CSC212

Data Structure

COMPUTER SCIENCE
CITY COLLEGE OF NEW YORK

Lecture 14

Binary Search Trees

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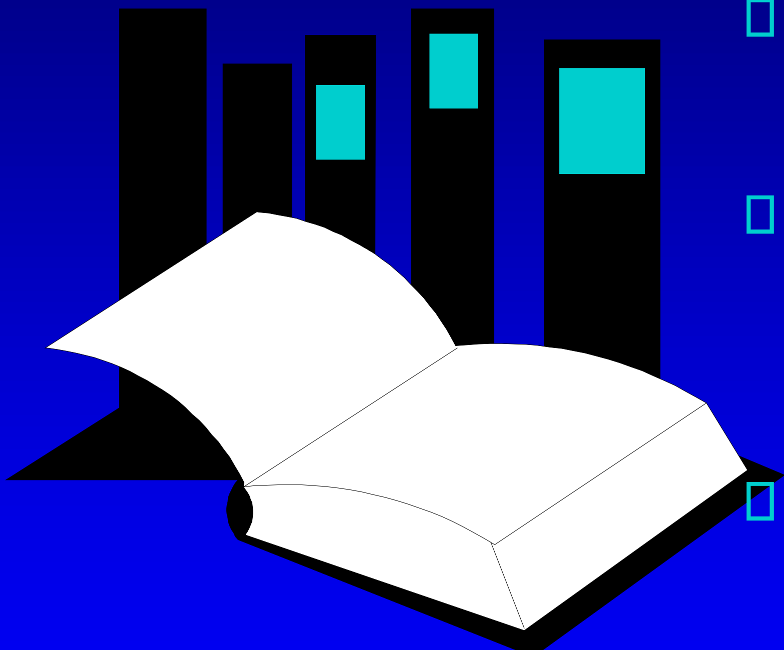
Binary Search Trees

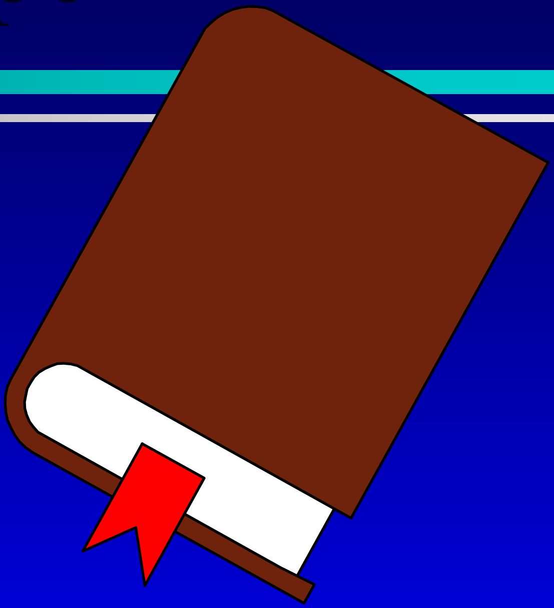


- One of the tree applications in Chapter 10 is **binary search trees**.
- In Chapter 10, binary search trees are used to implement bags and sets.
- This presentation illustrates how another data type called a **dictionary** is implemented with binary search trees.

Binary Search Tree Definition

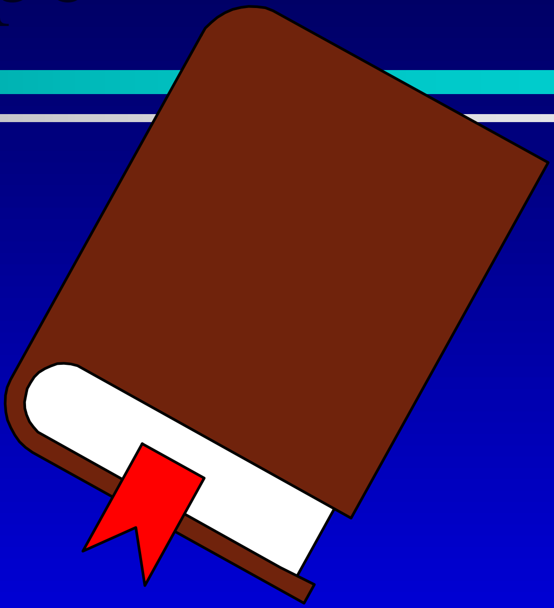
- In a binary search tree, the entries of the nodes can be compared with a strict weak ordering. Two rules are followed for every node n:
  - The entry in node n is NEVER less than an entry in its left subtree
  - The entry in the node n is less than every entry in its right subtree.

The Dictionary Data Type



- A dictionary is a collection of items, similar to a bag.
- But unlike a bag, each item has a string attached to it, called the item's key.

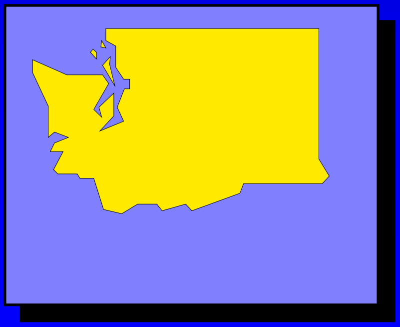
The Dictionary Data Type



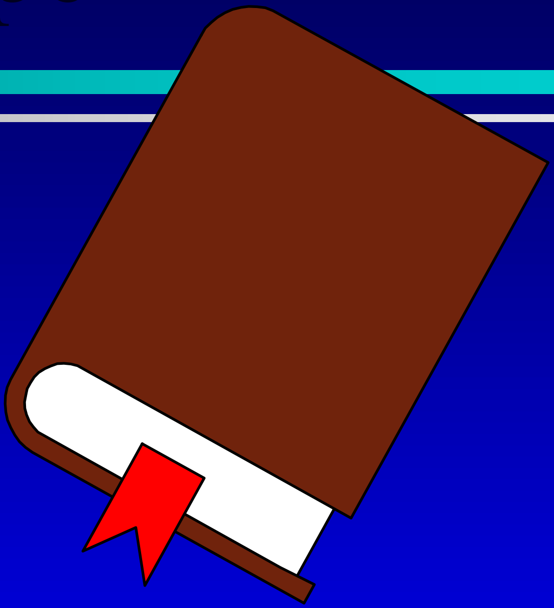
- A dictionary is a collection of **items**, similar to a bag.
- But unlike a bag, each item has a string attached to it, called the item's **key**.

Example:

The **items** I am storing are records containing data about a state.

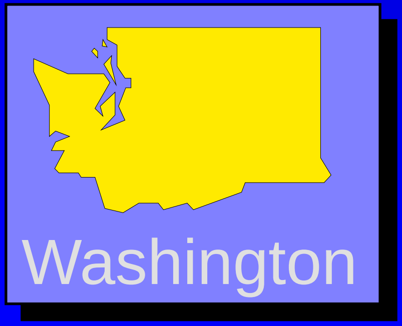


The Dictionary Data Type



- A dictionary is a collection of **items**, similar to a bag.
- But unlike a bag, each item has a string attached to it, called the item's **key**.

