



Machine Vision

Introduction

MCHE 470: Robotics

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Why Machine Vision?



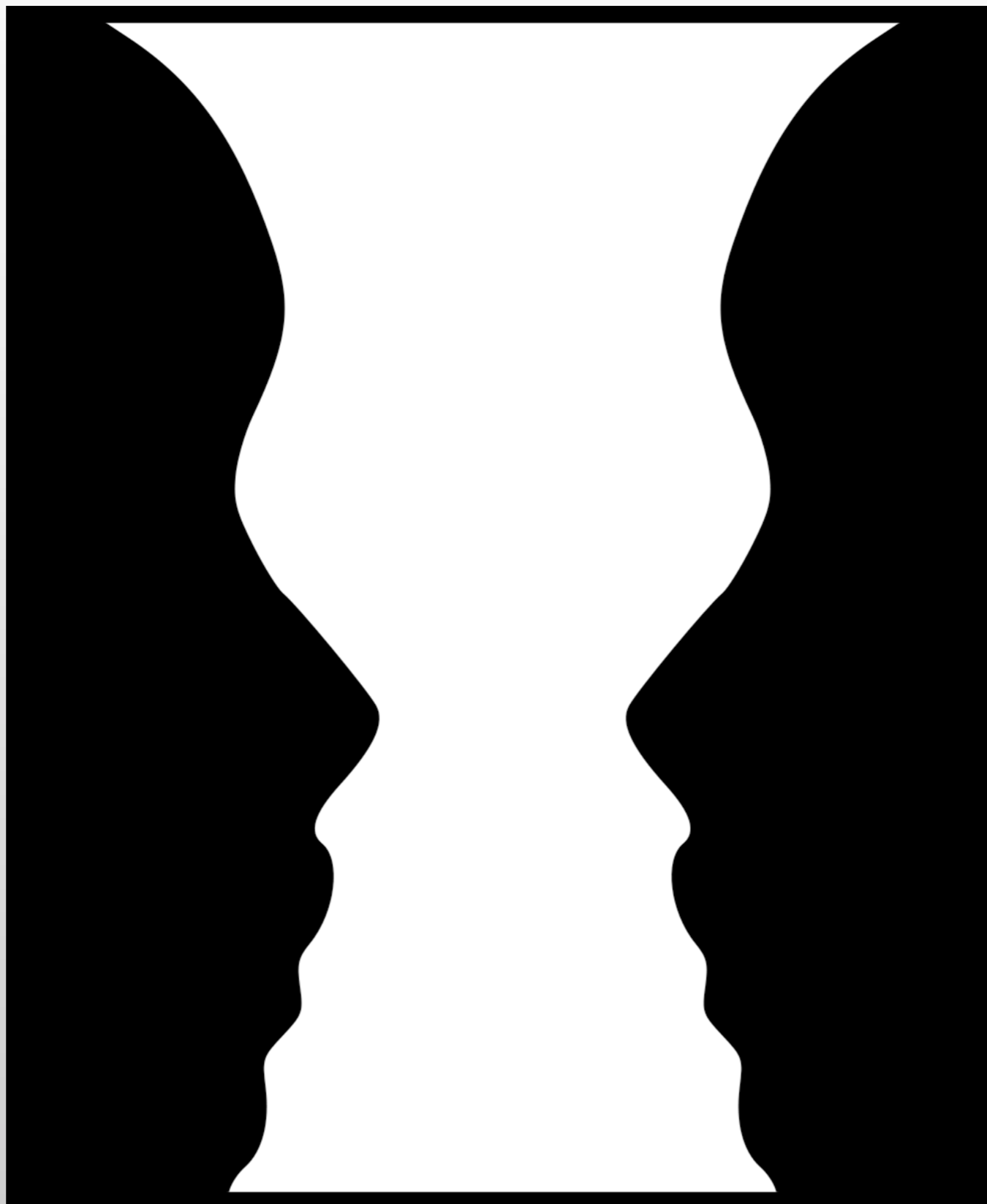
- Or... what can machine vision do for us?

Extremely Multi-disciplinary

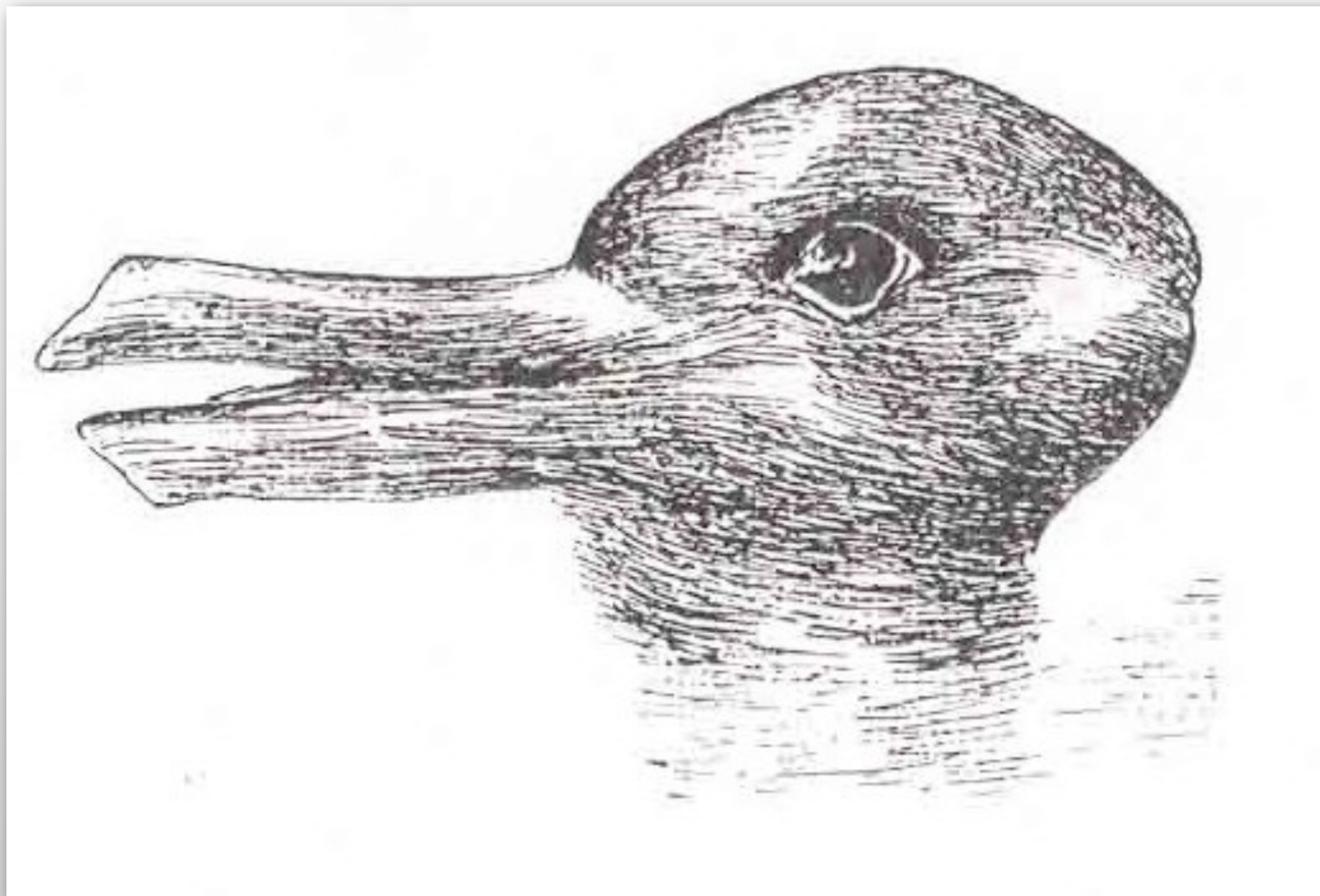


- Sensor Design
- Filter Design
- Optics
- Artificial Intelligence
- Linear Algebra
- ...

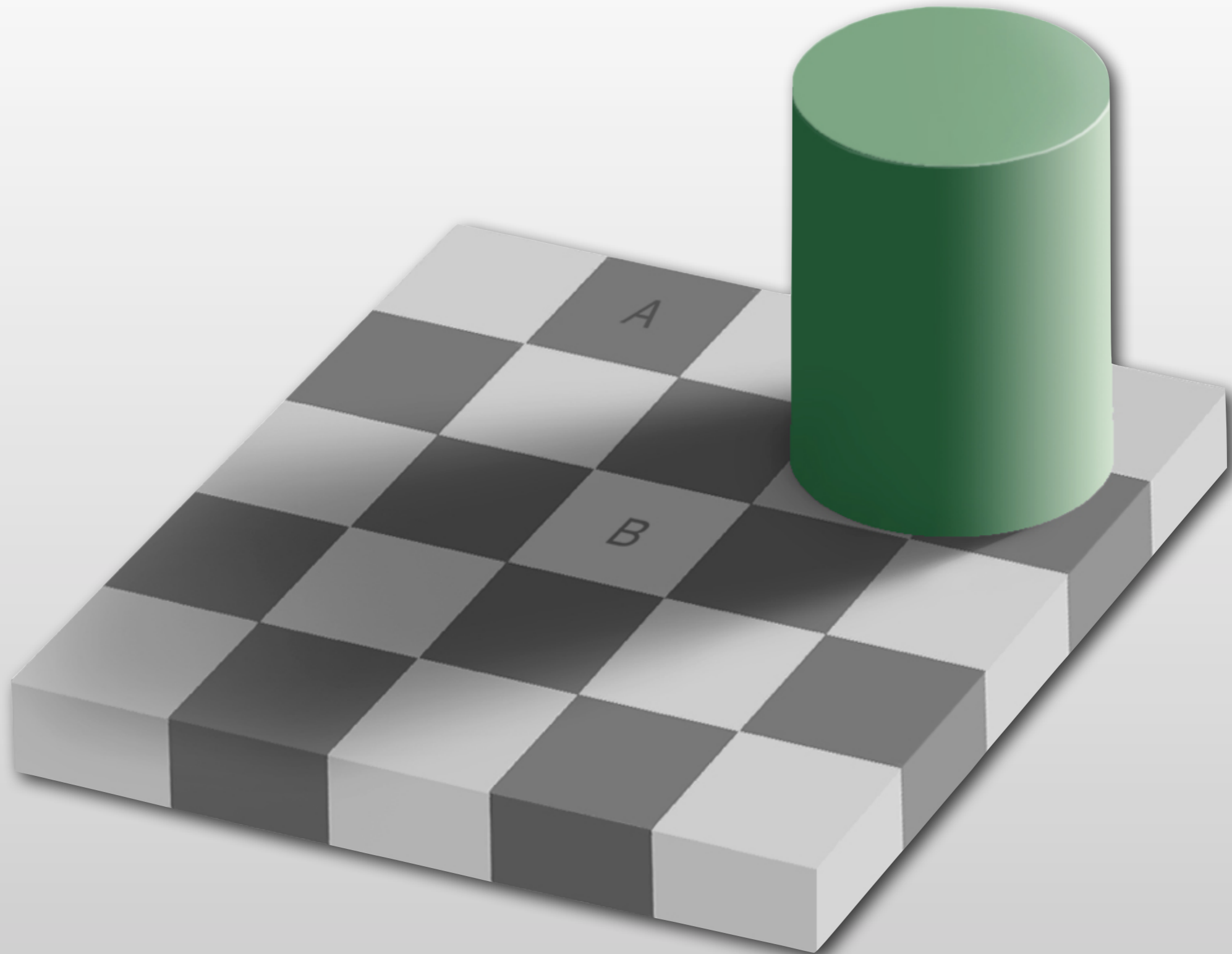
Doing all of that stuff is hard.



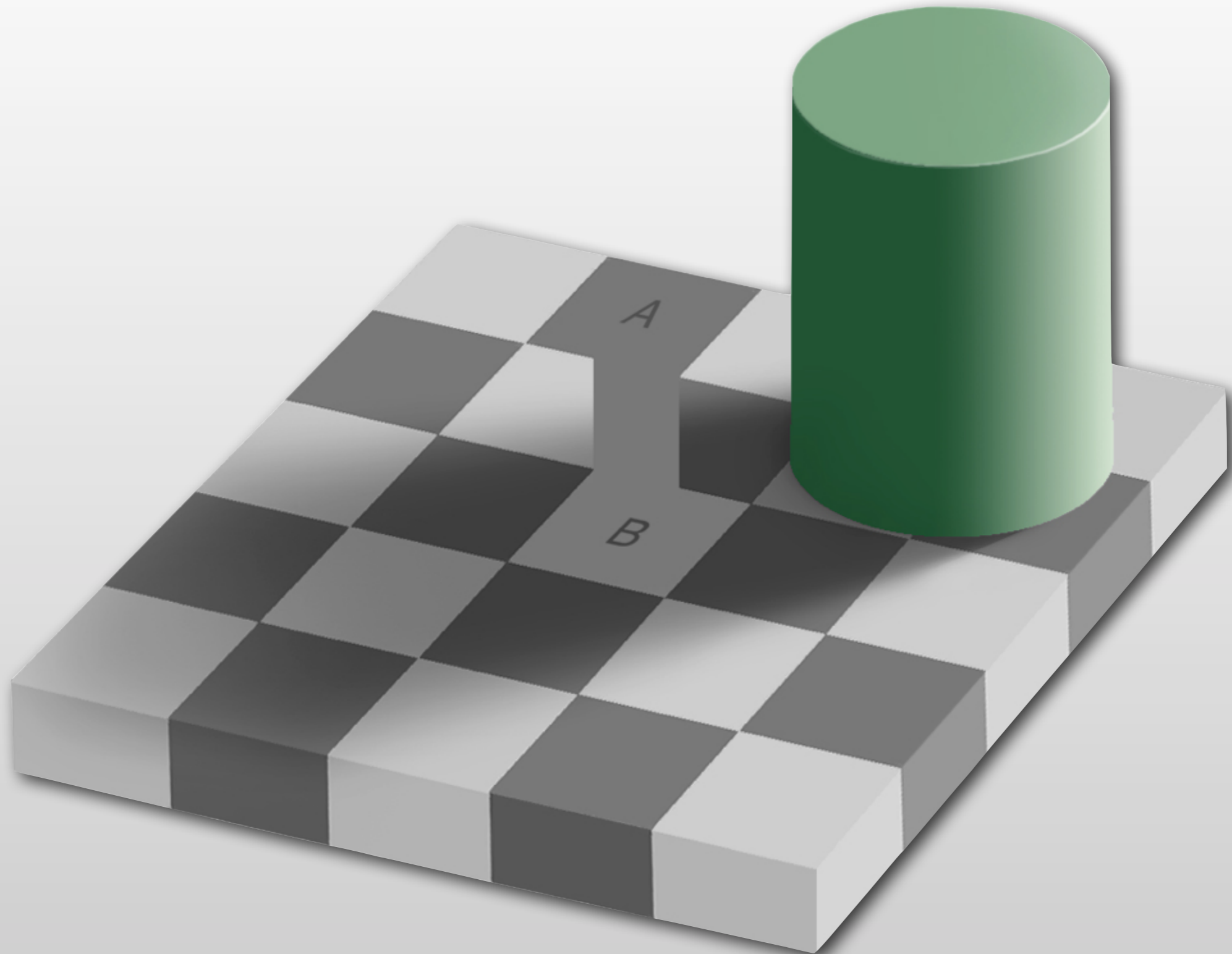
Doing all of that stuff is hard.



