LEC 15

CSE 121

2D Arrays

Questions during Class?

Raise hand or send here

sli.do #cse121

BEFORE WE START

Talk to your neighbors:

What computer application (website, app) do you use the most on a daily basis?

Music: ❄ CSE 121 26wi Lecture Tunes ❄

Instructors: Miya Natsuhara

TAs:

Amogh	Hayden	Anum	Sam	Shayna
William	Aki	Abdul	Ethan	Jesse
Johnathan	Spencer	Janvi	Jessica	Minh
Anant	Savannah	Navya	Paul	Cayden
Reese	Tamsyn	Ruslana	Carson	

Announcements, Reminders

- C3 released, due **Tuesday, March 3rd**
- R5 due next **Thursday, March 5th** (eligible: **P1**, C2, P2)
  - P1 cycling out of eligibility after R5
- Quiz 2 on **Thursday, March 5th**
  - can't make it? email Miya *before* your quiz!
- The end of the quarter is approaching…
  - Gumball & friends campus visit on Monday (March 16) 2-3:30pm
  - Your final exam on **Wednesday, March 18 12:30pm – 2:20pm**

Practice: Think

sli.do #cse121

```
public static void main(String[] args) {
    int x = 0;
    int[] a = new int[4];
    x++;

    mystery(x, a);
    System.out.println(x + " " + Arrays.toString(a));

    x++;
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}

public static void mystery(int x, int[] a) {
    x++;
    a[x]++;
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}
```

Four lines of output are produced by this code. What would those four lines be?

Practice: Pair

sli.do #cse121

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Practice: Think

sli.do #cse121

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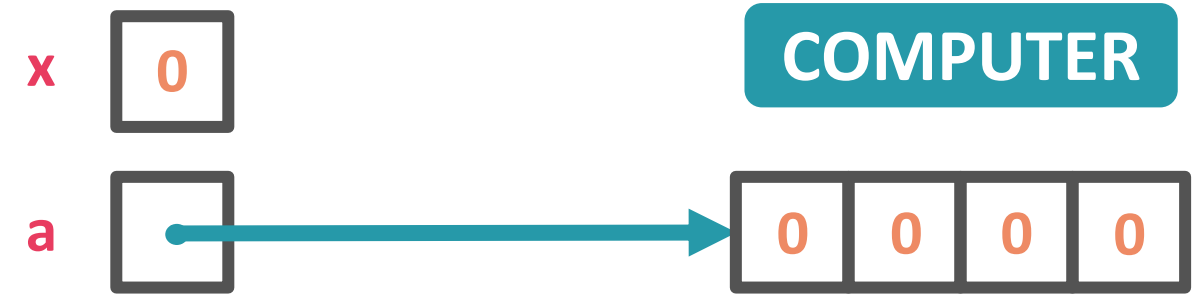

Practice: Think

sli.do #cse121

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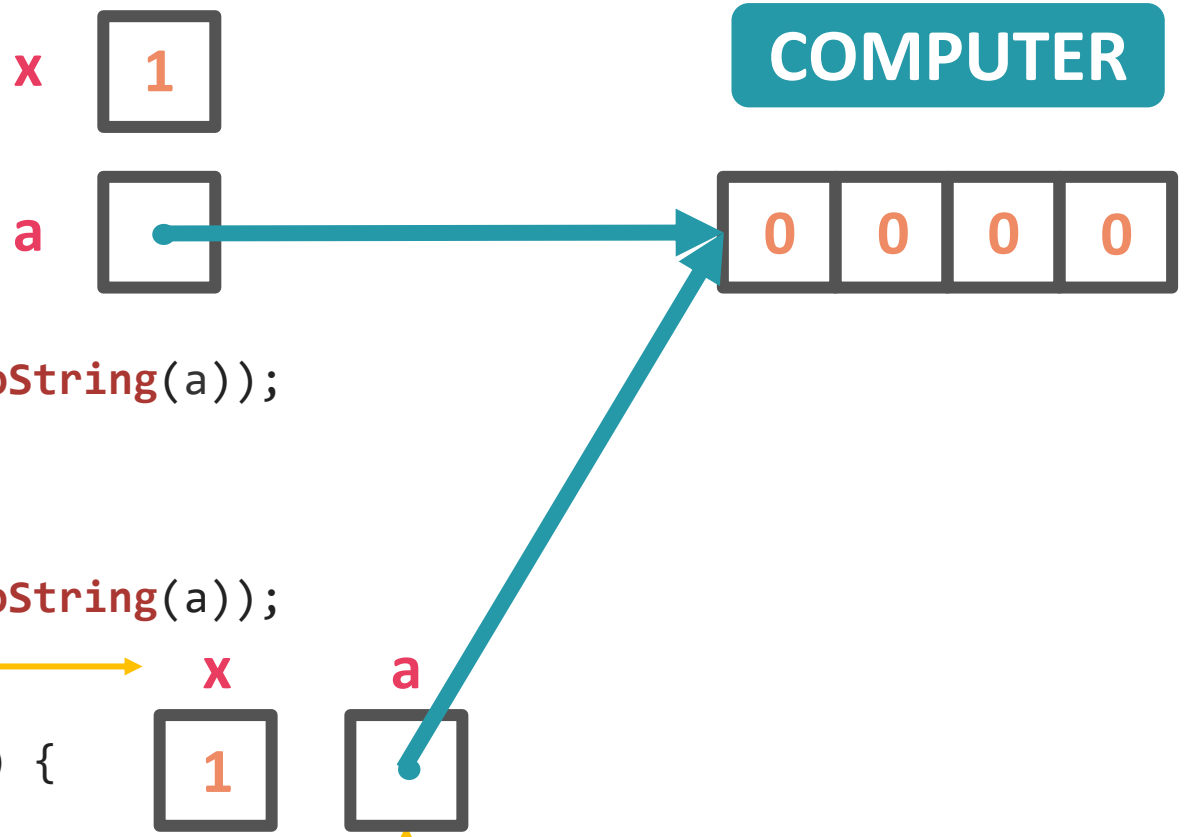

Practice: Think

sli.do #cse121

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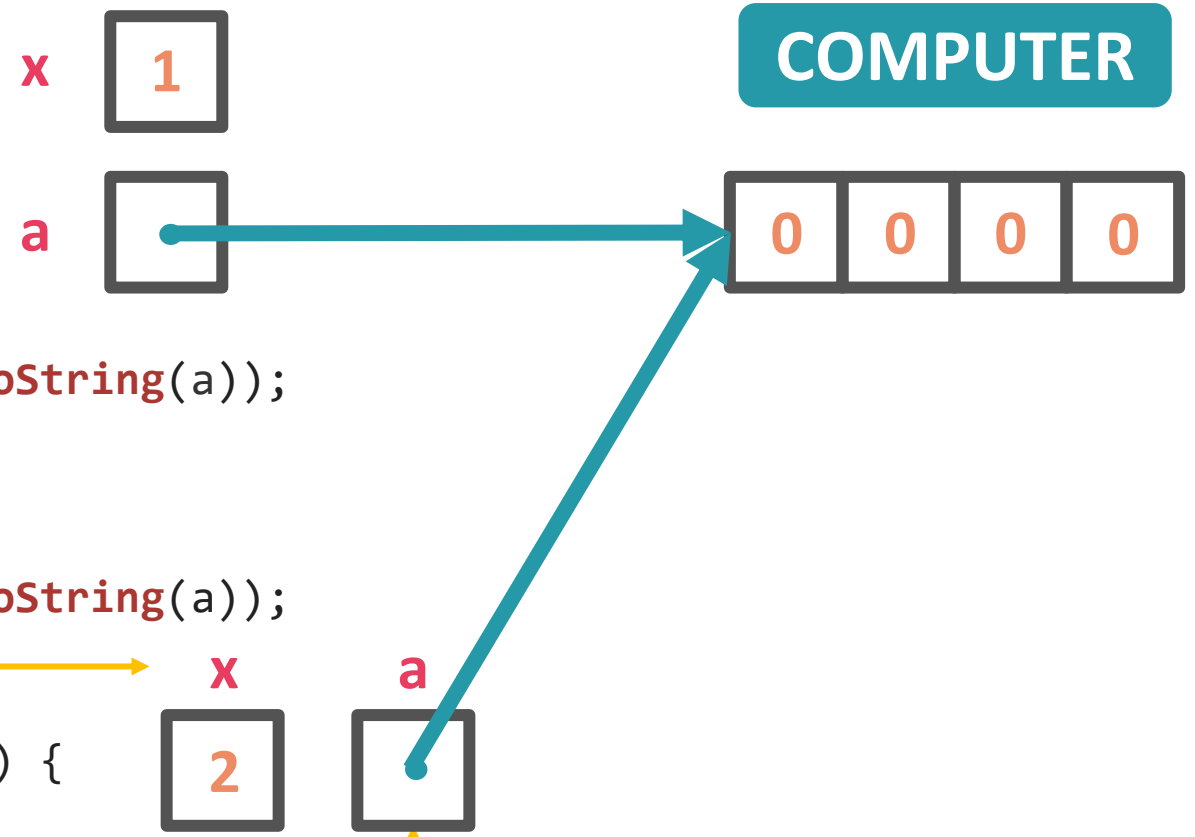