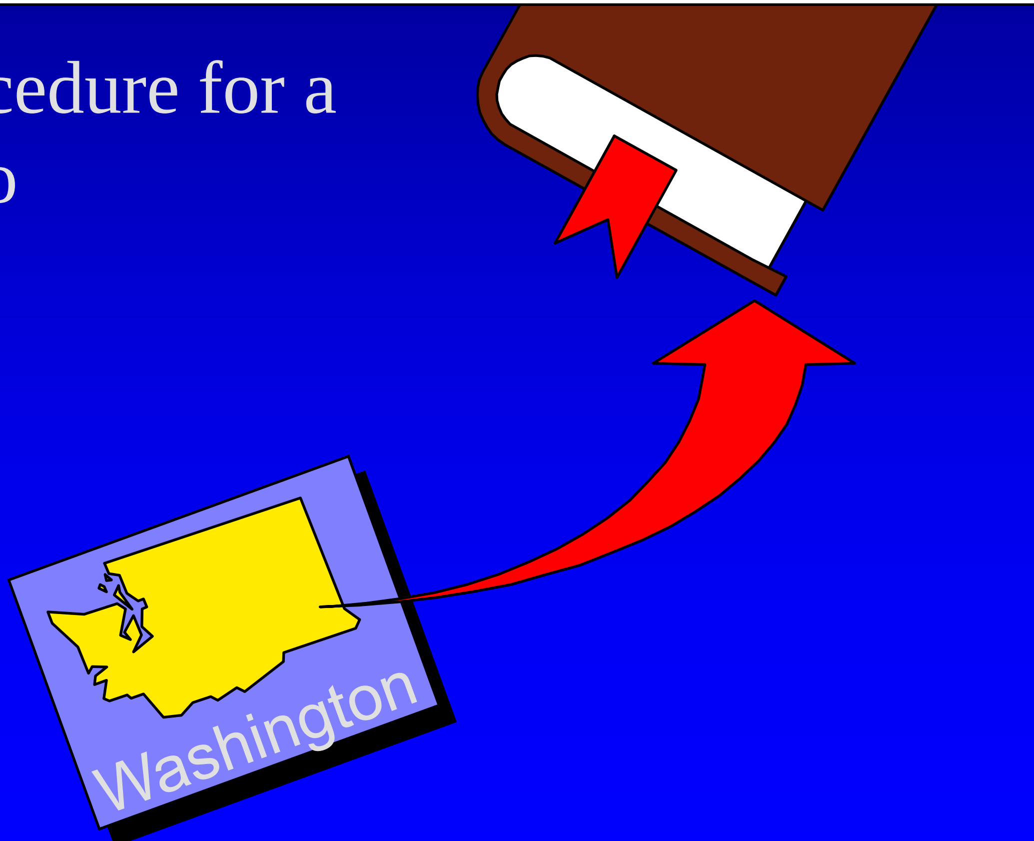
Example:
The **key** for each record is the name of the state.



The Dictionary Data Type

void Dictionary::insert(The key for the new item, The new item);

- The insertion procedure for a dictionary has two parameters.



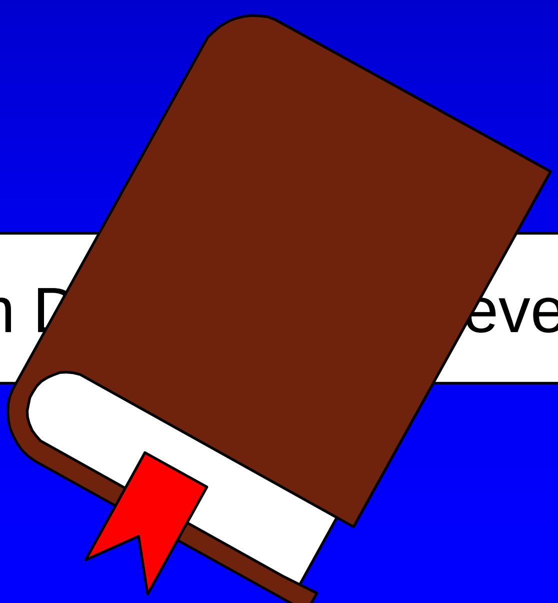
The Dictionary Data Type

- When you want to retrieve an item, you specify the **key**...

```
Item Dictionary::retrieve("Washington");
```

The Dictionary Data Type

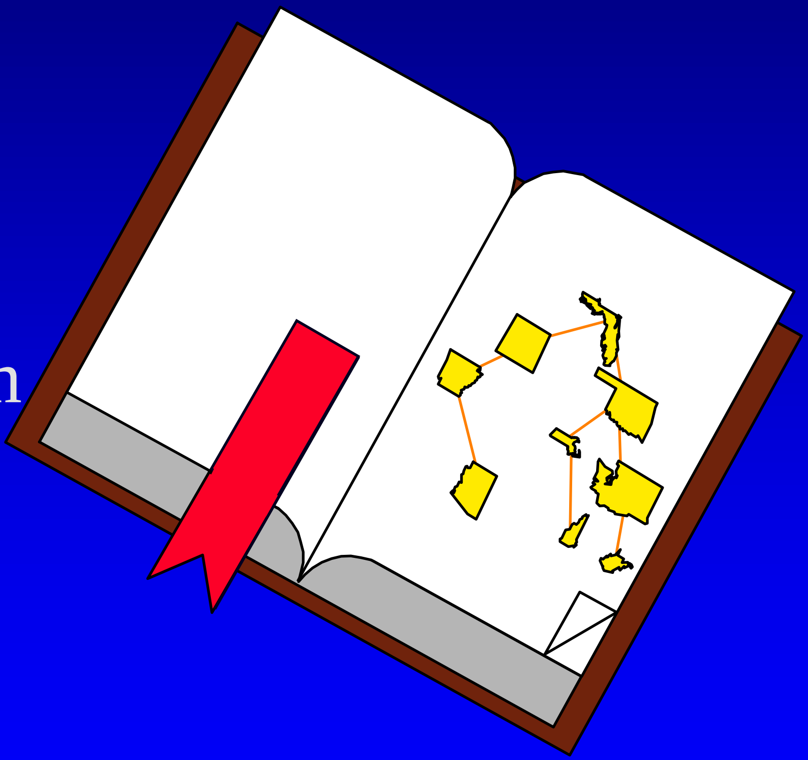
- When you want to retrieve an item, you specify the **key**...
  ... and the retrieval procedure returns the **item**.



Item D eve("Washington");

The Dictionary Data Type

- We'll look at how a binary tree can be used as the internal storage mechanism for the dictionary.



