Data Structures and Algorithms

CS245-2017S-09

General Trees

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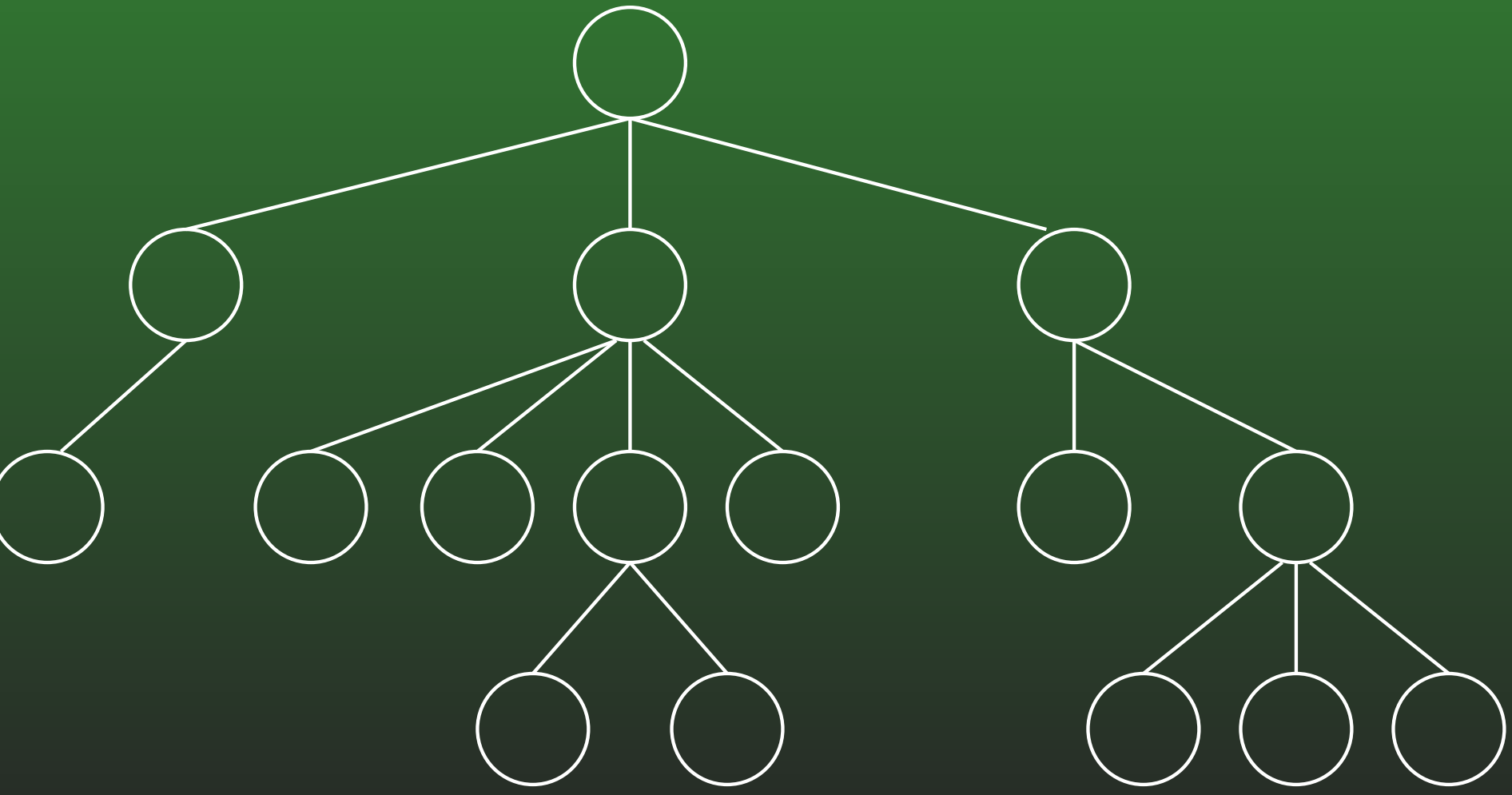
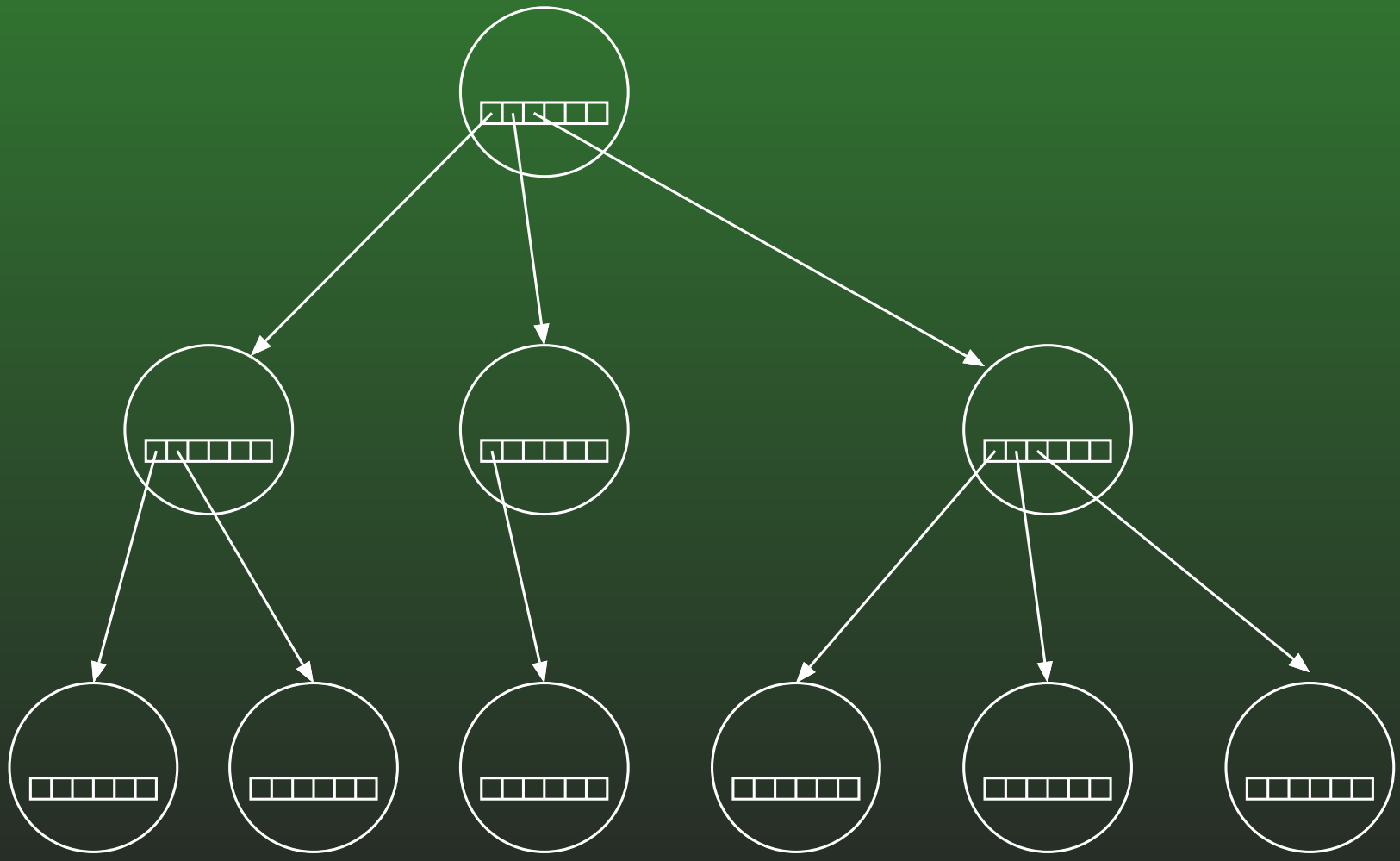
09-0: Trees with $>$ 2 children

