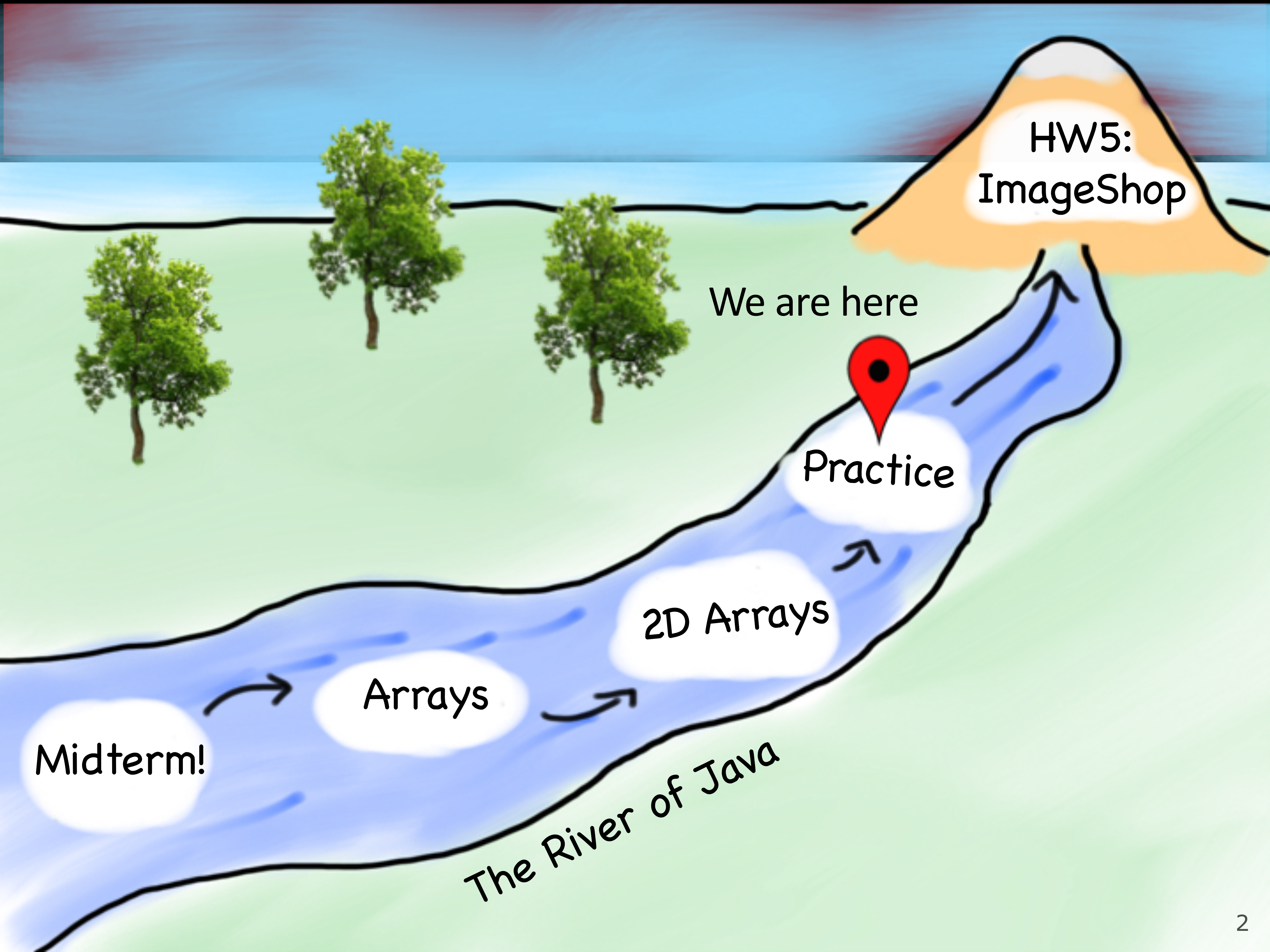
CS 106A, Lecture 18
Practice with 1D and 2D Arrays


HW5:
ImageShop
We are here
Practice
2D Arrays
Arrays
Midterm!
The River of Java

Plan for Today

- Recap: 2D Arrays and Images
- Practice: Shrink
- Practice: Cryptogram
- Practice: Tic-Tac-Toe

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The Matrix

Image used under "fair use" for educational purposes.
Source: https://www.themarysue.com/decoding-the-transgender-matrix-the-matrix-as-a-transgender-coming-out-story/

2D Arrays ("Matrices")

