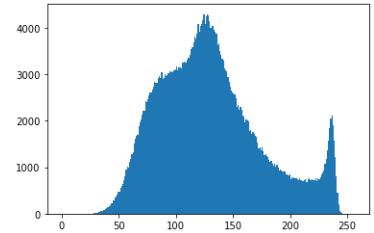
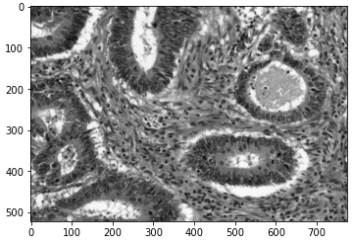
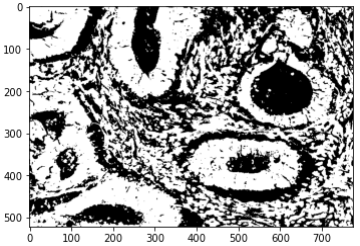
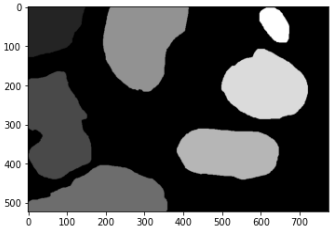
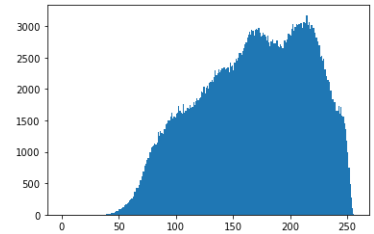
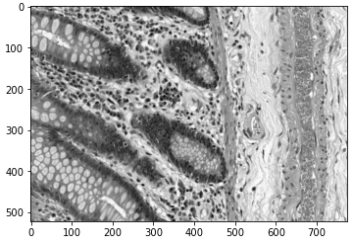
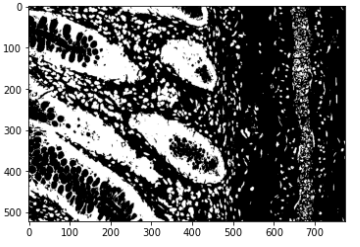
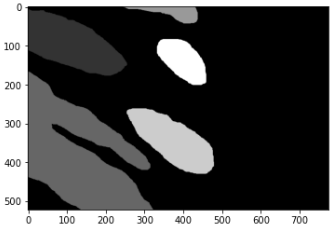
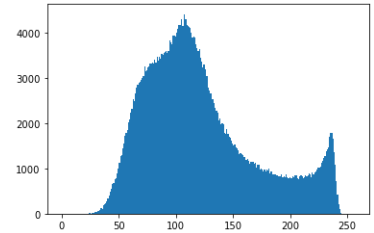
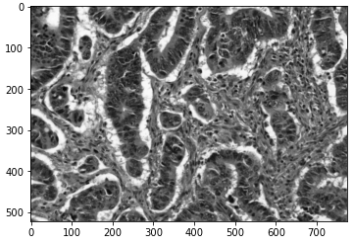
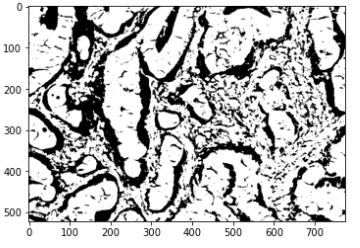
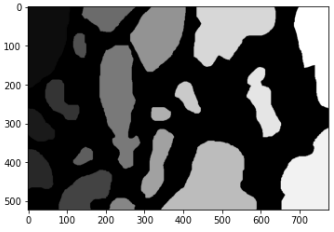
Part 1