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



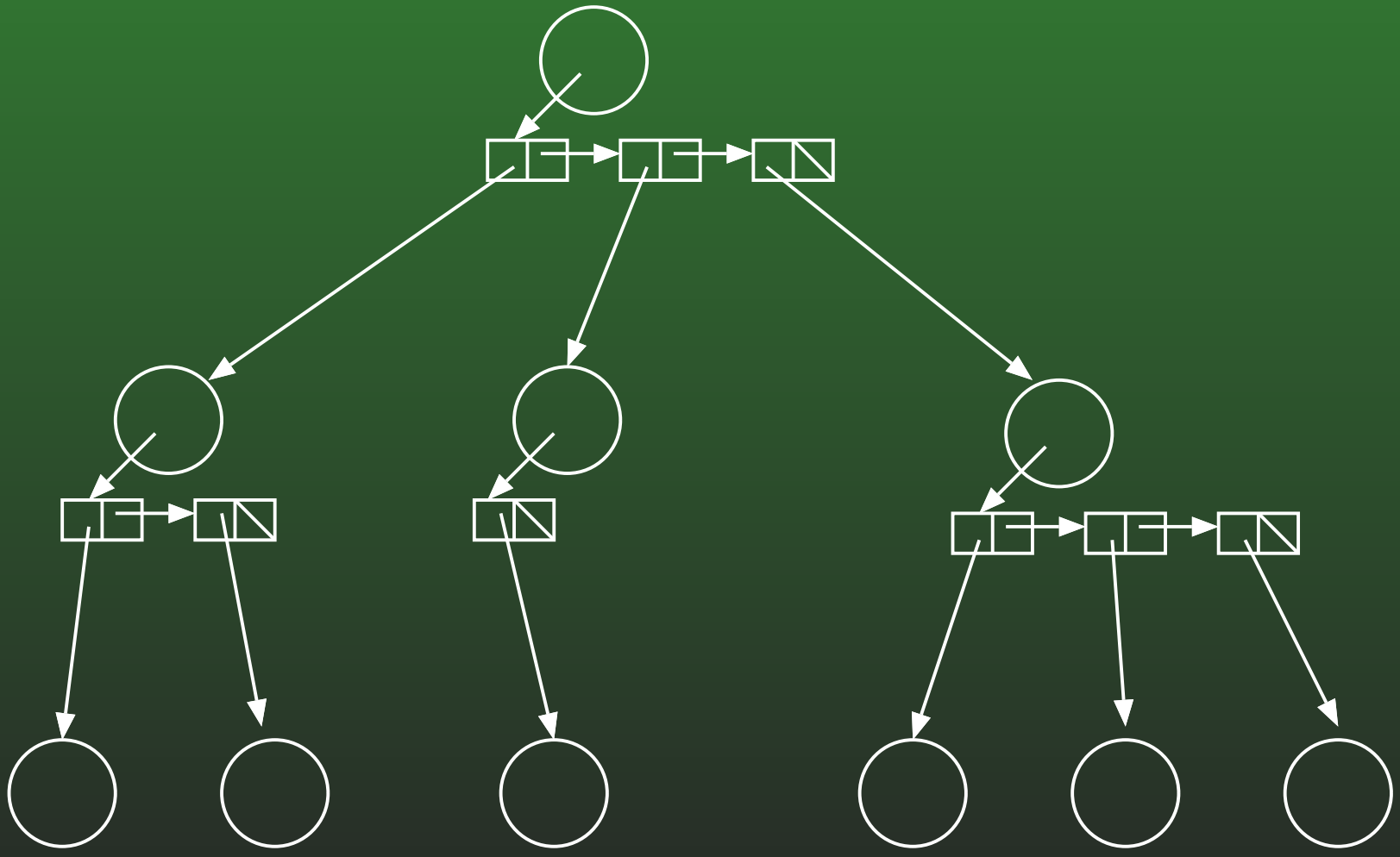
09-1: Trees with $>$ 2 children

- Array of Children



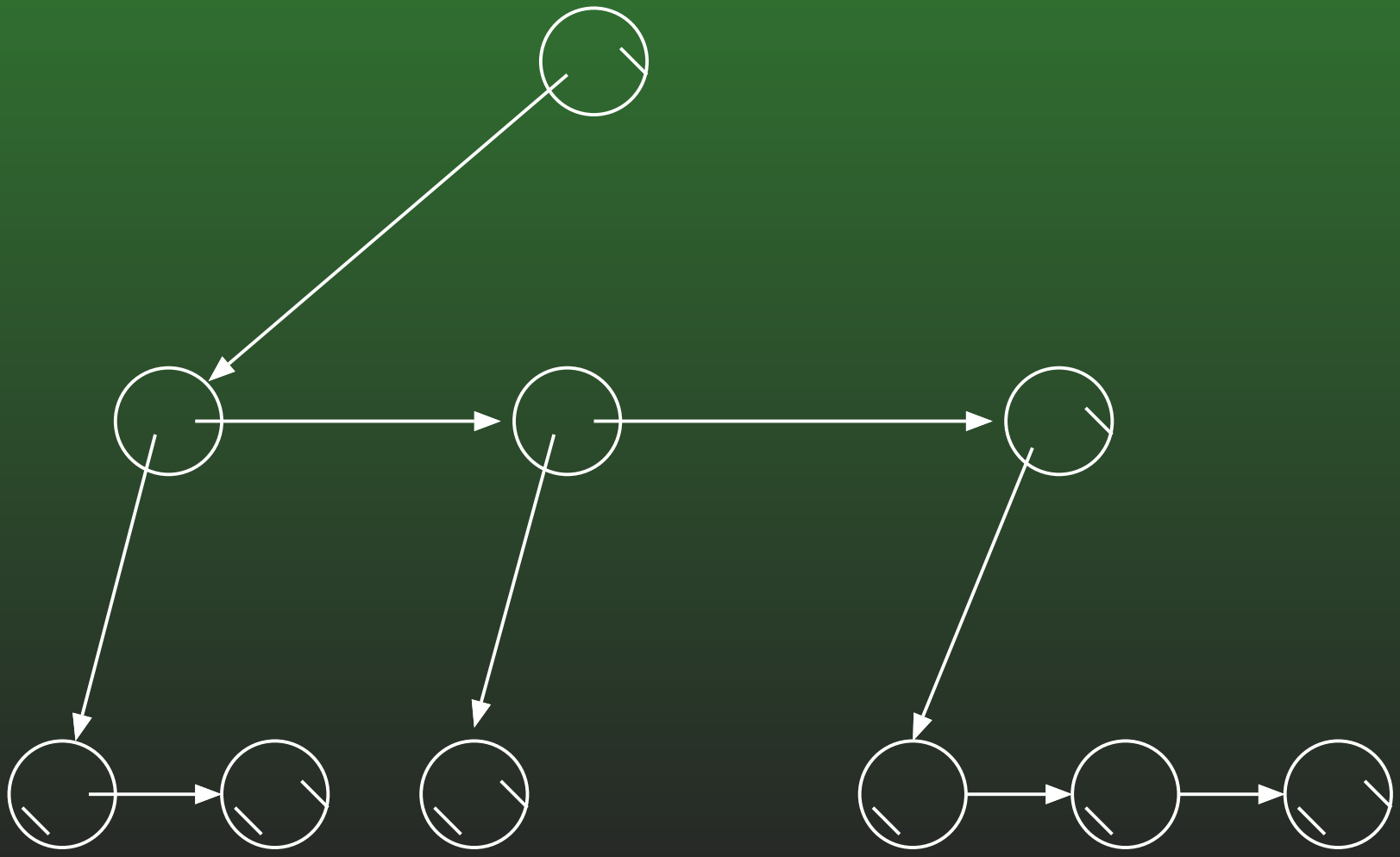
09-2: Trees with $>$ 2 children

- Linked List of Children



09-3: Left Child / Right Sibling

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



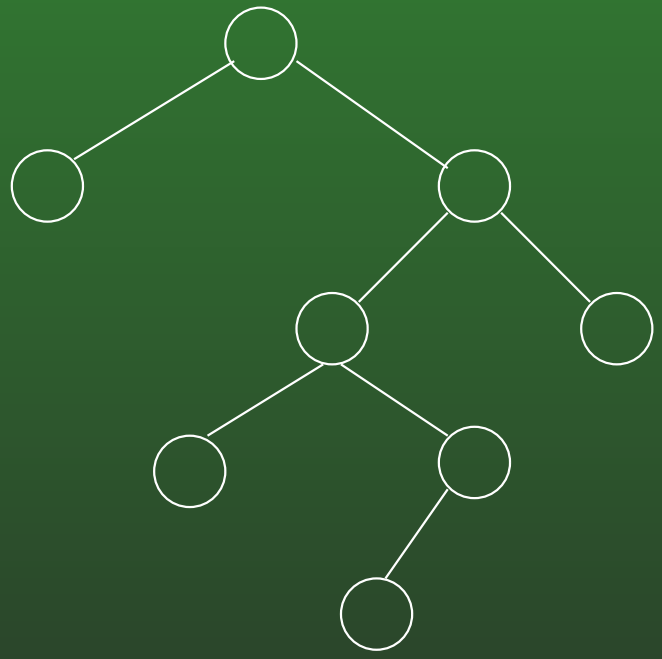
09-4: Working with General Tree

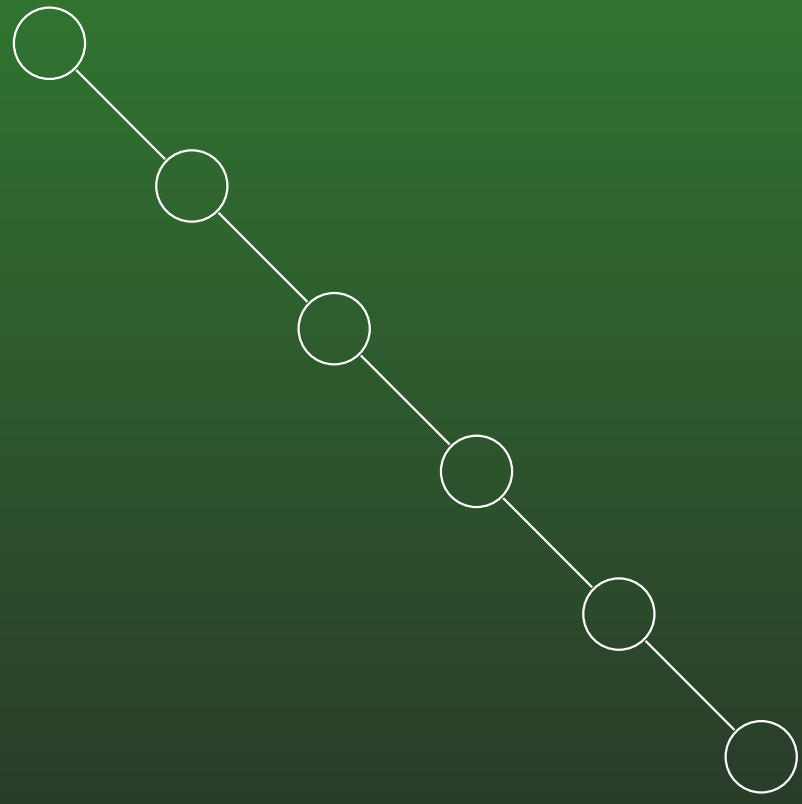
