Lab: Binary Search Trees

In this lab, you will need the Display class, TreeUtil class and the TreeNode class from your Binary Trees lab.

Exercise: Searching and Inserting

Download BSTUtilities.java. Implement the `contains` and `insert` methods, which should each run in O(*h*) time, where *h* is the height of the tree. (Note that `insert` should ignore attempts to add duplicate elements.) To help you debug your work (and to add some fun to the lab), be sure to call `display`'s `visit` method to light up the path your search takes. Then go and test that these two methods work correctly together.

```
public static boolean contains(TreeNode t, Comparable x, TreeDisplay display)
public static TreeNode insert(TreeNode t, Comparable x, TreeDisplay display)
```

Exercise: Deleting

Deleting from a binary search tree is a valuable and challenging exercise (even though it won't appear on the AP test). We'll break down the problem into two methods.

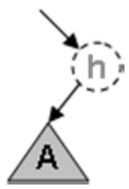
```
public static TreeNode delete(TreeNode t, Comparable x, TreeDisplay display)
private static TreeNode deleteNode(TreeNode t, TreeDisplay display)
```

The `delete` method finds the node in tree `t` that contains the value `x`, and then calls `deleteNode` to perform the actual deletion. We'll start by implementing the more difficult `deleteNode` method, which removes the value in a node `t` and returns a pointer to the resulting tree.

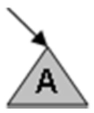
When we remove a value from the tree, we need to make sure that the remaining tree is still a valid binary search tree (with all values still in ascending order). It helps to consider three cases. In all three, we are deleting node *h*, and we need to determine *h*'s successor—the next node in ascending order.

Case 1: *h* has no successor

We simply return a pointer to the left subtree.



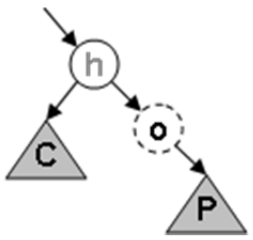
h has no successor



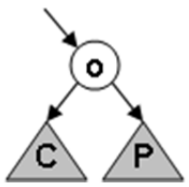
h has been deleted

Case 2: *h*'s successor is its right child

We need to "splice out" the node containing the successor, and replace *h* with the value from the successor.



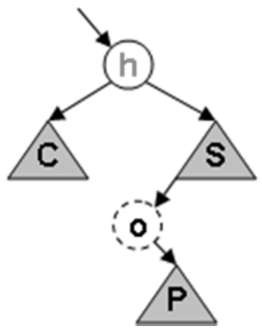
h's successor is its right child



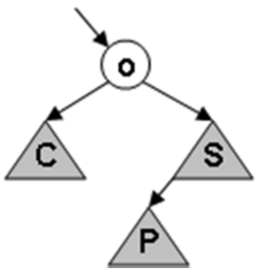
h has been deleted

Case 3: *h*'s successor is not its right child

Again, we "splice out" the successor, and replace *h* with this value.



h's successor is not its right child



h has been deleted

Once we've written `deleteNode`, writing the `delete` method is fairly straightforward. You may want to call `display`'s `visit` method from each of these, and test a variety of cases.

Exercise: `MyTreeSet<E>`

Download MyTreeSet.java, which will support the following standard `Set<E>` operations:

```
•  int size()
•  boolean contains(Object obj)
•  boolean add(E obj)         // if obj is not present in this set, adds obj and
                              // returns true; otherwise returns false
•  boolean remove(Object obj) // if obj is present in this set, removes obj and
                              // returns true; otherwise returns false
```

Internally, `MyTreeSet<E>` stores its data in a binary search tree. In addition, it should hold onto a single `TreeDisplay` object to display its contents at all times. It should also remember the number of elements in the tree, so that it can report its size in constant time. The `contains`, `add`, and `remove` methods should run in O(*h*) time, where *h* is the height of the tree.

Call your `BSTUtilities` methods, rather than re-implementing them! Then download TreeSetTester.java to test your work.

Exercise: MyTreeMap<K,V>

We can also use a binary search tree to make a map. Create a `MyTreeMap<K, V>` class, which should support the following operations:

```
•  int size()
•  boolean containsKey(Object key)
•  V put(K key, V value)         // associates key with value
                                 // returns the value formerly associated with key
                                 // or null if key was not present
•  V get(Object key)             // returns the value associated with key
                                 // or null if there is no associated value
•  V remove(Object key)       // removes and returns the value associated with key;
                              // returns null if there is no associated value
```

If you finish early

Add a method called `iterator`, which takes no arguments and returns an `Iterator`. The `Iterator` should return all values in the `MyTreeSet` in ascending order. You must do this by manipulating only the pointers within tree nodes. You may not create another data structure that stores the values contained in `MyTreeSet.` For example, you may not create a linked list or ArrayList representation by traversing the tree. (You may create additional data structures that hold pointers.)

One way to approach this problem is to consider how you can implement an inorder traversal of a binary tree iteratively. To accomplish this, you will need to be able to find the successor to a given node in the binary tree. Also, you will need to save pointers to the parts of the binary tree that are only partially explored.