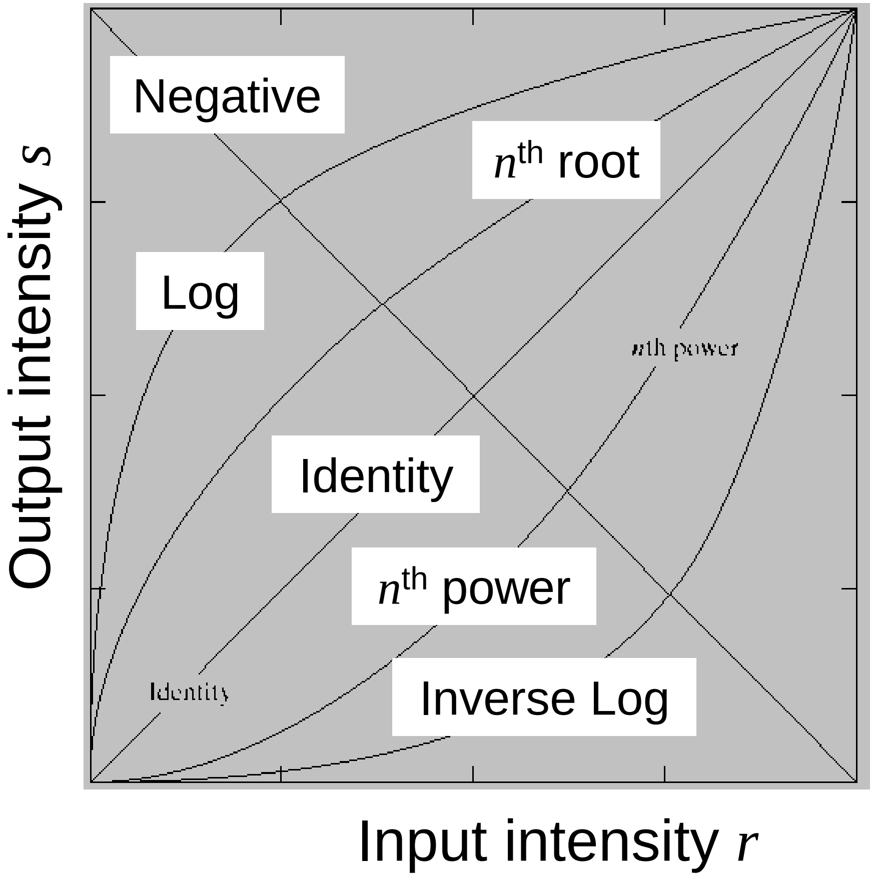
Intensity Transformations

Contrast Enhancements

Intensity Transformations

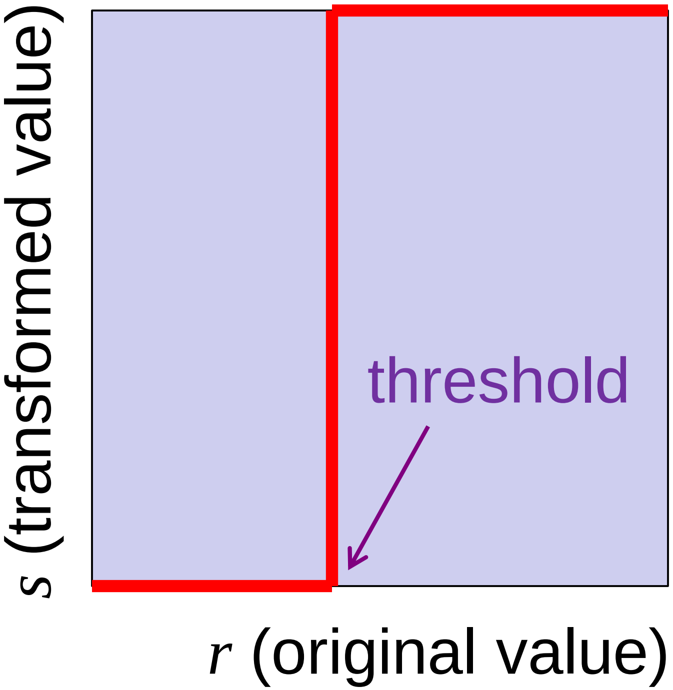
- Transform function $s=T(r)$, where s and r are the original and transformed intensity values, respectively.
- Per-pixel operation; values of neighboring pixels are not considered.

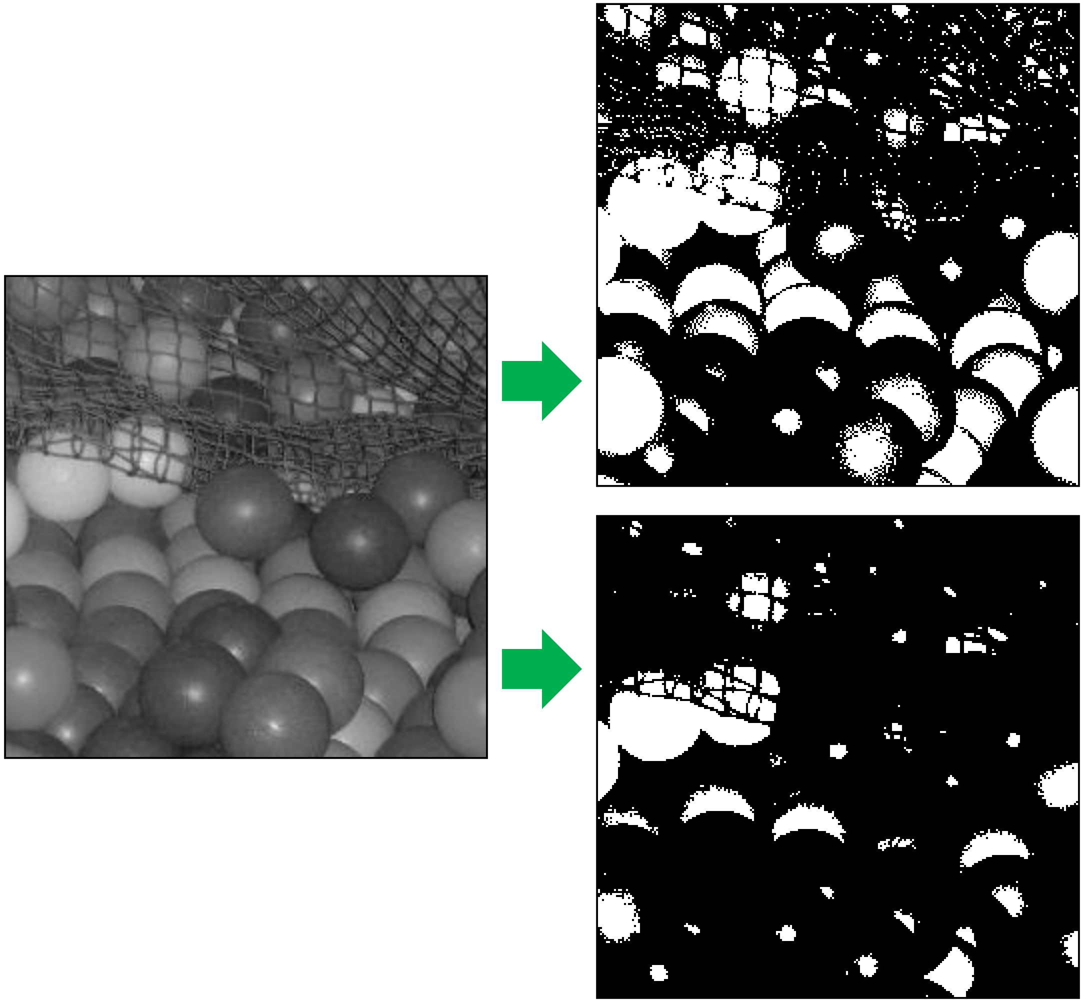
Some example intensity transformations:



