Building Java Programs

Binary Trees

reading: 17.1 – 17.3


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Road Map

CS Concepts

- Client/Implementer
- Efficiency
- Recursion
- Regular Expressions
- Grammars
- Sorting
- Backtracking
- Hashing
- Huffman Compression

Java Language

- Exceptions
- Interfaces
- References
- Generics
- Comparable
- Inheritance/Polymorphism
- Abstract Classes

Data Structures

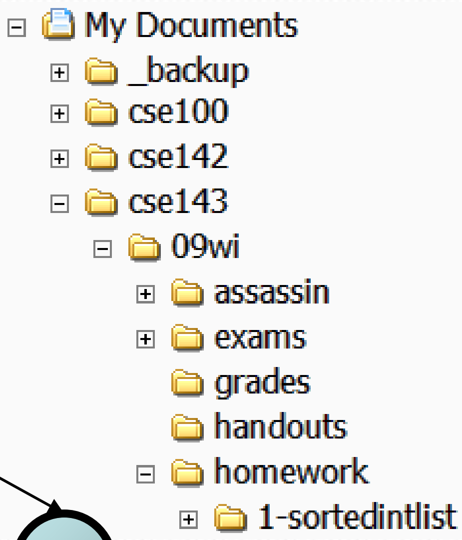
- Lists
- Stacks
- Queues
- Sets
- Maps
- Priority Queues

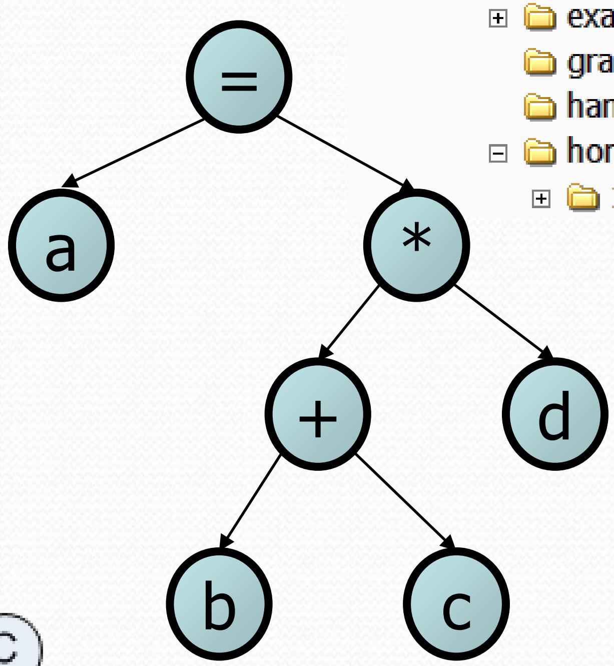
Java Collections

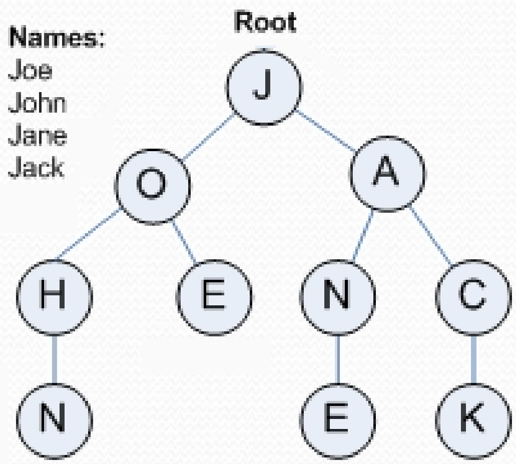
- Arrays
- ArrayList
- LinkedList
- Stack
- TreeSet / TreeMap
- HashSet / HashMap
- PriorityQueue

Trees in computer science

- TreeMap and TreeSet implementations
- folders/files on a computer
- family genealogy; organizational charts
- AI: decision trees
- compilers: parse tree
  - a = (b + c) * d;
- cell phone T9