```
class Node  {
  private Node leftchild_;
  private Node rightsib_;
  private Object element_;

  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

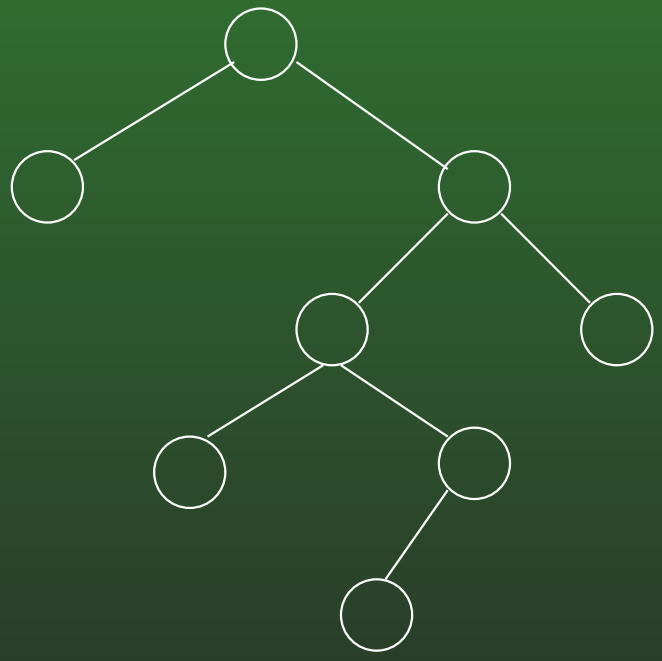
```
int numnodes(Node tree) {
  int descendants = 0;
  Node tmp;

  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

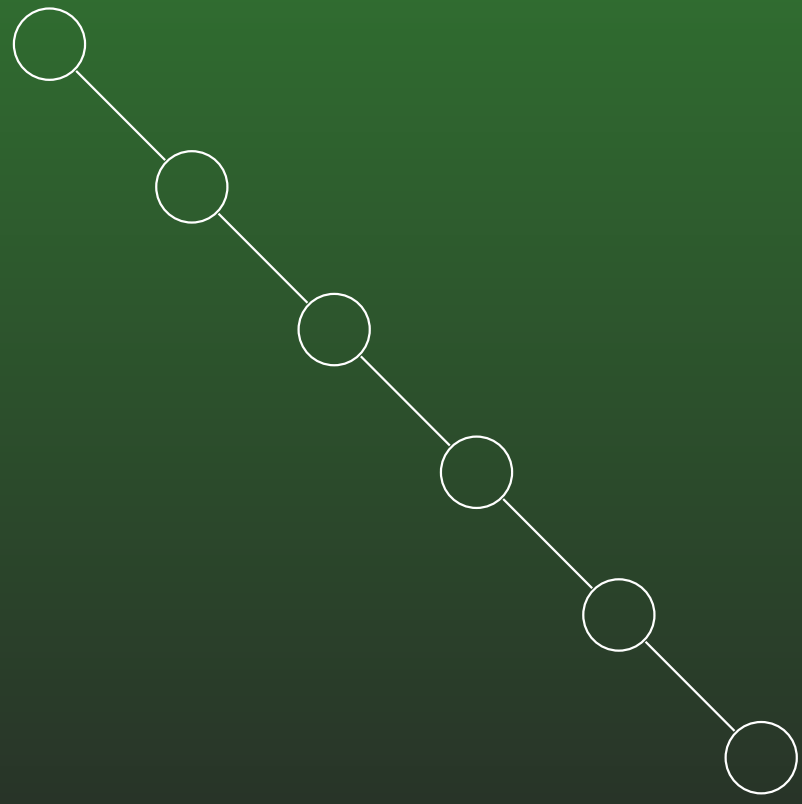
```
int numnodes(Node tree) {
  if (tree == null)
    return 0;
  return 1 + numnodes(tree.leftchild())
           + numnodes(tree.rightsib());
}
```

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

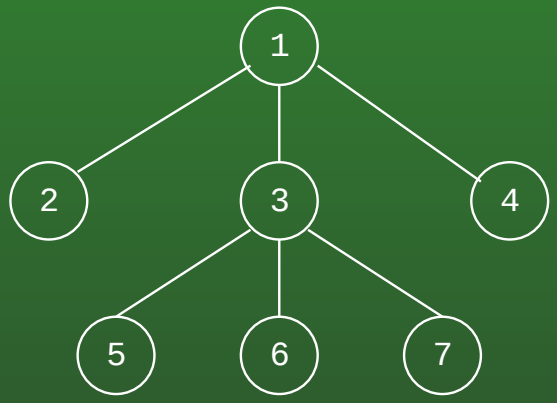
```
int height(Node tree) {
 if (tree == null)
  return 0;
 int childHeight = 0;
 for (Node tmp = tree.leftchild(); tmp != null;
                                   tmp=tmp.rightsib())
 {
  childHeight = MAX(childHeight, height(tmp));
 }
 return childHeight + 1;
}
```

