

Spatial Filtering

[Introduction to Computer Vision | Udacity](#)

Previously..

- Human Eye (Lens, retina, cones and rods)
- Image formation (3D world -> 2D image, pin-hole camera, stereo)
- Digital images (sampling and quantization) and Images as functions and matrices
- Image size, Image resolution and Spatial resolution
- (sampling theorem and the image coordinate system)

Today..

- Intensity transformations (point processing)
- Histogram-based methods (histogram equalization)
- (Neighborhood processing / filtering)

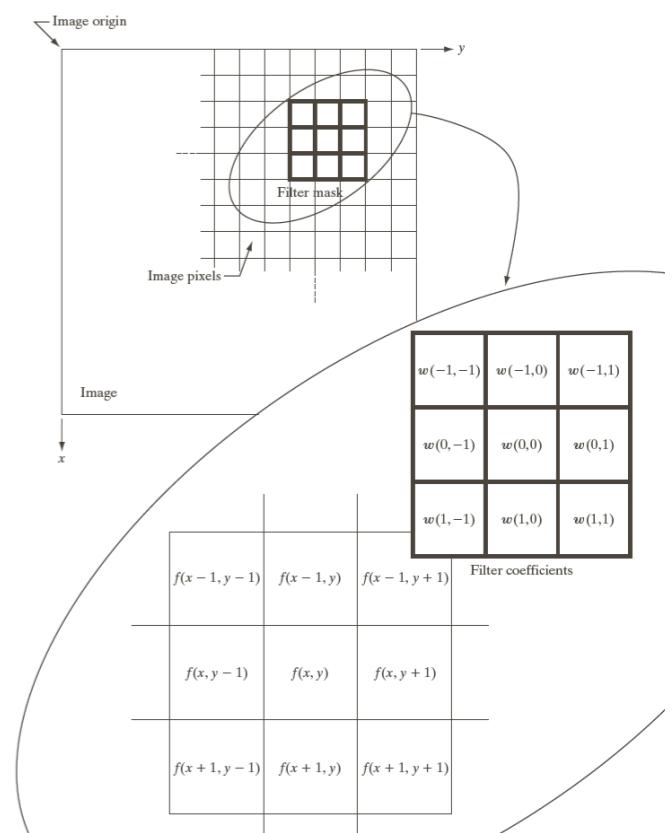
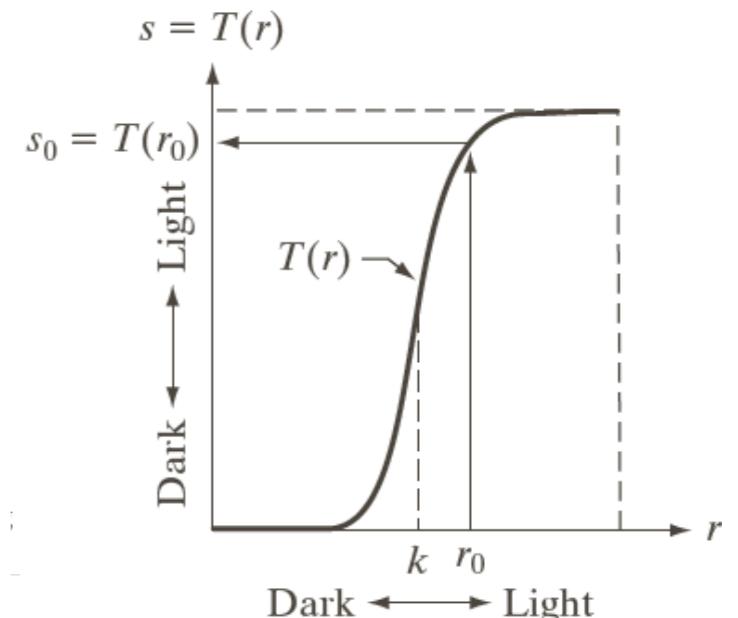


Image Enhancement

- Filtering in the **spatial** domain
 - Image *smoothing*
 - Image *sharpening*
- Filtering in the **frequency** domain
 - Image *smoothing*
 - Image *sharpening*

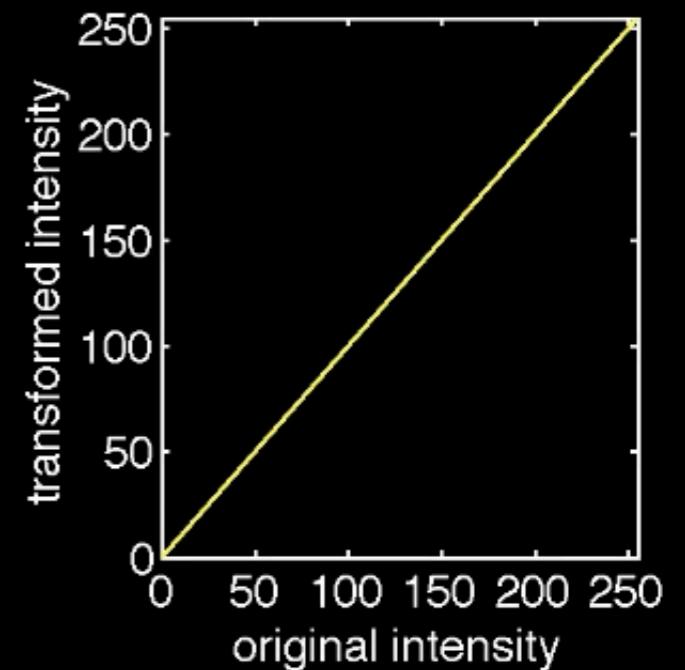
Image Enhancement

- *Image smoothing*
 - Filtering in the **spatial** domain
 - Filtering in the **frequency** domain
- *Image sharpening*
 - Filtering in the **spatial** domain
 - Filtering in the **frequency** domain

Intensity Transformations, Contrast & Image Histograms

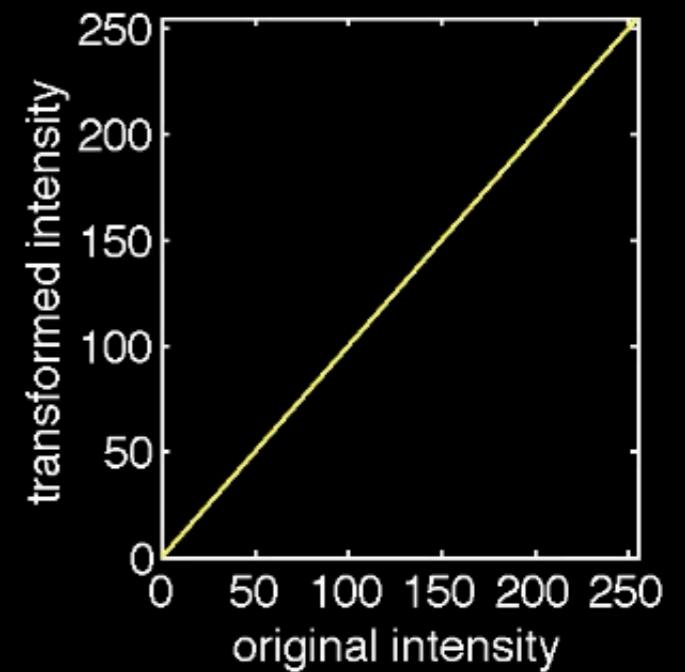
Building some intuition..

Original image & Intensity transf.

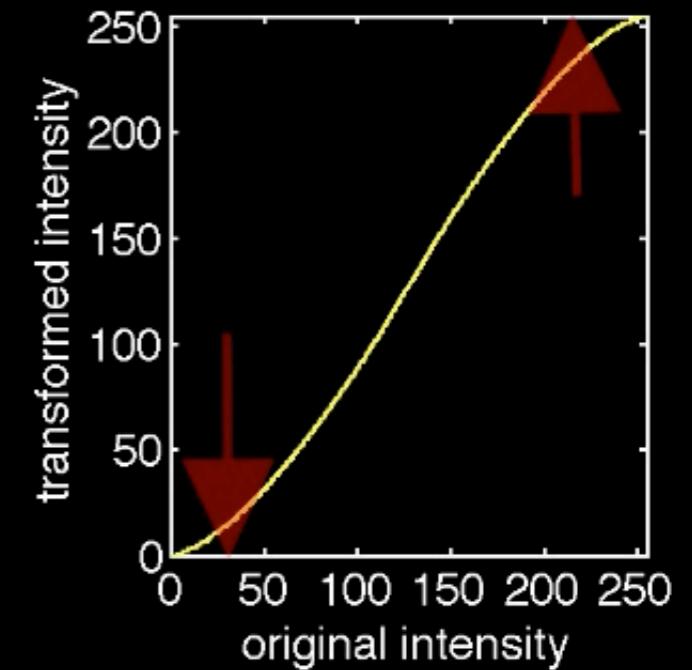


Introduction to Image Histograms (Timothy Schulz)

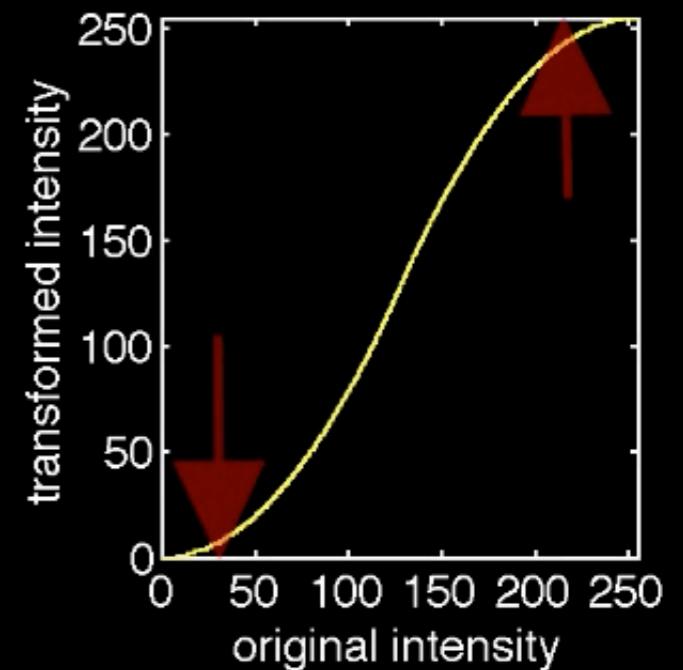
No change: output = input



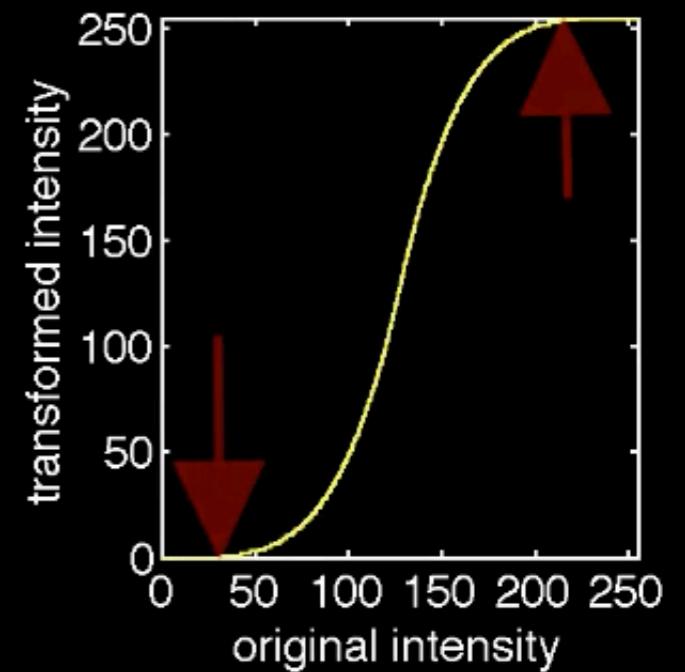
Decreasing low and increasing high values



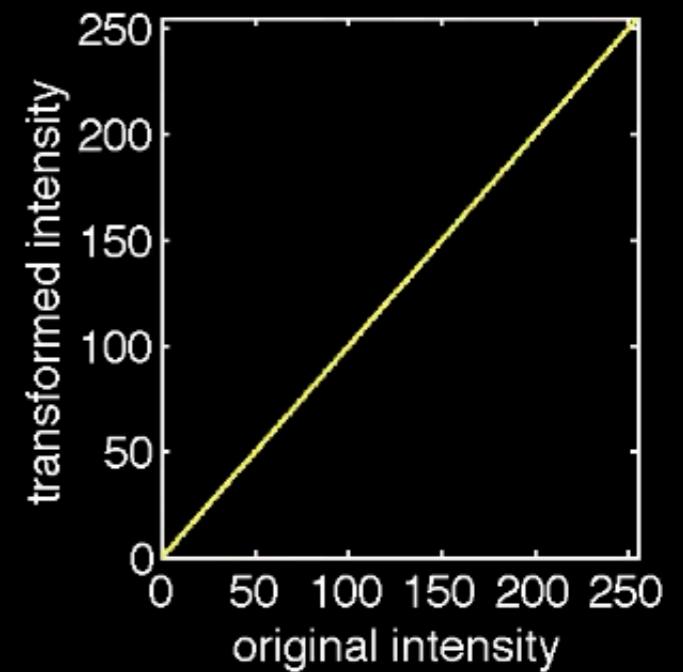
Higher contrast



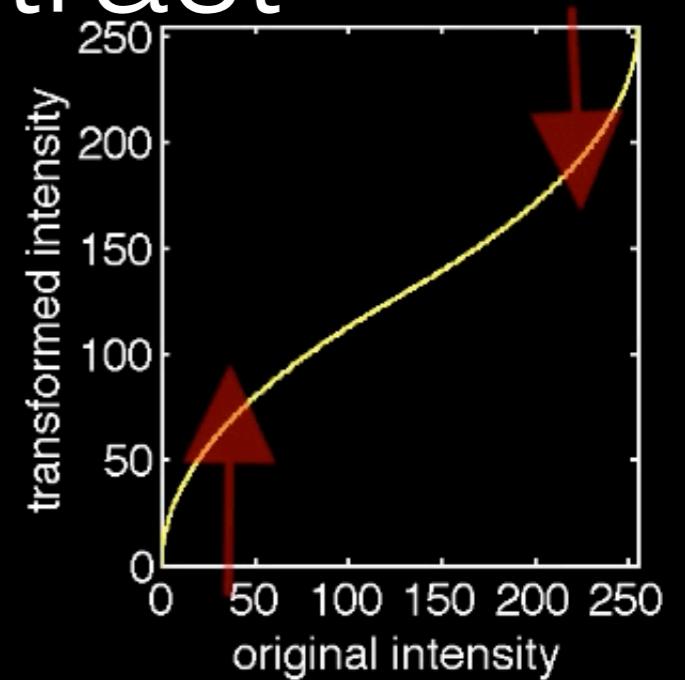
Too much..