Practice: Think

sli.do #cse121

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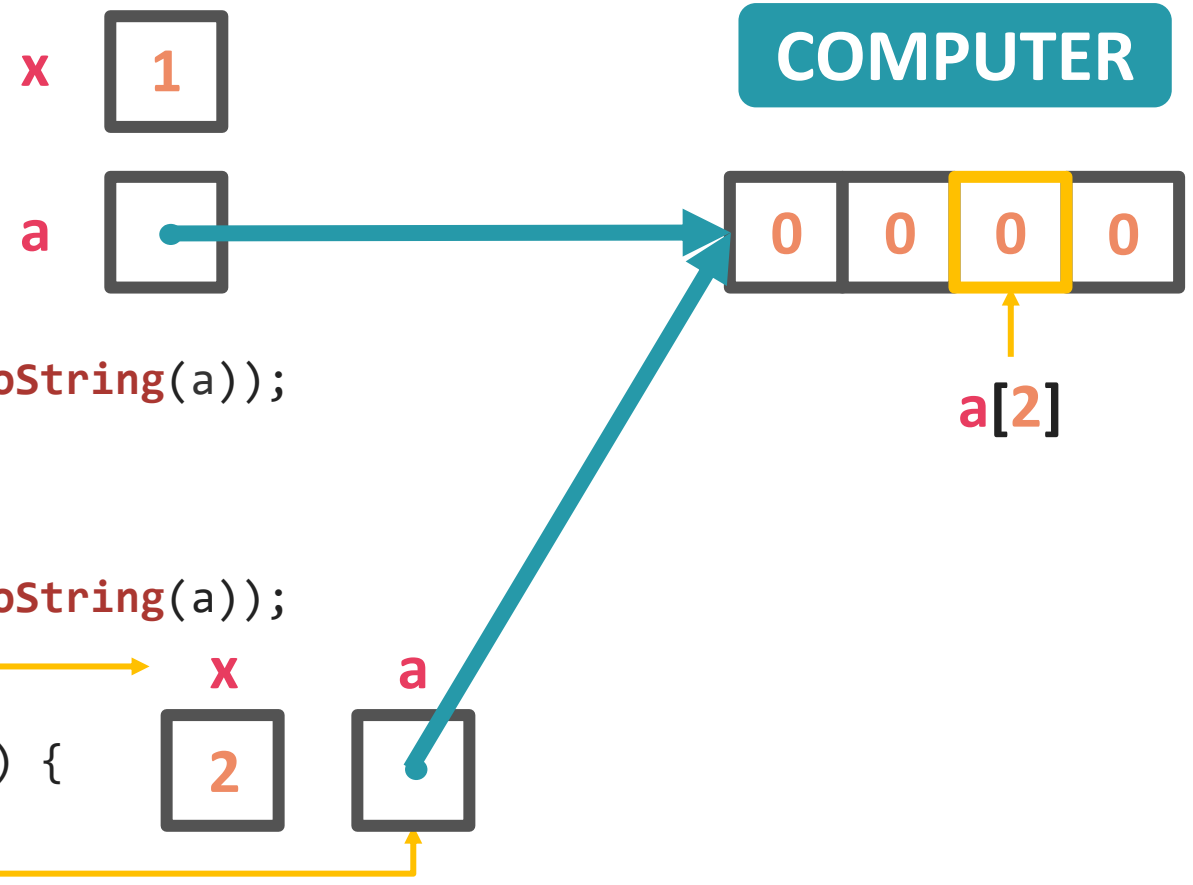

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sli.do #cse121

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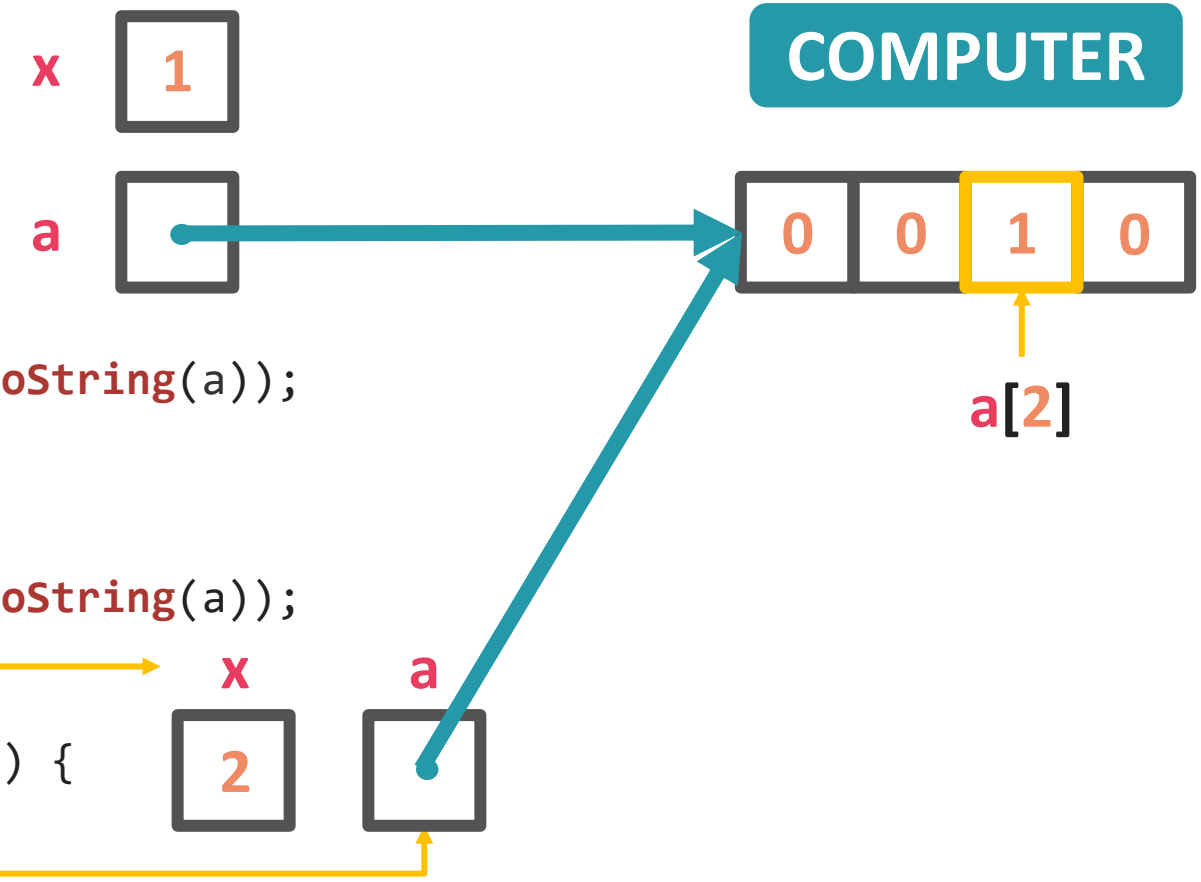

