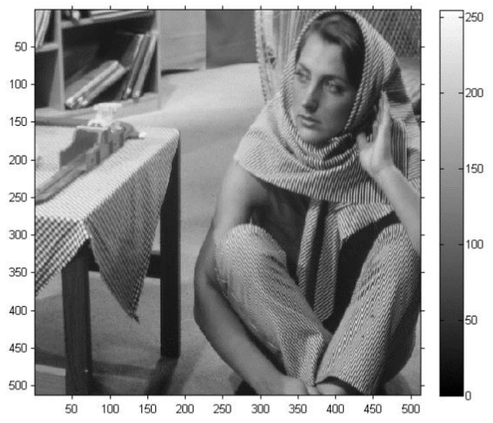
CS663: Digital Image Processing

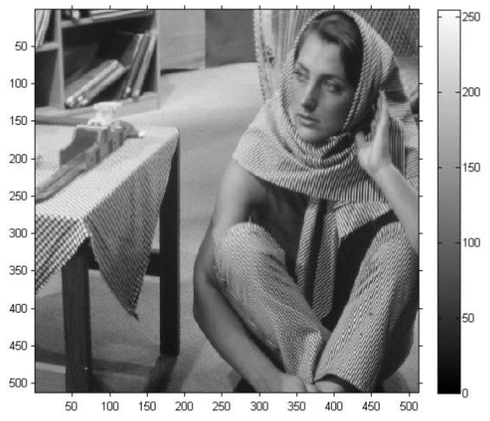
Assignment 1, Question 2

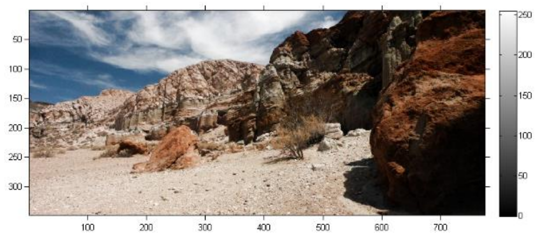
(a) Linear Contrast Stretching

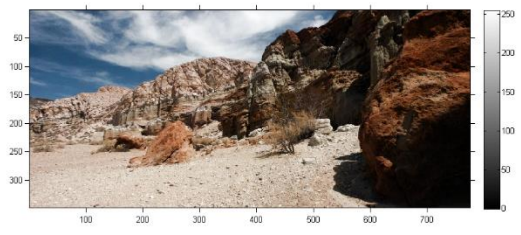
```
function [outputImage] = myLinearContrastStretching(inputImage)
        [sizeX, sizeY] = size(inputImage);
        outputImage = zeros(sizeX, sizeY, 'uint8');
        minVal = min(min(inputImage));
        maxVal = max(max(inputImage));
        f = @(x) uint8(255.0 .* double(x - minVal) ./ double(maxVal - minVal));
        outputImage = f(inputImage);
end
```

Code Explanation: The function myLinearContrastStreching takes inputImage as a single channel 8 bit image and returns outputImage i.e. a single channel 8 bit image with same dimensions. We first find out maximum and minimum of the image, *maxVal* and *minVal*. Then the range of image, [minVal, maxVal] is stretched to [0,255] by applying the transformation on $\mathrm{x} \rightarrow 255 * \frac{\mathrm{x-minVal}}{maxVal-minVal}$









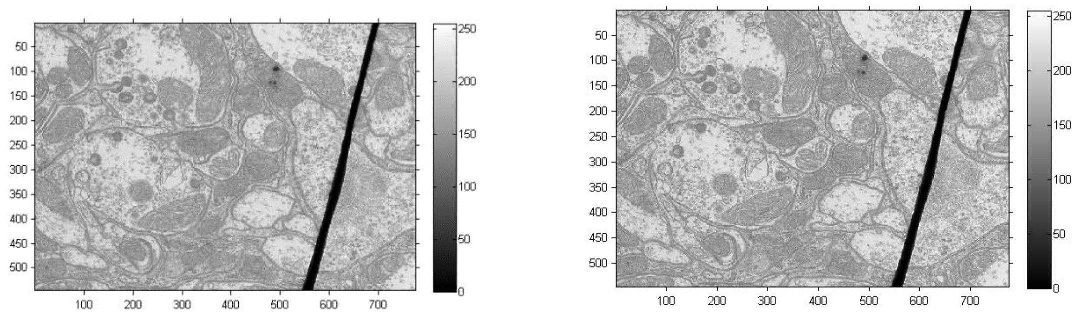


Figure. Images before and after Linear Contrast Stretching.