Intensity Transformations

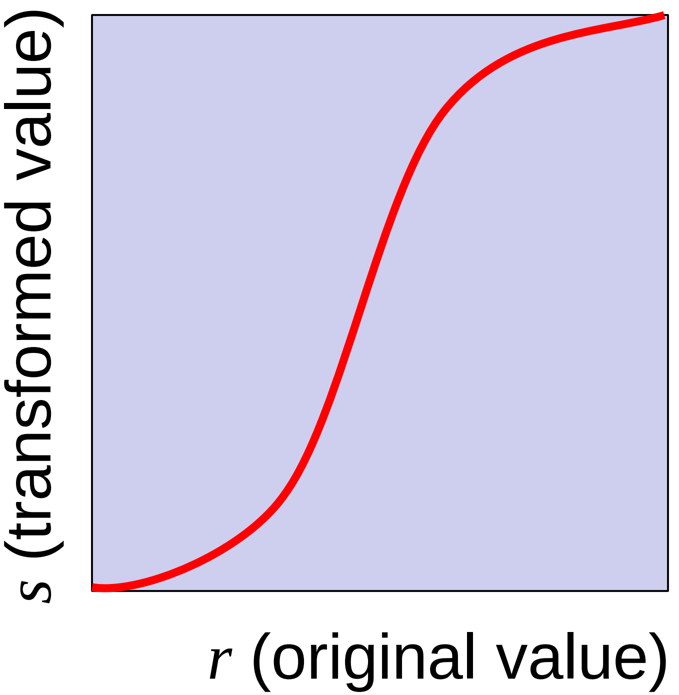
Example: **Thresholding**

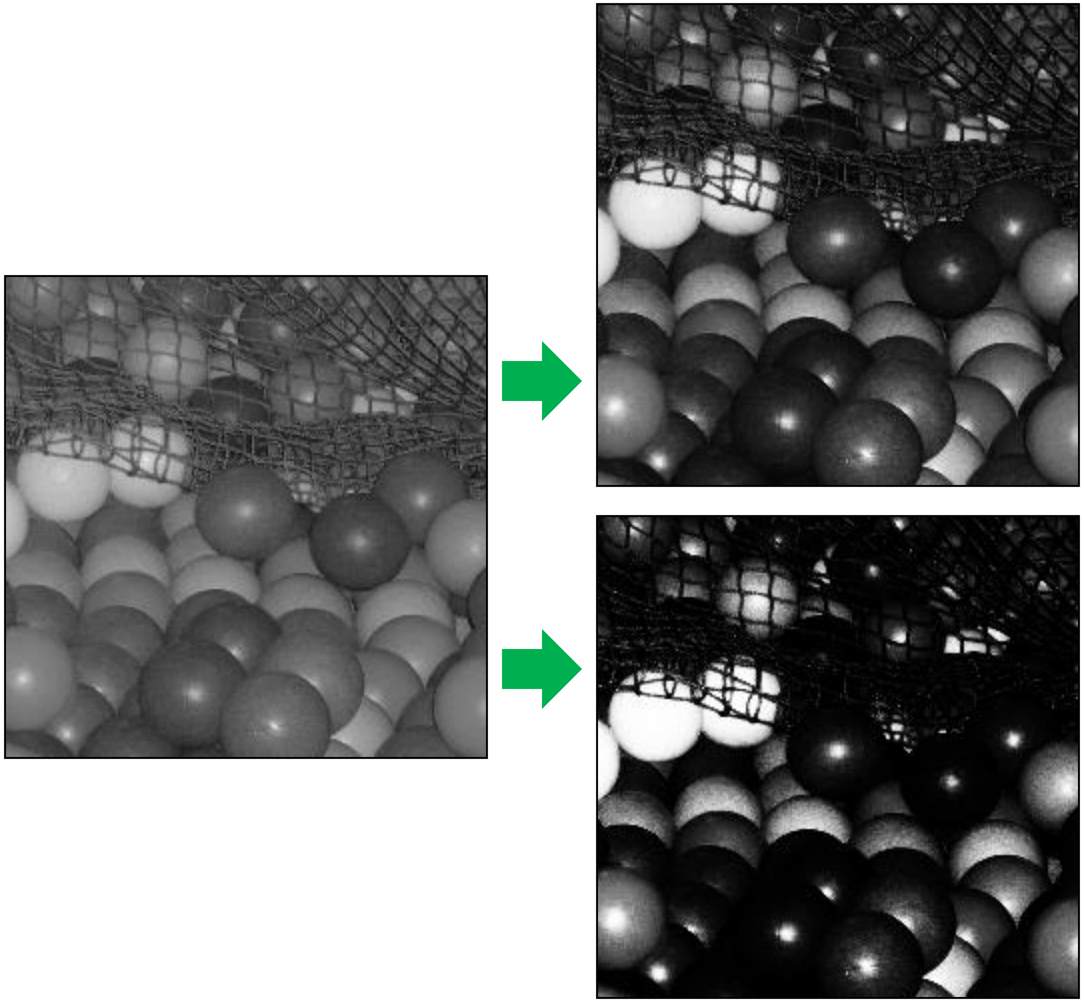




Intensity Transformations

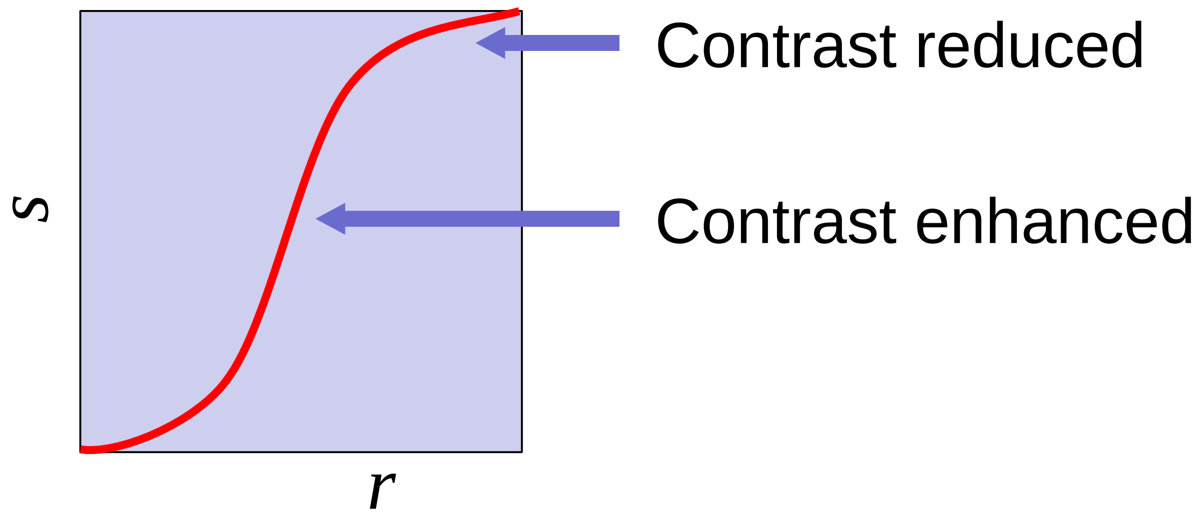
Example: Contrast Stretching





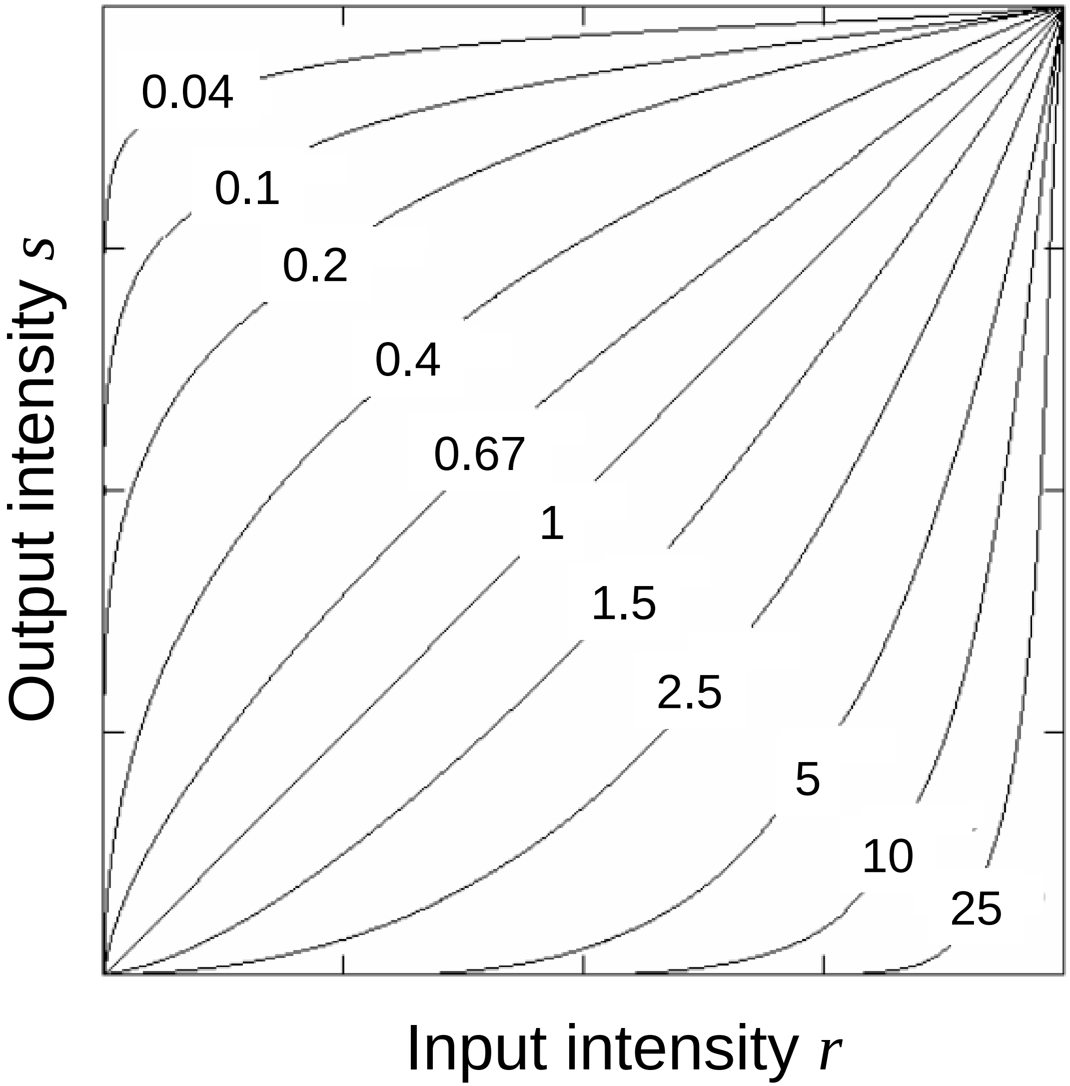
Intensity Transformations

- A major usage of intensity transformations is for contrast enhancement.
- The key to understand the behavior of a transform function is the slope (ds/dr).
  - Contrasts at r with $ds/dr > 1$ are enhanced.
  - Contrasts at r with $ds/dr < 1$ are reduced.