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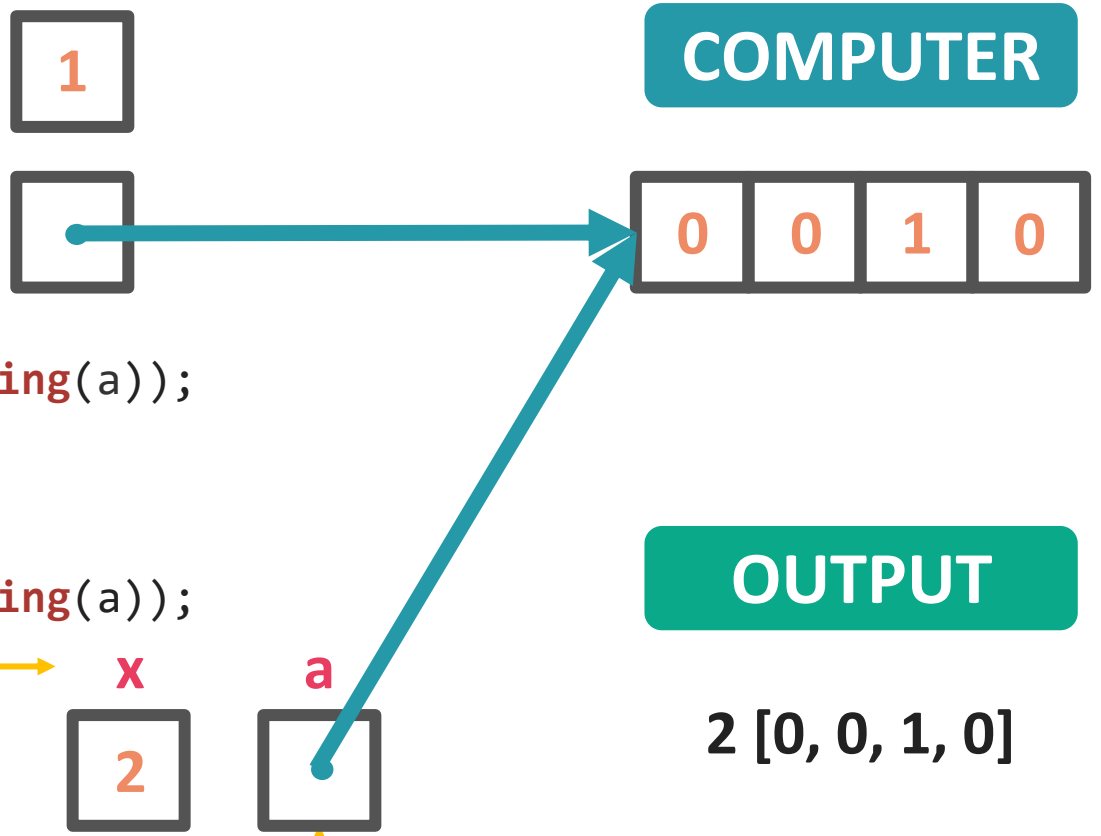

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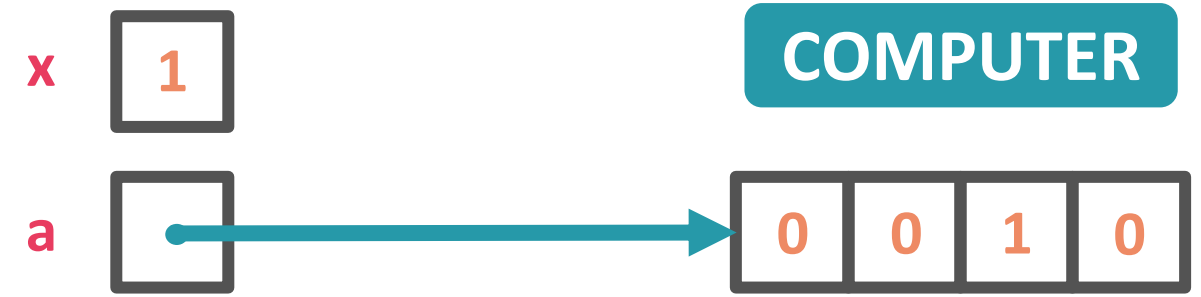
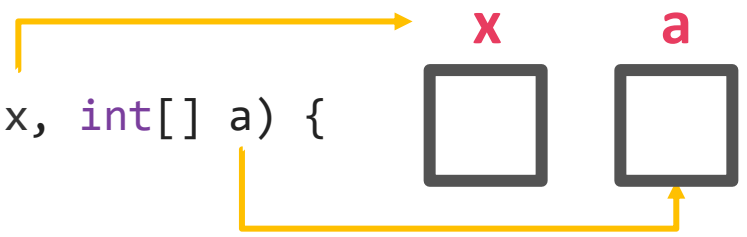


COMPUTER



OUTPUT

2 [0, 0, 1, 0]

1 [0, 0, 1, 0]

Practice: Think

sli.do #cse121

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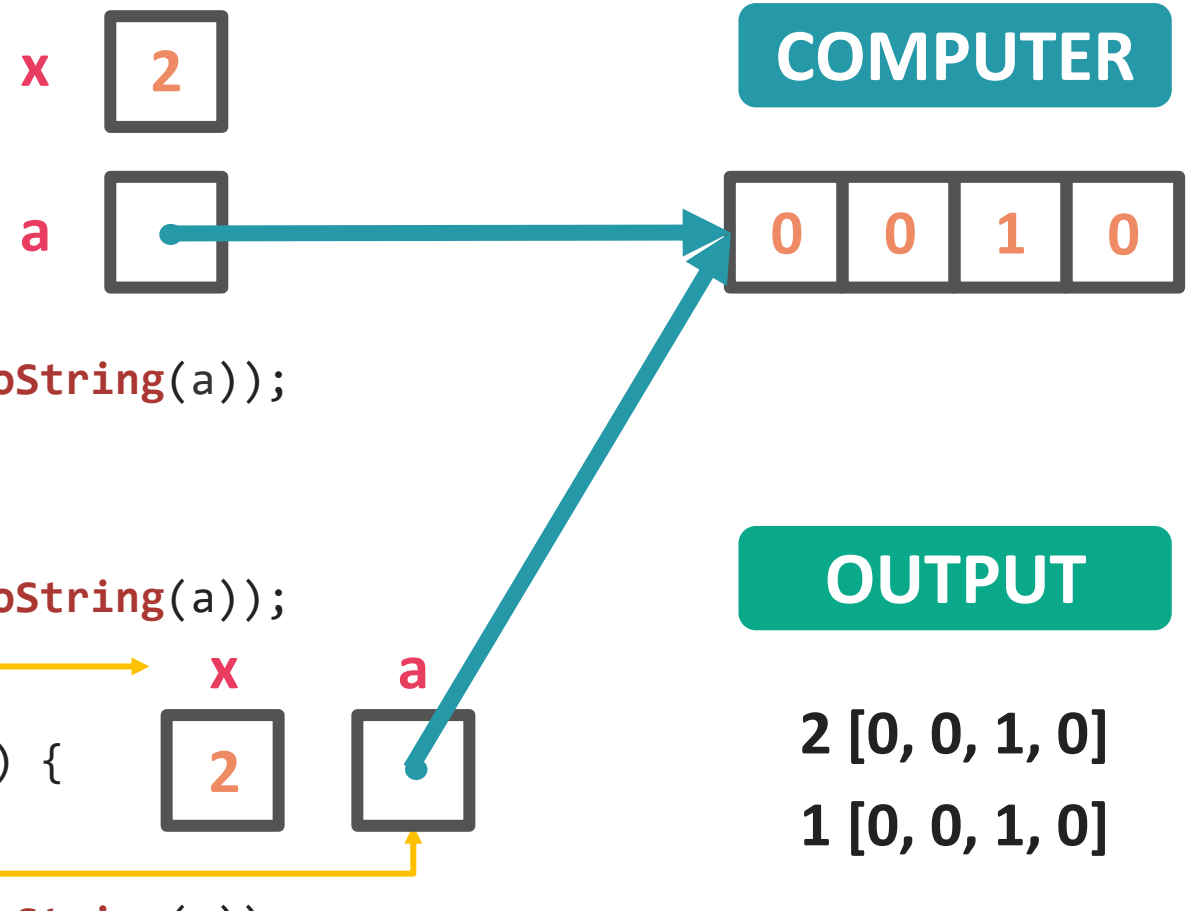

