"Computer Science is a science of abstraction - creating the right model for a problem and devising the appropriate mechanizable techniques to solve it."

-Alfred Aho and Jeffery Ullman

Based on slides for Building Java Programs by Reges/Stepp, found at http://faculty.washington.edu/stepp/book/
Arrays with multiple dimensions may be declared and used:

```java
int[][][] mat = new int[3][4][4];
```

The number of pairs of square brackets indicates the dimension of the array.

By convention, in a 2D array the first number indicates the row and the second the column.
Two Dimensional Arrays

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>column</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>1</td>
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<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

This is our abstract picture of the 2D array and treating it this way is acceptable.

(actual implementation is different)

```java
mat[2][1] = 12;
```
What is What?

int[][] mat = new int[10][12];

// mat is a reference to the whole 2d array

// mat[0] or mat[r] are references to a single row

// mat[0][1] or mat[r][c] are references to single elements

// no way to refer to a single column
2D Array Problems

- Write a method to mind the max value in a 2d array of ints

- Write a method that finds the sum of values in each column of a 2d array of doubles

- Write a method to print out the elements of a 2d array of ints in row order.
  - row 0, then row 1, then row 2 ...

- Write a method to print out the elements of a 2d array of ints in column order
  - column 0, then column 1, then column 2 ...
What is output by the following code?

```java
String[][] strTable = new String[5][8];
System.out.print(strTable.length + " ");
System.out.print(strTable[0].length + " ");
System.out.print(strTable[2][3].length());
```

A. 40 0 0
B. 8 5 0
C. 5 8 0
D. 5 8 then a runtime error occurs
E. No output due to a syntax error.
Use of Two Dimensional Arrays

- 2D arrays are often used when I need a table of data or want to represent things that have 2 dimensions.

- For instance an area of a simulation
Example of using a 2D array

- Conway's game of life
  - a cellular automaton designed by John Conway, a mathematician
  - not really a game
  - a simulation
  - takes place on a 2d grid
  - each element of the grid is occupied or empty
Simulation

- http://conwaysgameoflife.appspot.com/
- http://activeden.net/item/game-of-life/136281
- www.ibiblio.org/lifepatterns/
* indicates occupied, . indicates empty
<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
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<tr>
<td>3</td>
<td></td>
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</tr>
</tbody>
</table>
# Generation 1

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>.</td>
<td>*</td>
<td>.</td>
<td>*</td>
<td>.</td>
<td>*</td>
</tr>
<tr>
<td>1</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>*</td>
</tr>
<tr>
<td>2</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>*</td>
</tr>
</tbody>
</table>

* indicates occupied, . indicates empty
Rules of the Game

- If a cell is occupied in this generation.
  - it survives if it has 2 or 3 neighbors in this generation
  - it dies if it has 0 or 1 neighbors in this generation
  - it dies if it has 4 or more neighbors in this generation

- If a cell is unoccupied in this generation.
  - there is a birth if it has exactly 3 neighboring cells that are occupied in this generation

- Neighboring cells are up, down, left, right, and diagonal. In general a cell has 8 neighboring cells
Problem

- Implement a program to run the simulation