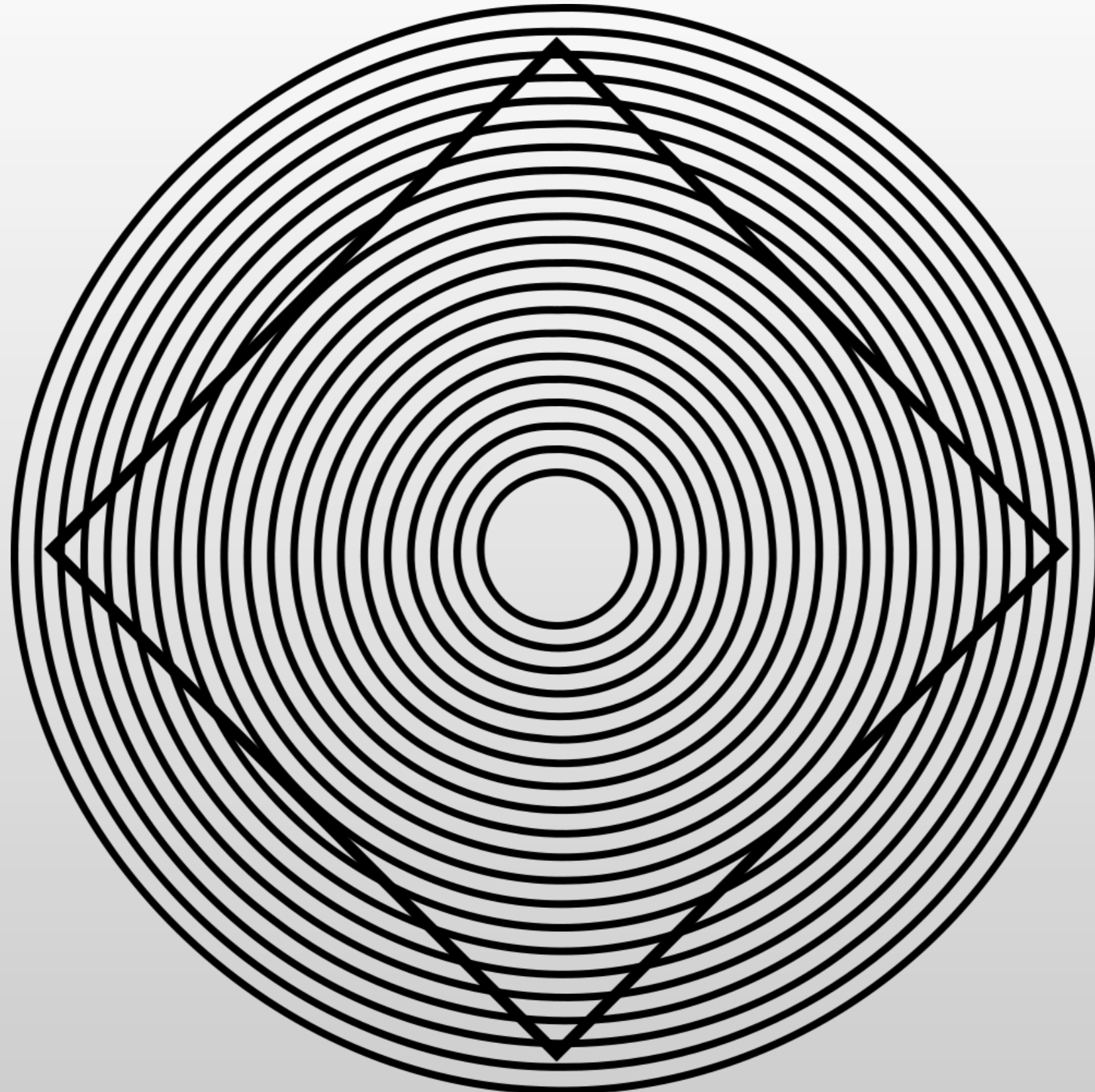
Are A & B the same?



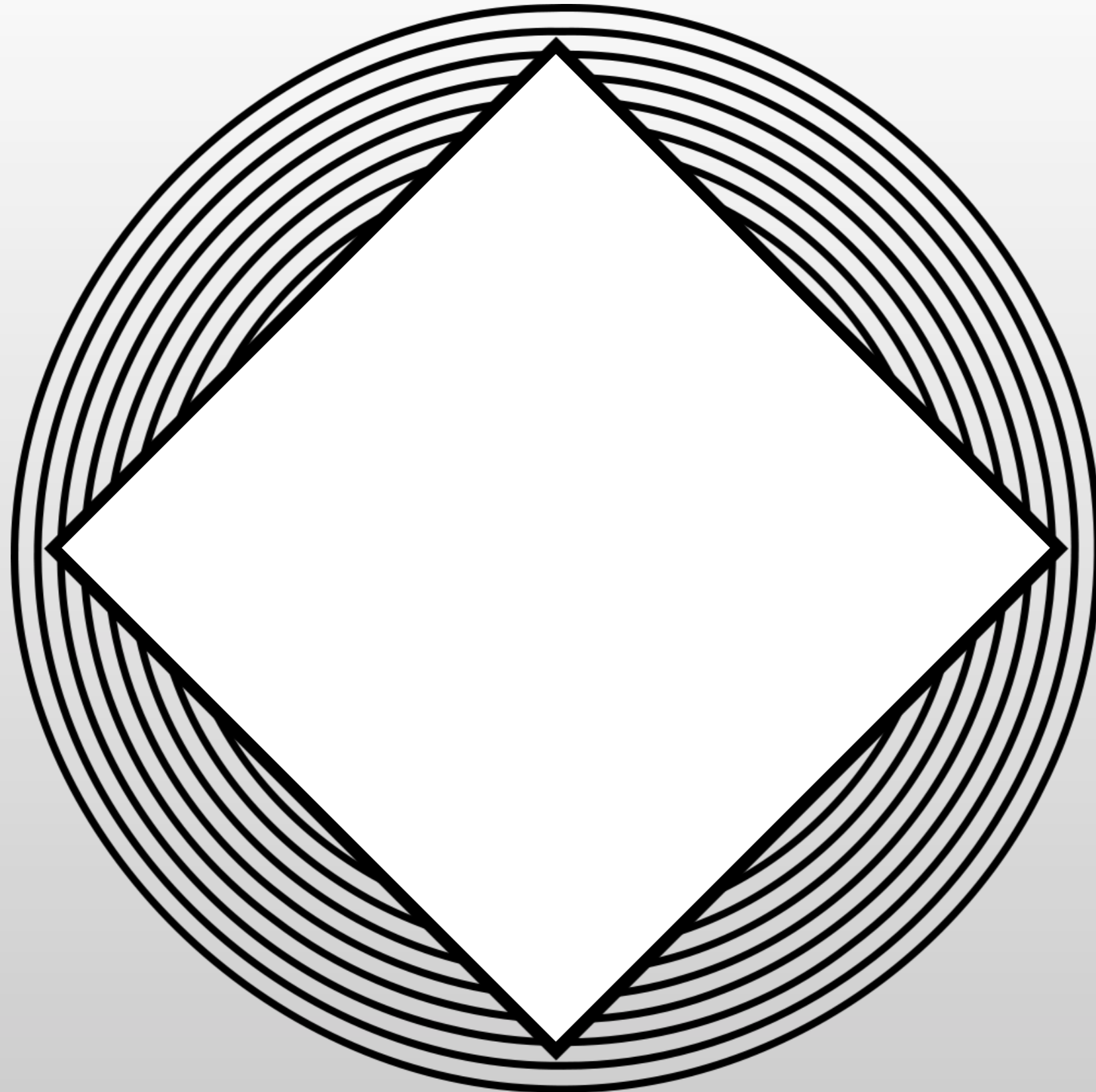
Are A & B the same?



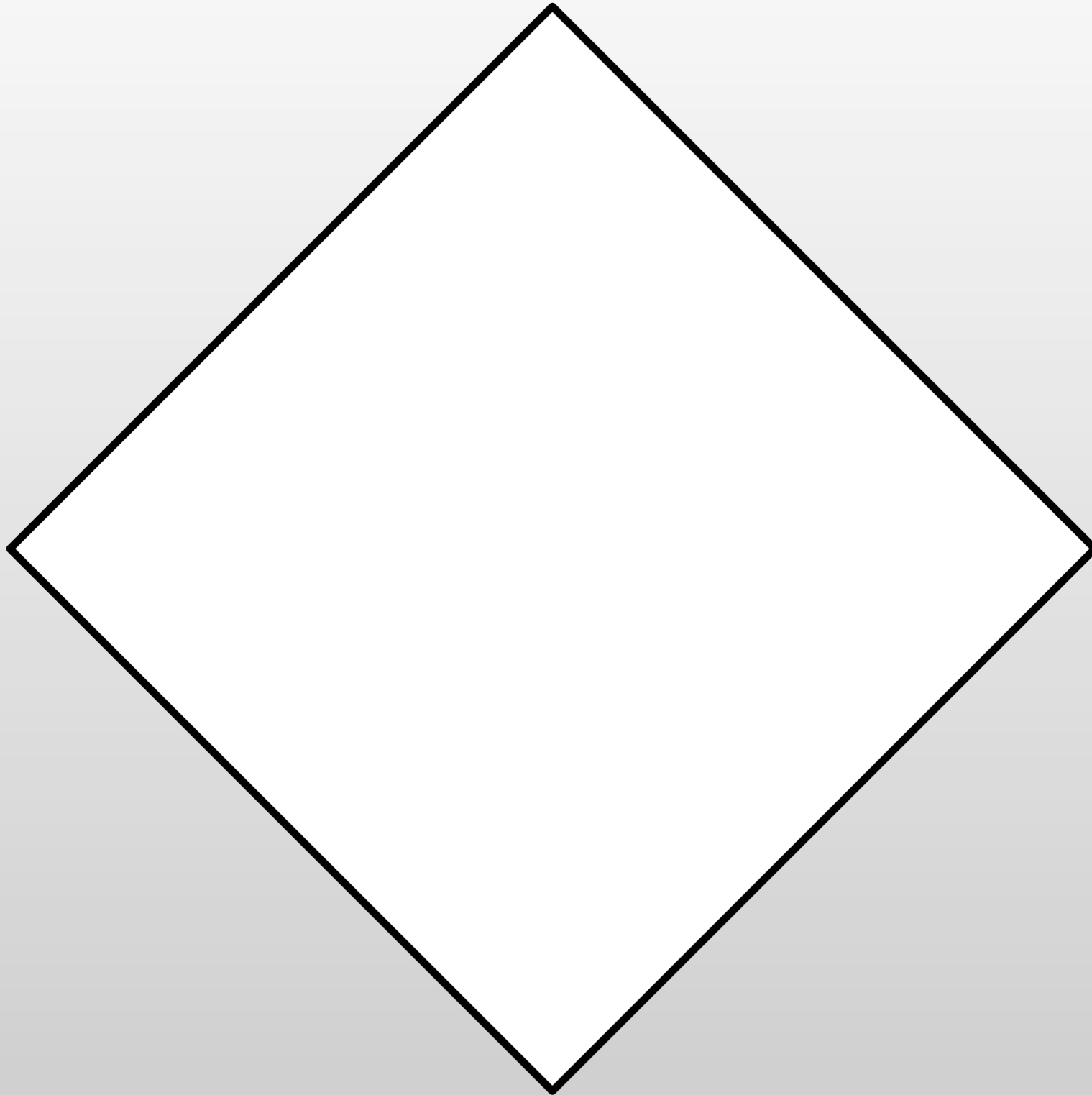
Square?



Square?



Square?



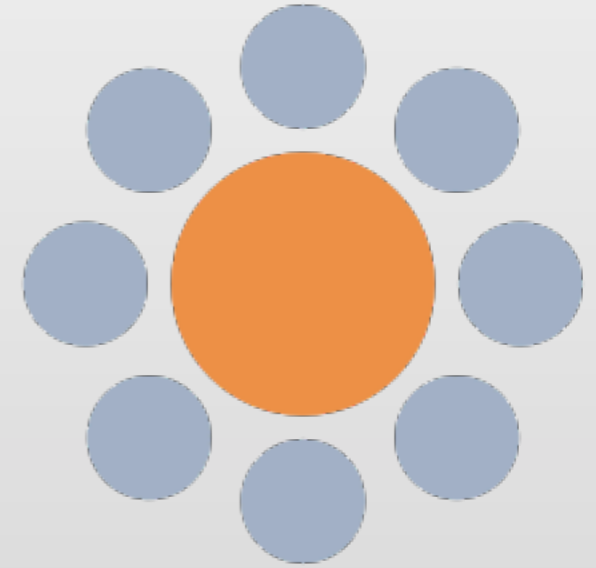
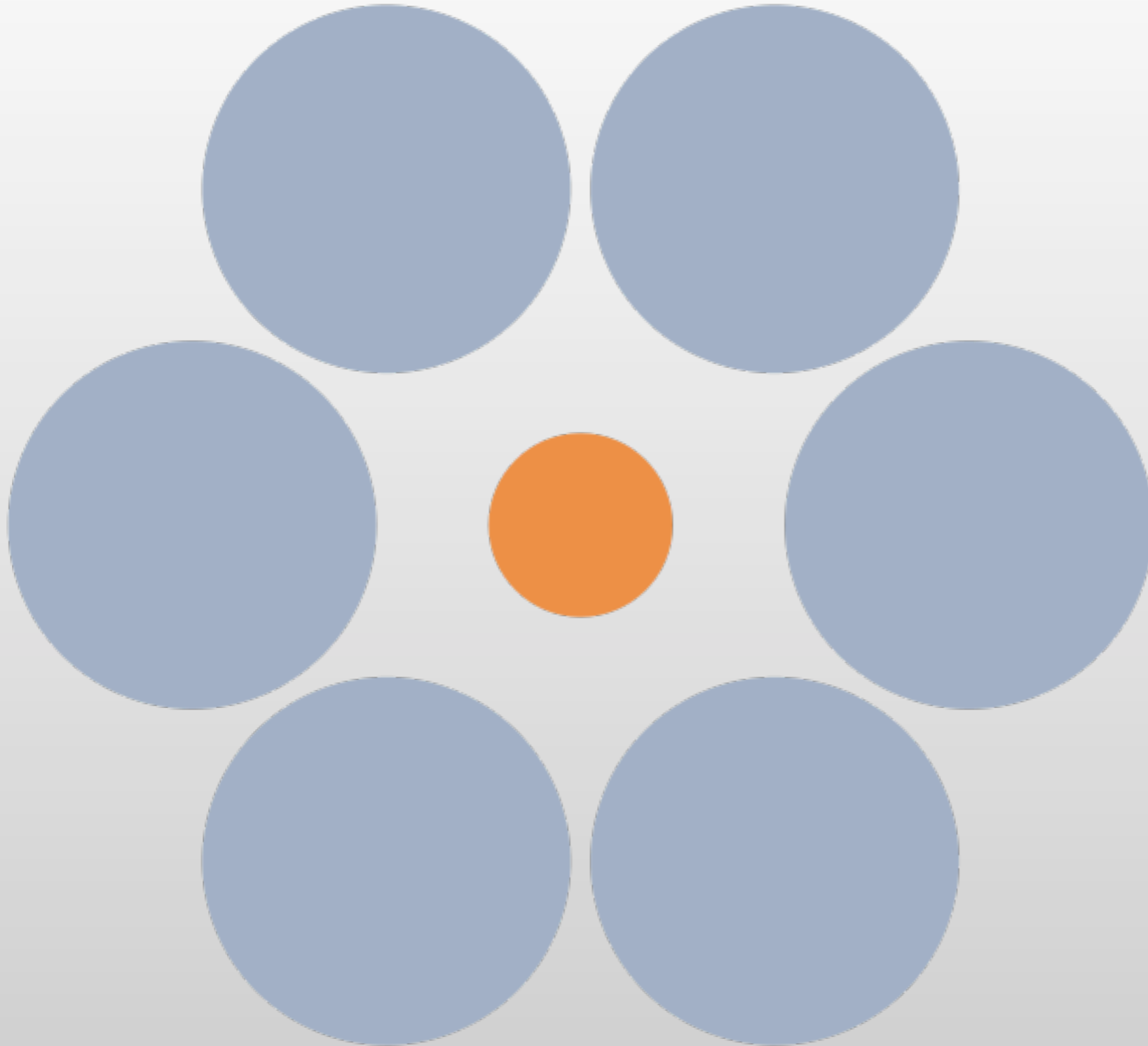
Which is longer?