2D Arrays

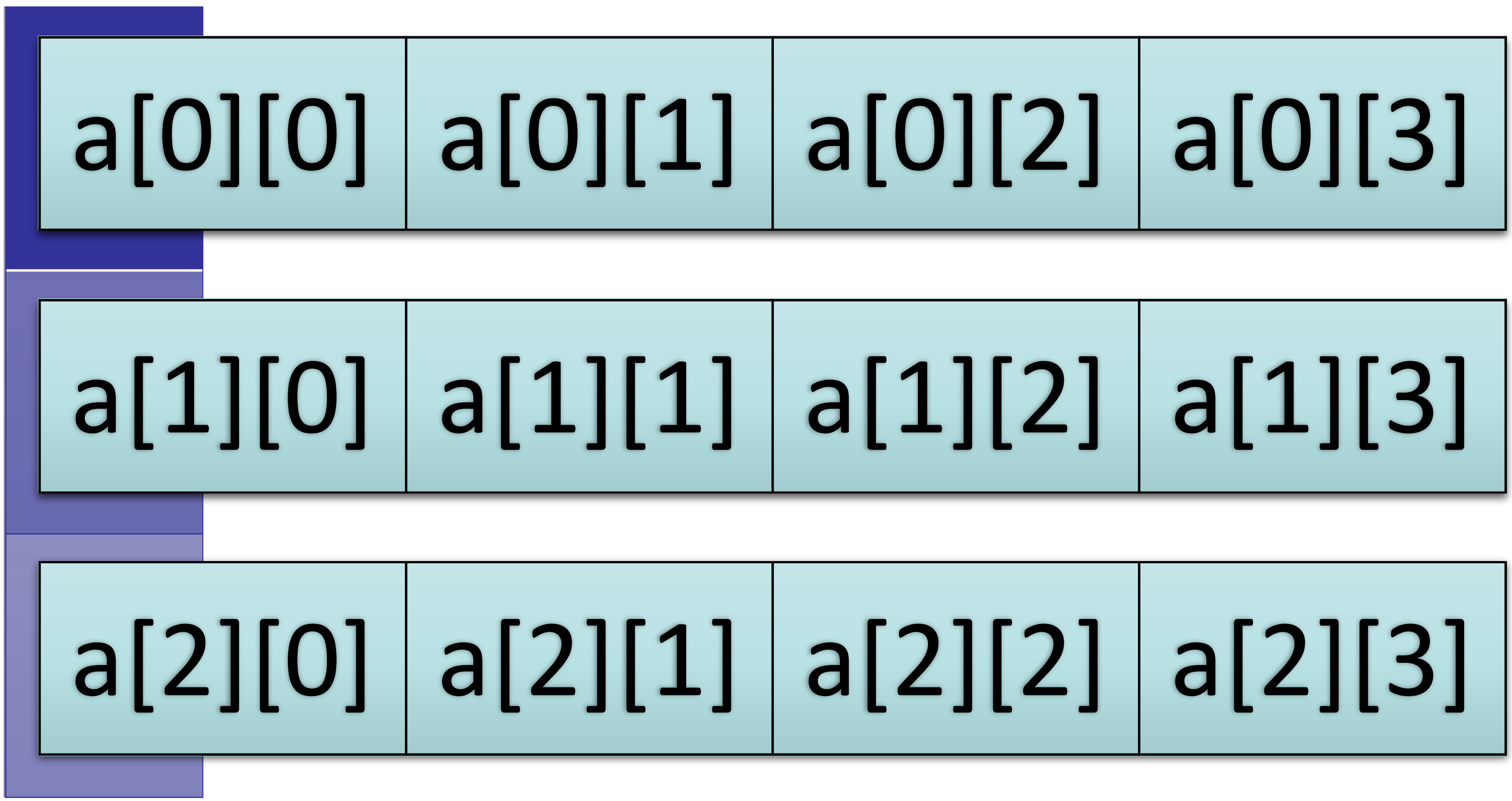
```
type[][] name = new type[rows][columns];
```

```
int[][] a = new int[3][5];
```

	0	1	2	3	4
0	a[0][0]	a[0][1]	a[0][2]	a[0][3]	a[0][4]
1	a[1][0]	a[1][1]	a[1][2]	a[1][3]	a[1][4]
2	a[2][0]	a[2][1]	a[2][2]	a[2][3]	a[2][4]

2D Arrays = Arrays of Arrays!

```
int[][] a = new int[3][4];
int[] firstRow = a[0];
```



Summary: 2D Arrays

- Make a new 2D array

```
type[][] name = new type[rows][columns];
```

- Get and set values using bracket notation

```
name[row][col]              // get elem at row,col
name[row][col] = value;     // set elem at row,col
```

- Get the number of rows and columns

```
arr.length     // # rows
arr[0].length  // # columns
```

- Iterate over a 2D array using a double for-loop

```
for (int row = 0; row < arr.length; row++) {
    for (int col = 0; col < arr[0].length; col++) {
        // do something with arr[row][col];
    }
}
```

Limitations of 2D Arrays

- Unlike 1D arrays, you *cannot compare 2D arrays with* **`Arrays.equals`**. You must use **`Arrays.deepEquals`**.

```
int[][] a1 = ...
int[][] a2 = ...
if (Arrays.deepEquals(a1, a2)) {  ... }
```

- A 2D array does not know how to print itself:

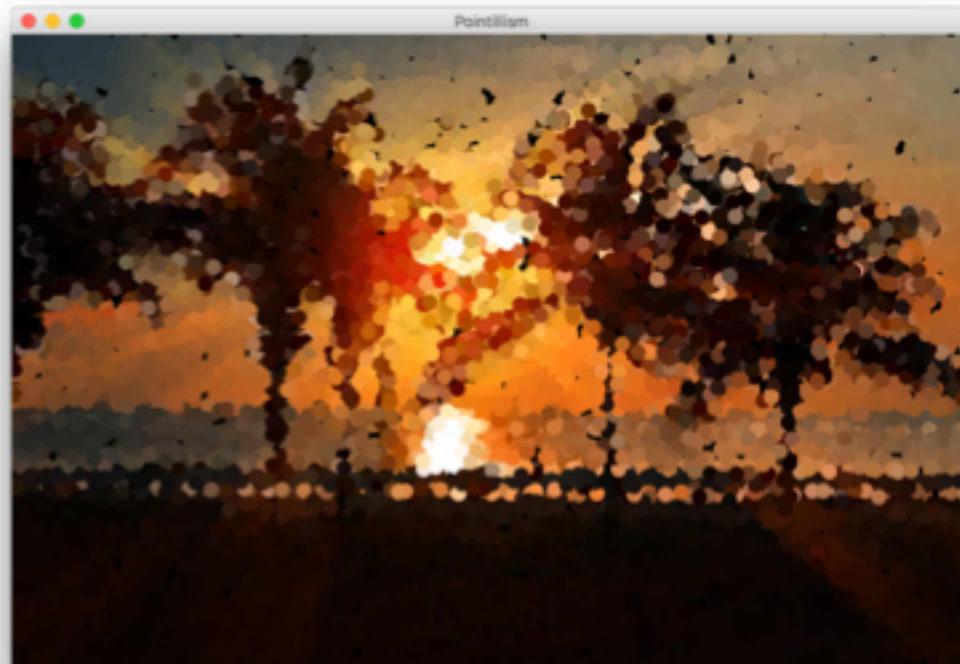
```
int[][] a = new int[rows][cols];
println(a);                         // [[I@8cf420
println(Arrays.toString(a));    // [[I@6b3f44,[I@32c2a8]...

// [[0, 1, 2, 3, 4], [1, 2, ...
println(Arrays.deepToString(a));
```

Images

Images are just grids (2D arrays) of pixels! Pixels are just integer values that have red, green, and blue components (each between 0 and 255).

Example: Pointillism

Pointillism is an art style where many small dots of color are combined to make a larger image.



Red, Green and Blue in one int?

Images *encode* the R, G, and B values (between 0 and 255) of a pixel into a single integer. You can convert between this **pixel value** and the individual **RGB values**.

```
int[][] pixels = image.getPixelArray();
int px = pixels[0][0];
int red = GImage.getRed(px);
int green = GImage.getGreen(px);
int blue = GImage.getBlue(px);
```

Creating New Pixels

Images *encode* the R, G, and B values (between 0 and 255) of a pixel into a single integer. You can convert between this **pixel value** and the individual **RGB values**.

You can also create pixels with your own RGB values.

```
int r = ...
int g = ...
int b = ...
int pixel = GImage.createRGBPixel(r, g, b);
```

Images as 2D Arrays

We can get a GImage as a 2D array of pixels, and modify it any way we want. Then, we can create a new GImage with the modified pixels.

```
GImage img = new GImage("res/snowman.jpg");
int[][] pixels = img.getPixelArray();
... // (modify pixels)
img.setPixelArray(pixels);  // update image

// or make a new GImage
GImage newImg = new GImage(pixels);
```

Modifying Image Pixels

- There are many cool image algorithms based around modifying individual pixels in an image: grayscale, brighten, normalize, remove red-eye…

grayscale

zoom

GImage Pixel Methods

```
GImage img = new GImage("res/daisy.jpg");
```

Method name	Description
img`.getPixelArray()`	returns pixels as 2D array of ints, where each int in the array contains all 3 of Red, Green, and Blue merged into a single integer
img`.setPixelArray(`***array***`);`	updates pixels using the given 2D array of ints
`GImage.createRGBPixel(`***r***`, `***g***`, `***b***`)`	returns an int that merges the given amounts of red, green and blue (each 0-255)

`GImage.getRed(`***px***`)`
`GImage.getGreen(`***px***`)`
`GImage.getBlue(`***px***`)`
	returns the redness, greenness, or blueness of the given pixel as an integer from 0-255

Recap: Modifying Pixels

- **Extract** pixel RGB colors with `GImage.getRed/Blue/Green`.

```
int red   = GImage.getRed(pixels[0][0]);    // 0-255
int green = GImage.getGreen(pixels[0][0]);  // 0-255
int blue  = GImage.getBlue(pixels[0][0]);   // 0-255
```

- **Modify** the color components for a given pixel.

```
red = 0;    // remove redness
```

- **Combine** the RGB back together into a single `int`.

```
pixels[0][0] = GImage.createRGBPixel(red, green, blue);
```

- **Update** the image with your modified pixels when finished.

```
image.setPixelArray(pixels);
```

