Tables and Priority Queues

Tables

- Previously: each node stored one item
- Now: Groups of related information in records
  - Records indexed by key
  - Key is just one of the pieces of information – the one you want to be able to search on
- Support fast searching by key – O(logn)
- Also support scanning for other information in records
  - But not as fast – O(n) instead of O(logn)
- Examples
  - Student records
  - List of pirated MP3s

Table ADT – Operations

1. Create an empty table
2. Determine whether a table is empty
3. Determine the number of items in a table
4. Insert a new item into the table
5. Delete the item with a given search key from the table
6. Retrieve the item with a given search key from the table
7. Traverse the items in a table in sorted search-key order

SearchKeys

```
public abstract class KeyedItem {
    private Comparable searchKey;

    public KeyedItem(Comparable key) {
        searchKey = key;
    }

    public Comparable getKey() {
        return searchKey;
    }
}
```

City extends KeyedItem

```
public class City extends KeyedItem {
    private String country;
    private int population;
    public City(String theCity, String theCountry, int pop) {
        super(theCity);
        country = theCountry;
        population = pop;
    }
    public String toString() {
        return getKey() + ", " + country  + " " + population;
    }
    public void setPopulation(int pop) { population = pop; }
    public int getPopulation() { return population; }
    public String getCountry() { return Country; }
}
```

TableInterface

```
import searchkeys.*;
public interface TableInterface {
    public boolean tableIsEmpty();
    public int tableLength();
    public void tableInsert(KeyedItem newItem)
        throws TableException;
    public boolean tableDelete(Comparable searchKey);
    public KeyedItem tableRetrieve(
                                Comparable searchKey);
}
```

Implementing the Table

- Linear implementations
  - Unsorted array
  - Unsorted linked list
  - Sorted (by key) array
  - Sorted (by key) linked list
- Non-linear implementations
  - Binary search tree
- Criteria
  - What operations are needed?
  - How often will different operations be used?
  - How important are the different operations?

Examples

- Small, unsorted data, fixed size
  - Array
- Small, unsorted data, variable size
  - Linked list
- Small, sorted data, variable size
  - Linked list
- Large, unsorted data, variable size
  - Linked list
- Large, sorted data, variable size
  - Binary search tree

Comparison of Implementation Alternatives

	Insertion	Deletion	Retrieval	Traversal
Unsorted array	O(1)	O(n)	O(n)	O(n)
Unsorted linked list	O(1)	O(n)	O(n)	O(n)
Sorted array	O(n)	O(n)	O(logn)	O(n)
Sorted linked list	O(n)	O(n)	O(n)	O(n)
Binary search tree	O(logn)	O(logn)	O(logn)	O(n)

See Table Code

Priority Queue

- It is often useful to assign a **priority** to different data items
  - so that urgent items can be processed first
- Examples
  - Time in a todo list
  - Importance in a list of phone calls to make
  - …

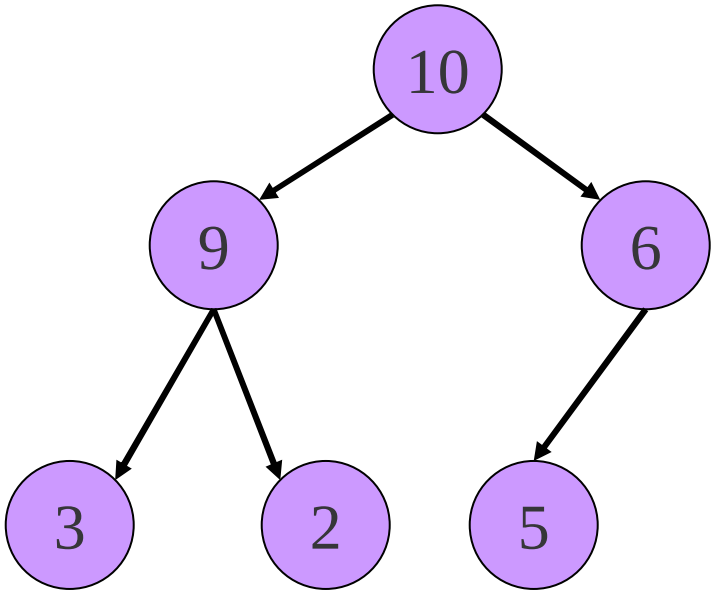
Priority Queue ADT

1. Create an empty priority queue
2. Determine whether a priority queue is empty
3. Insert a new item into a priority queue
4. Retrieve and then delete the item in a priority queue with the highest priority