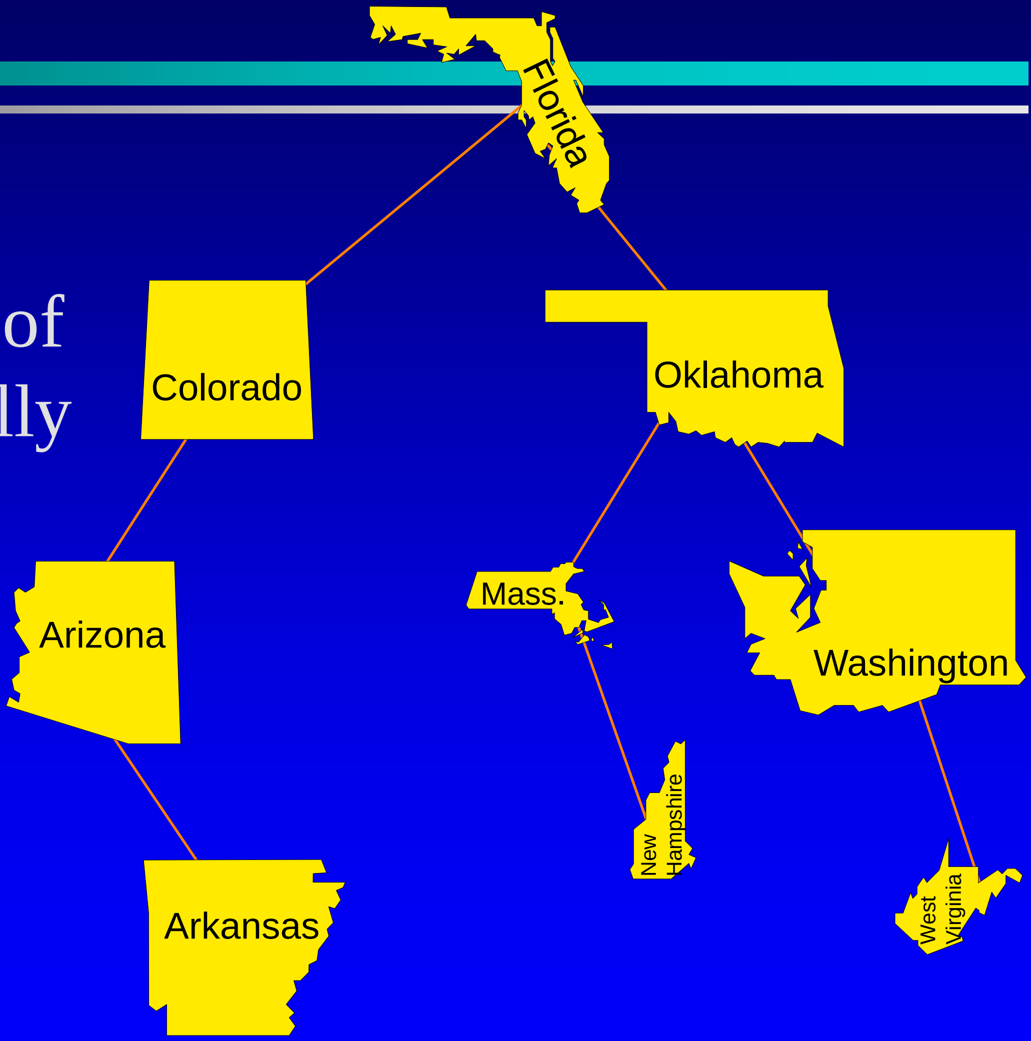
A Binary Search Tree of States

The data in the dictionary will be stored in a binary tree, with each node containing an **item** and a **key**.

A Binary Search Tree of States

Storage rules:

- Every key to the **left** of a node is alphabetically **before** the key of the node.

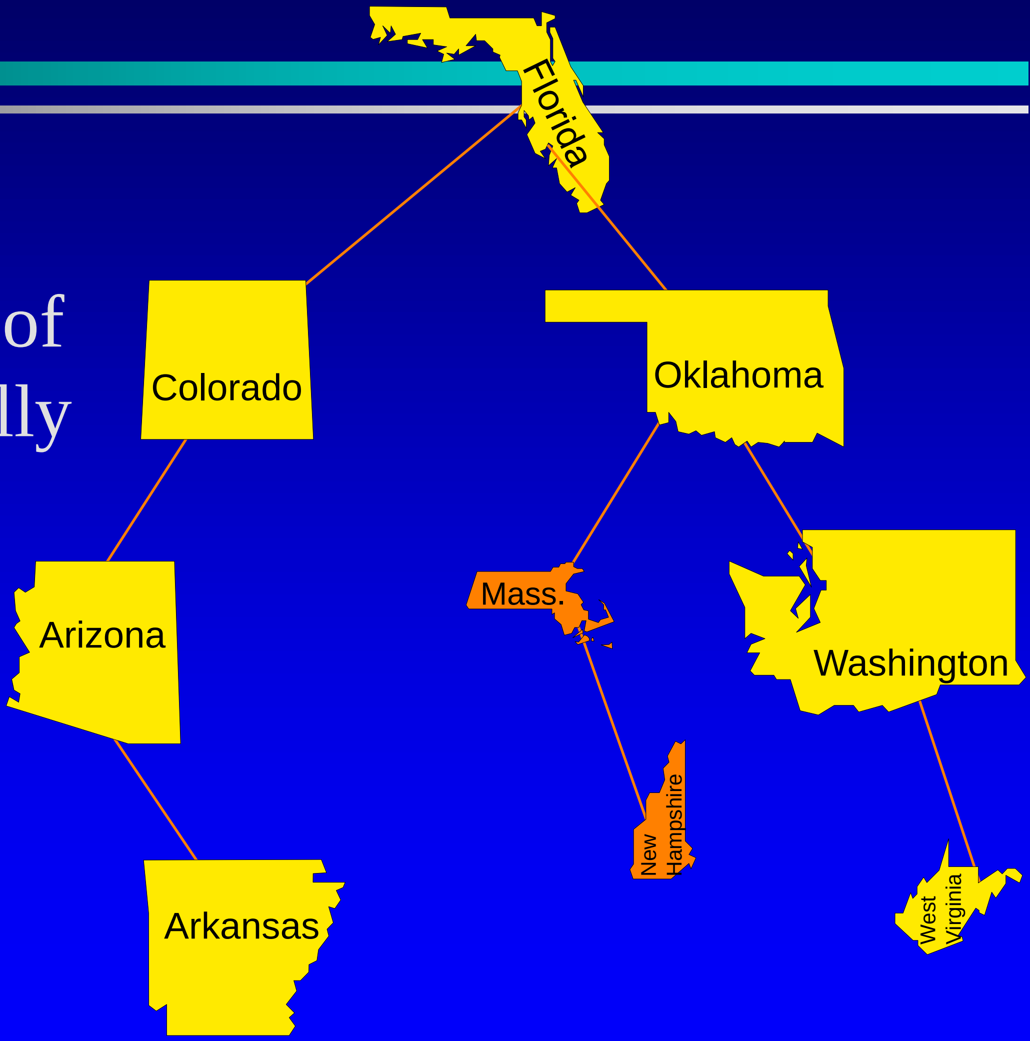


A Binary Search Tree of States

Storage rules:

- Every key to the **left** of a node is alphabetically **before** the key of the node.