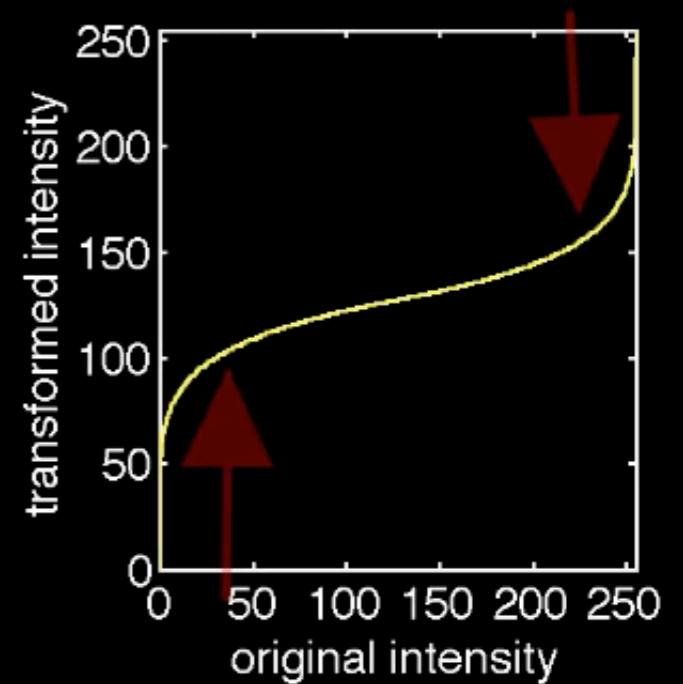
Original image



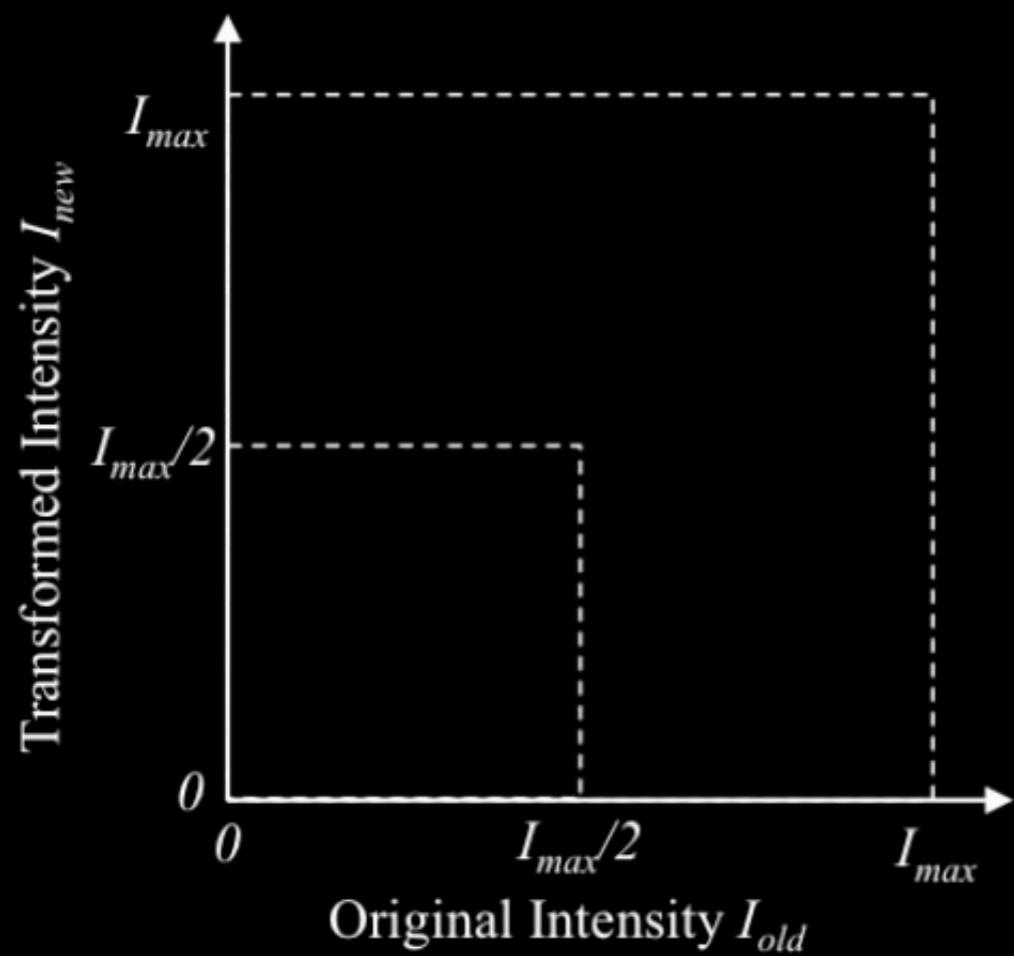
Increasing low and decreasing high values: Lower contrast



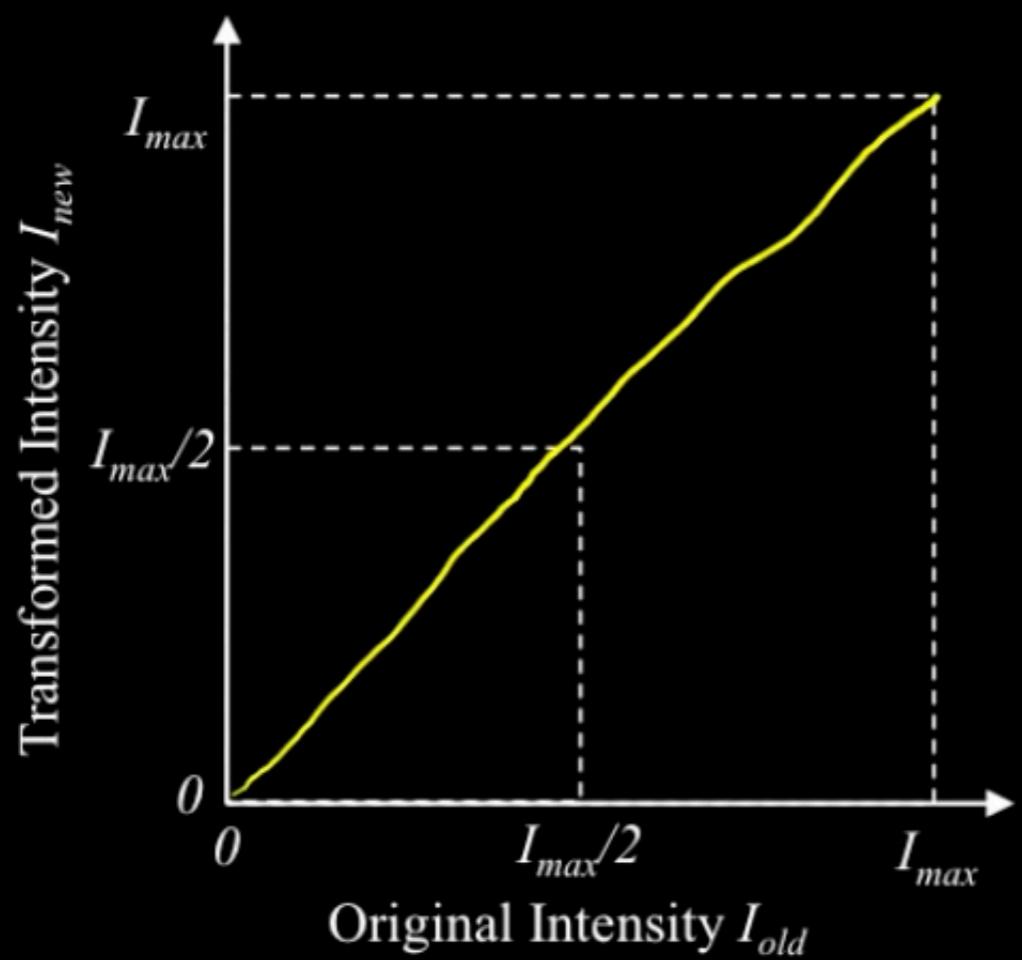
Too much..



