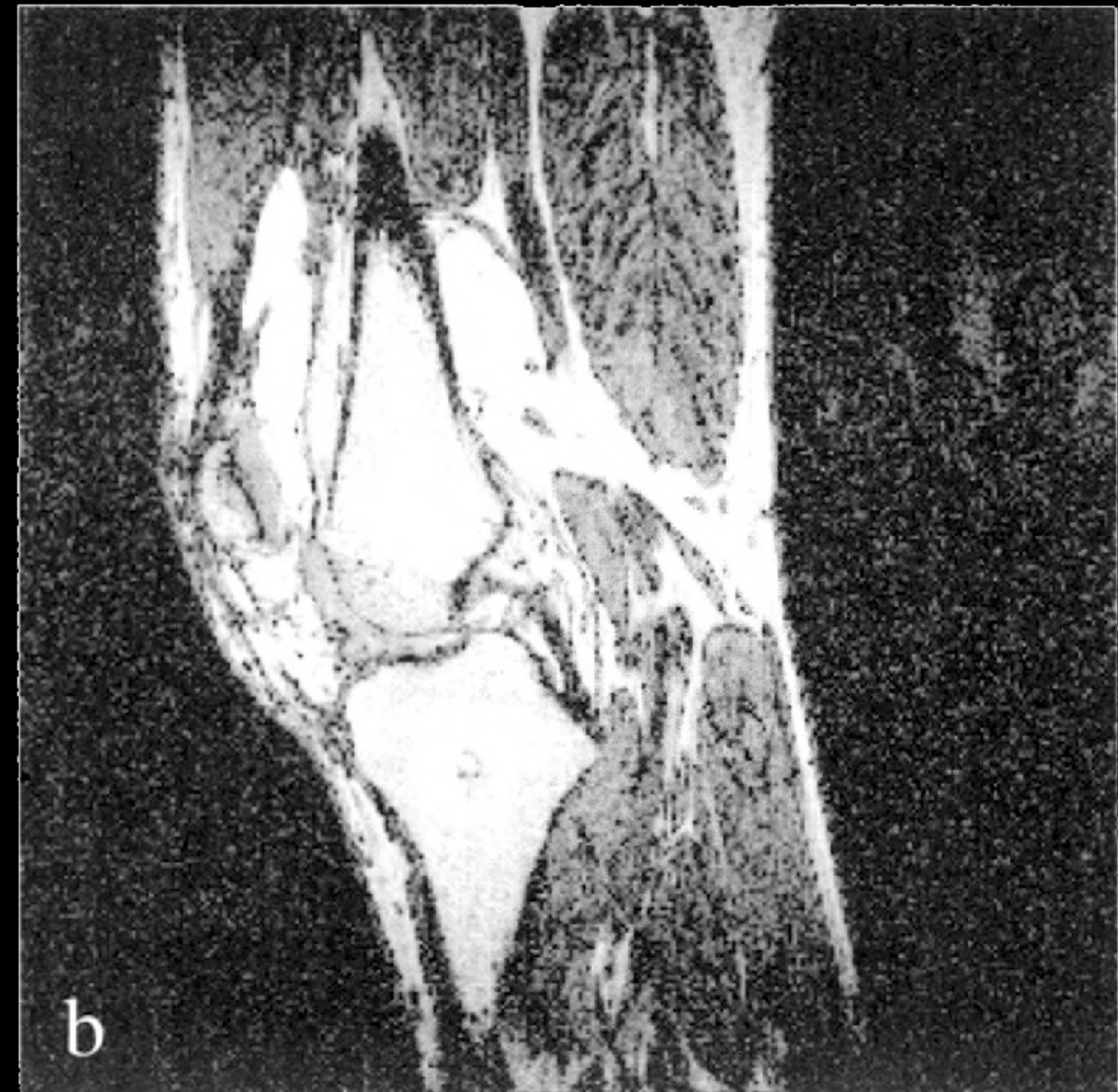
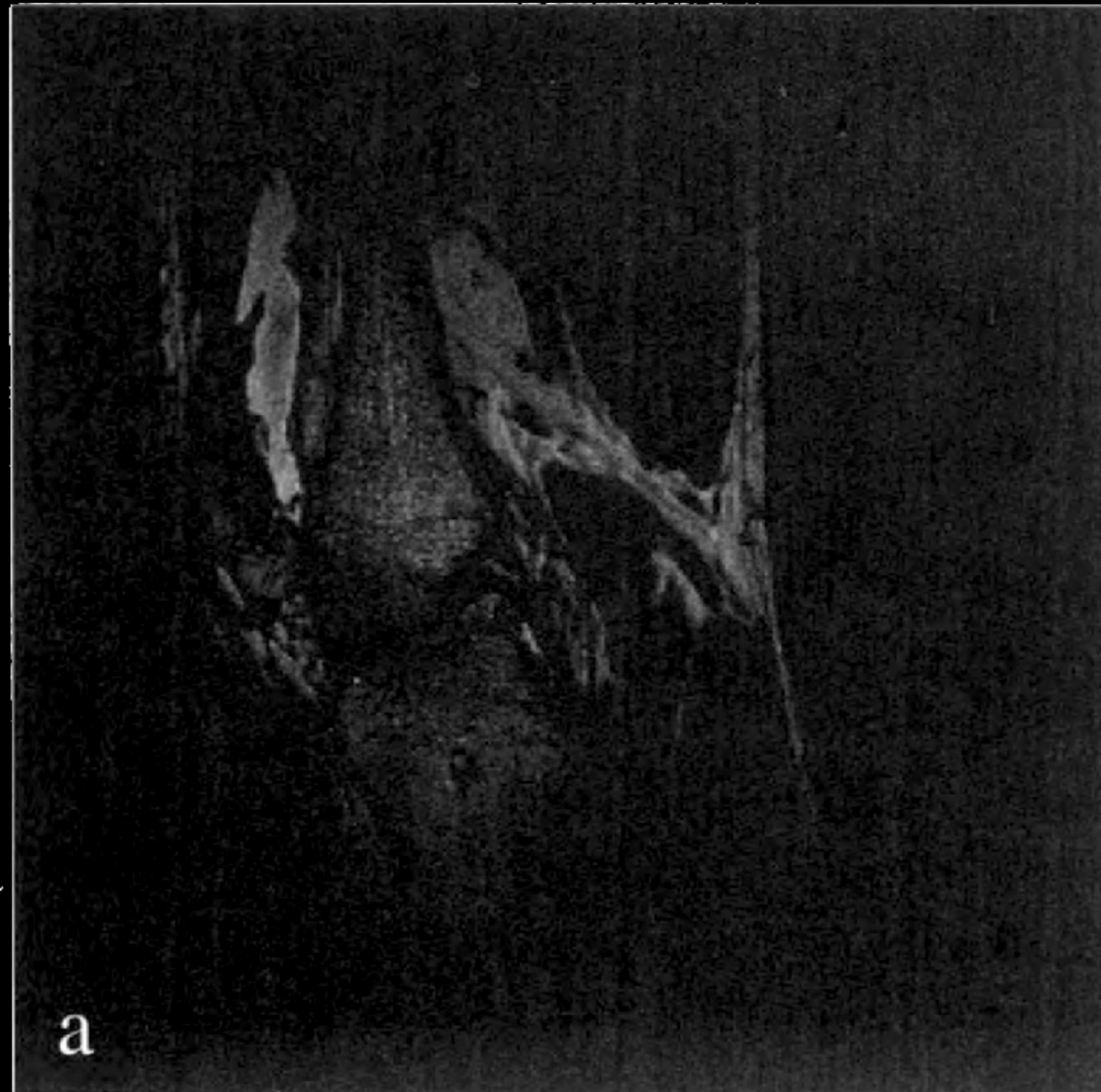


Limitation of global histogram processing: less frequent intensities get squashed together

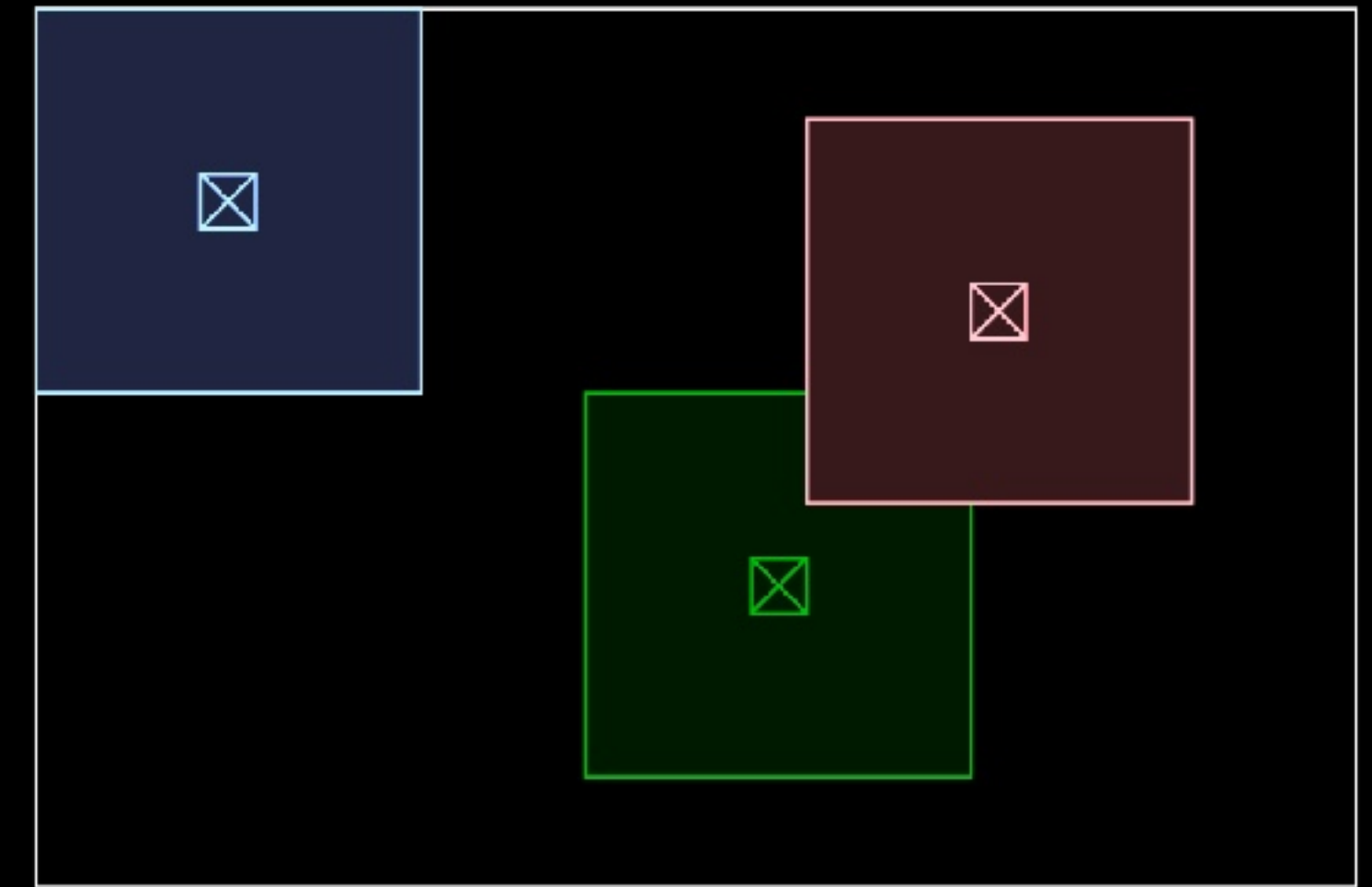
$$\text{CDF}(r) \approx \text{CDF}(r+1) \Rightarrow (L-1)*\text{CDF}(r) \approx (L-1)*\text{CDF}(r+1)$$