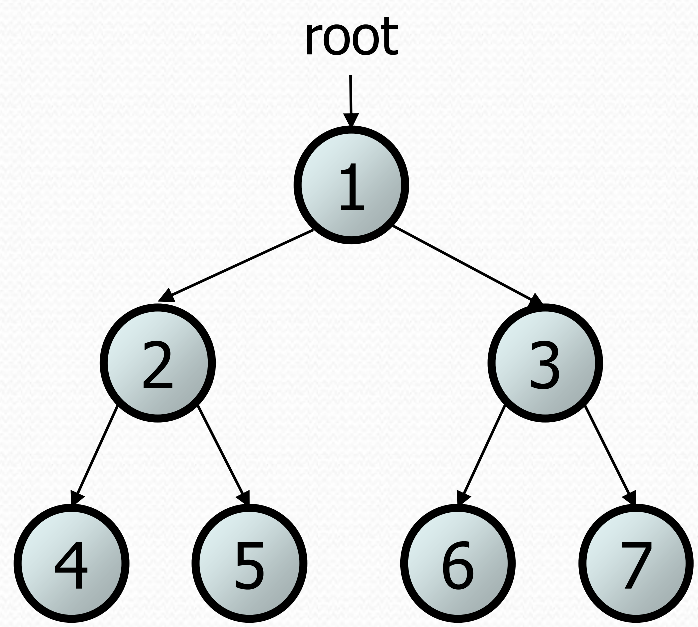






Trees

- **tree**: Nodes linked together in some hierarchical fashion
- **binary tree**: One where each node has at most two children.
- *Recursive definition:* A tree is either:
  - empty (`null`), or
  - a **root** node that contains:
    - **data**,
    - a **left** subtree, and