Example:
' Massachusetts' and
' New Hampshire'
are alphabetically
before 'Oklahoma'



A Binary Search Tree of States

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A Binary Search Tree of States

Storage rules:

- Every key to the **left** of a node is alphabetically **before** the key of the node.
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Retrieving Data

Start at the root.

- If the current node has the key, then stop and retrieve the data.
- If the current node's key is too **large**, move **left** and repeat 1-3.
- If the current node's key is too **small**, move **right** and repeat 1-3.

Retrieve 'New Hampshire'

Start at the root.

- If the current node has the key, then stop and retrieve the data.
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Retrieve 'New Hampshire'

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Retrieve 'New Hampshire'

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- If the current node has the key, then stop and retrieve the data.
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Adding a New Item with a Given Key

- Pretend that you are trying to find the key, but stop when there is no node to move to.
- Add the new node at the spot where you would have moved to if there had been a node.

Adding

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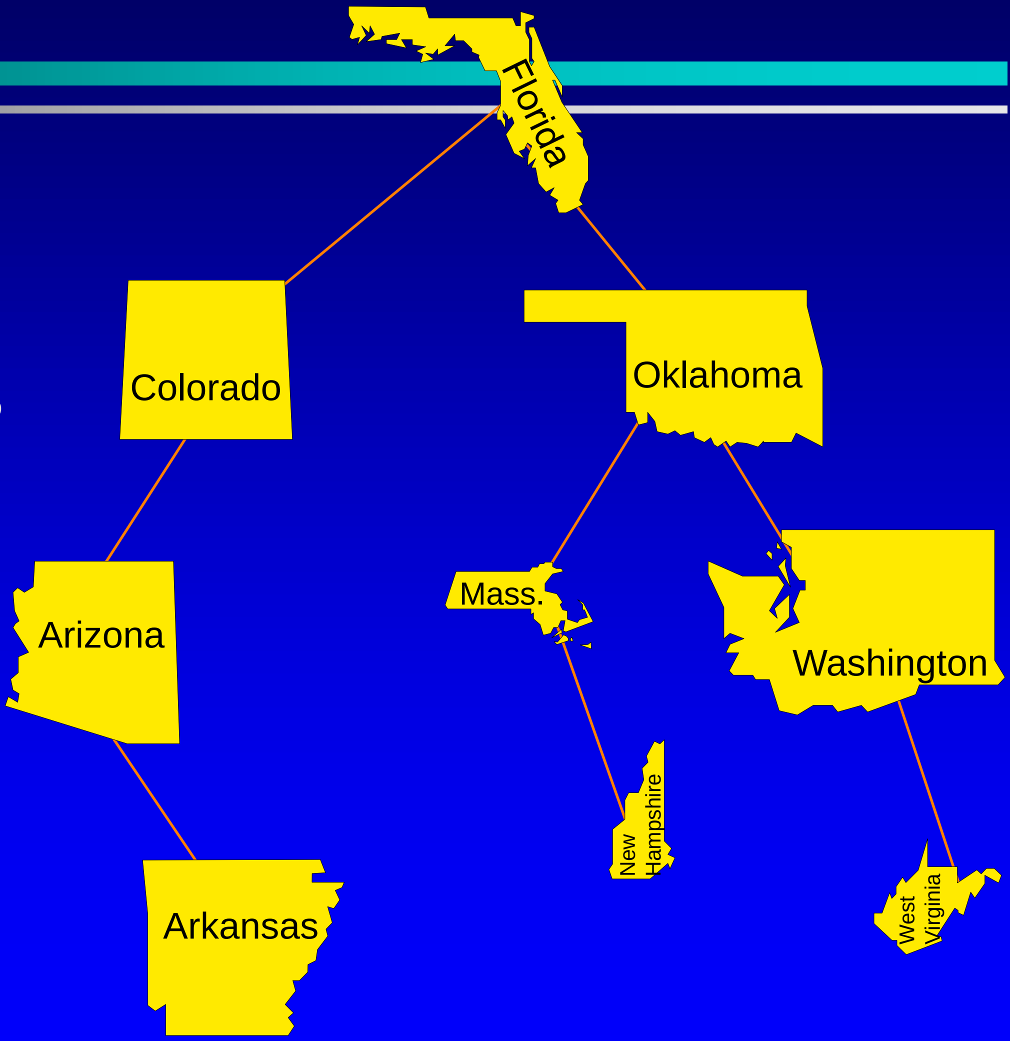

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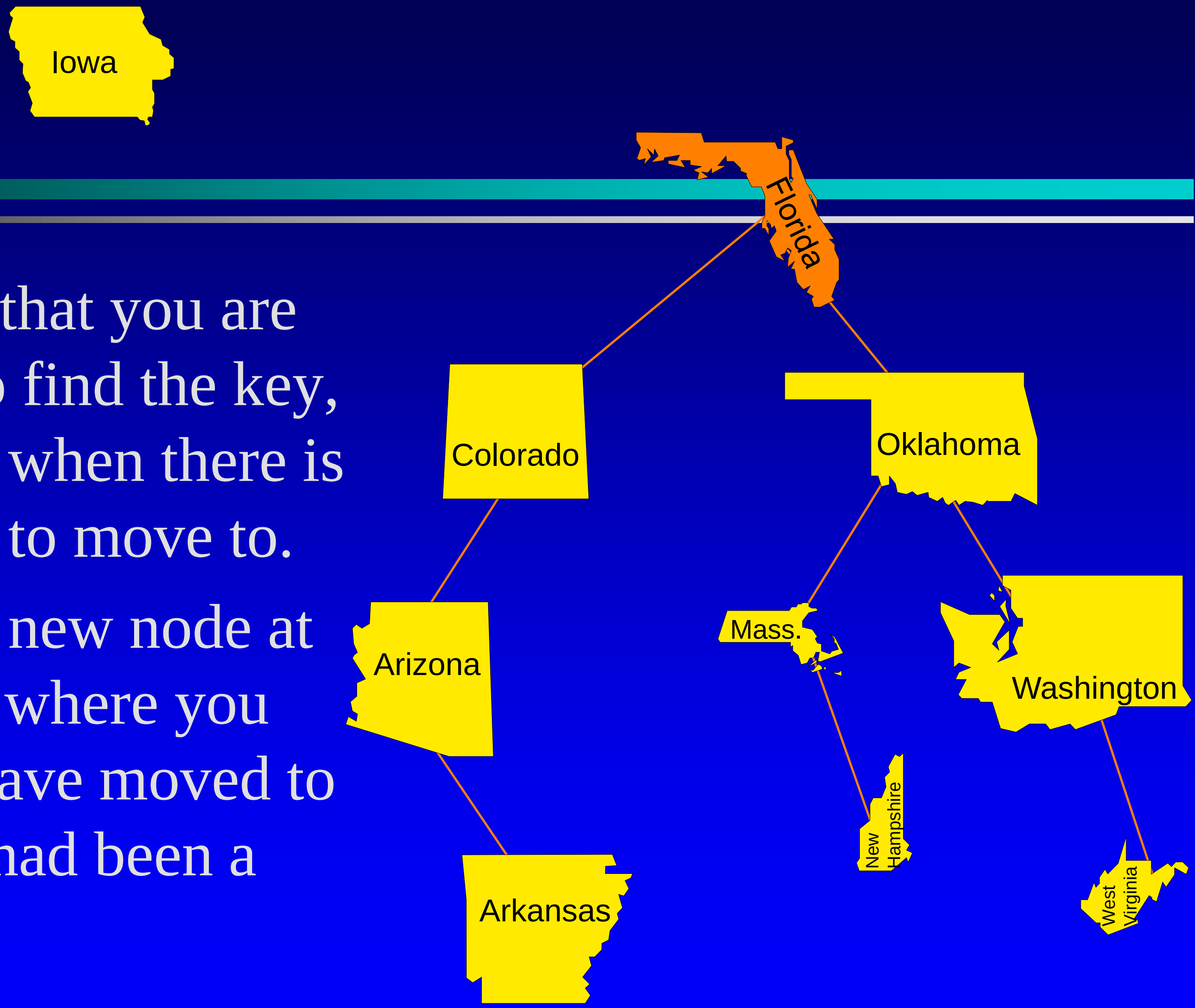