Local Histogram Equalization

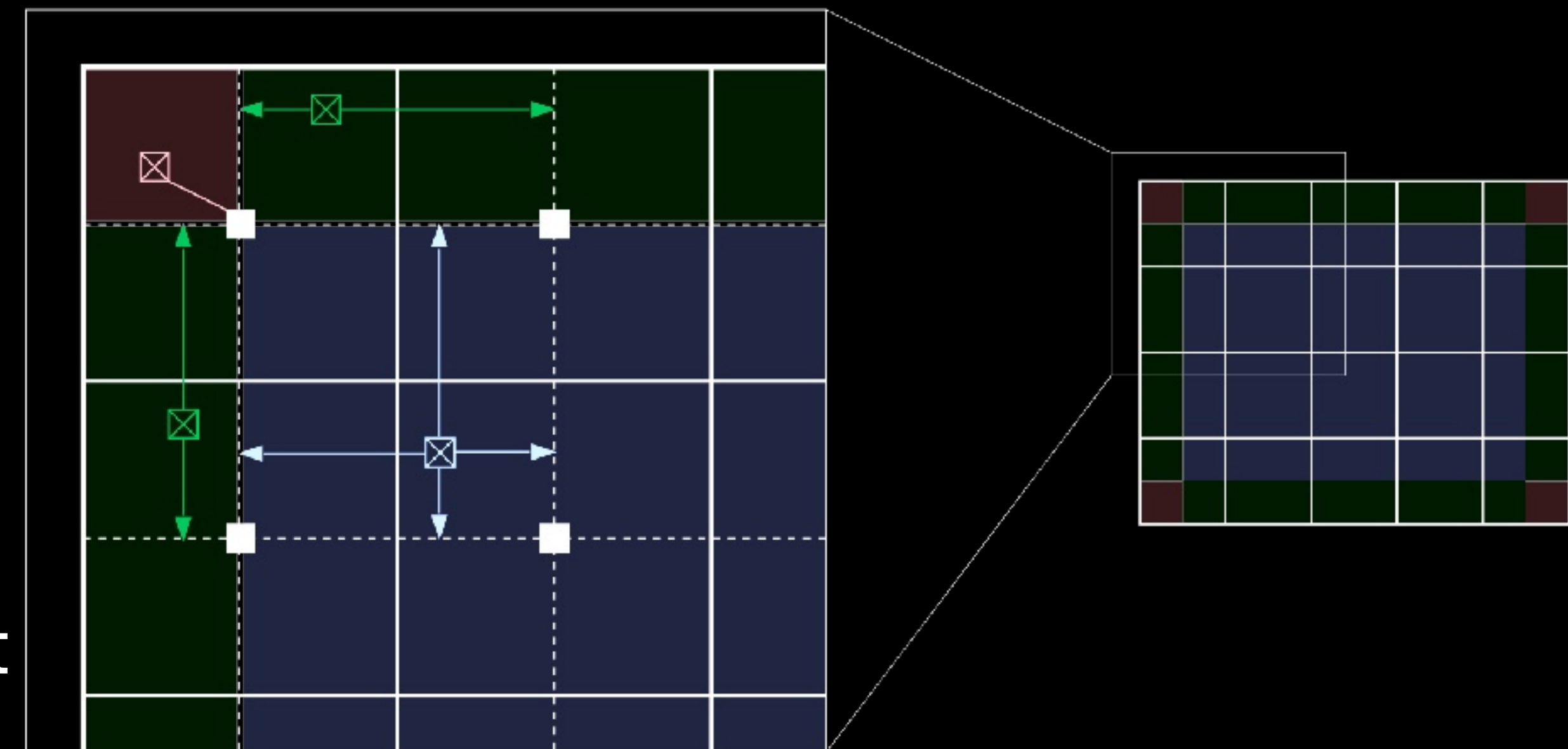
For each pixel $r = f(x, y)$:

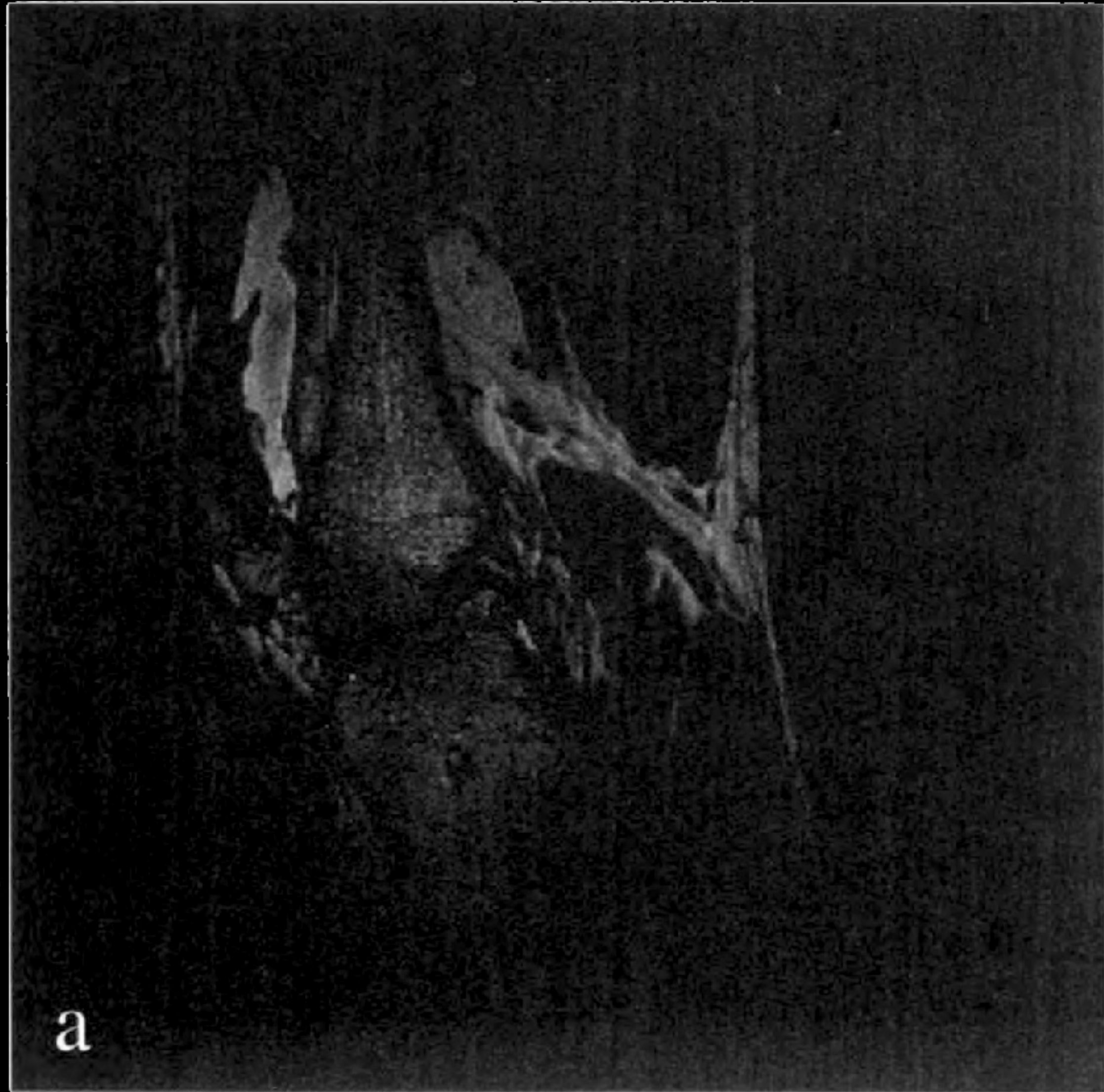
1. Compute histogram of $m \times n$ region centered at (x, y)
2. Compute intensity transformation T using histogram
3. Set new intensity $s = T(r)$



Fast approximation:

- Divide image into blocks
- Compute T for each block
- For each pixel, set new intensity by interpolating transformations with respect to neighboring blocks $T_A(r)$, $T_B(r)$, ...





