Priority Queues
Abstract Classes

cs151

Abstract classes

- A class that should/can NEVER be instantiated.
  - From the Pets example
    - Pet, Dog should be defined as abstract classes
      - The only instances of each of these should be from more specific classes.
      - In taxonomy kingdom, phylum or division, class, order, family, and genus should all be abstract
        - only species should have instance

AbStract Classes

Pt 2

	Interface	Abstract Class	Class
stub methods	YES	YES	NO
full methods	NO	YES	YES
Instance Variables	NO	YES	YES
Multiple inheritance from	YES	NO	NO
Instantiatable	NO	NO	YES
Has Constructors	NO	NO	YES
May implement interfaces	YES	YES	YES
May extend classes	NO	YES	YES

Abstract Class

AbstractExample

```
public abstract class AbCl {
    private double km;

    public double getKM () {
        return km;
    }

    public double getMiles() {
        return km * 1.62;
    }

    /**
     * A really long comment so that implementers know exactly what to do
     * @param aaa
     * @param bbb
     */
    public abstract void populate(int aaa, int bbb);
}
```

Priority Queue

- A queue that maintains order of elements according to some priority
- Contrast to Queue which is FiFo

- **PriorityQueues are about the order in which things are removed, NOT the way in which they are stored.**
  - the items may or may not be sorted, or otherwise arranged.
  - This statement applies to stack and queues also, it is just convenient in those cases to arrange data to make retrieval easy

AbstractPriorityQueue

```
public abstract class AbstractPriorityQueue <K extends Comparable<K>, V> implements PriorityQInterface<K,V> {

    protected class Pair<L extends Comparable<L>, W> implements Comparable<Pair<L,W>> {
        /** Hold the key */
        final L theK;
        /** Hold the  value*/
        final W theV;
        /**
         * Create an Entry instance
         * @param kk the key
         * @param vv the value
         */
        public Pair(L kk, W vv) {
            theK = kk;
            theV = vv;
        }
        @Override
        public int compareTo(AbstractPriorityQueue<K, V>.Pair<L, W> o) {
            return theK.compareTo(o.theK);
        }

        public String toString() {
            return "{{"+theK+" " +theV+"}}";
        }

    }
```

PQ Implementation

- Questions:
  - How to store keys and values
    - handling of duplicate keys
  - Is the storage:
    - ordered?
    - size bound?

(Internally Unordered) Priority Q

```
public class PriorityQueue<K extends Comparable<K>, V>  extends AbstractPriorityQueue<K,V> {
    /** Default capacity */
    private static int CAPACITY = 200;
    private Pair<K,V>[] pqStore;
    /** The number of items in the priority queue */
    private int size;
    public PriorityQueue() {
        this(CAPACITY);
    }
    @SuppressWarnings("unchecked")
    /**
     * Return an array list of the given capacity
     * @param initialCapacity -- the capacity
     */
    public PriorityQueue(int initialCapacity) {
        pqStore = (Pair<K,V>[]) new Pair[initialCapacity];
        this.size=0;
    }
    public int size() {
        return size;
    }
    public boolean isEmpty() {
        return size==0;
    }
    public boolean offer(K newK, V newV) {
        if (size==CAPACITY)
            return false;
        Pair<K,V> entry = new Pair<>(newK, newV);
        pqStore[size]=entry;
        size++;
        return true;
    }
```

peek & poll

```java
public V peek() {
    if (isEmpty())
        return null;
    int lmin = getNext();
    Pair<K,V> entry = pqStore[lmin];
    return entry.theV;
}
```

```java
public V poll() {
    if (isEmpty())
        return null;
    int lmin = getNext();
    Pair<K,V> entry = pqStore[lmin];
    remove(lmin);
    return entry.theV;
}
```

getNext(), remove(lmin)

```
write them.
```

Example

```
PriorityQueue<Integer, String> pq = new PriorityQueue<>(Ordering.MIN);
        pq.offer(1,"Jane");
        pq.offer(10,"WET");
        pq.offer(5, "WAS");
        System.out.println(pq.poll());
        System.out.println(pq.poll());
        System.out.println(pq.poll());
        System.out.println();

        pq = new PriorityQueue<>(Ordering.MAX);
        pq.offer(1,"Jane");
        pq.offer(10,"WET");
        pq.offer(5, "WAS");
        System.out.println(pq.poll());
        System.out.println(pq.poll());
        System.out.println(pq.poll());
```