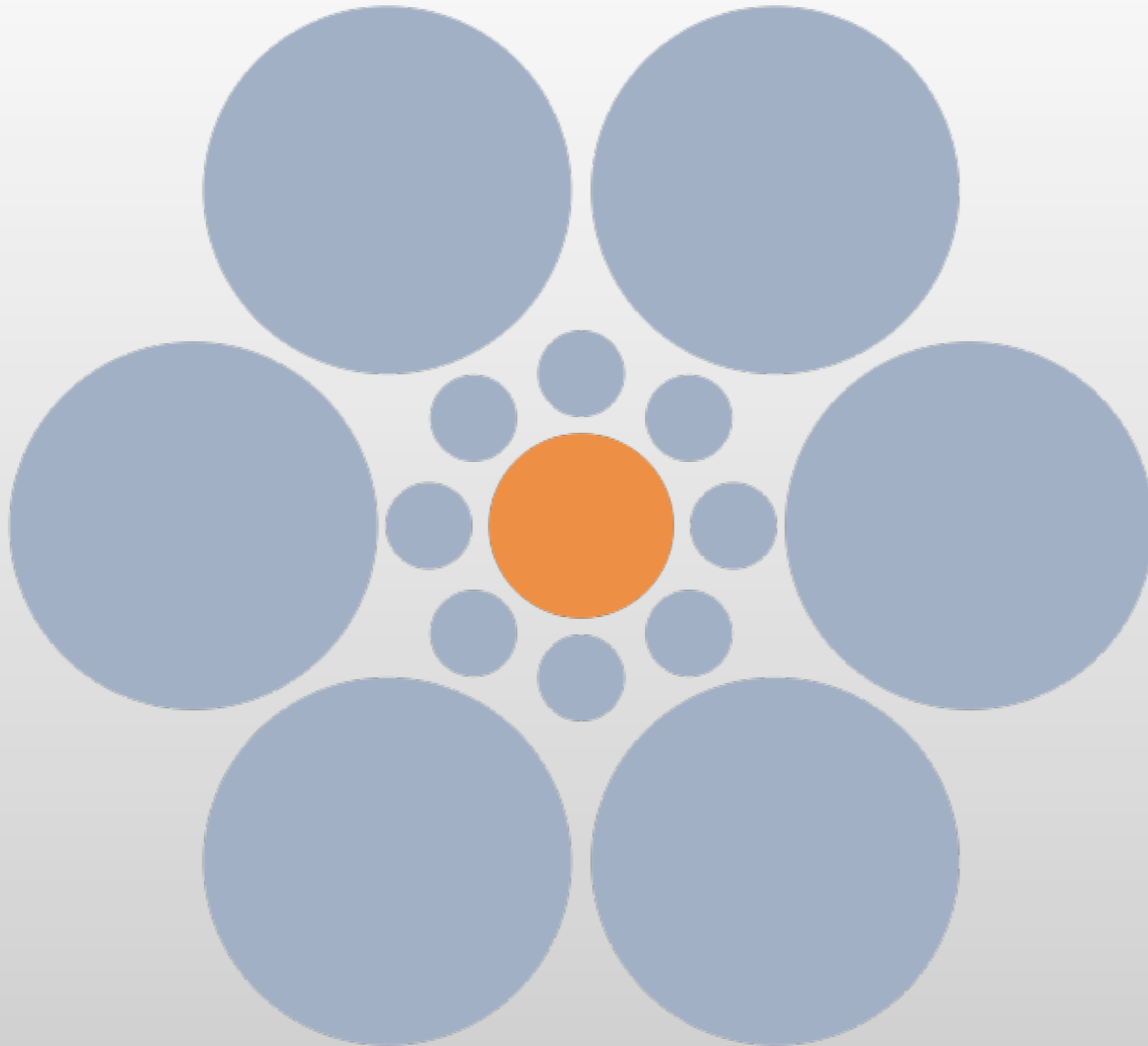
Which is longer?



Which is bigger?



Which is bigger?



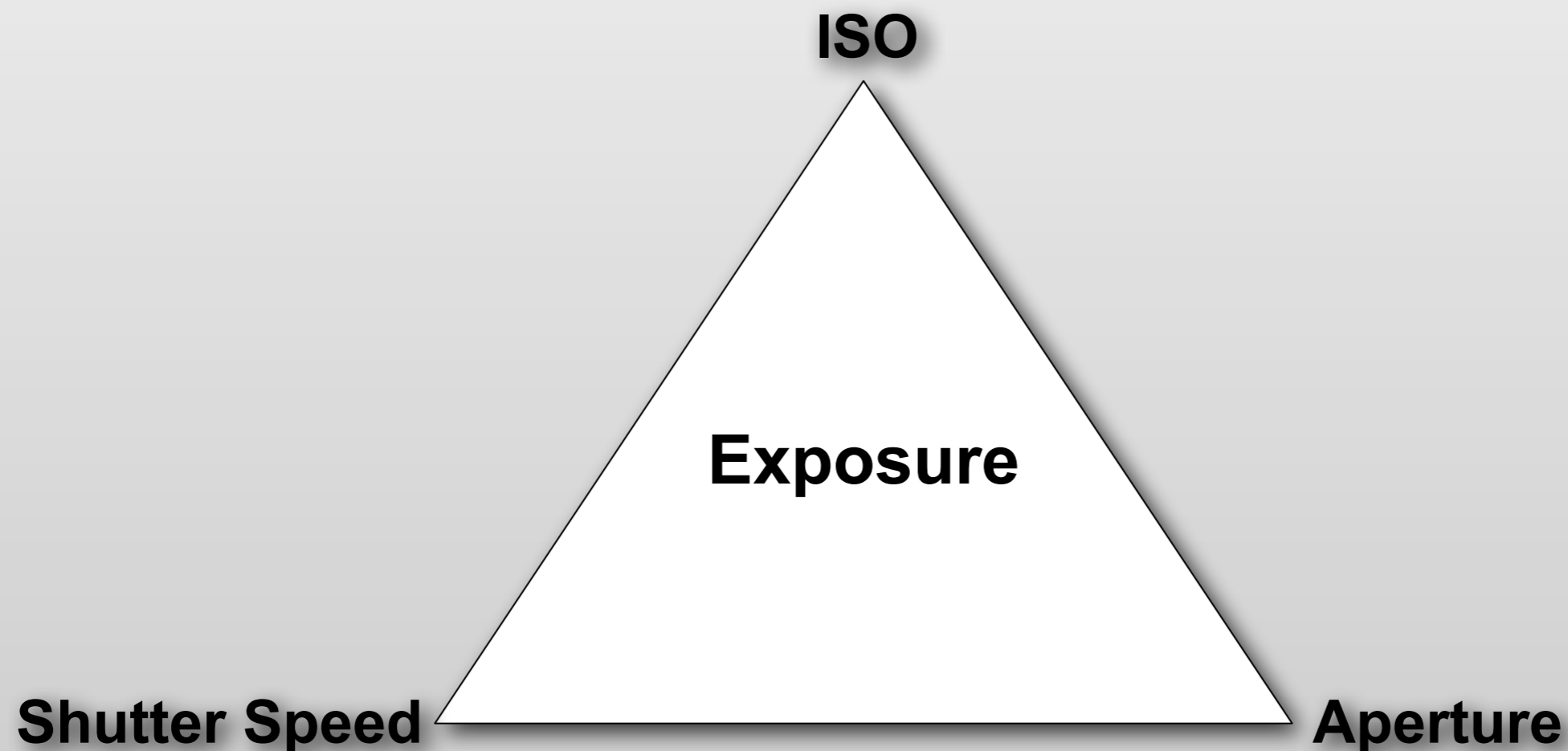


A Short Photography School

What affects exposure?



- ISO: How sensitive the sensor is to light
- Aperture: How big the lens opening is
- Shutter Speed: How long the shutter stays open



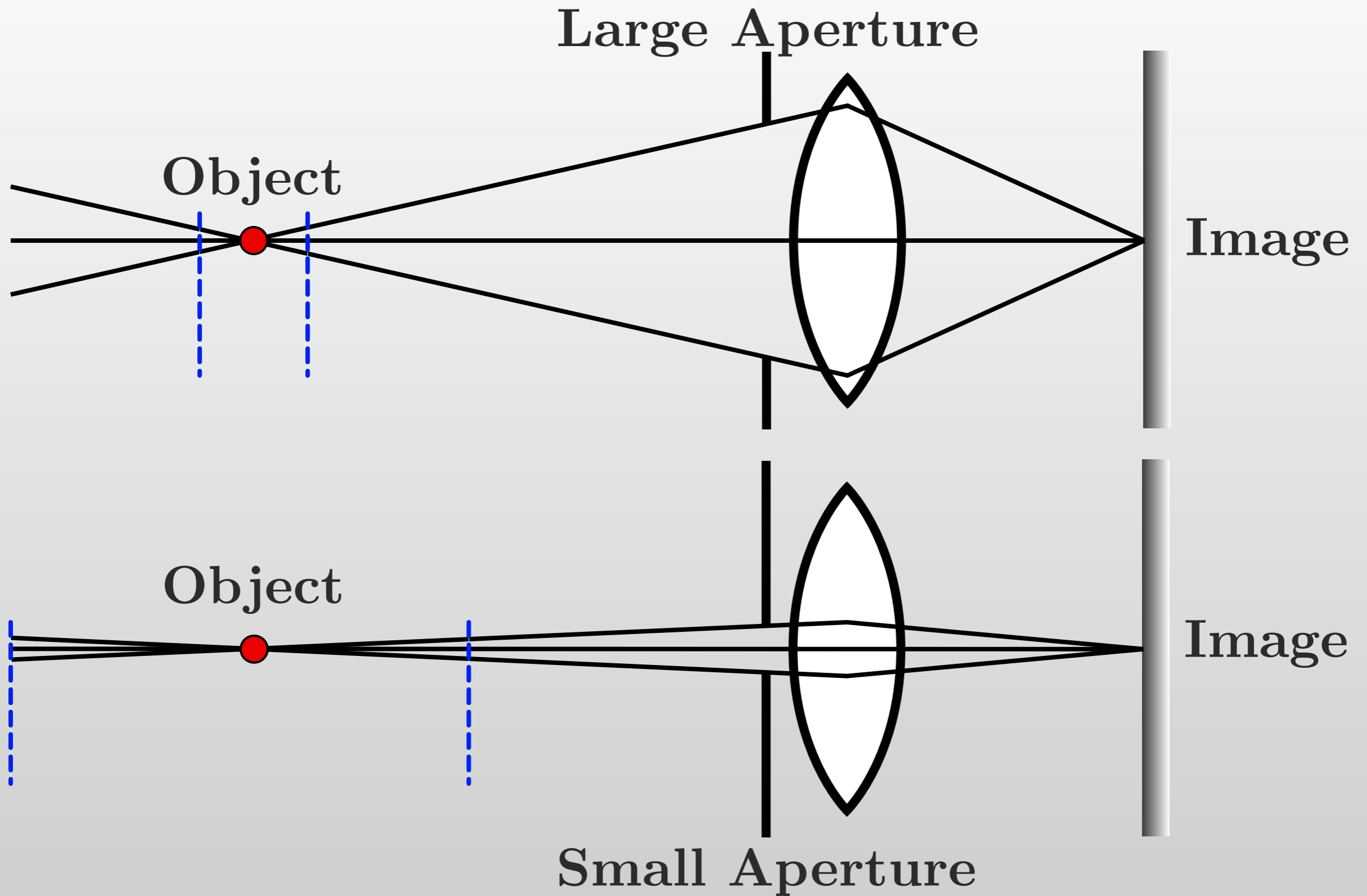
Depth of Field



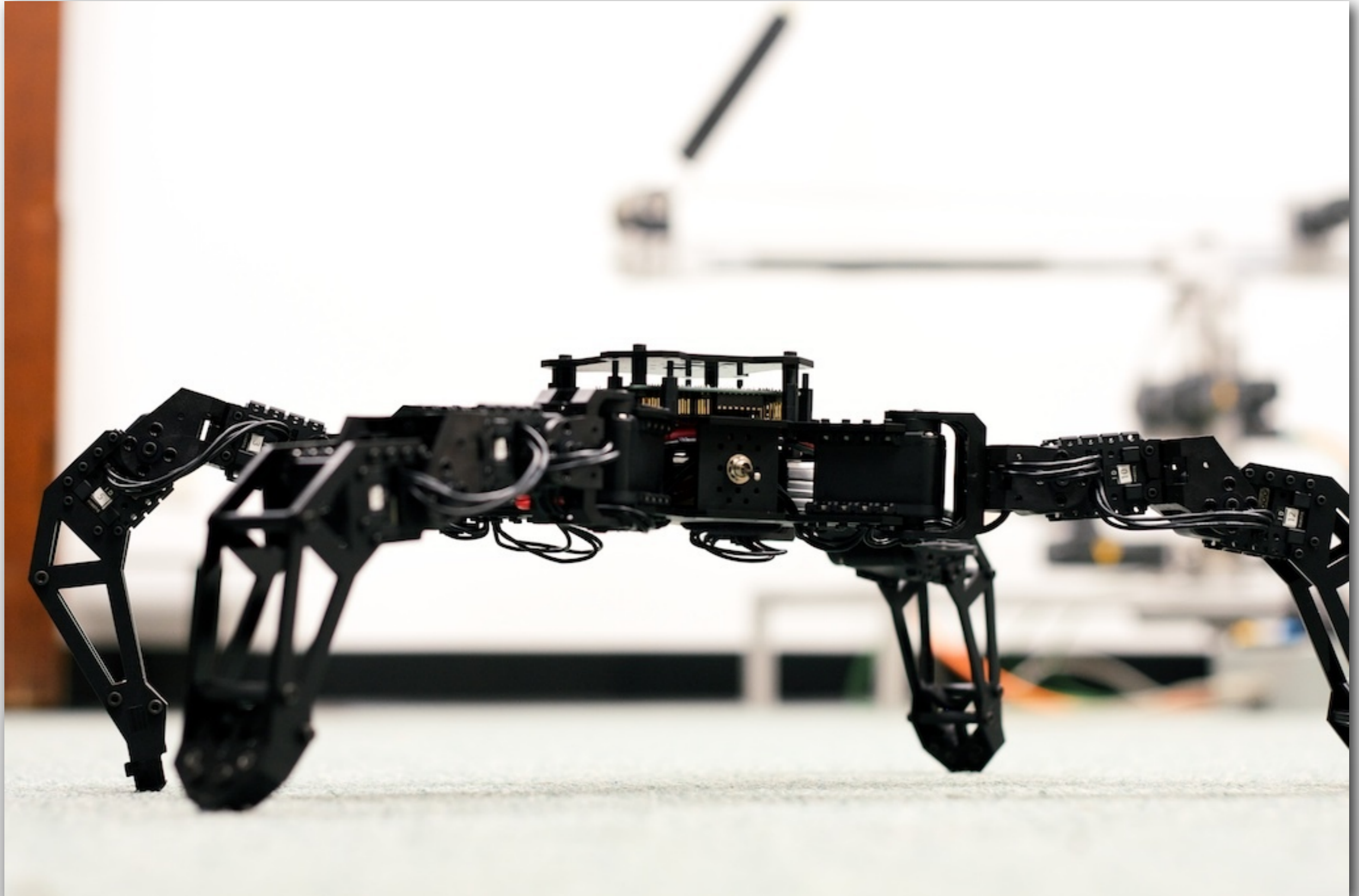
- How much of an image is in focus
 - Large Aperture → Small Depth of Field
 - Small Aperture → Large Depth of Field

} Why?