09-10: General Trees – Height

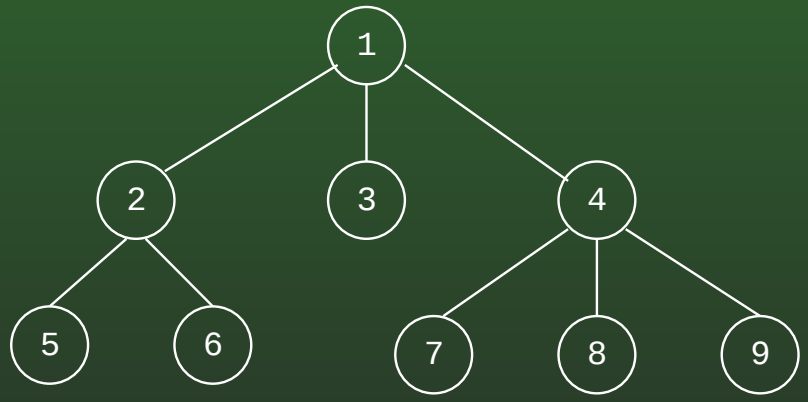
```
int height(Node tree) {
  if (tree == null)
    return 0;
  return MAX((1 + height(tree.leftchild())),
             height(tree.rightsib()));
}
```

09-11: General Trees

Tree 1



Tree 2



Tree 3

Write `numLeaves` and `print`

09-12: General Trees – numLeaves

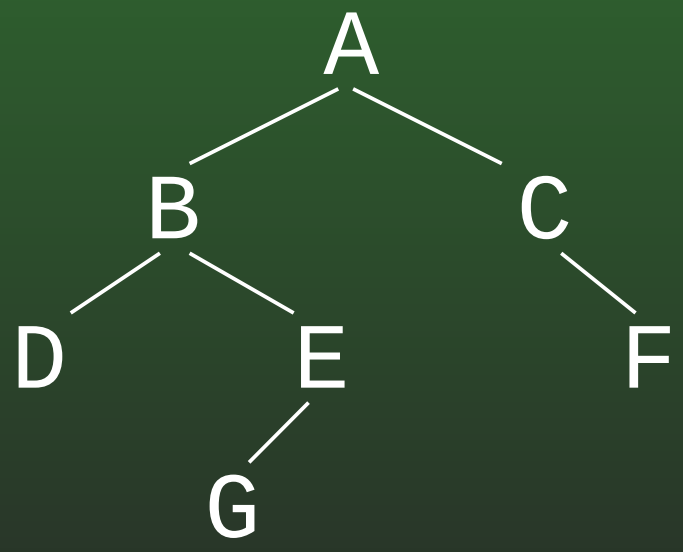
```
int numLeaves(Node tree) {

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

09-13: General Trees – numLeaves