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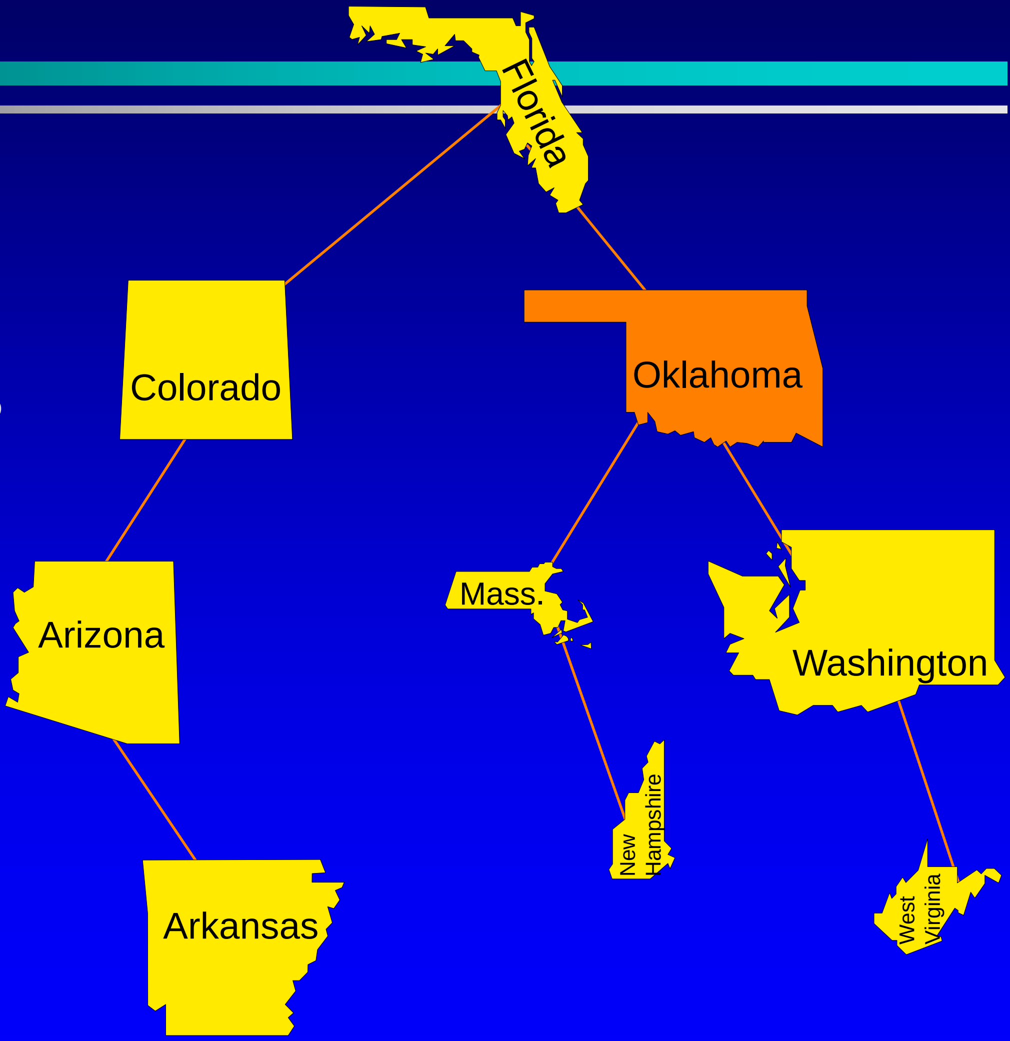

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Adding

Where would you add this state?

Adding

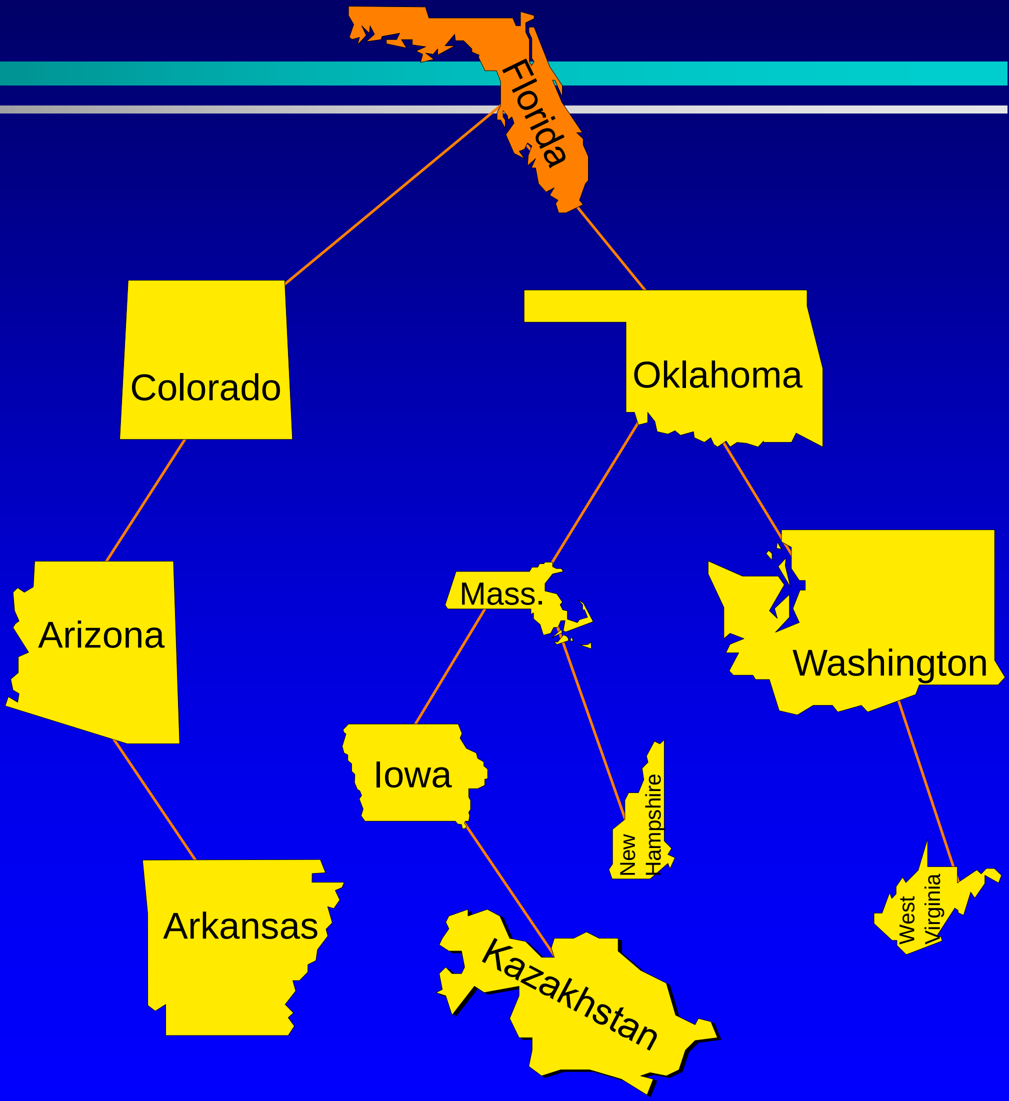
Kazakhstan is the new right child of Iowa?

