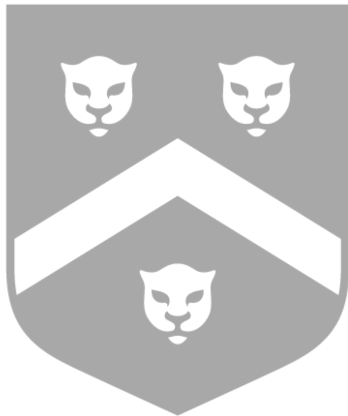
Binary Search Trees and Priority Queues



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Binary Search Trees

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Searching
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Interface
UML Diagram
find()
add()
add()

Priority Queues

Binary Search Trees

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Binary Search Trees

- BSTs follow the binary tree definition, with an additional property:
  - For every node, all values in the left subtree are less than that node
  - For every node, all values in the right subtree are greater than that node
- Visually, values are increasing moving from left to right – there aren't direct left-to-right connections to move in the actual structure
- Values are unique in our version (though that is not part of the definition)

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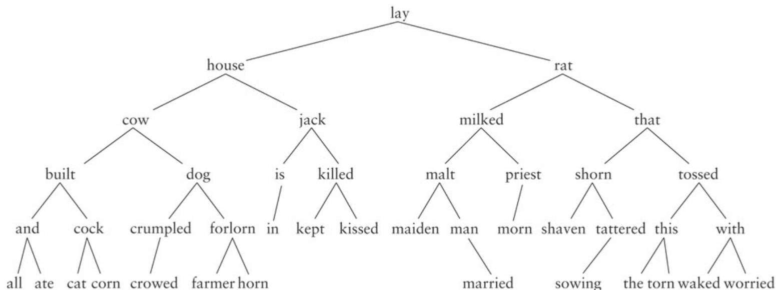
Example BST



Binary search tree with Strings – order is decided alphabetically

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Binary Search Algorithm

Starting at a tree's root, this algorithm recursively searches in a tree for a target:

SEARCH(tree, target)

1: **if** tree is empty **then**
2:     **return** null // target not found
3: **else if** target matches root of tree **then**
4:     **return** root node
5: **else if** target $<$ root node **then**
6:     **return** SEARCH(root's left child, target)
7: **else**
8:     **return** SEARCH(root's right child, target)

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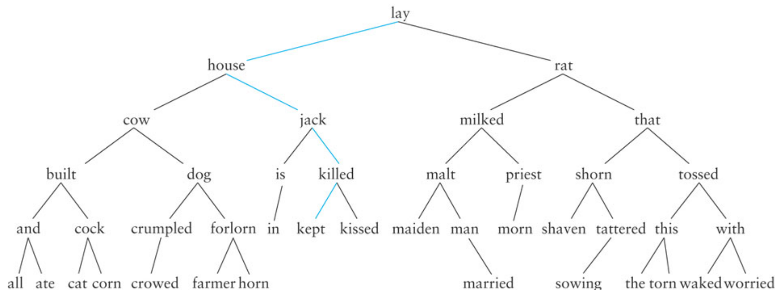
Example Search Path



Path to find “kept” – we only need to follow the highlighted connections

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Interface

Method	Behavior
`boolean add(E item)`	Inserts `item` where it belongs in the tree. Returns **`true`** if item is inserted; **`false`** if it isn't (already in tree).
`boolean contains(E target)`	Returns **`true`** if `target` is found in the tree.
`E find(E target)`	Returns a reference to the data in the node that is equal to `target`. If no such node is found, returns **`null`**.
`E delete(E target)`	Removes `target` (if found) from tree and returns it; otherwise, returns **`null`**.
`boolean remove(E target)`	Removes `target` (if found) from tree and returns **`true`**; otherwise, returns **`false`**.