    - a **right** subtree.
      - (The left and/or right subtree could be empty.)



Recursive data structure

- *Recursive definition:* A tree is either:
  - empty (`null`), or
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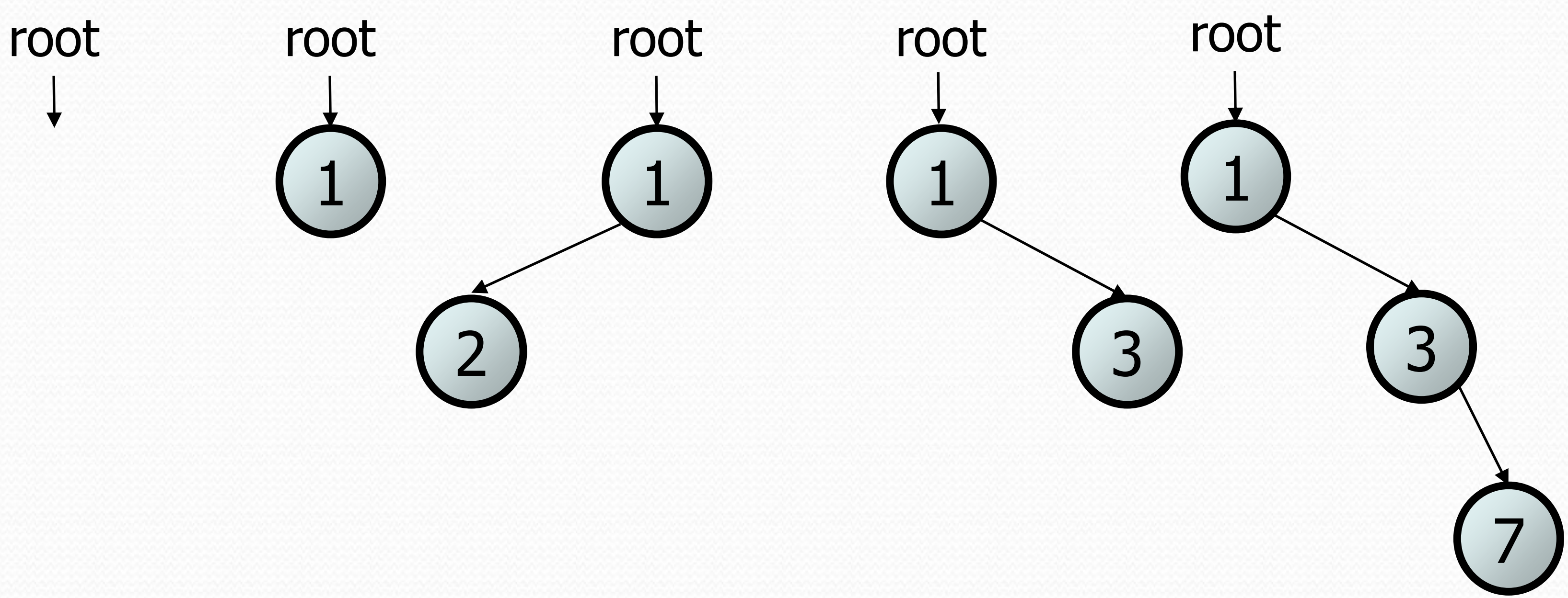
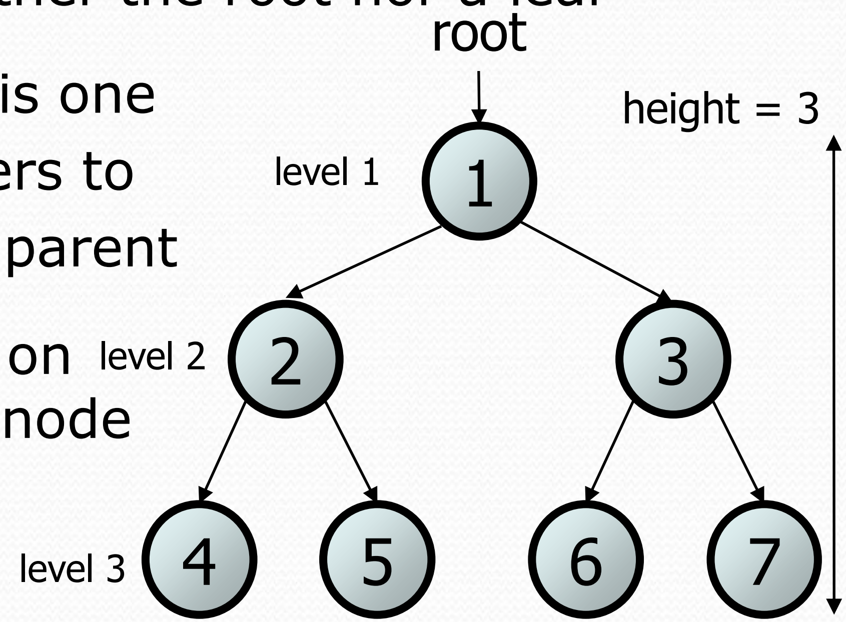


