Arrays of Arrays

In Java, a multidimensional array is an array whose elements are themselves arrays. You can declare an "array of arrays" by using two or more sets of brackets, such as `String[][]`.

Manager:		Recorder:	
Presenter:		Reflector:	

Content Learning Objectives

After completing this activity, students should be able to:

- Write nested for loops to traverse a two-dimensional array.
- Explain differences between rectangular and ragged arrays.
- Use two-dimensional arrays to model real-world problems.

Process Skill Goals

During the activity, students should make progress toward:

- Rewriting a group of repetitive statements as a for loop. (Information Processing)

Facilitation Notes

Encourage the presenters and recorders to work together on the second half of Model 1. For example, the presenter can send the final code to the recorder, or the recorder can simply retype everything the presenter does in real time.

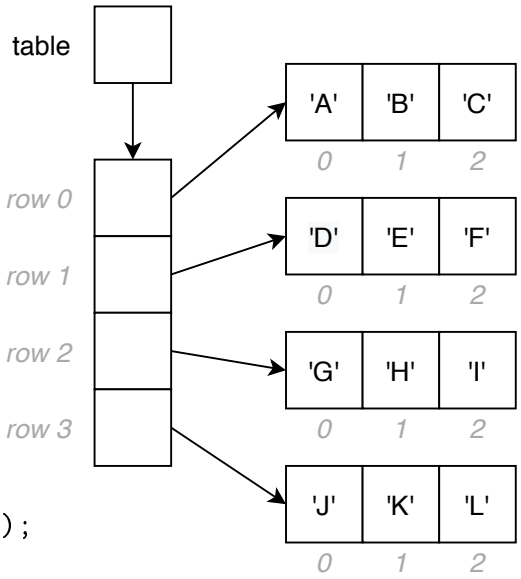
Key questions: #3, #11, #18

Source files: *Rectangular.java*, *Ragged.java*

Model 1 Rectangular Array

```java
import java.util.Arrays;  // for toString

public class Rectangular {
    public static void main(String[] args) {
        char[][] table = {
            {'A', 'B', 'C'},
            {'D', 'E', 'F'},
            {'G', 'H', 'I'},
            {'J', 'K', 'L'},
        };
        System.out.println(table.length);
        System.out.println(table[0].length);
        System.out.println(table[1][2]);
        System.out.println(Arrays.toString(table));
    }
}
```



Questions (25 min) Start time:

1. Run the program. What is the output of the following expressions?

a) `table.length` 4 b) `table[0].length` 3 c) `table[1][2]` F

d) `Arrays.toString(table)` `[[C@4dc63996, [C@d716361, [C@6ff3c5b5, [C@3764951d]`

2. Based on the model, what is the data type of the following expressions? Please answer using Java syntax, for example: `String[]`

a) `table` `char[][]` b) `table[0]` `char[]` c) `table[1][2]` `char`

3. Explain the output of `Arrays.toString(table)`. What exactly is stored in the array referenced by the variable `table`?

The output shows four memory addresses. In other words, it's an array of references to other arrays (of characters).

4. Consider the expression `table[1][2]`.

a) Which index (1 or 2) represents the row number? the first one

b) Which index (1 or 2) represents the column number? the second one

5. What is the result of the following expressions?

a) `table[2][1]` H

b) `table[0][0]` A

c) `table[3][2]` L

d) `table[2][3]` out of bounds

Presenter: Implement your team's answers for the following questions in Model1.java, at the end of the main method. Make sure the code compiles and runs correctly.

6. Write three statements to print the first row of the table, one letter at a time. The output should be `A B C ` with a space after each letter.

```
System.out.print(table[0][0] + " ");
System.out.print(table[0][1] + " ");
System.out.print(table[0][2] + " ");
```

7. Summarize the main difference in these three lines of code.

The second index changes from 0 to 1 to 2.

8. Rewrite your previous code using a `for` loop. Name the loop variable `col` (instead of `i`). Your code should work for any number of columns (not just 3).

```
for (int col = 0; col < table[0].length; col++) {
    System.out.print(table[0][col] + " ");
}
```

9. Copy your answer to the previous question and paste it below two times. Modify the code so that it prints row 2 and row 3. Add `println` statements so that each row ends with a newline.

```
for (int col = 0; col < table[1].length; col++) {
    System.out.print(table[1][col] + " ");
}
System.out.println();

for (int col = 0; col < table[2].length; col++) {
    System.out.print(table[2][col] + " ");
}
System.out.println();
```

10. Summarize the main differences in these two `for` loops.

The first index changes from 1 to 2, both in the loop condition and in the loop body.