BST interface – simple and efficient operations

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UML Diagram

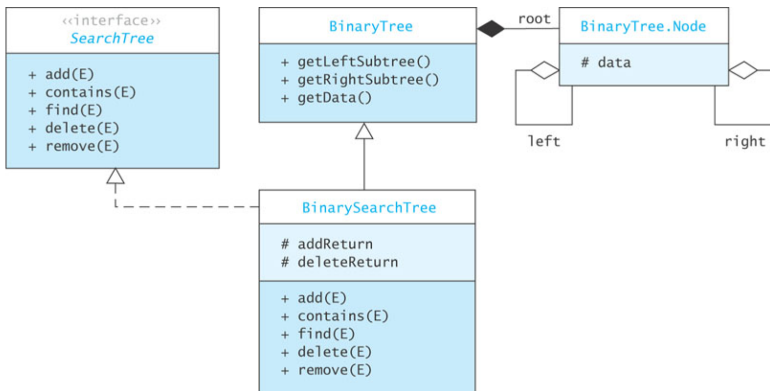

Diagram showing class models and relationships

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find() implementation

```
public E find(E target) {
    return find(root, target);
}

private E find(Node<E> localRoot, E target) {
  if (localRoot == null)
    return null;

  // Compare the target with the data at the root.
  int compResult = target.compareTo(localRoot.data);
  if (compResult == 0)
    return localRoot.data;
  else if (compResult < 0) {
    return find(localRoot.left, target);
  else
    return find(localRoot.right, target);
}
```

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add Algorithm

ADD(tree, item)

1: **if** tree is empty **then**
2: replace null with item node
3: **return** true
4: **else if** item matches root of tree **then**
5: **return** false
6: **else if** item $<$ root node **then**
7: **return** ADD(root's left child, item)
8: **else**
9: **return** ADD(root's right child, item)

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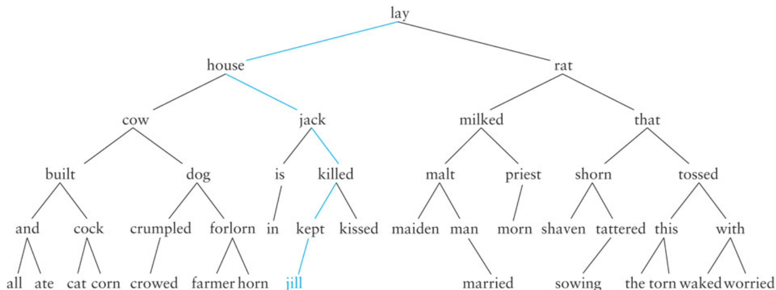
add path

Deciding where to add a new value follows a similar path to finding an existing value



adding “jill” in the appropriate place

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add() implementation

```
/** Starter method add.
    pre: The object to insert must implement the
         Comparable interface.
    @param item The object being inserted
    @return true if the object is inserted, false
      if the object already exists in the tree
*/
public boolean add(E item) {
    root = add(root, item);
    return addReturn;
}
```

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`add()` implementation

```
private Node<E> add(Node<E> localRoot, E item) {
  if (localRoot == null) {
    // item is not in the tree - insert it.
    addReturn = true;
    return new Node<E>(item);
  } else if (item.compareTo(localRoot.data) == 0) {
    addReturn = false;
    return localRoot;
  } else if (item.compareTo(localRoot.data) < 0) {
    localRoot.left = add(localRoot.left, item);
    return localRoot;
  } else {
    localRoot.right = add(localRoot.right, item);
    return localRoot;
  }
}
```

Binary Search Trees

Priority Queues

Definition

Heap

offer()

poll()

Java Class

Priority Queues

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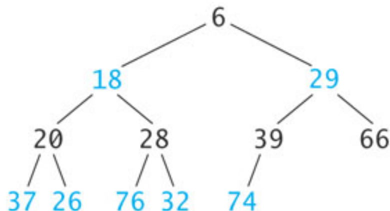
Definition

- A priority queue works like a queue with an extra feature:
  - Each item in the queue can be marked with a priority
  - Smallest priority item is always at the front
- Works like a queue when all items have the same priority
- Otherwise, items in the queue might need to be rearranged when a new item is added
- Same operations as queues: offer/poll/peek

Heap

- A **heap** is a complete binary tree with an additional property:
  - Each node in the heap is smaller than all of its descendants
- We can use a heap to efficiently implement a priority queue
- For each priority queue method that modifies the queue, we need to make sure that our heap stays consistent



offer Algorithm

OFFER(heap, item)

