# 04 B: Lists, Stacks, and Queues IV; Trees I

CS1102S: Data Structures and Algorithms

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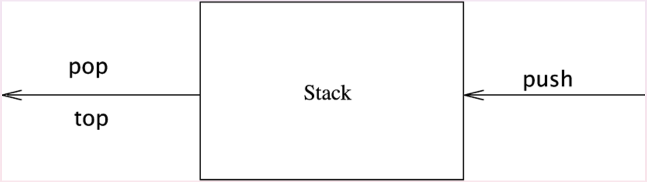
1. Review: The Stack ADT
   - Stack Model
   - Implementation of Stacks
2. The Queue ADT
3. Trees
4. Puzzlers

# Motivation

## Purpose of stacks

Collections that serve as intermediate storage of data items



# Stack Model

## Stack access

Only the top element of a stack is accessible through top and pop operations

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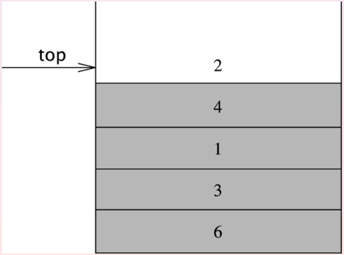


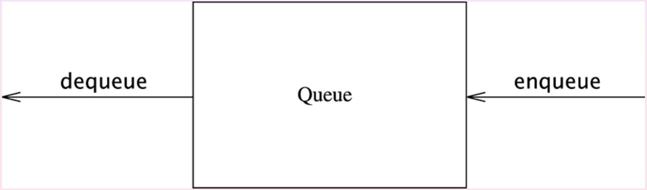
# Implementation of Stacks

- Possible based on either ArrayList or LinkedList
- Often Lists are used directly, for example by using a List and always using the index 0

# Motivation

## Purpose of queues

Collections that serve as intermediate storage of data items



# Queue Model

## Stack discipline

First in—first out: FIFO

# Implementation of Queues using LinkedList

```
class LinkedListQueue<E> extends LinkedList<E> {
   public boolean empty() {
      return size() == 0; }
   public void enqueue(E item) {
      add(item,0); return item; }
   public E dequeue() {
      if (empty())
         throw new EmptyQueueException();
      else return remove(size()-1); } }
```

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**Why does dequeue() run in $O(1)$?**

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**Why does dequeue() run in $O(1)$?**

See
API Specification.

# Implementation of Queues using Arrays

## General idea

Keep items in array similar to ArrayList

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## Access

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## Optimization

Wrap back and front around when end of array is reached

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Serve as basis for other efficient data structures, such as heaps

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## Trees in Java API

Covered by API classes TreeSet and TreeMap

# Definitions

## Tree

A *tree* is a collection of *nodes*. Non-empty trees have a distinguished node $r$, called *root*, and zero or more nonempty (sub)trees $T_1, T_2, \ldots, T_k$, each of whose roots are connected by a directed *edge* from $r$.

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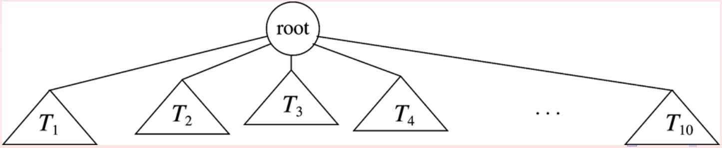
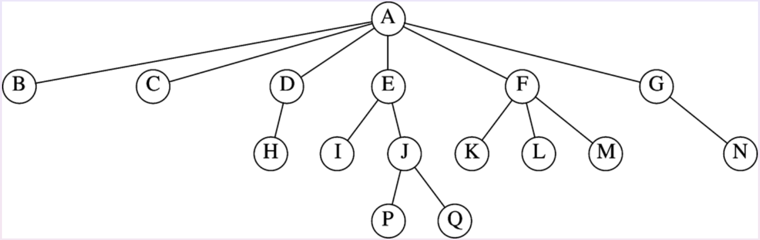
## Parent and child

The root of each subtree is called a *child* of $r$, and $r$ is the *parent* of each subtree root.