Removing an Item with a Given Key

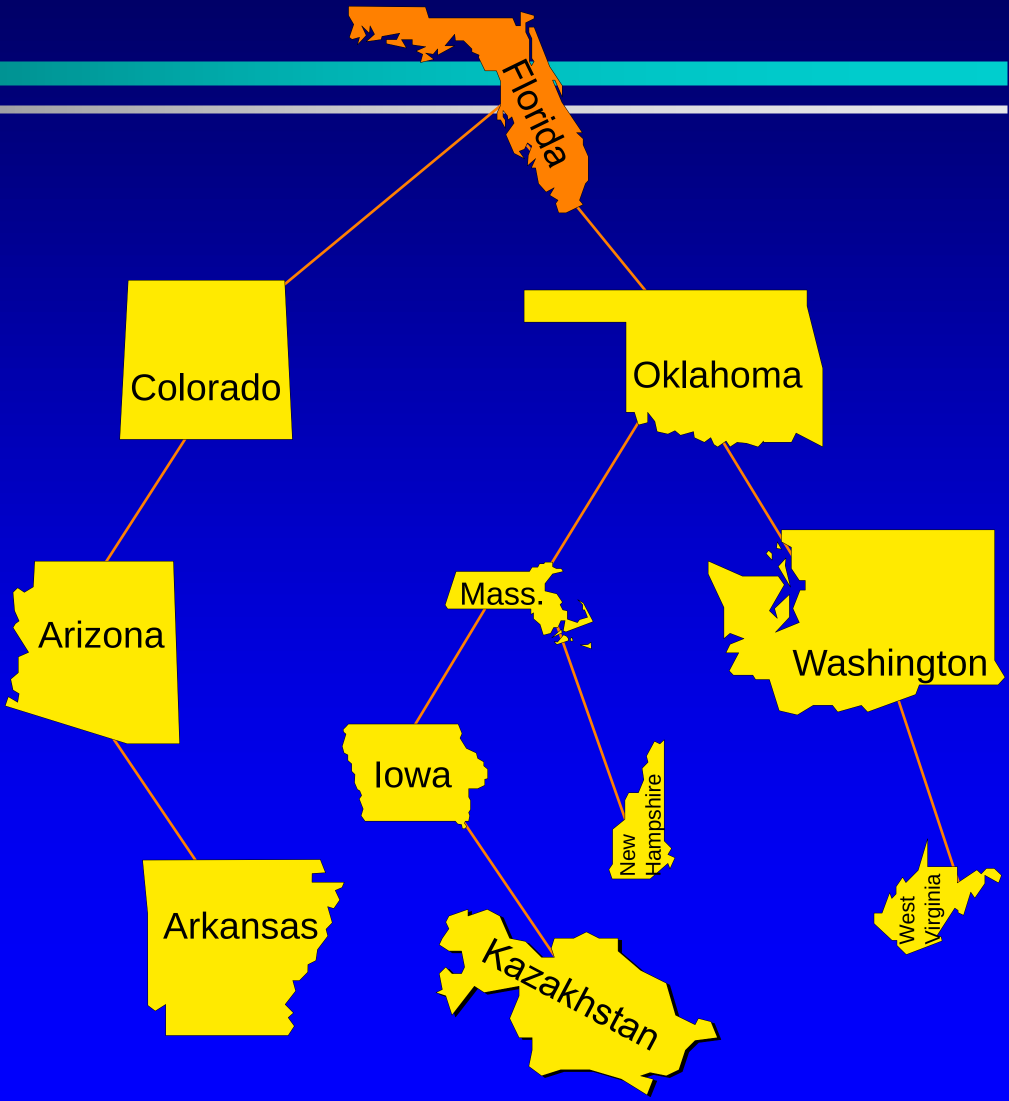
- Find the item.
- If necessary, swap the item with one that is easier to remove.
- Remove the item.

Removing 'Florida'

- **Find** the item.



Removing 'Florida'