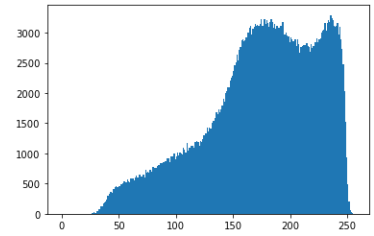
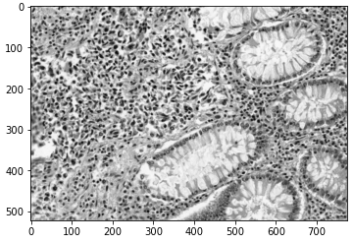
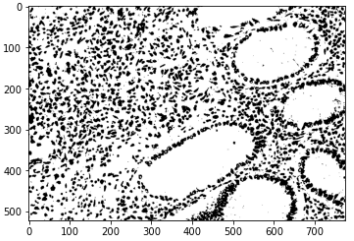
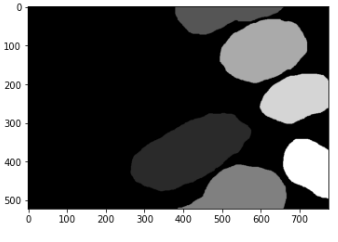
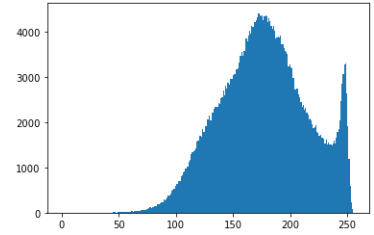
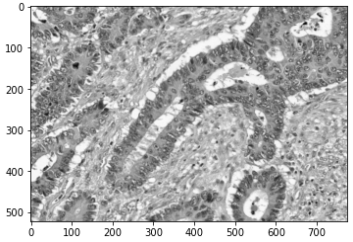
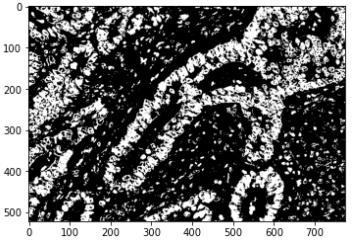
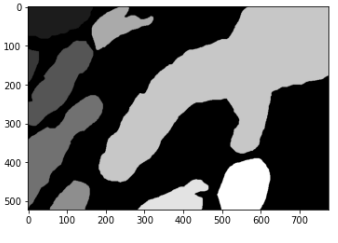
Thresholding Algorithm Used:

Based on visual inspection of histogram

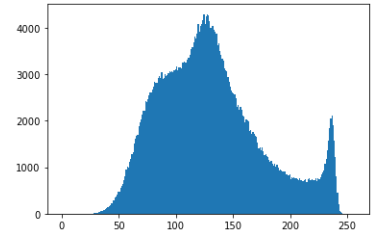
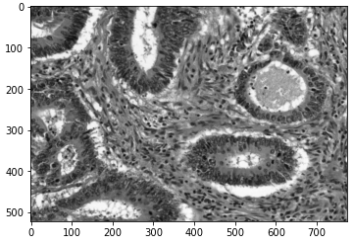
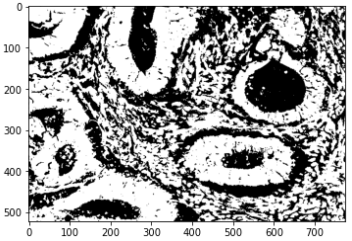
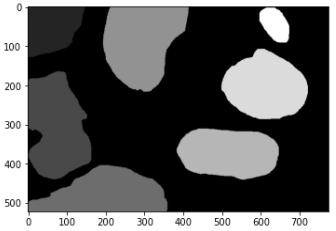
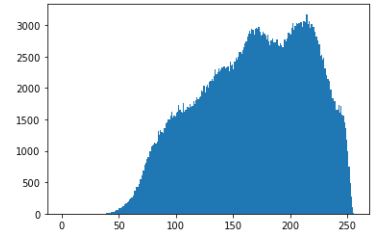
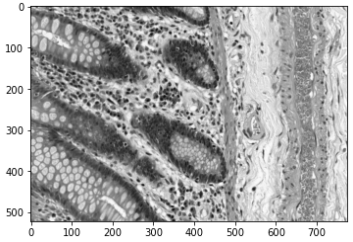
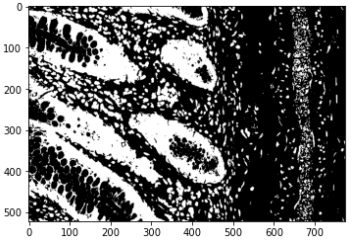
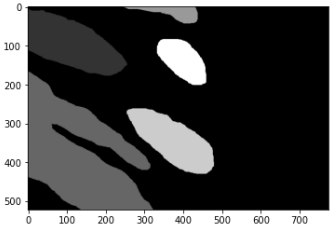
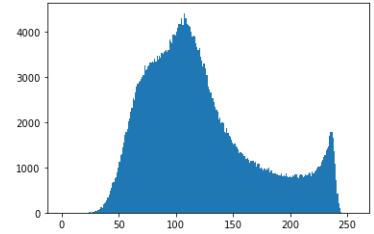
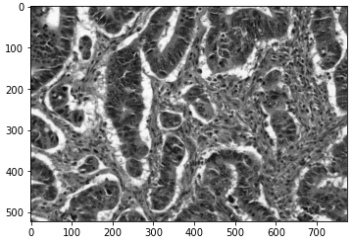
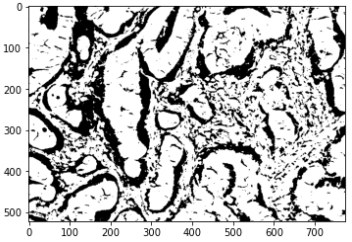
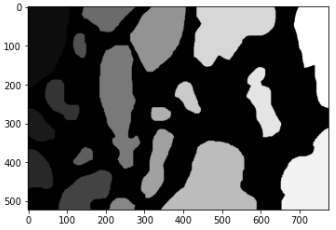
1. Select an initial estimate for **T**.
2. Segment the image using **T.** This will produce two groups of pixels: G_1 consisting of all pixels with gray level values > **T** and G_2 consisting of pixels with gray level values $\leq$ **T**
3. Compute the average gray level values μ_1 and μ_2 for the pixels in regions G_1 and G_2
4. Compute a new threshold value
5. **T** = 0.5 ($\mu_1 + \mu_2$)
6. Repeat steps 2 through 4 until the difference between the values of **T** in successive iterations is smaller than a predefined parameter **ΔT**.