Contrast-limiting

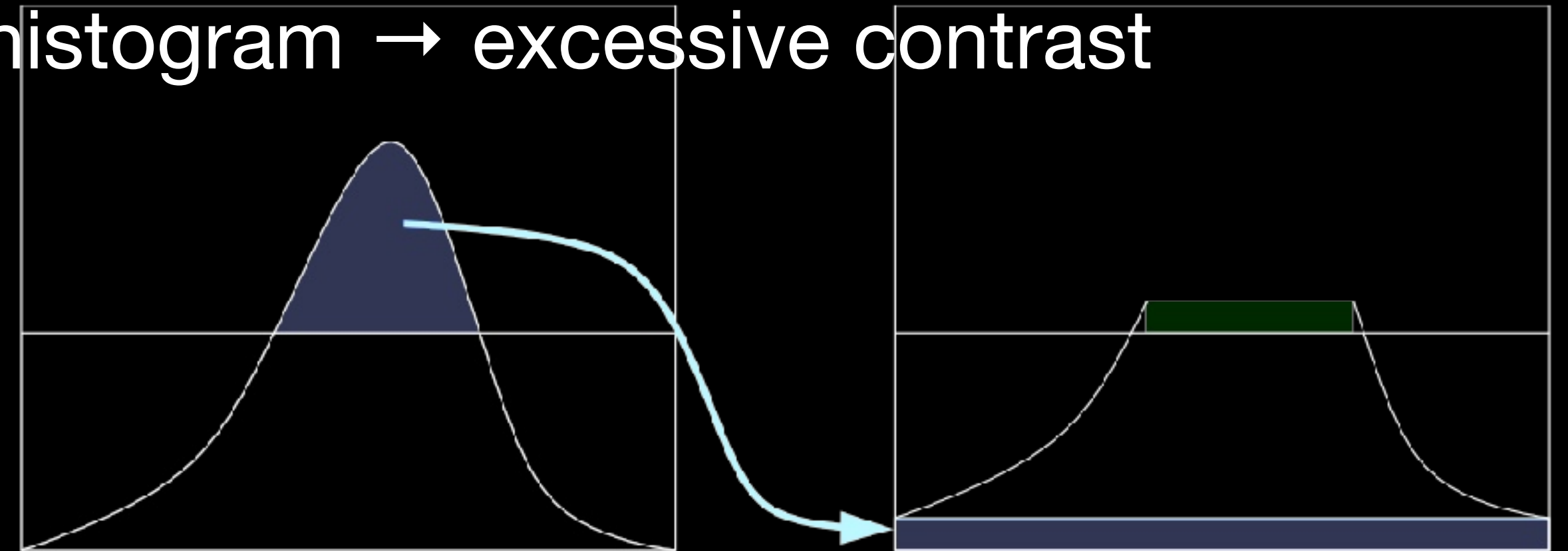
- Introduction of too much contrast is possible, *i.e.*, $T(r+1)$ and $T(r)$ have a large difference as,

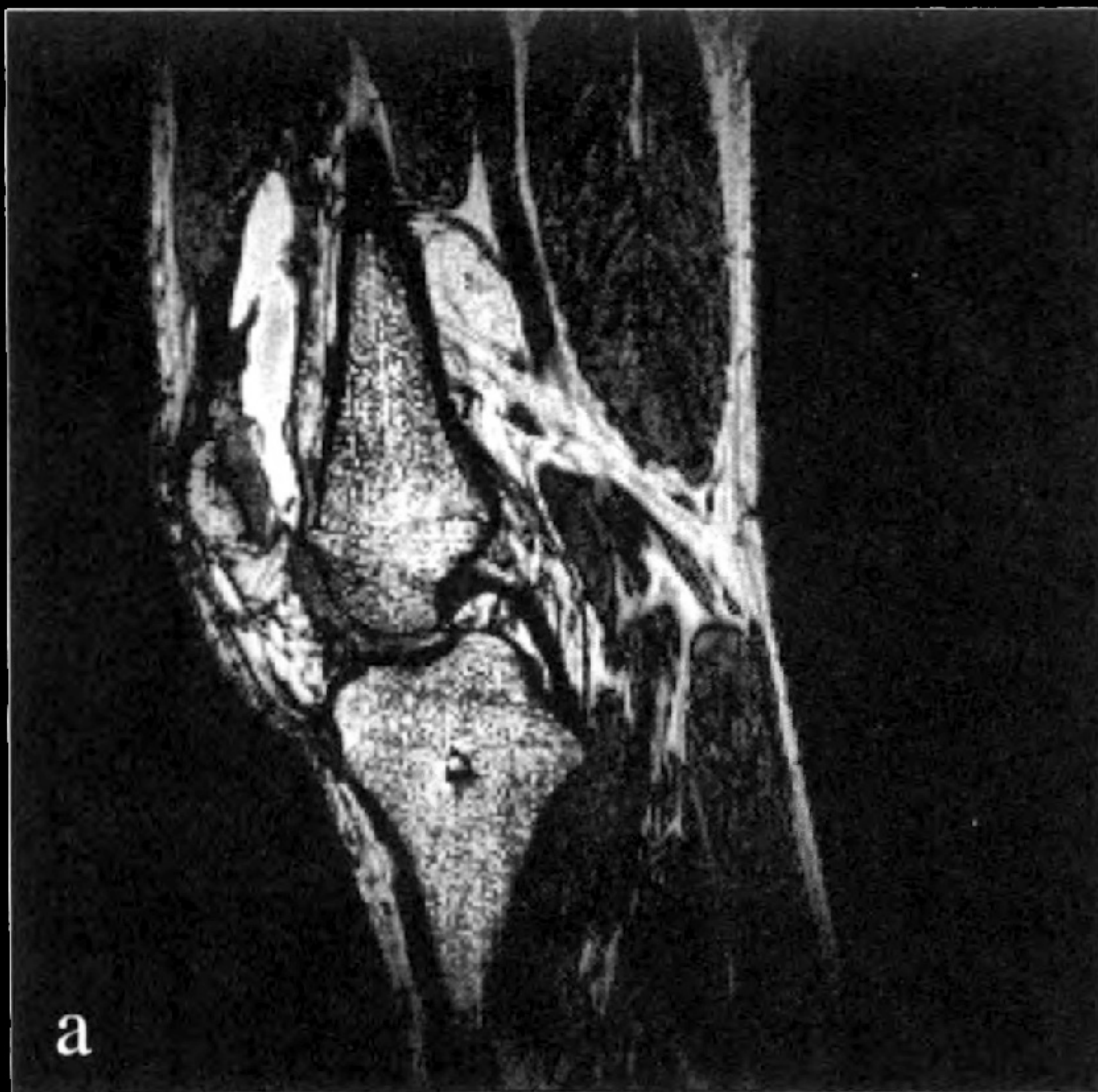
$$T(r+1) - T(r) \propto c(r+1) - c(r) = p_r(r+1)$$

- Homogeneous regions $\rightarrow$ high peaks in histogram $\rightarrow$ excessive contrast enhancement

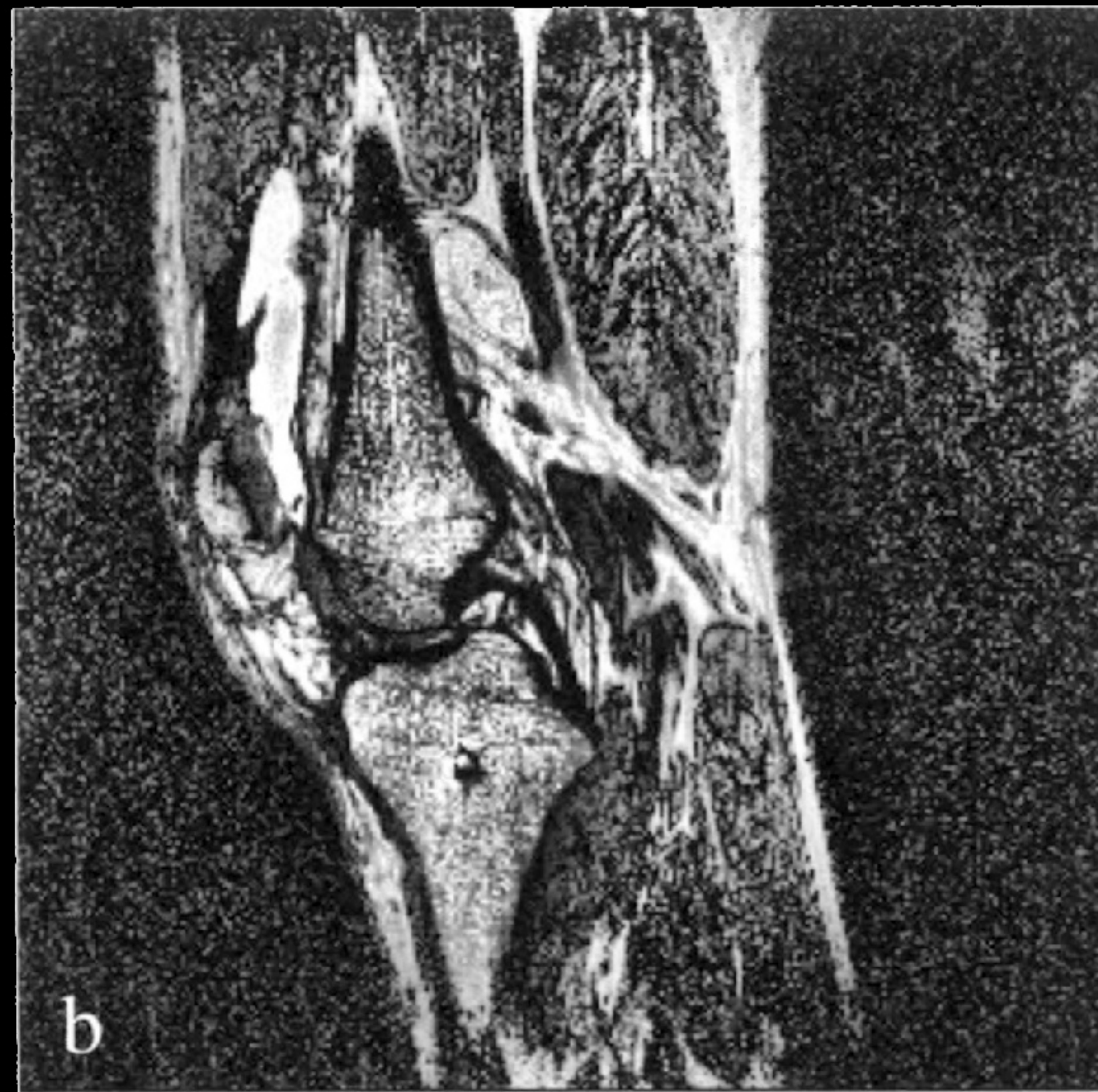
Solution:

- Clip histogram to a set maximum
- Redistribute the count of clipped pixels equally among all bins





Max contrast ratio = 3

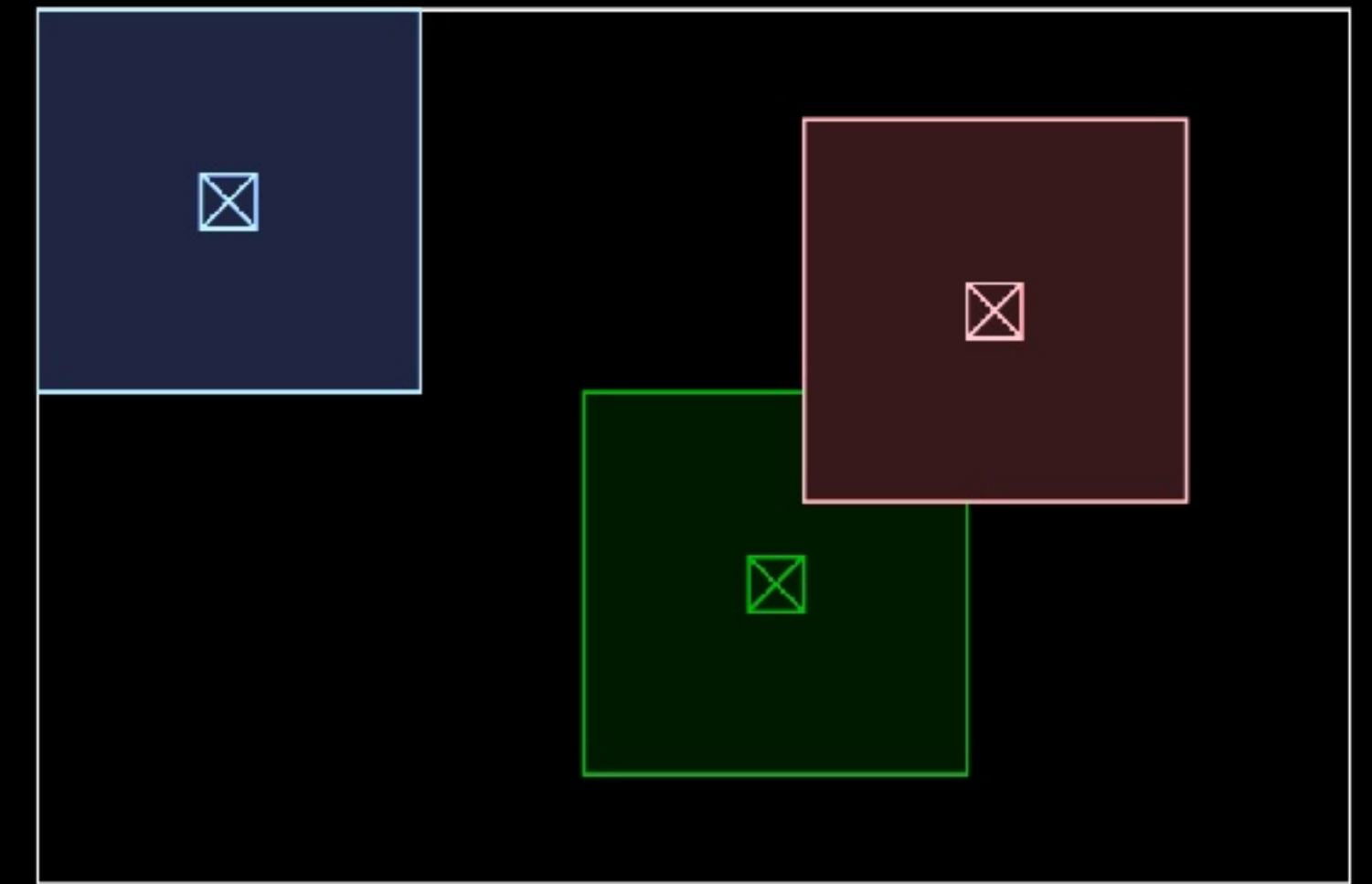
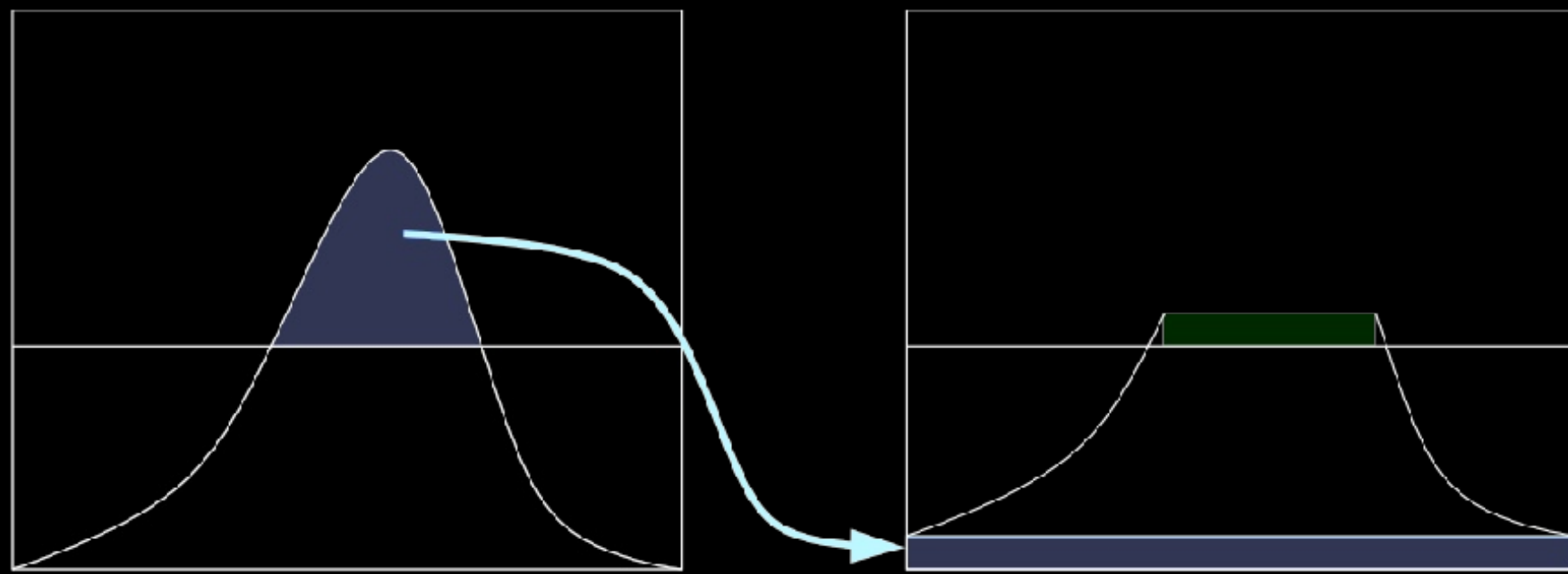


Max contrast ratio = 10

Contrast-limited Adaptive Histogram Equalization (CLAHE)



