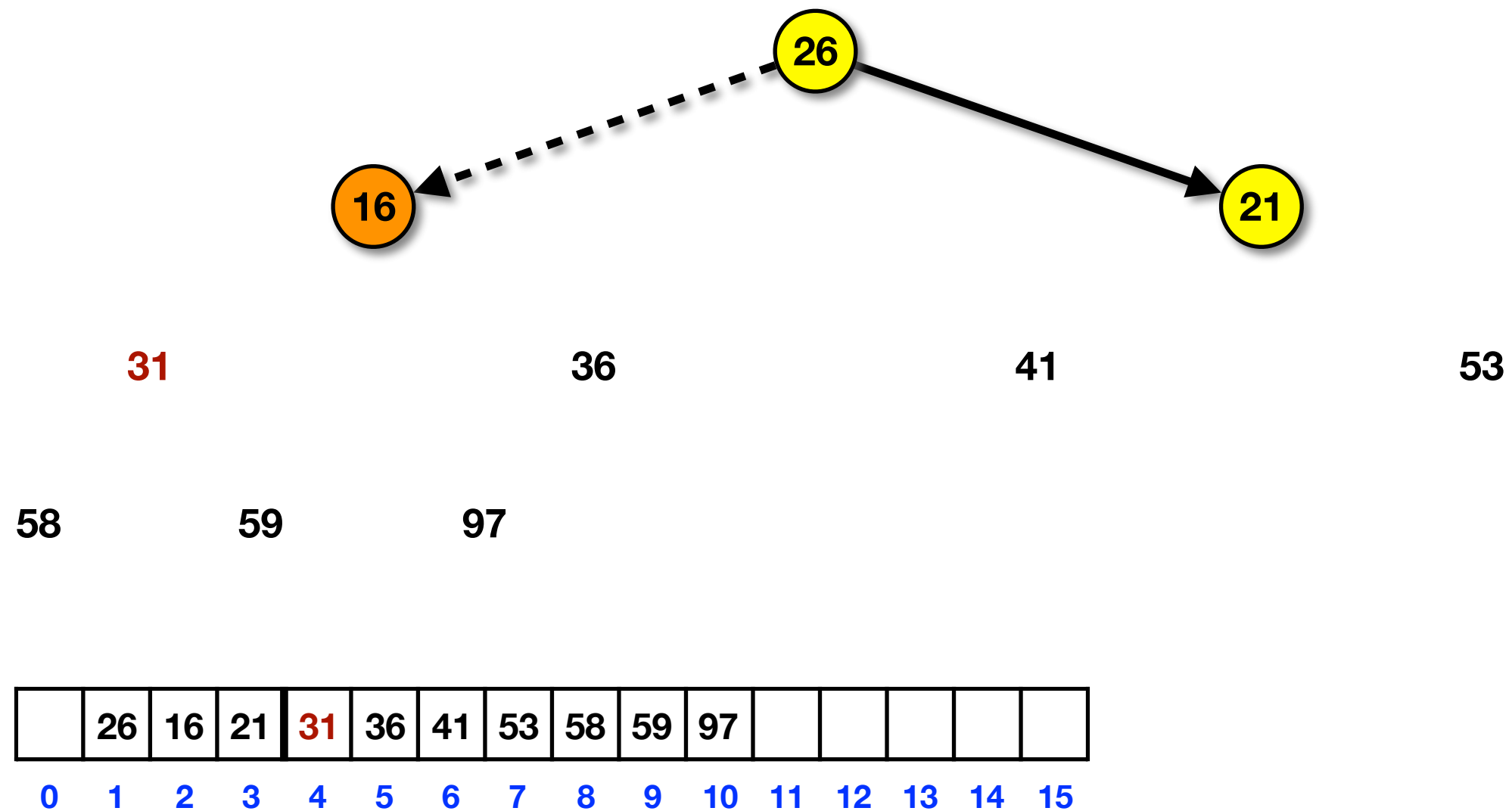
# Heapsort Example

- ▶ Call deleteMax method
- ▶ Swap node 16 with node 31 and shrink the size of the heap