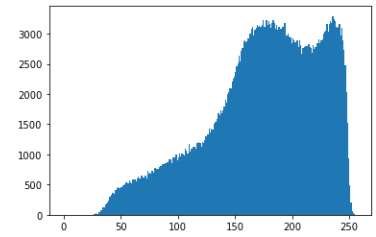
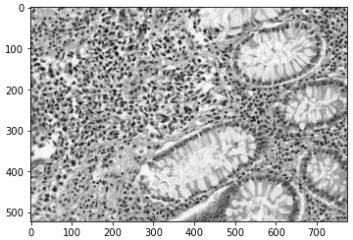
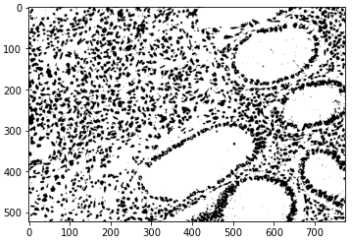
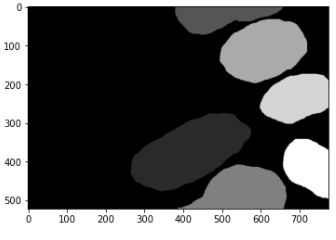
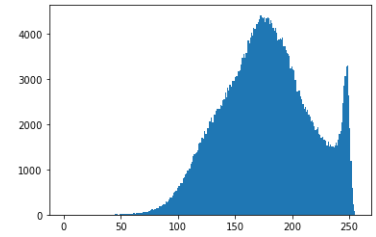
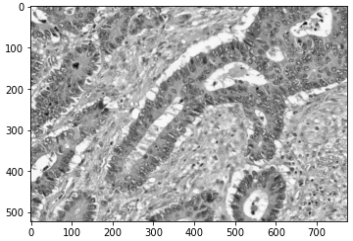
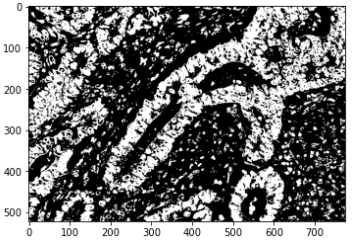
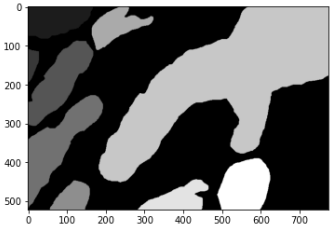
$\Delta T = 5$

Threshold	Histogram	Original Image	Segmented Image	Annotated Image
132.01				
143.94				
133.66				

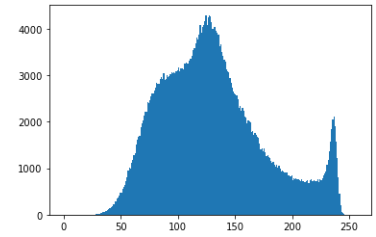
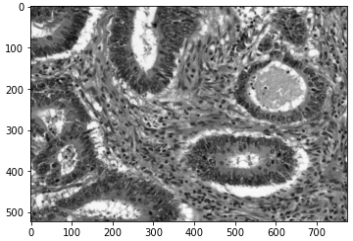
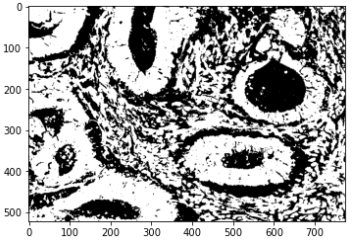
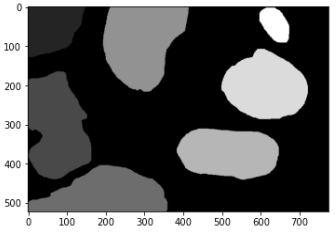
137.86				
154.98				