Implementing Priority Queues: Heaps

- A complete binary tree that is
  - Empty, or
  - Whose root has heaps as its subtrees, and
  - whose root contains a key greater than or equal to the key of each of its children
- Heaps are always balanced
- There is no order on the values of the keys of the two children of a node
  - Unlike binary search trees

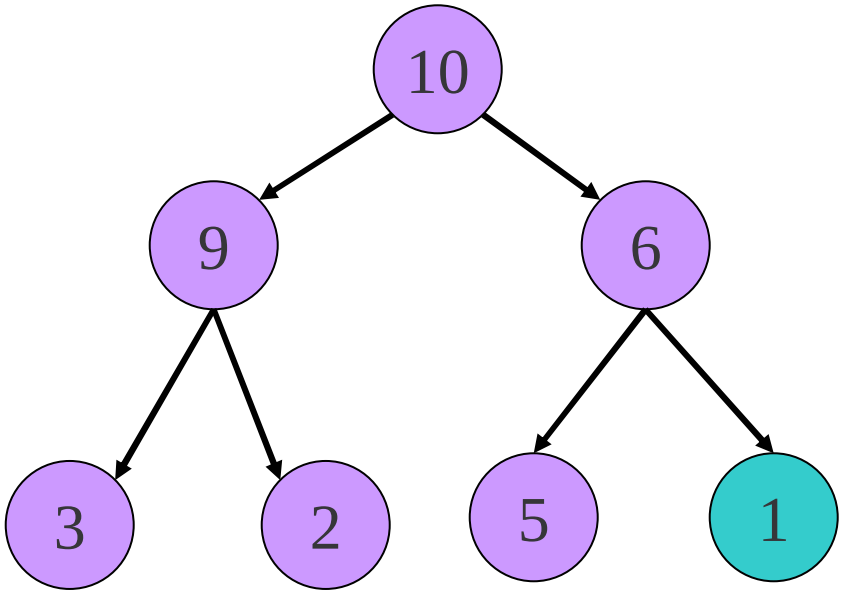
Array-based Implementation of a Heap



10
9
6
3
2