# Example and More Definitions



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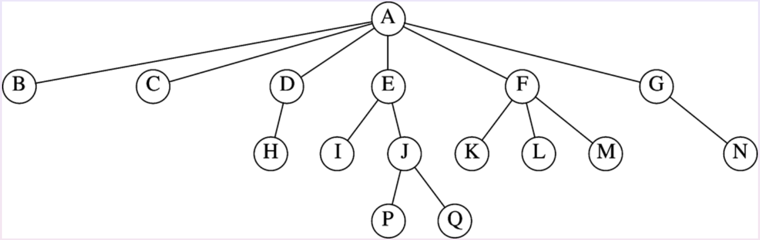
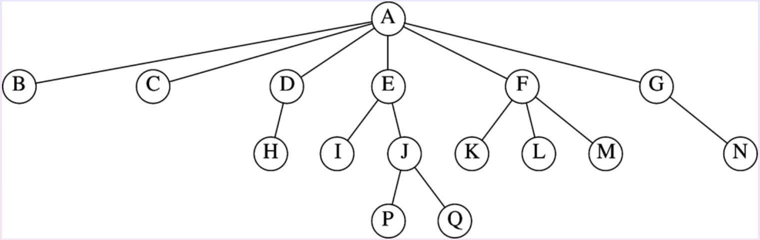



## Leaf

Nodes with no children are called *leaves*.

# Example and More Definitions



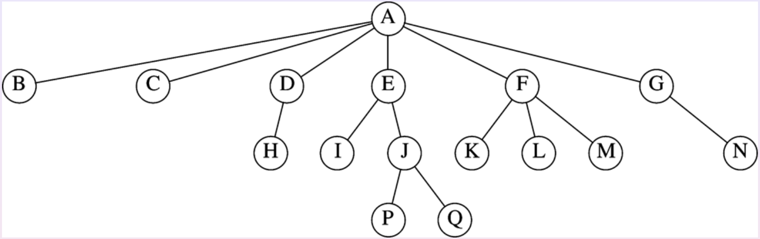

## Leaf

Nodes with no children are called *leaves*.

## Sibling

Nodes the same parents are called *siblings*.

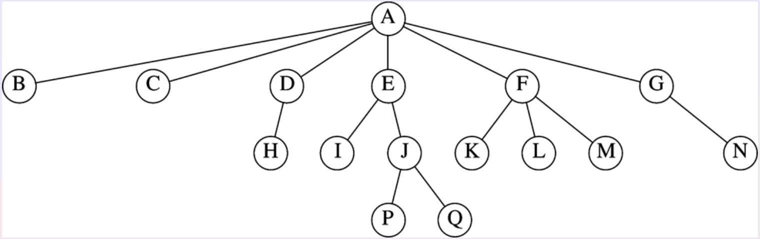
# Example and More Definitions




## Path

A *path* from node $n_1$ to $n_k$ id defined as a sequence of nodes $n_1, n_2, \ldots, n_k$ such that $n_i$ is the parent of $n_{i+1}$ for $1 \leq i < k$.

# Example and More Definitions

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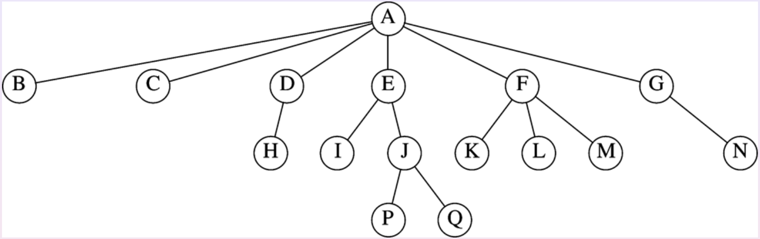
## Length of Path

The *length* of a path is the number of edges on the path, namely $k - 1$.

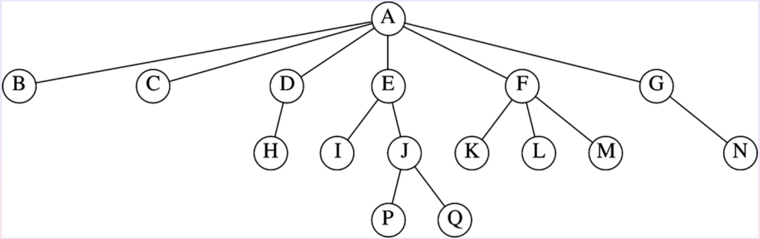
# Example and More Definitions




## Paths of length 0

There is a path of length 0 from every node to itself.