(Internally Ordered) Priority Q

```
public class PriorityQueueSAL<K extends Comparable<K>, V> extends AbstractPriorityQueue<K,V> {
   final private SAL<Pair<K,V>> pqStore;
   public PriorityQueueSAL() { this(Ordering.ASCENDING); }
    public PriorityQueueSAL(Ordering order) {
        this.order=order;
        pqStore = new SAL<>(SAL.Ordering.DESCENDING);
    }
   public int size() {
        return pqStore.size();
    }
   public boolean isEmpty() {
        return pqStore.isEmpty();
   }
    public boolean offer(K newK, V newV) {
        pqStore.add(new Pair<>(newK, newV));
              return true;  // Note that this always succeeds, so always return true.
    }
   public V poll() {
        if (isEmpty())
            return null;
        Pair<K,V> p = pqStore.getAndRemove(pqStore.size()-1);
        return p.theV;
    }
```

Complexity Analysis

	Unordered	Ordered (using SAL)	Heap Based
offer	O(1)	O(n)	
peek	O(n)	O(1)	
poll	O(n)	O(1)	

Unordered PQ == Selection Sort

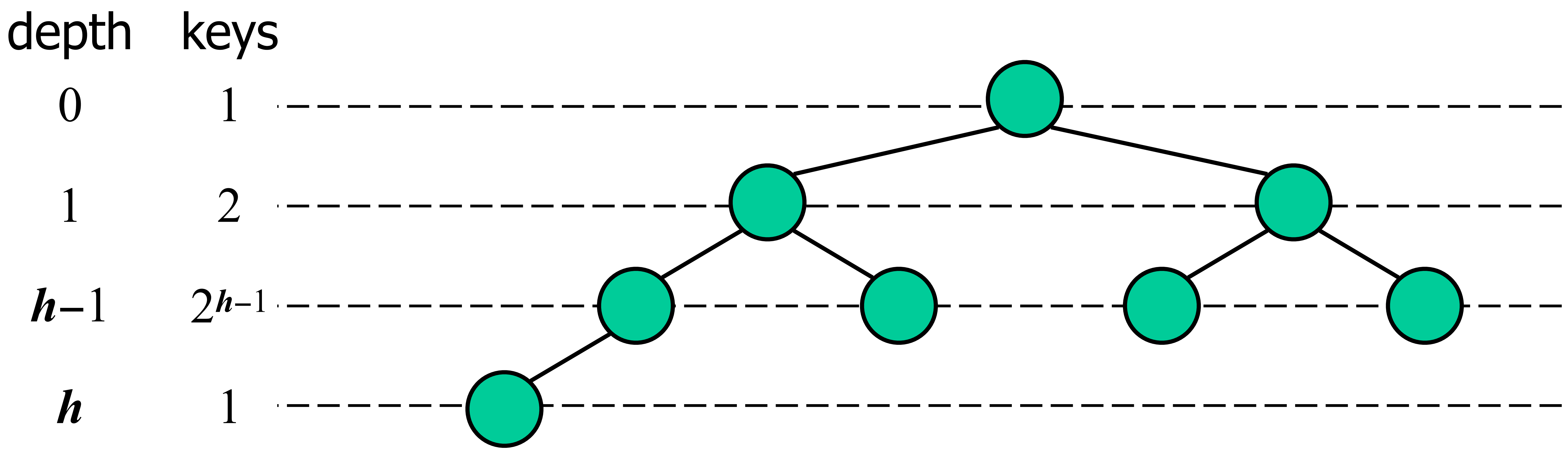
Ordered PQ = Insertion Sort

Binary Heap

- A heap is a “binary tree” storing keys at its nodes and satisfying:
  - heap-order: for every internal node v other than root, $key(v) \geq key(parent(v))$
  - Heap is filled from top down and within a level from left to right.
    - at depth h, the leaf nodes are in the leftmost positions
    - last node of a heap is the rightmost node of max depth