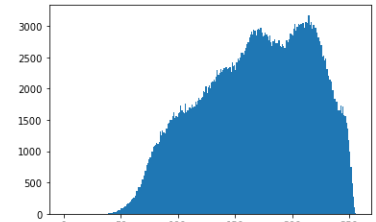
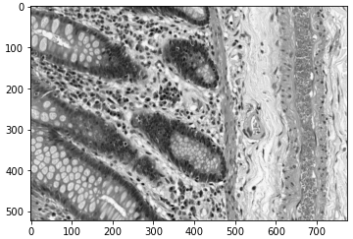
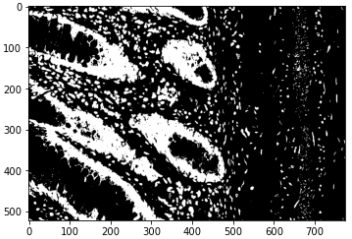
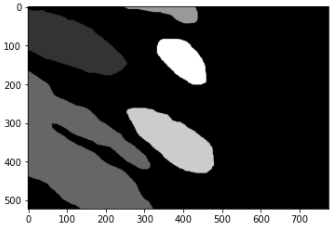
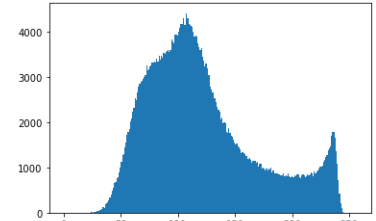
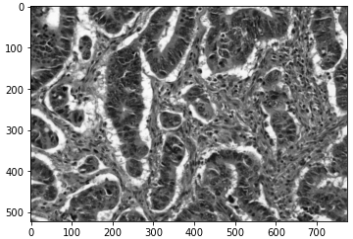
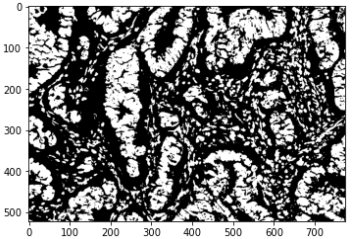
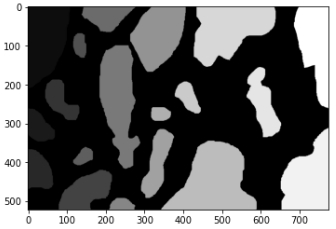
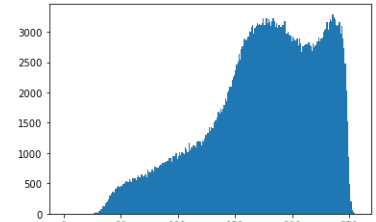
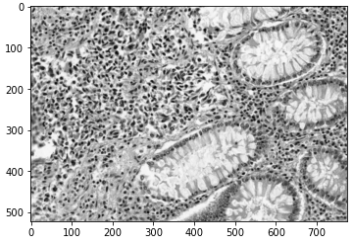
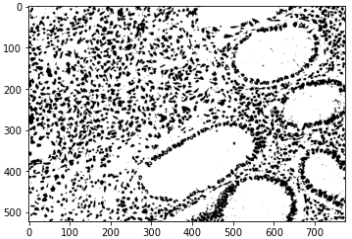
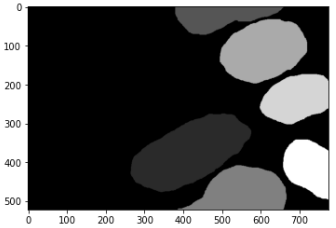
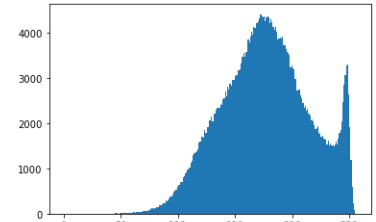
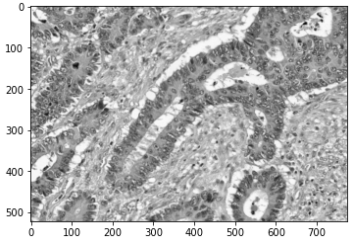
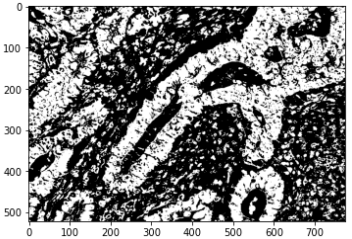
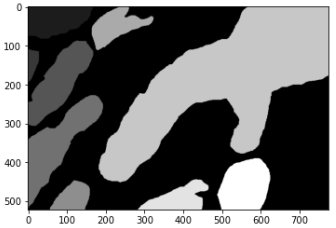
$\Delta T = 1$

