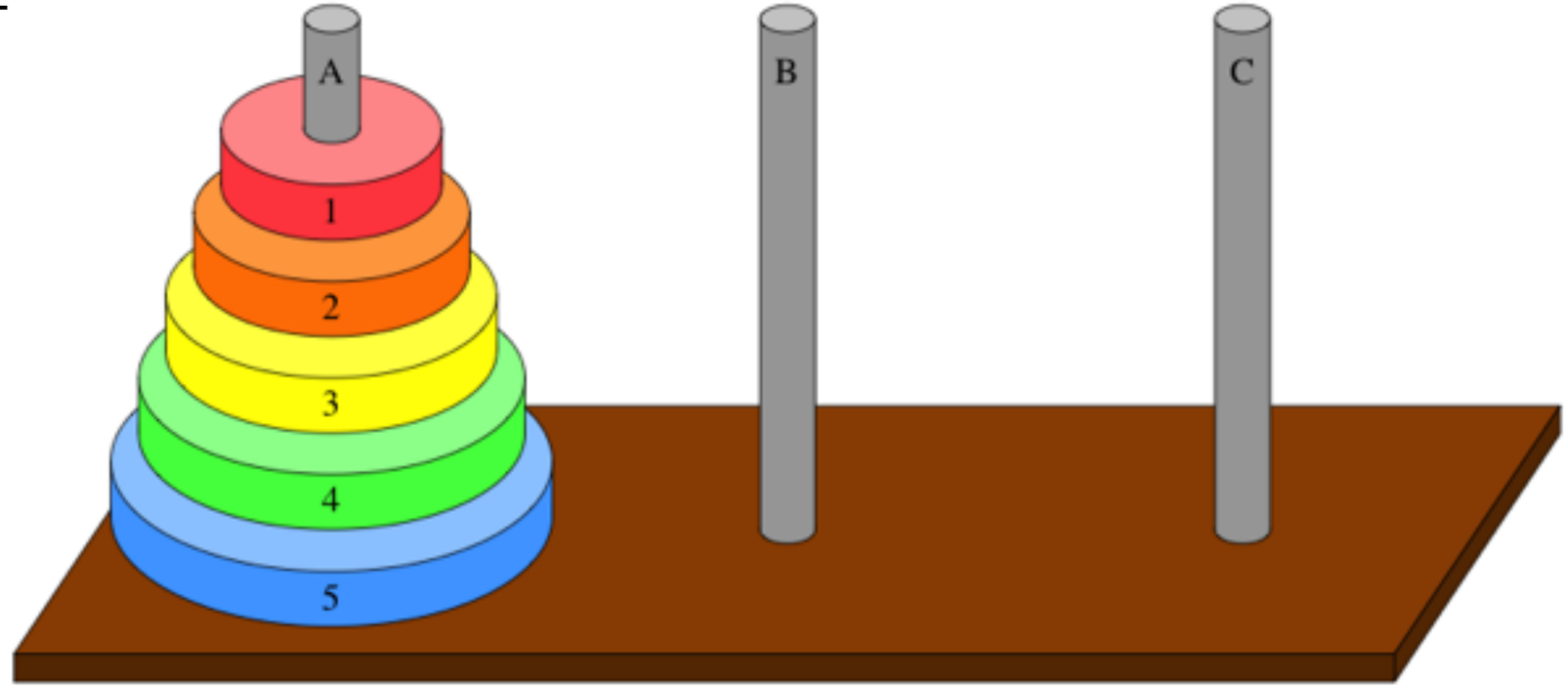
# Recursion — Pt 2

cs206 — April 6

# Towers of Hanoi




Extra Credit: +15 to homework grade

http://165.106.10.159/~gtowell/Towers/

Must be done by May 5

Must submit a believable time. +5 in-class final round.

# LAB

- For a binary search over an array containing the numbers 1..20, what is the sequence of recursive function calls to find 11
  - show all of the arguments to each recursive call

# Binary Search Code

```
    /**
     * Binary search, recursively on sorted internal array of ints
     * @param target the item to be found
     * @param lo the bottom of the range being searched
     * @param hi the top of the range being searched
     * @param steps the number of steps the search has taken
     * @return true if the target was found
     */
private boolean searchUtil(int target, int lo, int hi, int steps) {
    if (lo>hi) return false;
    int mid = (lo+hi)/2;
    System.out.println(target + " " + data[mid] + " " + lo + " " + hi + " " + steps
    if (data[mid]==target) return true;
    if (data[mid]<target)
        return searchUtil(target, mid+1, hi, steps+1);
    else
        return searchUtil(target, lo, mid-1, steps+1);
     }
```

# Calls to search Util

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

searchUtil(target, lo, hi, steps)

searchUtil(11, 0, 19, 0)
    mid = 9

searchUtil(11, 10, 19, 1)
    mid=14

searchUtil(11, 10, 13, 2)
    mid = 11

searchUtil(11, 10, 10, 3)
    return true

# Counter the number of occurrences of a letter in a string

```
public int numOccur1(char ch, String str) {
     if (str == null || str.equals("")) {
         return 0;
     }
     int count = 0;
     if (str.charAt(0) == ch) {
         count++;
     }
     numOccur1(ch, str.substring(1));
     return count;
 }
```

What does this return on “a” , “abc”
Why?