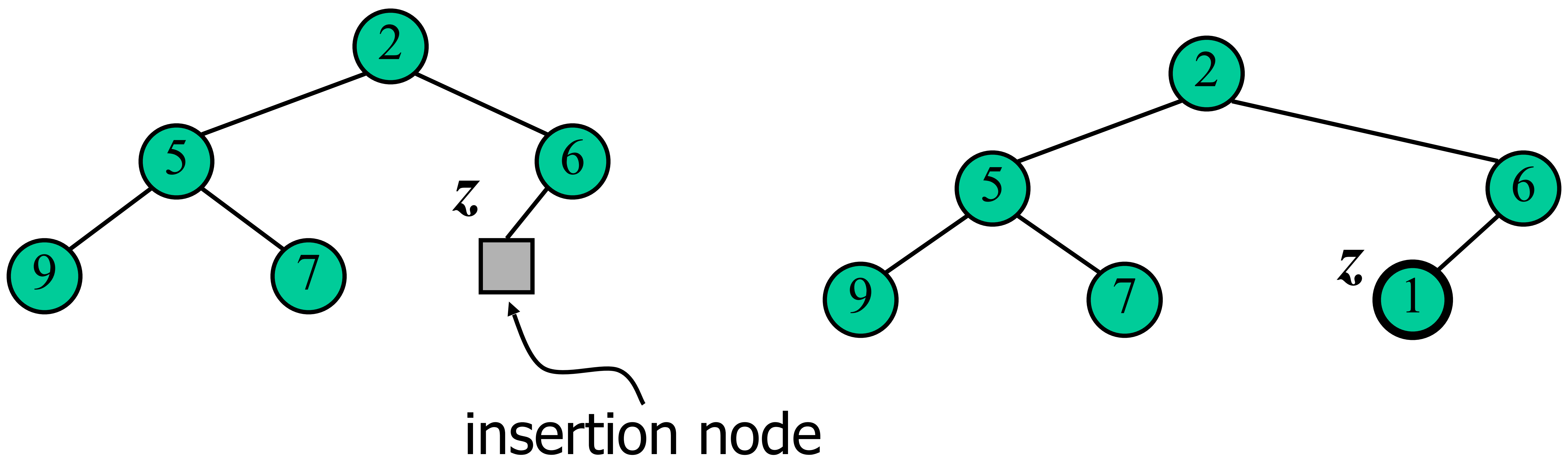
Height of a Heap

- A binary heap storing n keys has a height of $O(\log_2 n)$



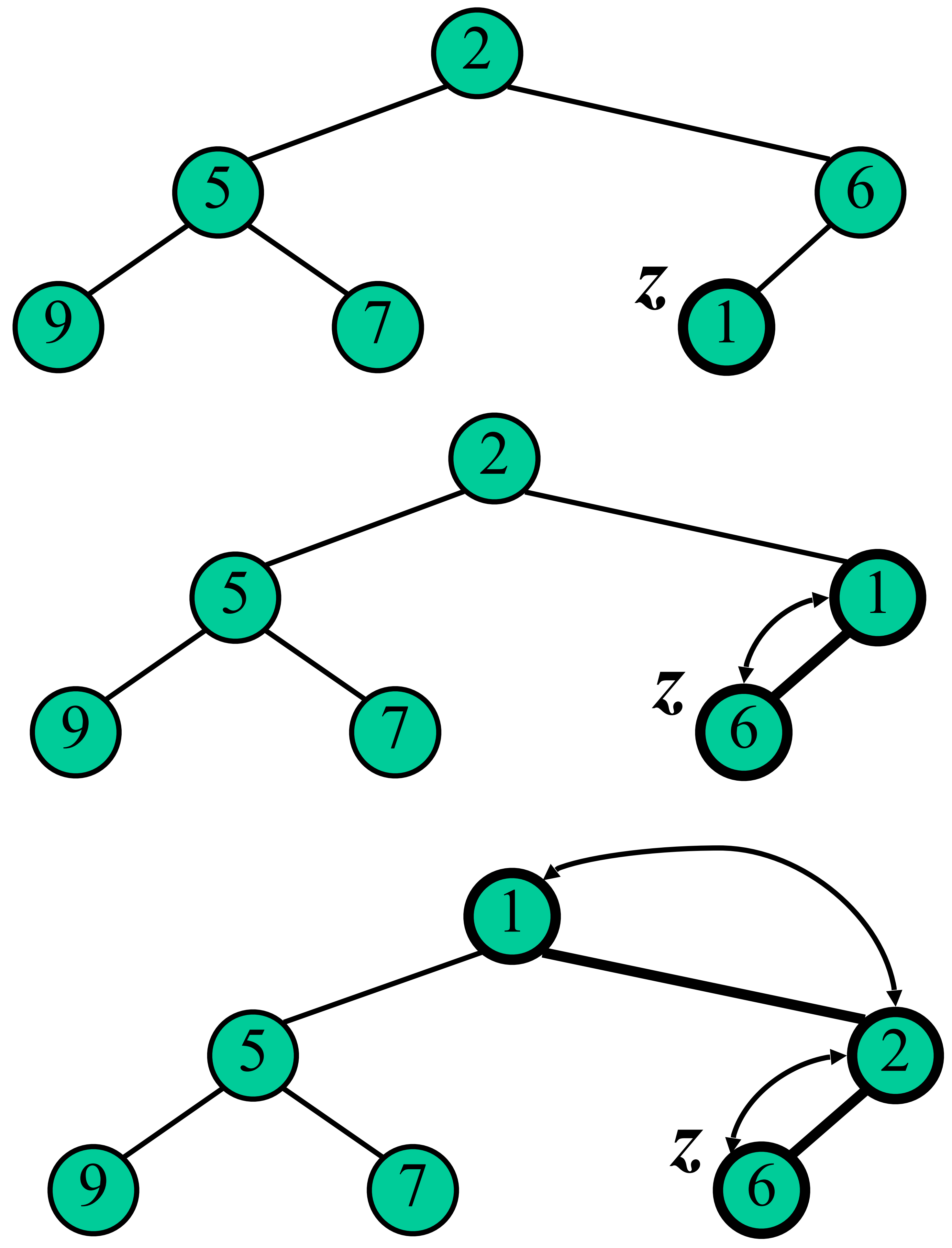
Insertion into a Heap

- Insert as new last node