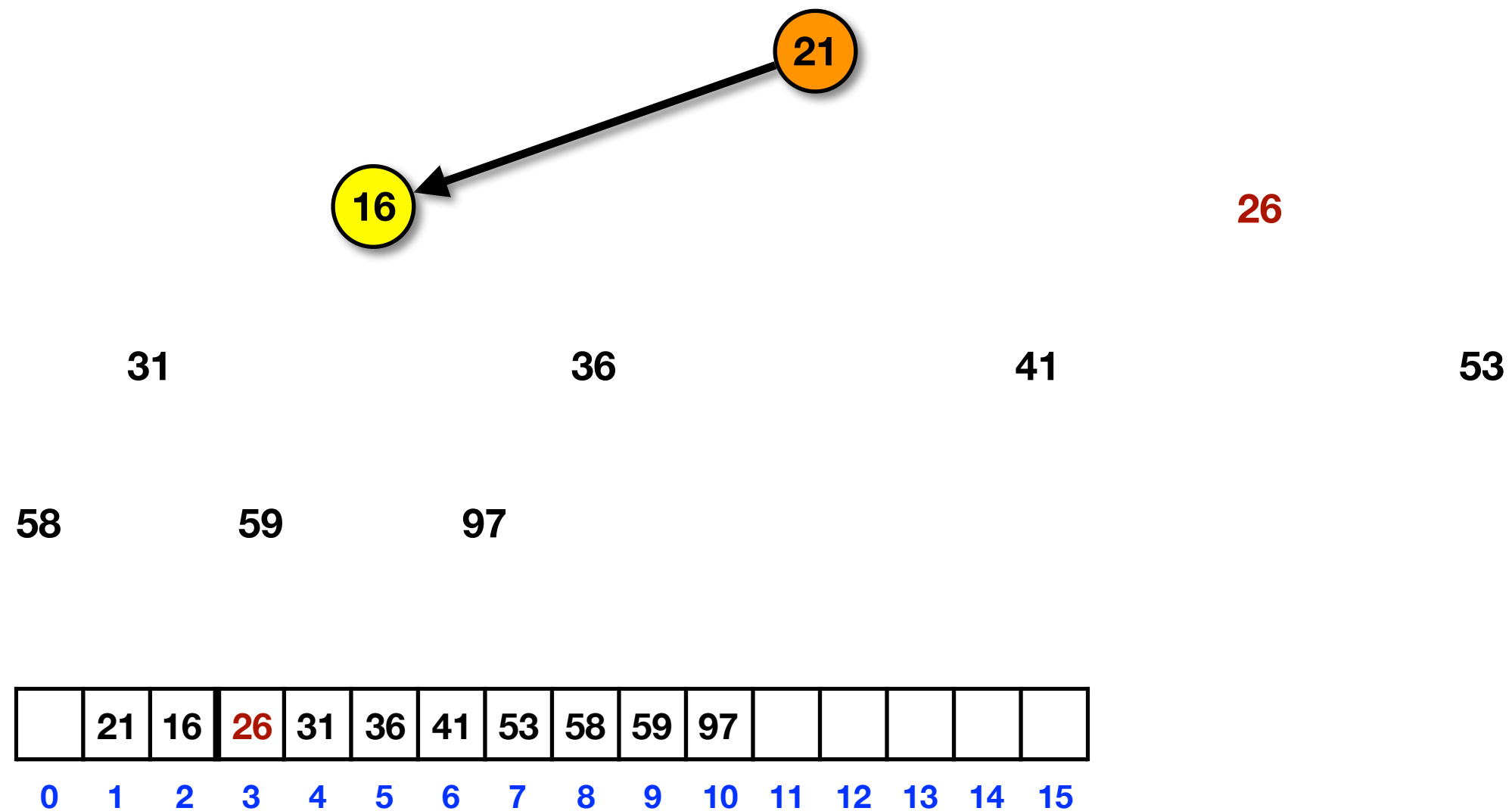
# Heapsort Example

- ▶ Call `percolateDown` on node 16



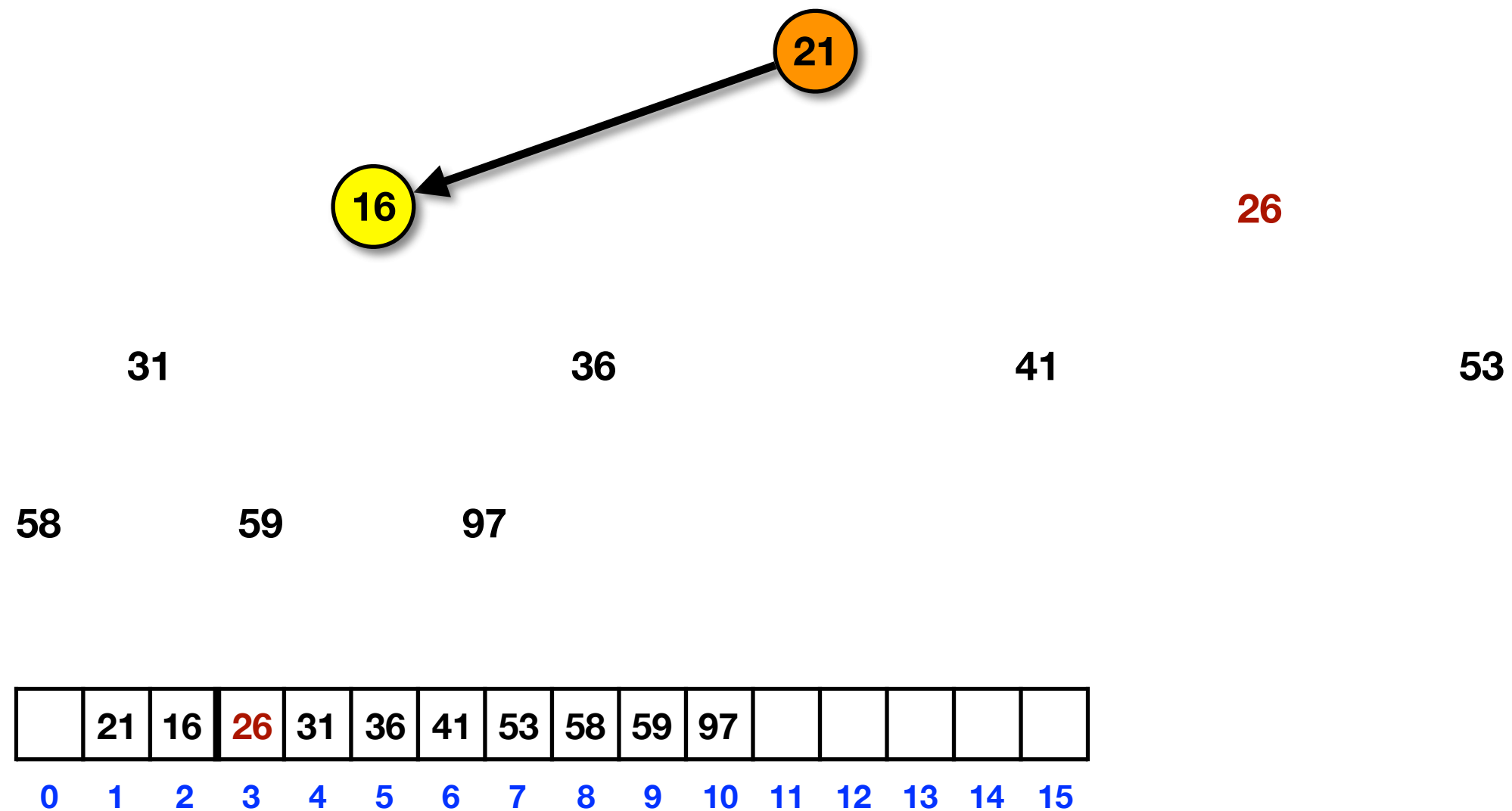
# Heapsort Example

- ▶ Call deleteMax method
- ▶ Swap node 21 with node 26 and shrink the size of the heap



