

# Data Structures and Algorithms

*CS245-2013S-09*

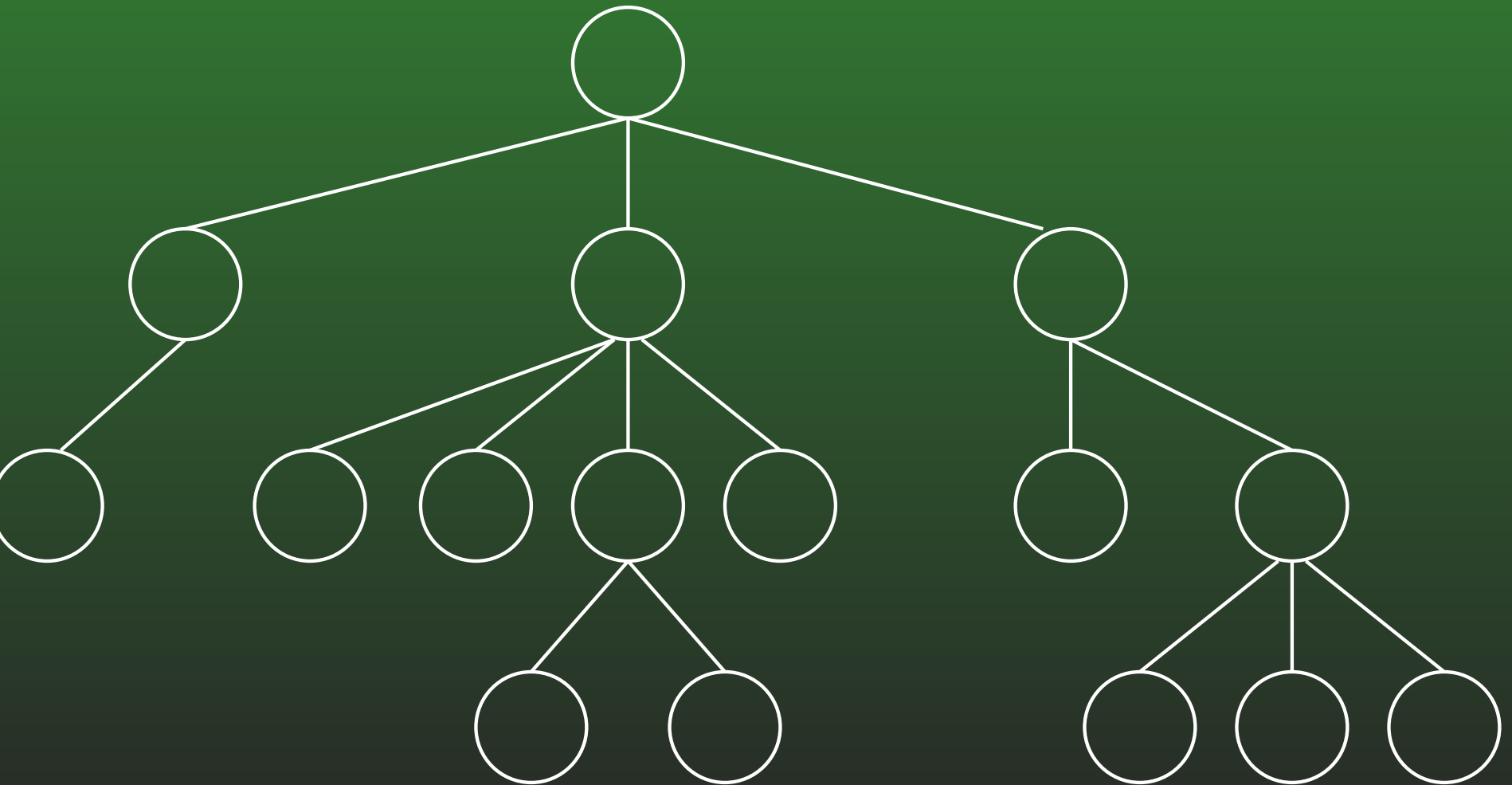
## *General Trees*

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University of San Francisco

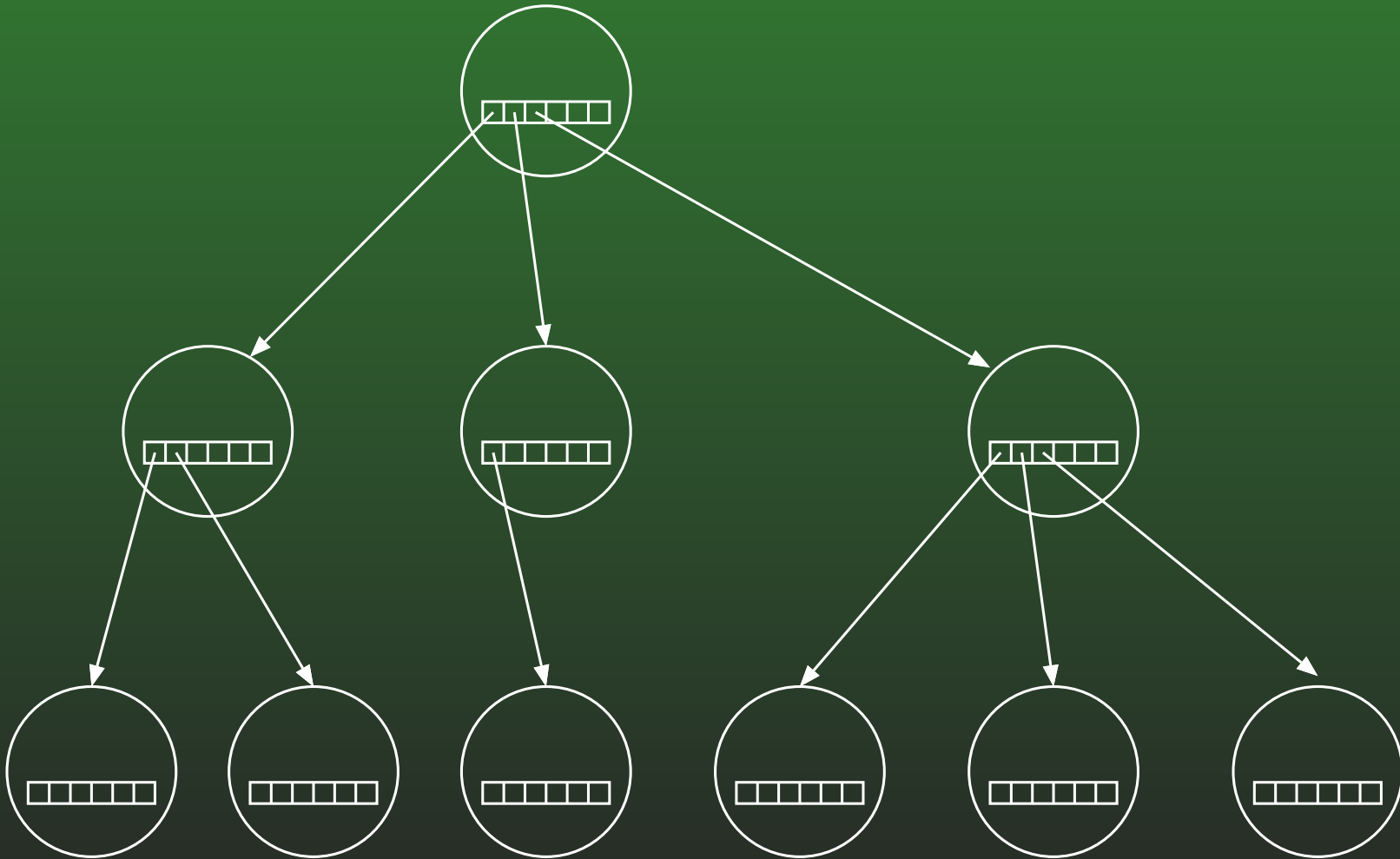
## 09-0: Trees with $> 2$ children

How can we implement trees with nodes that have  $> 2$  children?