Only one output value for each input Contrast Transformation

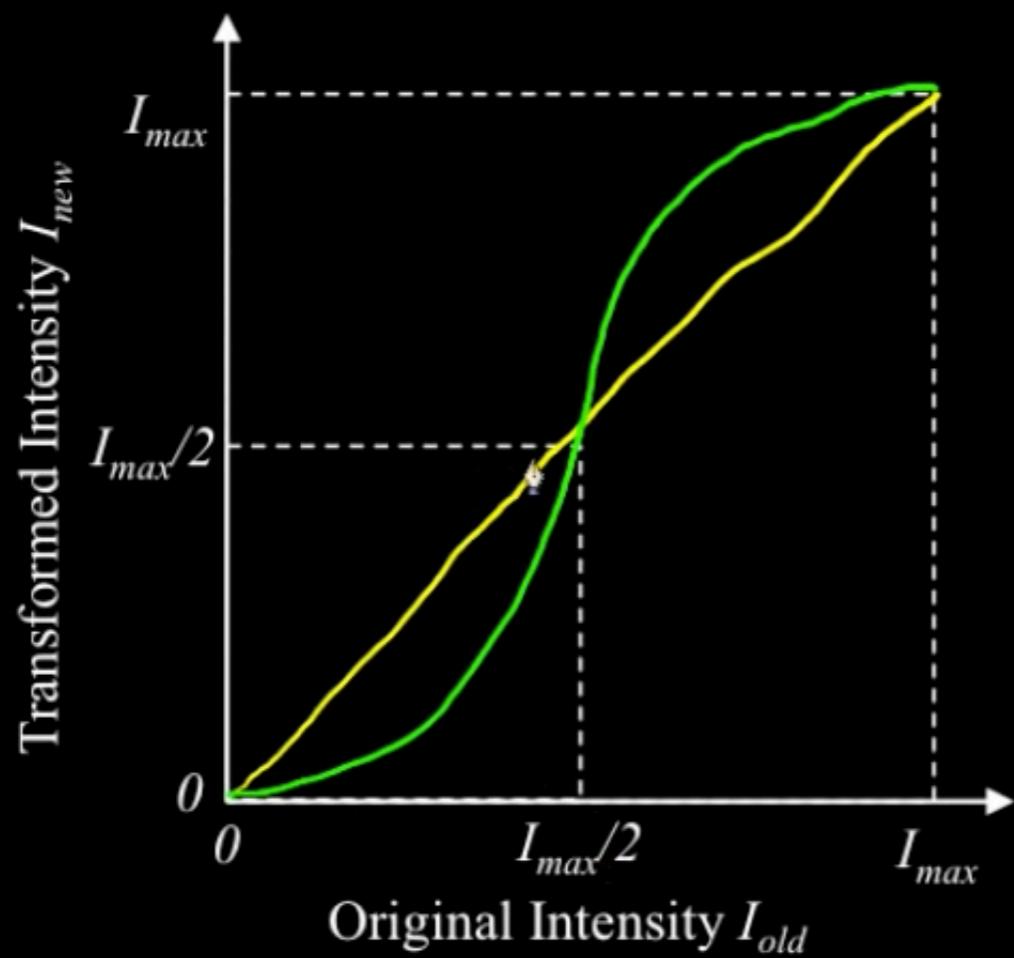


No change contrast Transformation



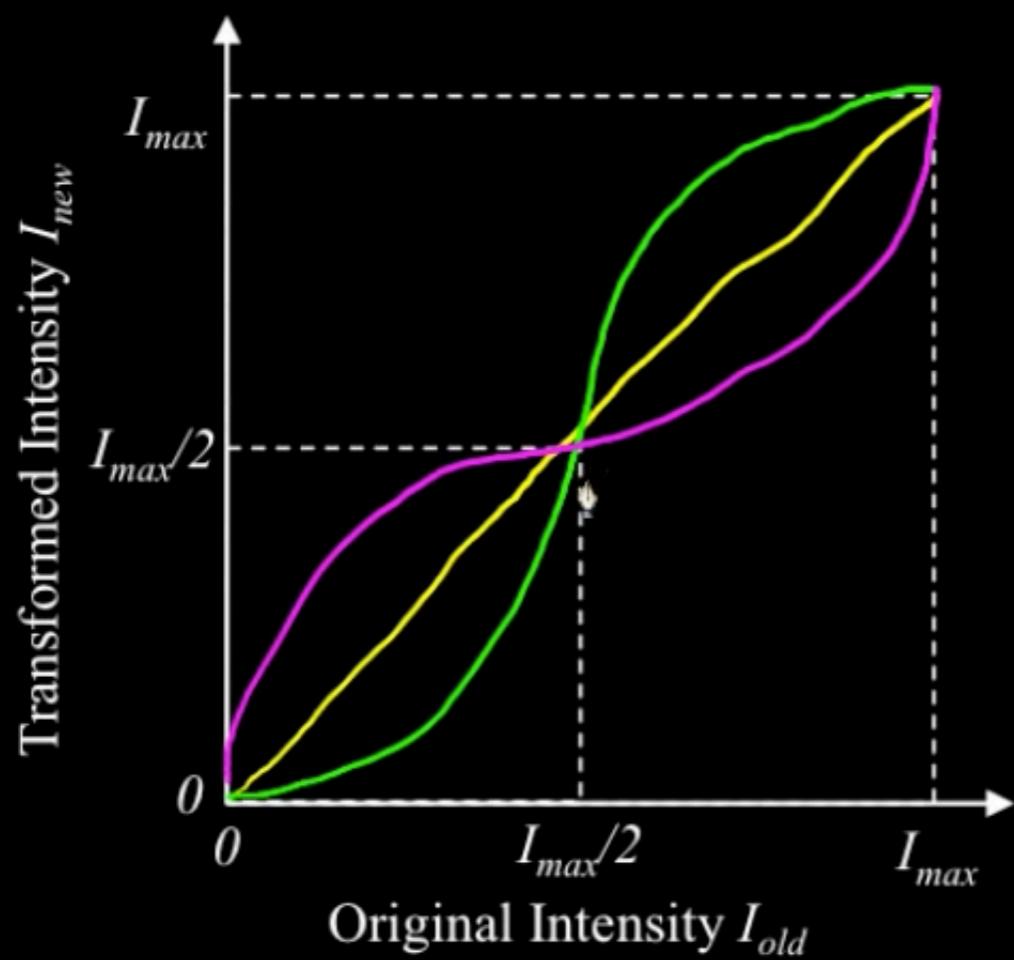
Enhance contrast

Contrast Transformation



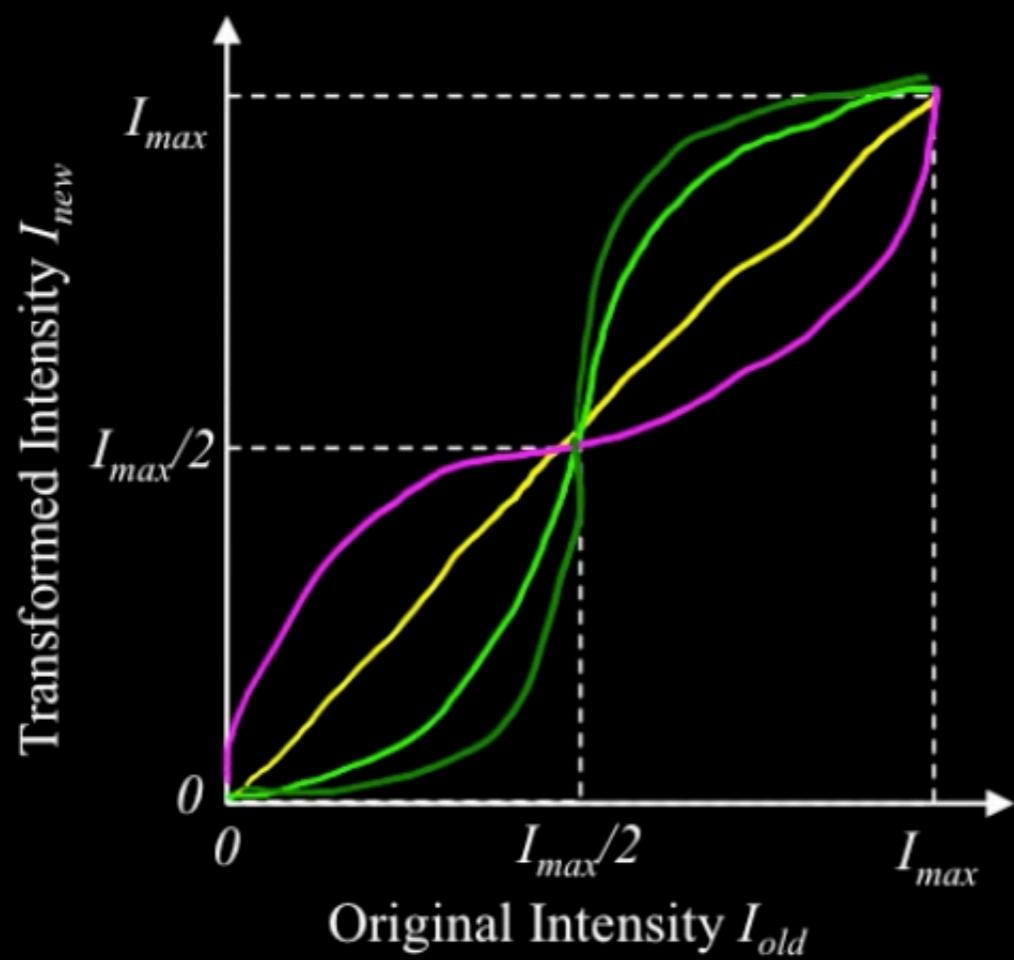
Reduce contrast

Contrast Transformation



Enhance contrast more

Contrast Transformation



Reduce contrast more

Contrast Transformation

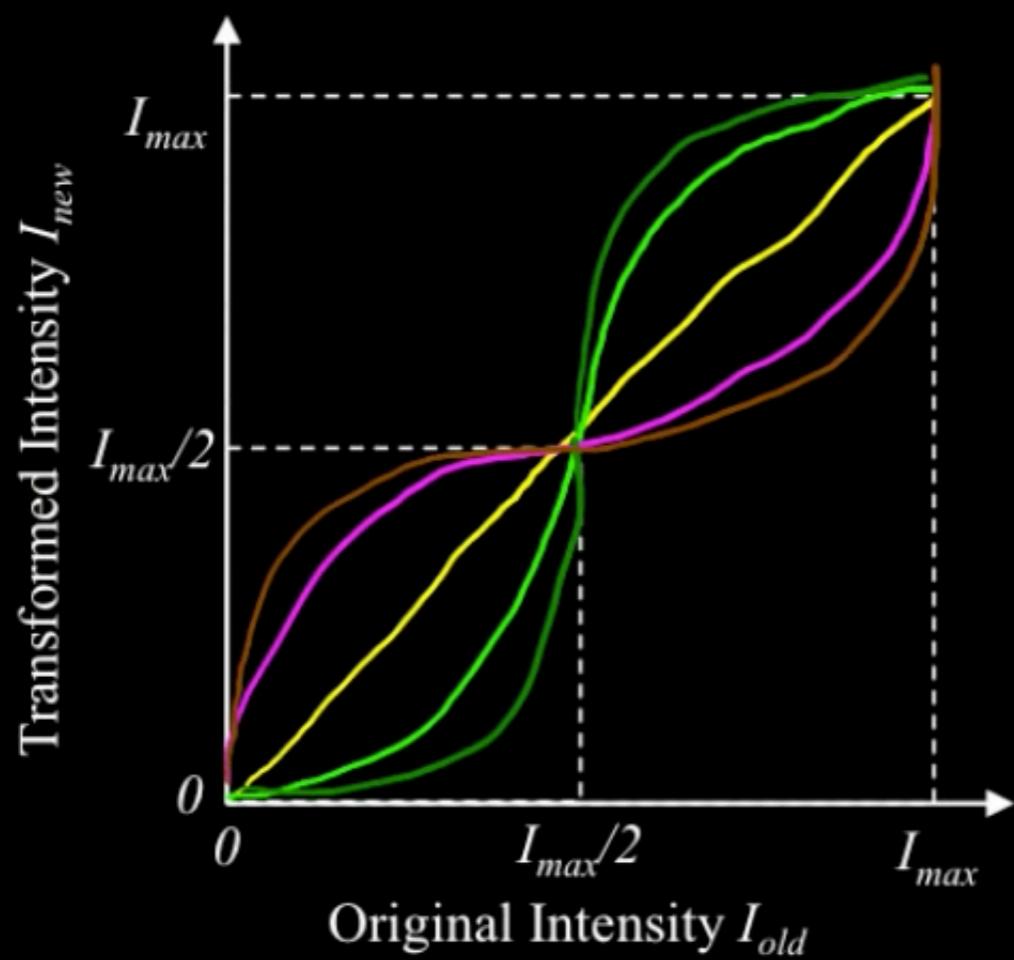
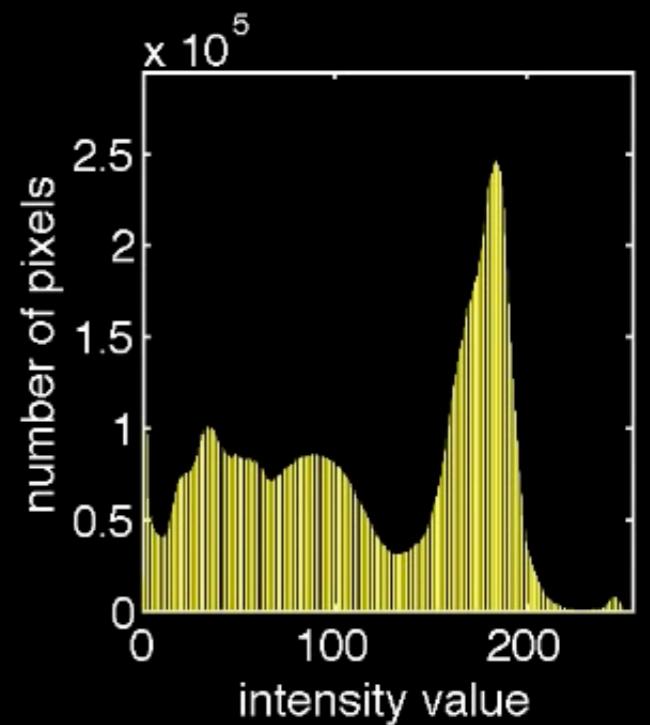
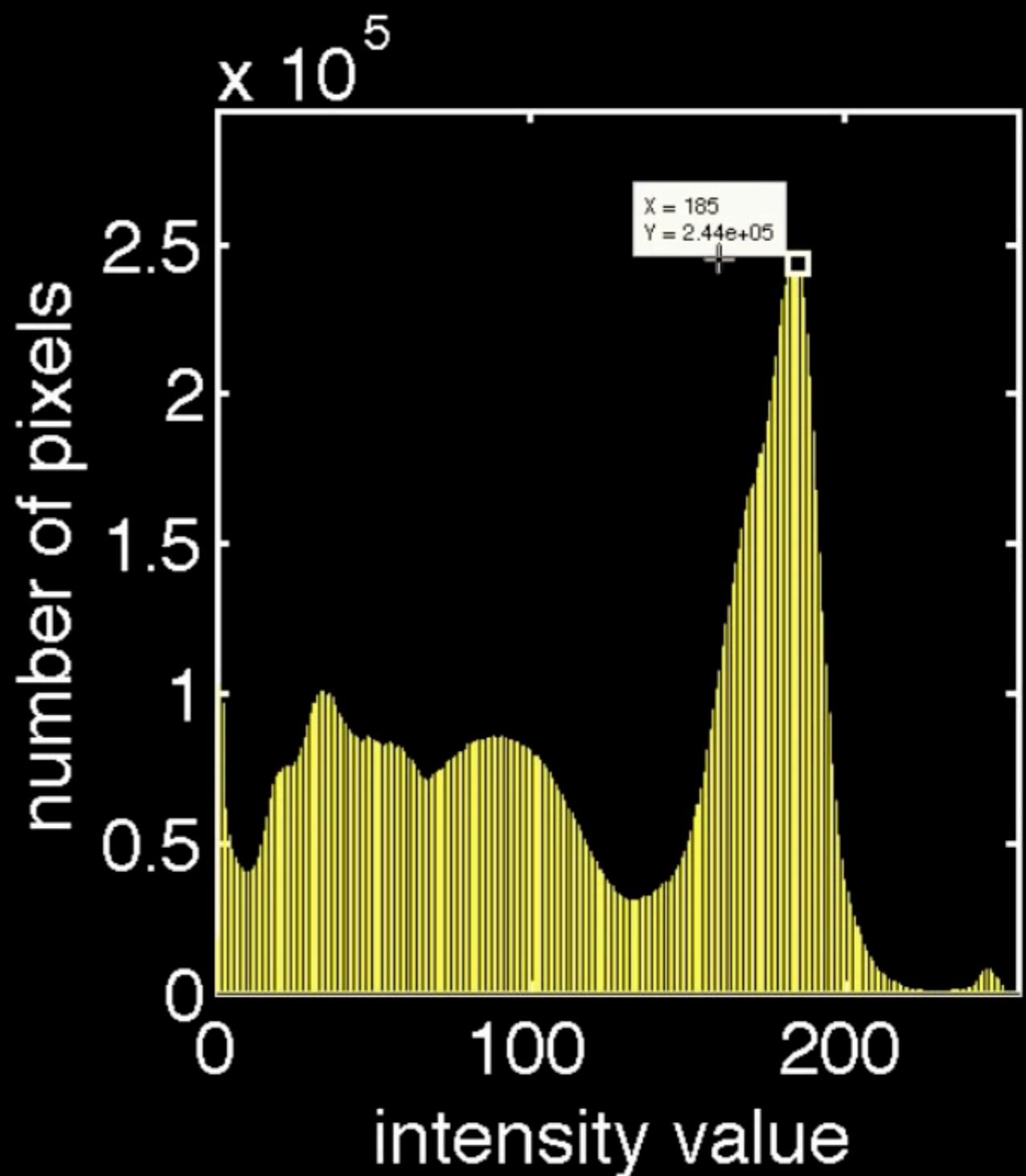