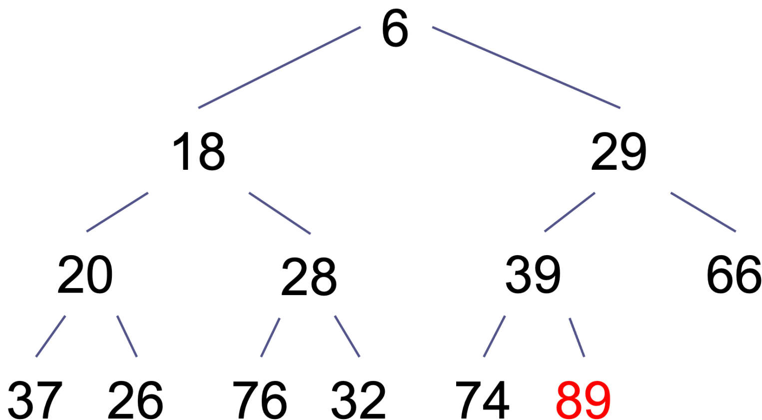
1: Insert new item at next position in bottom of heap
2: **while** new item < parent **do**
3: Swap new item and parent

Binary Search Trees

Priority Queues

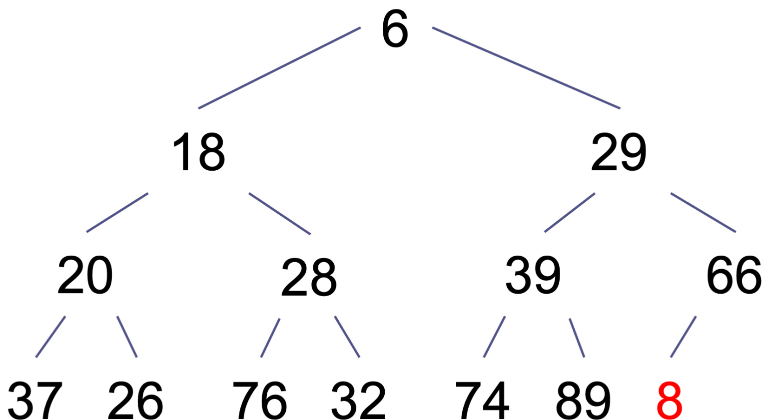
- Definition
- Heap
- offer()
- poll()
- Java Class

offer example



offer(89): insert at bottom, compare with 39 as parent

offer example



offer(8): insert at bottom, compare with 66 as parent

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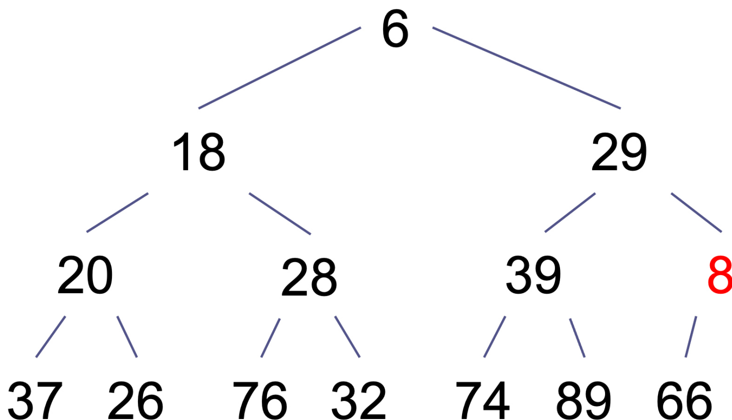
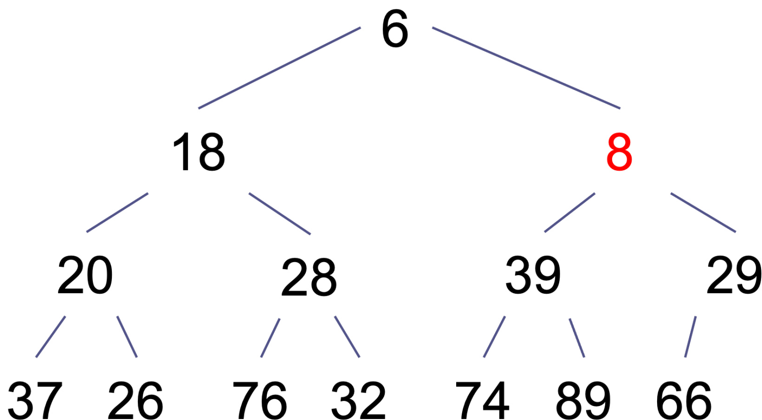
offer example



