CS 112 – Introduction to Computing II

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Today

- Introduction to Binary Search Trees
- Basic recursive algorithms on BSTs: member, insert, ….

Next Time:

- Recursive algorithms on BSTs: delete
- Recursive Tree Traversals

Computer Science

Binary Trees

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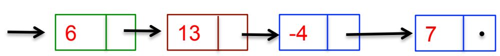
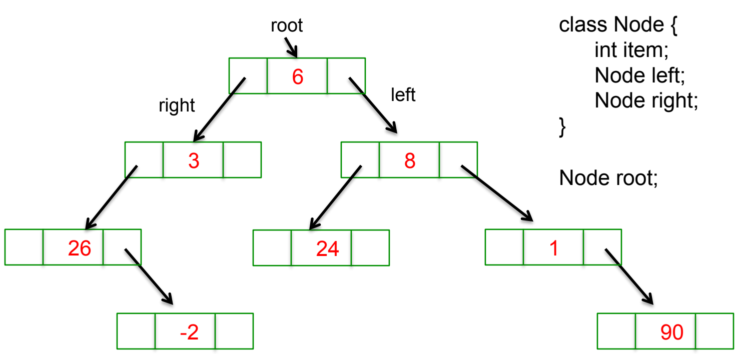
Linked lists have a single pointer to the next item in a linear sequence:



Recall that ordering a LL does not help much, so we can't use binary search! The next data structure is an attempt to fix this problem.

Binary Trees add an additional pointer, so that the linear sequence becomes an upside-down tree where each node has 0, 1, or 2 branches or "children":




```
class Node {
      int item;
      Node left;
      Node right;
}

Node root;
```

2

Binary Trees

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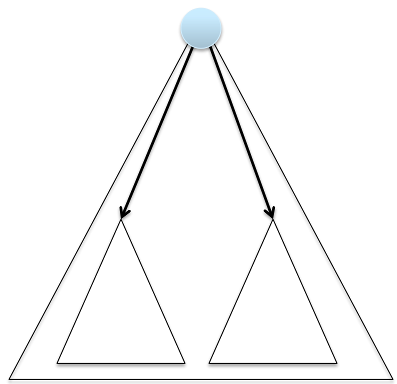
Binary Trees are an inherently recursive data structure and best manipulated by recursive algorithms:

Recursive Definition:

A Binary Tree is either

- Null (empty tree); or
- A node containing data, with pointers left and right to two Binary Trees



```
class Node {
    int item;
    Node left;
    Node right;
}
```

3

Binary Trees

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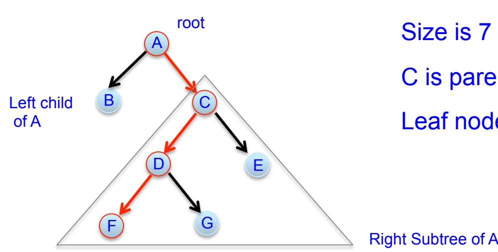
Some basic definitions:

- The root is the node at the top of the tree.
- Trees under a node are called subtrees of that node;
- The size of a tree is the number of nodes in it;
- If A points to B, then B is called the child of A;
- The parent of a node is the (unique) node which points to it (the root has no parent);
- A node is a leaf node if it has no children.



Root is A

Size is 7

C is parent of D

Leaf nodes: B, F, G, E

4

Binary Trees

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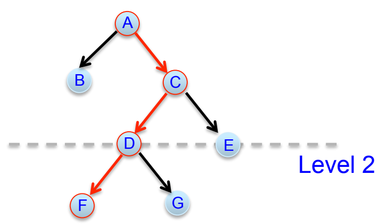
Some basic definitions:

- A path is a sequence of nodes connected by pointers (from parent to child);
- The length of the path is the number of links;
- If there is a path from A to B of length at least one, then A is an ancestor of B and B is a descendant of A.
- The depth of a node in a tree is the number of links on the path from the root;
- The height of a tree is the maximum depth among any of its nodes (or: the length of the longest path).
- Level K in a tree is all the nodes of depth K.



Path from A to F in red, of length 3

D is descendant of A

C is ancestor of G

Depth of D = 2

Height of tree = 3

5

Binary Trees

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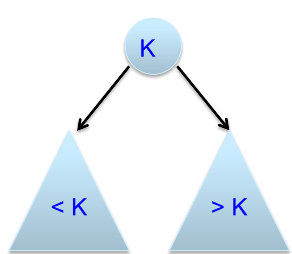
In order to use Binary Trees for search, we need to simulate binary search! This requires a different definition (still recursive):

A Binary Search Tree is either

- Null (empty tree); or
- A <u>node</u> containing a key K, with pointers <u>left</u> and <u>right</u> to two Binary Search Trees; all the keys in the left subtree are less than K, and all the keys in the right subtree are greater than K:



This is assuming no duplicates! If duplicates, replace > by >= in right subtree.

6

Binary Search Trees

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We will look at the following algorithms for BSTs on the board:

Size()
Height()
Lookup/member()
Insert()

[next time]
Delete()

Traversal()

Go to: www.cs.bu.edu/fac/snyder/cs112/CourseMaterials/BinaryTreeCode.html

7