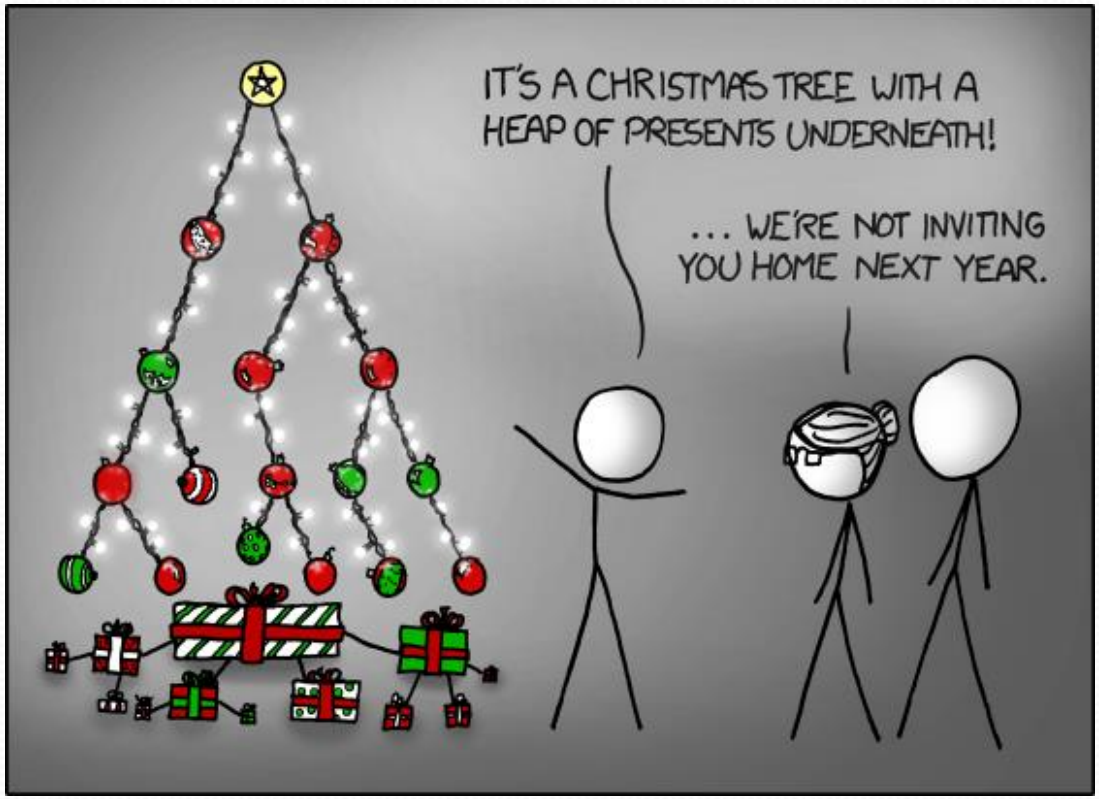
CSE 143

Binary Search Trees

reading: 17.3 – 17.4

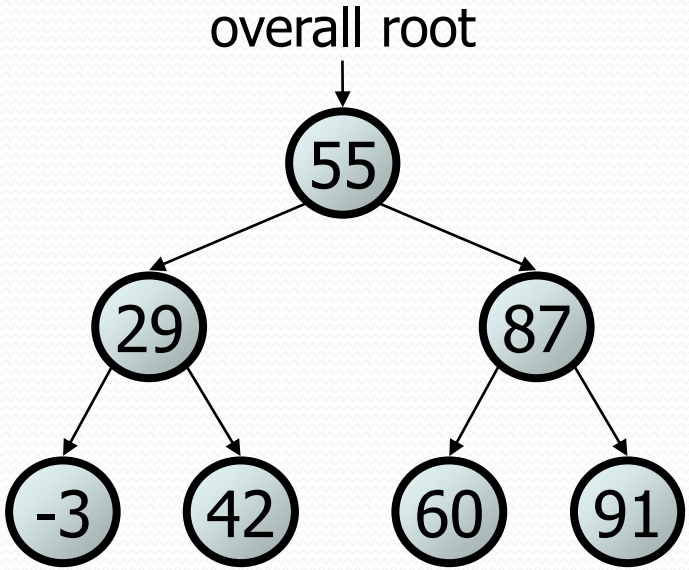


Binary search trees

- **binary search tree** ("BST"): a binary tree where each non-empty node R has the following properties:
  - elements of R's left subtree contain data "less than" R's data,
  - elements of R's right subtree contain data "greater than" R's,
  - R's left and right subtrees are also binary search trees.