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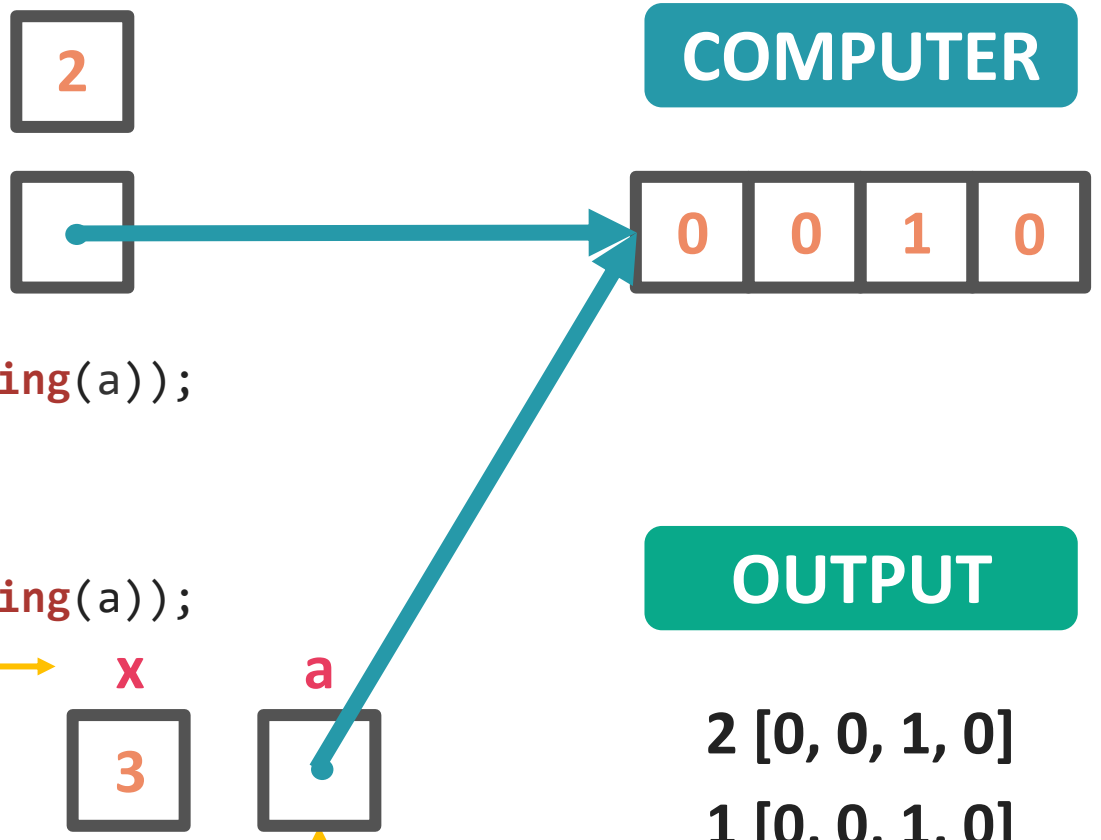

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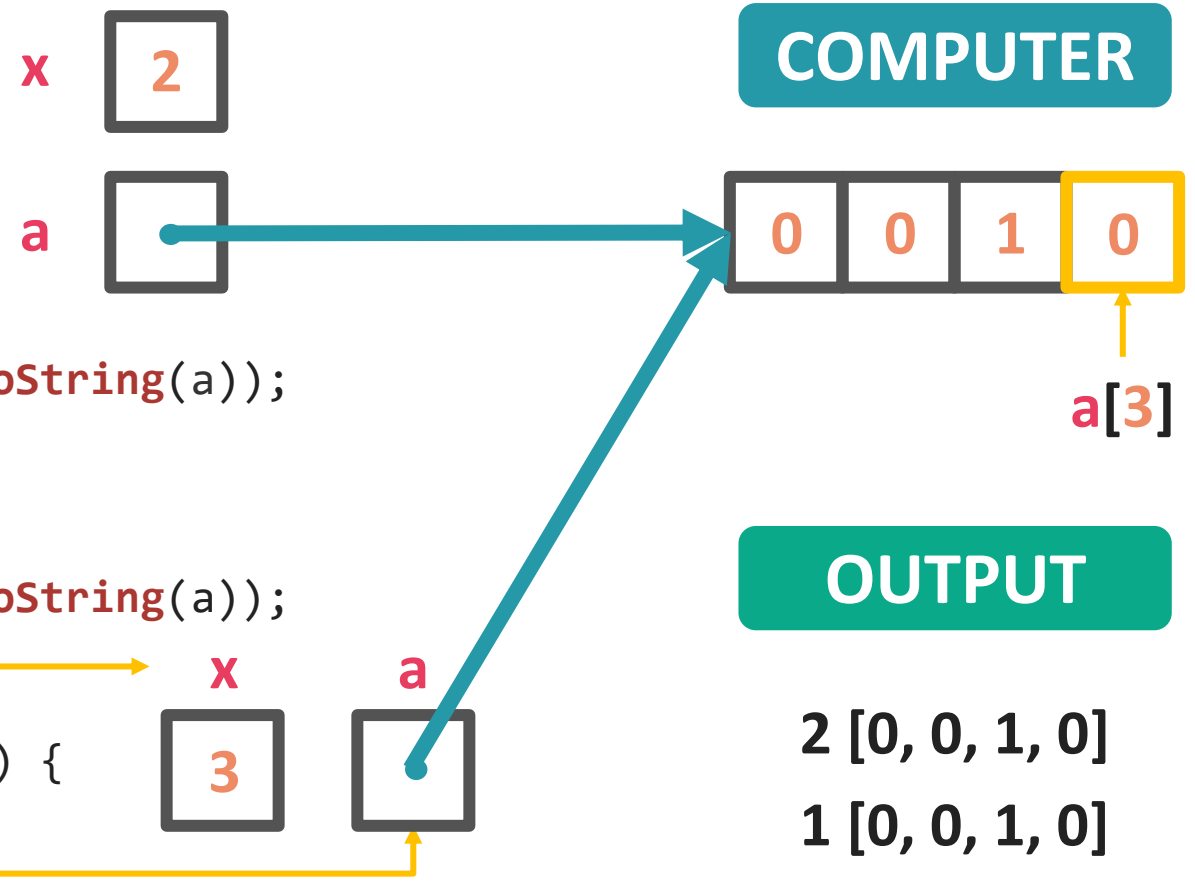