5

- Breadth-first order in the array
- Complete tree ⇒ no gaps in array

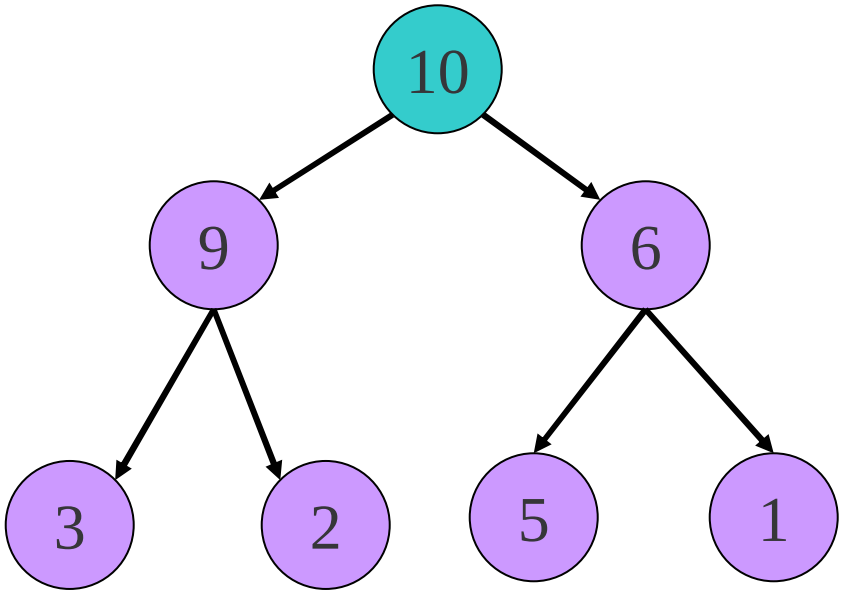
Inserting into the Heap



10
9
6
3
2
5
1

- Breadth-first order in the array
- Complete tree ⇒ no gaps in array

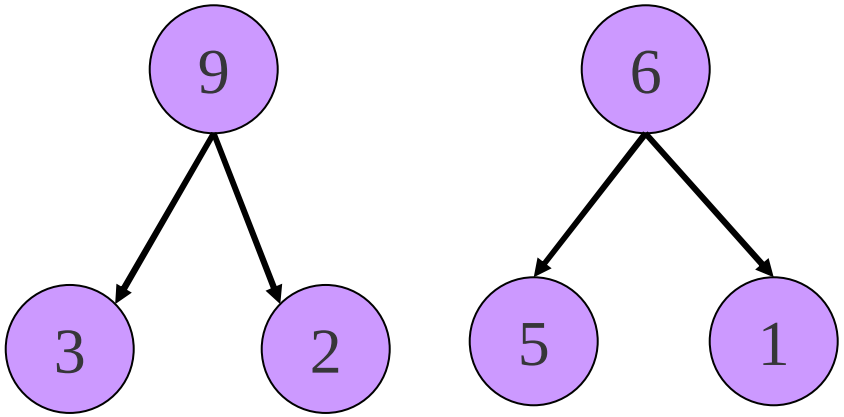
Deleting from the Heap (1)



10
9
6
3
2
5
1

- Always delete the root
  - It has the highest priority

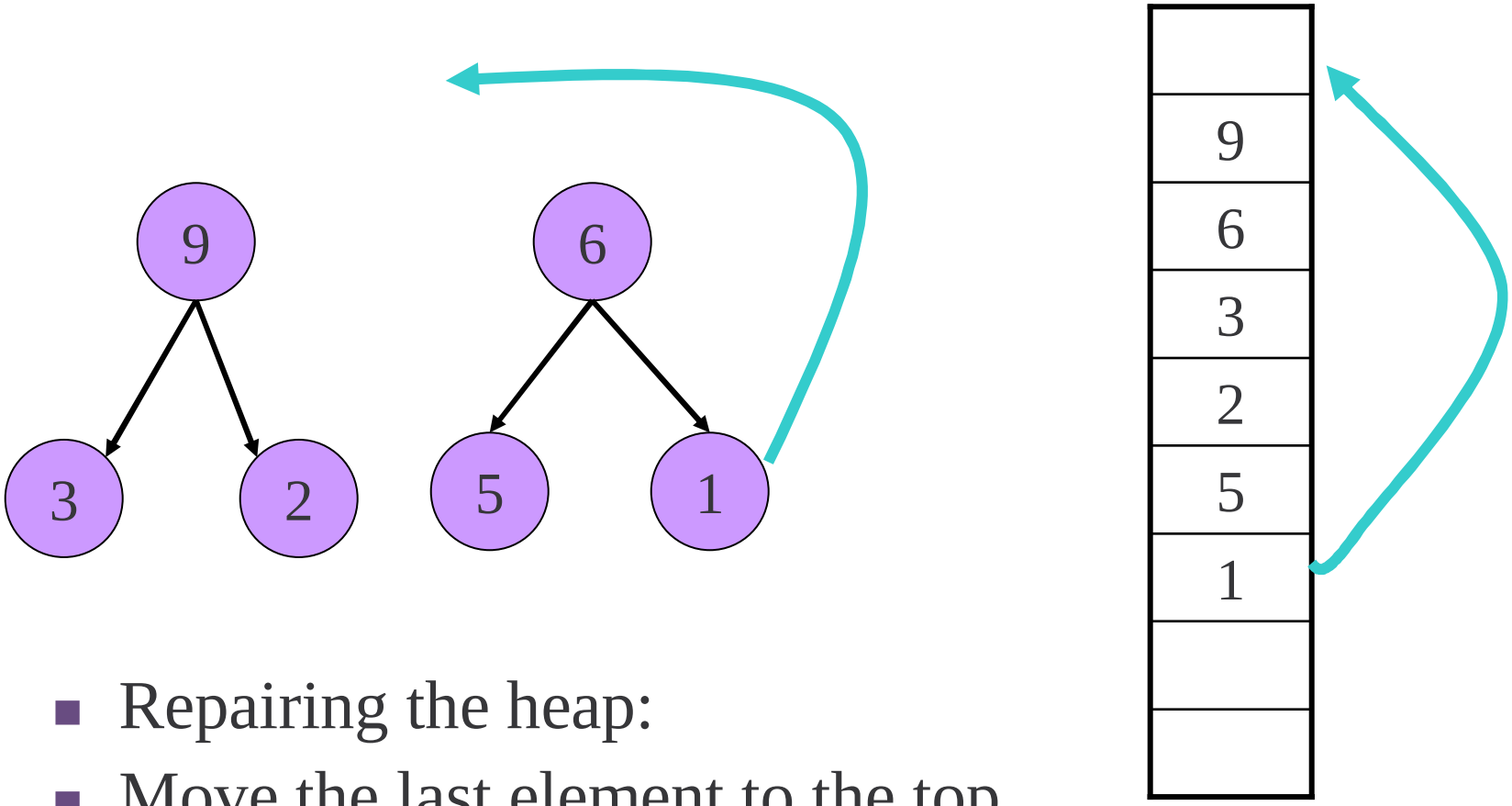
Deleting from the Heap (2)