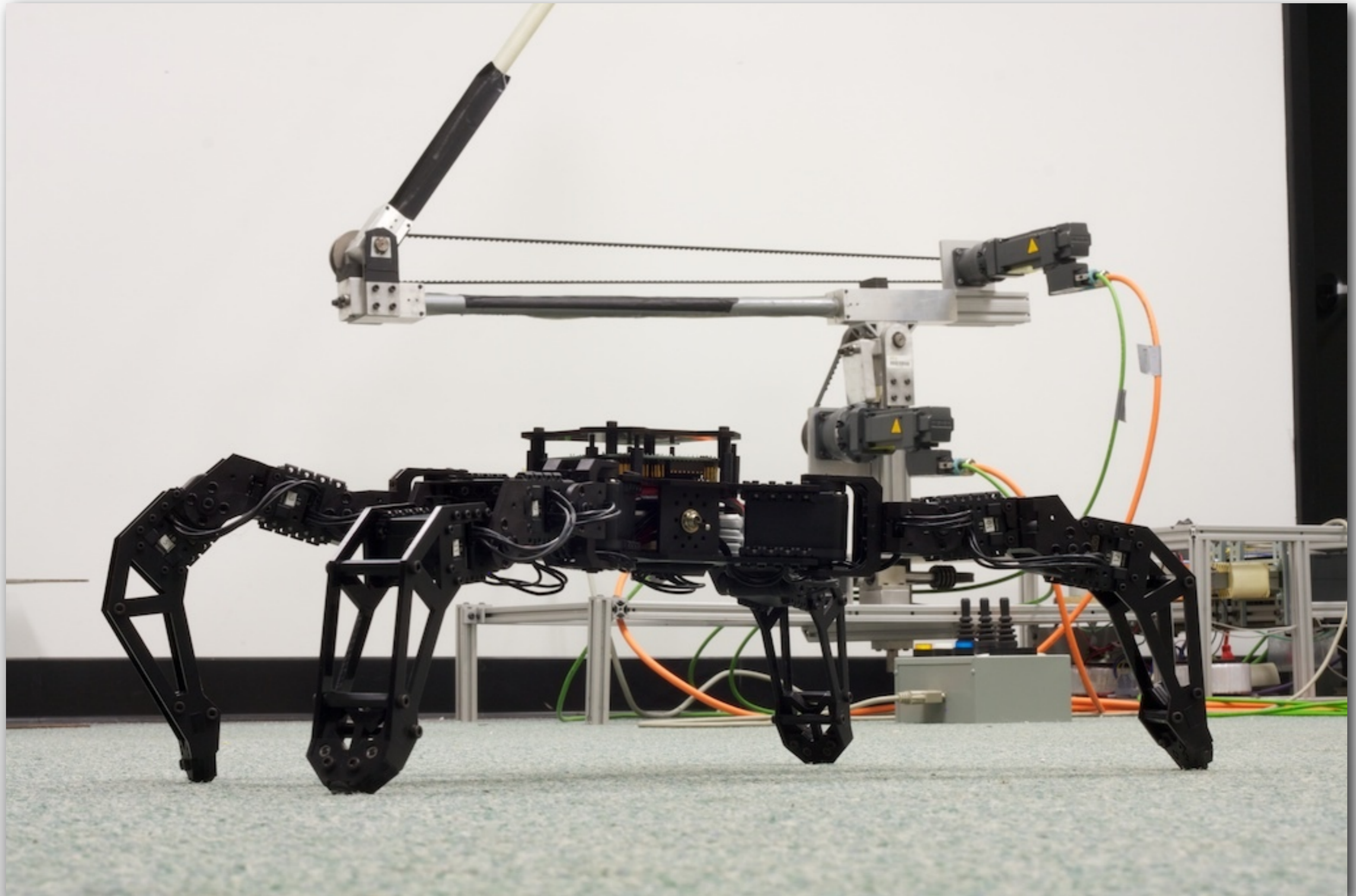
Aperture Affect on DoF



Shallow Depth of Field



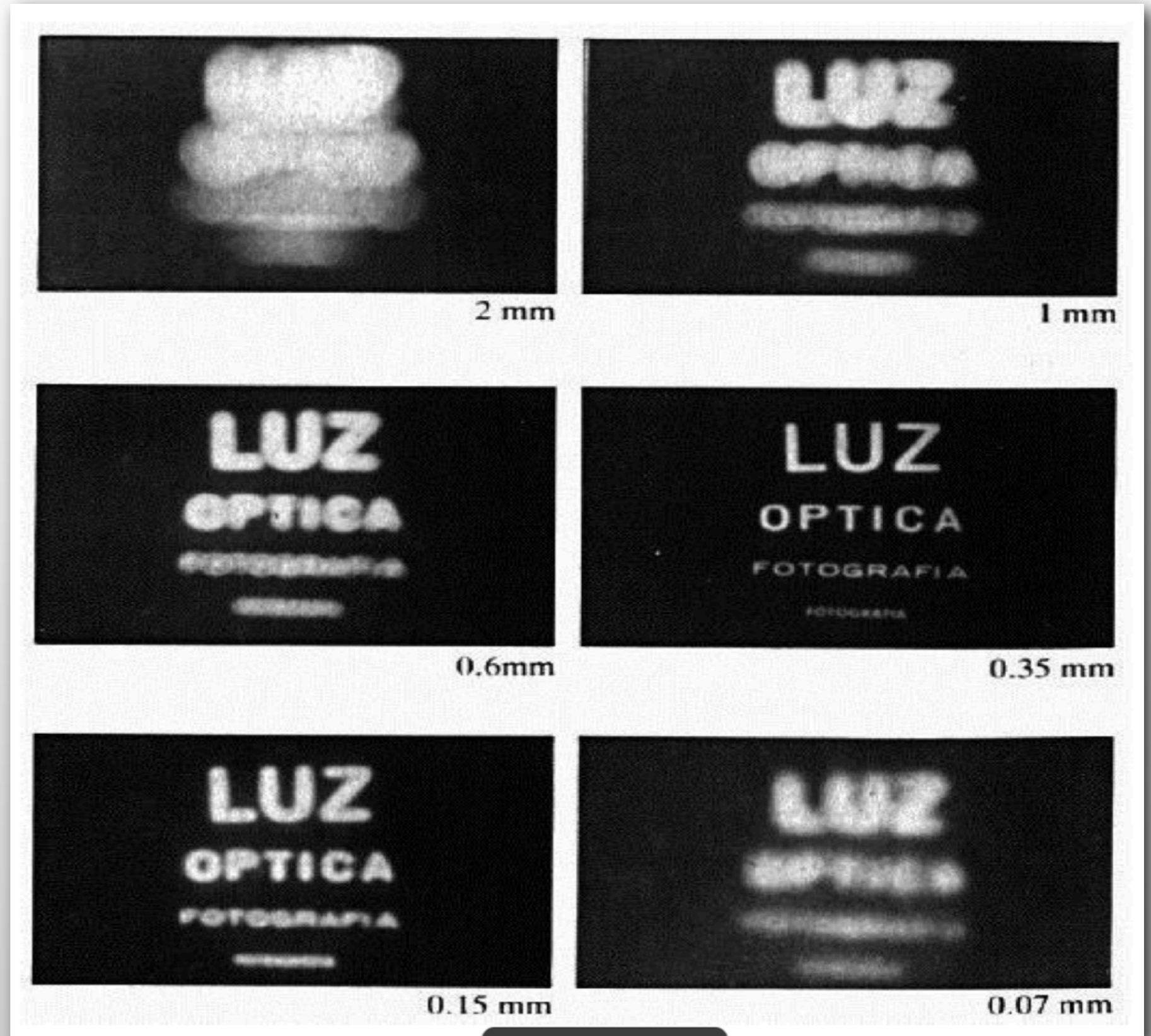
Large Depth of Field



Why not just minimize Aperture?



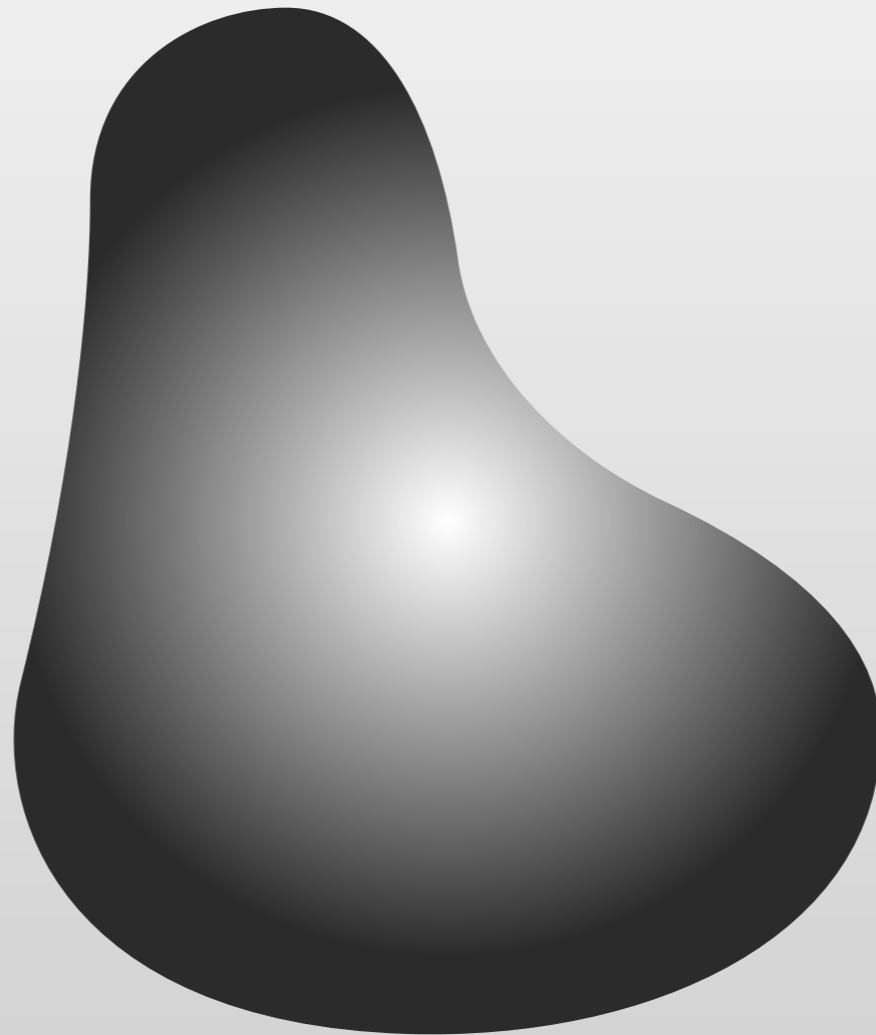
- Let's less light through
 - How does that affect exposure?
- Diffraction



Digital Imaging



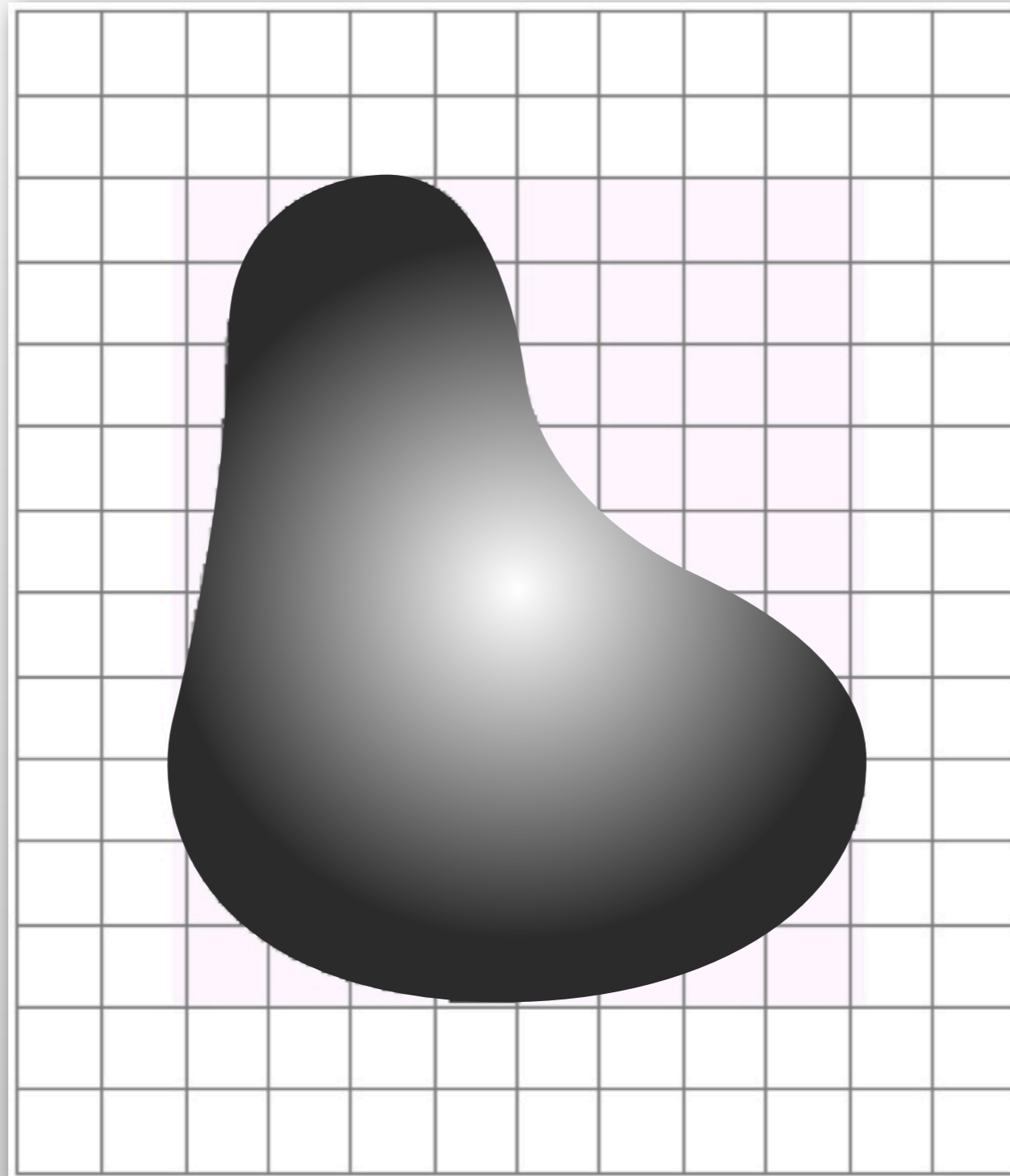
- How does a digital sensor see this?