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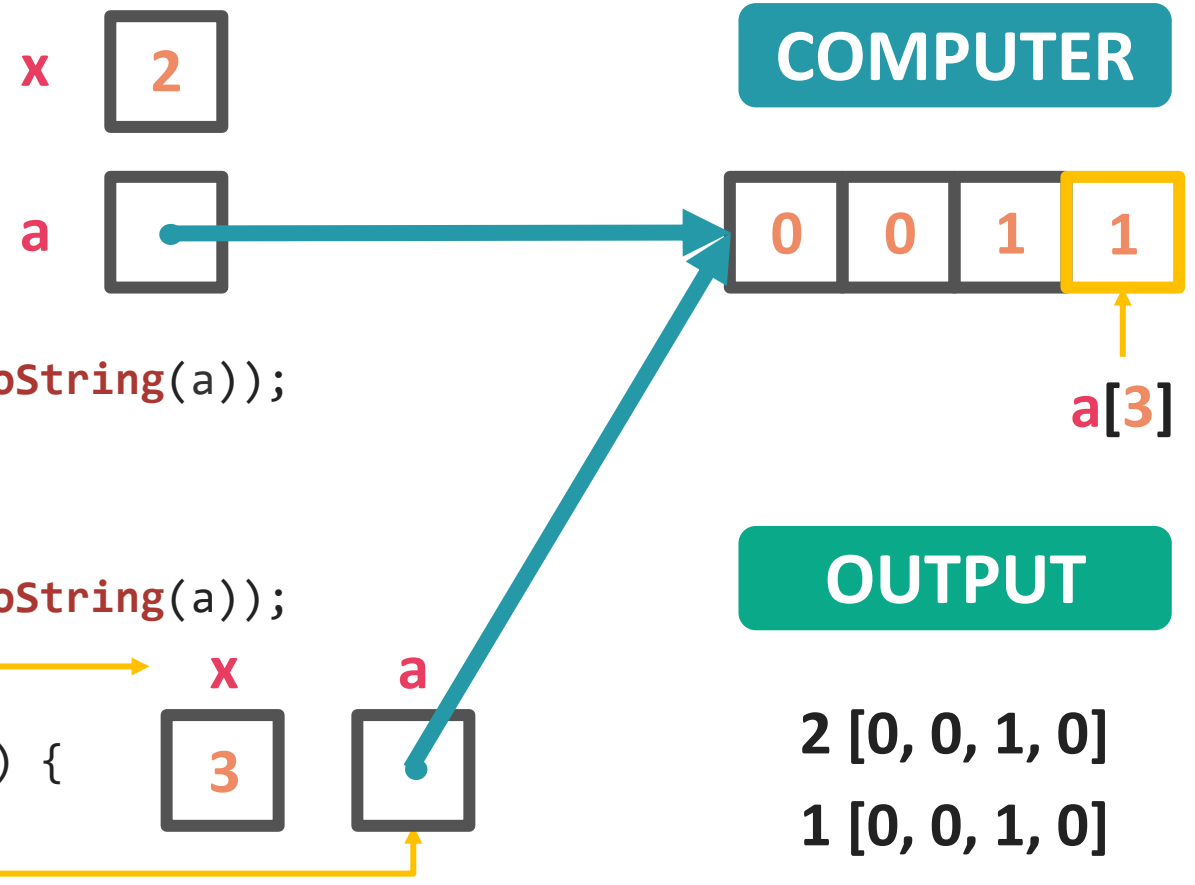

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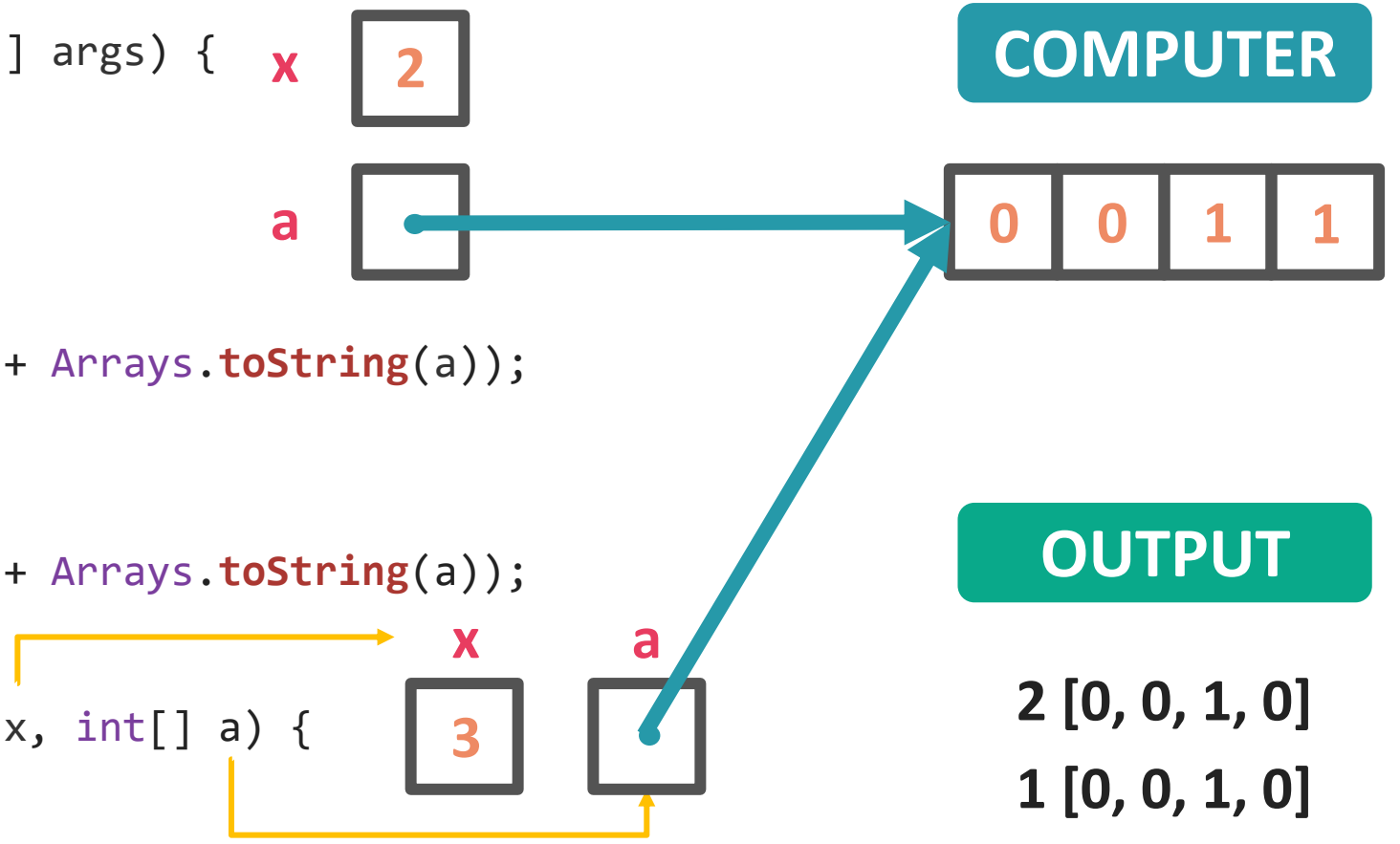

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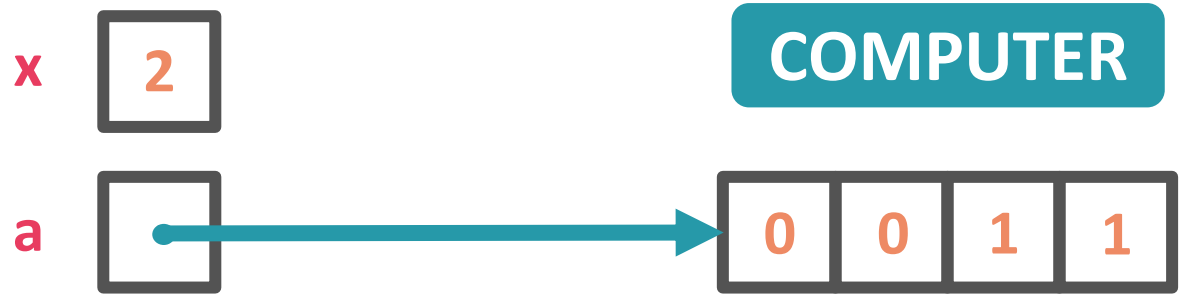
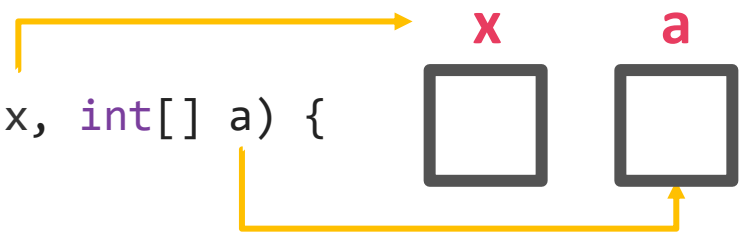


COMPUTER



OUTPUT

2 [0, 0, 1, 0]

1 [0, 0, 1, 0]

3 [0, 0, 1, 1]

2 [0, 0, 1, 1]

PCM Review: 2D Arrays

An array of arrays!