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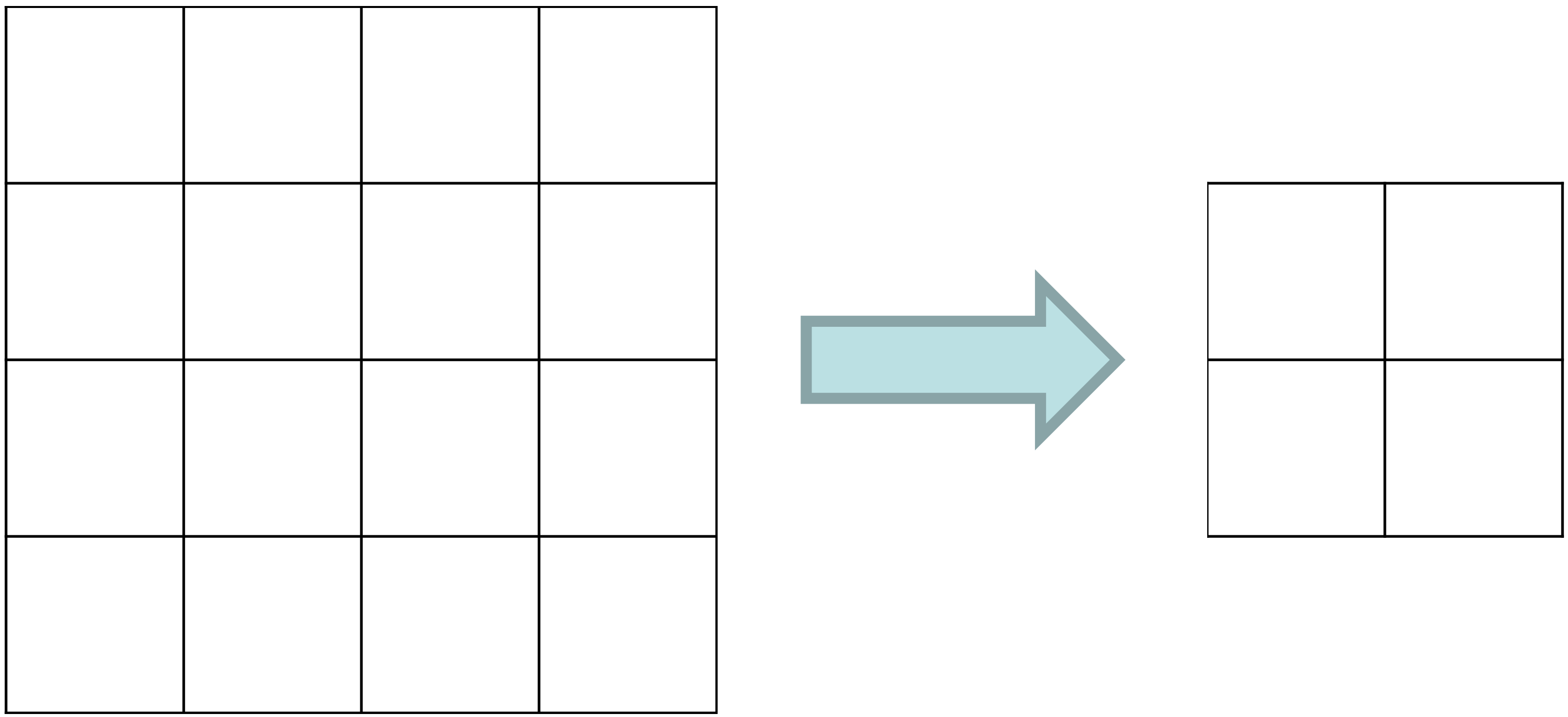
Shrink

Let's write a program that can *shrink* an image to ½ its original size.

Shrink

Given a pixel (x, y) in our smaller image, how do we know which pixel in our larger image should go there?