Contrast-limiting + Local histogram equalization



Ellen Borggreve



Original



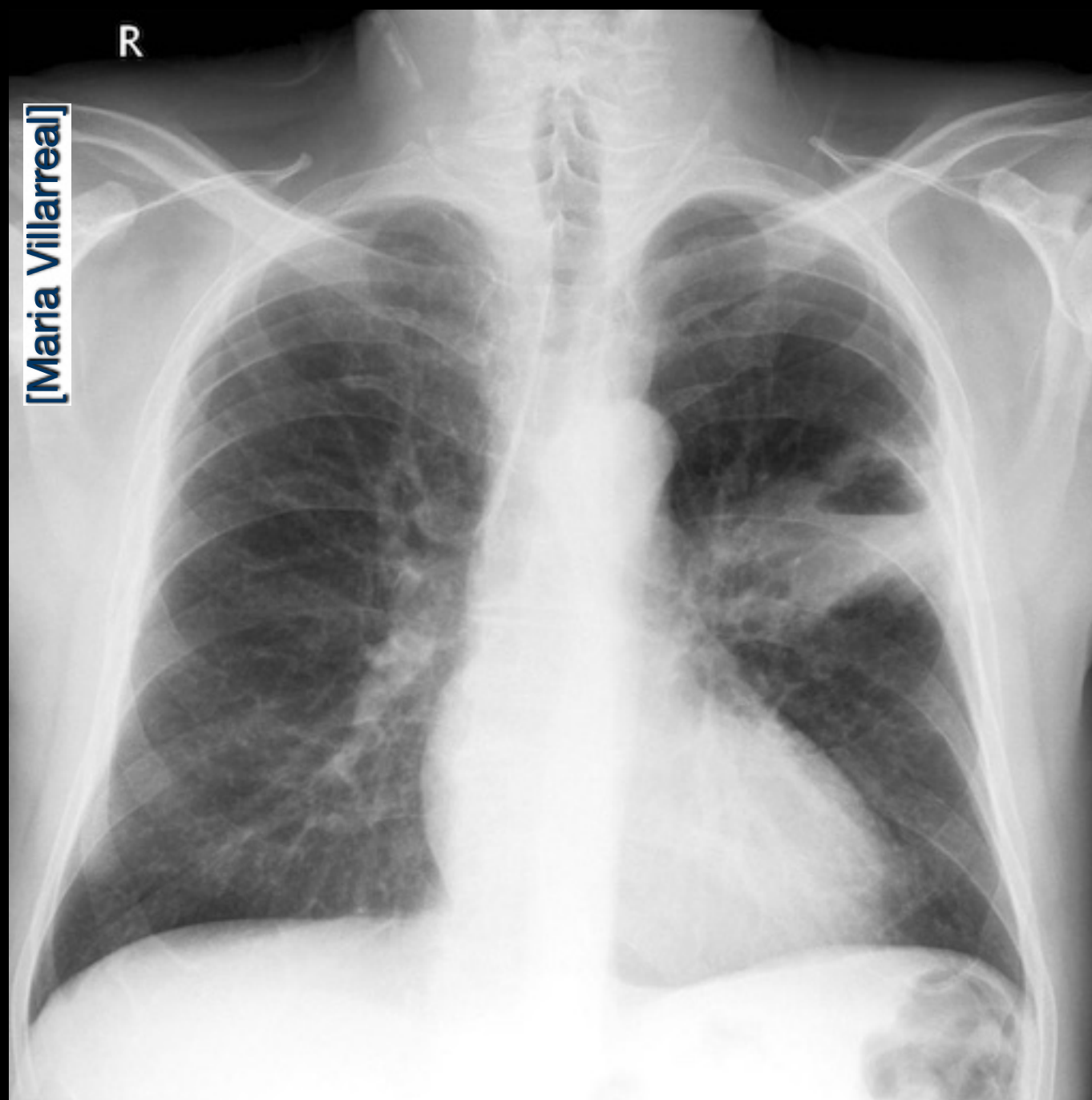
Global Equalization



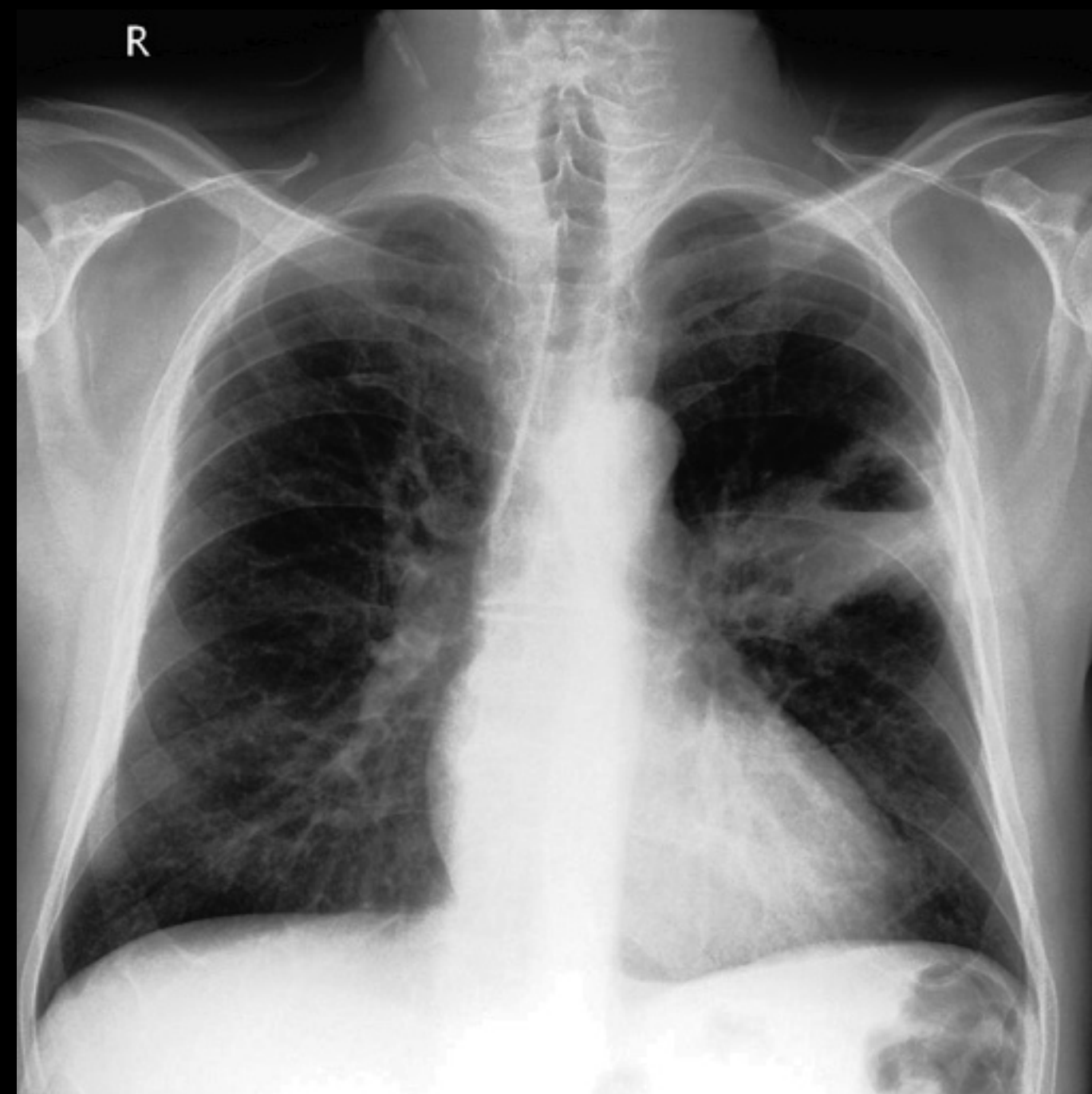
CLAHE



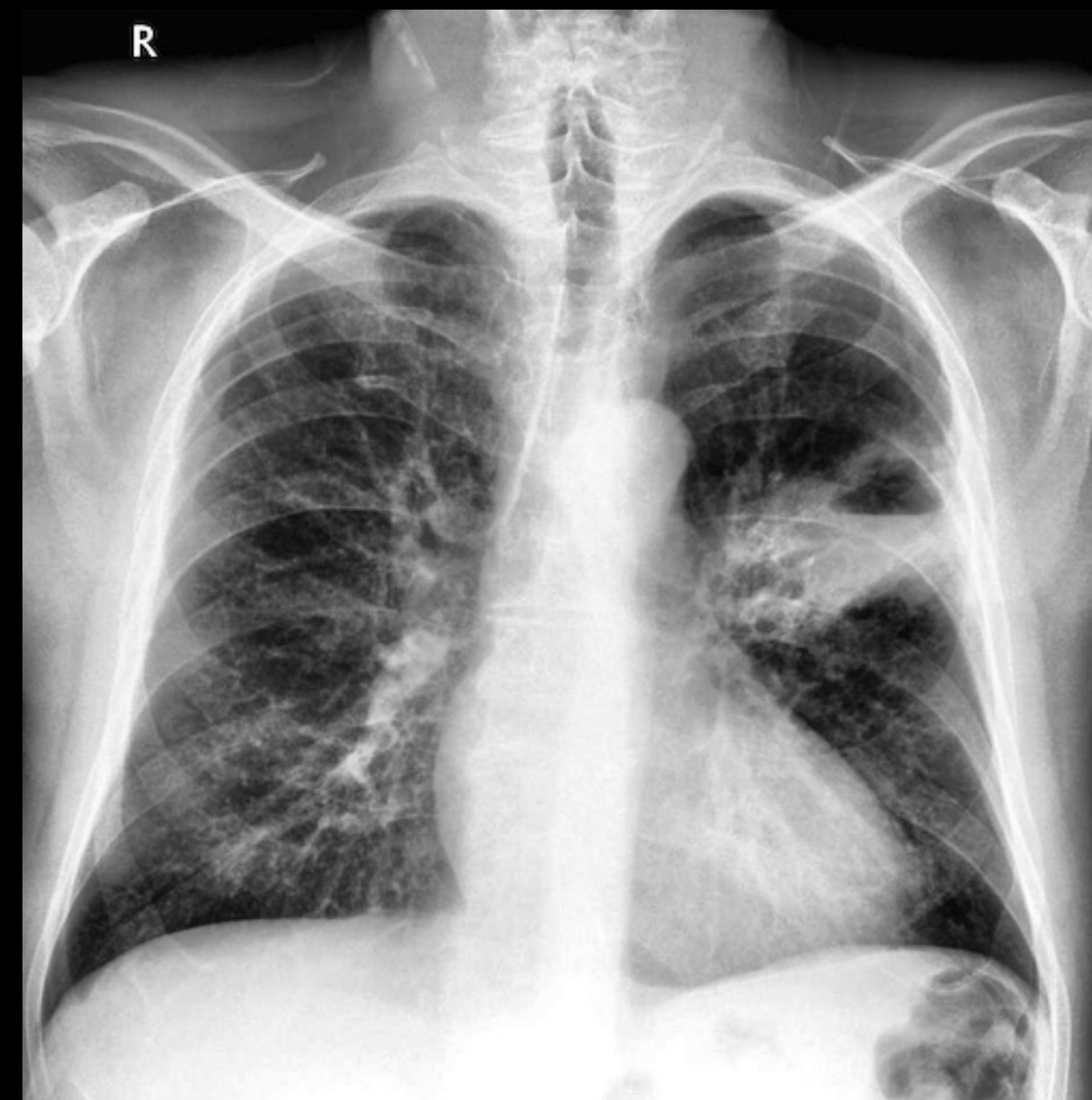
Local Equalization



Original



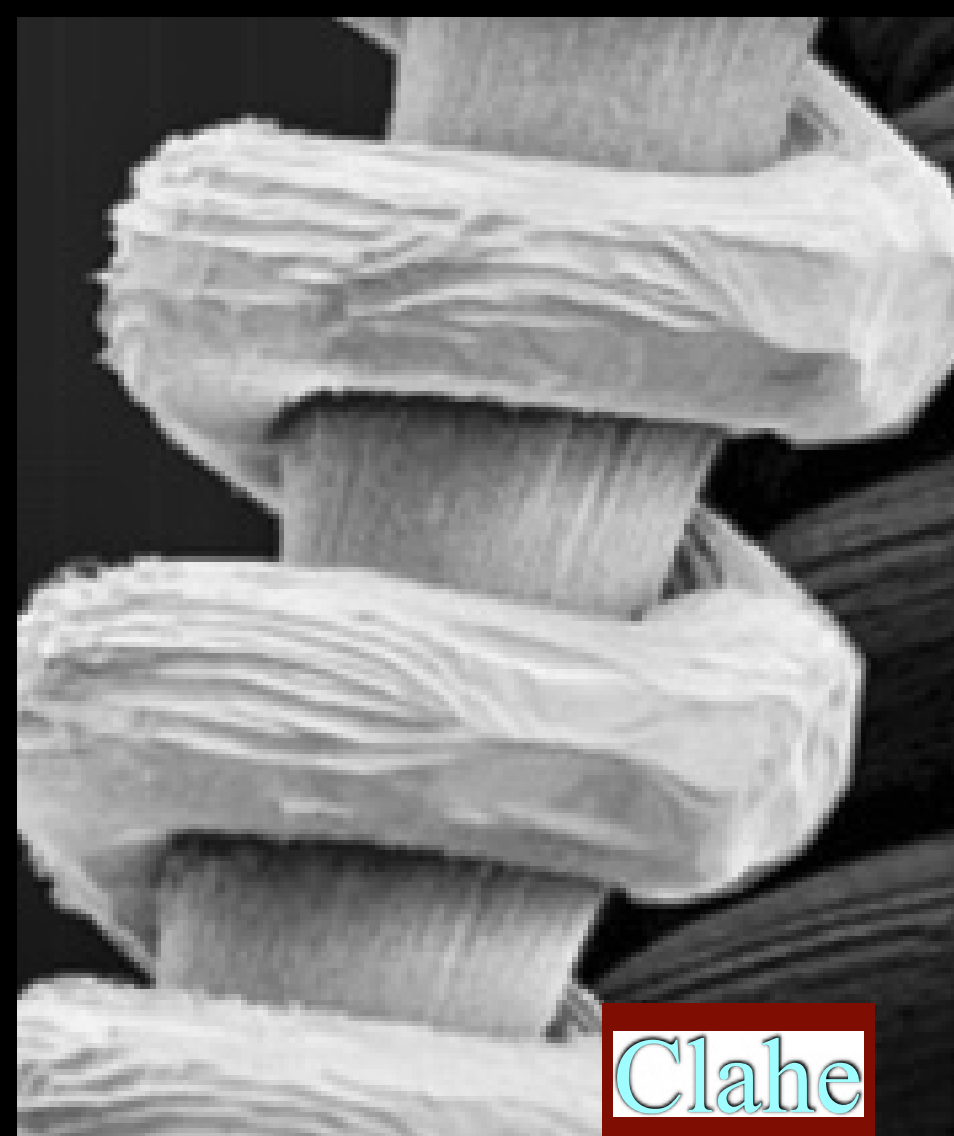
Global Equalization



CLAHE