# Example and More Definitions



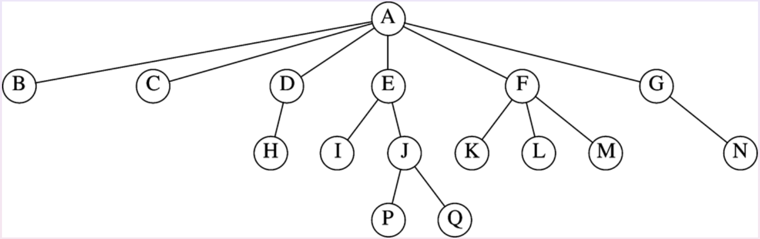

## Paths of length 0

There is a path of length 0 from every node to itself.

## Number of paths

There is exactly one path from the root to each node.

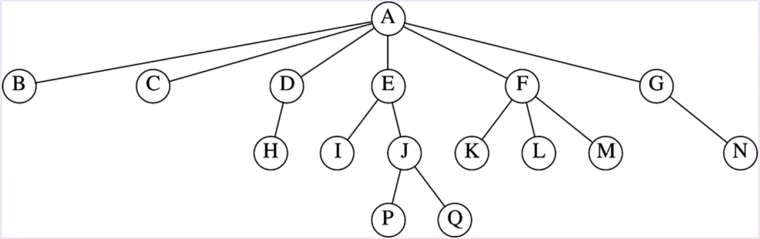
# Example and More Definitions




## Depth

The *depth* of node $n_i$ is the length of the unique path from the root to $n_i$.

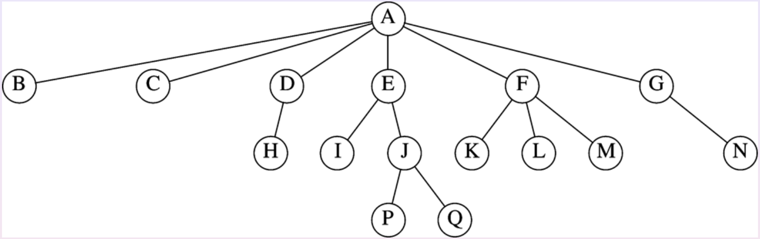
# Example and More Definitions




## Height

The *height* of $n_i$ is the length of the longest path from $n_i$ to a leaf.

# Example and More Definitions



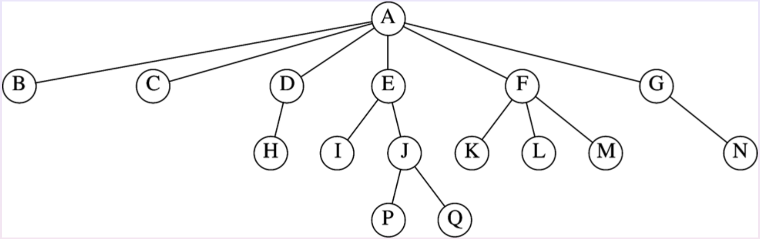

### Height

The *height* of $n_i$ is the length of the longest path from $n_i$ to a leaf.

### Height of a tree

The height of a tree is equal to the height of the root.

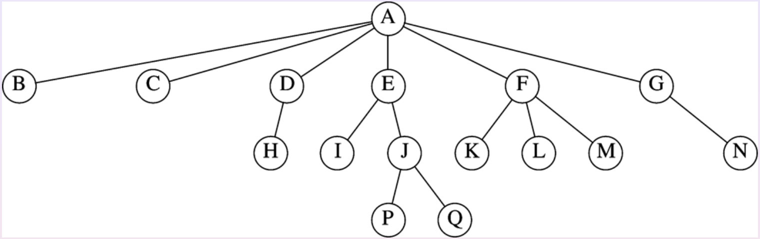
# Example and More Definitions




## Ancestor and descendant

If there is a path from $n_1$ to $n_2$, then $n_1$ is an *ancestor* of $n_2$, and $n_2$ is a *descendant* of $n_1$.

# Example and More Definitions

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If there is a path from $n_1$ to $n_2$, then $n_1$ is an *ancestor* of $n_2$, and $n_2$ is a *descendant* of $n_1$.

## Proper Ancestor and proper descendant

If $n_1 \neq n_2$, and $n_1$ is an ancestor of $n_2$, then $n_1$ is a *proper ancestor* of $n_2$ and $n_2$ is a *proper descendant* of $n_1$.