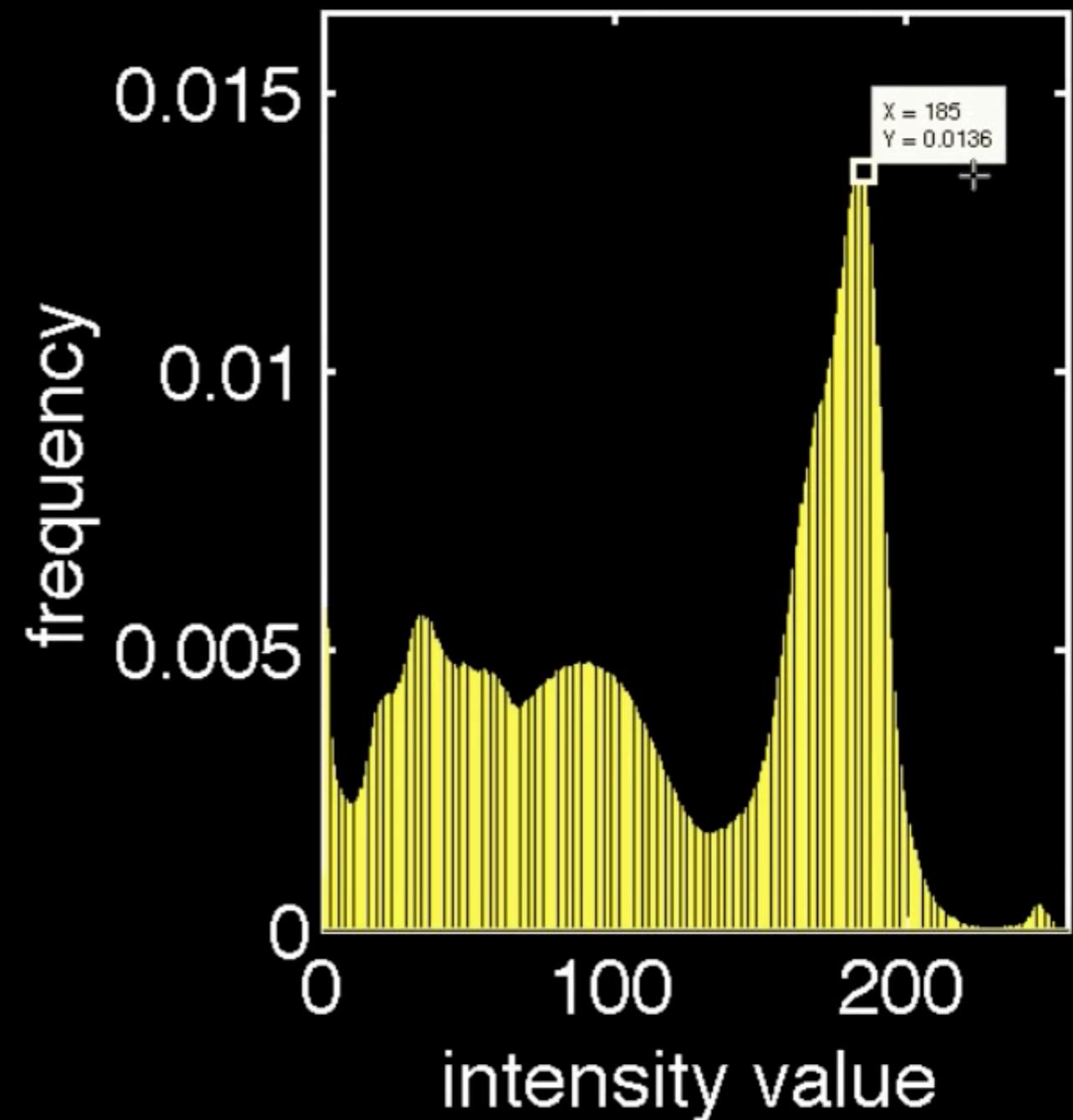
Image and corresponding histogram



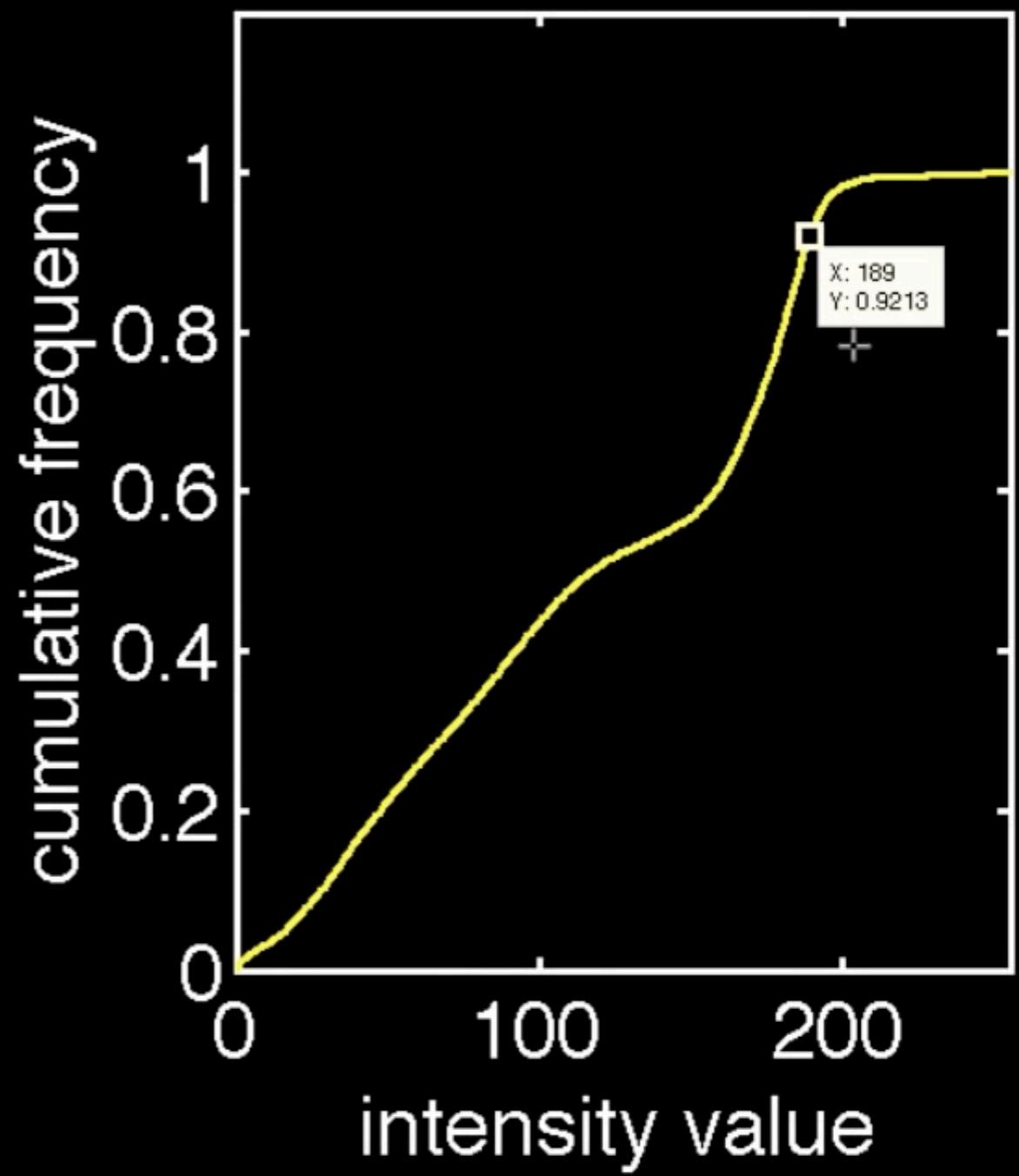
Histogram



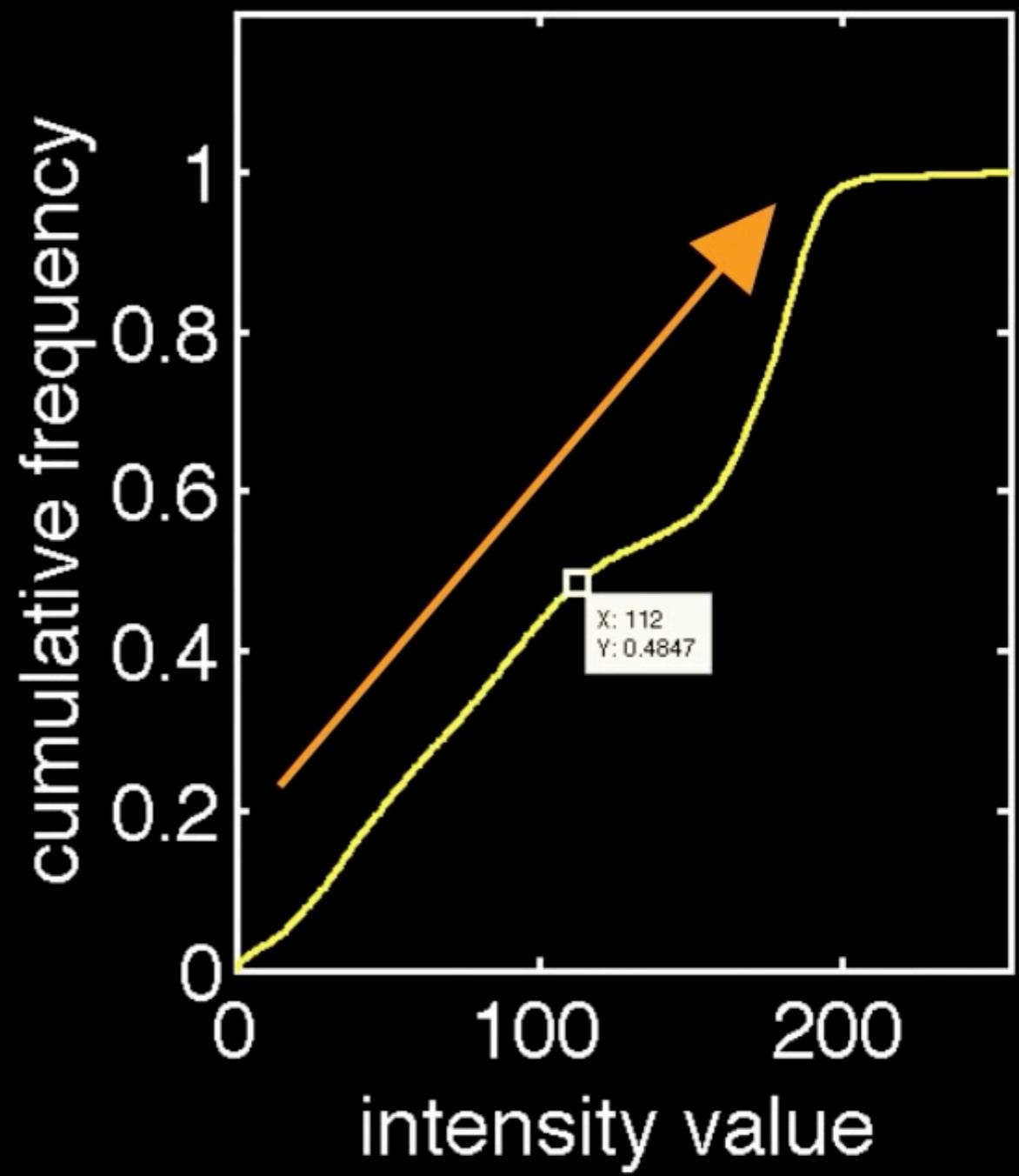
Normalized histogram (proportion, %)



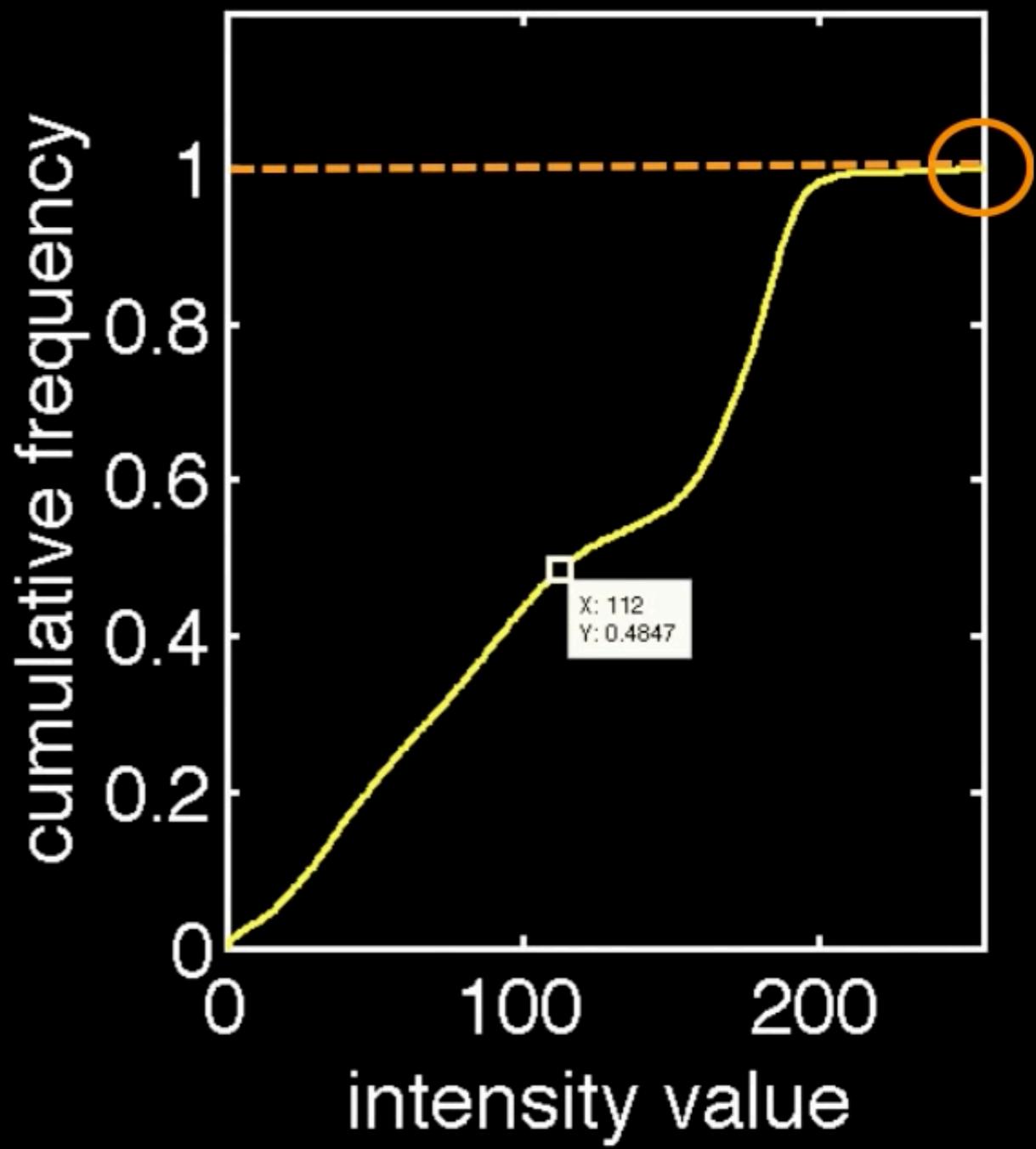
Cumulative histogram (% less or equal)



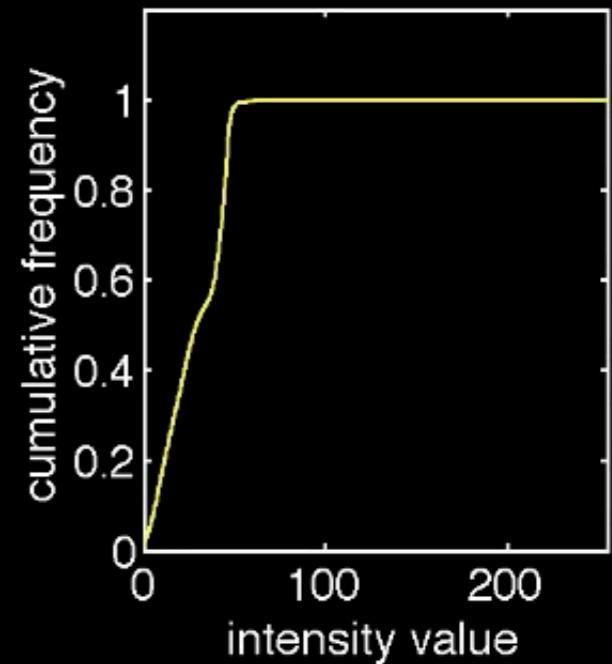
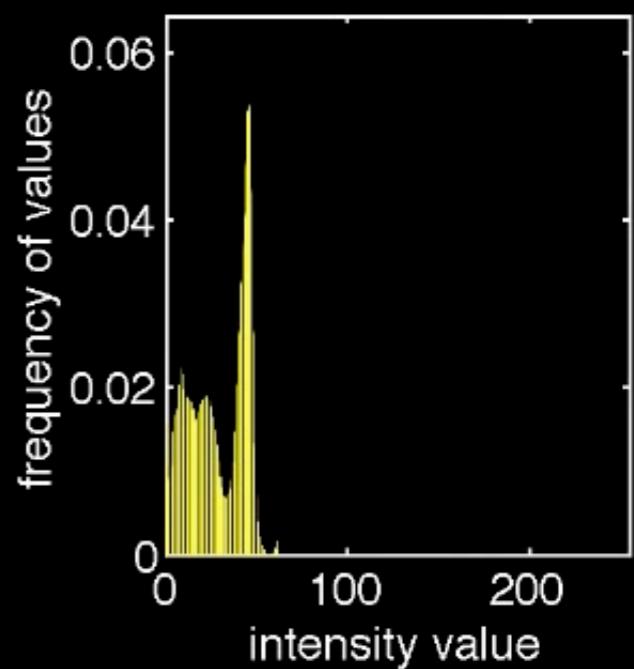
None decreasing