The type of each individual element is another array!

- Your first example of "**nested** data structures"
- There will be more if you take CSE 122!

```
int[][]        double[][]    String[][]

boolean[][]        char[][]
```

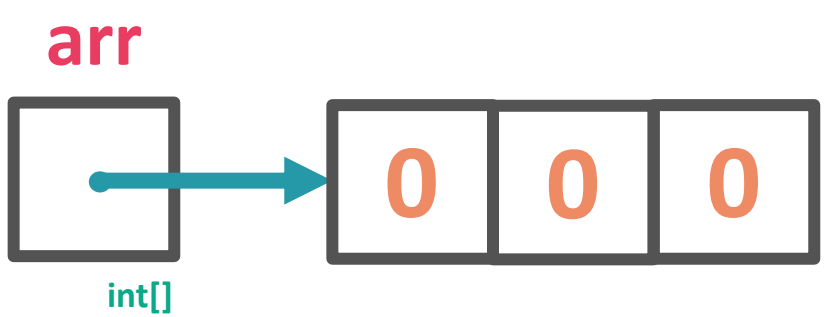
Recall: Arrays

type name value

```
int[] arr = new int[3];
```

declaration initialization

CODE



THINK

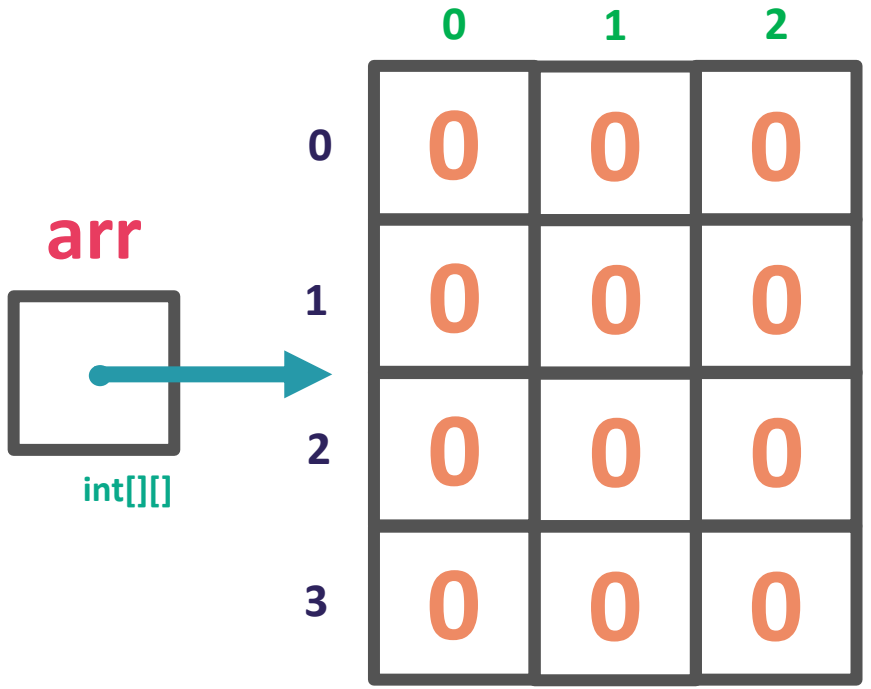
PCM Review: 2D Arrays as Rows and Columns 1