9
6
3
2
5
1

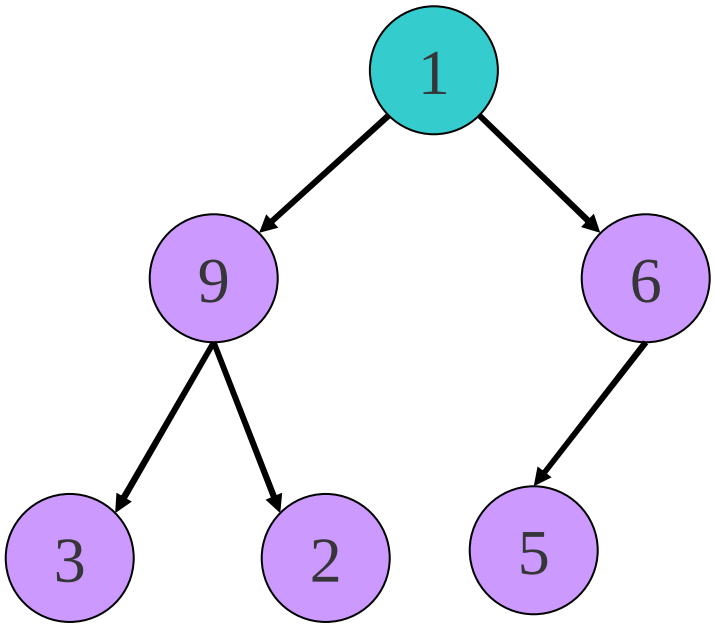
- Oops, now we have two heaps

Deleting from the Heap (3)



- Repairing the heap:
- Move the last element to the top

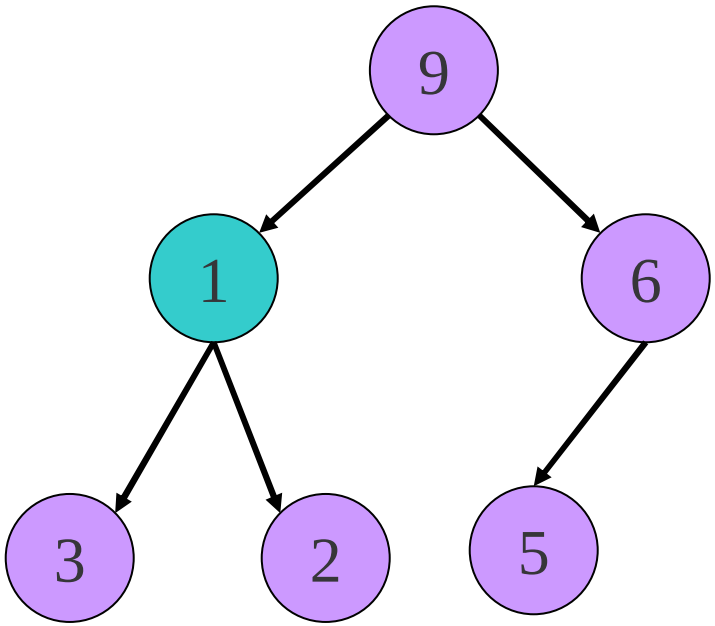
Deleting from the Heap (4)