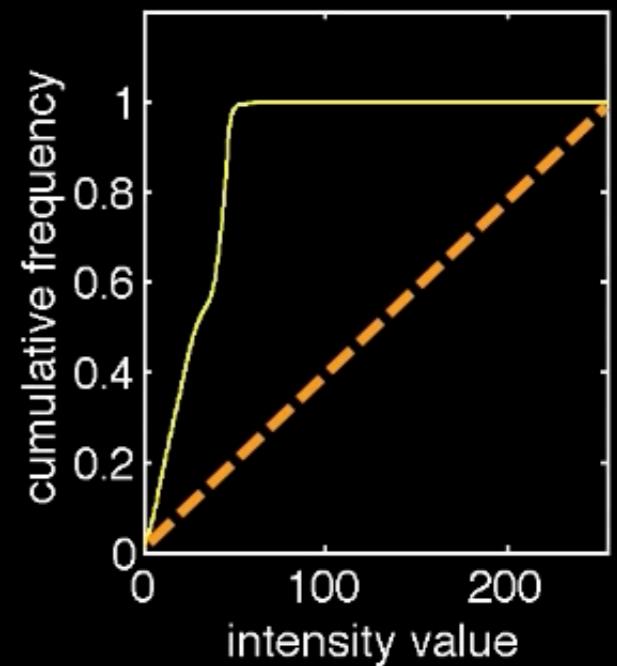
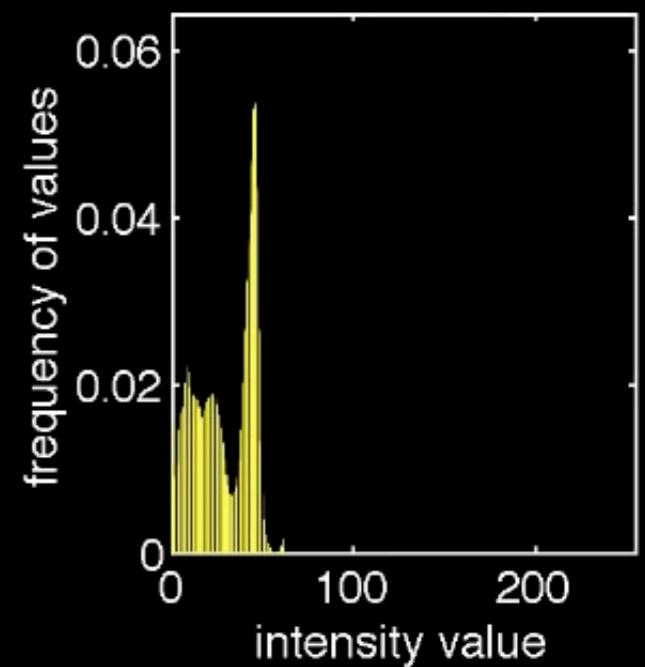
Max = 1



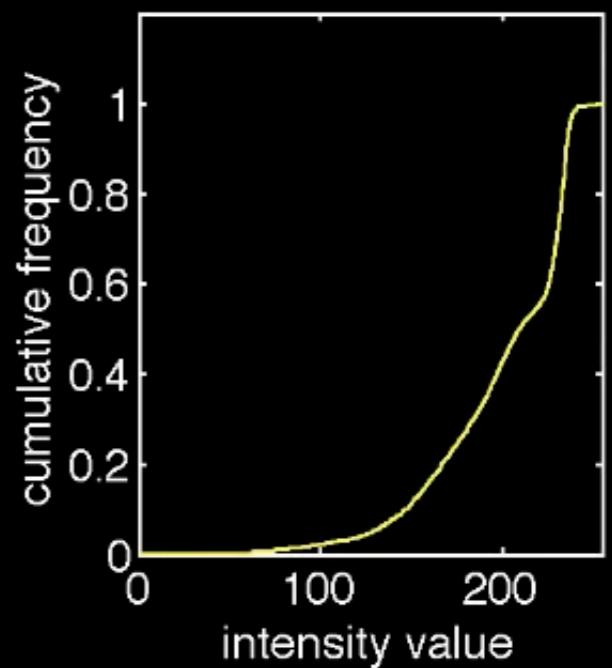
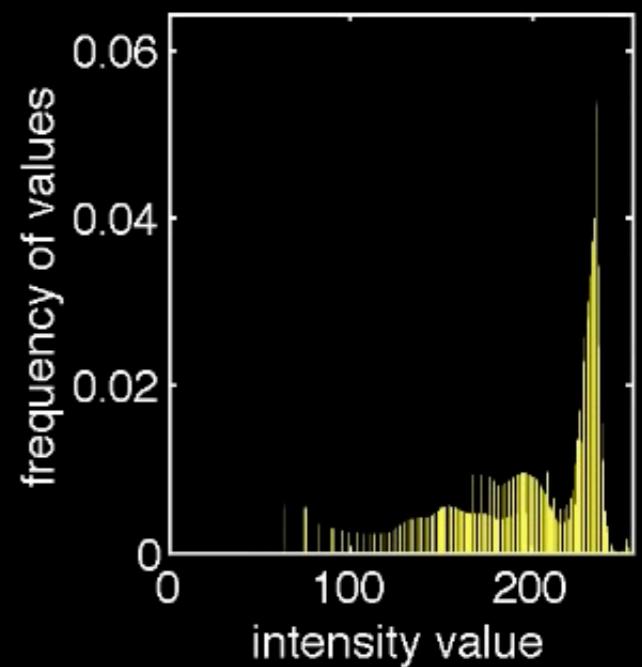
Dark image



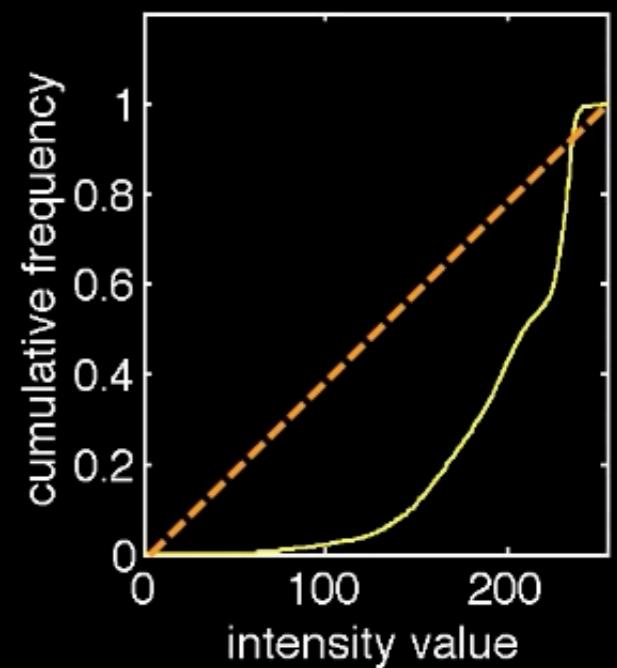
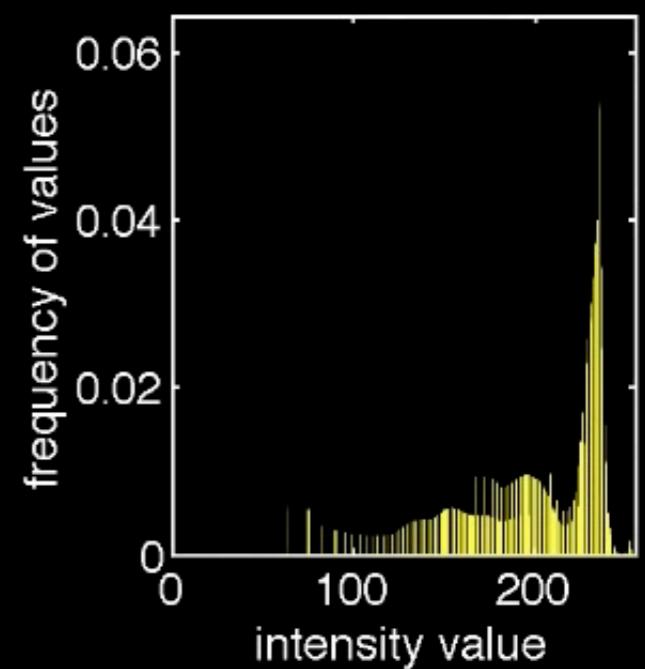
What if cum. hist = int. transf.: brighter



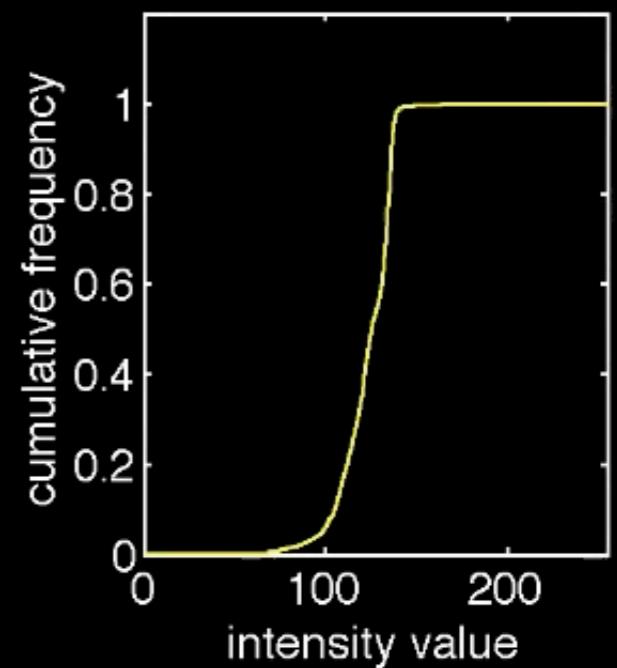
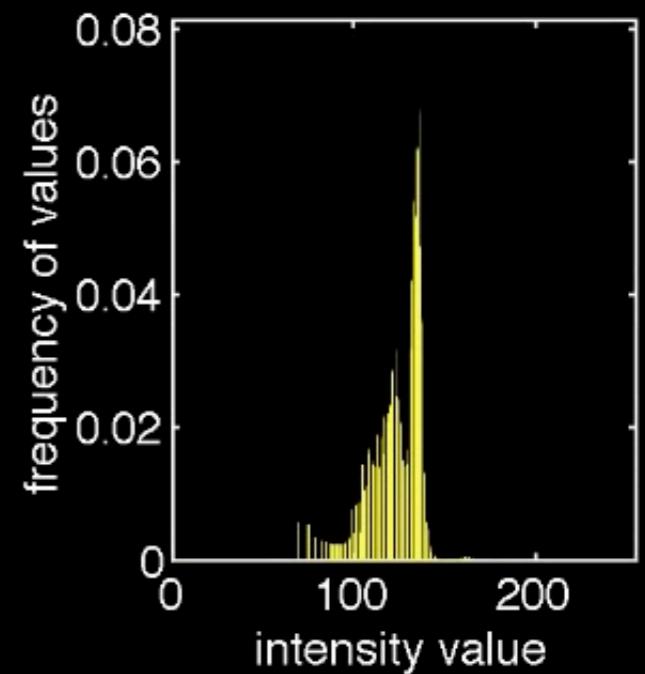
Bright image



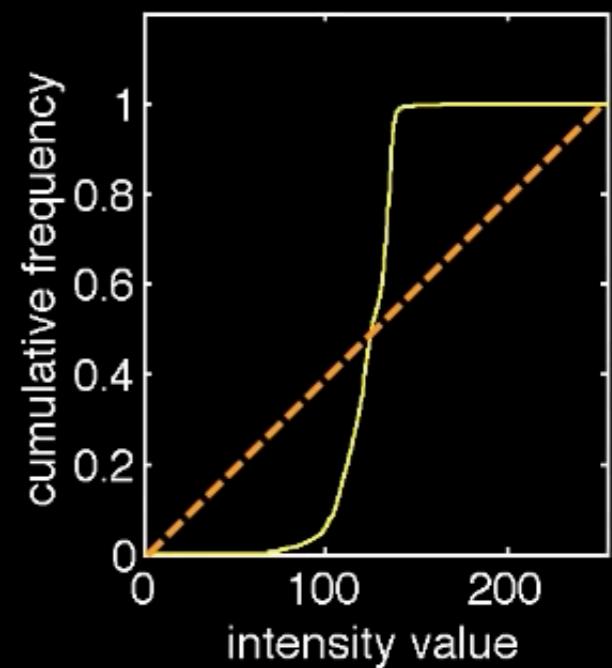
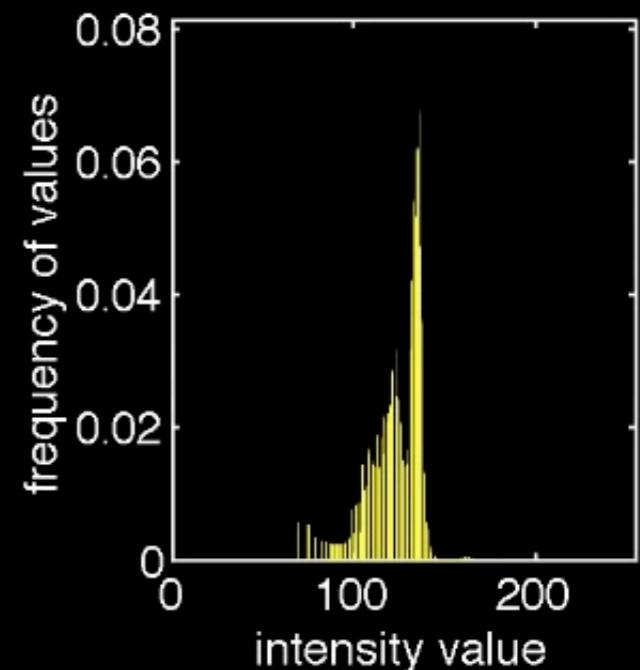
Below, decreased, less bright