- Need to restore heap order



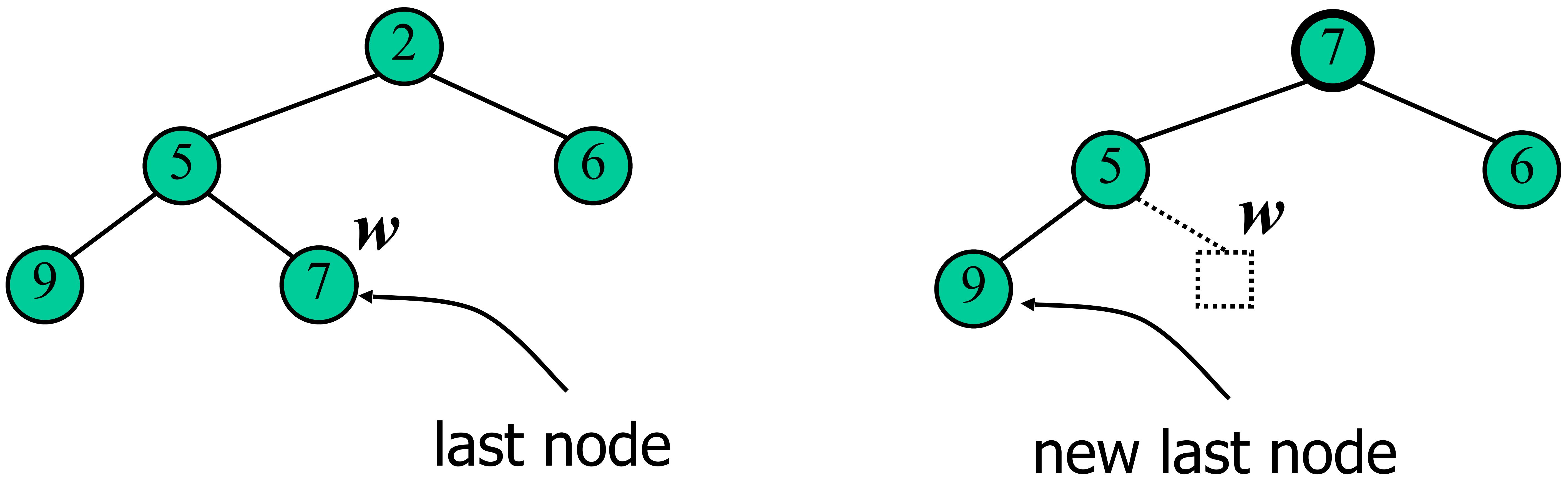
Upheap

- Restore heap order
  - swap upwards
  - stop when finding a smaller parent
  - or reach root
- $O(\log n)$