Shrink

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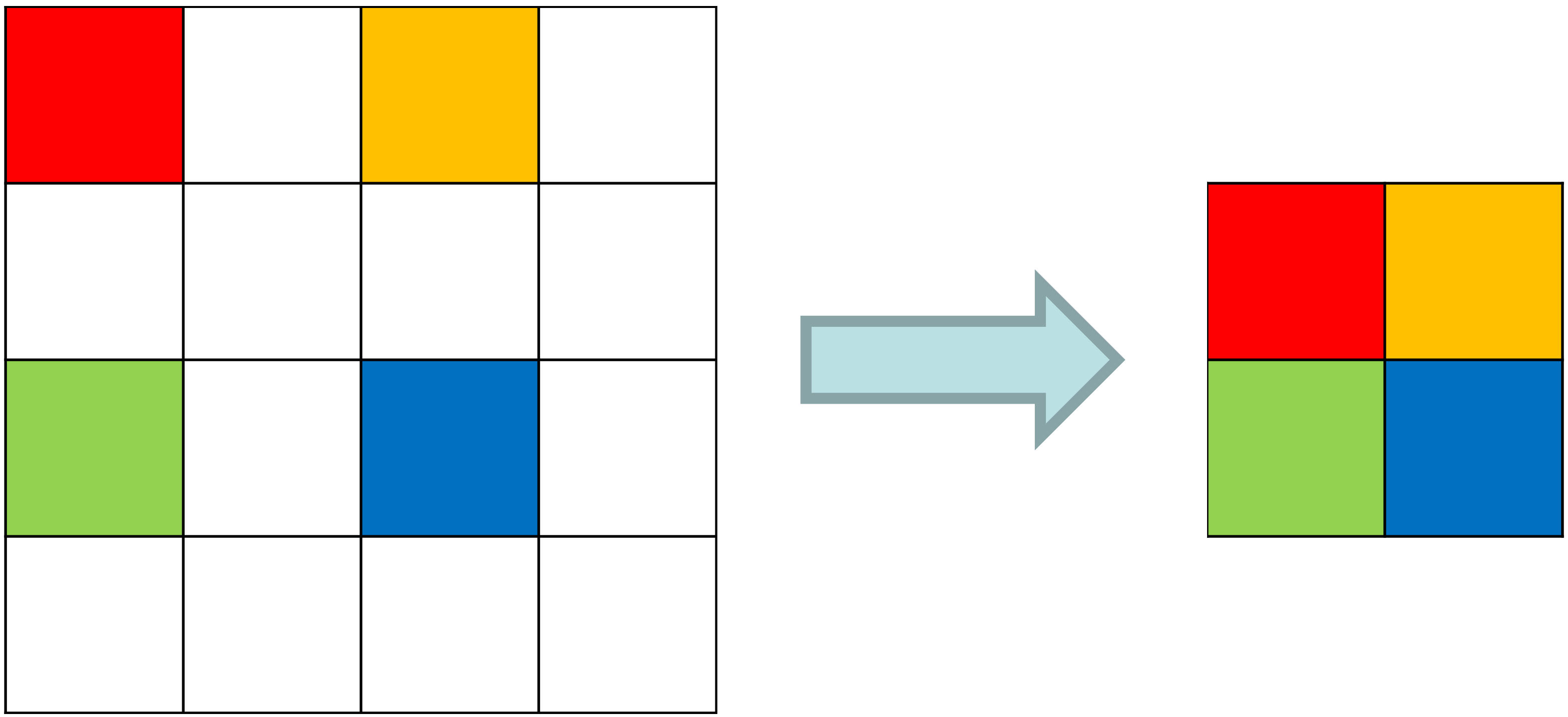