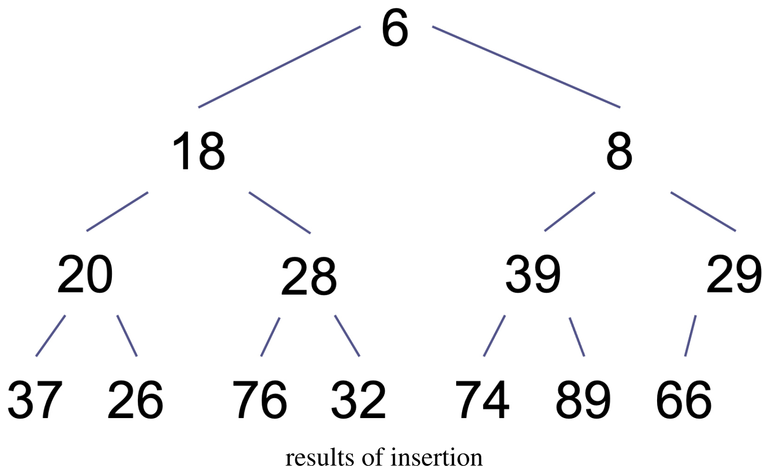
swap with parent, compare with 29 as new parent

offer example



swap with parent, compare with 6 as new parent

offer example



results of insertion

poll Algorithm

POLL(heap)

1: Remove root and replace it with last item in heap
2: **while** moved item > valid children **do**
3: Swap moved item and smallest child
4: Return old root

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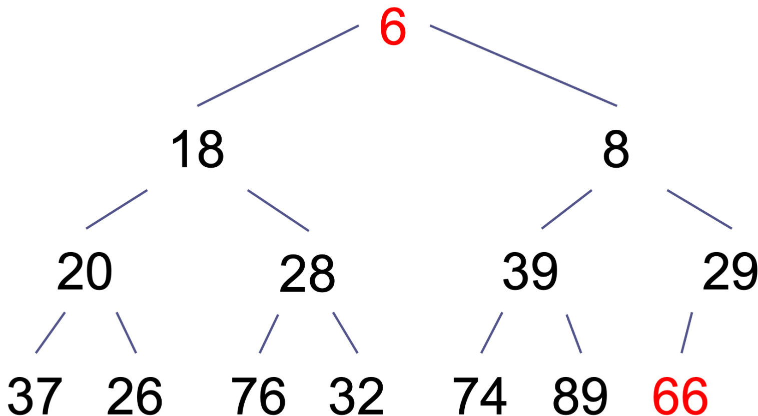
poll example



poll(): remove 6, move 66 to root location

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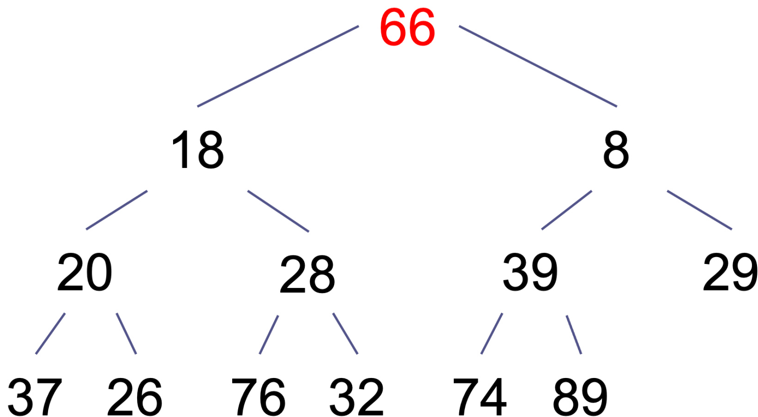
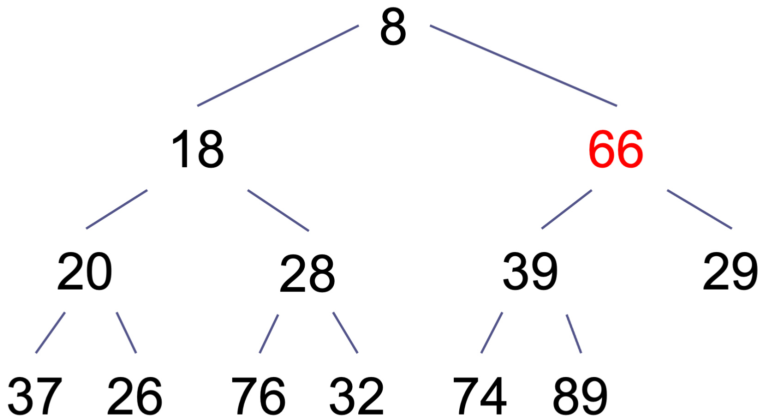
poll example