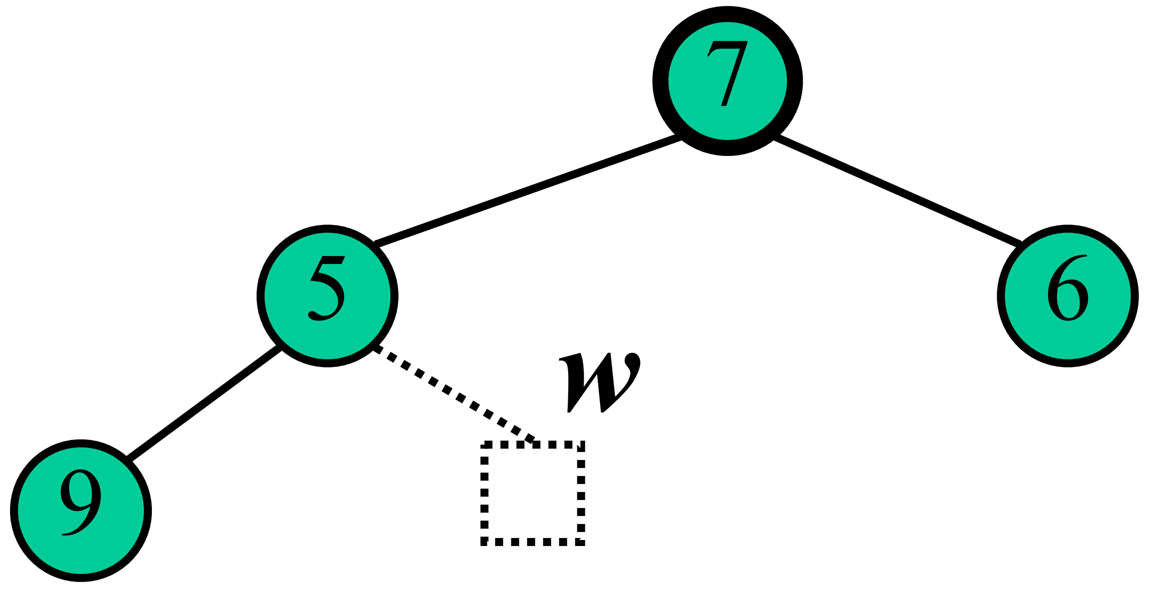
Poll

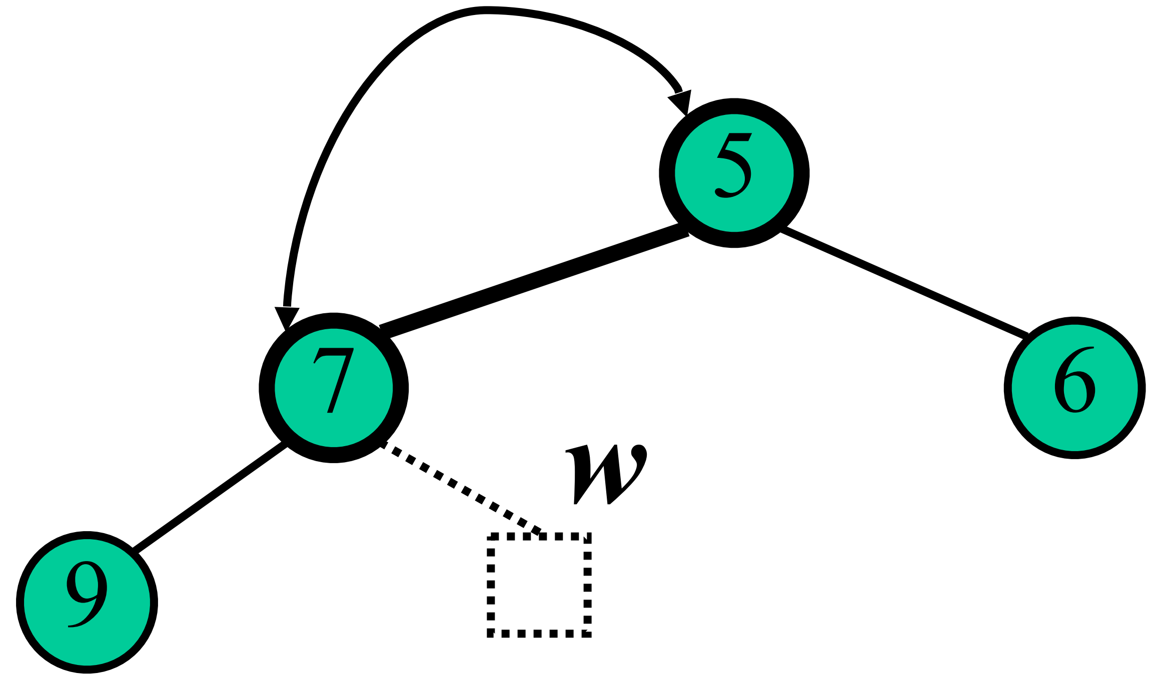
- Removing the root of the heap
  - Replace root with last node
  - Remove last node
  - Restore heap order