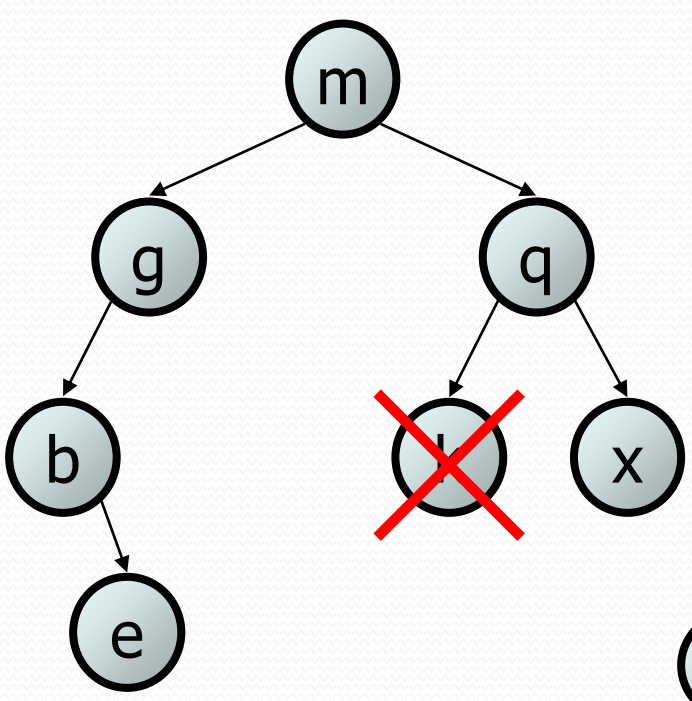
```
System.out.println(contains(42))
;
```

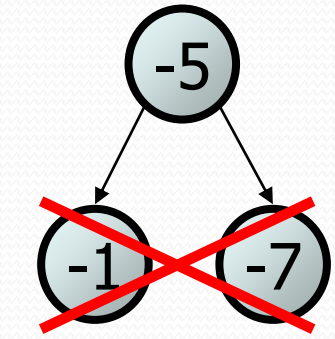
- BSTs store their elements in sorted order, which is helpful for searching/sorting tasks.