Shrink

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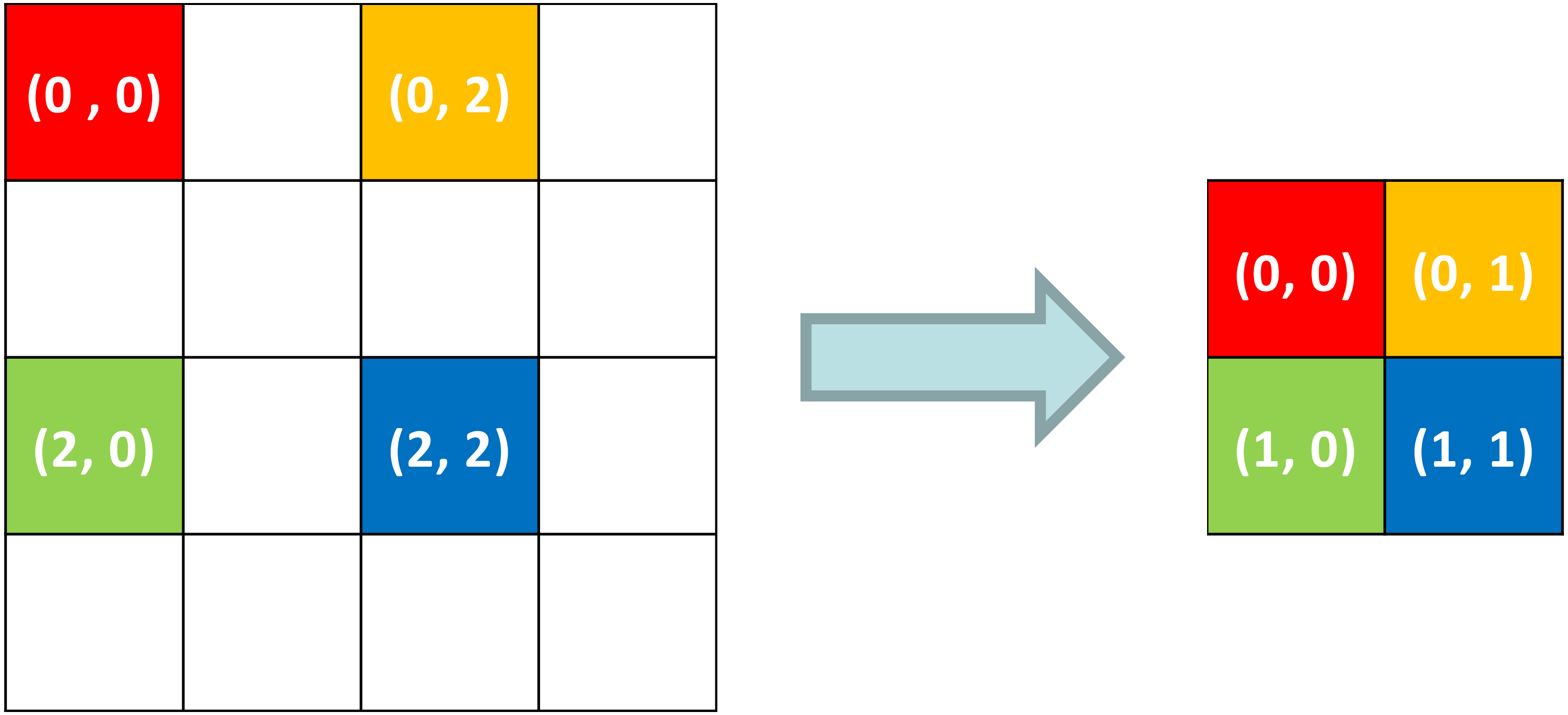
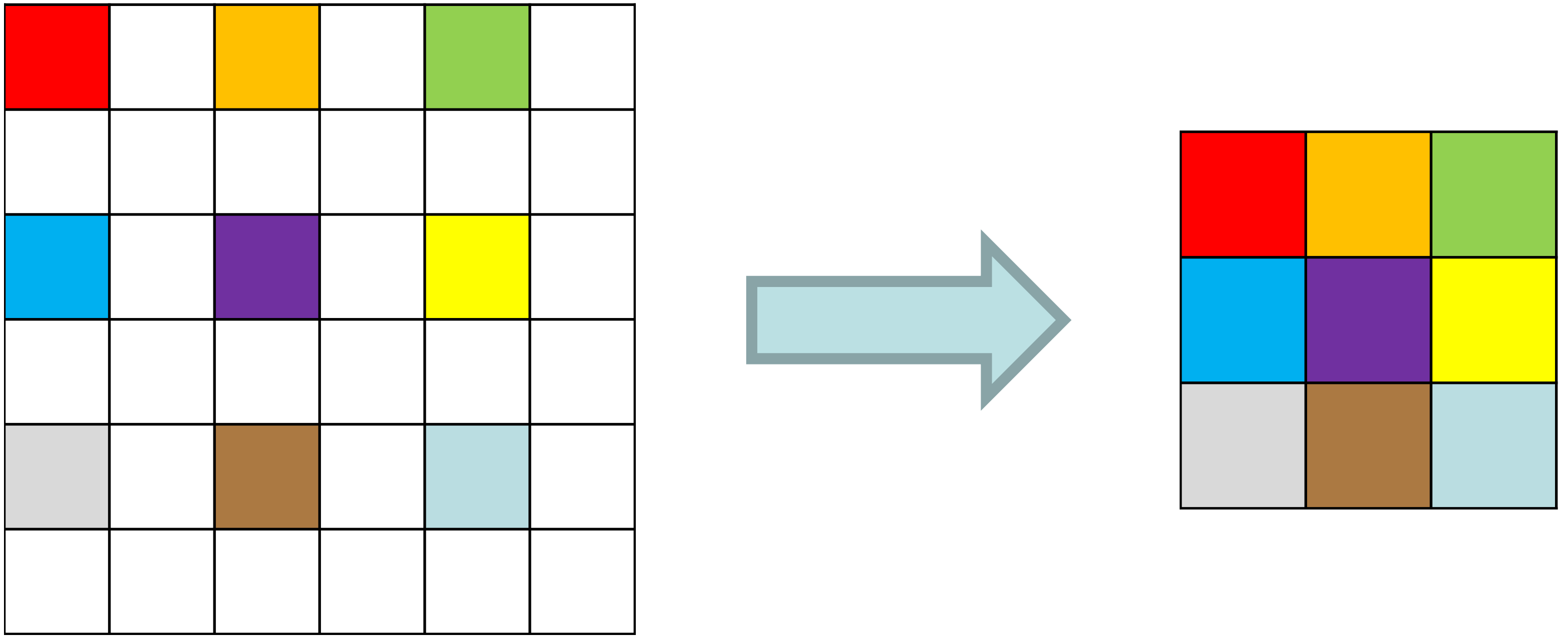


Shrink

Given a pixel (x, y) in our smaller image, how do we know which pixel in our larger image should go there?



Shrink

```
int[][] pixels = image.getPixelArray();
int[][] result =
      new int[pixels.length/2][pixels[0].length/2];

for (int r = 0; r < result.length; r++) {
      for (int c = 0; c < result[0].length; c++) {
            result[r][c] = pixels[r*2][c*2];
      }
}

image.setPixelArray(result);
```

Shrink

```
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    }
}

image.setPixelArray(result);
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Shrink

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Shrink

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          result[r][c] = pixels[r*2][c*2];
     }
}

image.setPixelArray(result);
```