type name value

```
int[][] arr = new int[4][3];
```

declaration initialization

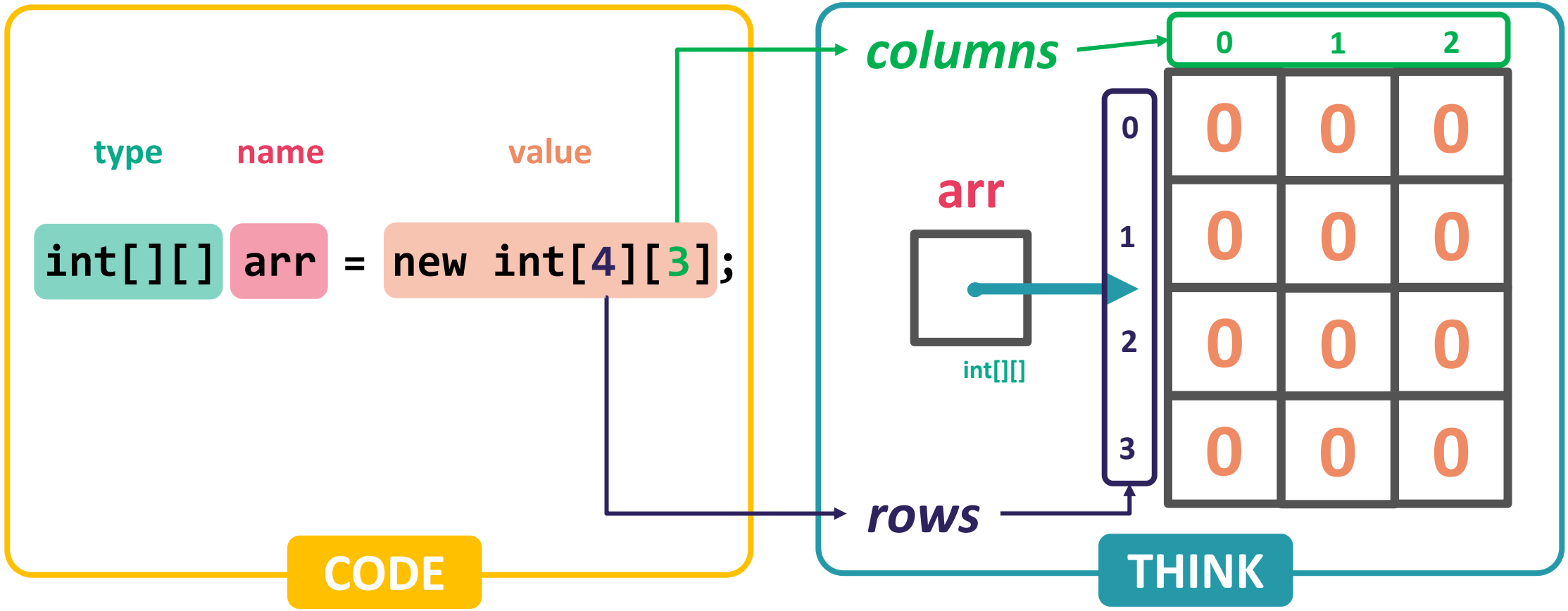
CODE



THINK

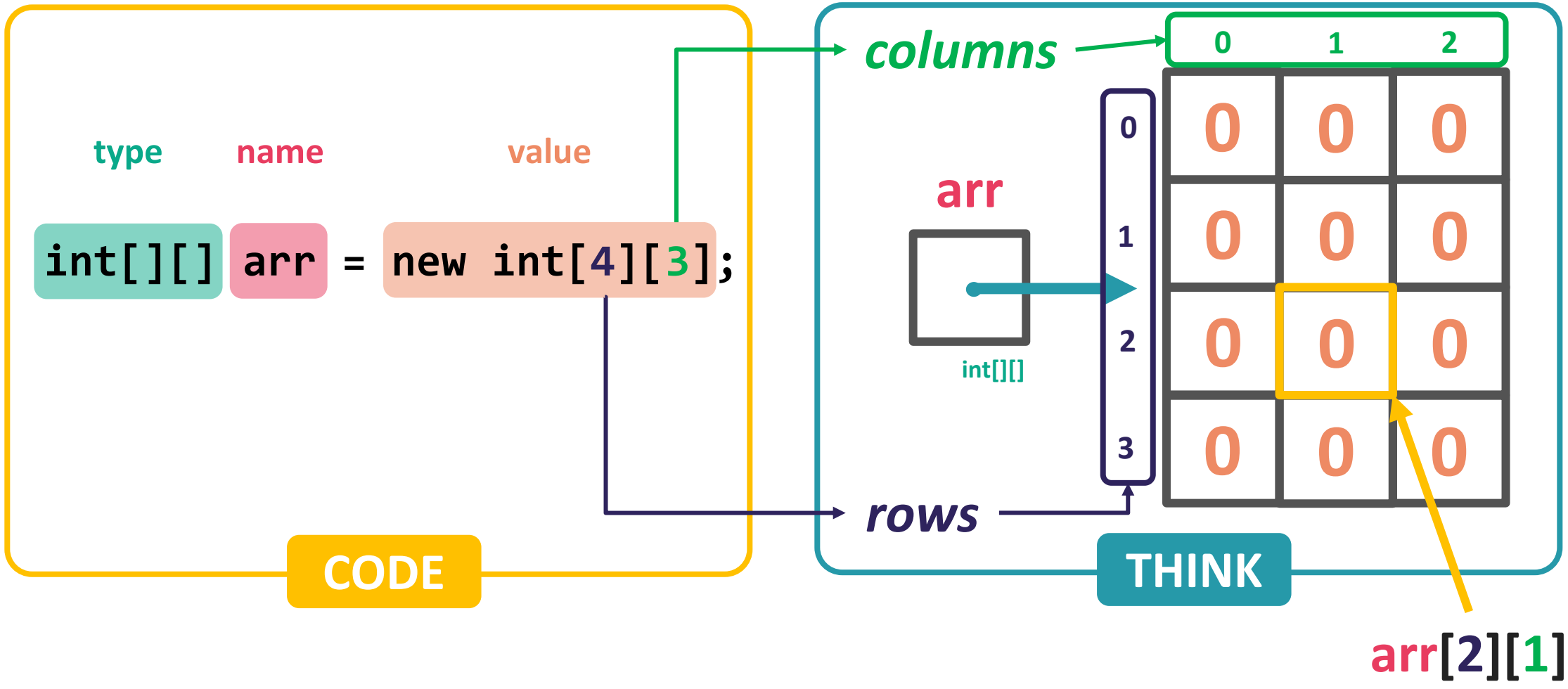
PCM Review: 2D Arrays as Rows and Columns 2

Individual elements are **row-first**, then **column** ("row-major")



PCM Review: 2D Arrays as Rows and Columns 3

Individual elements are **row-first**, then **column** ("row-major")



A More Accurate View (Reference Semantics)

type name value

```
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```
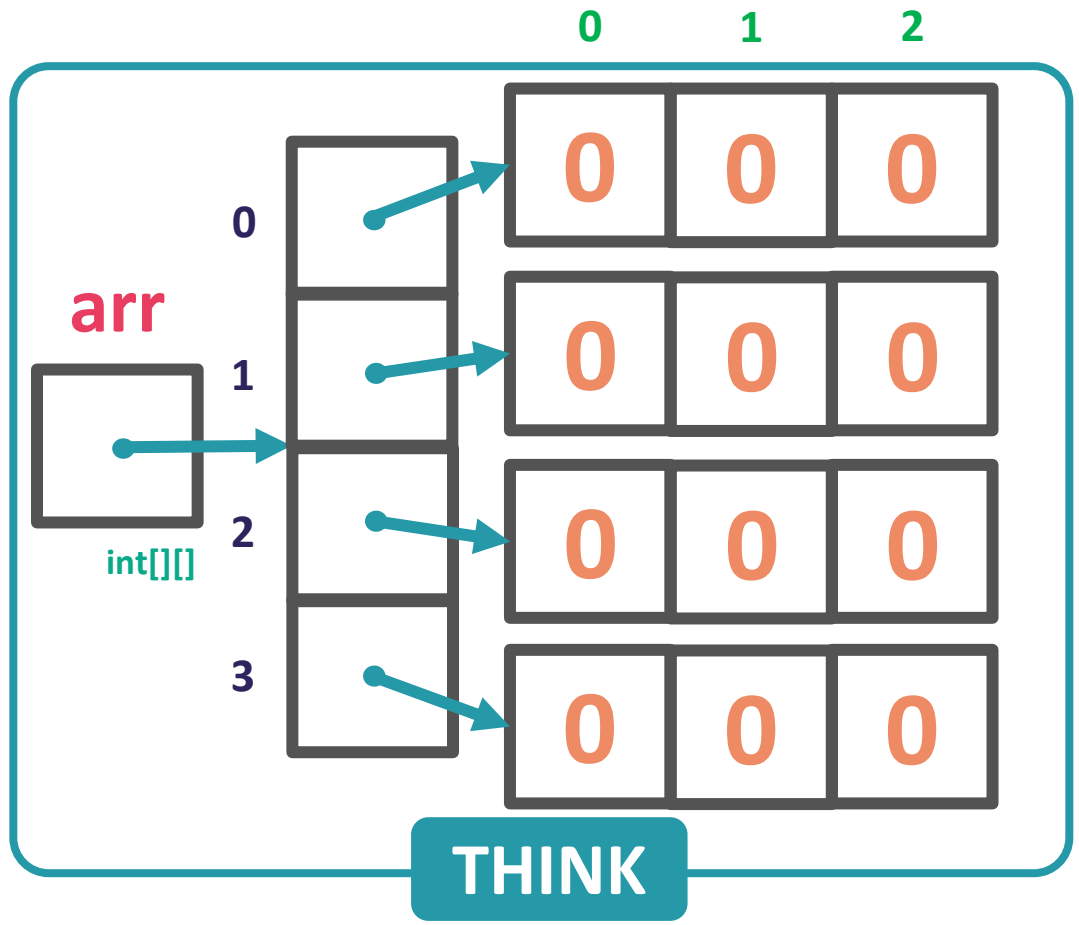

declaration initialization

CODE



THINK

PCM Review: 2D Array Traversals

for each row…

```
for (int i = 0; i < list.length; i++) {
    for (int j = 0; j < list[i].length; j++) {
        // do something with list[i][j]
    }
}
```

for each element within a row…

Arrays Utility Class (and methods)

Method	Description
`Arrays.toString(array);`	Returns a `String` representing the array, such as `"[10, 30, -25, 17]"`
`Arrays.equals(array1, array2);`	Returns `true` if the two arrays contain the same elements in the same order
`Arrays.deepToString(array);`	Returns a `String` representing the array; if the array contains other arrays as elements, the `String` represents their contents, and so on. For example, `"[[99, 151], [30, 5]]"`
`Arrays.deepEquals(array1, array2);`	Returns `true` if the two arrays contain the same elements in the same order; if the array(s) contain other arrays as elements, their contents are tested for equality, and so on.

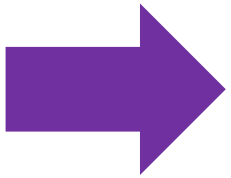
Applications of 2D Arrays

- **Matrices**
  - Useful in *so many* applications in math, engineering, and statistics
  - Fundamental to machine learning & AI
  - P3 is one real-life application of this! (bioinformatics)
- Board games
  - e.g. chess, checkers, tic-tac-toe, sudoku
- Tabular or grid-like data
  - e.g. scorekeeping, gradebook, census data
- Image processing

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

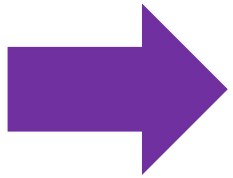
70	73	66	79	39
91	75	73	99	47
27	64	21	34	1



matrixAdd: first row

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1



```
i: 0
j: 0
```


matrixAdd: 0,0

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

70	73	66	79	39
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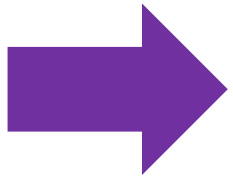
27	64	21	34	1



```
i: 0
j: 0
```

93				

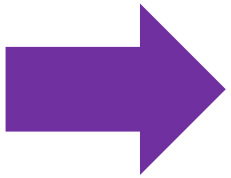
matrixAdd: 0,1

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

i: 0

j: 1

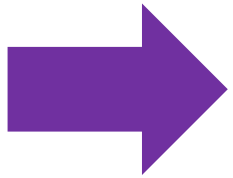


93	169			

matrixAdd: 0,2

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1