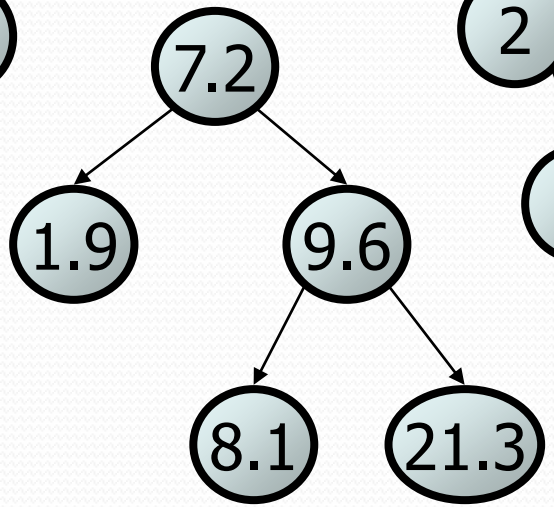


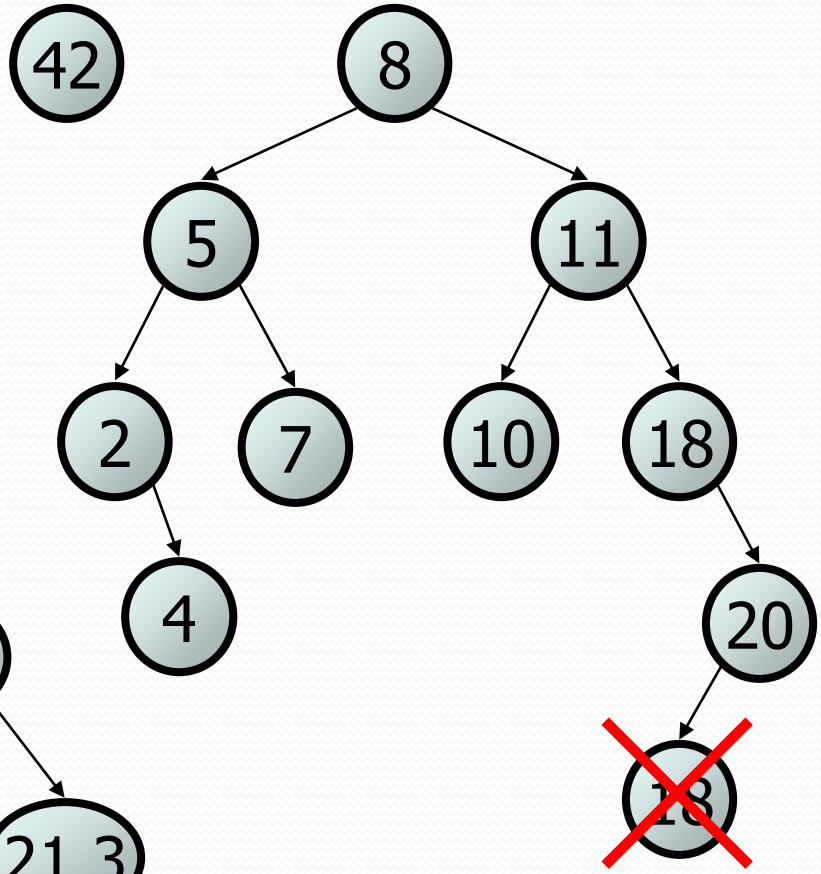
BST examples

- Which of the trees shown are legal binary search trees?



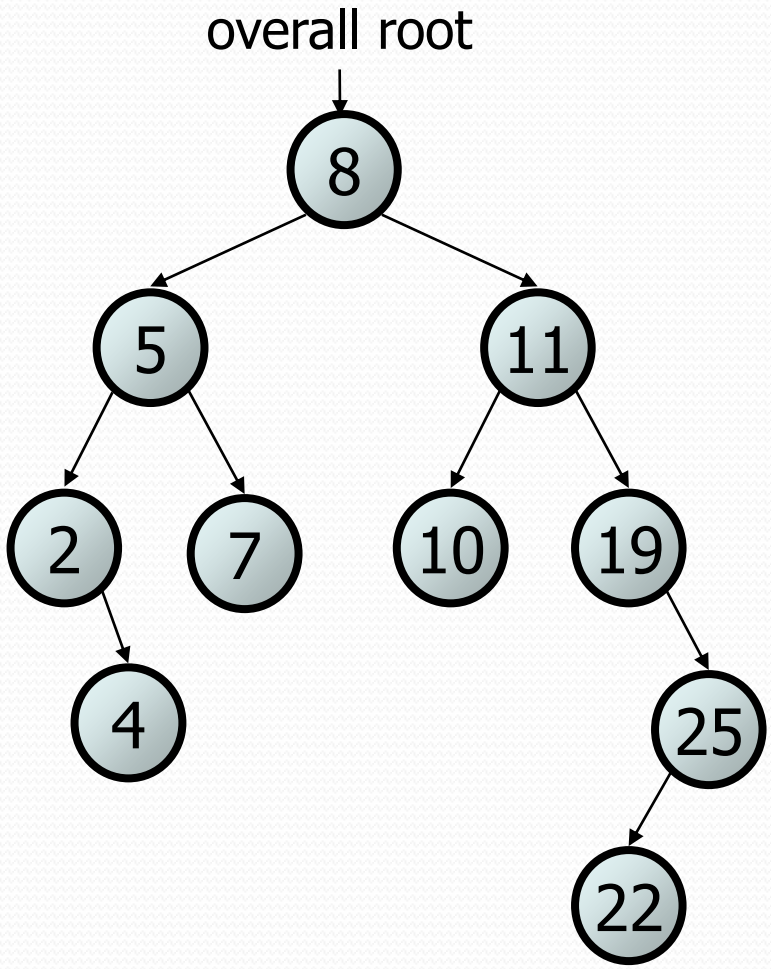






Adding to a BST

- Suppose we want to add new values to the BST below.
  - Where should the value 14 be added?
  - Where should 3 be added? 7?
  - If the tree is empty, where should a new value be added?
- What is the general algorithm?