11. Rewrite your previous code using nested `for` loops. Name the outer loop variable `row` and the inner loop variable `col`. Your code should work for any number of rows and columns.

```
for (int row = 0; row < table.length; row++) {
    for (int col = 0; col < table[row].length; col++) {
        System.out.print(table[row][col] + " ");
    }
    System.out.println();
}
```

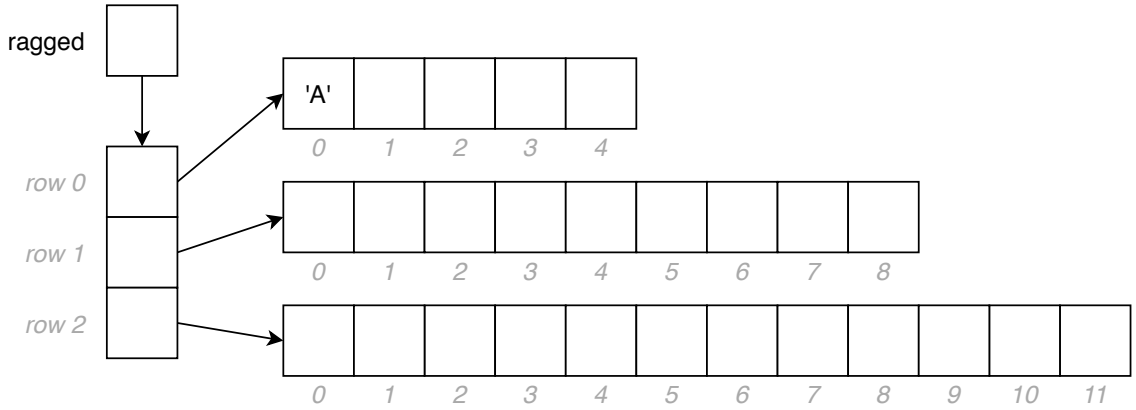
12. How would you modify your code in the previous question to print only the top half of the table? (You may assume there is an even number of rows.)

Simply change the for loop header to be:

```
for (int row = 0; row < table.length / 2; row++)
```

Model 2 Ragged Array

```
1  public class Ragged {
2      public static void main(String[] args) {
3          char[][] ragged = new char[3][];
4          ragged[0] = new char[5];
5          ragged[1] = new char[9];
6          ragged[2] = new char[12];
7
8          char letter = 'A';
9          ragged[0][0] = letter;
10         letter++;
11         System.out.println(letter);
12     }
13 }
```



Questions (20 min) Start time:

13. Based on the `main` method above:

a) How many rows are in this 2D array? 3

b) How many columns are in the first row? 5

c) How many columns are in the second row? 9

d) How many columns are in the third row? 12

14. Run the program. What is the value of `letter` at the end? `'B'`

15. Describe what happens when you increment a `char` variable.

The next letter in the (Unicode) alphabet is assigned.

Note: Characters in Java are represented by 16-bit integers.

16. Summarize the main difference in shape between the "rectangular" array of Model 1 and the "ragged" array of Model 2.

Rectangular arrays have the same number of columns on each row. Ragged arrays do not.

17. Examine your code for Question #3. Would it work for the `ragged` array? Explain why or why not.

It would still work, because the inner loop processes only the number of elements in that particular row.

18. Complete the following steps to fill the contents of the `ragged` array:

a) Copy your code from Question #3 and paste it in Model2.java at the end of the main method. Replace the variable `table` with `ragged` so that it compiles.

b) Comment out lines 9–11 so that `letter` is not modified and printed before the first loop.

c) Modify your code so that it sets the first element of `ragged` to `'A'`, the second element to `'B'`, and so on, until the last element is set to `'Z'`. (Hint: Move lines 9–10 into the loop.)

d) Copy your code from Question #3 again and paste it in Model2.java at the end of the main method. Run the program to verify that all letters were set correctly.

e) Paste your code from step c) in the space below:

```
for (int row = 0; row < ragged.length; row++) {
    for (int col = 0; col < ragged[row].length; col++) {
        ragged[row][col] = letter;
        letter++;
    }
}
```

19. Which kind of 2D array (rectangular or ragged) would you use to represent the lanes of a highway, where the array elements are car objects? Justify your answer.

A ragged array, because there could be a different number of cars in each lane of the highway.

20. Which kind of 2D array (rectangular or ragged) would you use to represent a matrix in mathematics, where the array elements are integers? Justify your answer.

A rectangular array, because matrices have the same number of columns on each row.