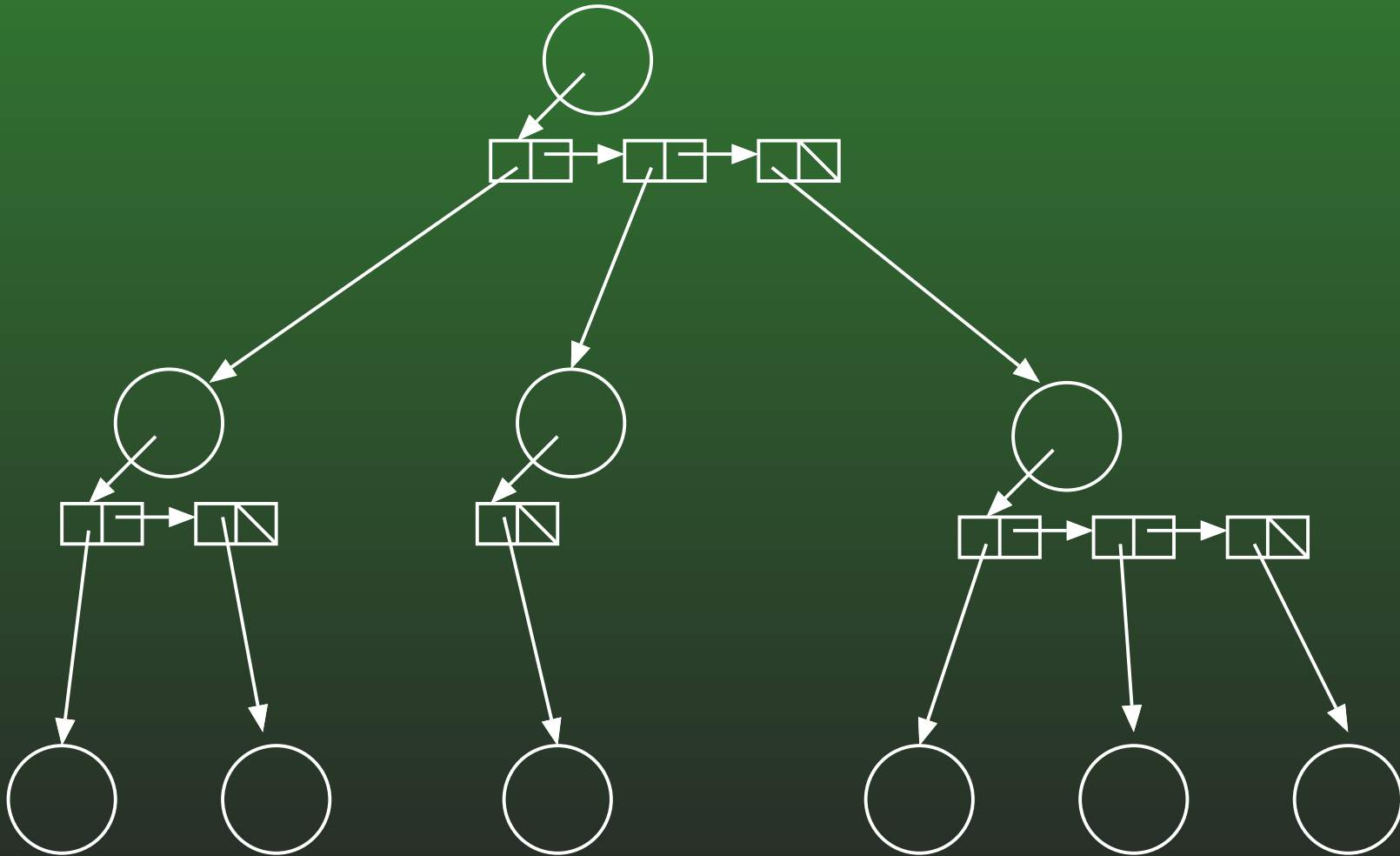
# 09-1: Trees with $> 2$ children

- Array of Children



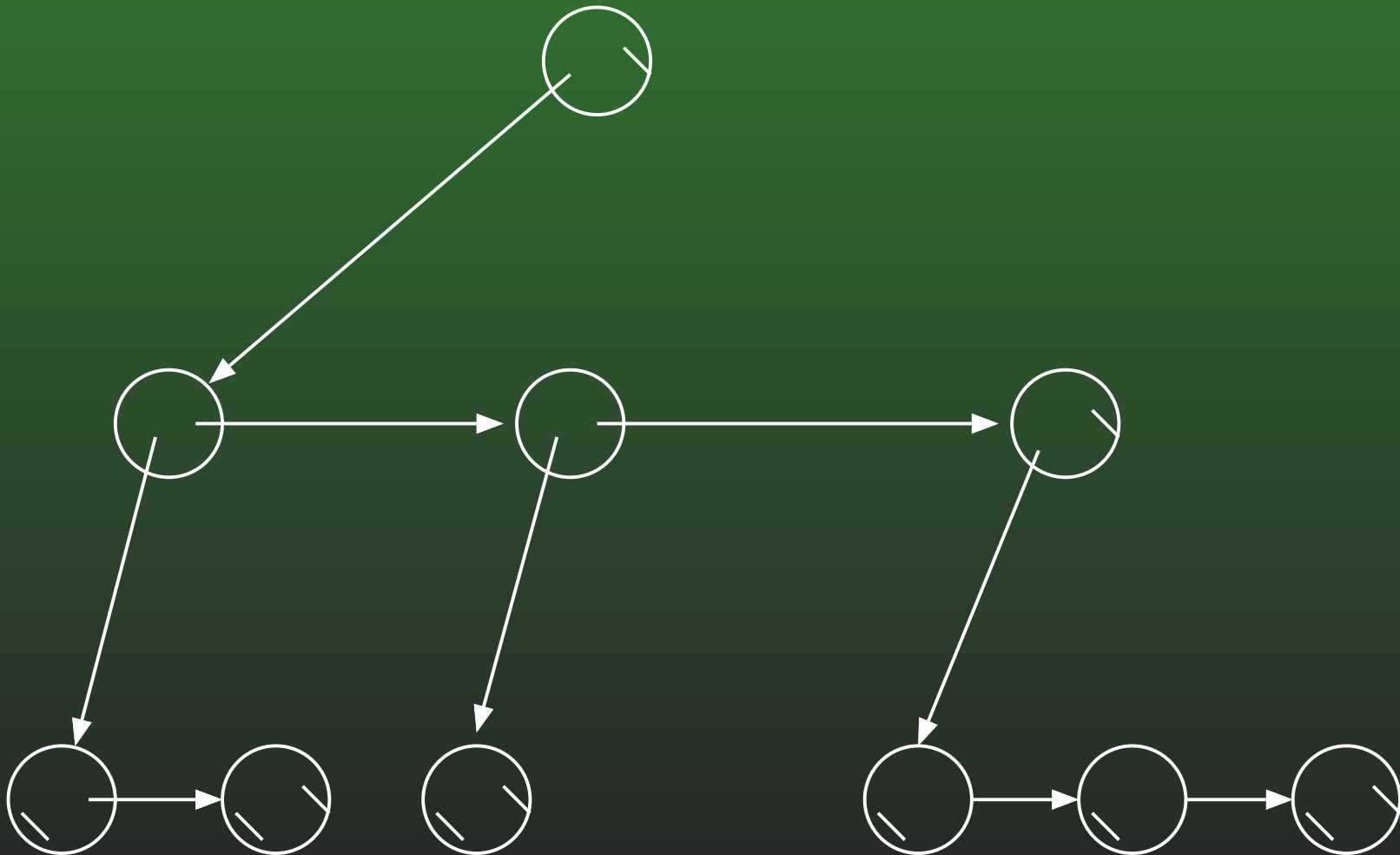
## 09-2: Trees with $> 2$ children

- Linked List of Children



## 09-3: Left Child / Right Sibling

- We can integrate the linked lists with the nodes themselves:



## 09-4: Working with General Tree

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```