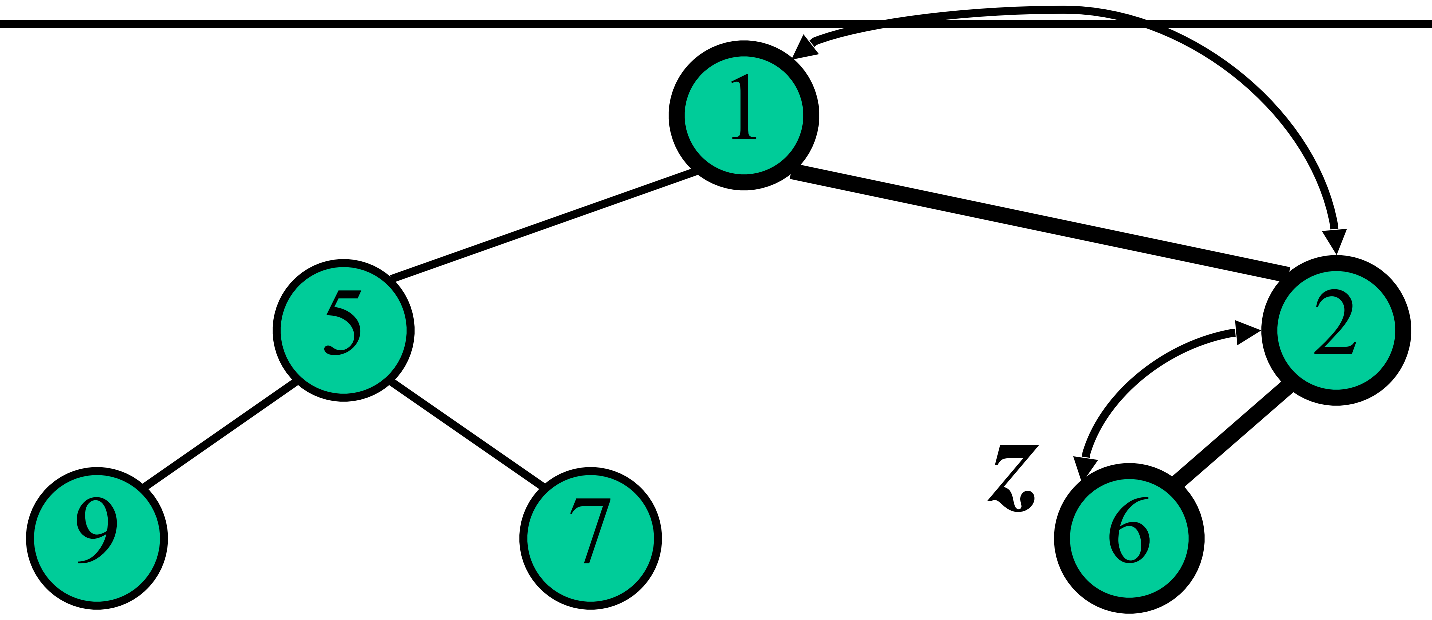
Downheap

- Restore heap order
  - swap downwards
  - swap with smaller child
  - stop when finding larger children
  - or reach a leaf
- $O(\log n)$





Heaps are built on Arrays



Add to Heap here

0	1	2	3	4	5	6	7
1	5	2	9	7	6		

Locations of Parents and children are in strict mathematical relationship

- Parent from child
  - suppose child is at location childLoc in array
    - parentLoc = (childLoc-1)/2
- Child from Parent
  - suppose parent is at parentLoc in array
    - leftChild = parentLoc*2+1
    - rightChild = parentLoc*2+2

- Parent from child
  - child at loc 4 (value 7)
  - parent is at (4-1)/2 = 1 (value 5)
- Child from Parent
  - parent at loc 2 (value 6)
    - leftChild =2*2+1 = 5 (value 1)
    - rightChild = 2*2+2 = 6 (value — not used)

Priority Queue using Heaps

startup

```
public class PriorityQHeap<K extends Comparable<K>, V> extends AbstractPriorityQueue<K, V>
{

   private static final int CAPACITY = 1032;
   private Pair<K,V>[] backArray;
   private int size;

    public PriorityQHeap() {
        this(CAPACITY);
    }

    public PriorityQHeap(int capacity) {
        size=0;
        backArray = new Pair[capacity];
    }
    @Override
    public int size()
    {
        return size;
    }

    @Override
    public boolean isEmpty()
    {
        return size==0;
    }
```

Heap Insertion

Priority Queue offer method

```
public boolean offer(K key, V value)
    {
        if (size>=(backArray.length-1))
            return false;
    // put new item in at end data items
    int loc = size++;