```
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);
  }
}
```

09-14: Serializing Binary Trees

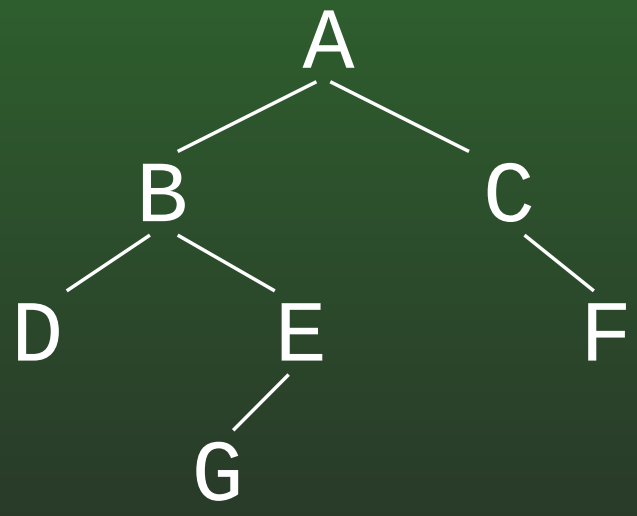
- Print a tree to a file, saving structure information
- First Try: Print out nodes, in order that they would appear in a PREORDER traversal.
  - Why doesn't this work?



$$ABDEGCF$$

09-15: Serializing Binary Trees

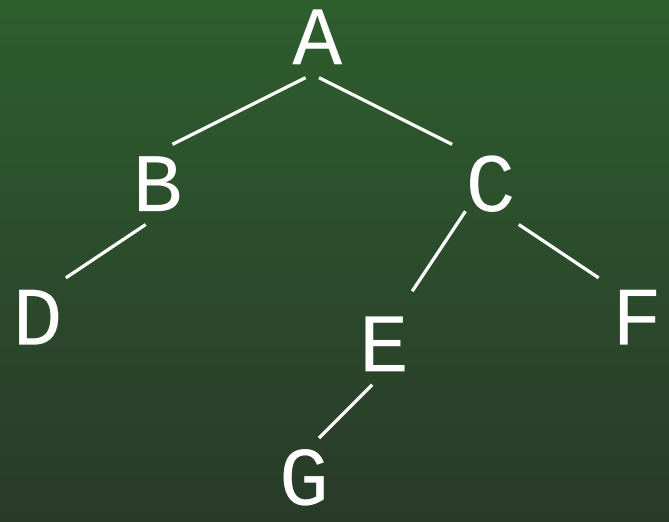
- Printing out nodes, in order that they would appear in a PREORDER traversal does not work, because we don't know when we've hit a null pointer
- Store null pointers, too!



$$ABD//EG///C/F//$$

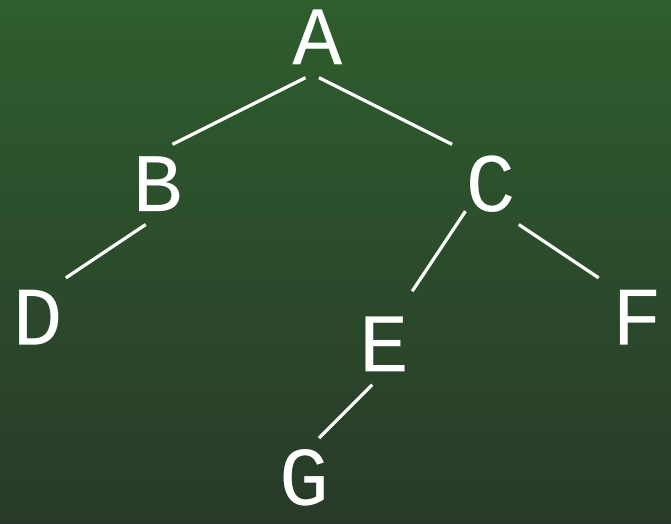
09-16: Serializing Binary Trees

- 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!



09-17: 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!



$$ABD|||CEG|||F||$$

09-18: Serializing Binary Trees

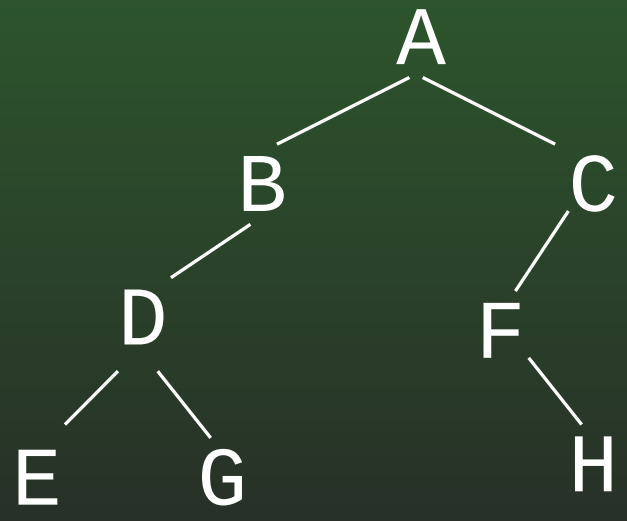
- Printing out nodes, in order that they would appear in a PREORDER traversal does not work, because we don't know when we've hit a null pointer