Threshold	Histogram	Original Image	Segmented Image	Annotated Image
133.87				
143.94				
133.66				

137.86				
162.48				

Manual Thresholding:

Threshold	Histogram	Original Image	Segmented Image	Annotated Image
110				

123				
100				
137				
170				

Observations:

- The allowance value (delta threshold) plays a major role in determining the correct threshold value, although the visible difference is less.
- Basic global thresholding gives results with variable accuracy depending on the histogram distribution of the image.
- Images where the background and foreground pixel intensities lie in a very narrow range don't do well, case in study image 4.
- The algorithm works very well on images 2,3 and 5 where background and foreground intensities are distinct.
- Manually choosing the threshold gives much better results. On further inspection, the general procedure followed in manual thresholding is to try to find the change in the first derivative of the histogram graph.
- One way to make an algorithm for this would be to look for the point where the first derivative changes by the maximum point, bounded by certain pixel intensity values.

Part 2

Image 1

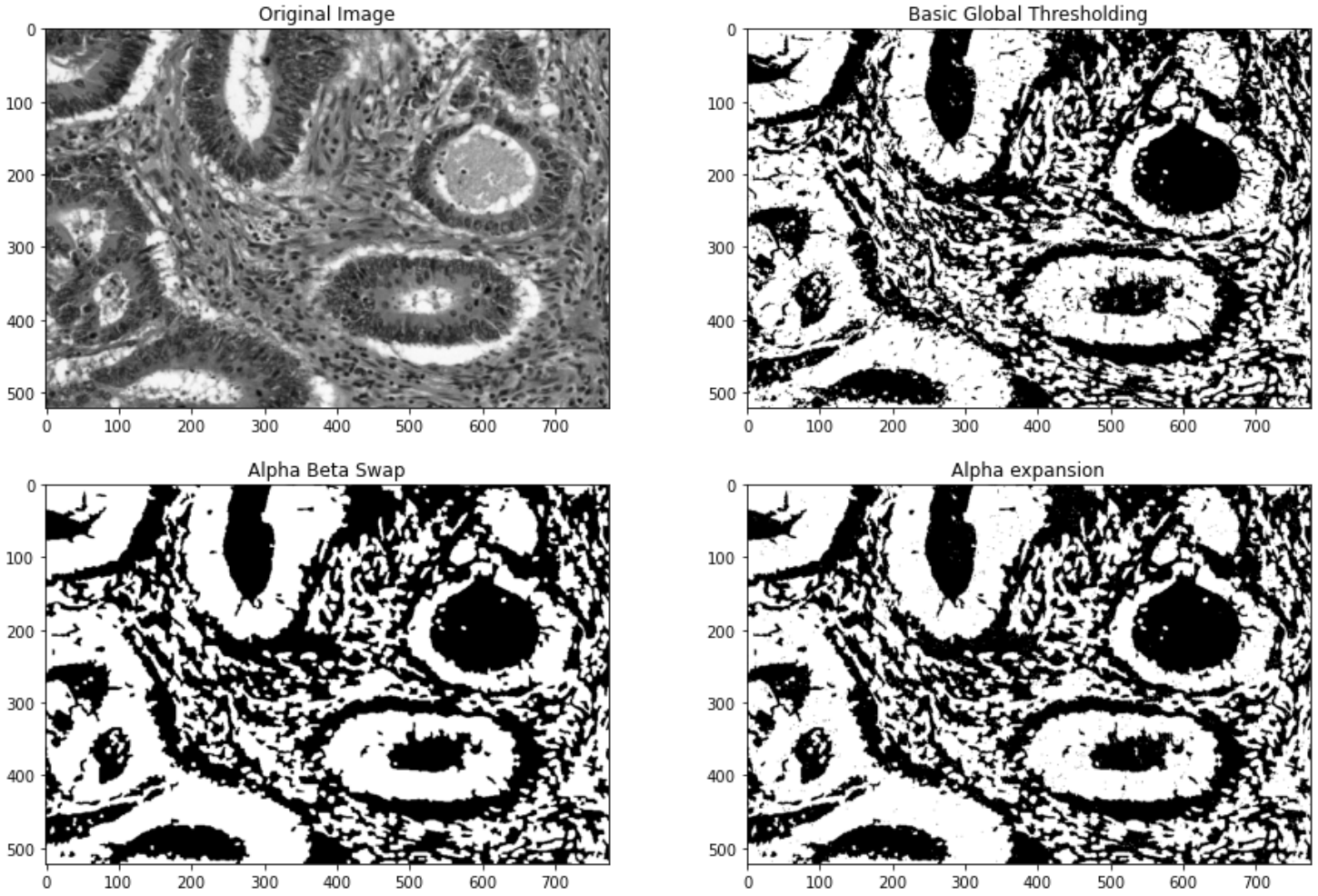


Image 2

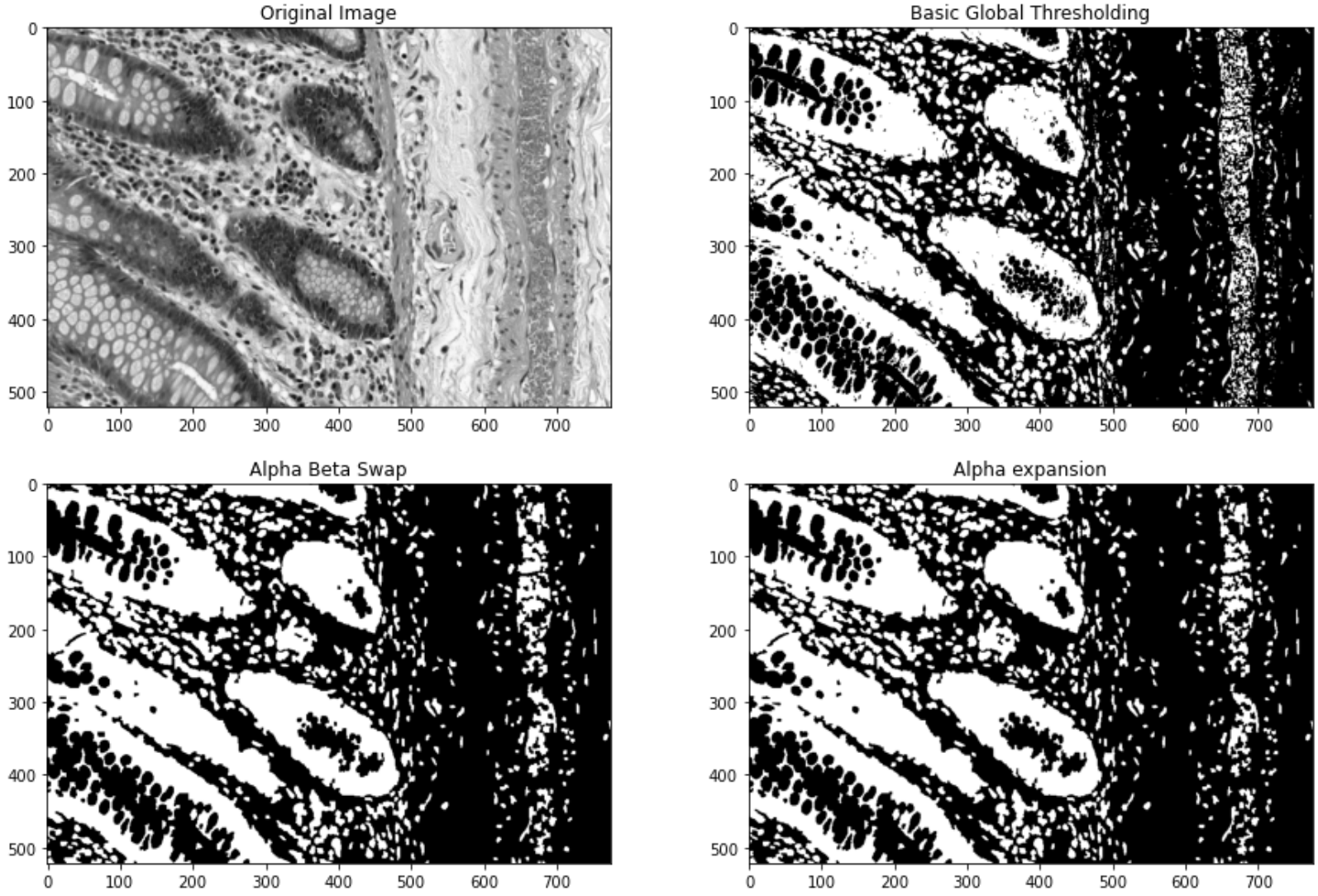
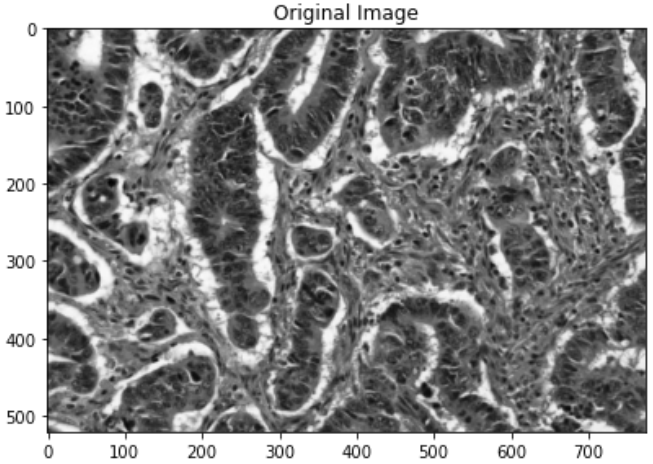
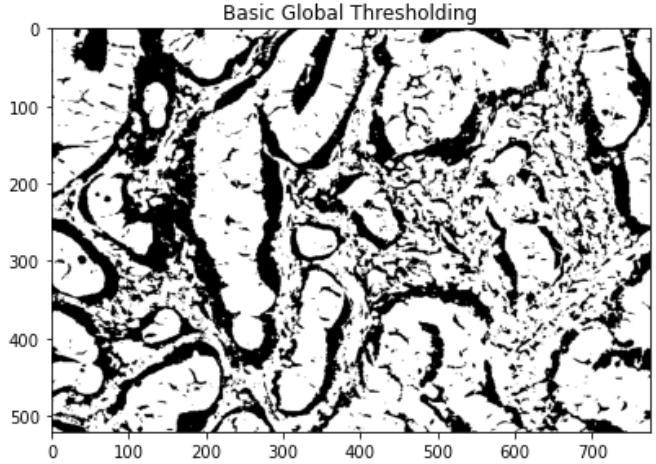
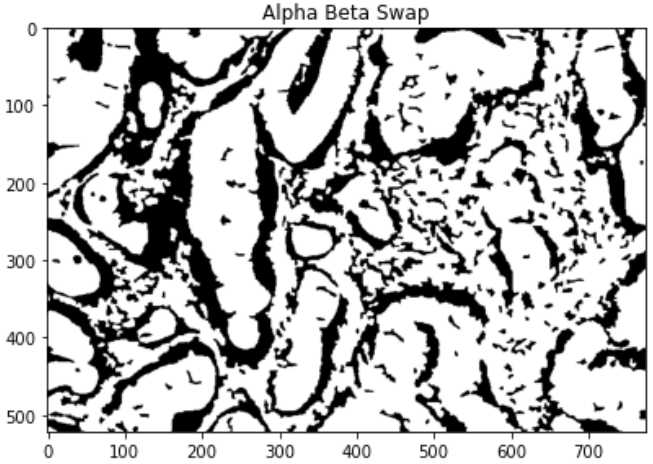