# Implementation

## First idea

In each node, keep its data, and a reference to each child

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We don't know how many children a node may have (can also change, later)

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## Problem

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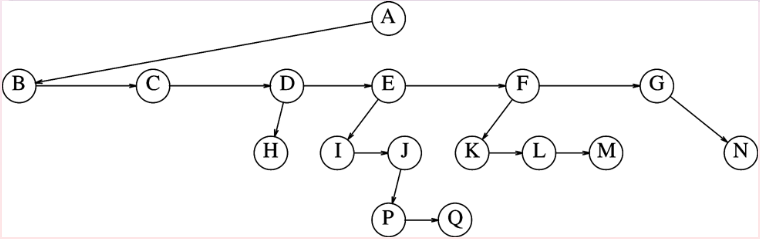
## Solution

Keep children of each node in a linked list of tree nodes

# Implementation

## Node data type

```
class TreeNode<Any> {
    Any element;
    TreeNode<Any> firstChild;
    TreeNode<Any> nextSibling;
}
```



# Tree Traversal

## Common use of trees

File and folder structure in Windows and Unix: folder are nodes, ordinary files are leaf nodes

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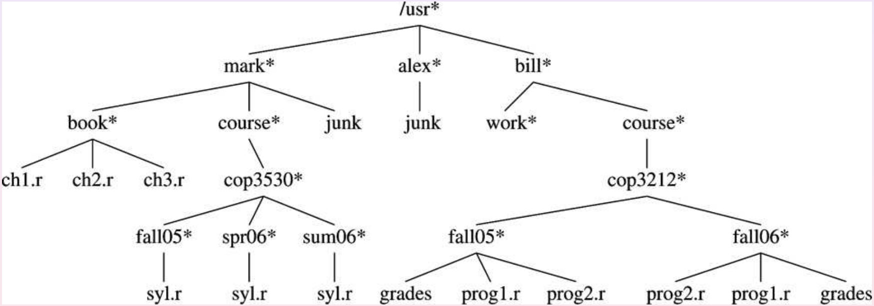
File and folder structure in Windows and Unix: folder are nodes, ordinary files are leaf nodes

## Common tasks involving files and folders

- List all files in a folder (and its subfolders)
- Compute the size of a folder (including all subfolders)

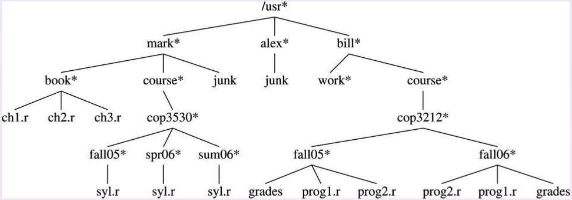
# Example


/usr*
mark*
alex*
bill*
book*
course*
junk
junk
work*
course*
ch1.r
ch2.r
ch3.r
cop3530*
cop3212*
fall05*
spr06*
sum06*
fall05*
fall06*
syl.r
syl.r
syl.r
grades
prog1.r
prog2.r
prog2.r
prog1.r
grades

# Algorithm for File Listing

```
private void listAll( int depth ) {
  printName( depth ); // print name of object
    if( isDirectory( ) )
      for each file c in this directory
        c.listAll( depth + 1 );
}
public void listAll( ) {
  listAll( 0 );
}
```

# Example




```
/usr
    mark
        book
            ch1.r
            ch2.r
            ch3.r
        course
            cop3530
...
```

# Reflection

**What is going on?**

Work (print file name) is done at each node *before* the children of the node are visited

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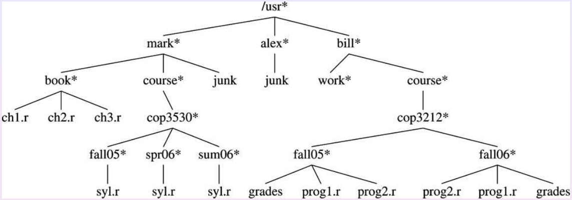
## Tree traversal

If the work at each node is done *before* the children are visited, we talk about *preorder traversal*

# Algorithm for File Size Calculation

```
public int size( ) {
  int totalSize = sizeOfThisFile( );
  if( isDirectory( ) )
    for each file c in this directory
      totalSize += c.size( );
  print(totalSize); // print size of object
  return totalSize;
}
```

# Example




```
        ch1.r          3
        ch2.r          2
        ch3.r          4
      book            10
      ...
    mark              30
    ...
/usr                  72
```