- Store null pointers, too!

$$ABDE//G///CF/H///$$

09-19: Serializing Binary Trees

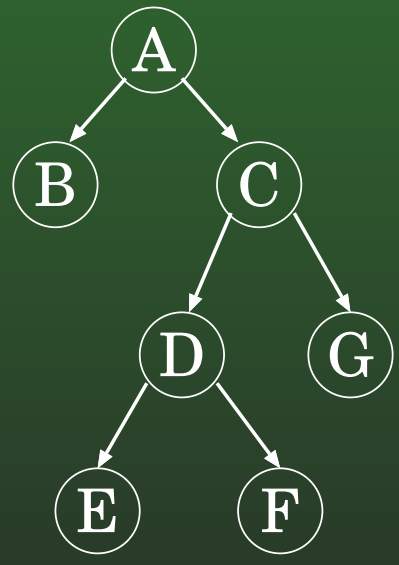
- Printing out nodes, in order that they would appear in a PREORDER traversal does not work, because we don't know when we've hit a null pointer
- Store null pointers, too!

$$ABDE//G///CF/H///$$



09-20: Serializing Binary Trees

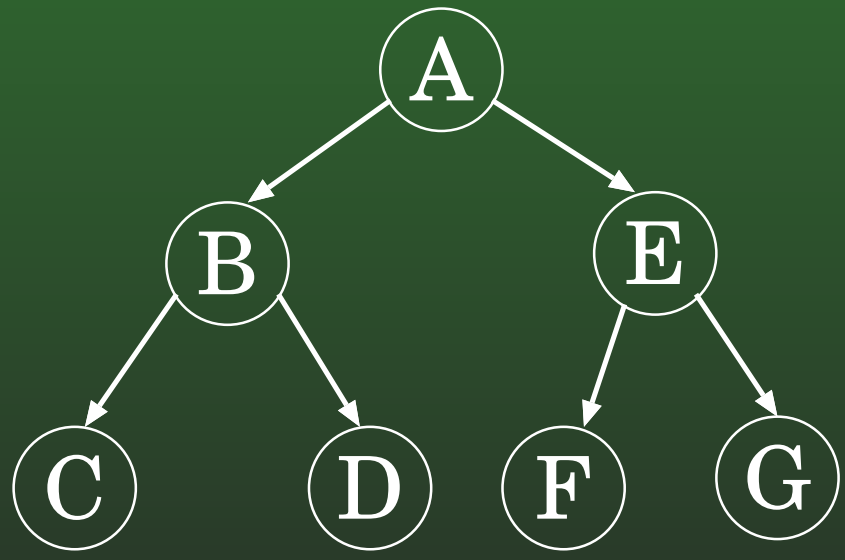
- If we are searializing a full binary tree (each node contains exactly 0 or 2 children), we can store a single extra bit for each node 0 for an internal node, 1 for a leaf:



$$A_0 B_1 C_0 D_0 E_1 F_1 G_1$$

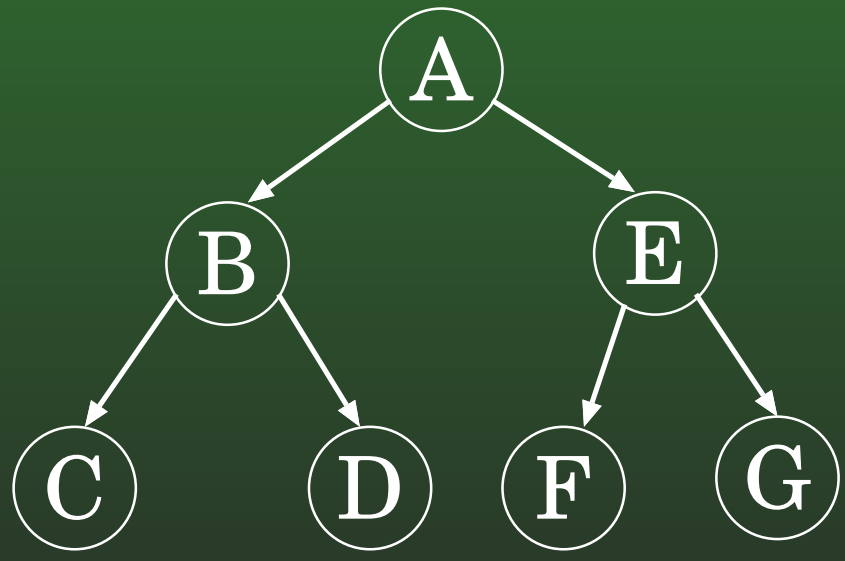
09-21: Serializing Binary Trees

- If we are searializing 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:



09-22: Serializing Binary Trees

- If we are searializing 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:



$$A_0 B_0 C_1 D_1 E_0 F_1 G_1$$

09-23: Serializing Binary Trees

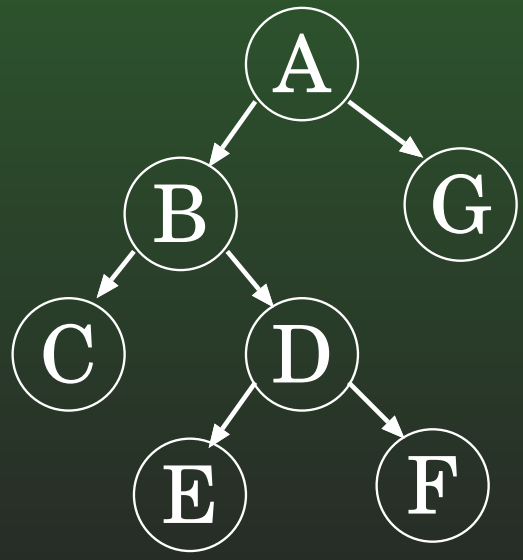