Comments: Note that there was no noticeable difference between two images as the minimum and maximum values of the intensities in image were close 0 and 255 respectively.

(b) Global Histogram Equalization

```
function [outputImage] = myHE(inputImage)

% myAHE takes the inputImage, 8 bit single channel image as the input and
% enhances it using Histogram equalisation

  [sizeX, sizeY] = size(inputImage);
  outputImage = zeros(sizeX, sizeY, 'uint8');
  ColorNumber = 256;
  bins = zeros(ColorNumber, 1);
  cdf = zeros(ColorNumber, 1);

  for i = 1:sizeX
    for j = 1:sizeY
      bins(int32(inputImage(i,j))+1, 1) = bins(int32(inputImage(i,j))+1, 1) + 1;
    end
  end

  bins = bins ./ (sizeX*sizeY);
  sum = 0;

  for i = 1:ColorNumber
    sum = sum + bins(i);
    cdf(i,1) = sum;
  end

  for i = 1:sizeX
    for j = 1:sizeY
      outputImage(i,j) = uint8(255.0*cdf(inputImage(i,j)+1));
    end
  end
end
```

Code Explanation: The function myHE takes inputImage as a single channel 8 bit image and returns outputImage i.e. a single channel 8 bit image with same dimensions. We first calculate the histogram by calculating the total number of pixels with intensity a, for all intensities [0,255]. Then the cumulative distribution function (c.d.f.) is calculated and the intensity x is applied the following transformation for each pixel:

$x \rightarrow 255 * \mathrm{cdf}(x)$

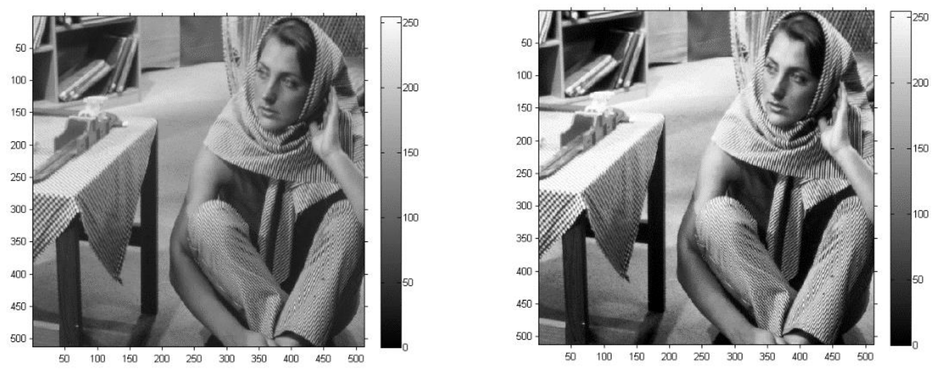


Figure. (left) Barbara, original image, (right) After global histogram equalization

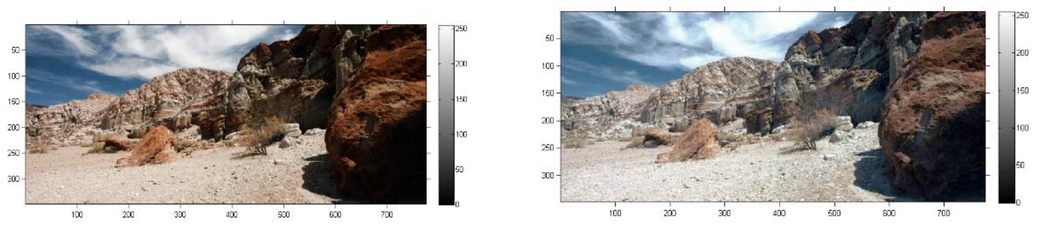


Figure. (left) canyon, original image, (right) After global histogram equalization