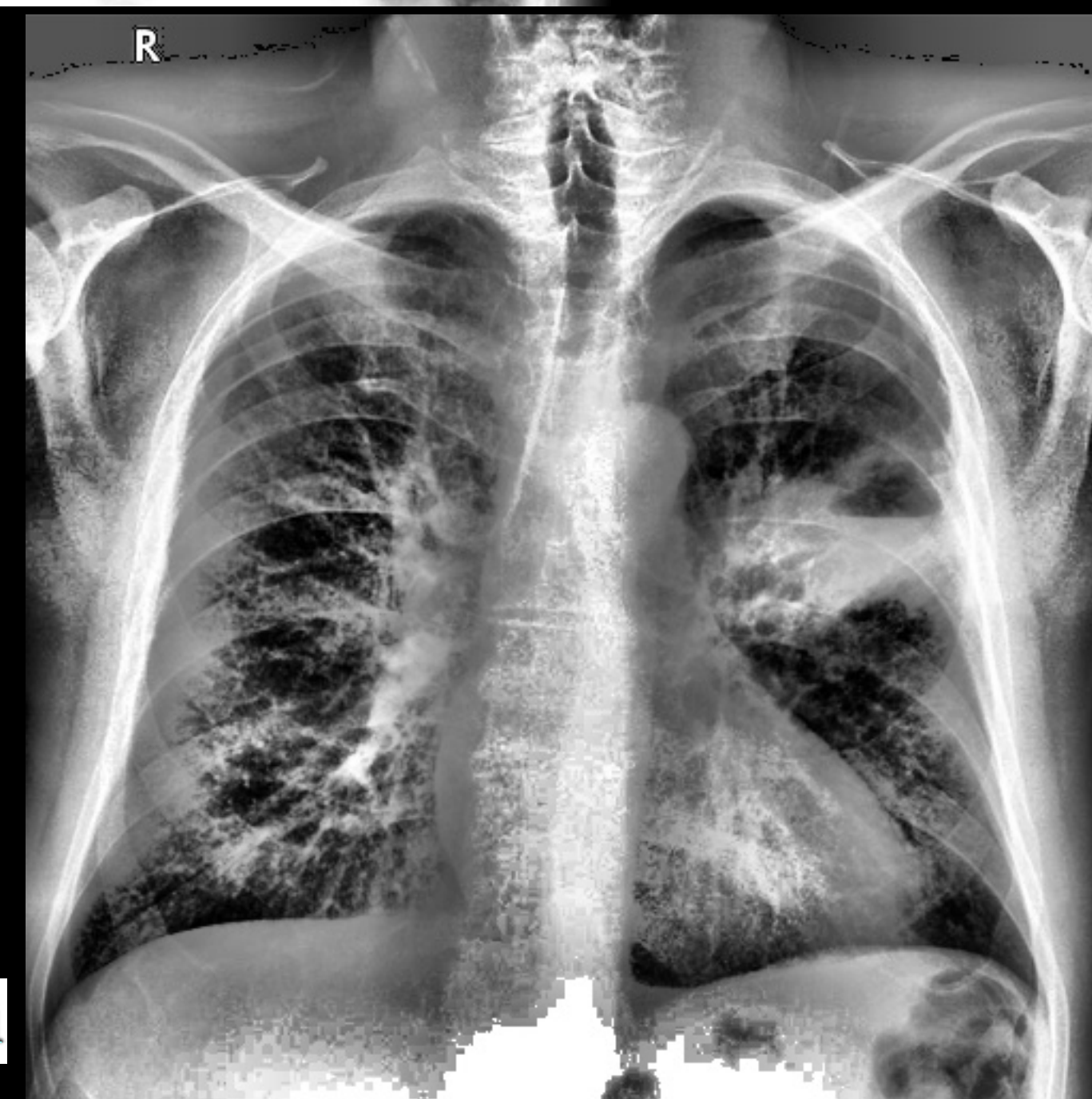


Original

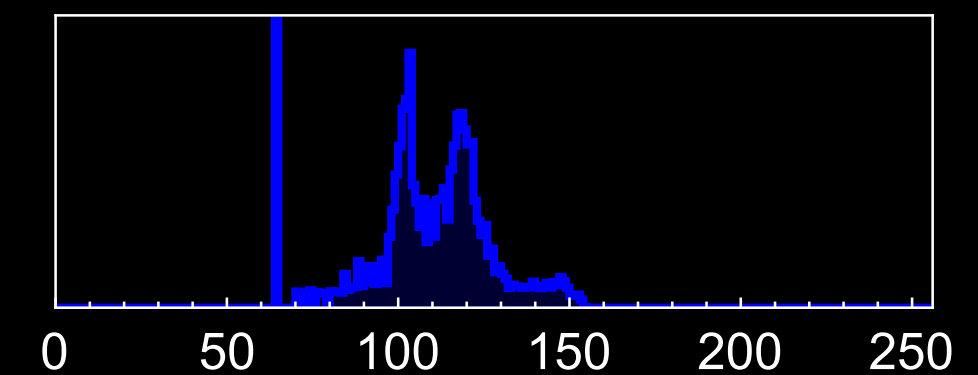
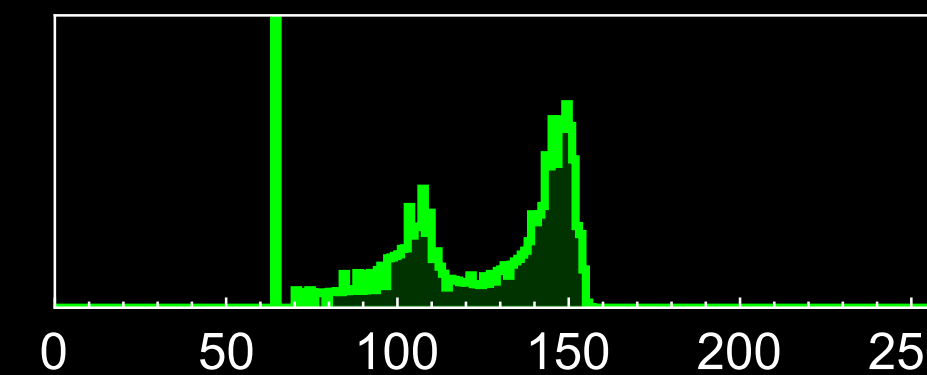
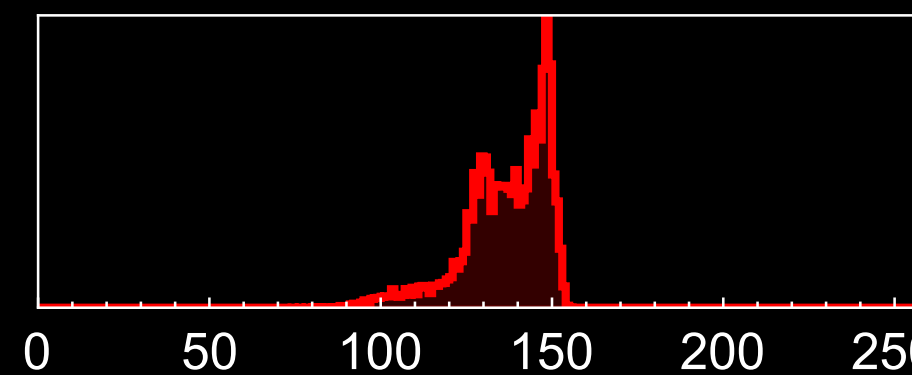


Clahe

Local Equalization



Histogram Processing of Color Images



- Process each component's histogram independently...
- ...or convert to HSI and process only histogram of I component?