class Node {
    private Node leftchild_;
    private Node rightsib_;
    private Object element_;

    Node leftchild() {
        return leftchild_;
    }

    Node rightsib() {
        return rightsib_;
    }

    Node element() {
        return element_;
    }

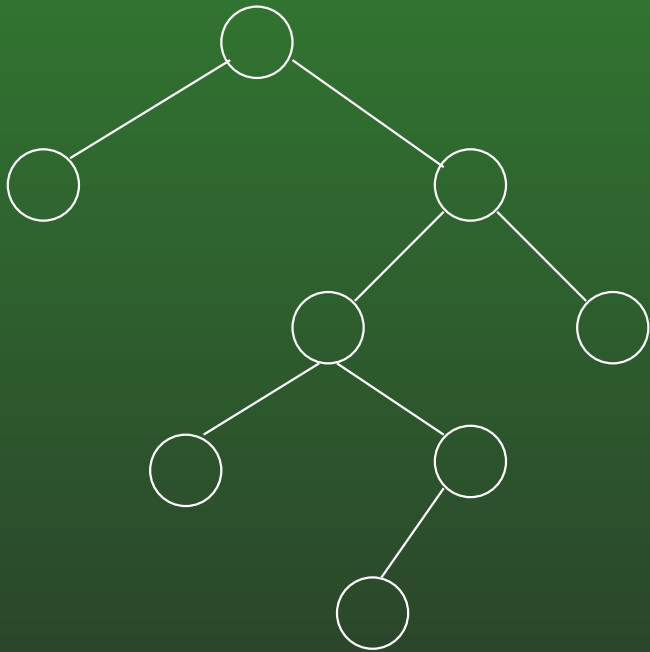
    void setLeftchild(Node leftchild) {
        leftchild_ = leftchild;
    }