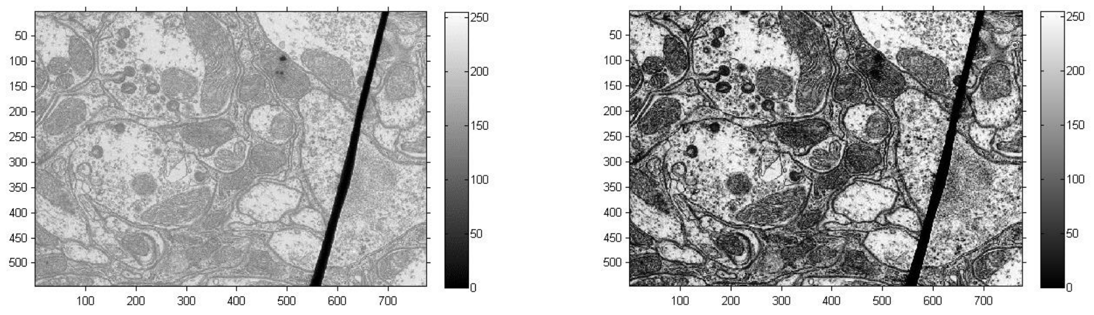
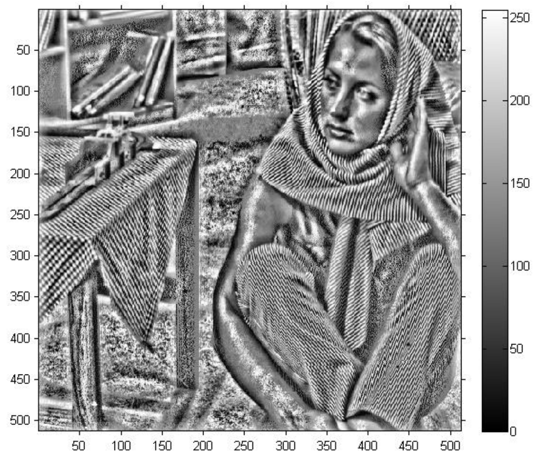


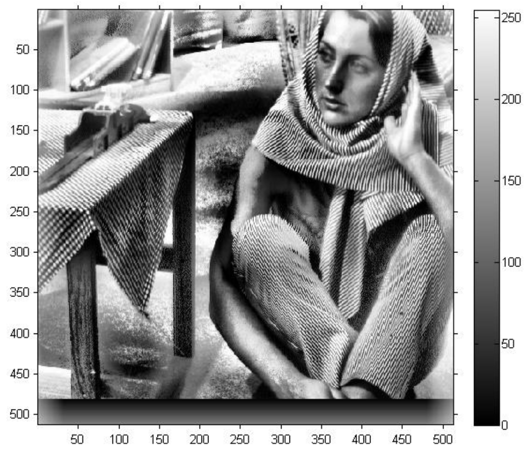
Figure. (left) TEM, original image, (right) After global histogram equalization

(c) Adaptive Histogram Equalization

```
function [outputImage] = myAHE(inputImage, N)
    % Applies adaptive histogram equalization on inputImage with window size N
    % and returns output Image
    funAHE = @(x) myAHEHelper(x);
    outputImage = nlfilter(inputImage, [N, N], funAHE);
end

function [outputValue] = myAHEHelper(inputImage)
    % myAHE takes the inputImage, 8 bit single channel image as the input and
    % enhances it using Adaptive Histogram equalisation

    [sizeX, sizeY] = size(inputImage);
    ColorNumber = 256;
    bins = zeros(ColorNumber, 1);
    cdf = zeros(ColorNumber, 1);
    for i = 1:sizeX
        for j = 1:sizeY
            bins(int32(inputImage(i,j))+1, 1) = bins(int32(inputImage(i,j))+1, 1) + 1;
        end
    end

    bins = bins ./ (sizeX*sizeY);
    sum = 0;

    for i = 1:ColorNumber
        sum = sum + bins(i);
        cdf(i,1) = sum;
    end

    outputValue = uint8(255.0*cdf(inputImage(int32(sizeX/2), int32(sizeY/2))+1));
end
```

Code Explanation: The function myAHE takes inputImage as a single channel 8 bit image and window size N as an input and returns outputImage i.e. a single channel 8 bit image with same dimensions. Using function *myAHEHelper* and *nfilter*, histogram equalisation is done for window of size NXN surrounding each pixel. myAHEHelper does the histogram equalization for each window and returns a scalar, the intensity of the central pixel of the window after histogram equalization.