    backArray[loc] = new Pair<K,V>(key, value);
    // up heap
    int upp = (loc-1)/2; //the location of the parent
    while (loc!=0) {
        if (0 > backArray[loc].compareTo(backArray[upp])) {
            // swap and climb
            Pair<K,V> tmp = backArray[upp];
            backArray[upp] = backArray[loc];
            backArray[loc] = tmp;
            loc = upp;
            upp = (loc-1)/2;
            }
        else
        {
            break;
        }
    }
    return true;
    }
```

Peek and Poll

```
@Override
public V poll() {
    if (isEmpty())
        return null;
    Entry<K,V> tmp = backArray[0];
    removeTop();
    return tmp.theV;
}

@Override
public V peek() {
    if (isEmpty())
        return null;
    return backArray[0].theV;
}
```

Remove head item from Heap

```
private void removeTop()
{
    backArray[0] = backArray[size-1];
    backArray[size-1]=null;
    size--;
    int upp=0;
    while (true)
    {
        int dwn;
        int dwn1 = upp*2+1;
        if (dwn1>size) break;
        int dwn2 = upp*2+2;
        if (dwn2>size) {  dwn=dwn1;
        } else {
            int cmp = backArray[dwn1].compareTo(backArray[dwn2]);
            if (cmp<=0)  dwn=dwn1;
            else dwn=dwn2;
        }
        if (0 > backArray[dwn].compareTo(backArray[upp]))
        {
            Pair<K,V> tmp = backArray[dwn];
            backArray[dwn] = backArray[upp];
            backArray[upp] = tmp;
            upp=dwn;                }
        else {  break;              } } }
```

General Removal

- swap with last node
- delete last node
- may need to upheap or downheap