    void setRightsib(Node leftchild) {
        rightsib_ = rightsib;
    }

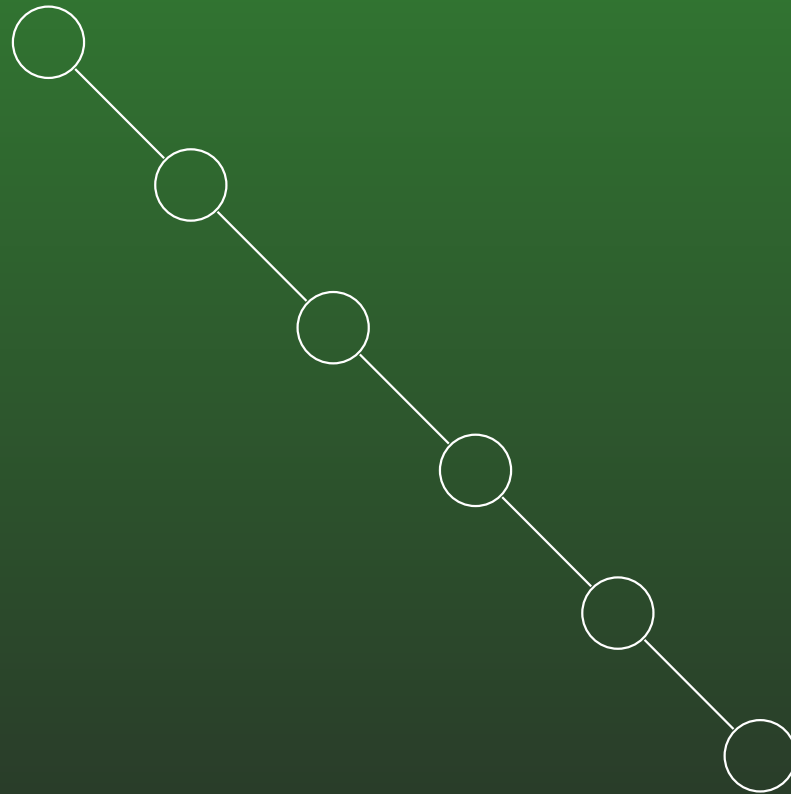
    void setElement(Object element) {
        element_ = element;
    }
}
```

## 09-5: General Trees – NumNodes

- Returns the number of nodes in a tree



Number of Nodes = 8



Number of Nodes = 6

## 09-6: General Trees – NumNodes

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```
int numnodes(Node tree) {  
    int descendants = 0;  
    Node tmp;  
  
    if (tree == null)  
        return 0;  
    for (tmp = tree.leftchild(); tmp != null;  
         tmp = tmp.rightsib())  
        descendants = descendants + numnodes(tmp);  
  
    return descendants + 1;  
}
```



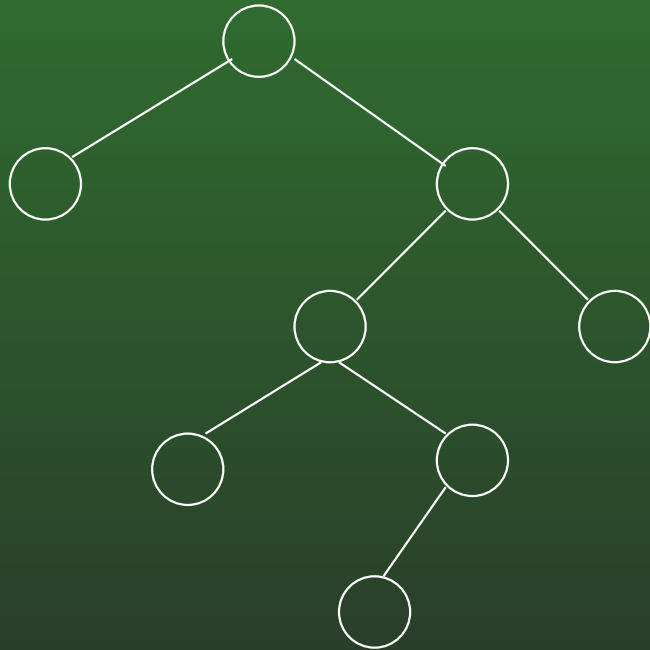
## 09-7: General Trees – NumNodes II

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```
int numnodes(Node tree) {  
    if (tree == null)  
        return 0;  
    return 1 + numnodes(tree.leftchild())  
        + numnodes(tree.rightsib());  
}
```

## 09-8: Tree Operations – Height

- Returns the height of the tree
  - (Length of the path to the deepest leaf) + 1



Height = 5

Height = 6

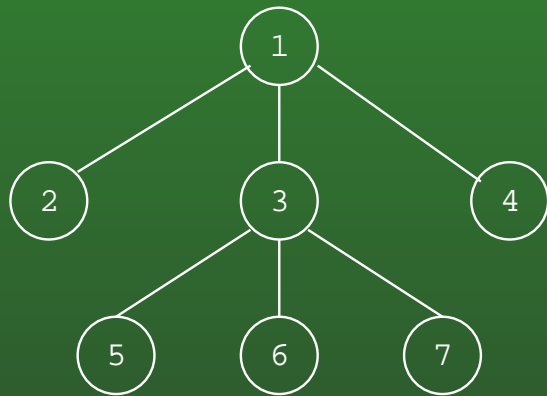
## 09-9: General Trees – Height

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```
int height(Node tree) {  
    if (tree == null)  
        return 0;  
    return MAX((1 + height(tree.leftchild())),  
               height(tree.rightsib()));  
}
```