Power-Law Transformations

Form: $s = c\, r^{\gamma}$

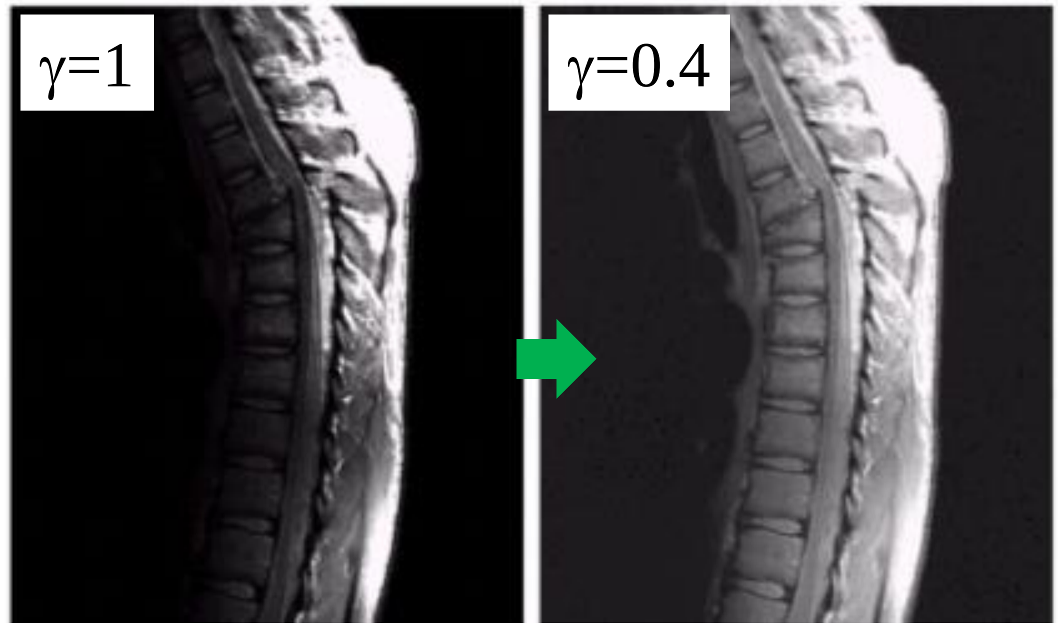


This is commonly called **gamma correction** and normally $c = 1$ (with both s and r scaled to between 0 and 1.)

Power-Law Transformations

Examples:

Under-exposure:



Over-exposure:

Image Histograms

Histogram is a simple and efficient way to characterize the intensity distribution of an image so that appropriate intensity transforms can be chosed automatically.

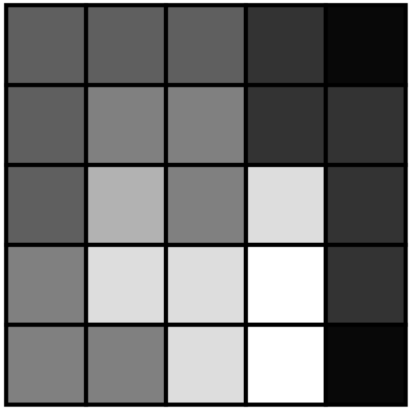
Definition of a histogram: $h(r_k) = n_k$

Histogram of a gray-level image:

r_k: the k^{th} gray level

n_k: the number of pixels with gray-level value r_k

Normalized histogram: $p(r_k) = n_k / n$



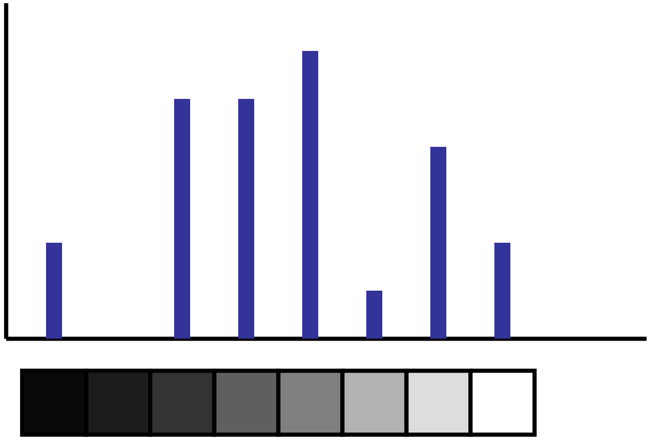
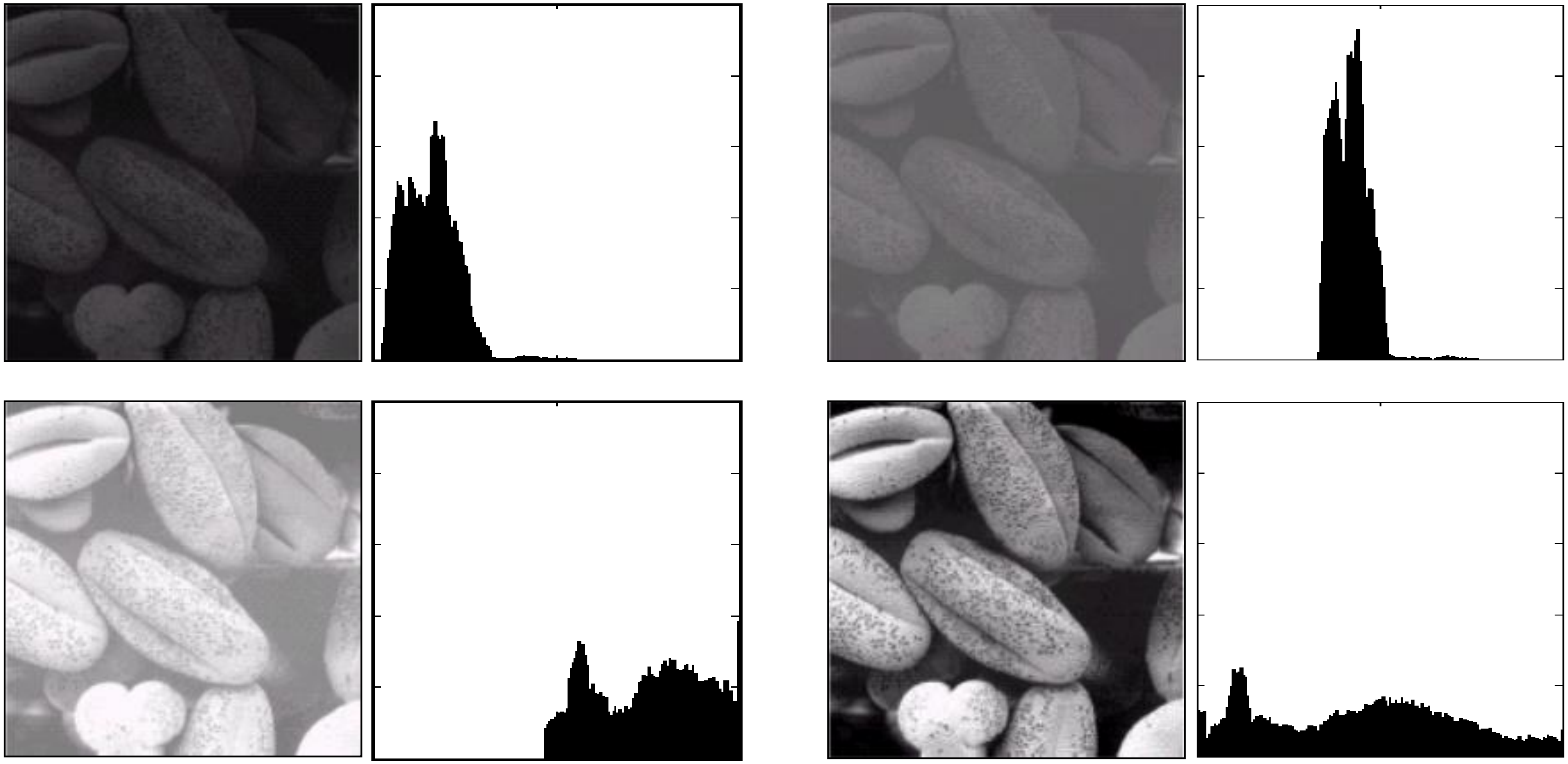


Image Histograms (Single-Channel)



We can see that a more uniform histogram generally corresponds to better overall contrast of the image. This observation leads to the technique of **histogram equalization**.