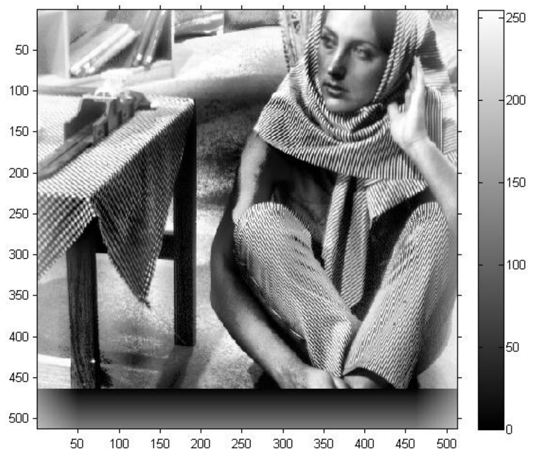
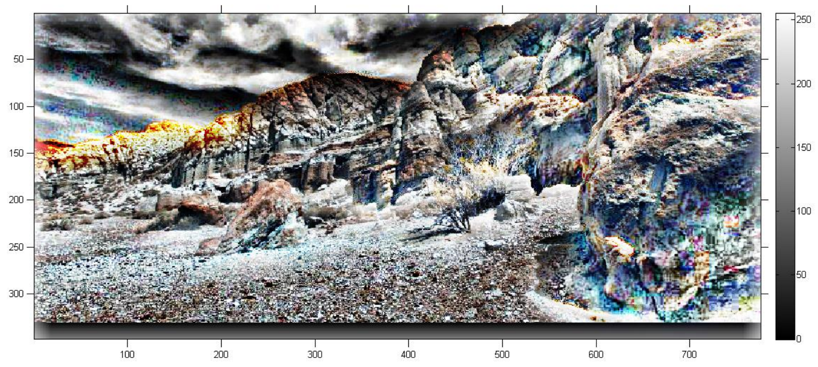
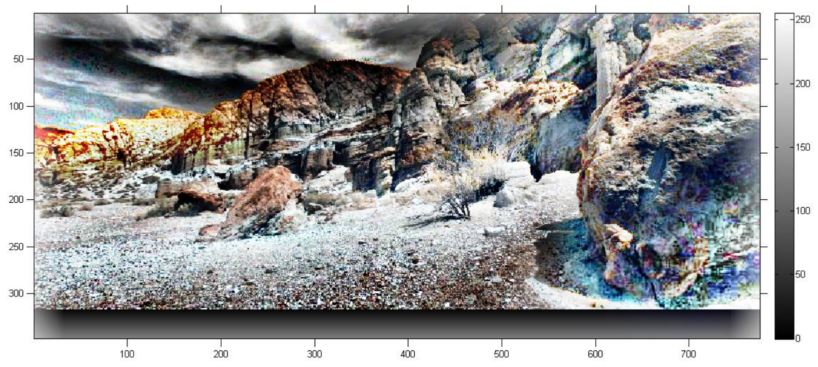


Figure. barbara after Adaptive Histogram Equalization: N= 25 (top), N = 64 (center), N=100 (bottom)





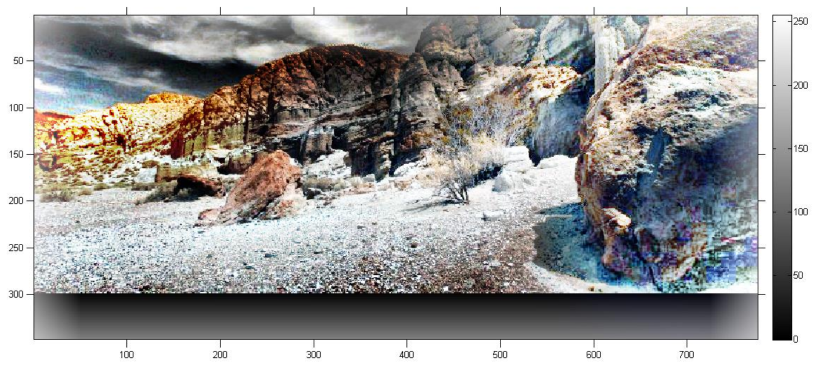
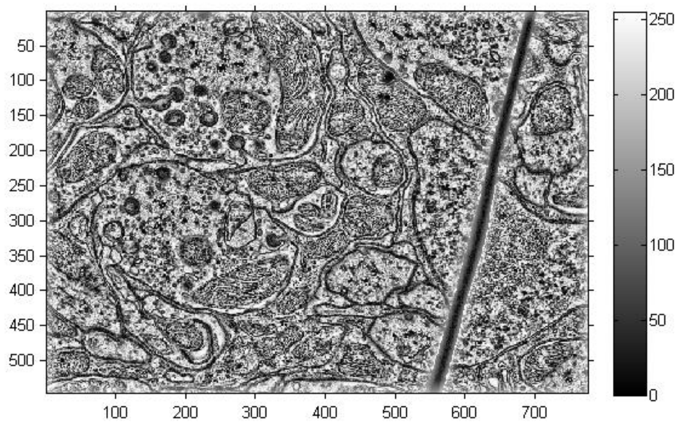
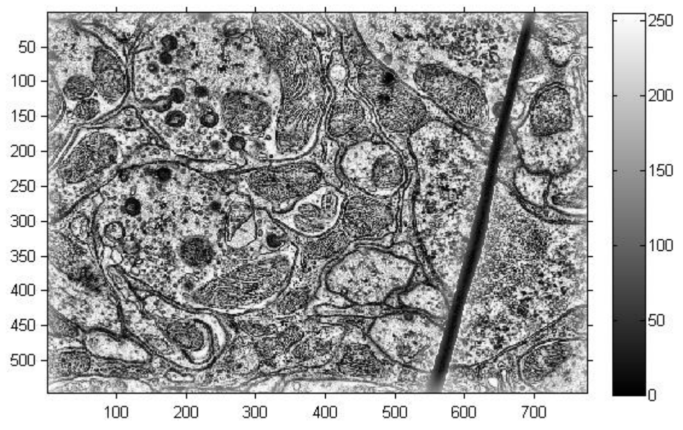