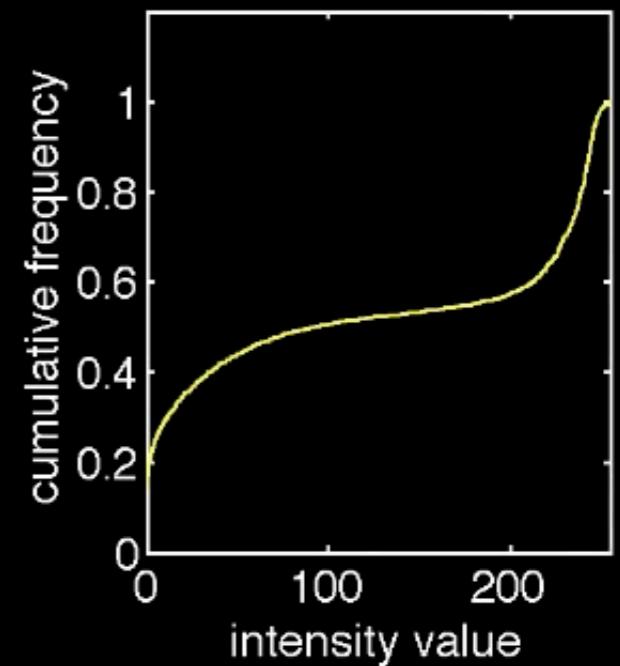
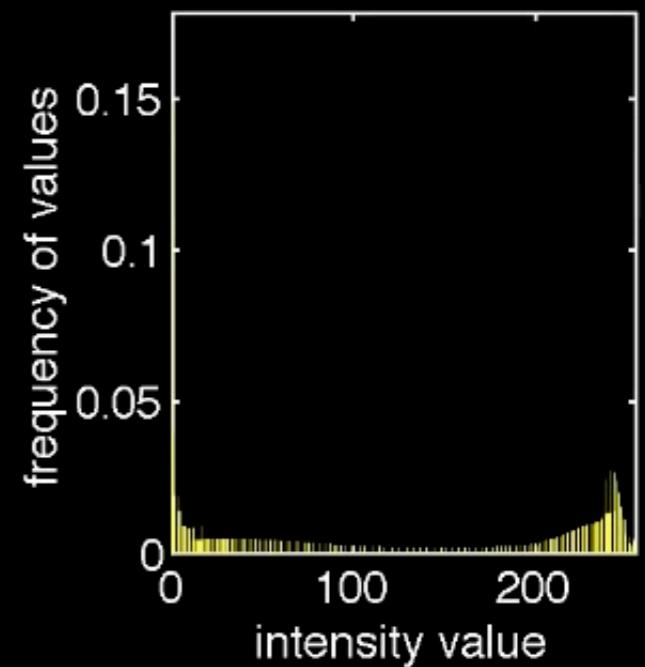
Low contrast image



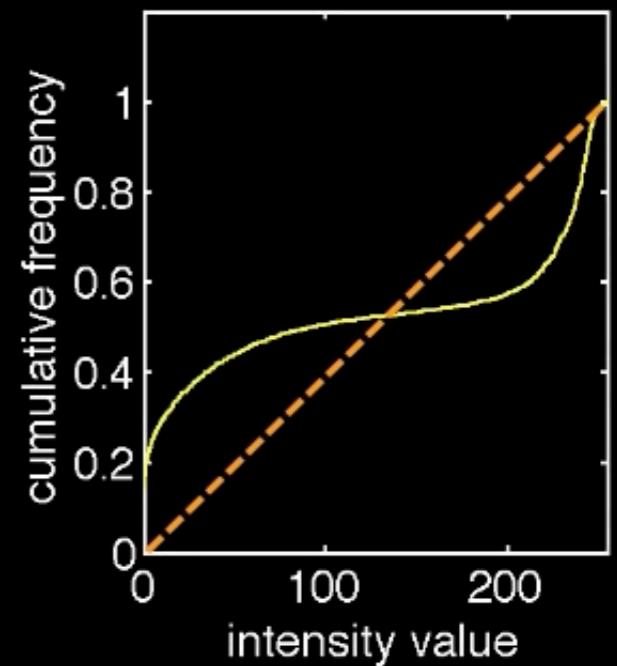
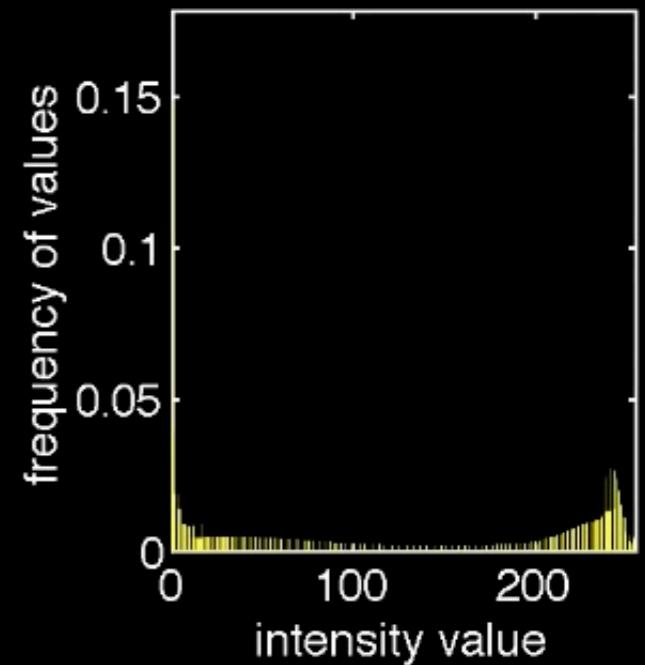
Increase contrast



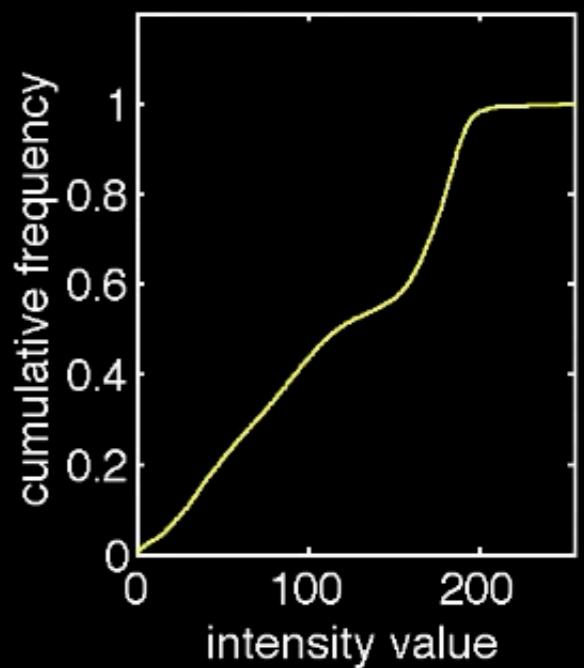
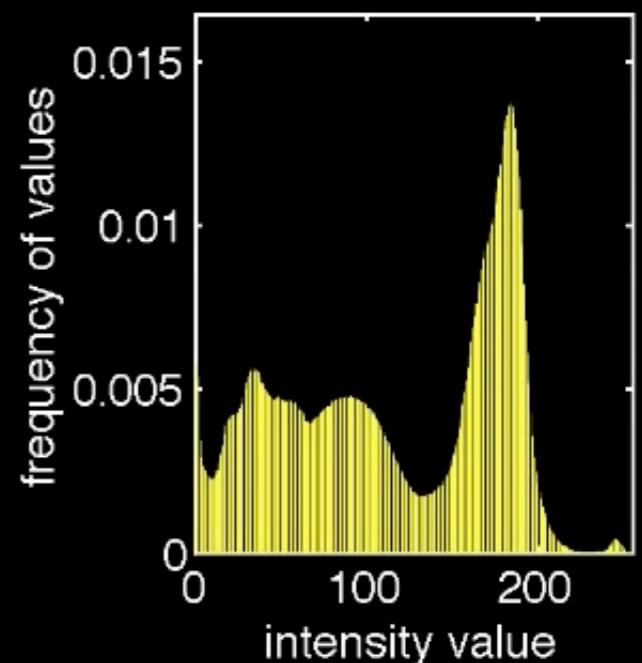
(too) High contrast



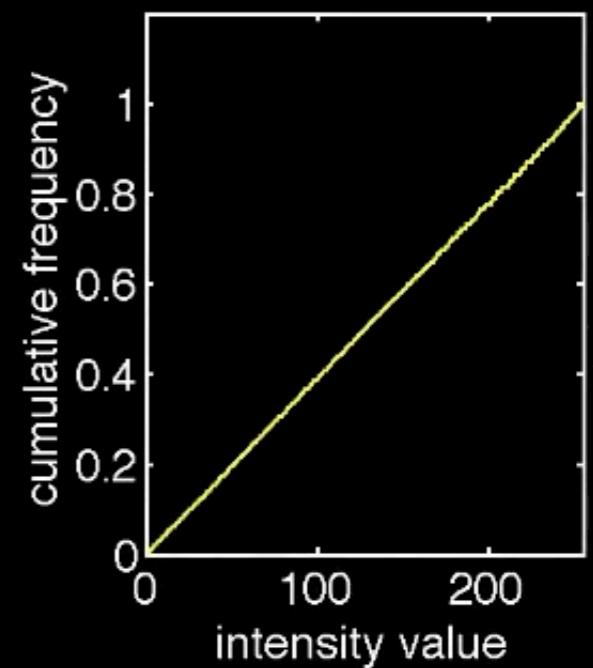
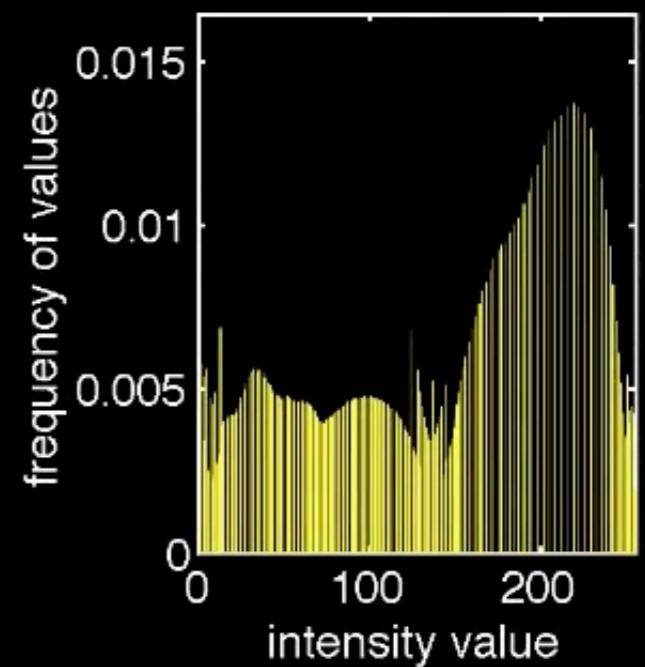
Decrease contrast



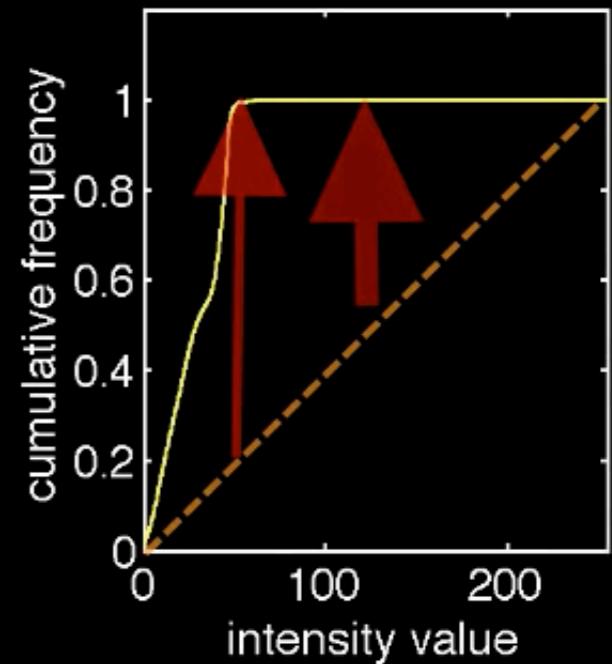
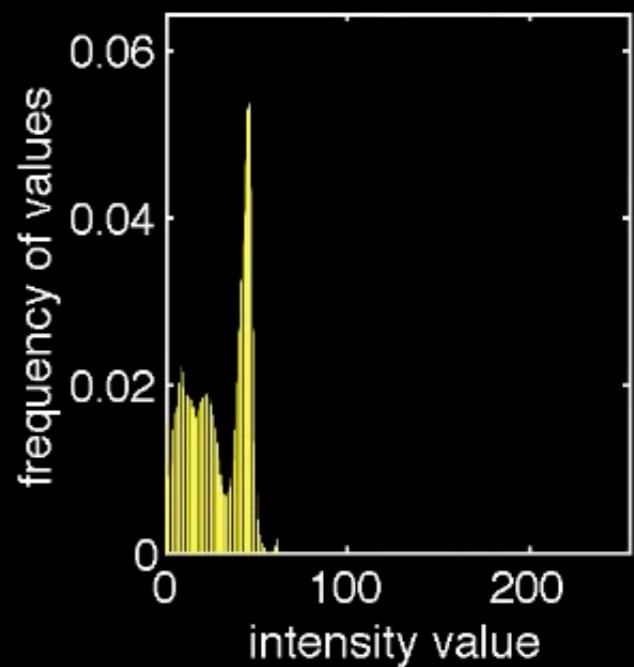
Original image