1
9
6
3
2
5

- Repairing the heap:
- Now “trickle down” by comparing and swapping until heap is restored

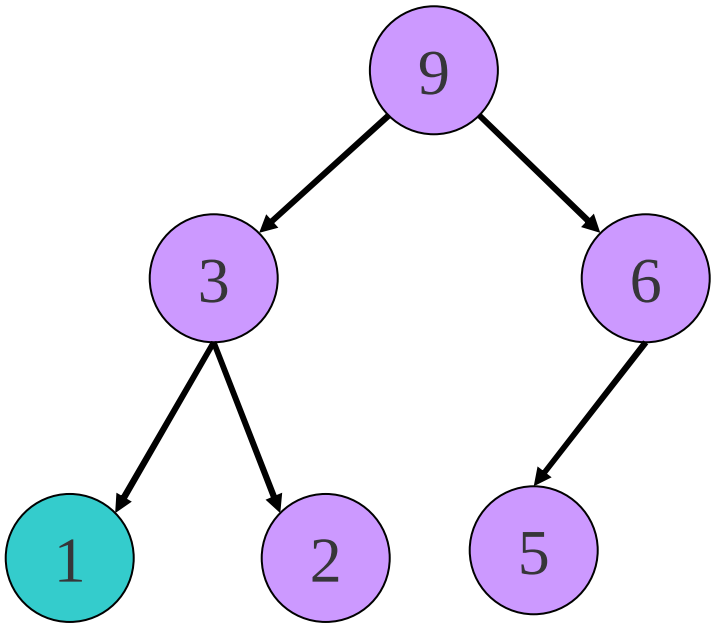
Deleting from the Heap (5)



9
1
6
3
2
5

- Repairing the heap:
- Now “trickle down” by comparing and swapping until heap is restored

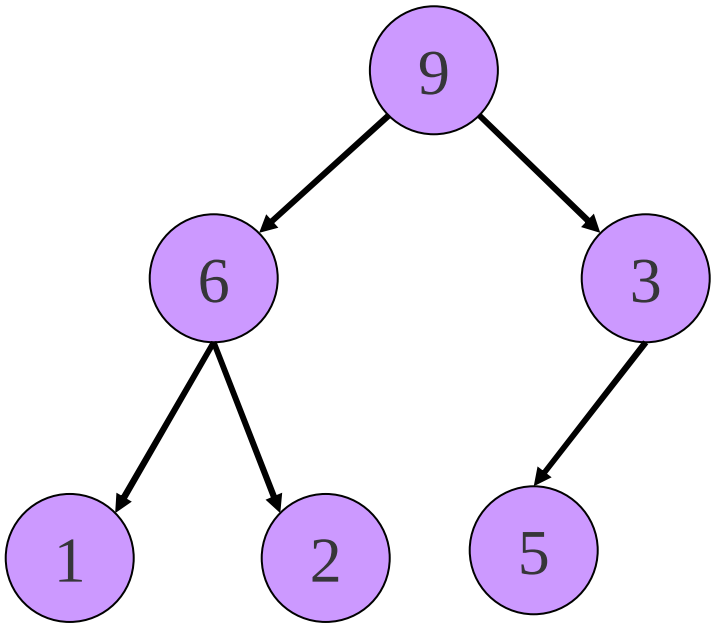
Deleting from the Heap (6)



9
3
6
1
2
5

- Calculating indices:
  - leftchild = 2*parent+1
  - Rightchild = 2*parent+2

Deleting from the Heap (7)



9
6
3
1
2
5

- Now it's a heap again
- Total time O(logn)

Inserting to a heap

- The opposite of deleting
- Insert at the bottom, then “trickle up”

Heapsort

- One way
  - Insert everything into the heap, then
  - Take everything back out
- Faster way

1. Make it a heap

```
for(int index = n/2; n >= 0; n--) {
    heapRebuild(array, index, n);
}
```

2. Swap the first item (largest) with the last (last--)
3. heapRebuild(array, index, last);
4. Repeat until all items are in the right place