Digital Imaging



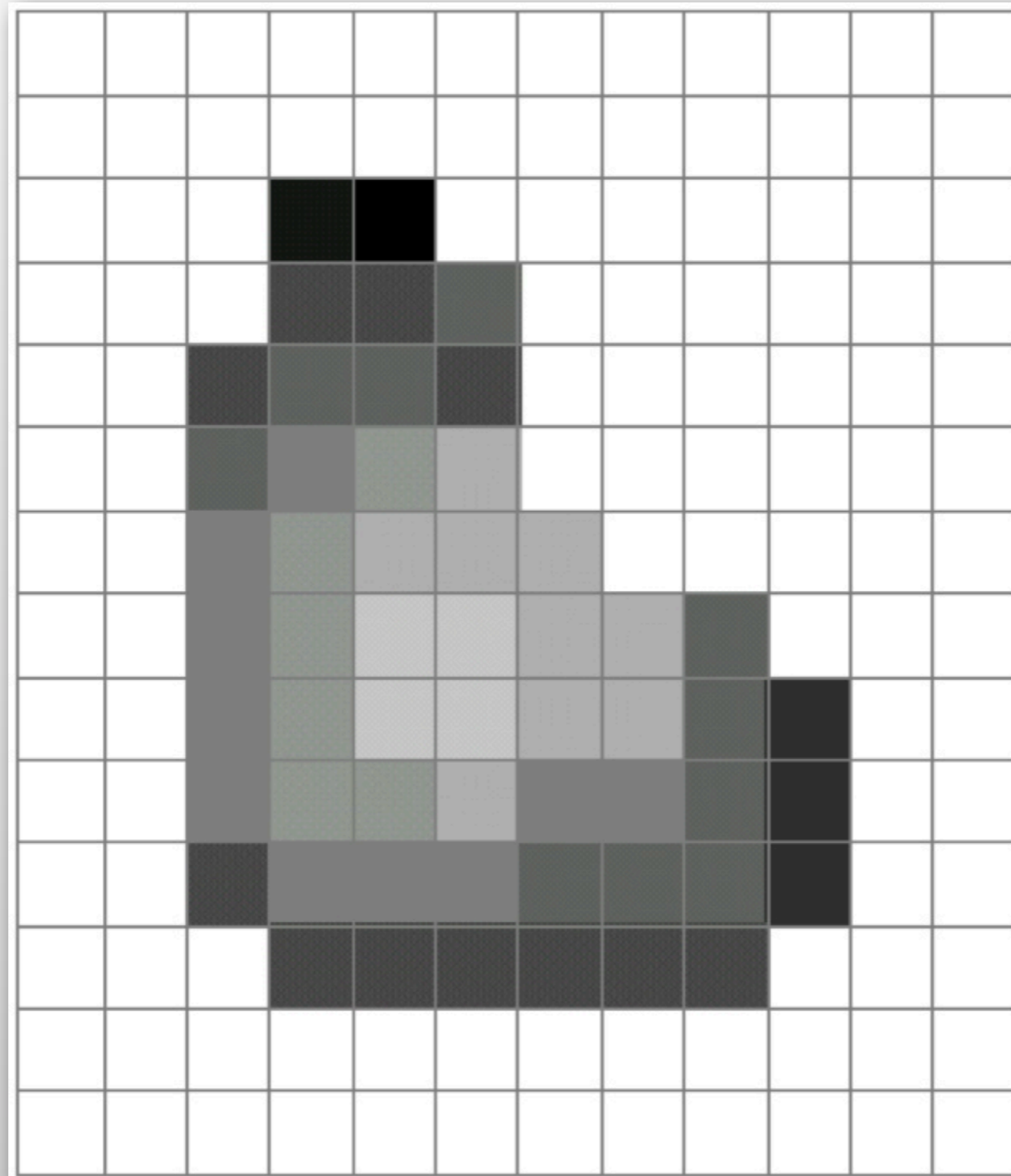
- How does a digital sensor see this?



Digital Imaging



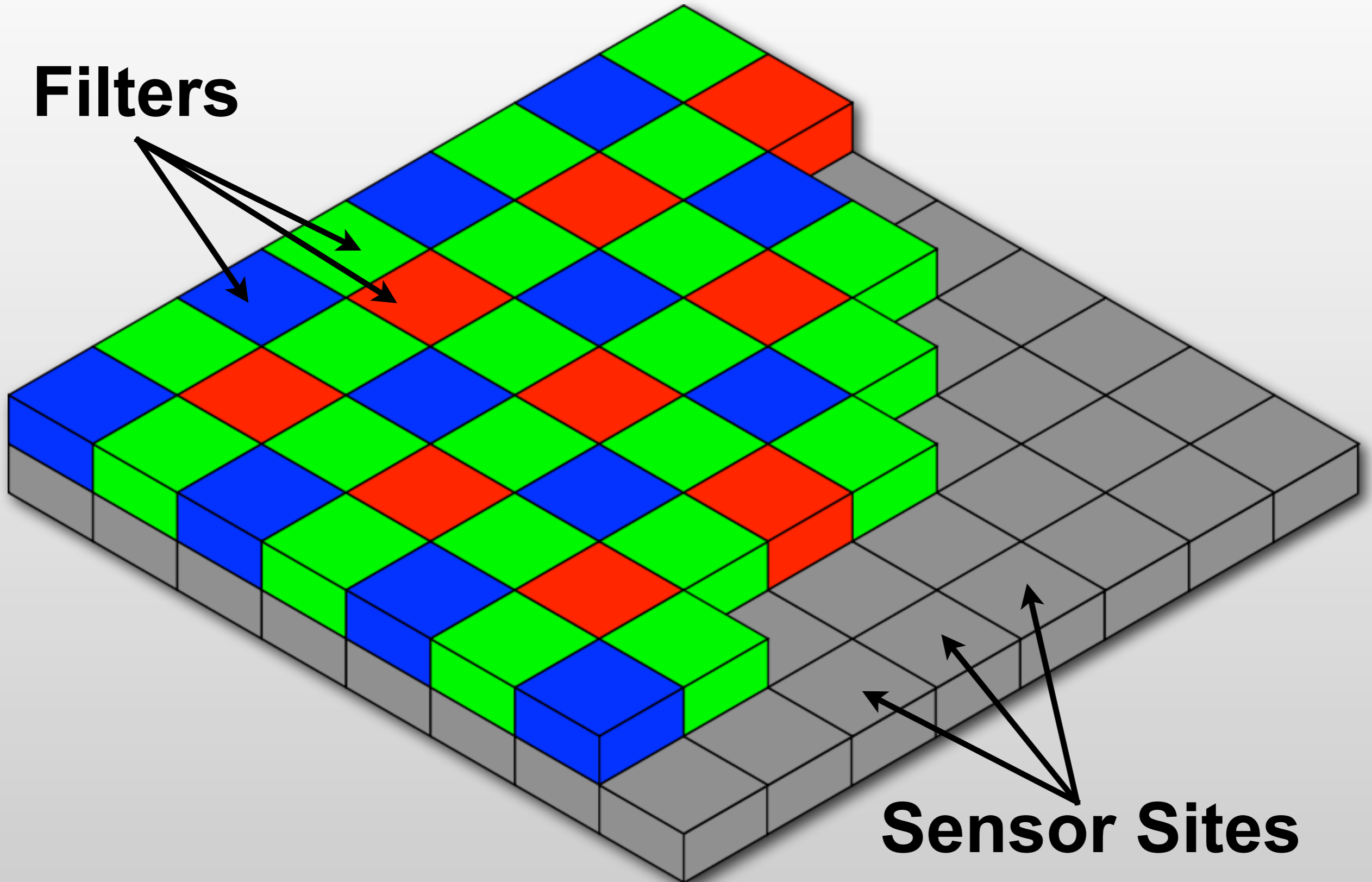
- How does a digital sensor see this?



What about color?

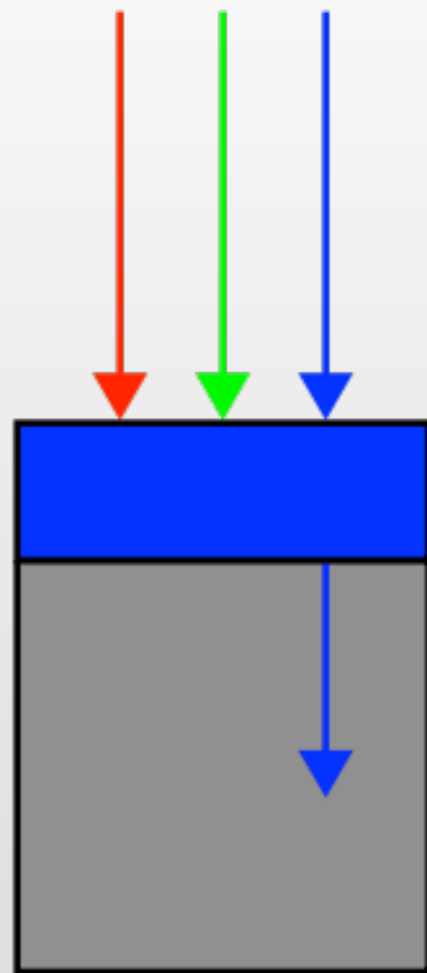
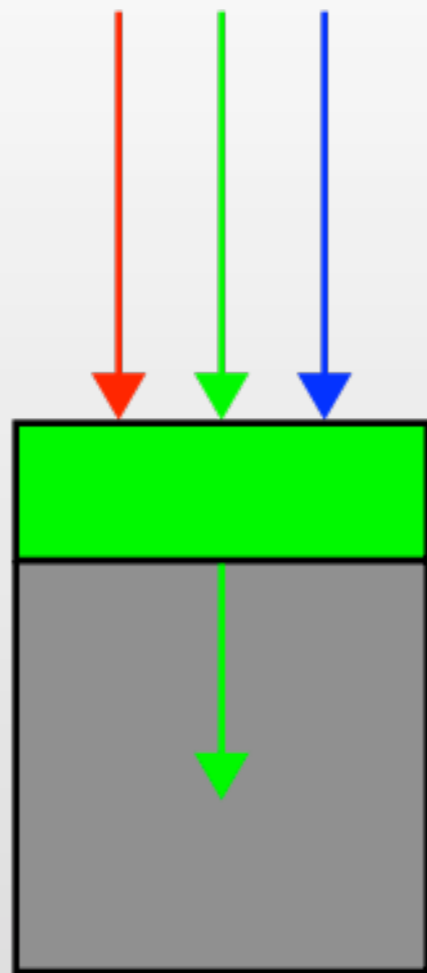
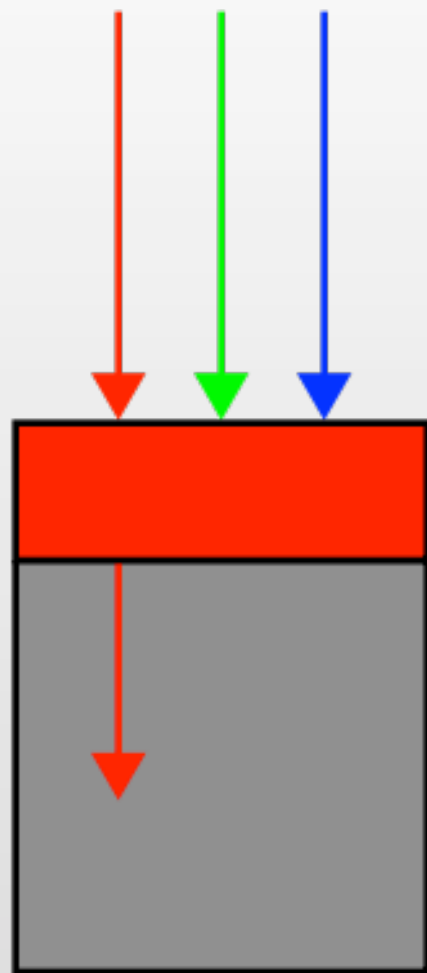


Filters



Sensor Sites

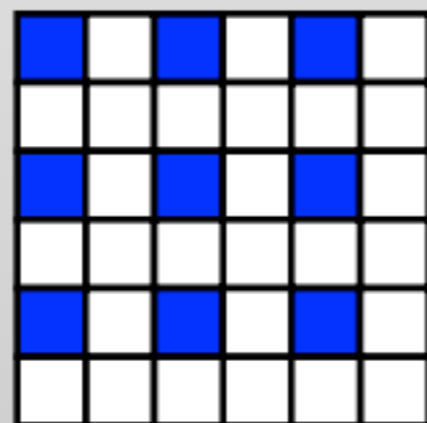
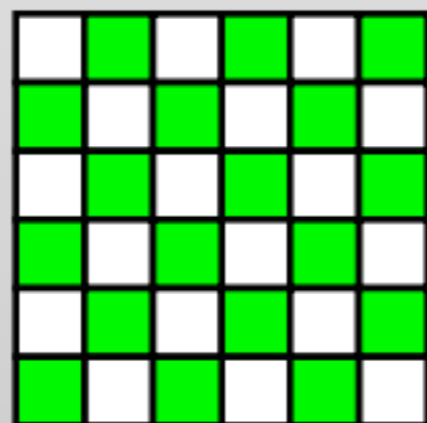
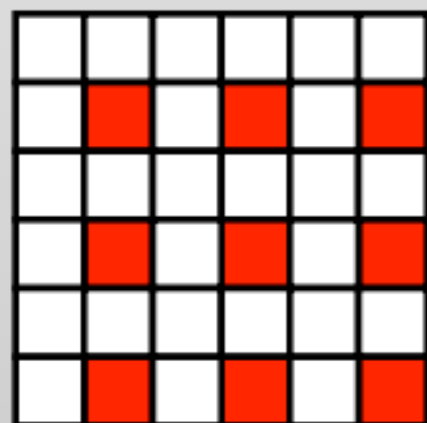
From Another Angle