# Occurrence count v2

```
int acount = 0;

 public int numOccur2(char ch, String str) {
     if (str == null || str.equals("")) {
         return 0;
     }
     if (str.charAt(0) == ch) {
         acount++;
     }
     numOccur2(ch, str.substring(1));
     return acount;
 }
```

Correct answer, but a BAD solution

# Occurrence count v3 and v4

```
public int numOccur3(char ch, String str) {
    if (str == null || str.equals("")) { return 0; }
    int count = 0;
    if (str.charAt(0) == ch) { count = 1; }
    return count + numOccur3(ch, str.substring(1));
}


public int numOccur4(char ch, String str) {
    return numOccur4Util(ch, str, 0);
}
private int numOccur4Util(char ch, String str, int count) {
    if (str == null || str.equals("")) { return count; }
    if (str.charAt(0) == ch) { count++; }
    return numOccur4Util(ch, str.substring(1), count);
}
```

# v5 and v6

```
public int numOccur5(char ch, String str) {
        if (str == null || str.length()==0)
            return 0;
        return numOccur5Util(ch, str, 0, 0);
    }
    private int numOccur5Util(char ch, String str, int loc, int count) {
        if (loc >= str.length())
            return count;
        if (str.charAt(loc) == ch) { count++; }
        return numOccur5Util(ch, str, loc+1, count);
    }

public int numOccur6(char ch, String str) {
        if (str == null || str.length()==0)
            return 0;
        return numOccur6Util(ch, str, 0);
    }
    private int numOccur6Util(char ch, String str, int loc) {
        if (loc >= str.length())
            return 0;
        int cc = 0;
        if (str.charAt(loc) == ch) { cc=1; }
        return cc+numOccur6Util(ch, str, loc+1);
    }
```

# more returning values

```
public ArrayList<Integer> rAccmulate(int count)
 {
     if (count <= 0)
         return new ArrayList<Integer>();
     ArrayList<Integer> alAcc = rAccmulate(count - 1);
     alAcc.add(count);
     return alAcc;
 }
```

```
public ArrayList<Integer> rAccmulateB(int count) {
    ArrayList<Integer> ret = new ArrayList<>(count);
    rAccumulateUtil(count, ret);
    return ret;
}

private void rAccumulateUtil(int count, ArrayList<Integer> arrLis) {
    if (count <= 0)
        return;
    arrLis.add(count);
    rAccumulateUtil(count - 1, arrLis);
}
```

```
public static void main(String[] args) {
    System.out.println("AA " + (new AB()).rAccmulate(5));
    System.out.println("BB " + (new AB()).rAccmulateB(5));

}
```

What is the output?

# Recursion and Backtracking

- All problems considered so far progress steadily towards an answer.
- Consider a maze.  Sometimes you need to “backtrack”.
- Idea:
  - somehow  make a copy of where you are,
  - try going forward using your copy,
  - If that fails back up and go some other direction using your original

- Alternately
  - when backing up, undo your change
- Twiddle
  - especially with mazes mark places you have been so you do not retry failed paths

# N Queens problem

- Place N queens on an NxN chessboard such that no queen can take another
- Strategy:
  - on row N
    - move across columns trying a spot for OK
      - if OK, then recur with N+1
    - if have checked everything in a column and there is no place that is OK
      - backtrack
        - undo placement of queen in row N-1 and continue across that row

# N Queens

## setup

- board just a 2d array of chars
- will do recursion with a private utility function

```
public class NQueens {
    private char[][] board;
    private int size = 0;

    public NQueens(int siz) {
        size = siz;
        board = new char[siz][siz];
        for (int i = 0; i < siz; i++) {
            for (int j = 0; j < siz; j++) {
                board[i][j] = '.';
            }
        }
    }

    private void showBoard() {
        for (int r = 0; r < size; r++) {
            for (int c = 0; c < size; c++) {
                System.out.print(board[r][c]);
            }
            System.out.print("\n");
        }
    }


    public void doQueens() {
        doQueensUtil(0);
    }
```

# N Queens

## recursion

- base case:
  - the row being asked to consider is off board
    - return true;
- in the row
  - go across every column
    - put queen in a column
      - check if that is OK
        - if it is, go to recur to next row
        - if found solution return true;
      - if NOT OK, remove queen from column
  - if cannot find a place to put a queen, return false

```
private boolean doQueensUtil(int roww) {
    if (roww >= size)
        return true;
    for (int col = 0; col < size; col++) {
        board[roww][col] = 'Q';
        if (OKBoard()) {
            boolean v = doQueensUtil(roww + 1);
            if (v)
                return true;
        }
        board[roww][col] = '-';
    }
    return false;
}
```

What are the base case(s)?