Heapsort

- Make it a heap by doing heapRebuild to each node
  - Starting with leaf nodes

9
6
3
1
2
5

Heapsort

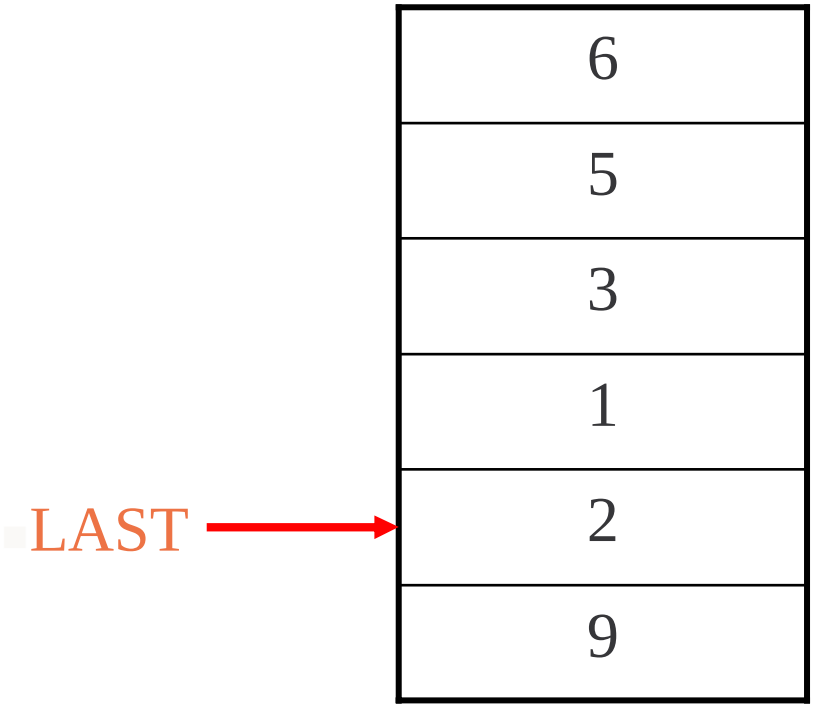
- Swap first and “last”

5
6
3
1
2
9

LAST

Heapsort

- last = last – 1
- heapRebuild()



Heapsort

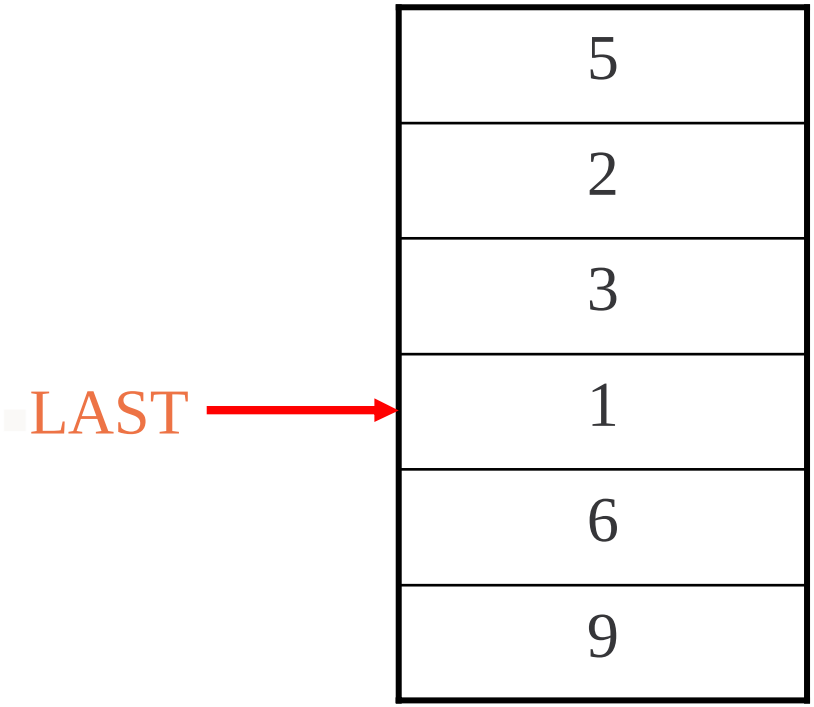
- Swap first and “last”