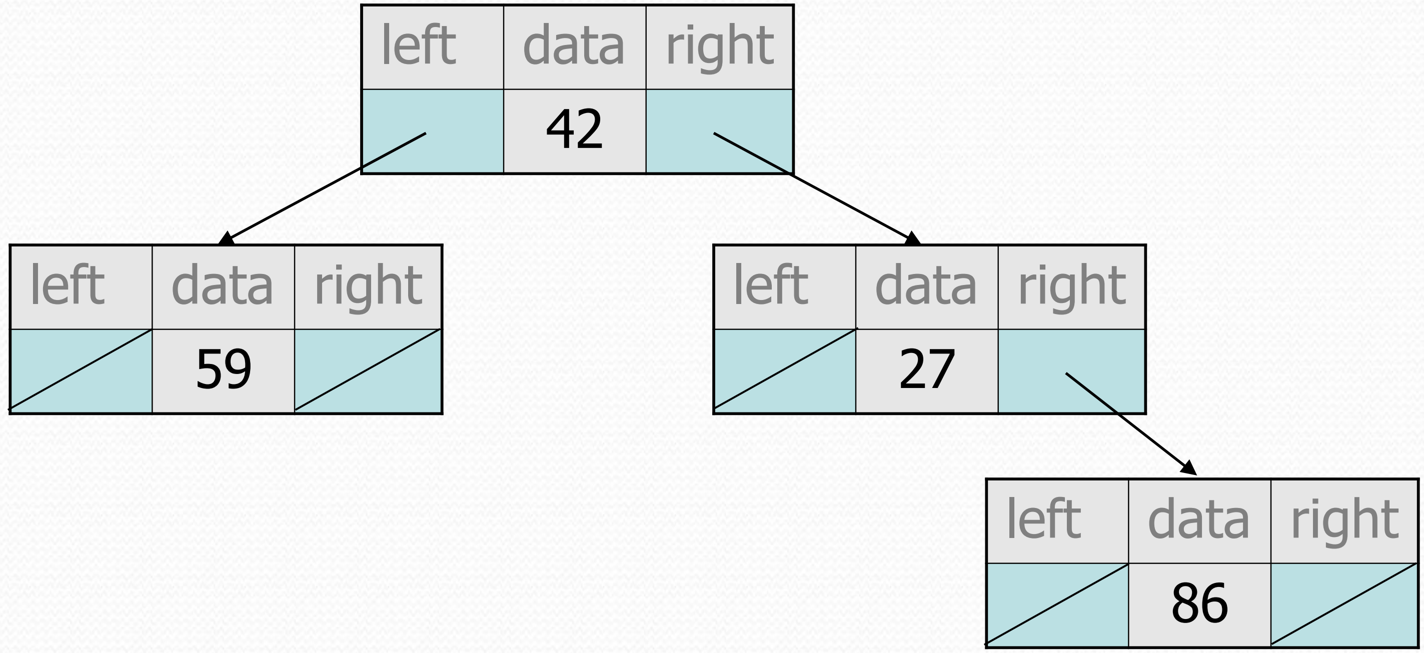
Terminology

- **node**: an object containing a data value and left/right children
  - **root**: topmost node of a tree
  - **leaf**: a node that has no children
  - **branch**: any internal node; neither the root nor a leaf
  - **parent**: a node that refers to this one
  - **child**: a node that this node refers to
  - **sibling**: a node with a common parent
- **subtree**: the smaller tree of nodes on the left or right of the current node
- **height**: length of the longest path from the root to any node
- **level** or **depth**: length of the path from a root to a given node



A tree node for integers

- A basic **tree node object** stores data, refers to left/right
  - Multiple nodes can be linked together into a larger tree

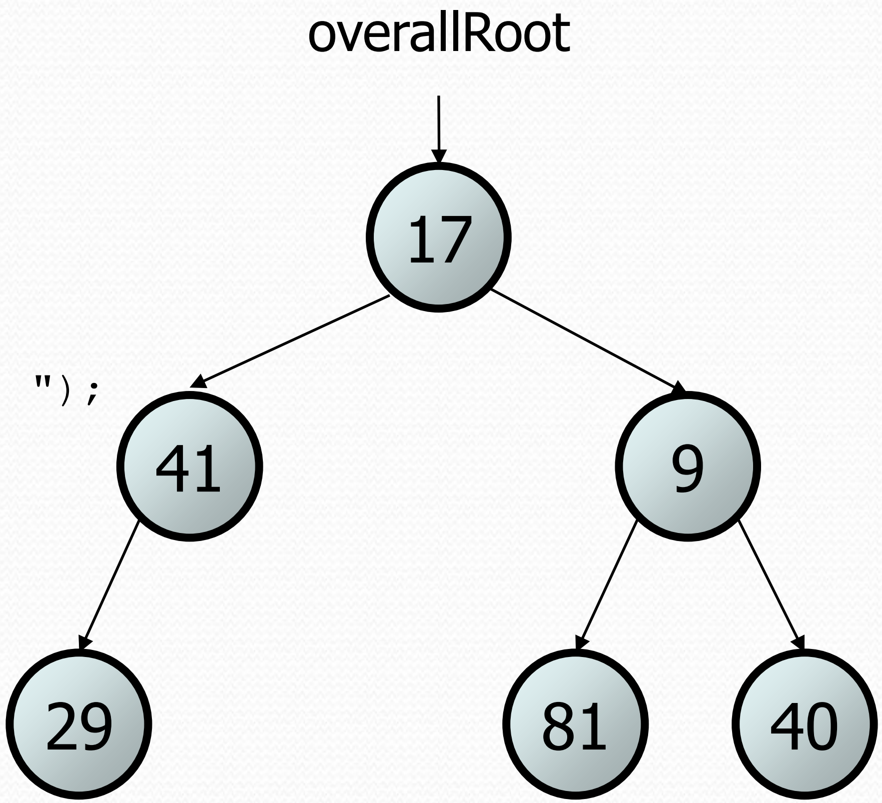


Print `IntTree`

- We want to write a method that prints out the contents of an `IntTree`.
- Here is the output we want

```
17 41 29 9 81 40
```

```
private void print(IntTreeNode root) {
    if (root != null) {
        System.out.print(root.data + " ");
        print(root.left);
        print(root.right);
    }
}
```