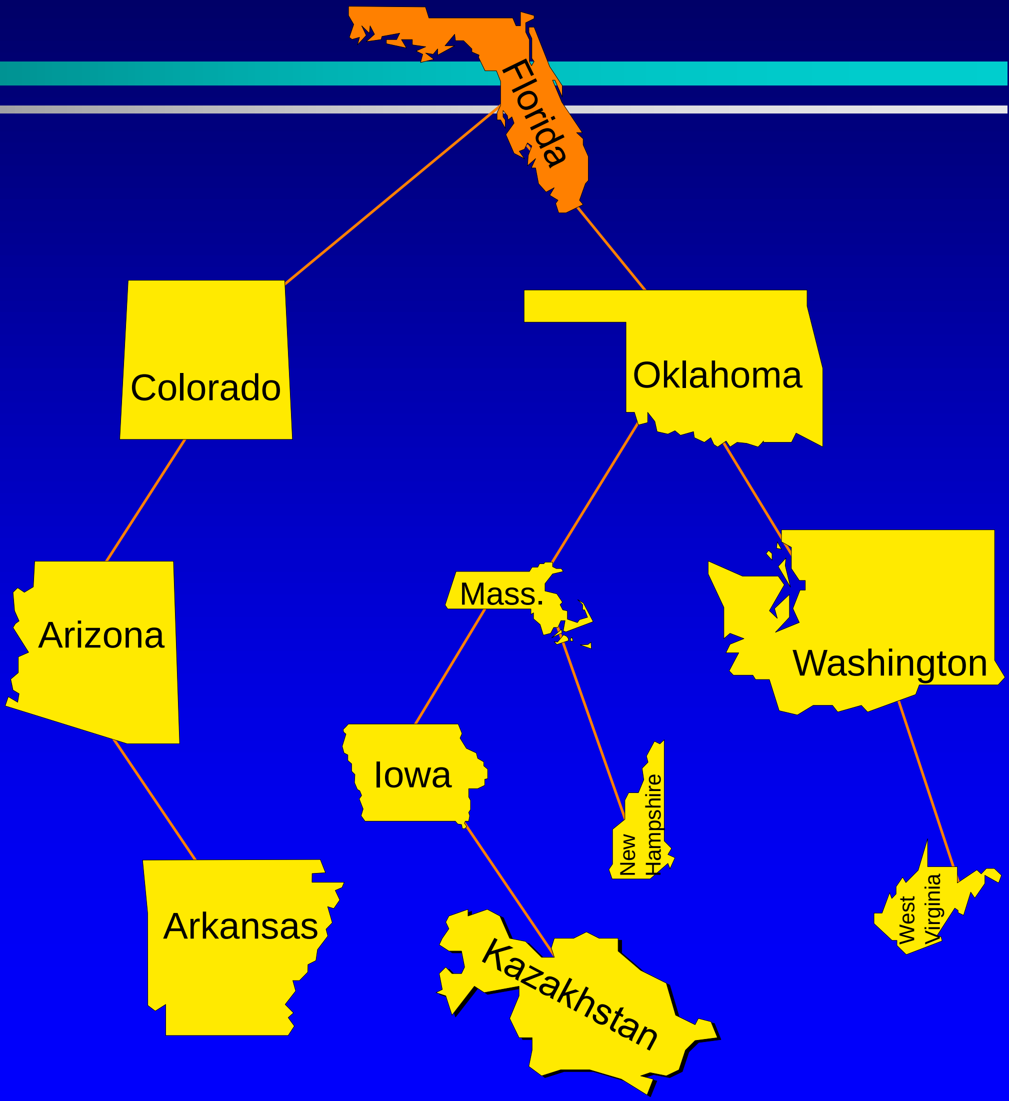
Florida cannot be removed at the moment...

Removing 'Florida'

... because removing Florida would break the tree into two pieces.

Removing 'Florida'

- If necessary, do some rearranging.



The problem of breaking the tree happens because Florida has 2 children.

Removing 'Florida'

- If necessary, do some rearranging.

For the rearranging, take the **smallest** item in the right subtree...

Work for multi-set?

Removing 'Florida'

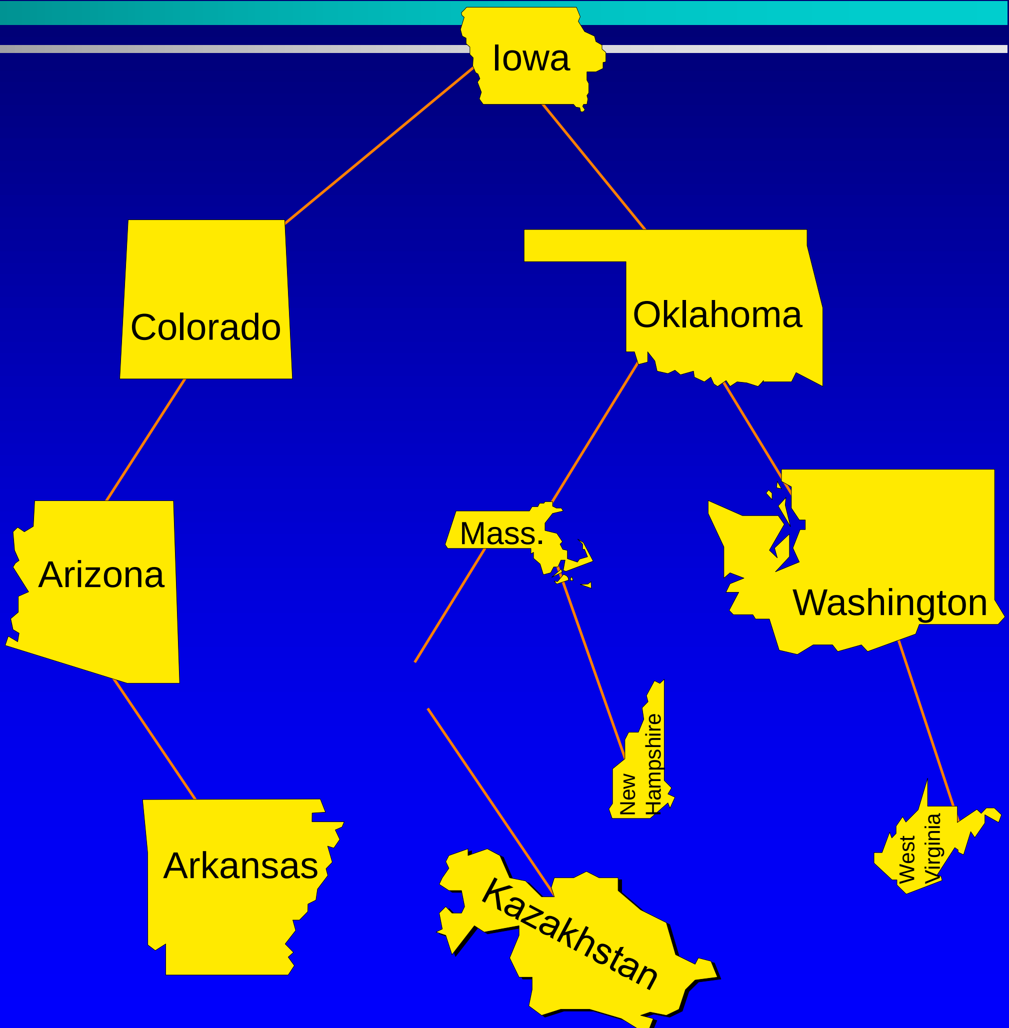
- If necessary, do some rearranging.

...**copy** that smallest item onto the item that we're removing...

Removing 'Florida'

- If necessary, do some rearranging.