2
5
3
1
6
9

LAST

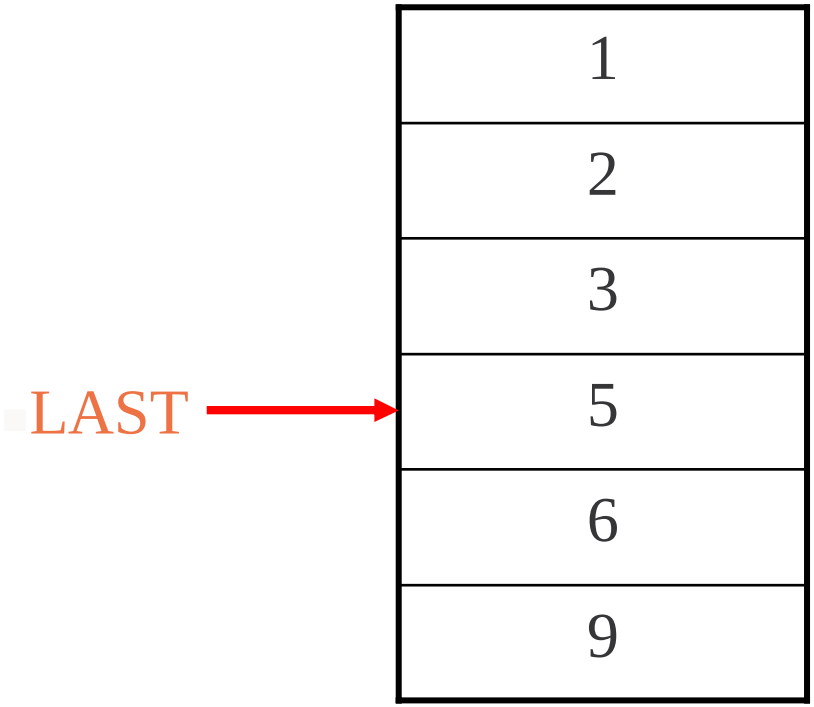
Heapsort

- last = last - 1
- heapRebuild()



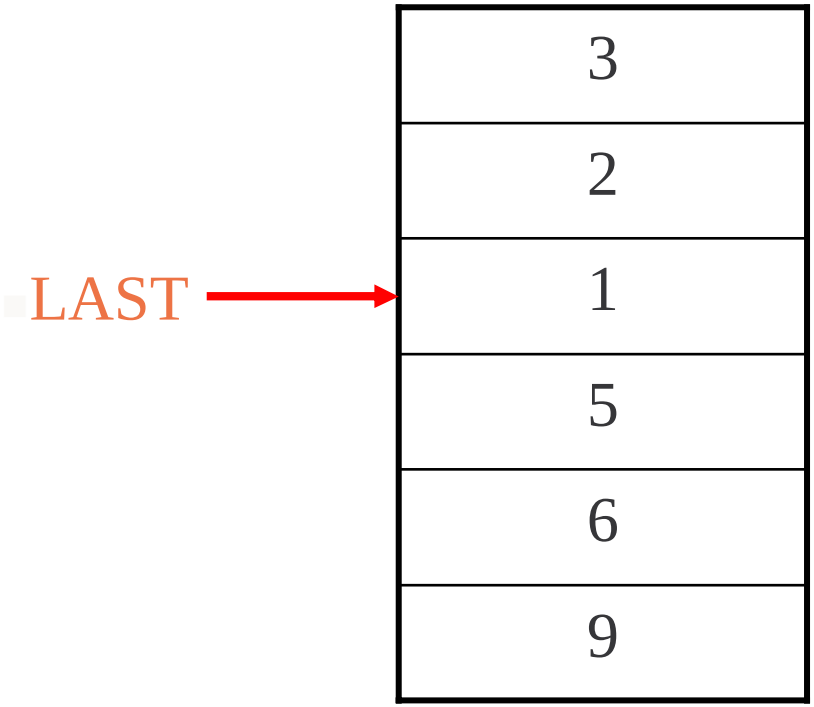
Heapsort

- Swap first and “last”