Incoming Light

Filter Array

Sensor

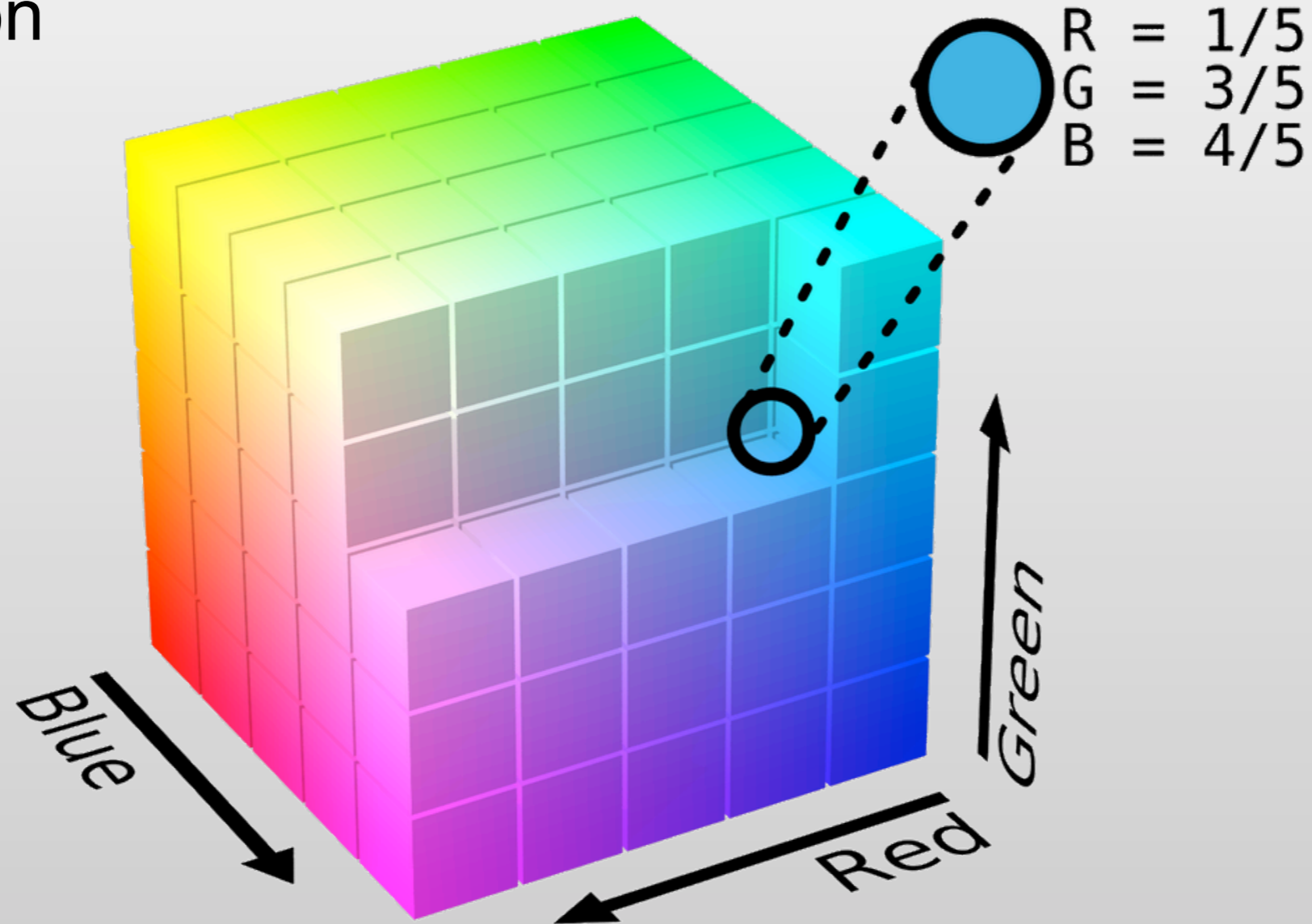


Resulting Pattern

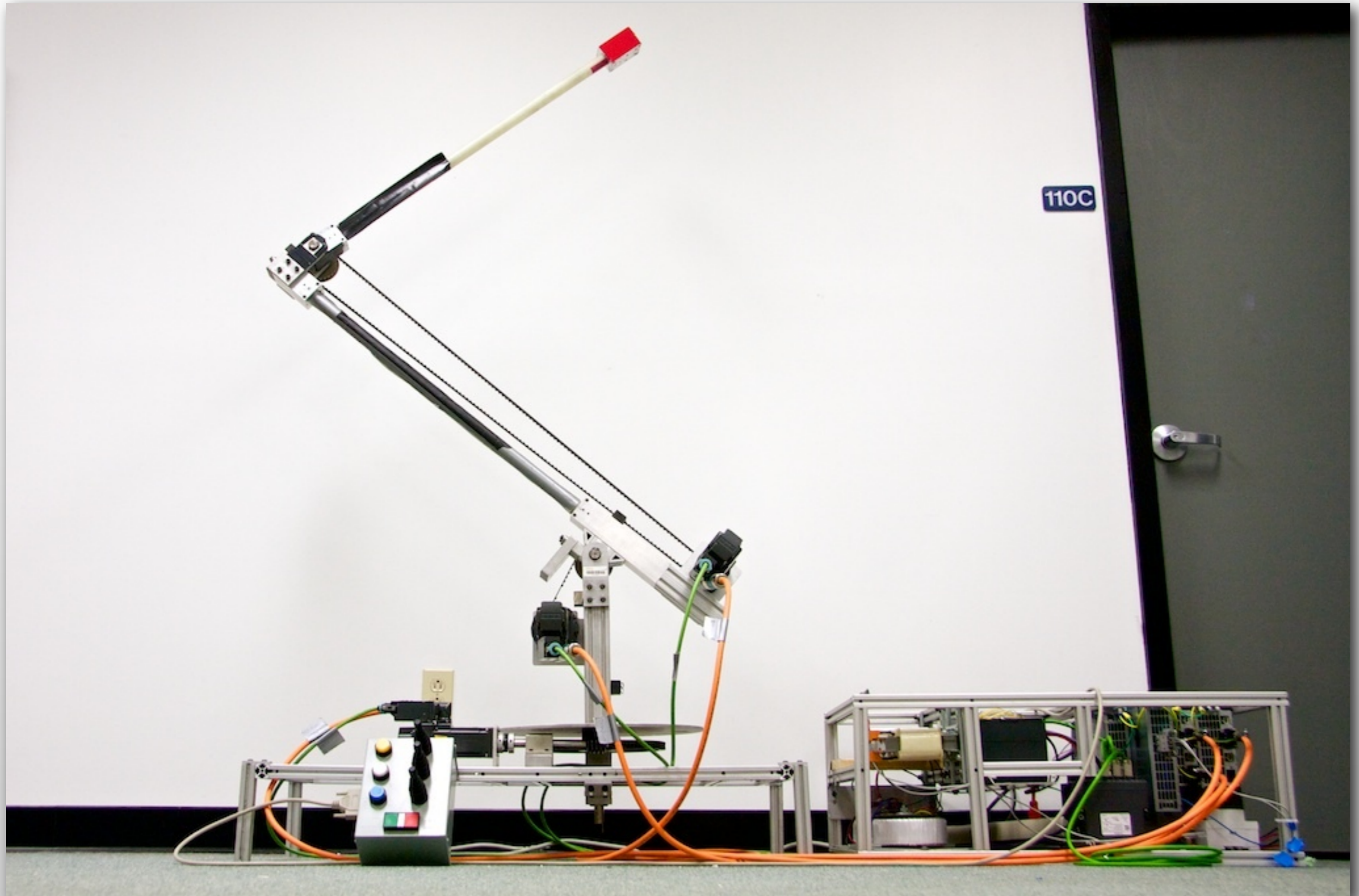
Color Space/Models - RGB



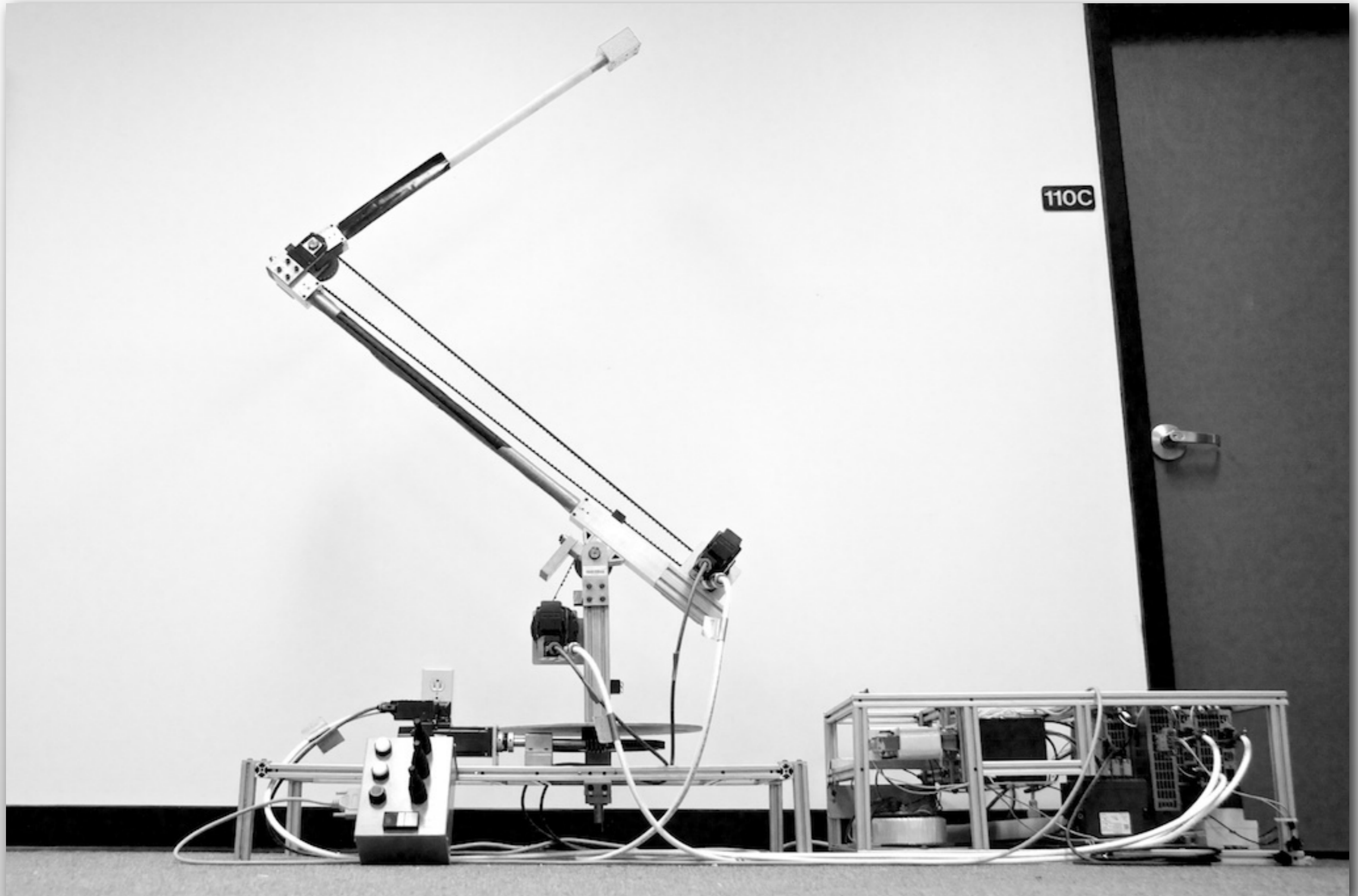
- One way to describe an images
- How much Red, Green, and Blue exist
 - Any point is represented by the mix of RGB at that location



An Example



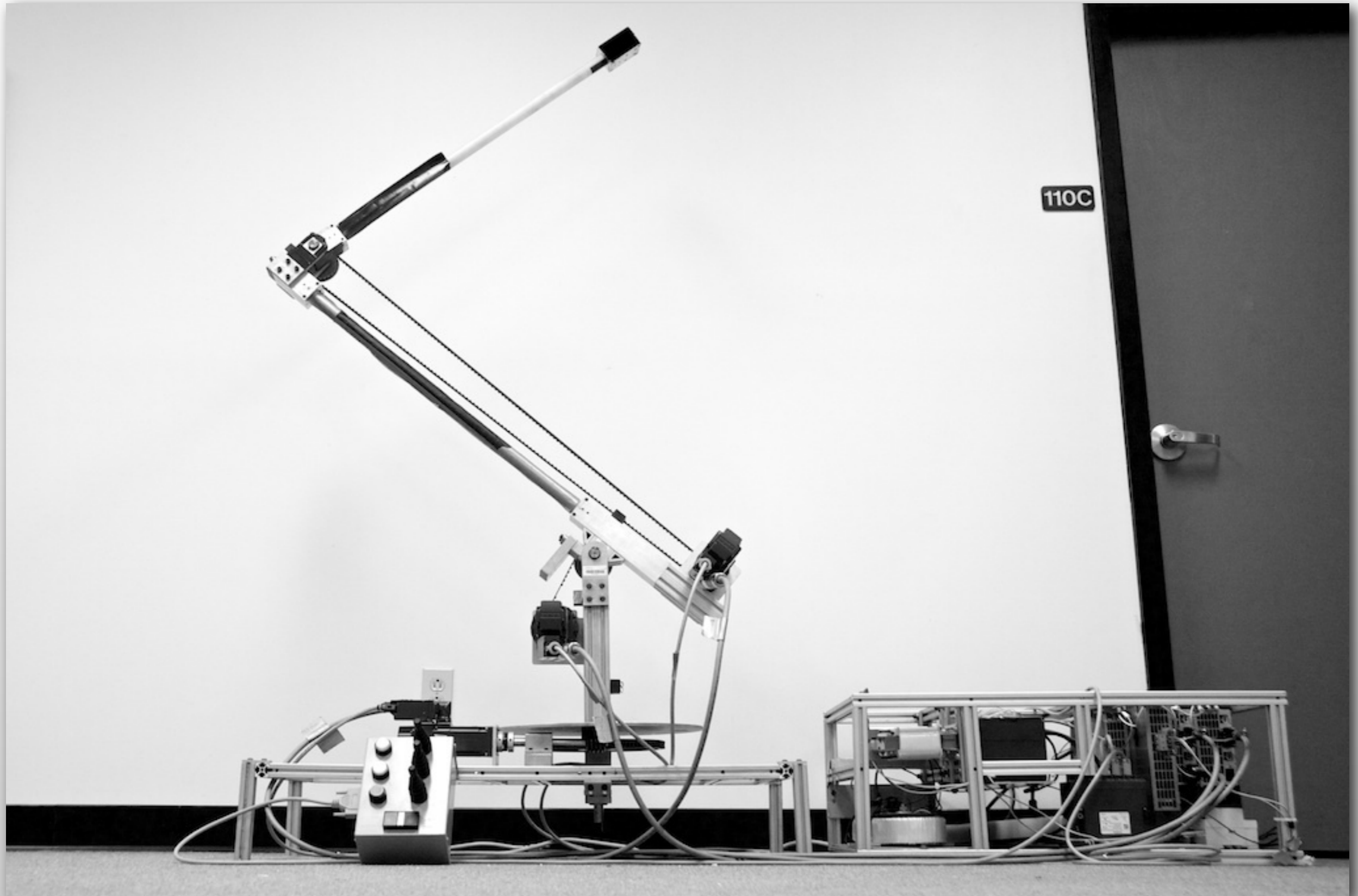
Red Channel



Blue Channel



Green Channel





In the Computer

- RGB as an array, size H x W x 3

Often (0,0)

row ↓ **column** →

0.92	0.93	0.94	0.97	0.62	0.37	0.85	0.97	0.93	0.92	0.99				
0.95	0.89	0.82	0.89	0.56	0.31	0.75	0.92	0.81	0.95	0.91				
0.89	0.72	0.51	0.55	0.51	0.42	0.57	0.41	0.49	0.91	0.92				
0.96	0.95	0.88	0.94	0.56	0.46	0.91	0.87	0.90	0.97	0.95				
0.71	0.81	0.81	0.87	0.57	0.37	0.80	0.88	0.89	0.79	0.85				
0.49	0.62	0.60	0.58	0.50	0.60	0.58	0.50	0.61	0.45	0.33				
0.86	0.84	0.74	0.58	0.51	0.39	0.73	0.92	0.91	0.49	0.74				
0.96	0.67	0.54	0.85	0.48	0.37	0.88	0.90	0.94	0.82	0.93				
0.69	0.49	0.56	0.66	0.43	0.42	0.77	0.73	0.71	0.90	0.99				
0.79	0.73	0.90	0.67	0.33	0.61	0.69	0.79	0.73	0.93	0.97				
0.91	0.94	0.89	0.49	0.41	0.78	0.78	0.77	0.89	0.99	0.93				
		0.79	0.73	0.90	0.67	0.33	0.61	0.69	0.79	0.73	0.93	0.97		
		0.91	0.94	0.89	0.49	0.41	0.78	0.78	0.77	0.89	0.99	0.93		
				0.79	0.73	0.90	0.67	0.33	0.61	0.69	0.79	0.73	0.93	0.97
				0.91	0.94	0.89	0.49	0.41	0.78	0.78	0.77	0.89	0.99	0.93