Histogram Equalization

Let's start with continuous r and s. (values of 0~1)

Now $p_r(r)$ and $p_s(s)$ are the normalized histograms (in the continuous sense) before and after the transformation, respectively.

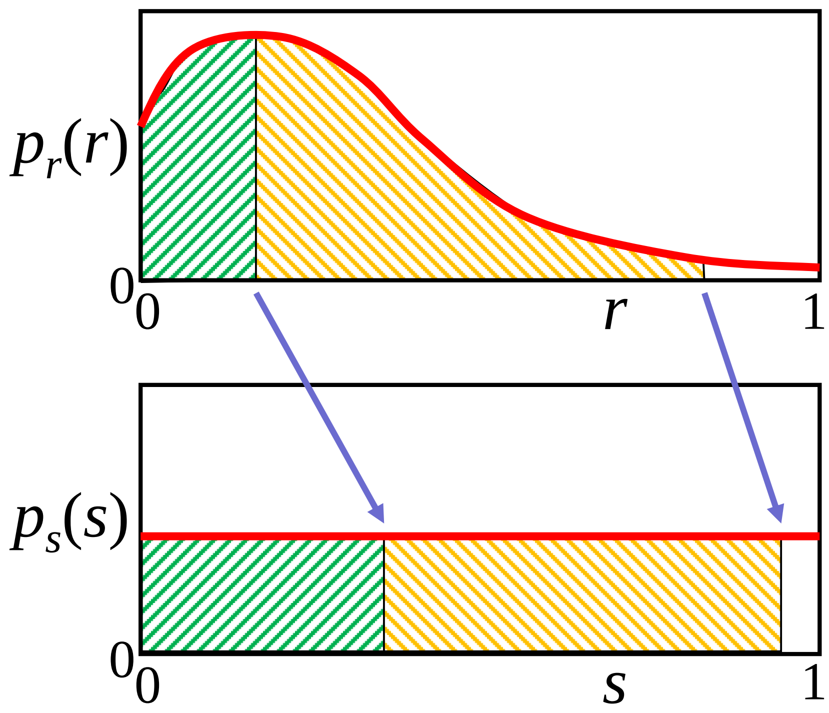
Transformation function:

$$s = T(r) = \int_0^r p_r(r')dr'$$

We get:

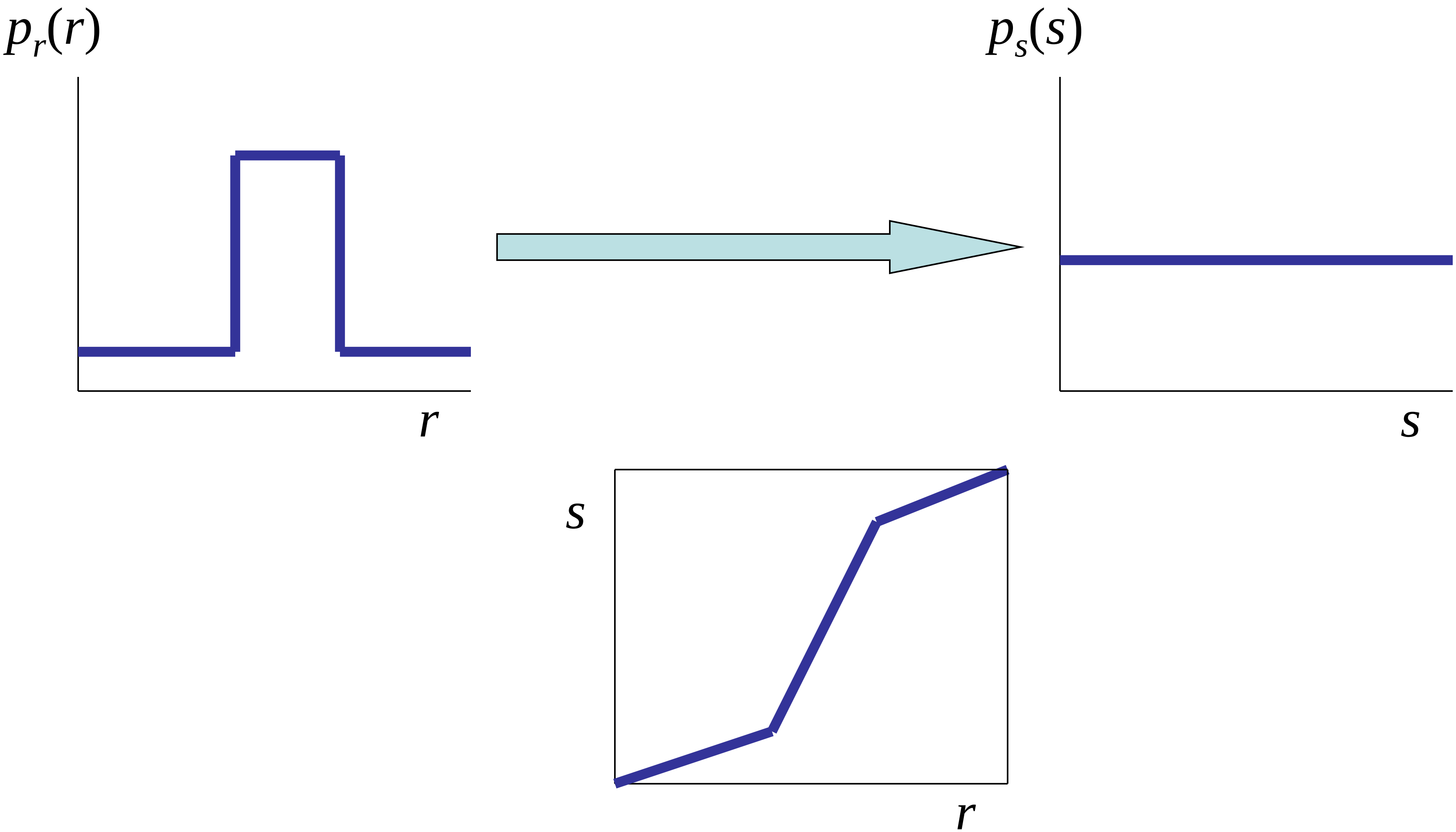
$$p_s(s) = 1$$

Illustration:



Histogram Equalization

Example:



Histogram Equalization

Now let us consider the discrete case (value range $0 \sim L{-}1$):