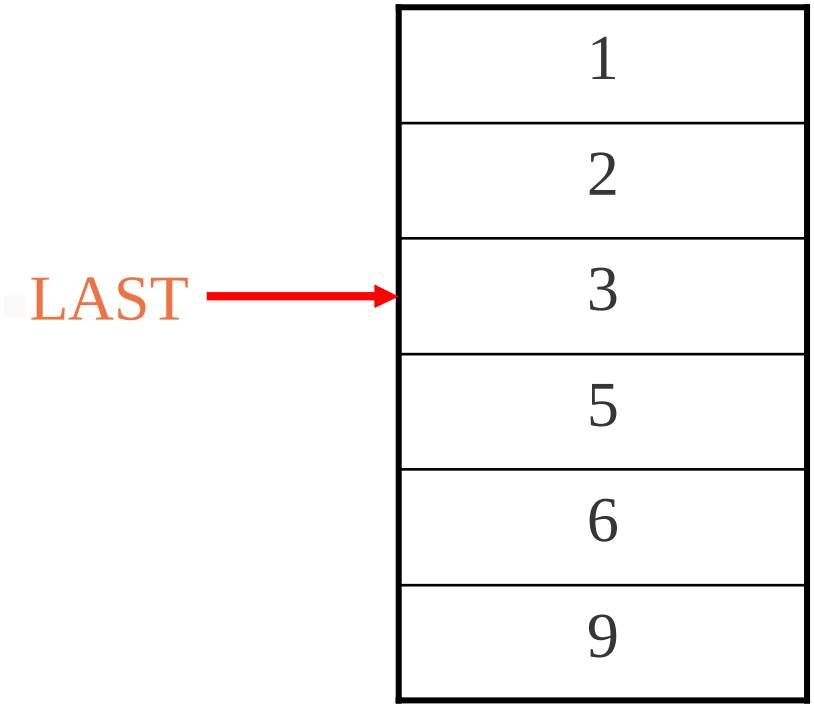
Heapsort

- last = last - 1
- heapRebuild()



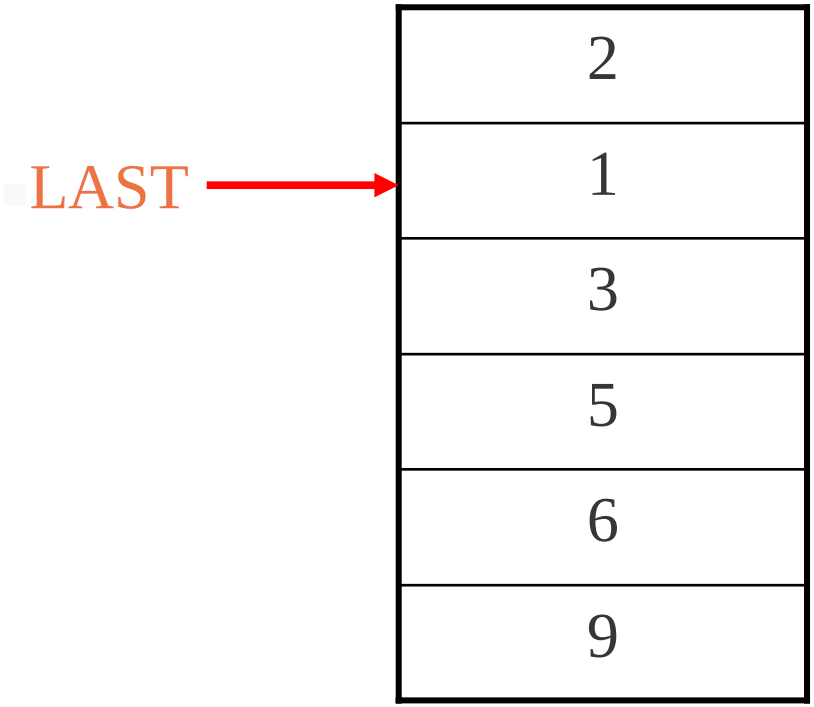
Heapsort

- Swap first and “last”



Heapsort

- last = last – 1
- heapRebuild()



Heapsort

- Swap first and “last”
- Done!