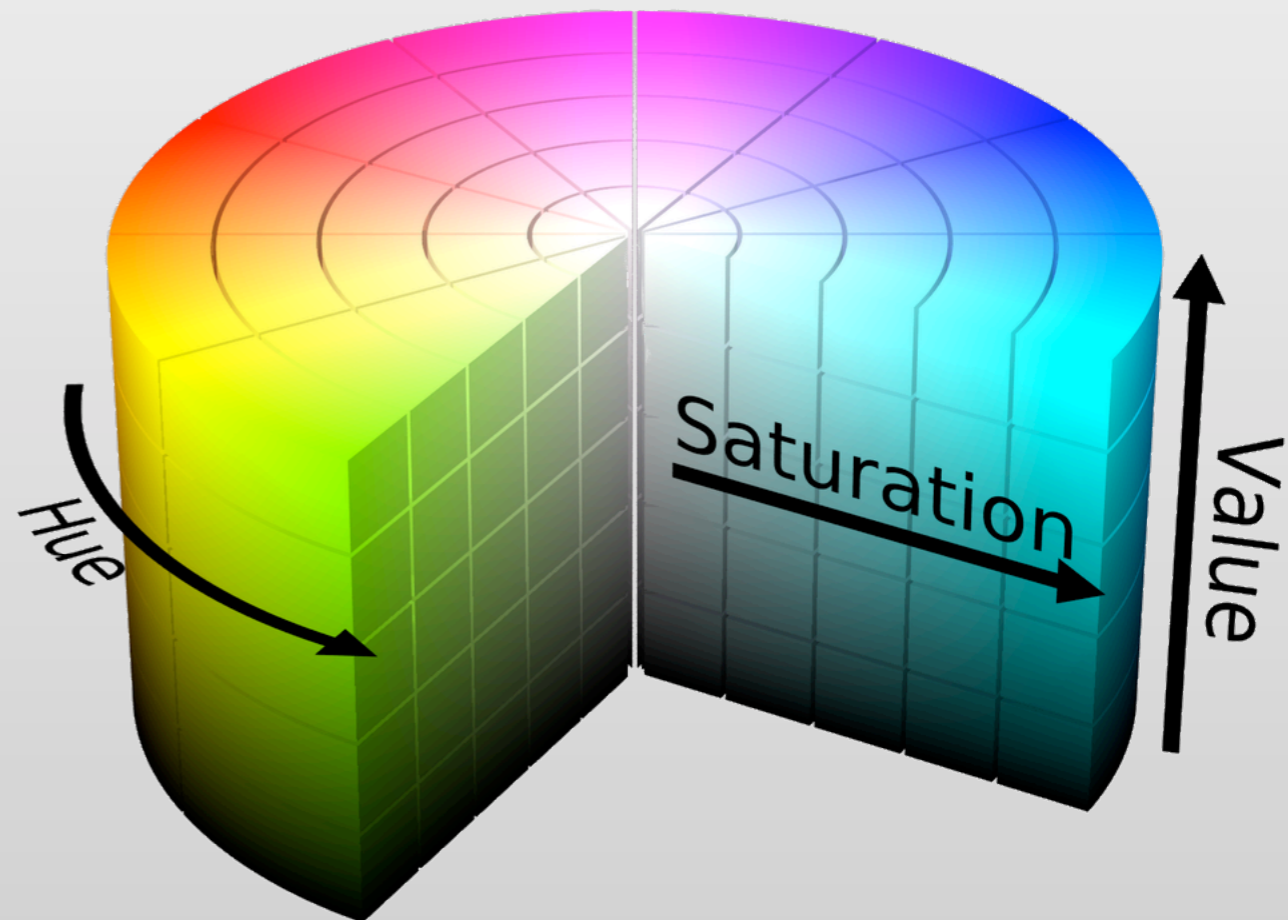
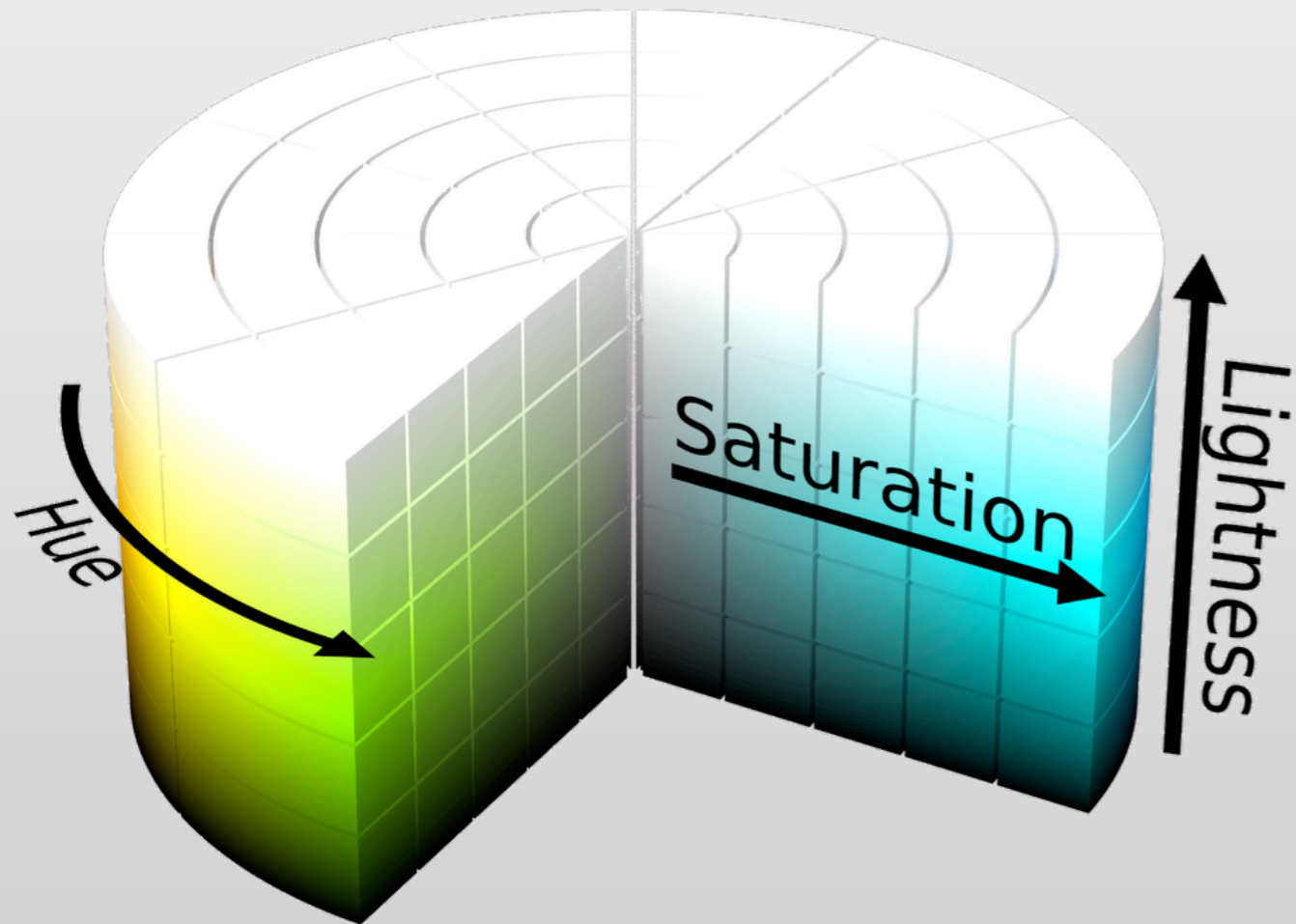
R **G** **B**

Detailed description: The diagram illustrates the storage of an RGB image as a 3D array. It shows a 12x12 grid of numerical values representing the red (R), green (G), and blue (B) channels. The main 12x12 grid represents the red channel. To its right, there are two 12x2 grids representing the green and blue channels, stacked vertically. A green arrow labeled 'row' points downwards on the left, and another green arrow labeled 'column' points to the right across the top. The labels 'R', 'G', and 'B' are placed to the right of their respective grid sections. The origin (0,0) is indicated by an arrow pointing to the top-left corner of the main grid.

HSV/HSL Color Space/Model



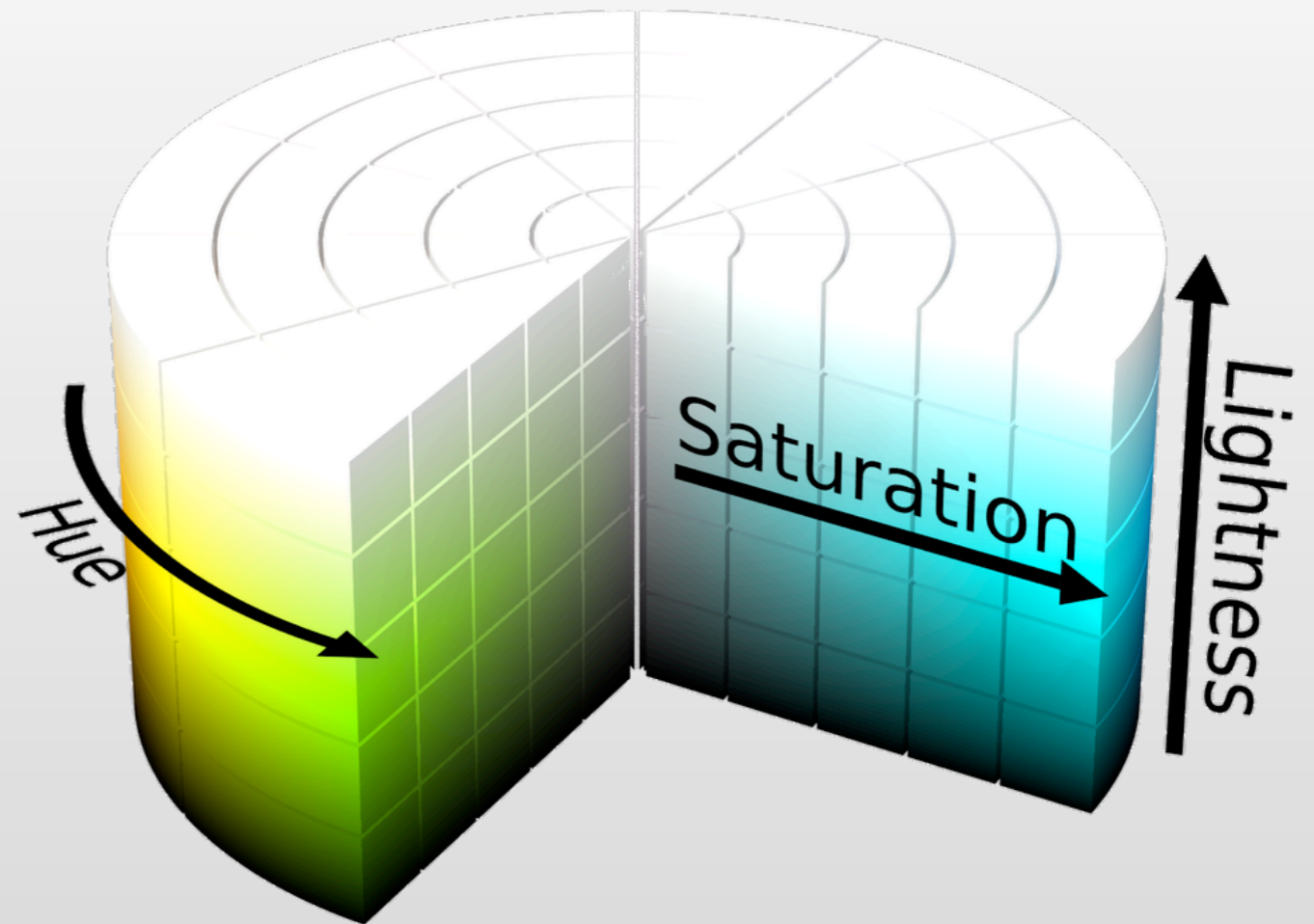
- Hue, Saturation, and Value
 - Hue, Saturation, and Lightness
- } Slightly Different