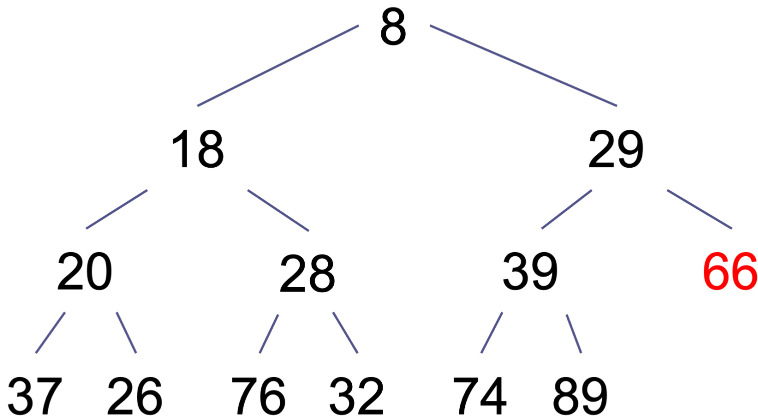
compare with children, swap with smaller child (right child)

poll example



compare with children, swap with smaller child (right child)

poll example



no children to compare to, return 6 as polled value

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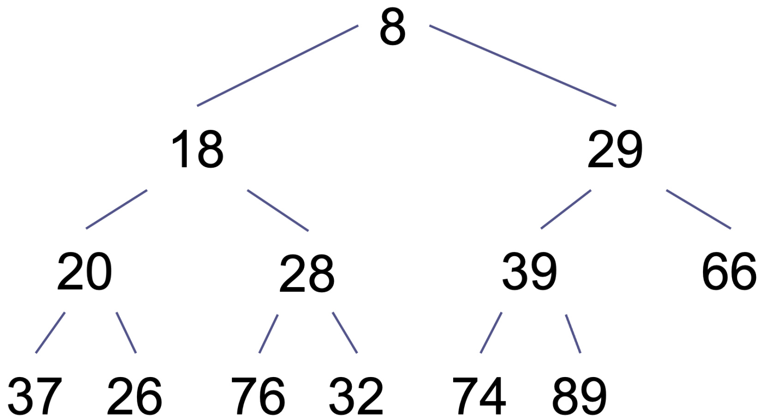
poll example



no children to compare to, return 6 as polled value

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PriorityQueue Java Class

Data Field	Attribute
`ArrayList<E> theData`	An `ArrayList` to hold the data.
`Comparator<E> comparator`	An optional object that implements the `Comparator<E>` interface by providing a `compare` method.
Method	**Behavior**
`KWPriorityQueue()`	Constructs a heap-based priority queue that uses the elements' natural ordering.
`KWPriorityQueue (Comparator<E> comp)`	Constructs a heap-based priority queue that uses the `compare` method of `Comparator comp` to determine the ordering of the elements.
`private int compare(E left, E right)`	Compares two objects and returns a negative number if object `left` is less than object `right`, zero if they are equal, and a positive number if object `left` is greater than object `right`.
`private void swap(int i, int j)`	Exchanges the object references in `theData` at indexes `i` and `j`.