Traversals

- Orderings for traversals
  - **pre-order:** process root node, then its left/right subtrees
  - **in-order:** process left subtree, then root node, then right
  - **post-order:** process left/right subtrees, then root node

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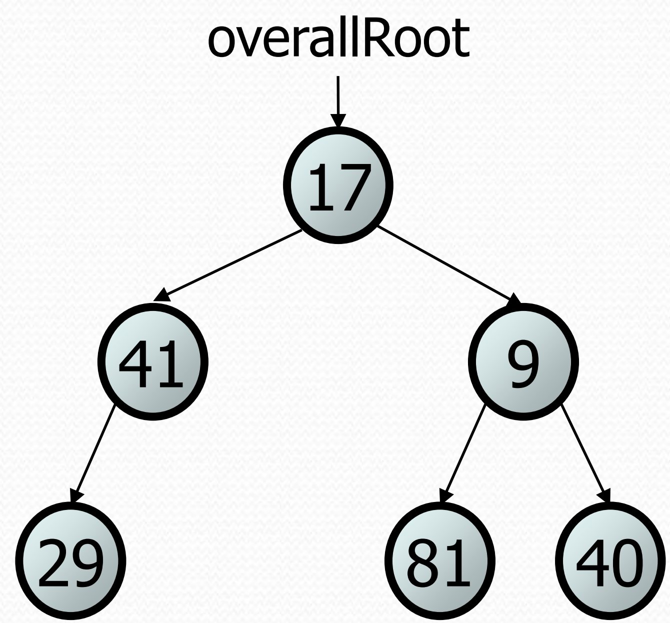

- pre-order: `17 41 29 9 81 40`

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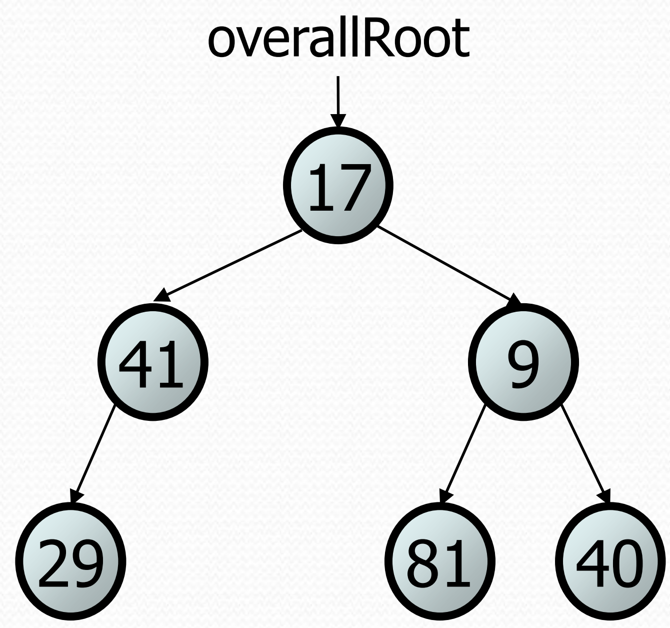