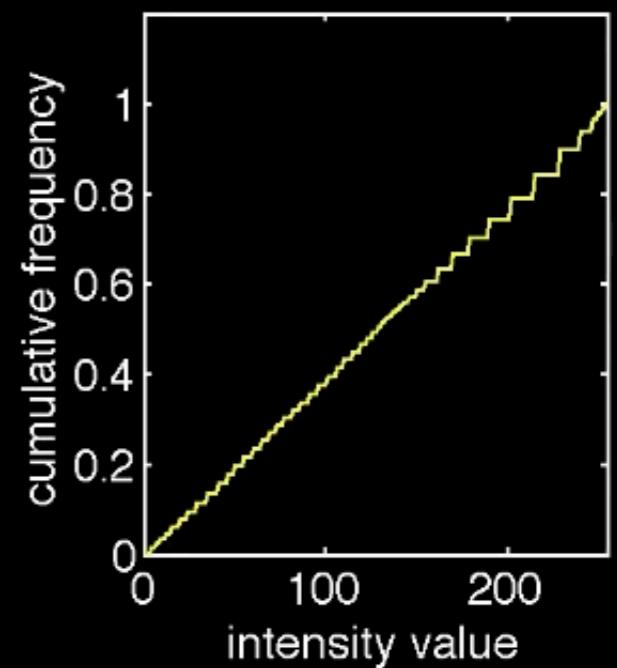
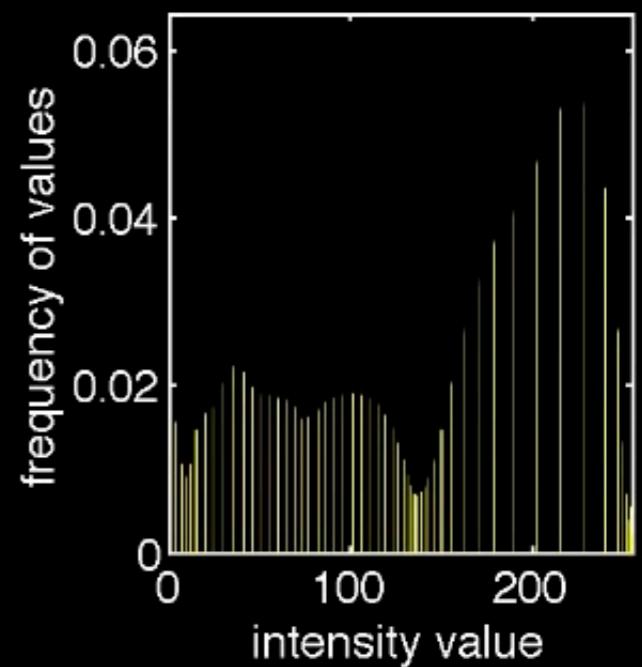
Original image: Result



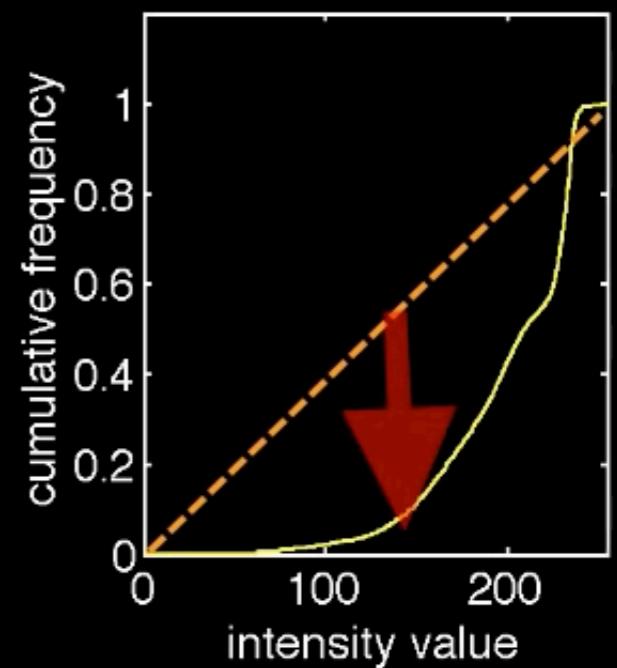
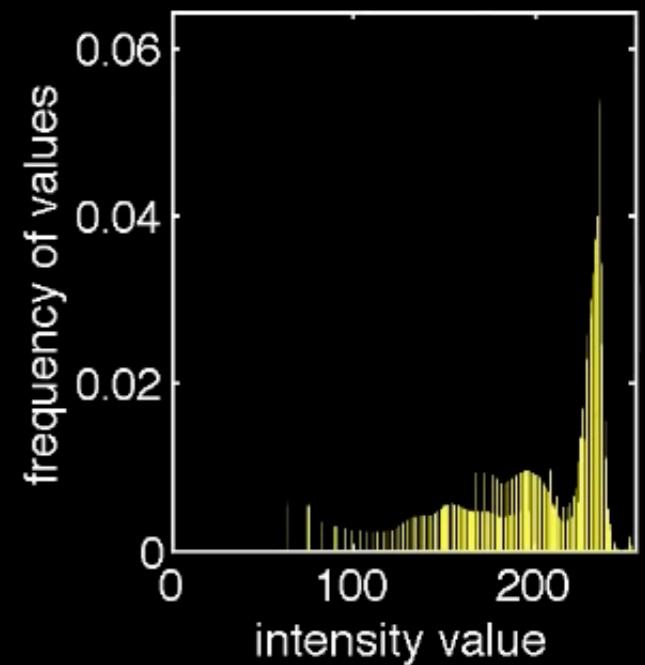
Dark image



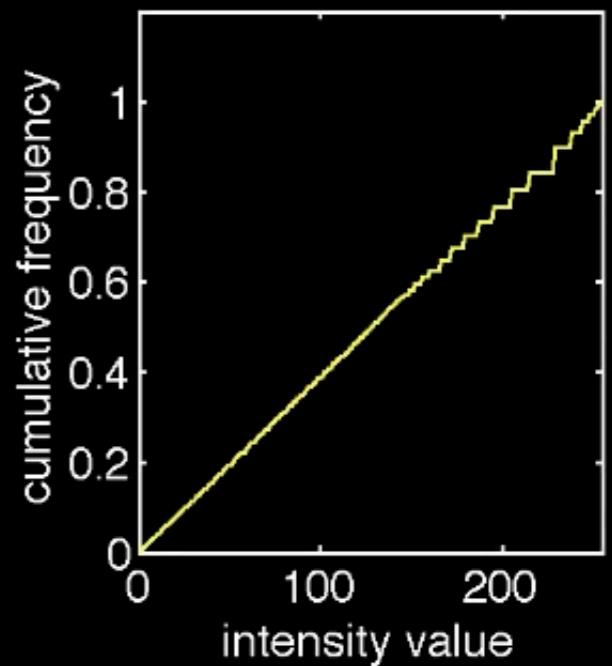
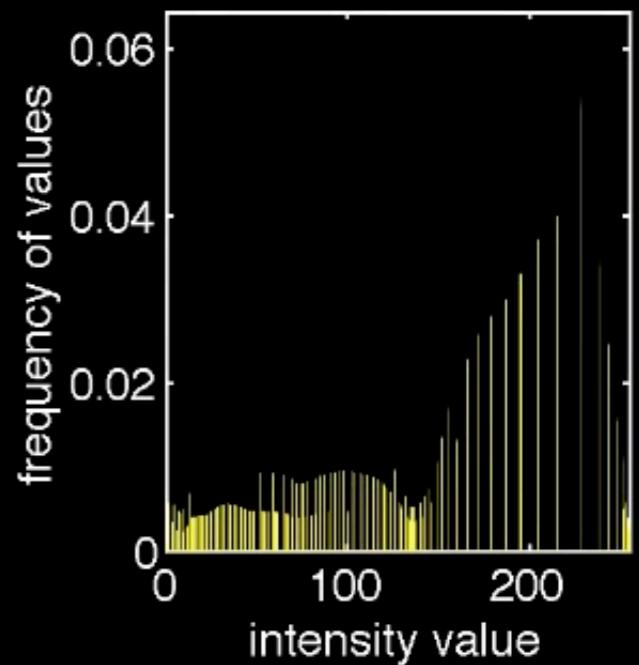
Dark image: Result



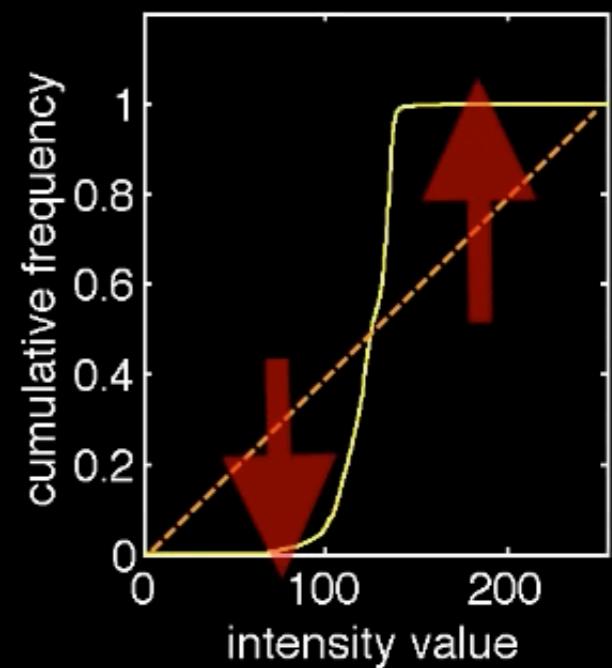
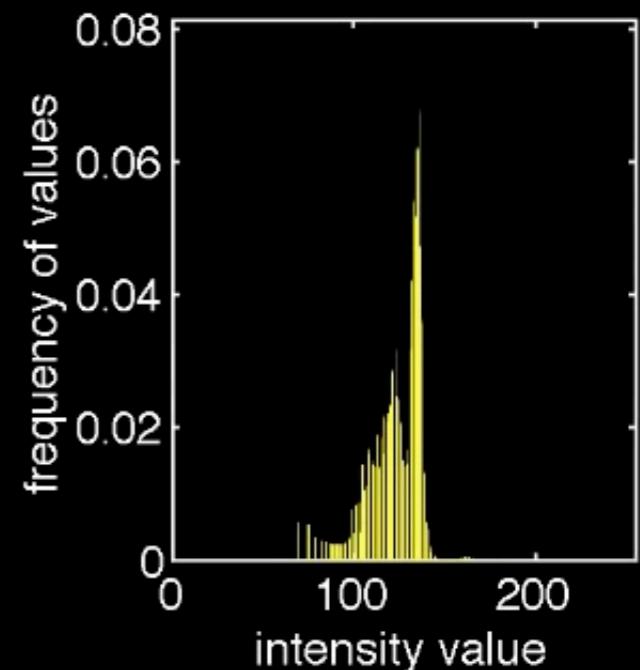
Bright image



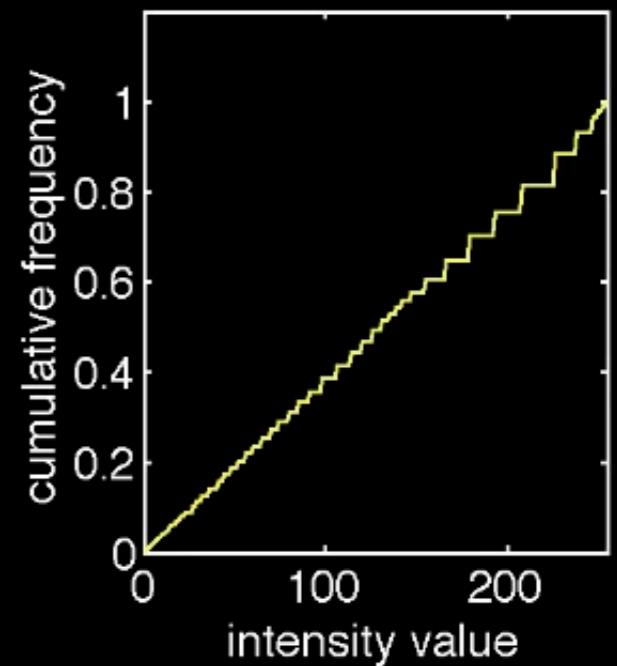
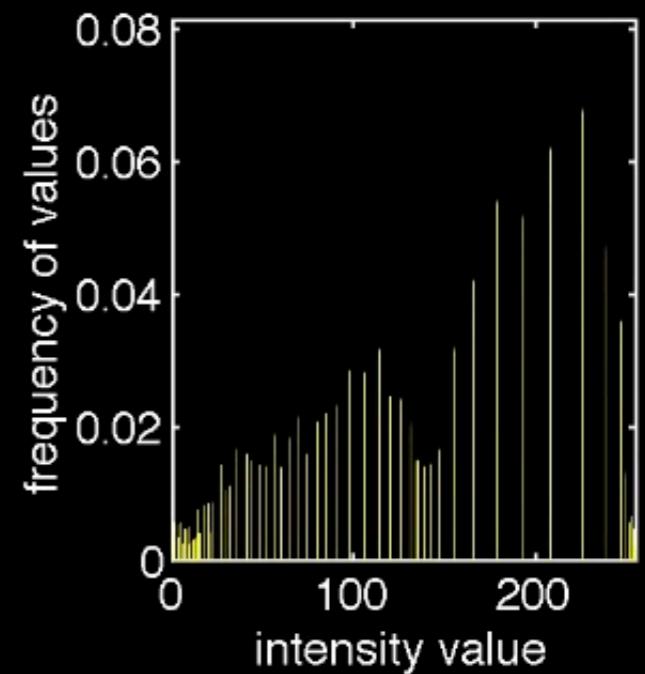
Bright image: Result