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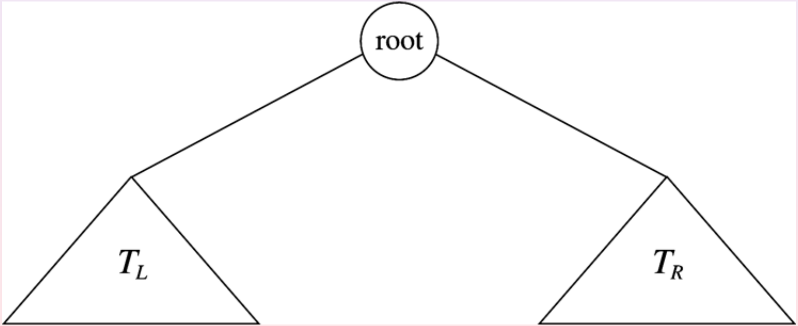
# Binary Trees

**Definition**

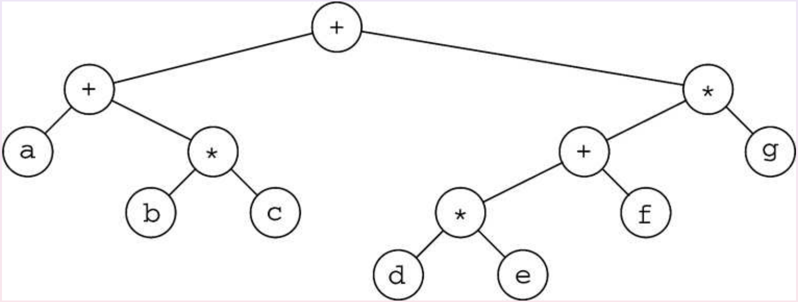
A binary tree is a tree in which no node can have more than two children.



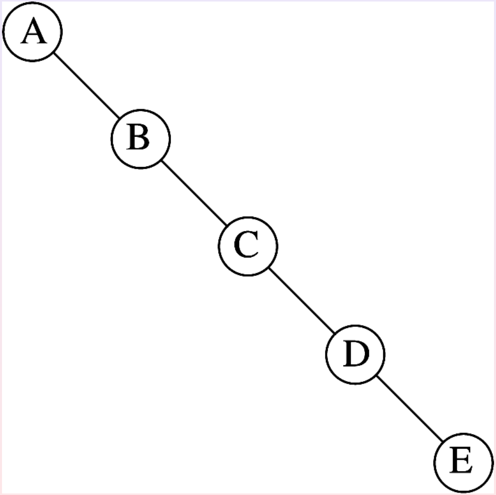
# Implementation

```
class BinaryNode {
  // accessible by other package routines
  Object      element;       // The data in the node
  BinaryNode  left;          // Left child
  BinaryNode  right;         // Right child
}
```

# Example: Expression Trees



# Example: Degenerate Binary Tree



1. Review: The Stack ADT
2. The Queue ADT
3. Trees
4. Puzzlers
   - Solution Puzzler “Animal Farm”
   - New Puzzler: “Generic Drugs”

# Puzzler: Animal Farm

```
public class AnimalFarm {
  public static void main(String[] args) {
    final String pig = "length: 10";
    final String dog = "length: " + pig.length();
    System.out.println("Animals are equal: "
                       + pig == dog);
  }
}
```

# Solution

Operator + has higher precedence than ==.
Thus

```
System.out.println("Animals are equal: "
                   + pig == dog);
```

means

```
System.out.println(
    ("Animals are equal: " + pig) == dog
);
```

# A Quick Fix

```
System.out.println("Animals are equal: "
                   + (pig == dog));
```

What will be printed?

# What does == mean?

## Primitive Data Types

For primitive data types, == implements literal equality. It tests whether the values are identical (to the bit).

# New Puzzler: Generic Drugs

```
public class LinkedList<E> {
  private Node<E> head = null;
  private class Node<E> {
    E value;
      Node<E> next;
      // constructor links the node as new head
      Node(E value) {
        this.value = value;
        this.next = head;
        head = this;
      }
  }
```

# New Puzzler: Generic Drugs

```
  public void add(E e) {
    new Node<E>(e); // Link node as new head
  }
  public void dump() {
    for (Node<E> n = head; n != null; n = n.next)
      System.out.print(n.value + " ");
  }
  public static void main(String[] args) {
    LinkedList<String> list
    = new LinkedList<String>();
    list.add("world");
    list.add("Hello");
    list.dump();
} }
```

# Next Week

- Monday:
  - Lab: Lab tasks on lists, queues, stacks
  - Assignment 3 due
- Wednesday: Lecture on Binary Trees
- Thursday: Tutorial on Assignment 3
- Friday: Midterm 1 on first 100 pages