Figure. canyon after Adaptive Histogram Equalization: N= 36 (top), N = 64 (center), N=100 (bottom)





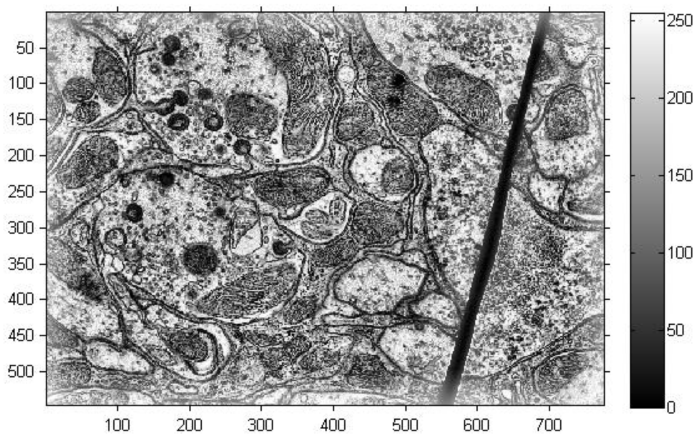


Figure. TEM after Adaptive Histogram Equalization: N= 36 (top), N = 64 (center), N=100 (bottom)

Comments: As we increase N from the optimal value, the amount of detail doesn't increase a lot as seen from the difference in images of N = 100 and N= 64. The image gets effectively cropped and takes significantly larger computational time.
Decreasing N leads higher noise amplification in the image as seen in images with N = 36.

(c) Contrast Limited Adaptive Histogram Equalization

```
function [outputValue] = myCLAHEHelper(inputImage, C)
    % myAHE takes the inputImage, 8 bit single channel image as the input and
    % enhances it using Histogram equalisation

    [sizeX, sizeY] = size(inputImage);
    ColorNumber = 256;
    bins = zeros(ColorNumber, 1);
    cdf = zeros(ColorNumber, 1);

    for i = 1:sizeX
        for j = 1:sizeY
            bins(int32(inputImage(i,j))+1, 1) = bins(int32(inputImage(i,j))+1, 1) + 1;
        end
    end

    C = C * sizeX * sizeY;
    points = 0;
    for i = 1:ColorNumber
        if bins(i) > C
            points = points + (bins(i) - C);
            bins(i) = C;
        end
    end

    points = points ./ ColorNumber;
    bins = (bins + points) ./ (sizeX * sizeY);

    sum = 0;
    for i = 1:ColorNumber
        sum = sum + bins(i);
        cdf(i,1) = sum;
    end
    outputValue = uint8(255.0*cdf(inputImage(int32(sizeX/2), int32(sizeY/2))+1));
end
```

Code Explanation: The function myCLAHE takes inputImage as a single channel 8 bit image, window size N and threshold parameter C as an input and returns outputImage i.e. a single channel 8 bit image with same dimensions. Using function *myCLAHEHelper* and *nfilter*, contrast limited histogram equalisation is done for window of size NXN surrounding each pixel. myCLAHEHelper calculates the histogram for each window. Then the total weight of the histogram lying above the threshold parameter C is cutoff from the histogram and added equally to each bin of the histogram. Then cdf is calculated using the modified histogram and following transformation is applied on the intensity of the center pixel x

$$x \rightarrow 255 * \mathrm{cdf}(x)$$

and the new intensity of the pixel is given as the output for each window.