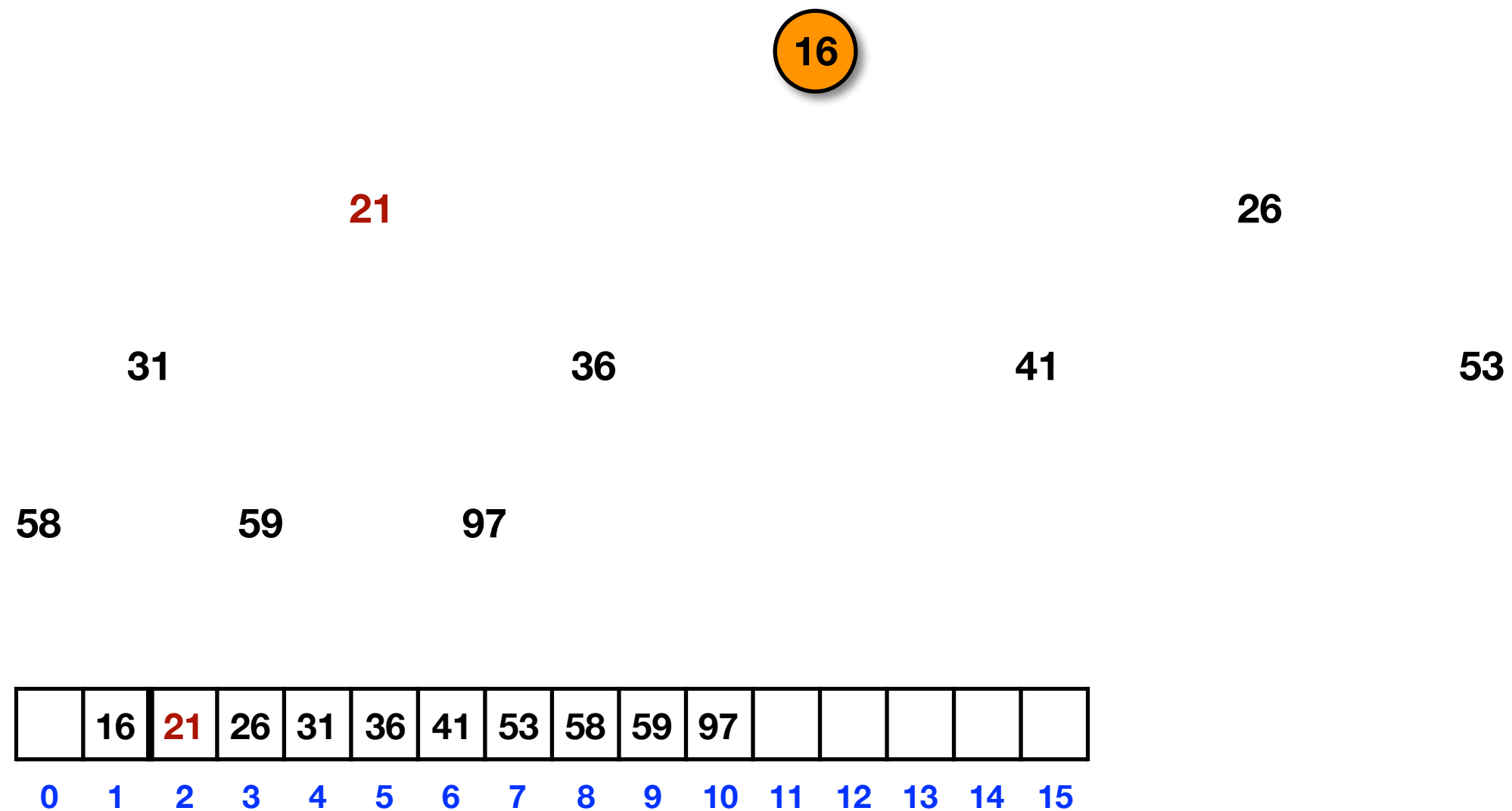
# Heapsort Example

- ▶ Call `percolateDown` on node 21



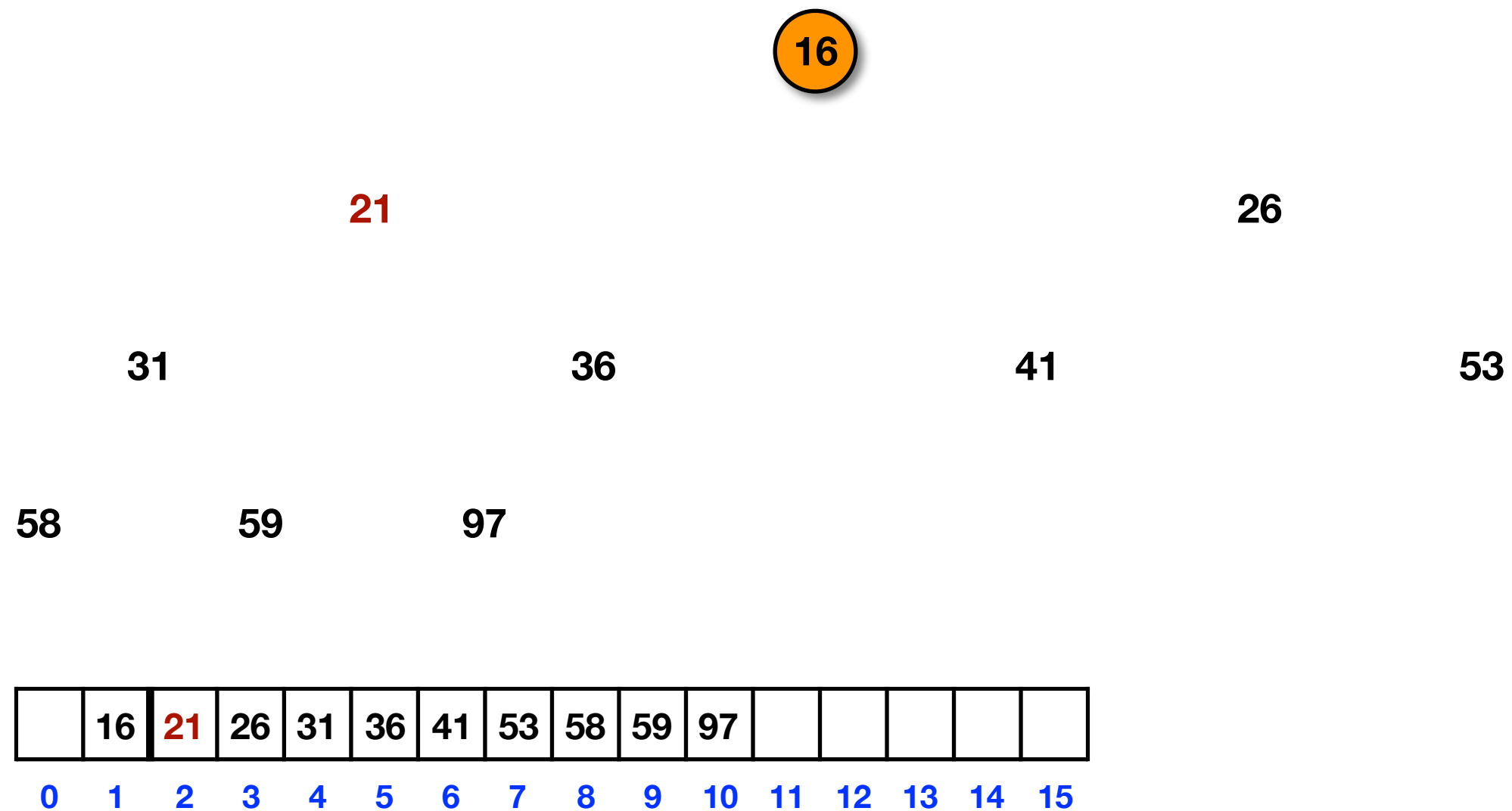
# Heapsort Example

- ▶ Call deleteMax method
- ▶ Swap node 16 with node 21 and shrink the size of the heap