- If we are searializing a full binary tree (each node contains exactly 0 or 2 children), we can store a single extra bit for each node 0 for an internal node, 1 for a leaf:

$$A_0 B_0 C_1 D_0 E_1 F_1 G_1$$

09-24: Serializing Binary Trees

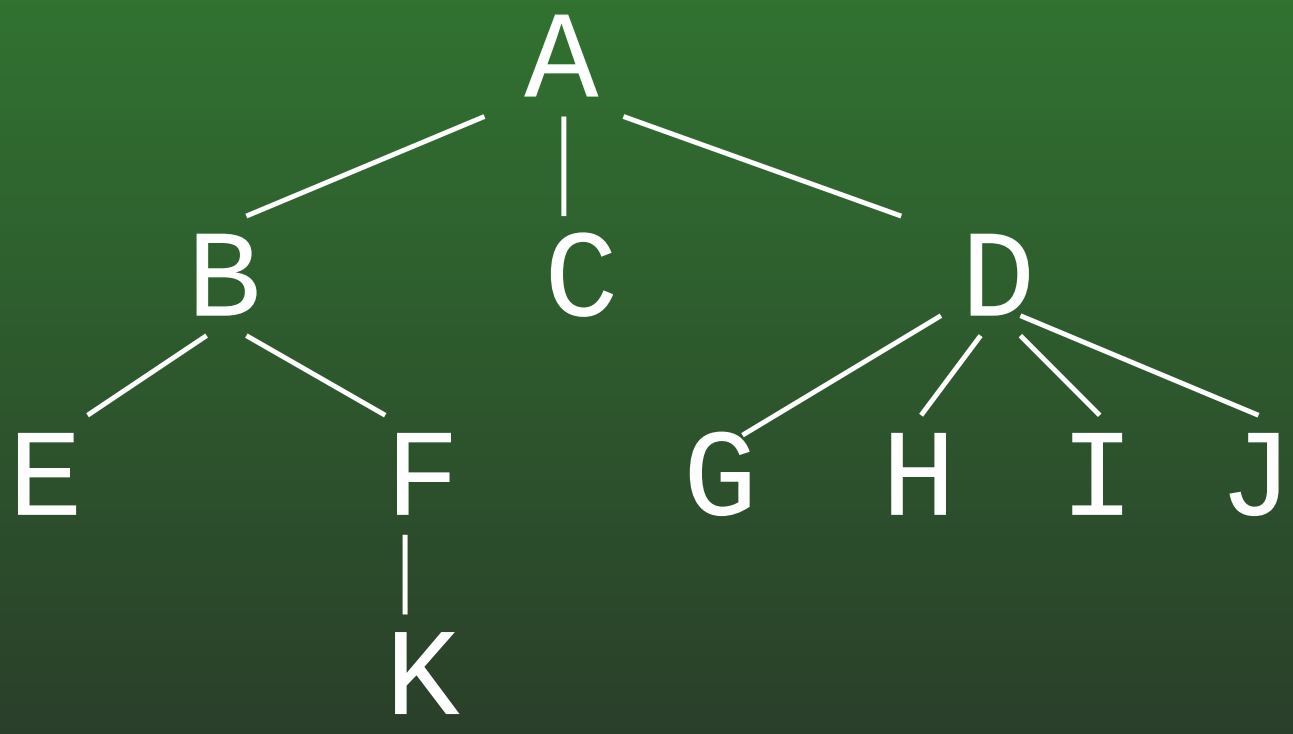
- If we are searializing a full binary tree (each node contains exactly 0 or 2 children), we can store a single extra bit for each node 0 for an internal node, 1 for a leaf:

$$A_0 B_0 C_1 D_0 E_1 F_1 G_1$$



09-25: Serializing General Trees

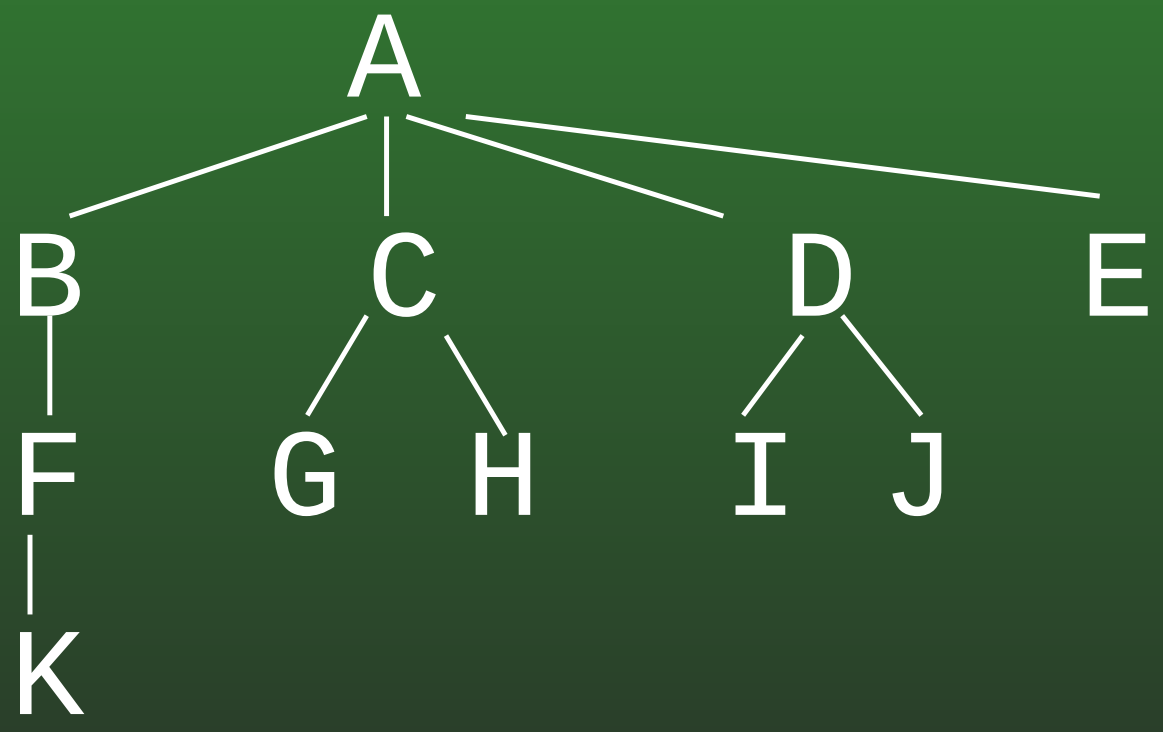
- Store an “end of children” marker



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

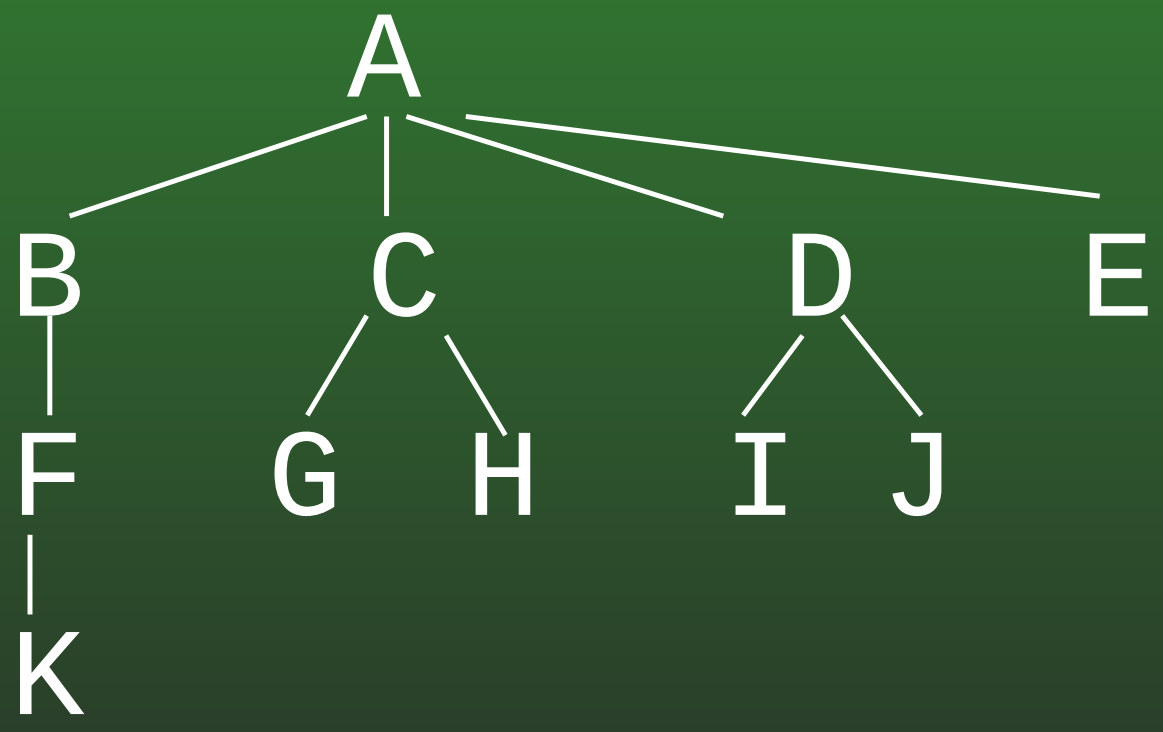
09-26: Serializing General Trees

- Store an “end of children” marker



09-27: Serializing General Trees

- Store an “end of children” marker



$$ABFK)))CG)H))DI)J))E))$$

09-28: Serializing General Trees

- Store an “end of children” marker

$$ABDK)))CE)F)GI)J))H)))$$

09-29: Serializing General Trees

- Store an “end of children” marker

$$ABDK)))CE)F)GI)J))H)))$$