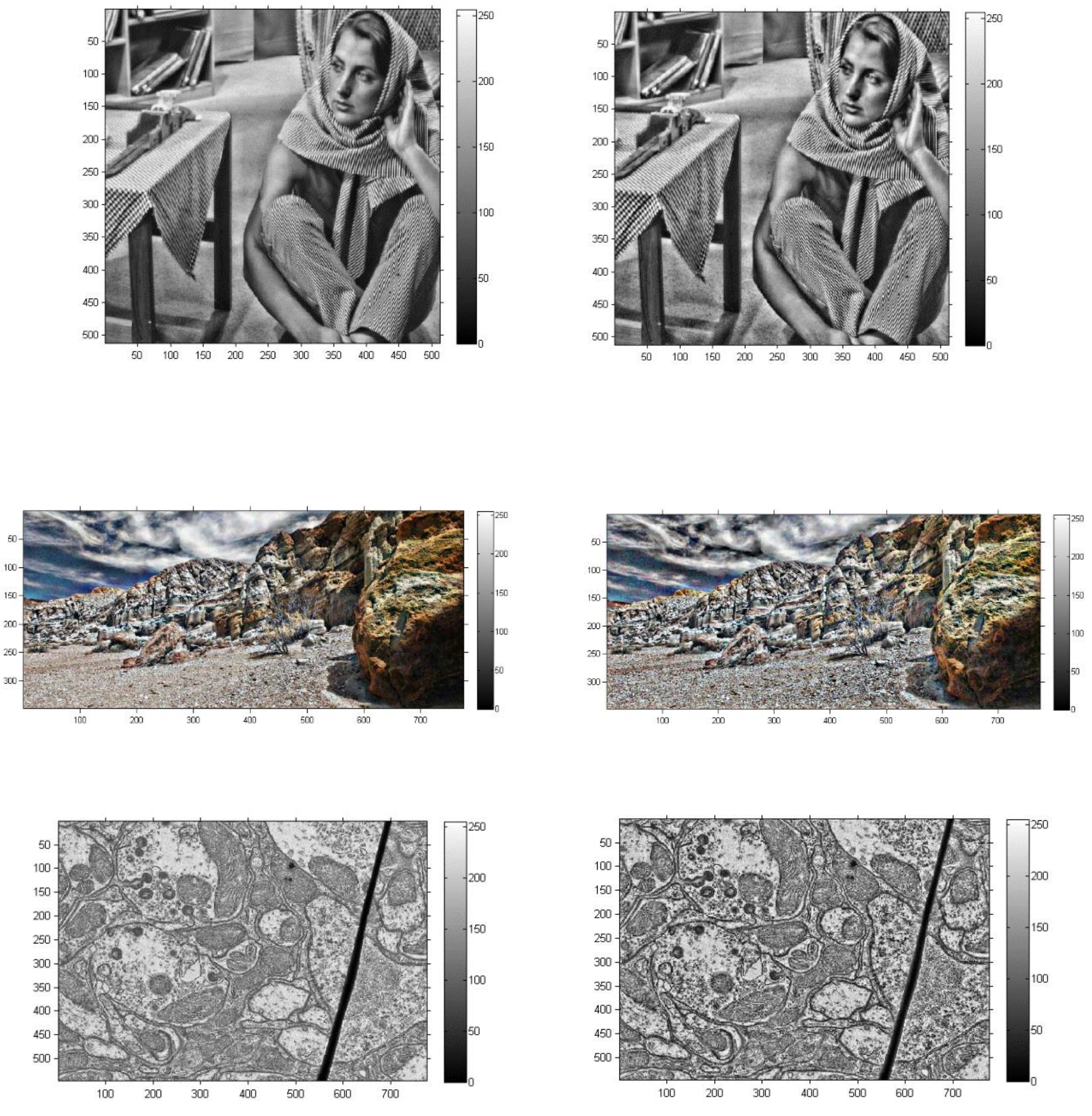


Figure. Images after Contrast Limited Adaptive Histogram equalization with (Left) N= 36, E = 0.005, (Right) N= 36, E =0.01

Comments: As we decrease E to half of its original value, the detail decreases and therefore the difference between the original and final image is also less apparent.