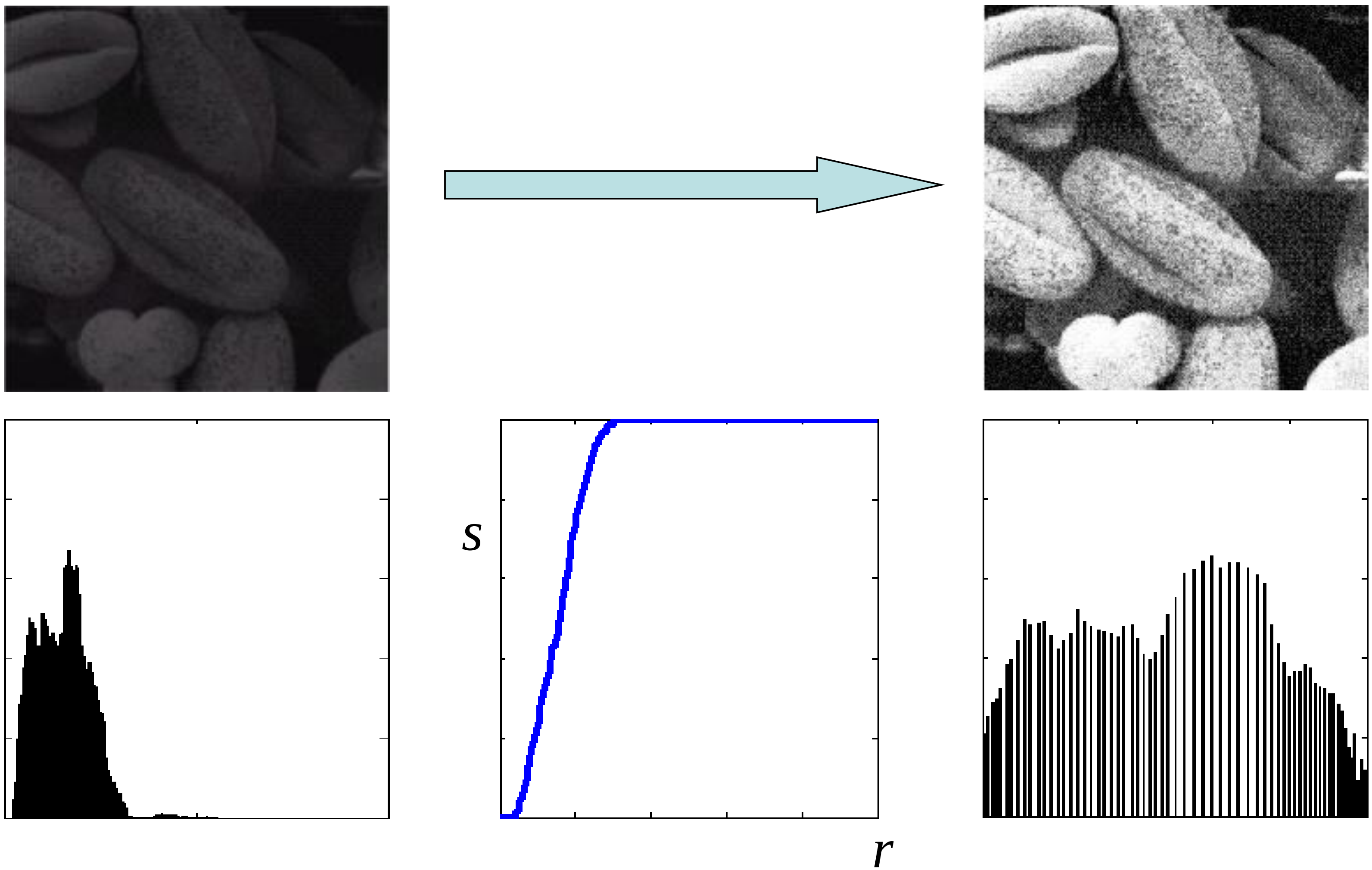
$$p_r(r_k) = \frac{n_k}{n}$$

Transformation function:

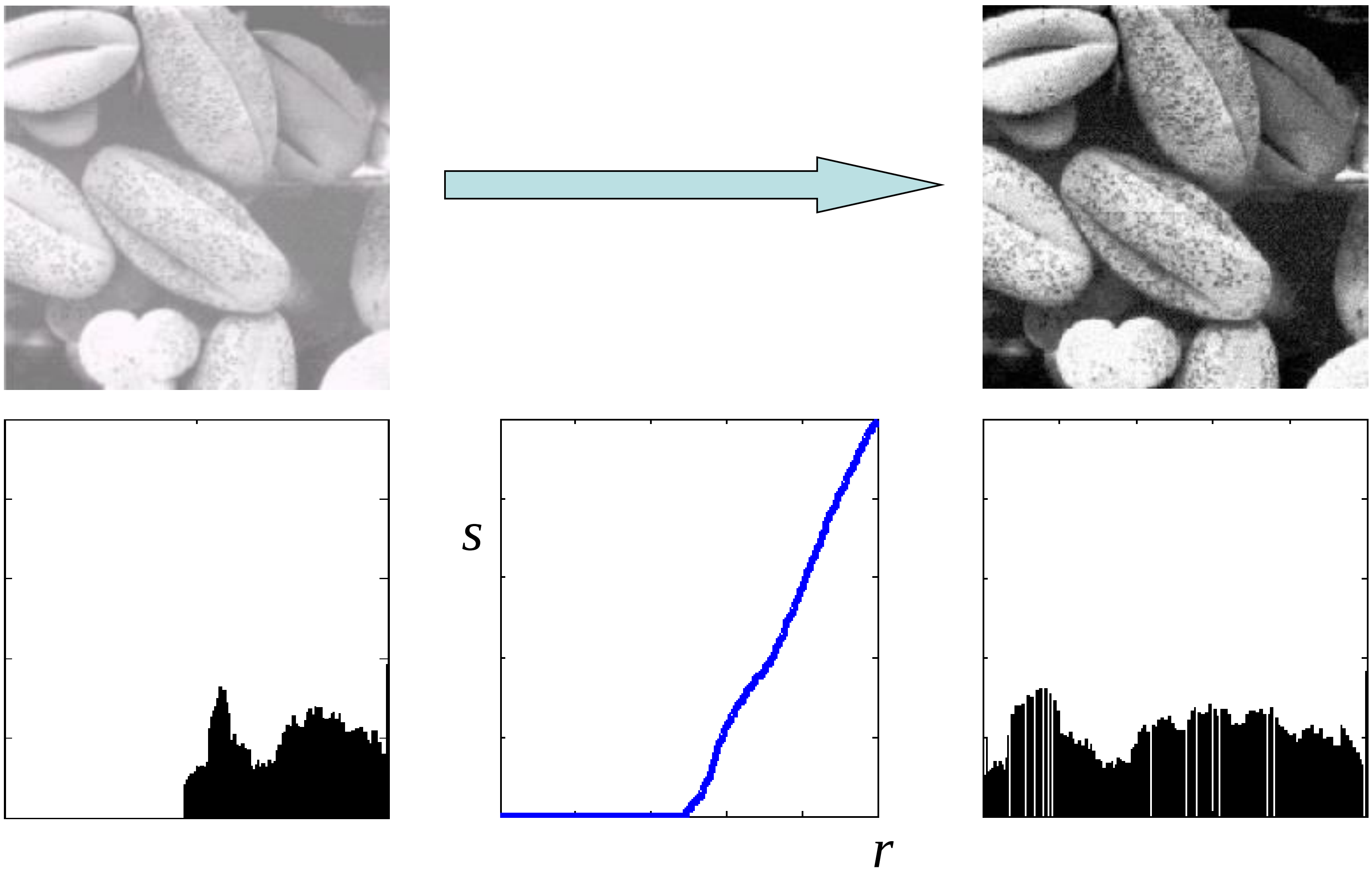
$$s_k = T(r_k) = \underbrace{(L-1)\sum_{j=0}^{k} p_r(r_j)}_{\text{We need to convert this to integers.}}$$