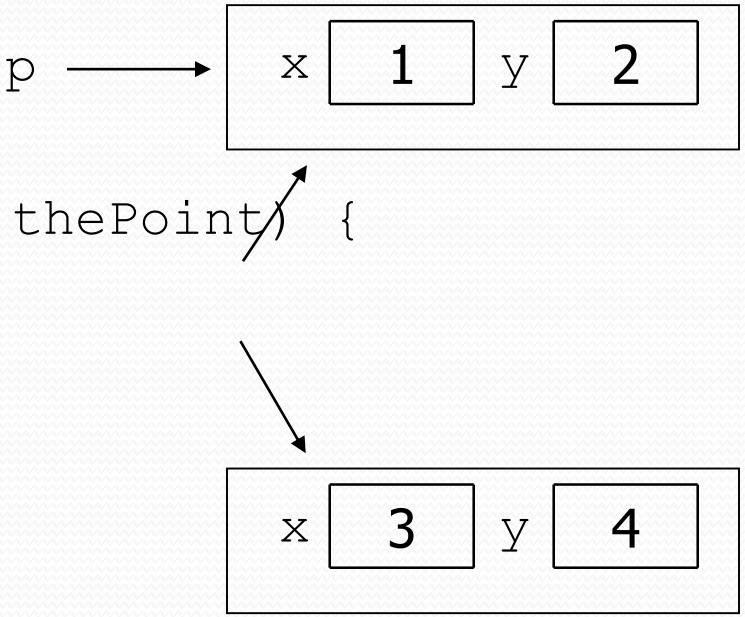
Change point, version 2

- What is the state of the object referred to by `p` after this code?

```
public static void main(String[] args) {
    Point p = new Point(1, 2);
    change(p);
    System.out.println(p);
}

public static void change(Point thePoint) {
    thePoint = new Point(3, 4);
}


// answer: (1, 2)
```



Changing references

- If a method *dereferences a variable* (with `.`) and modifies the object it refers to, that change will be seen by the caller.

```
public static void change(Point thePoint) {
    thePoint.x = 3;                    // affects p
    thePoint.setY(4);                  // affects p
```

- If a method *reassigns a variable to refer to a new object,* that change will *not* affect the variable passed in by the caller.

```
public static void change(Point thePoint) {
    thePoint = new Point(3, 4);        // p unchanged
    thePoint = null;                   // p unchanged
```

  - What if we want to make the variable passed in become `null`?