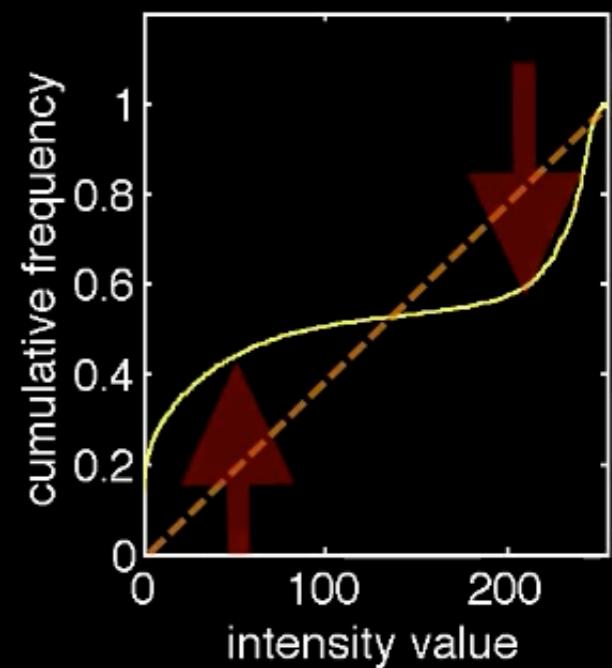
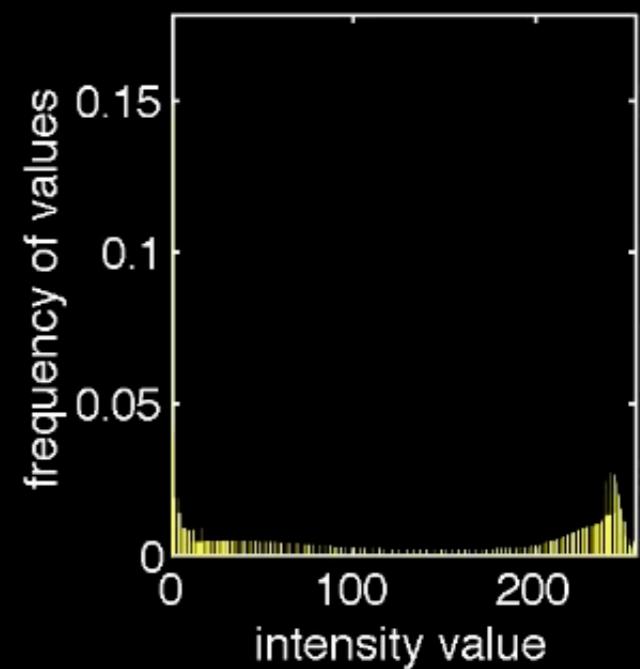
Low-contrast image



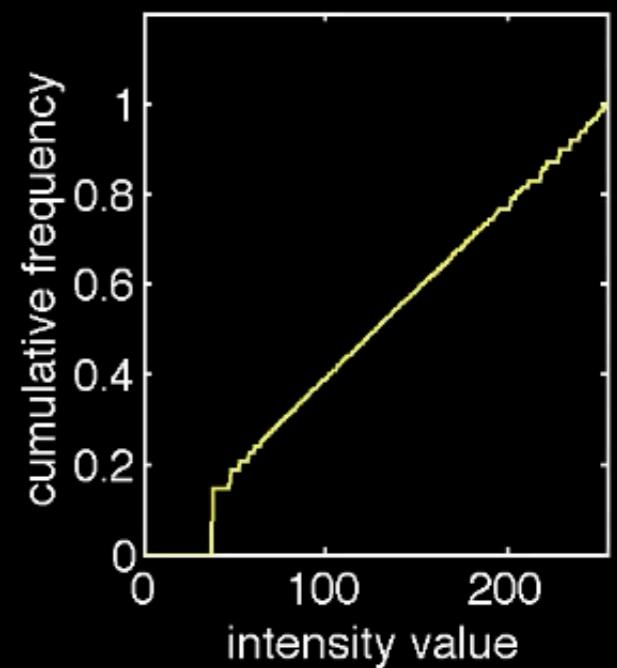
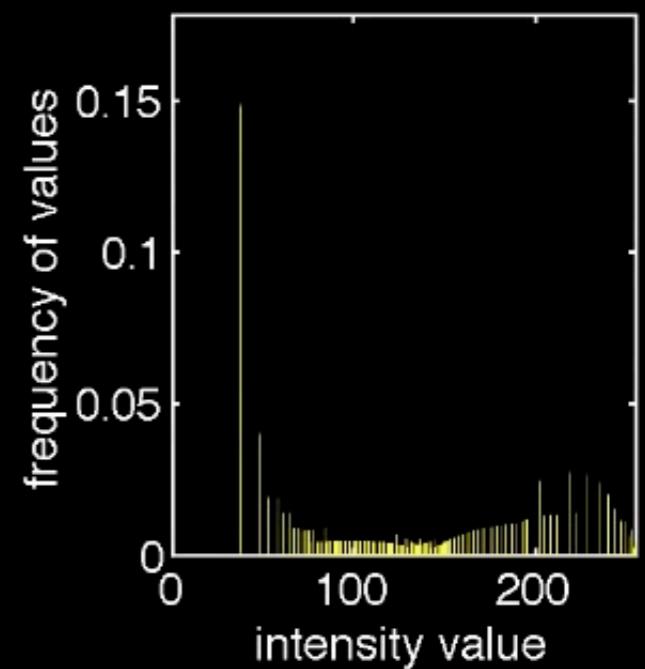
Low-contrast image: Result



High-contrast image



High-contrast image: Results



Histogram Equalization

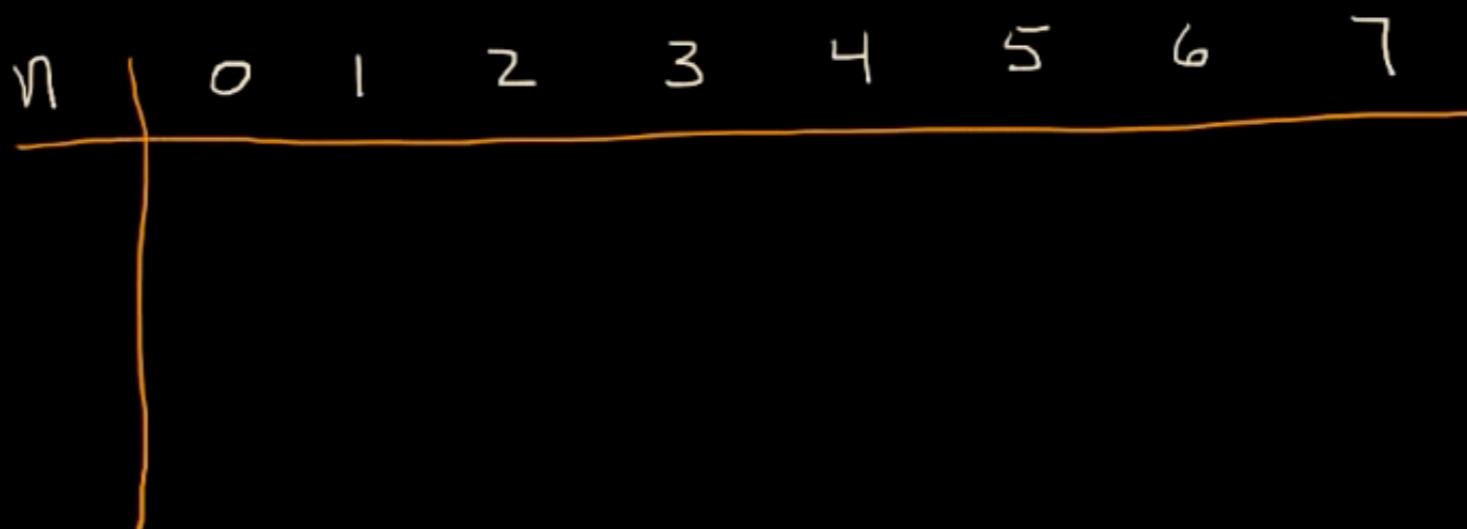
Frequency Histogram

5	2	1	4
7	3	0	2
2	1	6	3
5	1	4	0

*

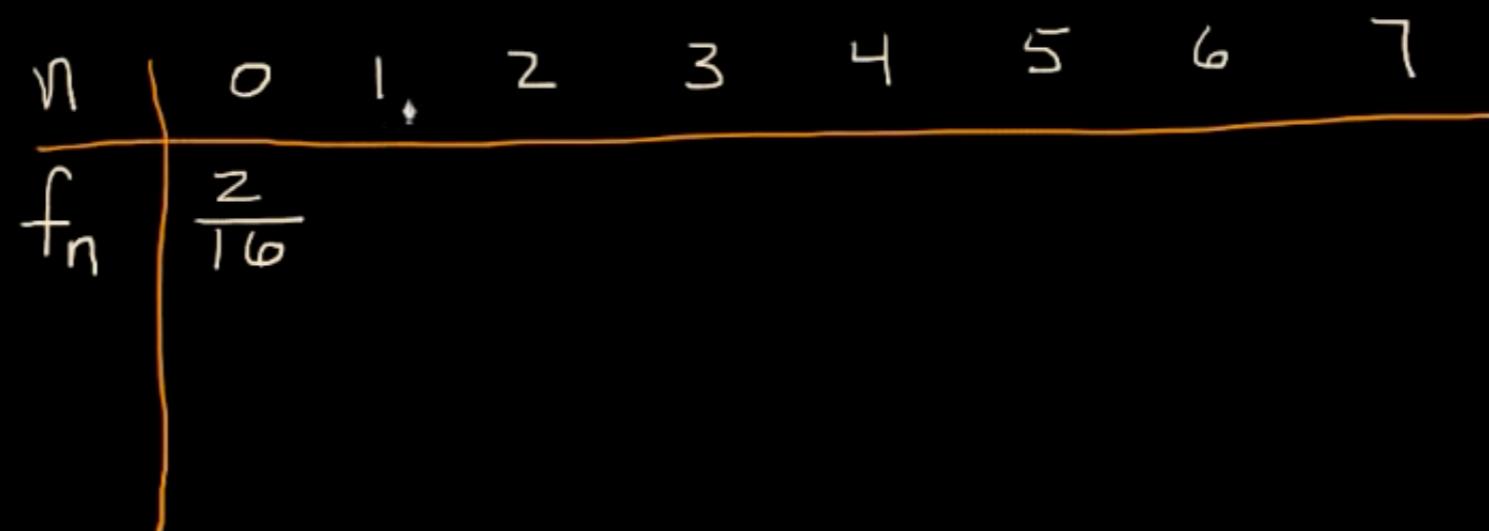
Frequency Histogram

5	2	1	4
7	3	0	2
2	1	6	3
5	1	4	0



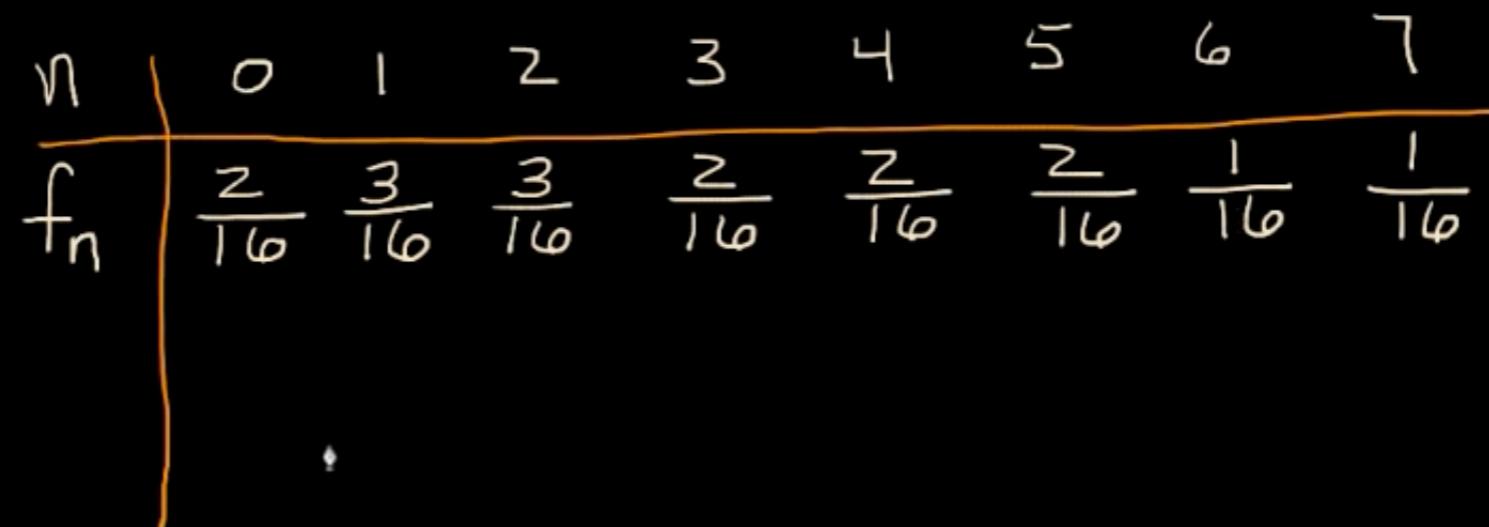
Frequency Histogram

5	2	1	4
7	3	0	2
2	1	6	3
5	1	4	0



Frequency Histogram

5	2	1	4
7	3	0	2
2	1	6	3
5	1	4	0



Frequency Histogram

5	2	1	4
7	3	0	2
2	1	6	3
5	1	4	0

n	0	1	2	3	4	5	6	7
f_n	$\frac{2}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{2}{16}$	$\frac{2}{16}$	$\frac{2}{16}$	$\frac{1}{16}$	$\frac{1}{16}$
F_n	$\frac{2}{16}$							

Frequency Histogram

5	2	1	4
7	3	0	2
2	1	6	3
5	1	4	0

n	0	1	2	3	4	5	6	7
f_n	$\frac{2}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{2}{16}$	$\frac{2}{16}$	$\frac{2}{16}$	$\frac{1}{16}$	$\frac{1}{16}$
F_n	$\frac{2}{16}$	$\frac{5}{16}$						

Frequency Histogram

5	2	1	4
7	3	0	2
2	1	6	3
5	1	4	0

n	0	1	2	3	4	5	6	7
f_n	$\frac{2}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{2}{16}$	$\frac{2}{16}$	$\frac{2}{16}$	$\frac{1}{16}$	$\frac{1}{16}$
F_n	$\frac{2}{16}$	$\frac{5}{16}$	$\frac{8}{16}$	$\frac{10}{16}$	$\frac{12}{16}$	$\frac{14}{16}$	$\frac{15}{16}$	$\frac{16}{16}$

*

5	2	1	4
7	3	0	2
2	1	6	3
5	1	4	0

n	0	1	2	3	4	5	6	7
f_n	$\frac{2}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{2}{16}$	$\frac{2}{16}$	$\frac{2}{16}$	$\frac{1}{16}$	$\frac{1}{16}$
F_n	$\frac{2}{16}$	$\frac{5}{16}$	$\frac{8}{16}$	$\frac{10}{16}$	$\frac{12}{16}$	$\frac{14}{16}$	$\frac{15}{16}$	$\frac{16}{16}$

$$F_0 = f_0$$

$$F_1 = F_0 + f_1$$

$$F_2 = F_1 + f_2$$

⋮

$$F_n = F_{n-1} + f_n$$

↓