# Heapsort Example

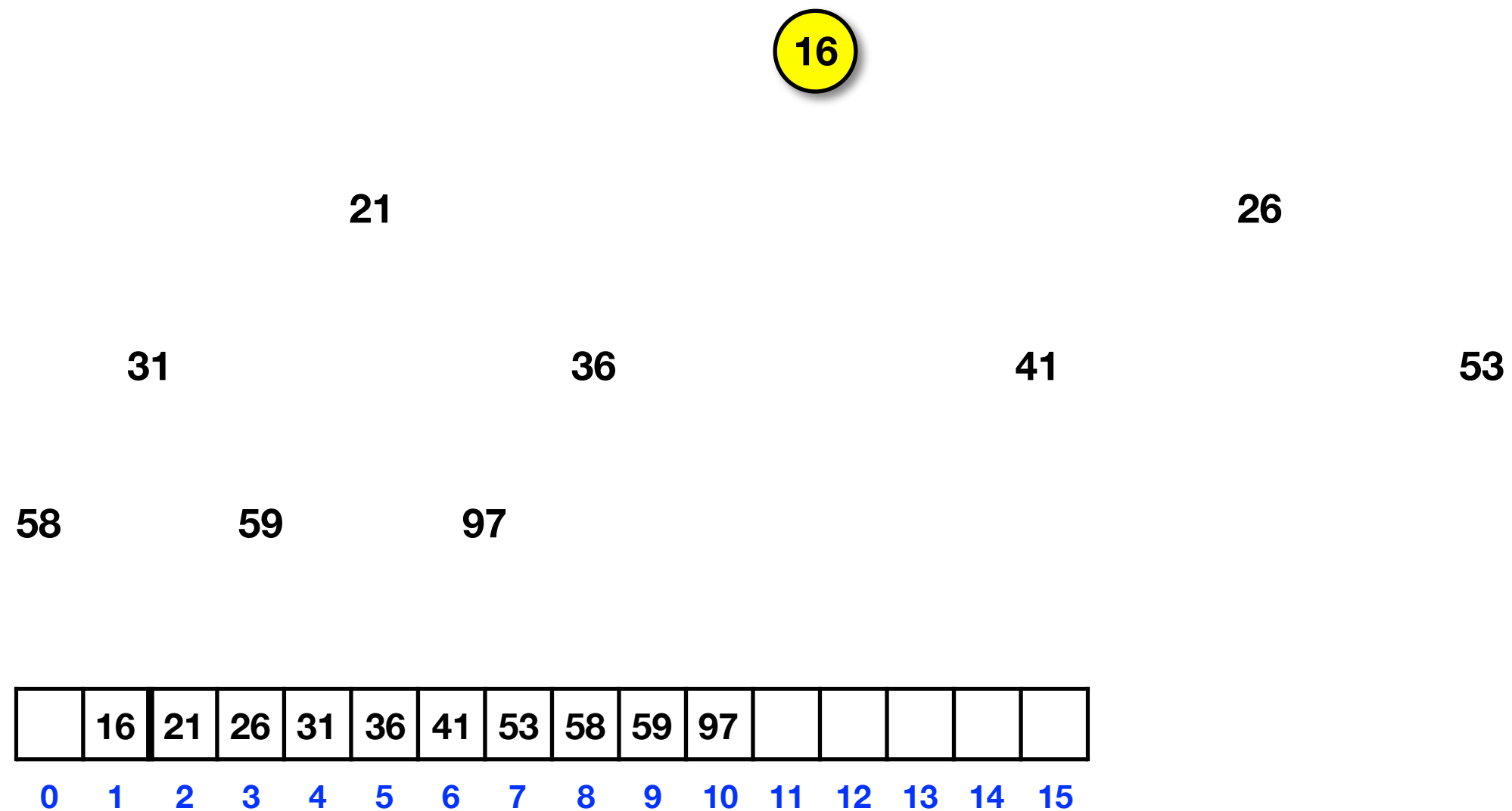
- ▶ Call `percolateDown` on node 16





# Heapsort Example

- ▶ Since node 16 is the last node, no need to call deleteMax again
- ▶ Heapsort is complete



# Heapsort Example

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