Histogram equalization
on R, G, B components



Histogram equalization
on I component of HSI



Histogram equalization
on I component of HSI,
then S component scaled by 3



Per-component Filter



Original



Gaussian filter

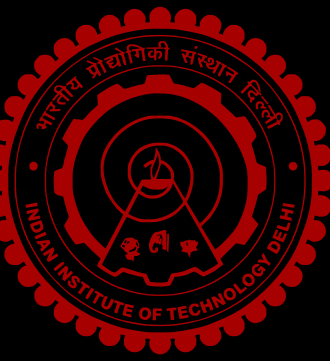
Per-component Filter



Original



Excessive high-boost filtering
leads to color halos



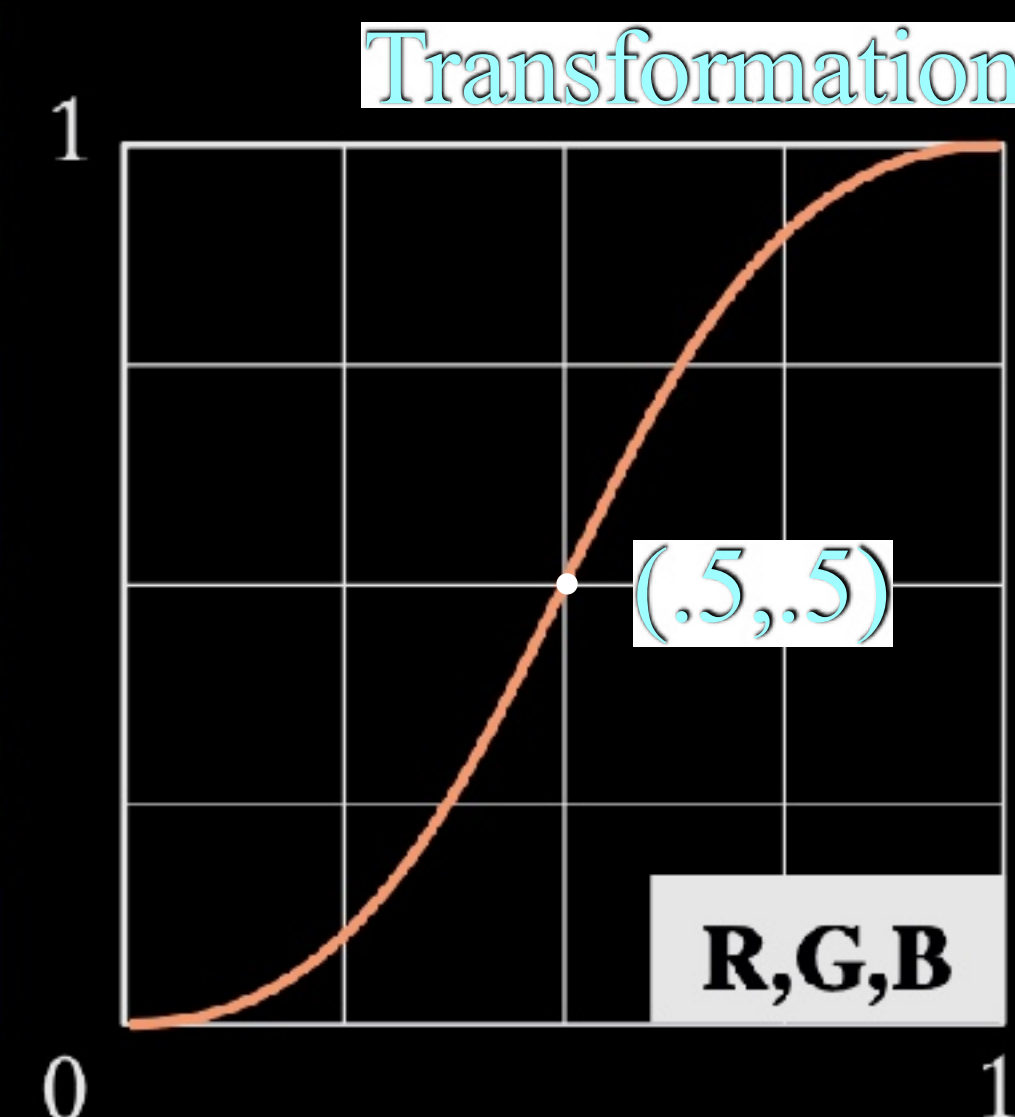
Color Corrections

- Tone correction
 - Focuses on brightness and contrast (analogous to intensity transformations of grayscale images)
 - Often applied to intensity (e.g., I component of HSI, L component of $L^*a^*b^*$)
 - Also independently applies to each component (e.g., RGB)
- Color correction
 - Adjust chromaticity (relative ratios of components)



Flat

Corrected



Common transfer
function shape

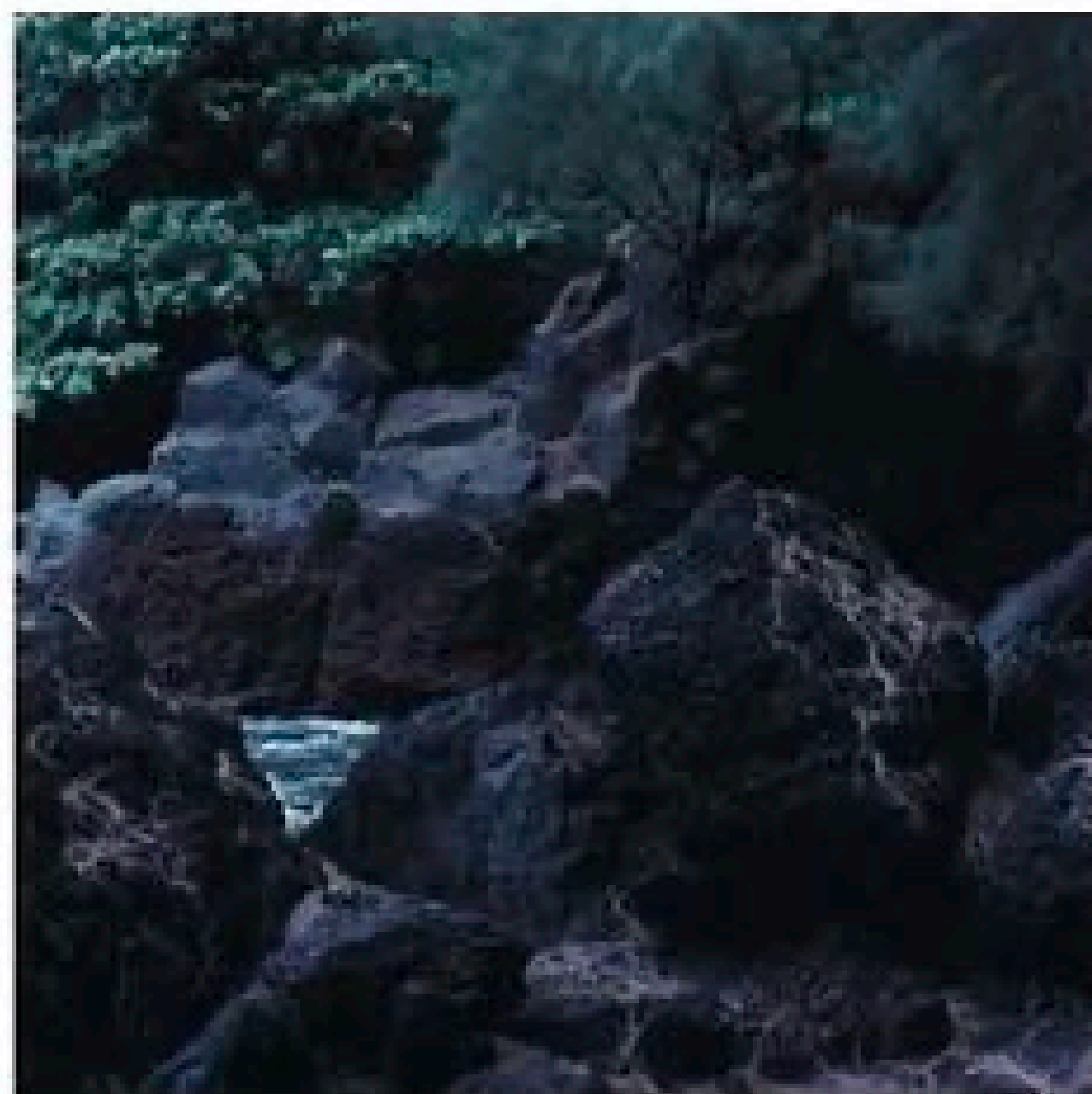
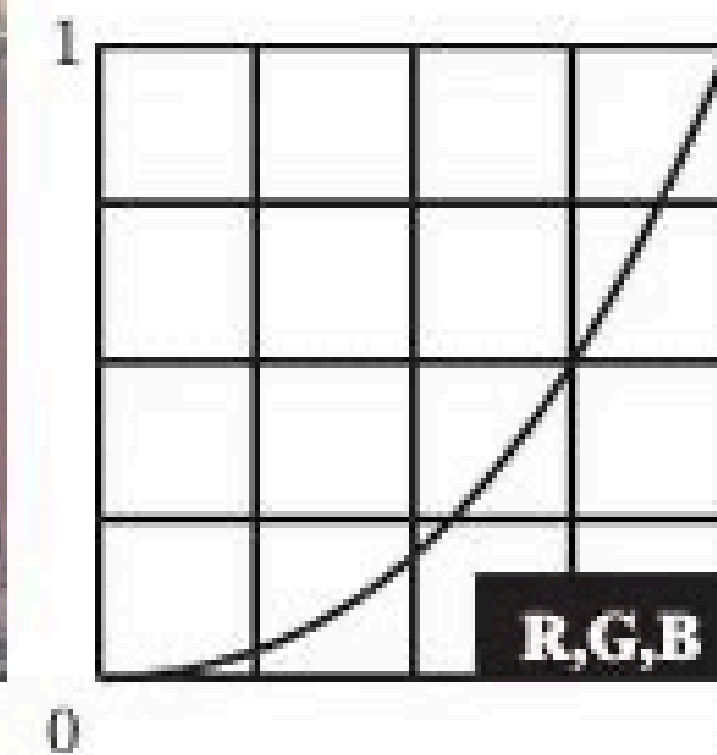