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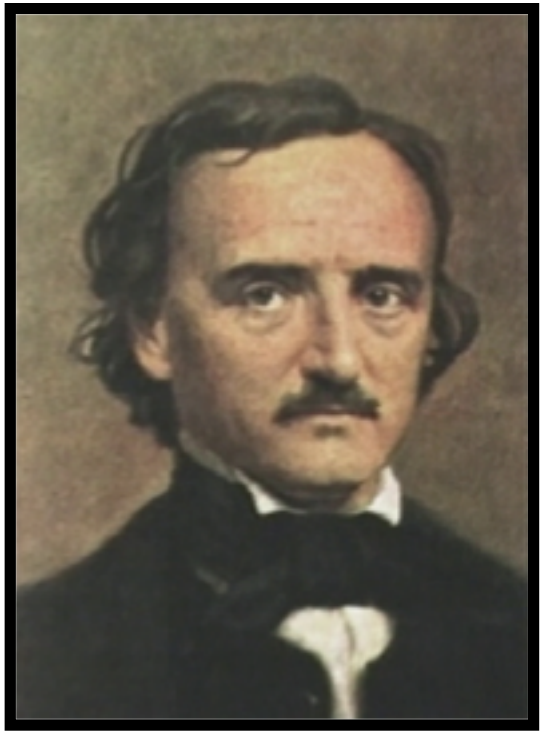
Cryptogram

A ***cryptogram*** is a puzzle in which a message is encoded by replacing each letter in the original text with some other letter. Your job in solving a cryptogram is figuring out this substitution pattern.

A common technique is assuming the most common letters in the coded message correspond to the most common letters in English.

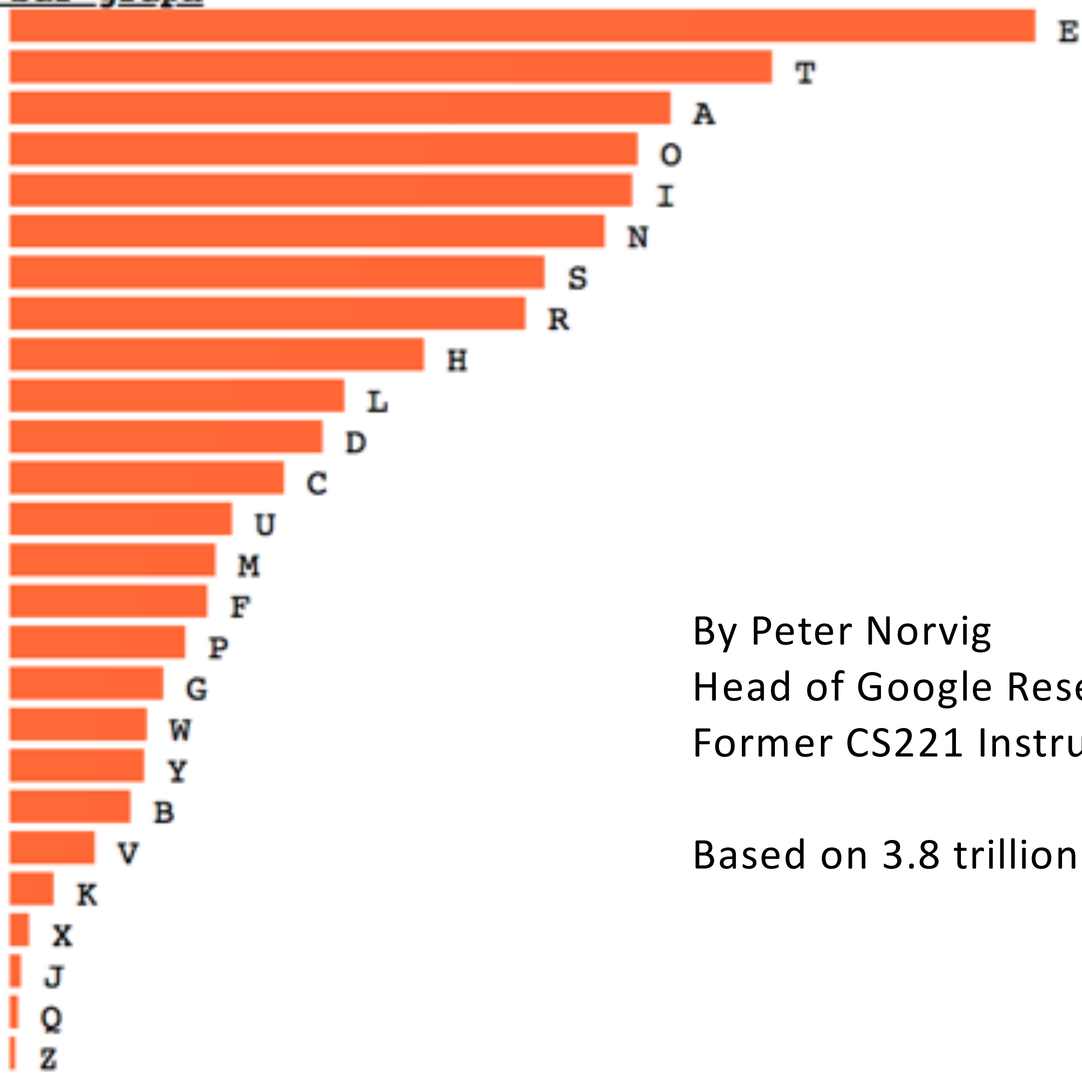


Edgar Allan Poe (1809-1849)