For efficiency, this transform is usually implemented as a look-up table (LUT) in practice. The same can be applied to other intensity transforms.

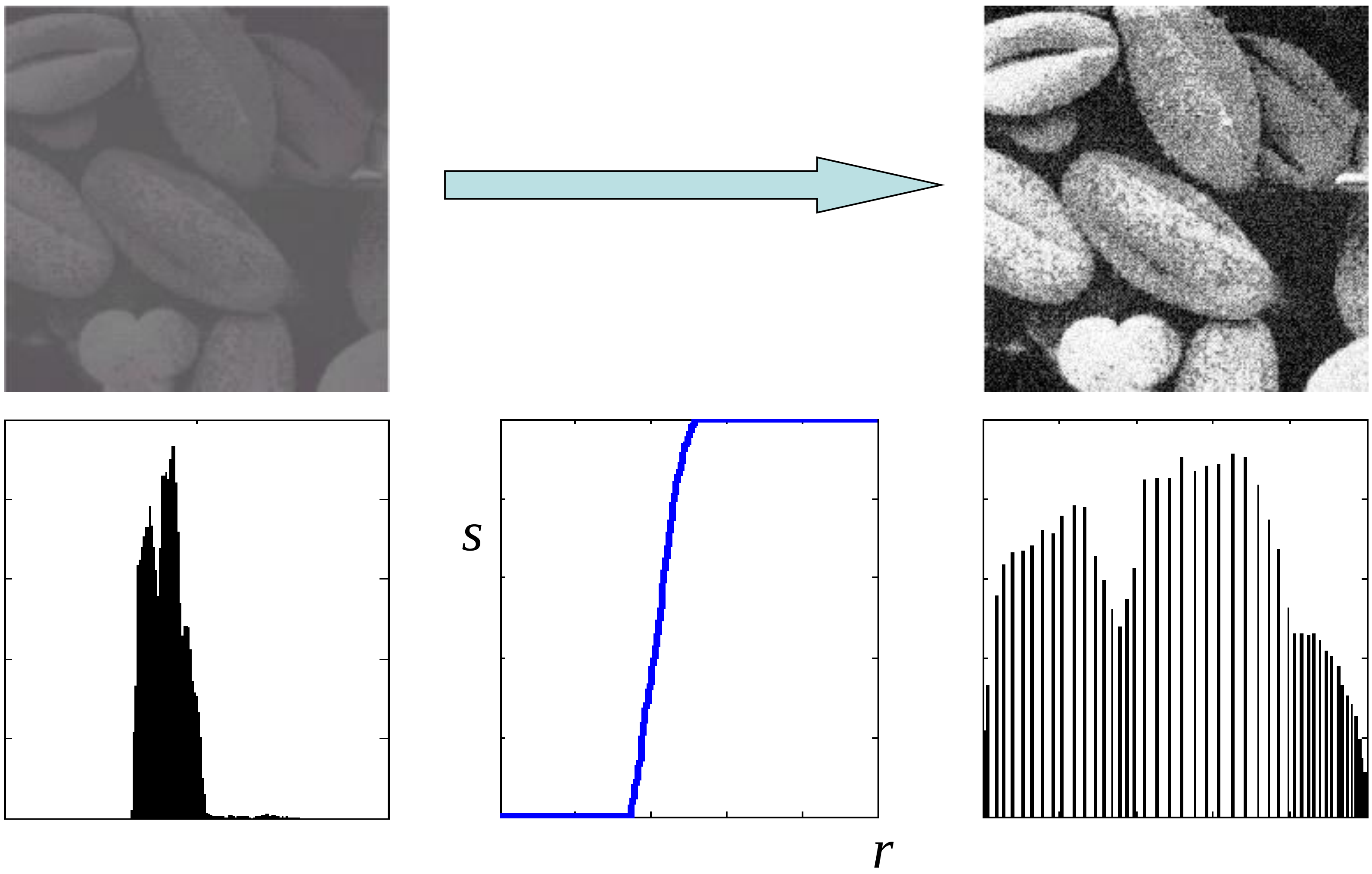
Histogram Equalization



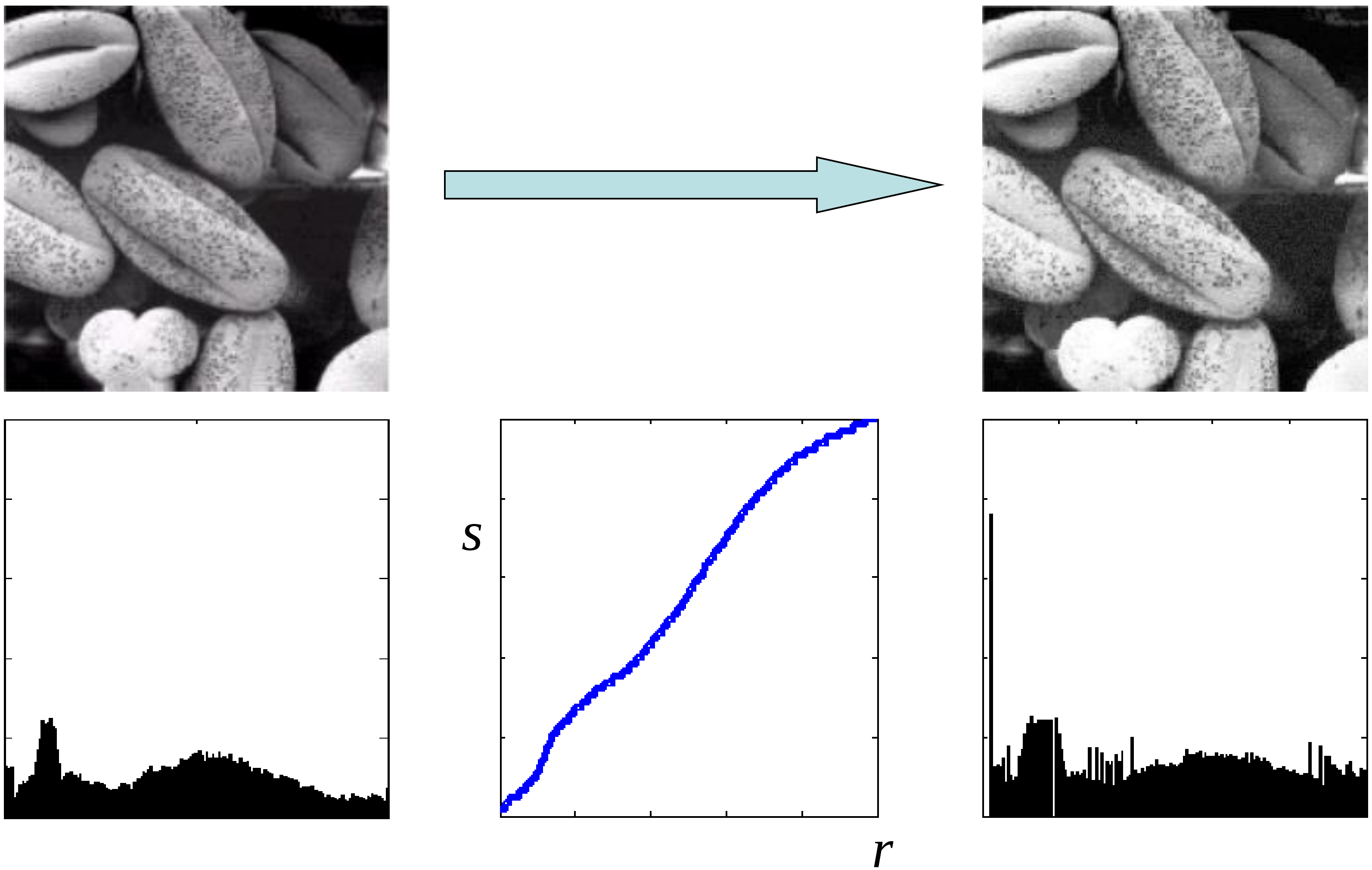
Histogram Equalization



Histogram Equalization



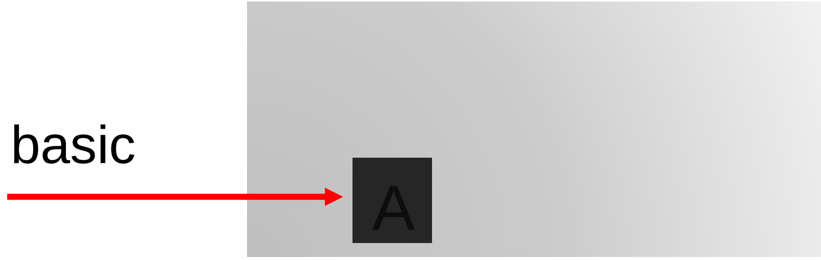
Histogram Equalization



Adaptive Histogram Equalization (AHE)

- One problem of basic histogram equalization is that the intensity transformation is computed from the whole image.
- Contrast in regions that are significantly brighter or darker than the majority of the image can actually be *suppressed*.

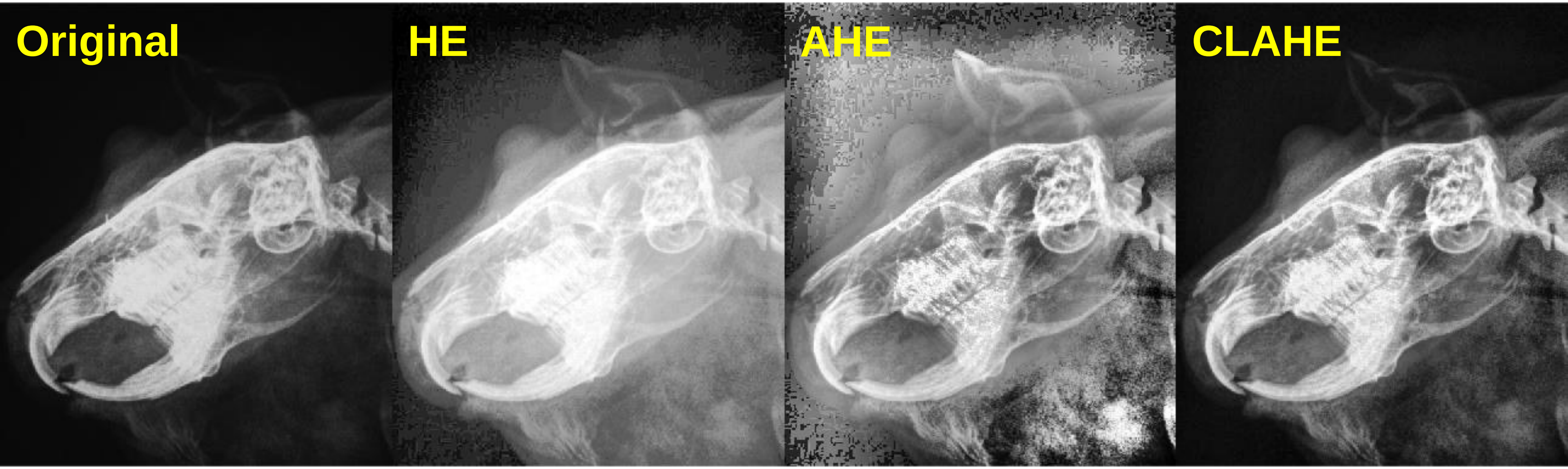
Contrast here reduced by basic histogram equalization



- Basic idea: Compute histograms *locally*.
- Approach:
  - Divide the image into blocks and compute their individual intensity transformations.
  - The new intensity of a pixel is *interpolated* from its transformed values from the per-block transformations.

Adaptive Histogram Equalization (AHE)

- Common problem of AHE: Over-amplification of noise and small intensity change from more homogeneous image blocks. (The "slope" in the s-r curve can become very steep for homogeneous regions.)
- **Contrast-limited adaptive histogram equalization** (**CLAHE**) attempts to solve this problem by limiting the degree of contrast enhancement (i.e., the slope).



Contrast Enhancement for Color Images

- Intensity transformations are single-channel operations, so how do we apply them to color images?
- Method 1: Do it separately for the RGB channels.
- This can change color characteristics of an image.
- Example (HE):

Contrast Enhancement for Color Images

- Intensity transformations are single-channel operations, so how do we apply them to color images?
- Method 2: Apply only to the luminance channel.
- This is generally preferred.
- Example (HE):

Color Filtering / Corrections

- Transformation applied to individual channels can be used to apply color filtering or correction to images.
- Example (Gamma correction with γ=0.7 applied to Red):

https://twitter.com/arbrax/status/1193639696729038850