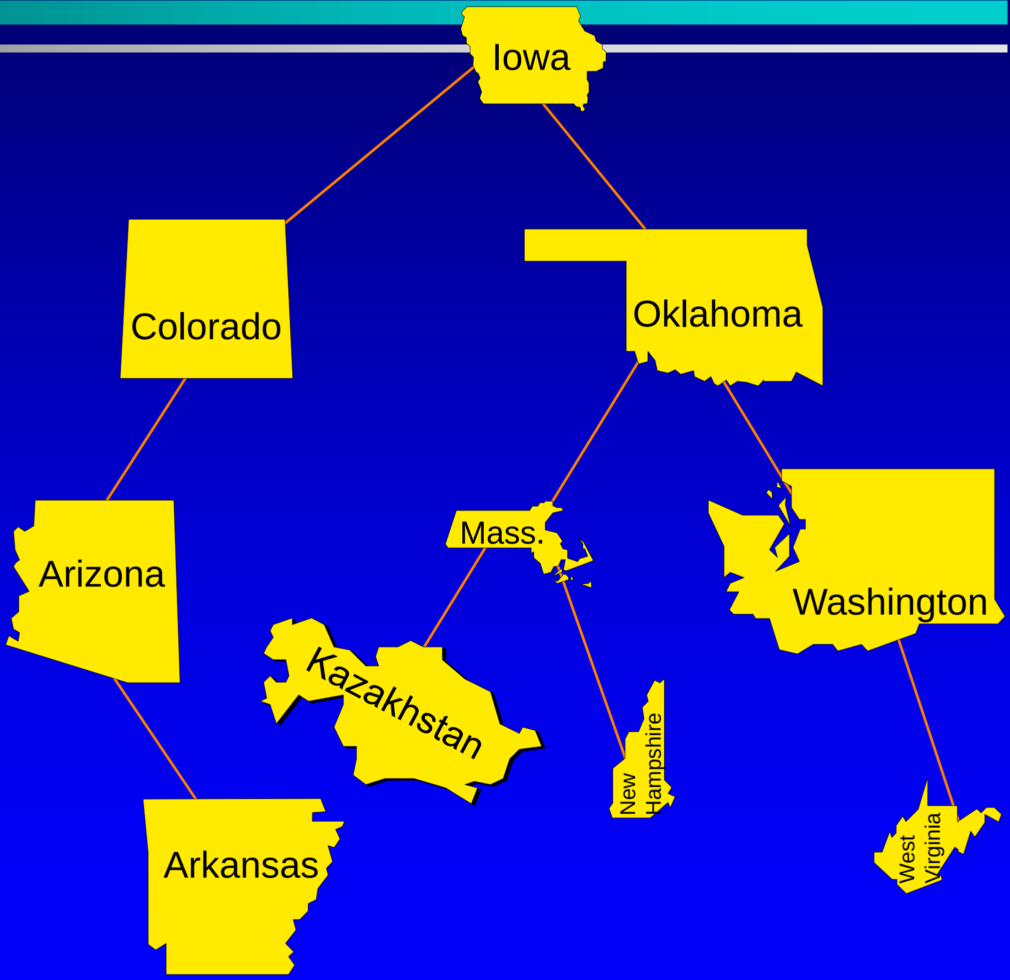
... and then remove the extra copy of the item we copied...



Removing 'Florida'

- If necessary, do some rearranging.

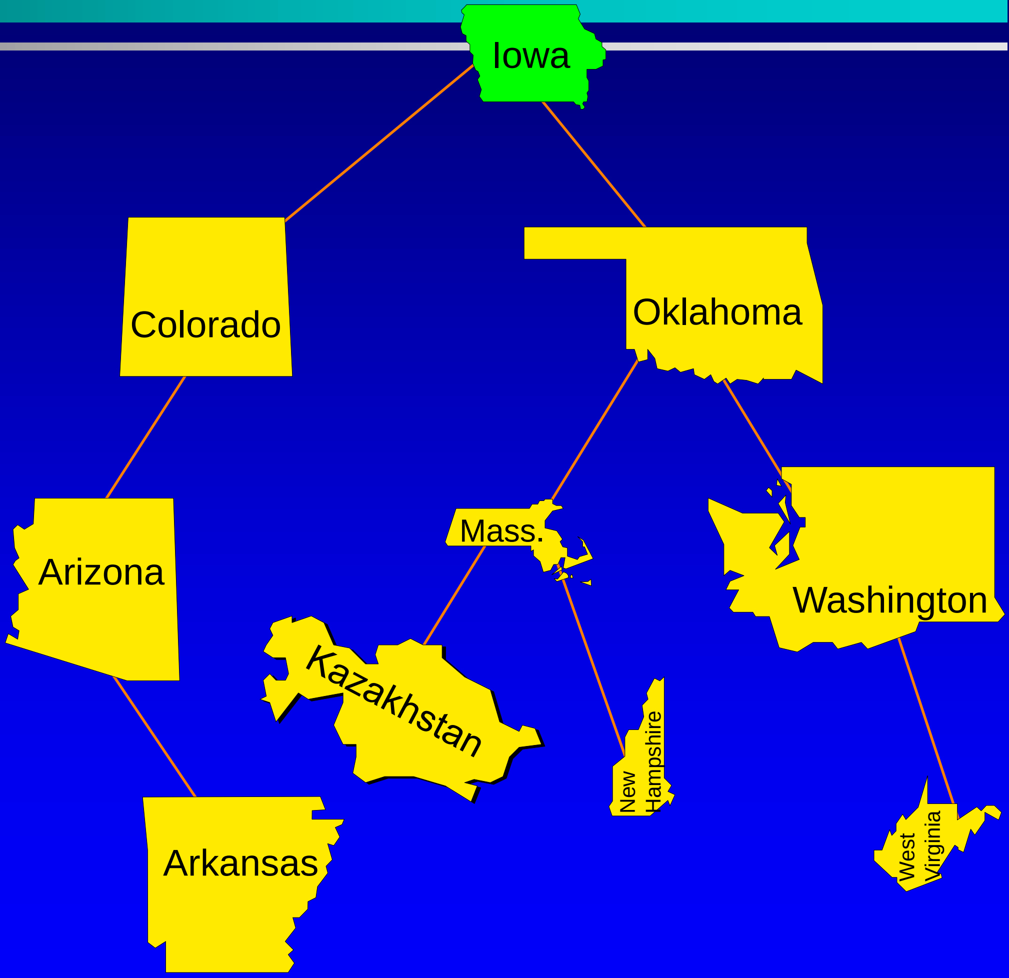
... and reconnect the tree



Removing 'Florida'

Why did I choose the ***smallest*** *item in the right subtree?*

Removing 'Florida'



Because every key must be smaller than the keys in its right subtree

Removing an Item with a Given Key

- Find the item.
- If the item has a right child, rearrange the tree:
  - Find smallest item in the right subtree
  - Copy that smallest item onto the one that you want to remove
  - Remove the extra copy of the smallest item (making sure that you keep the tree connected)

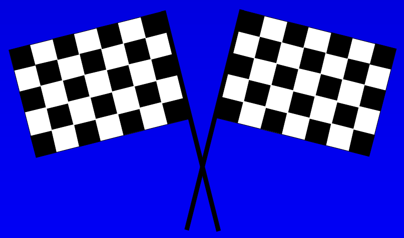
else just remove the item.

Summary

- Binary search trees are a good implementation of data types such as sets, bags, and dictionaries.
- Searching for an item is generally quick since you move from the root to the item, without looking at many other items.
- Adding and deleting items is also quick.
- But as you'll see later, it is possible for the quickness to fail in some cases -- can you see why?

Assignment

- Read Section 10.5
- Assignment – Bag class with a BST
  - Memeber functions
    - void insert(const Item& entry);
    - size_type count (const Item& target);
  - Non-member functions
    - viod bst_remove_all(binary_tree_node<Item>*& root const Item& target);
    - void bst_remove_max(binary_tree_node<Item>*& root, Item& removed);



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