- in-order: `29 41 17 81 9 40`

Traversals

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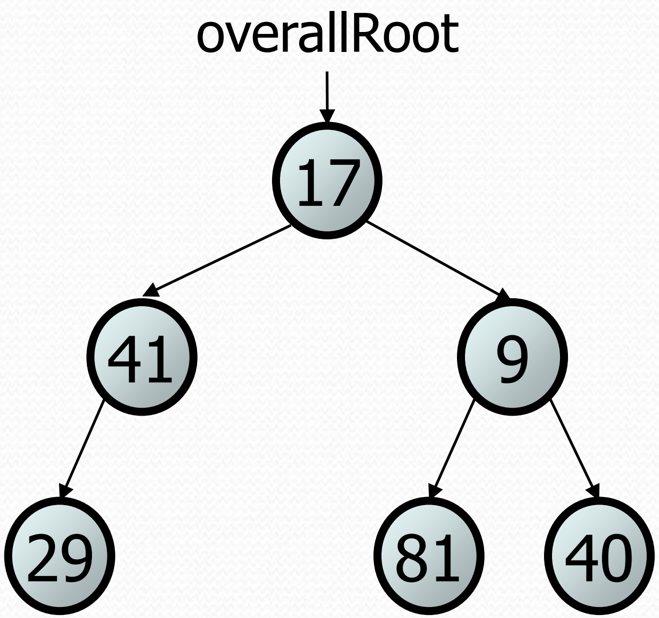
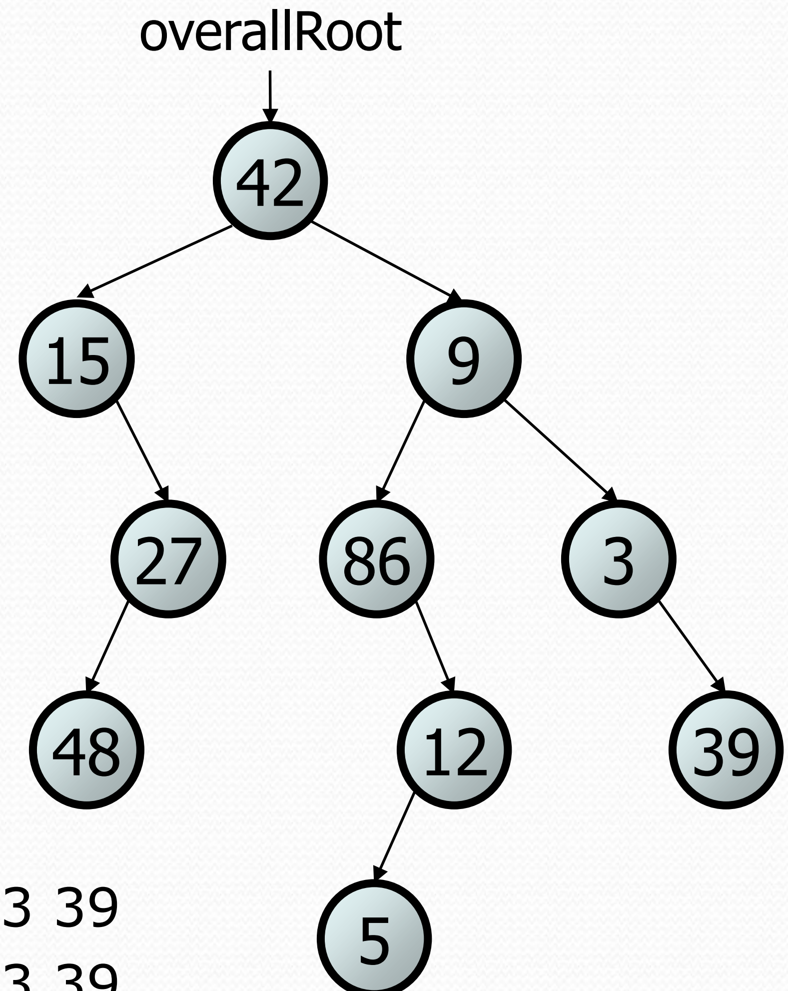