Light



Corrected

Common transfer
function shape

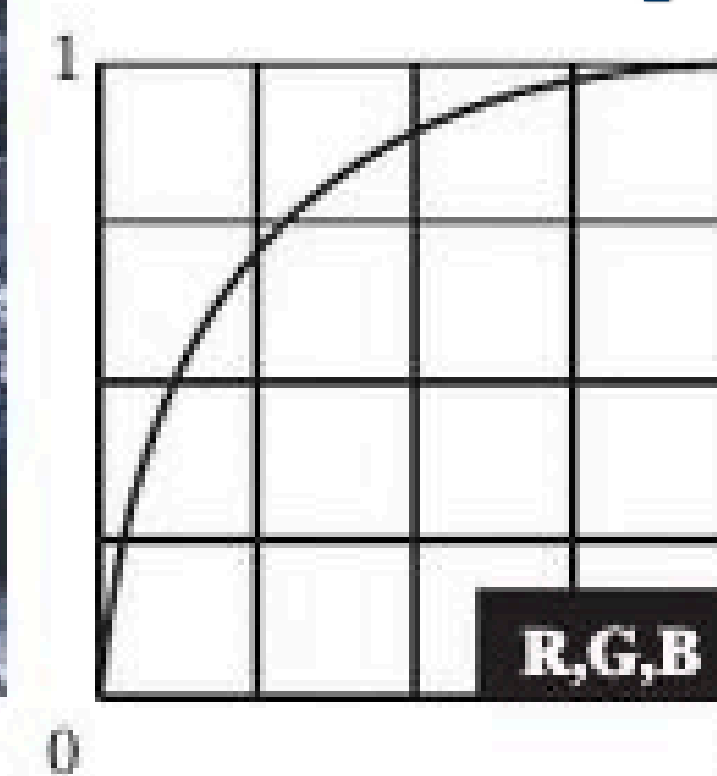


Dark



Corrected

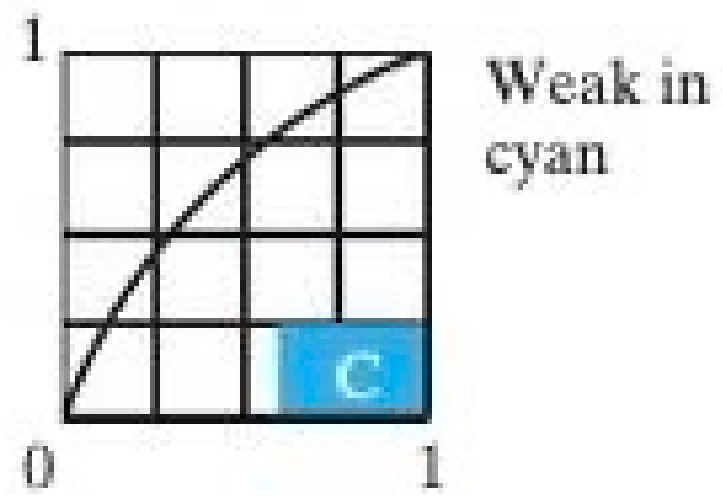
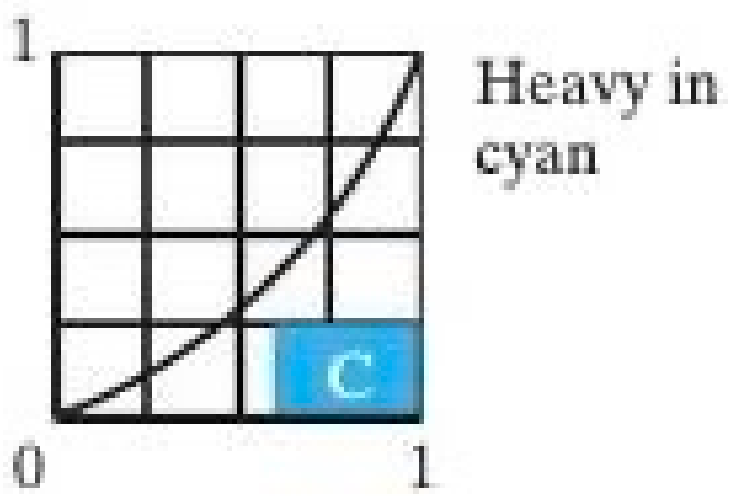
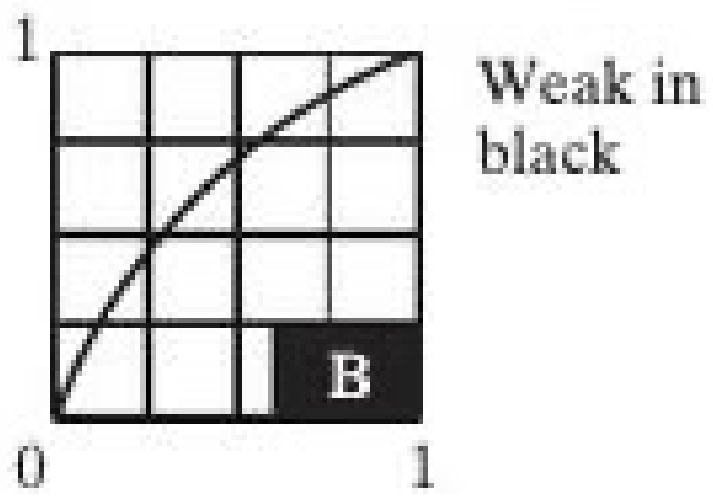
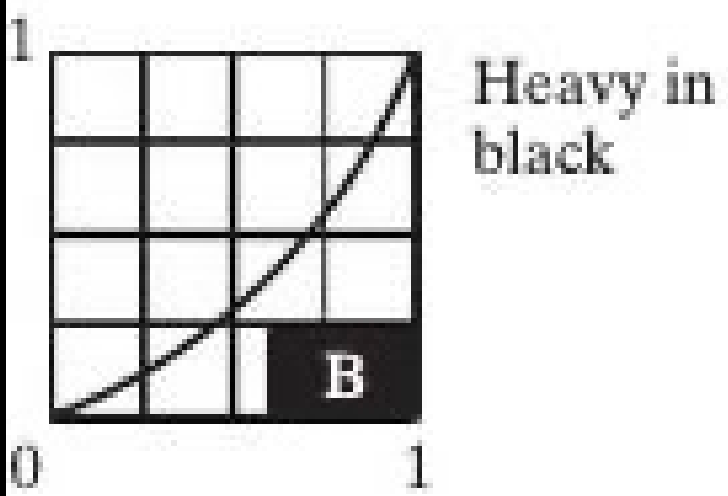
Common transfer
function shape





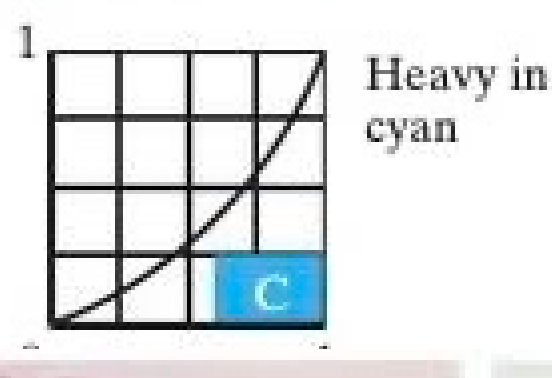
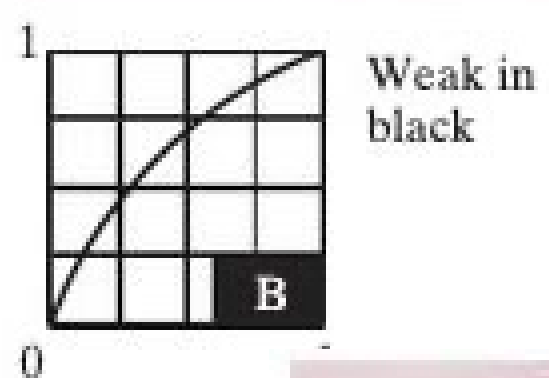
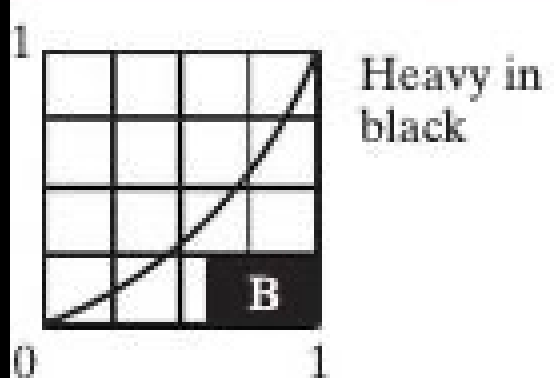
Original/Corrected

CMYK Correction





Original/Corrected



CMYK Correction