Letter Frequency

LET	COUNT	PERCENT
E	445.2 B	12.49%
T	330.5 B	9.28%
A	286.5 B	8.04%
O	272.3 B	7.64%
I	269.7 B	7.57%
N	257.8 B	7.23%
S	232.1 B	6.51%
R	223.8 B	6.28%
H	180.1 B	5.05%
L	145.0 B	4.07%
D	136.0 B	3.82%
C	119.2 B	3.34%
U	97.3 B	2.73%
M	89.5 B	2.51%
F	85.6 B	2.40%
P	76.1 B	2.14%
G	66.6 B	1.87%
W	59.7 B	1.68%
Y	59.3 B	1.66%
B	52.9 B	1.48%
V	37.5 B	1.05%
K	19.3 B	0.54%
X	8.4 B	0.23%
J	5.7 B	0.16%
Q	4.3 B	0.12%
Z	3.2 B	0.09%

bar graph



By Peter Norvig
Head of Google Research
Former CS221 Instructor

Based on 3.8 trillion letters

Poe's Cryptographic Puzzle

53‡‡†305))6*;4826)4‡•)4‡);806*;48†8¶
60))85;1‡(;:‡*8†83(88)5*†;46(;88*96*
?;8)*‡(;485);5*†2:*‡(;4956*2(5*—4)8¶
8*;4069285);)6†8)4‡‡;1(‡9;48081;8:8‡
1;48†85;4)485†528806*81(‡9;48;(88;4(
‡?34;48)4‡;161;:188;‡?;

8	33
;	26
4	19
‡	16
)	16
*	13
5	12
6	11
(	10
†	8
1	8
0	6
9	5
2	5
:	4
3	4
?	3
¶	2
—	1
•	1

AGOODGLASSINTHEBISHOPSHOSTELINTHEDEV
ILSSEATFORTYONEDEGREESANDTHIRTEENMIN
UTESNORTHEASTANDBYNORTHMAINBRANCHSEV
ENTHLIMBEASTSIDESHOOTFROMTHELEFTEYEO
FTHEDEATHSHEADABEELINEFROMTHETREETHR
OUGHTHESHOTFIFTYFEETOUT

Poe’s Cryptographic Puzzle

```
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```

```
AGOODGLASSINTHEBISHOPSHOSTELINTHEDEV
ILSSEATFORTYONEDEGREESANDTHIRTEENMIN
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ENTHLIMBEASTSIDESHOOTFROMTHELEFTEYEO
FTHEDEATHSHEADABEELINEFROMTHETREETHR
OUGHTHESHOTFIFTYFEETOUT
```

8	33
;	26
4	19
‡	16
)	16
*	13
5	12
6	11
(	10
†	8
1	8
0	6
9	5
2	5
:	4
3	4
?	3
¶	2
–	1
•	1

Idea: Array of Counters

- For problems like this, where we want to keep count of many things, a *frequency table* (or *tally array*) can be a clever solution.
  - *Idea:* The element at index *i* will store a counter for the character value *'A' + i*.
  - example: count of letter frequency for "FIDDLE"

letter	...	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*J*	*L*	...
index	...	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	...
value		2	1	**1**	0	0	1	0	0	1	

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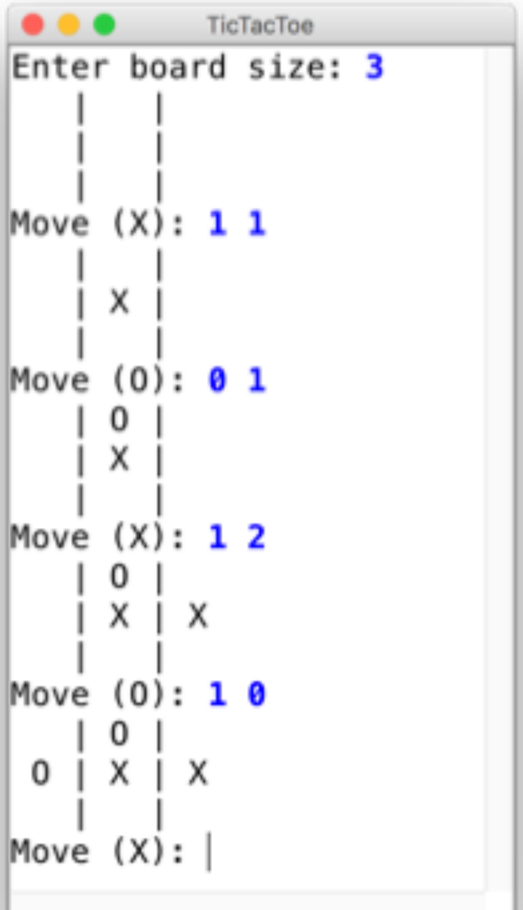
Tic-Tac-Toe

Let’s use 2D arrays to create a ConsoleProgram version of Tic-Tac-Toe.



Recap

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Next Time: More data structures