- post-order: `29 41 81 40 9 17`

Exercise

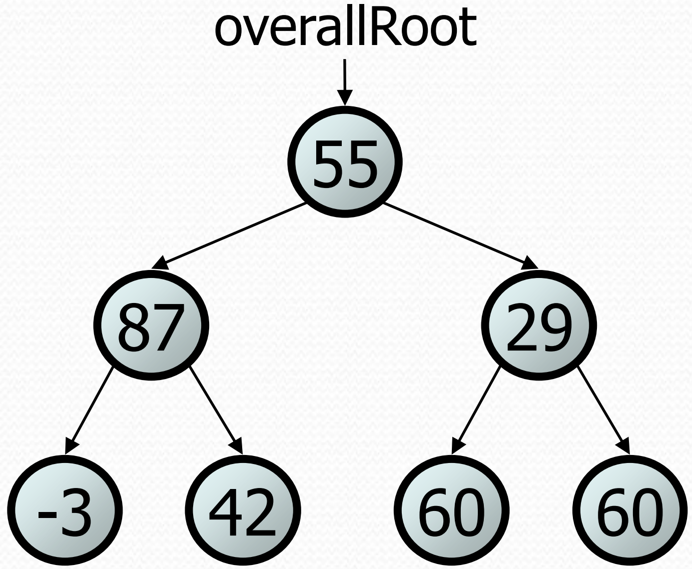
- Give pre-, in-, and post-order traversals for the following tree:



  - pre: 42 15 27 48 9 86 12 5 3 39
  - in: 15 48 27 42 86 5 12 9 3 39
  - post: 48 27 15 5 12 86 39 3 42

Exercise

- Add a method `contains` to the `IntTree` class that searches the tree for a given integer, returning `true` if it is found.
  - If an `IntTree` variable `tree` referred to the tree below, the following calls would have these results:
    - `tree.contains(87)` → `true`
    - `tree.contains(60)` → `true`
    - `tree.contains(63)` → `false`
    - `tree.contains(42)` → `false`



Exercise solution

```
// Returns whether this tree contains the given integer.
public boolean contains(int value) {
    return contains(overallRoot, value);
}

private boolean contains(IntTreeNode node, int value) {
    if (node == null) {
        return false;   // base case: not found here
    } else if (node.data == value) {
        return true;    // base case: found here
    } else {
        // recursive case: search left/right subtrees
        return contains(node.left, value) ||
               contains(node.right, value);
    }
}
```

Template for tree methods

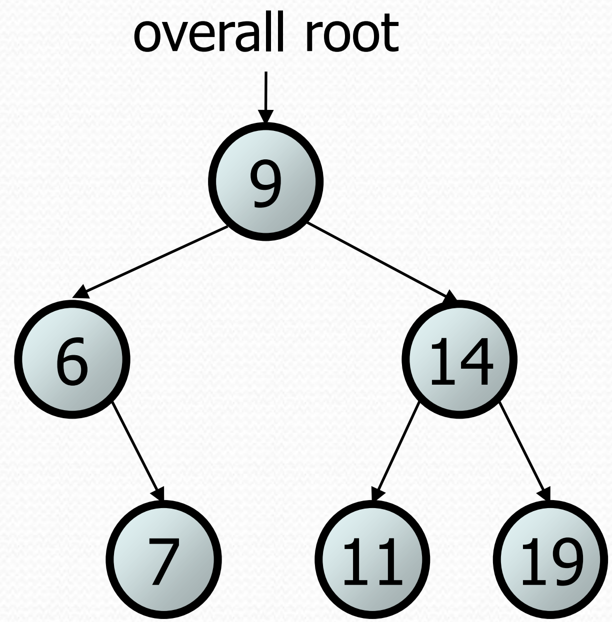
```
public class IntTree {
    private IntTreeNode overallRoot;
    ...


    public type name(parameters) {
        name(overallRoot, parameters);
    }

    private type name(IntTreeNode root, parameters) {
        ...
    }
}
```

- Tree methods are often implemented recursively
  - with a public/private pair
  - the private version accepts the root node to process

Exercise

- Add a method named `printSideways` to the `IntTree` class that prints the tree in a sideways indented format, with right nodes above roots above left nodes, with each level 4 spaces more indented than the one above it.
  - Example: Output from the tree below:

```
        19
    14
        11
9
        7
    6
```



Exercise solution

```
// Prints the tree in a sideways indented format.
public void printSideways() {
    printSideways(overallRoot, "");
}

private void printSideways(IntTreeNode root,
                           String indent) {
    if (root != null) {
        printSideways(root.right, indent + "    ");
        System.out.println(indent + root.data);
        printSideways(root.left, indent + "    ");
    }
}
```