```
i: 0
j: 2
```

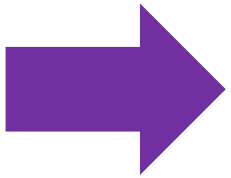
93	169	84		

matrixAdd: 0,3

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

```
i: 0
j: 3
```

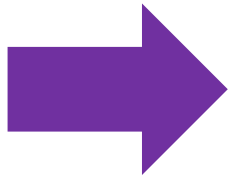


93	169	84	83	

matrixAdd: 0,4

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1



```
i: 0
j: 4
```

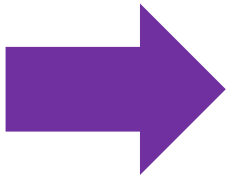
93	169	84	83	103

matrixAdd: 1,0

23	96	18	4	64
45	**40**	**18**	**44**	**34**
92	13	77	71	12

70	73	66	79	39
91	**75**	**73**	**99**	**47**
27	64	21	34	1

```
i: 1
j: 0
```



93	169	84	83	103
136				

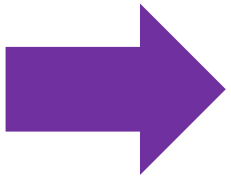
matrixAdd: 1,1

23	96	18	4	64
45	**40**	**18**	**44**	**34**
92	13	77	71	12

70	73	66	79	39
91	**75**	**73**	**99**	**47**
27	64	21	34	1

i: 1

j: 1



93	169	84	83	103
136	**115**			

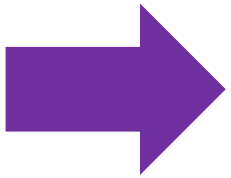
matrixAdd: 1,2

23	96	18	4	64
45	**40**	**18**	**44**	**34**
92	13	77	71	12

70	73	66	79	39
91	**75**	**73**	**99**	**47**
27	64	21	34	1

i: 1

j: 2



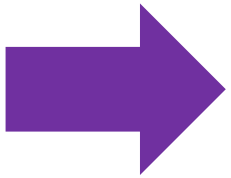
93	169	84	83	103
136	**115**	**91**		

matrixAdd: 1,3

23	96	18	4	64
45	**40**	**18**	**44**	**34**
92	13	77	71	12

70	73	66	79	39
91	**75**	**73**	**99**	**47**
27	64	21	34	1

```
i: 1
j: 3
```



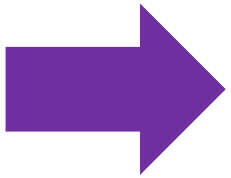
93	169	84	83	103
136	**115**	**91**	**143**	

matrixAdd: 1,4

23	96	18	4	64
45	**40**	**18**	**44**	**34**
92	13	77	71	12

70	73	66	79	39
91	**75**	**73**	**99**	**47**
27	64	21	34	1

```
i: 1
j: 4
```



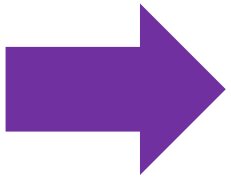
93	169	84	83	103
136	**115**	**91**	**143**	**81**

matrixAdd: 2,0

23	96	18	4	64
45	40	18	44	34
92	**13**	**77**	**71**	**12**

70	73	66	79	39
91	75	73	99	47
27	**64**	**21**	**34**	**1**

```
i: 2
j: 0
```



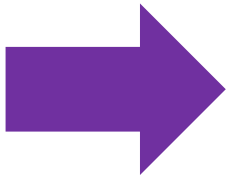
93	169	84	83	103
136	115	91	143	81
119				

matrixAdd: 2,1

23	96	18	4	64
45	40	18	44	34
92	**13**	**77**	**71**	**12**

70	73	66	79	39
91	75	73	99	47
27	**64**	**21**	**34**	**1**

```
i: 2
j: 1
```



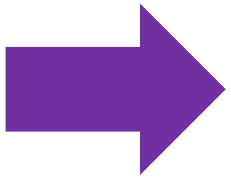
93	169	84	83	103
136	115	91	143	81
119	**77**			

matrixAdd: 2,2

23	96	18	4	64
45	40	18	44	34
92	**13**	**77**	**71**	**12**

70	73	66	79	39
91	75	73	99	47
27	**64**	**21**	**34**	**1**

```
i: 2
j: 2
```

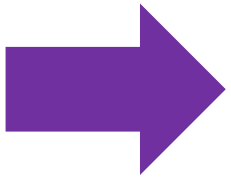


93	169	84	83	103
136	115	91	143	81
119	**77**	**98**		

matrixAdd: 2,3

23	96	18	4	64
45	40	18	44	34
92	**13**	**77**	**71**	**12**

70	73	66	79	39
91	75	73	99	47
27	**64**	**21**	**34**	**1**



```
i: 2
j: 3
```

93	169	84	83	103
136	115	91	143	81
119	**77**	**98**	**105**	

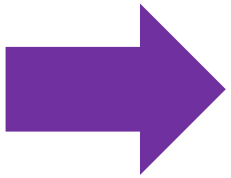
matrixAdd: 2,4

23	96	18	4	64
45	40	18	44	34
92	**13**	**77**	**71**	**12**

70	73	66	79	39
91	75	73	99	47
27	**64**	**21**	**34**	**1**

i: 2

j: 4

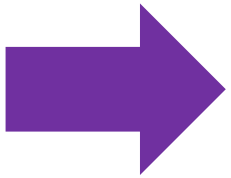


93	169	84	83	103
136	115	91	143	81
119	**77**	**98**	**105**	**13**

matrixAdd: finished!

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1



93	169	84	83	103
136	115	91	143	81
119	77	98	105	13

readData: processing input

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma? 40
  Temperature in Bothell? 43
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma? 40
  Temperature in Bothell? 44
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma? 41
  Temperature in Bothell? 43
...
```

readData: days

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
...
```

	Seattle	Tacoma	Bothell
1			
2			
3			

readData: 1, Seattle

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma?
  Temperature in Bothell?
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
...
```

	Seattle	Tacoma	Bothell
1	44		
2			
3			

readData: 1, Tacoma

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma? 40
  Temperature in Bothell?
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
...
```

	Seattle	Tacoma	Bothell
1	44	40	
2			
3			

readData: 1, Bothell

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma? 40
  Temperature in Bothell? 43
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
...
```

	Seattle	Tacoma	Bothell
1	44	40	43
2			
3			

readData: 2, Seattle

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma? 40
  Temperature in Bothell? 43
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma?
  Temperature in Bothell?
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
...
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42		
3			

readData: 2, Tacoma

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma? 40
  Temperature in Bothell? 43
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma? 40
  Temperature in Bothell?
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
...
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	
3			

readData: 2, Bothell

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma? 40
  Temperature in Bothell? 43
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma? 40
  Temperature in Bothell? 44
Next day's data:
  Temperature in Seattle?
  Temperature in Tacoma?
  Temperature in Bothell?
...
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3			

readData: 2, Seattle

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma? 40
  Temperature in Bothell? 43
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma? 40
  Temperature in Bothell? 44
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma?
  Temperature in Bothell?
...
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3	42		

readData: 2, Tacoma

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma? 40
  Temperature in Bothell? 43
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma? 40
  Temperature in Bothell? 44
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma? 41
  Temperature in Bothell?
...
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3	42	41	

readData: 2, Bothell

```
How many days' data would you like to input? 3
Next day's data:
  Temperature in Seattle? 44
  Temperature in Tacoma? 40
  Temperature in Bothell? 43
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma? 40
  Temperature in Bothell? 44
Next day's data:
  Temperature in Seattle? 42
  Temperature in Tacoma? 41
  Temperature in Bothell? 43
...
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3	42	41	43

computeAverages

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3	42	41	43

```
How many days' data would you like to input? 3
…
The average values for each location were
[42.66666666666664, 40.333333333333336,
43.333333333333336]
```

42.667	40.333	43.333

Average of Seattle temperatures
(44 + 42 + 42) / 3