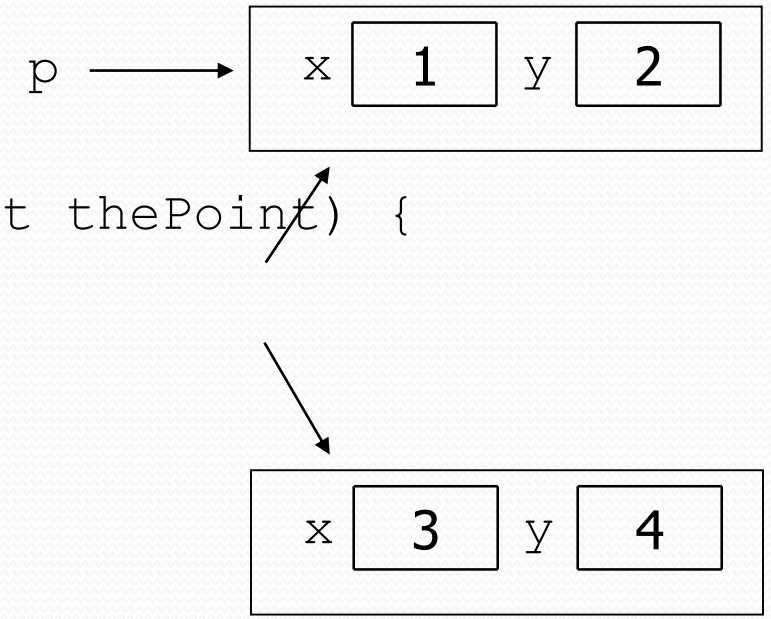
Change point, version 3

- What is the state of the object referred to by `p` after this code?

```
public static void main(String[] args) {
    Point p = new Point(1, 2);
    change(p);
    System.out.println(p);
}

public static Point change(Point thePoint) {
    thePoint = new Point(3, 4);
    return thePoint;
}

// answer: (1, 2)
```



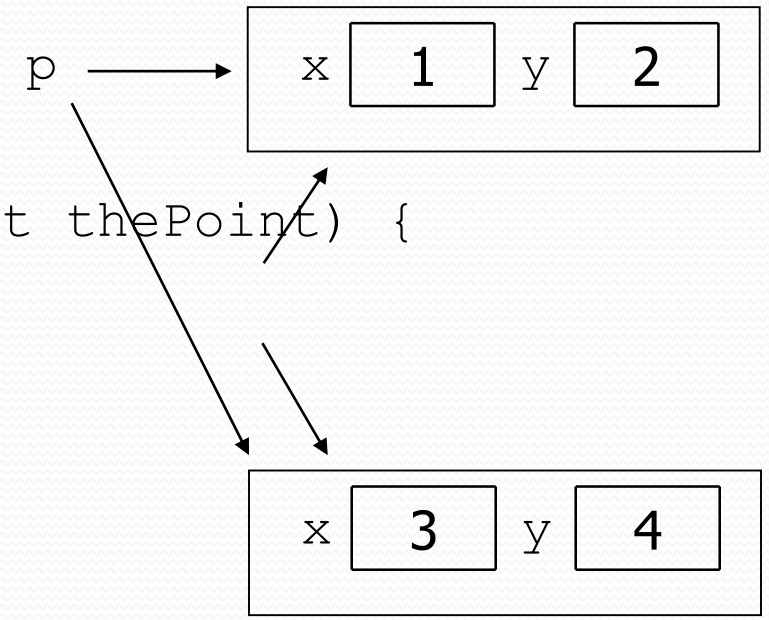
Change point, version 4

- What is the state of the object referred to by `p` after this code?

```
public static void main(String[] args) {
    Point p = new Point(1, 2);
    p = change(p);
    System.out.println(p);
}

public static Point change(Point thePoint) {
    thePoint = new Point(3, 4);
    return thePoint;
}

// answer: (3, 4)
```



x = change(x);

- If you want to write a method that can change the object that a variable refers to, you must do three things:
  1. **pass** in the original state of the object to the method
  2. **return** the new (possibly changed) object from the method
  3. **re-assign** the caller's variable to store the returned result

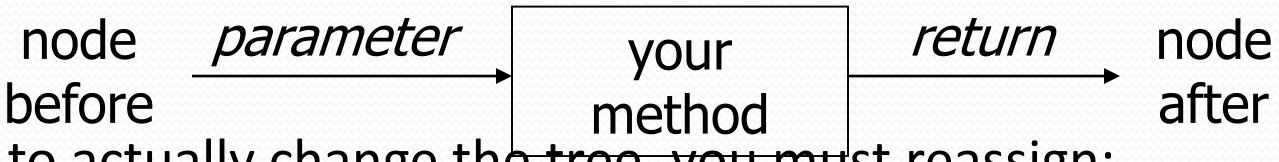
```
p = change(p);      // in main

public static Point change(Point thePoint) {
    thePoint = new Point(99, -1);
    return thePoint;
```

- We call this general algorithmic pattern **x = change(x);**
  - also seen with strings: `s = s.toUpperCase();`

Applying x = change(x)

- Methods that modify a tree should have the following pattern:
  - input (parameter): old state of the node
  - output (return): new state of the node



- In order to actually change the tree, you must reassign:

```
node          = change(node, parameters);
node.left     = change(node.left, parameters);
node.right    = change(node.right, parameters);
overallRoot   = change(overallRoot, parameters);
```