# 09-10: General Trees

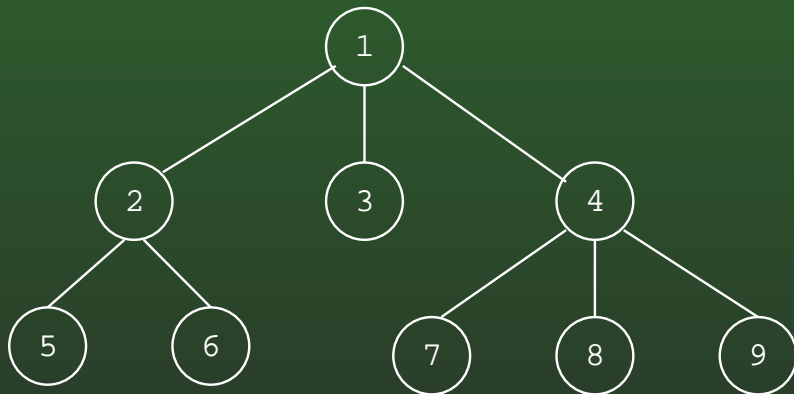
Tree 1



Tree 2



Tree 3



Write numLeaves and print

## 09-11: General Trees – numLeaves

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```
int numLeaves(Node tree) {  
  
    if (tree == null)  
        return 0;  
    if (tree.leftchild() == null)  
        return 1 + numLeaves(tree.rightsib());  
    return numLeaves(tree.leftchild()) +  
           numLeaves(tree.rightsib());  
}
```

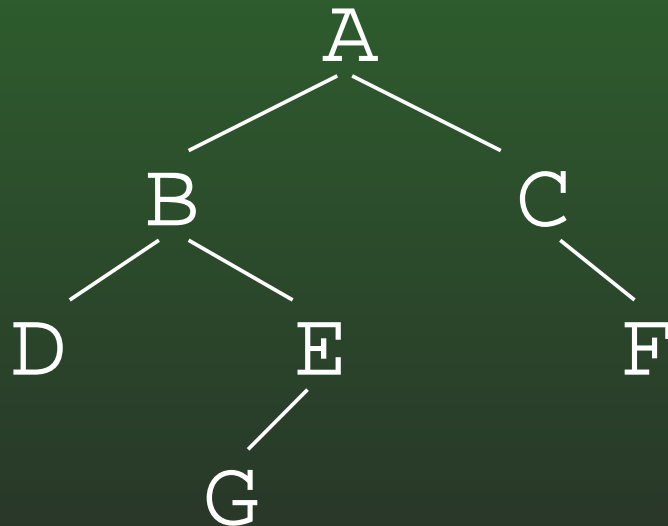
## 09-12: General Trees – numLeaves

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```
void print(Node tree, int offset) {  
  
    if (tree != null)  
    {  
        for (int i = 0; i < offset; i++)  
            System.out.print("\t");  
        System.out.println(tree.element());  
        print(tree.leftchild(), offset+1);  
        print(tree.rightsib(), offset);  
    }  
}
```

## 09-13: Serializing Binary Trees

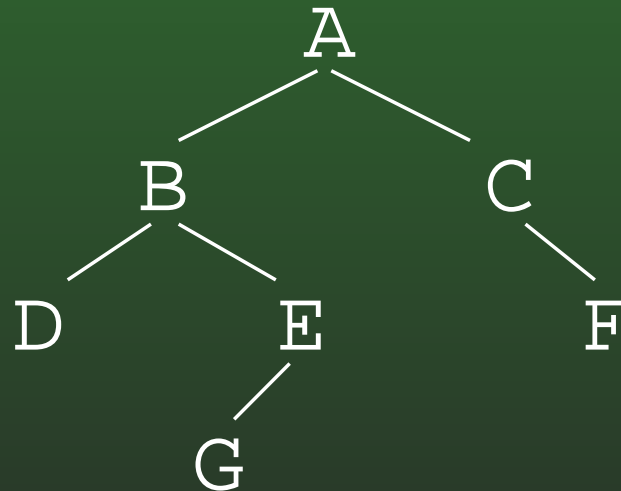
- Print a tree to a file, saving structure information
- First Try: Print out nodes, in order that they would appear in a PREORDER traversal.
  - Why doesn't this work?



*ABDEGCF*

## 09-14: Serializing Binary Trees

- Printing out nodes, in order that they would appear in a PREORDER traversal does not work, because we don't know when we've hit a null pointer
- Store null pointers, too!