HSL



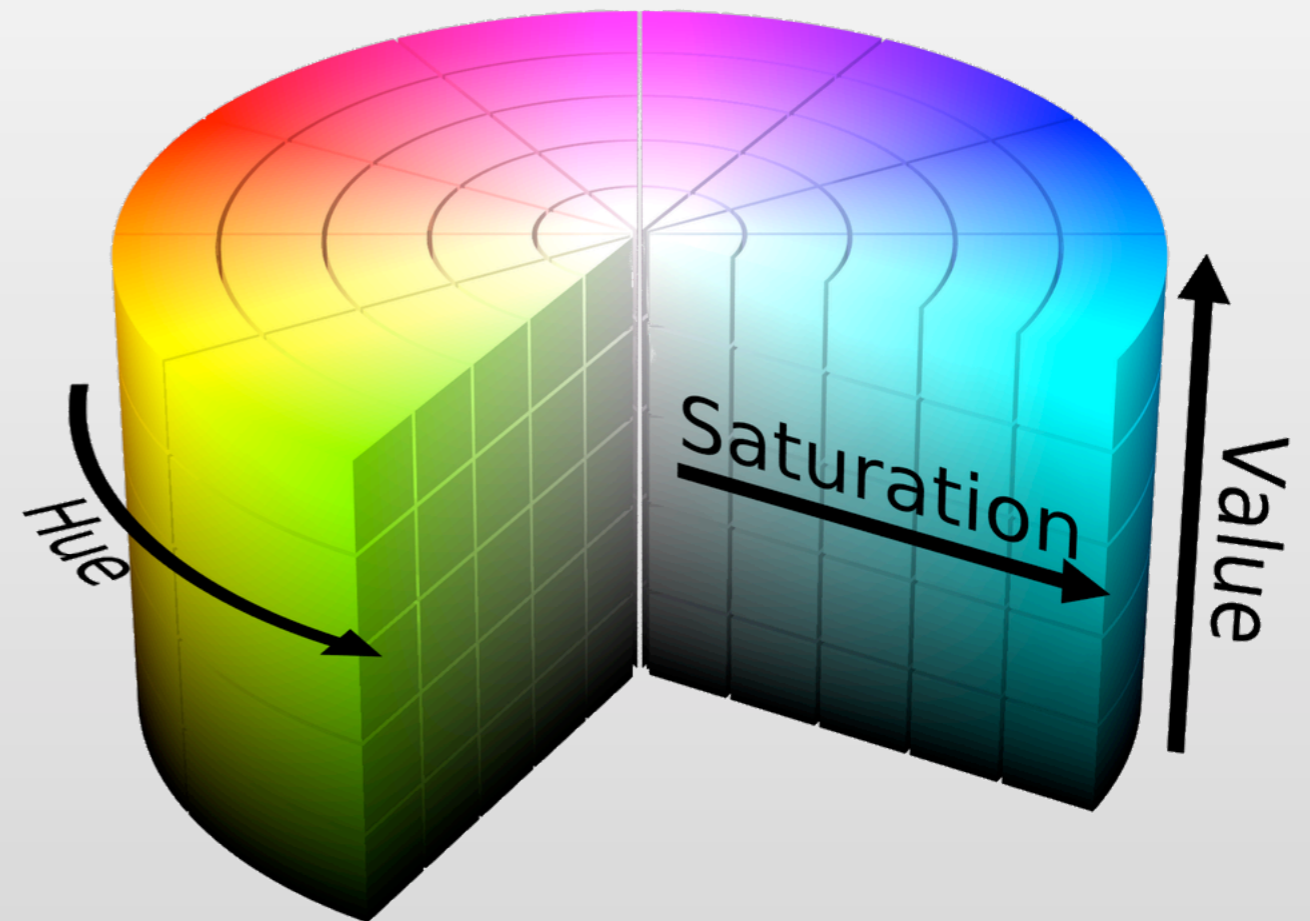
- Hue
 - Red - 0deg
 - Green - 120deg
 - Blue - 240deg
 - Red - 360deg
- Saturation
 - “Pure” Colors - 0.5
- Lightness
 - Black - 0
 - White - 1



HSV



- Hue
 - Red - 0deg
 - Green - 120deg
 - Blue - 240deg
 - Red - 360deg
- Saturation
 - “Pure” Colors - 1
- Value
 - Black - 0
 - White - 1



Other Color Spaces/Models



- CMYK
 - Cyan, Magenta, Yellow, Black
 - Most often used in printing
- YCbCr
 - Luminance, Blue-Difference Chroma, Red-Difference-Chroma
 - Used for TV
- Many others...

Filtering

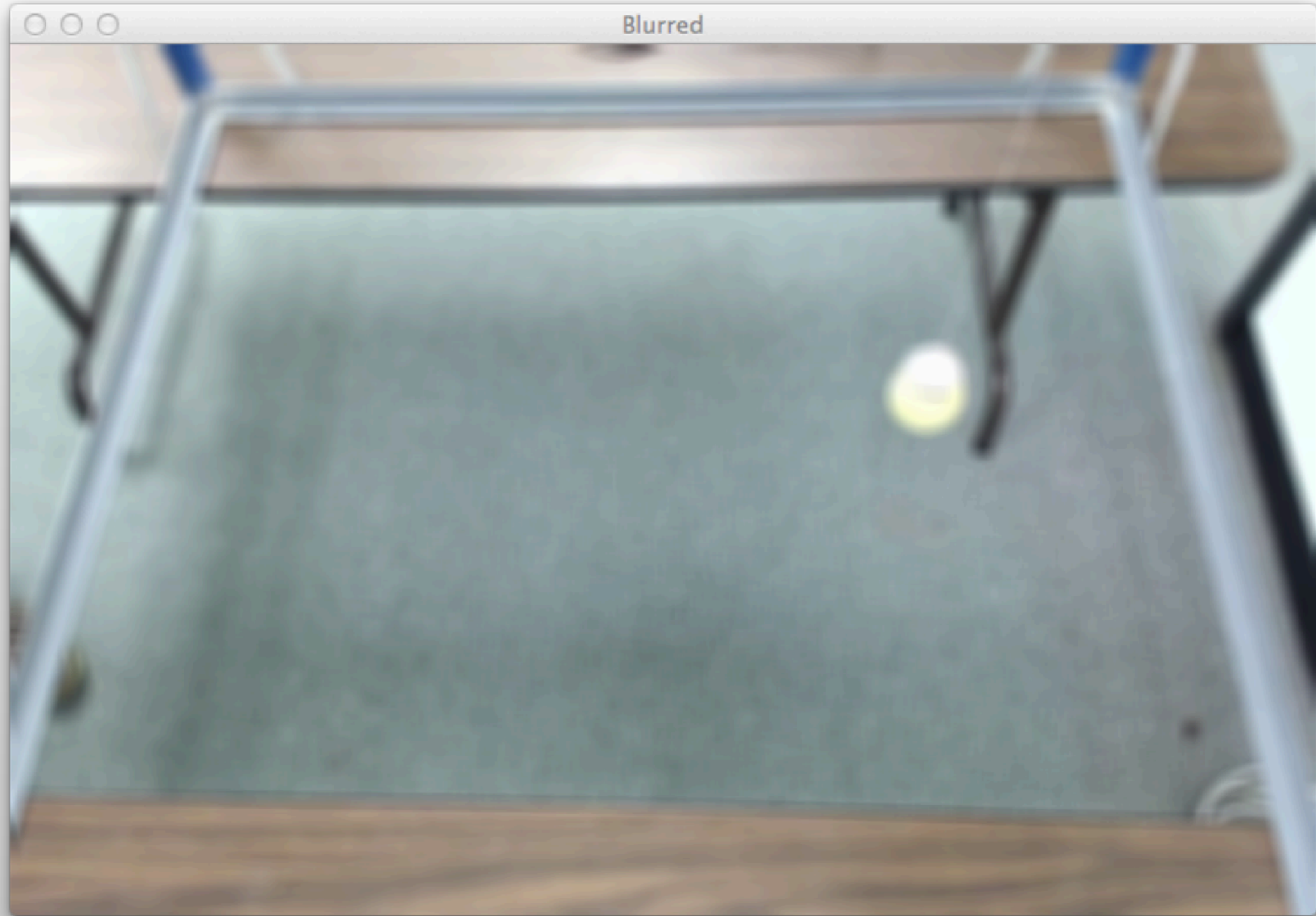


- In machine vision: used to make the image easier to process
- In Instagram: used to make your boring picture more interesting

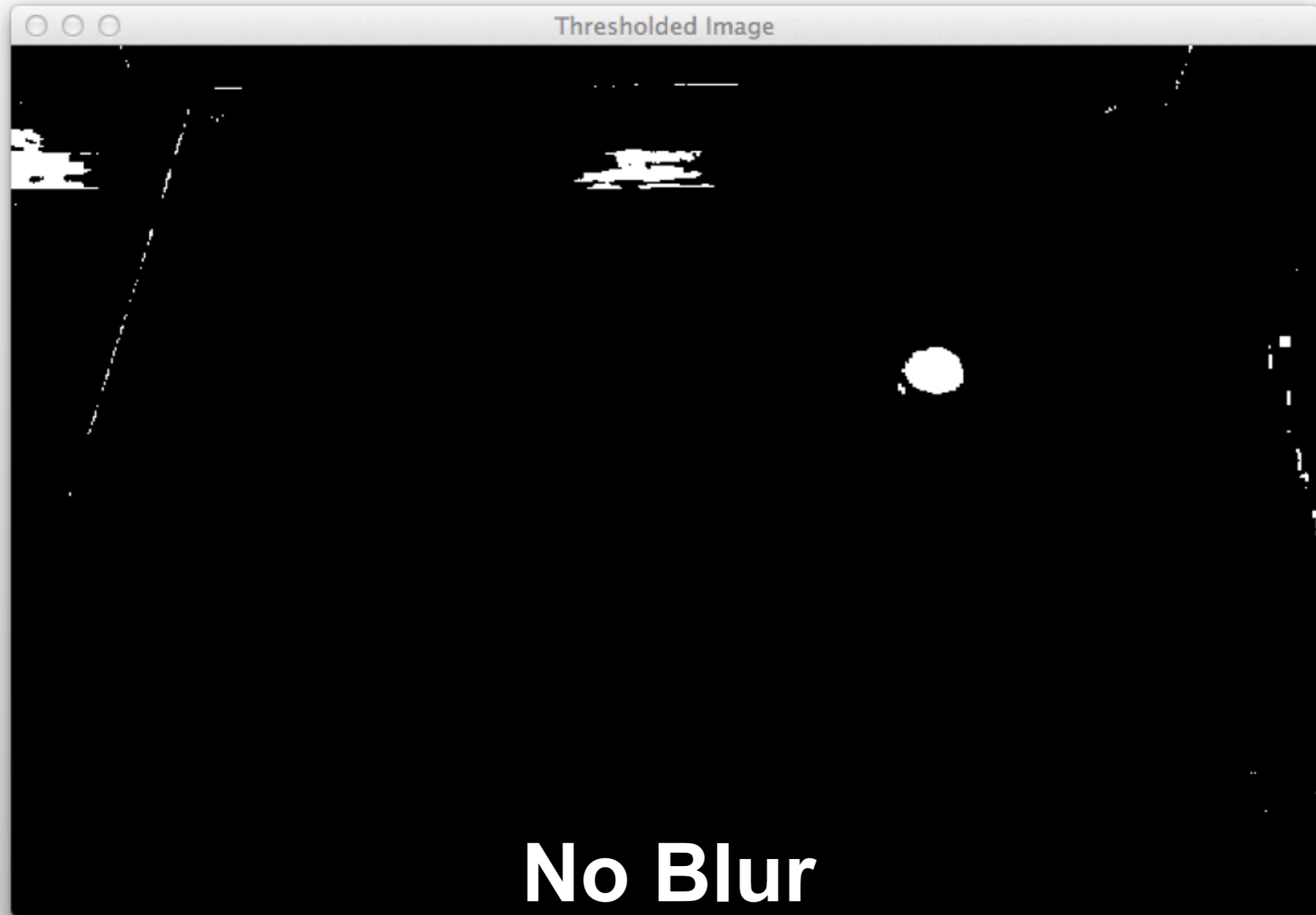
Blurring Makes the Image Clearer?



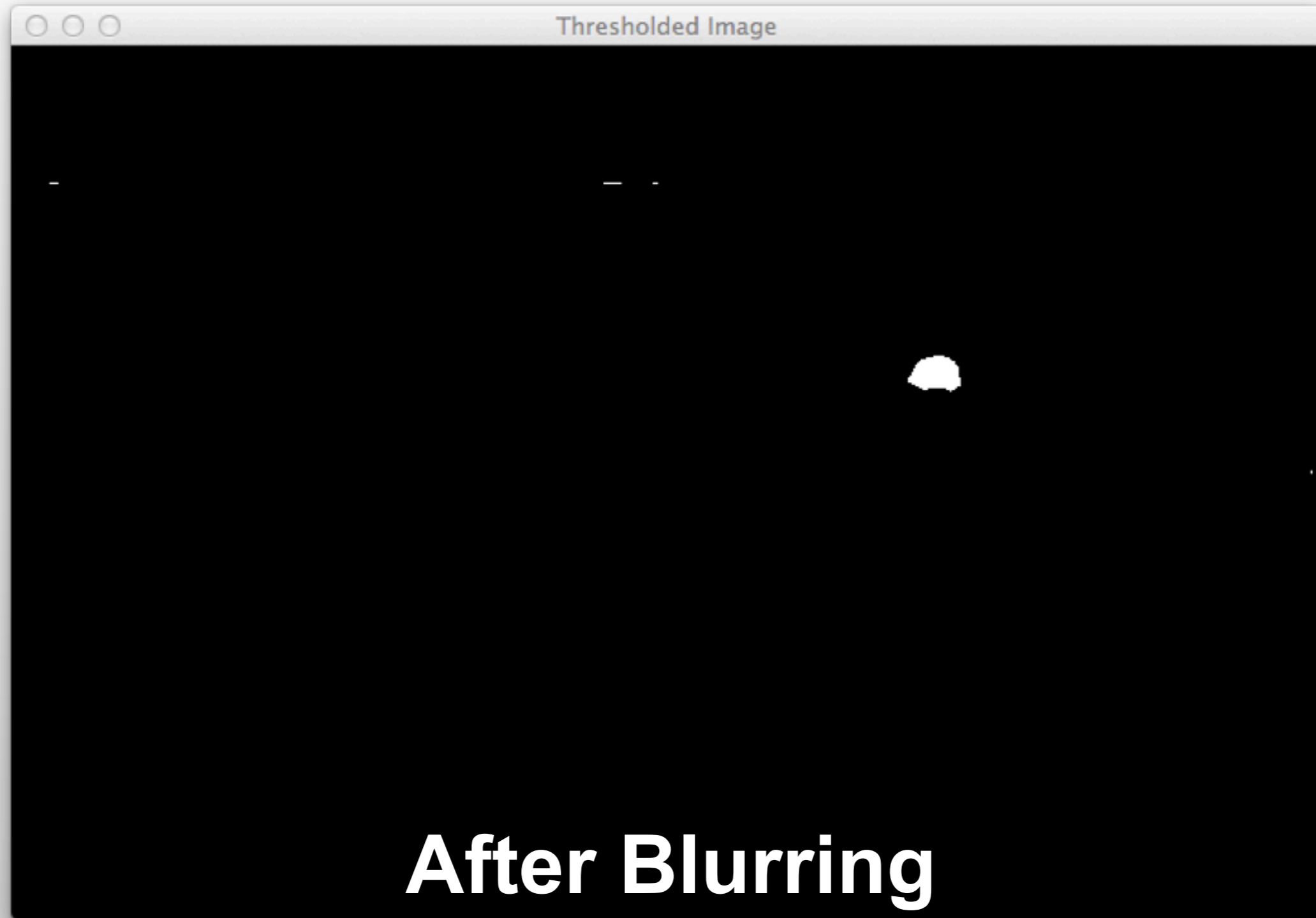
Blurring Makes the Image Clearer?



Once Masked for White



Once Masked for White



How to Blur?



- Box Filter (a type of linear filter)
 - Make every pixel the average of itself and those around it
 - Removes “sharp” features
 - Form:

	1	1	1
1/9	1	1	1
	1	1	1

Example Box Filter Process



33	68	47	44	96	78	46	63	10	66
88	34	84	67	54	55	56	1	65	83
56	98	65	72	80	11	30	17	43	82
46	89	24	50	52	37	0	5	48	67
85	49	82	17	6	93	98	39	62	92
89	35	58	81	34	84	36	29	60	70
45	81	6	88	32	16	65	75	86	22
98	16	49	33	33	35	48	55	47	37
14	39	20	97	36	11	23	77	66	51
7	94	22	28	91	21	48	11	46	11

$$1/9 * (73+50+66+19+73+27+22+56+9) = 44$$

Aside: How could we sharpen?



0	0	0
0	2	0
0	0	0

- $\frac{1}{9}$

1	1	1
1	1	1
1	1	1

- Sharpening makes differences from local average *more* apparent