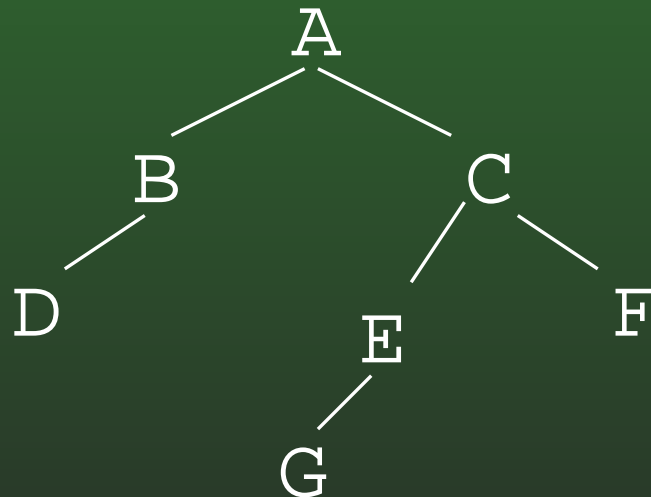


*ABD//EG///C/F//*



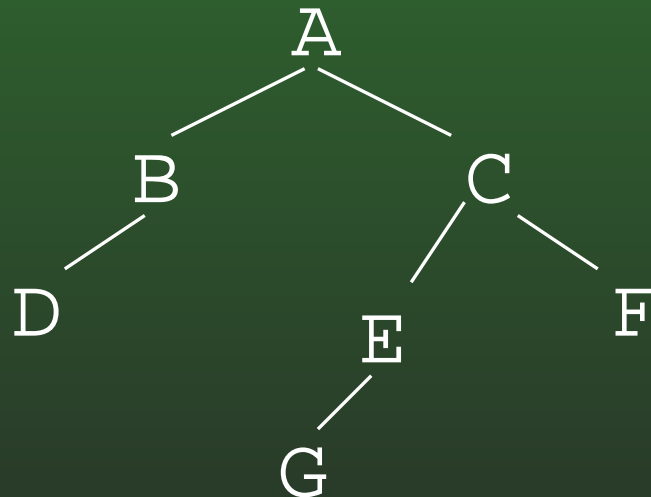
## 09-15: Serializing Binary Trees

- Printing out nodes, in order that they would appear in a PREORDER traversal does not work, because we don't know when we've hit a null pointer
- Store null pointers, too!



## 09-16: Serializing Binary Trees

- Printing out nodes, in order that they would appear in a PREORDER traversal does not work, because we don't know when we've hit a null pointer
- Store null pointers, too!



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## 09-17: Serializing Binary Trees

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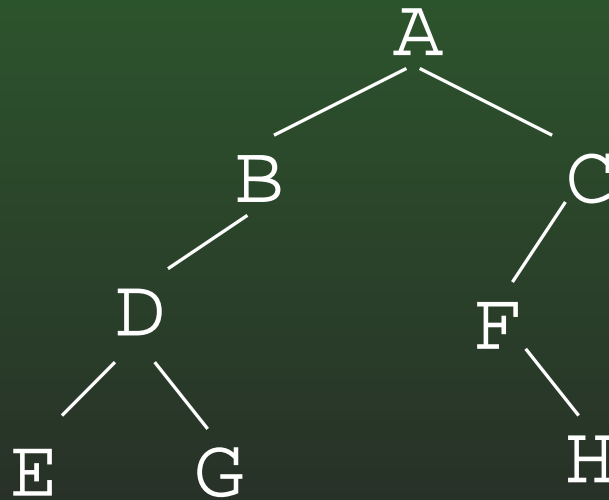
- Printing out nodes, in order that they would appear in a PREORDER traversal does not work, because we don't know when we've hit a null pointer
- Store null pointers, too!

*ABDE//G///CF/H///*

## 09-18: Serializing Binary Trees

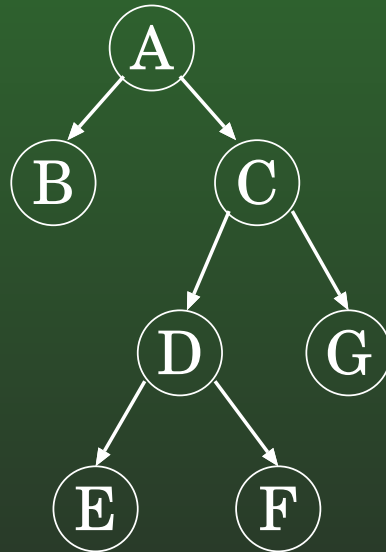
- Printing out nodes, in order that they would appear in a PREORDER traversal does not work, because we don't know when we've hit a null pointer
- Store null pointers, too!

*ABDE//G///CF/H///*



## 09-19: Serializing Binary Trees

- If we are serializing a full binary tree (each node contains exactly 0 or 2 children), we can store a single extra bit for each node 0 for an internal node, 1 for a leaf:

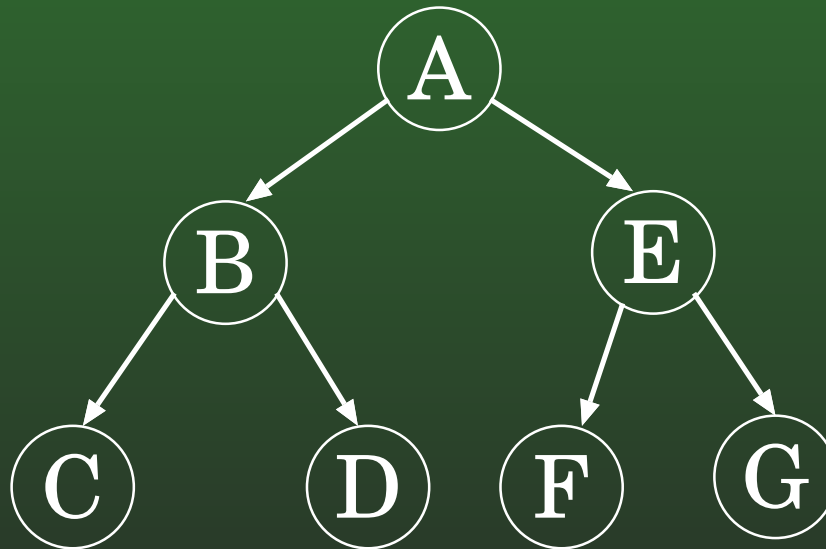


$A_0 B_1 C_0 D_0 E_1 F_1 G_1$

## 09-20: Serializing Binary Trees

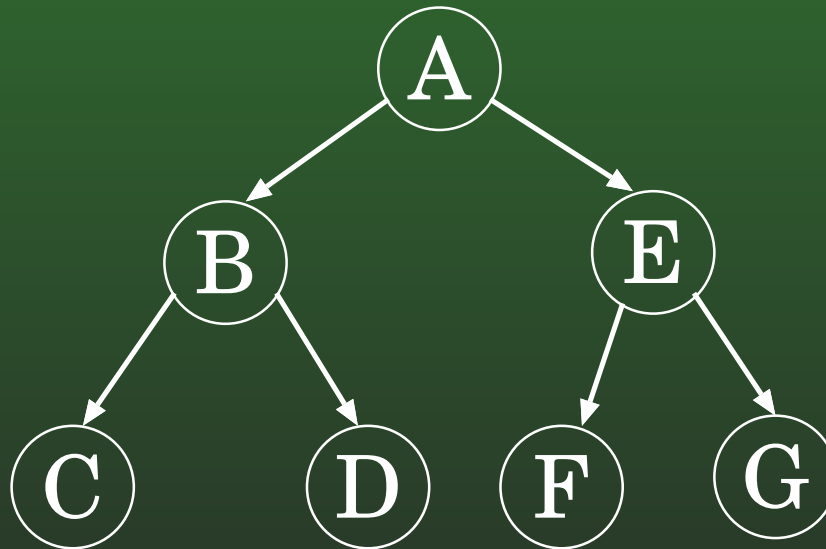
---

- If we are serializing a full binary tree (each node contains exactly 0 or 2 children), we can store a single extra bit for each node 0 for an internal node, 1 for a leaf:



## 09-21: Serializing Binary Trees

- If we are serializing a full binary tree (each node contains exactly 0 or 2 children), we can store a single extra bit for each node 0 for an internal node, 1 for a leaf:



$A_0 B_0 C_1 D_1 E_0 F_1 G_1$

## 09-22: Serializing Binary Trees

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- If we are serializing a full binary tree (each node contains exactly 0 or 2 children), we can store a single extra bit for each node 0 for an internal node, 1 for a leaf:

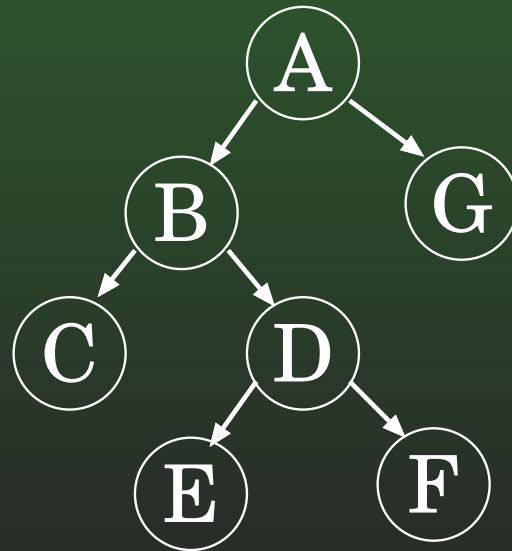
$$A_0 B_0 C_1 D_0 E_1 F_1 G_1$$



## 09-23: Serializing Binary Trees

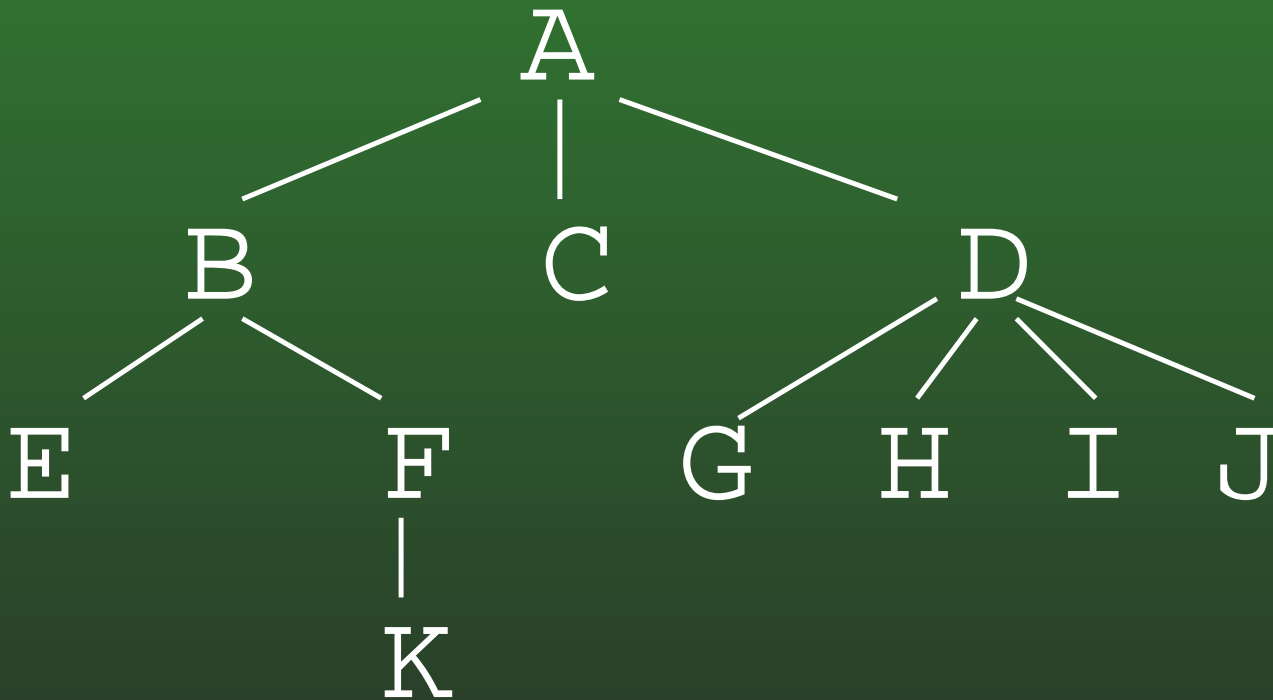
- If we are serializing a full binary tree (each node contains exactly 0 or 2 children), we can store a single extra bit for each node 0 for an internal node, 1 for a leaf:

$A_0 B_0 C_1 D_0 E_1 F_1 G_1$



## 09-24: Serializing General Trees

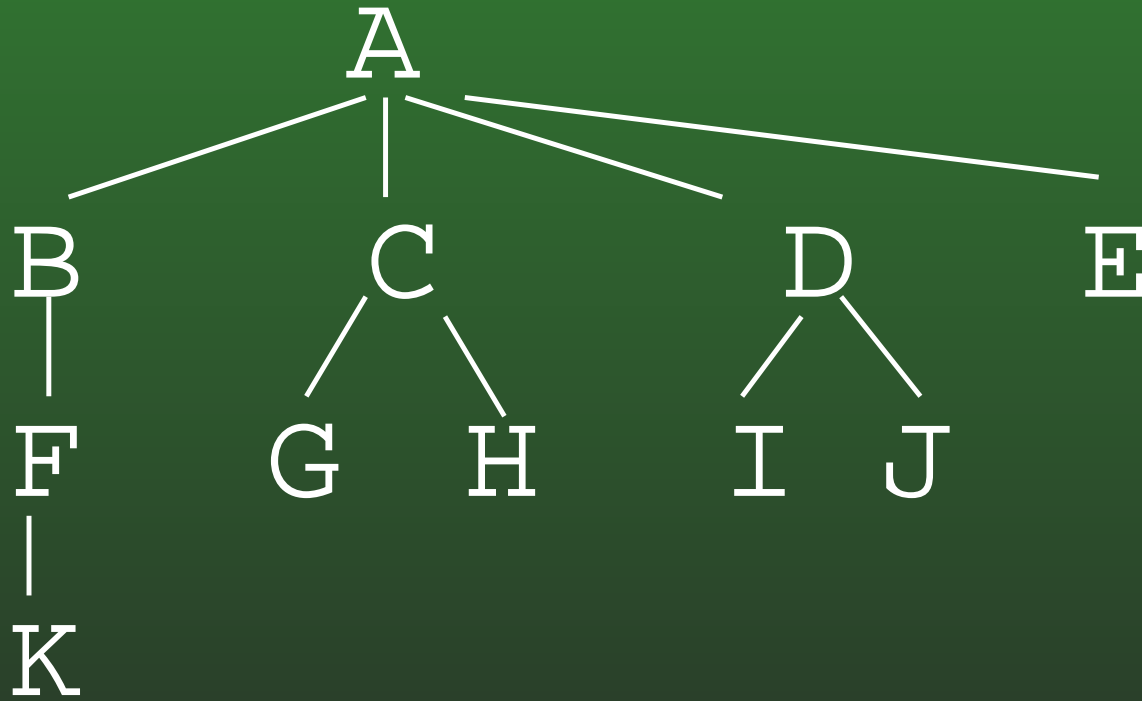
- Store an “end of children” marker



*ABE)FK))C)DG)H)I)J))*

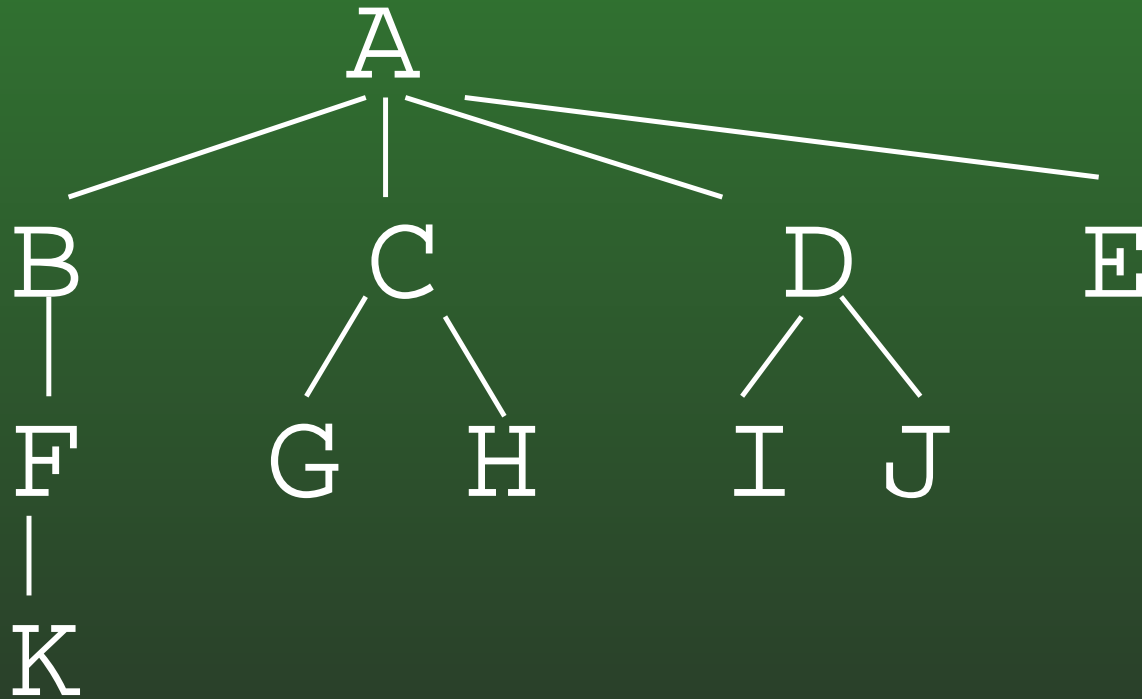
## 09-25: Serializing General Trees

- Store an “end of children” marker



## 09-26: Serializing General Trees

- Store an “end of children” marker



*ABFK)))CG)H))DI)J))E))*

## 09-27: Serializing General Trees

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- Store an “end of children” marker

*ABDK)))CE)F)GI)J))H)))*

## 09-28: Serializing General Trees

- Store an “end of children” marker

*ABDK)))CE)F)GI)J))H)))*