Original Image
Basic Global Thresholding
Alpha Beta Swap
Alpha expansion
0
100
200
300
400
500
600
700

Image 3


Original Image
0
100
200
300
400
500
0
100
200
300
400
500
600
700


Basic Global Thresholding
0
100
200
300
400
500
0
100
200
300
400
500
600
700


Alpha Beta Swap
0
100
200
300
400
500
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100
200
300
400
500
600
700

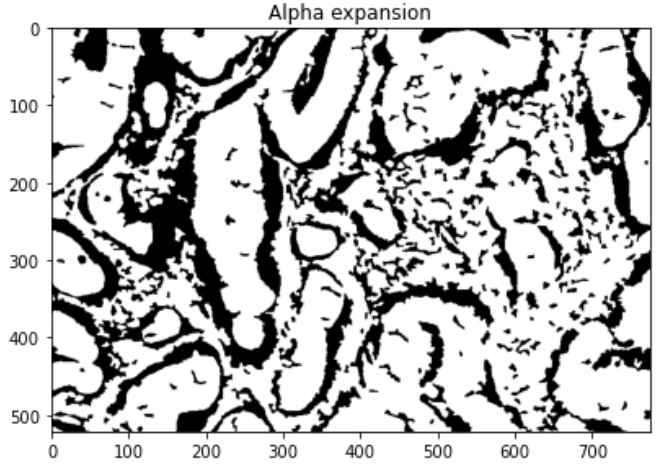
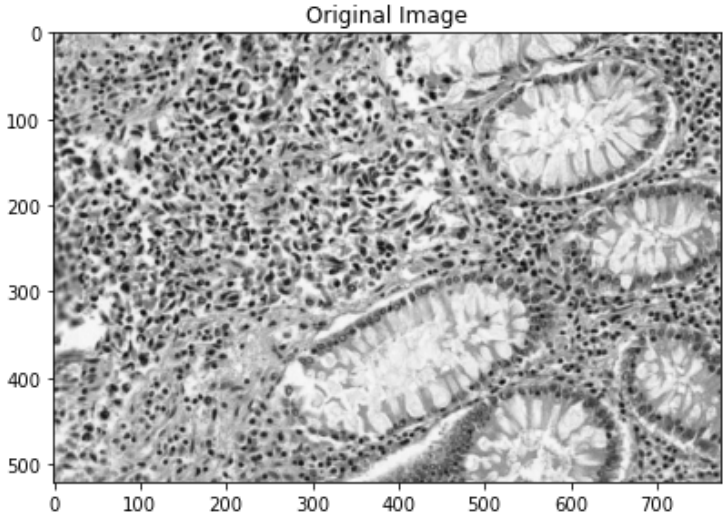
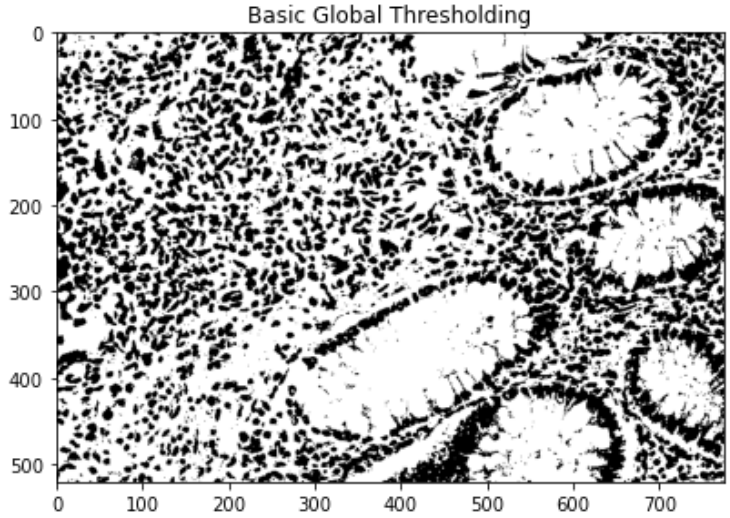

Alpha expansion
0
100
200
300
400
500
0
100
200
300
400
500
600
700

Image 4


Original Image
0
100
200
300
400
500
0
100
200
300
400
500
600
700


Basic Global Thresholding
0
100
200
300
400
500
0
100
200
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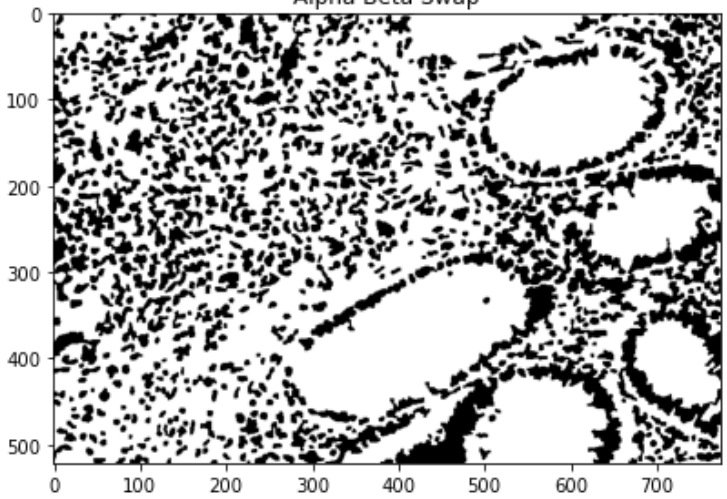
400
500
600
700


Alpha Beta Swap
0
100
200
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400
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0
100
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400
500
600
700

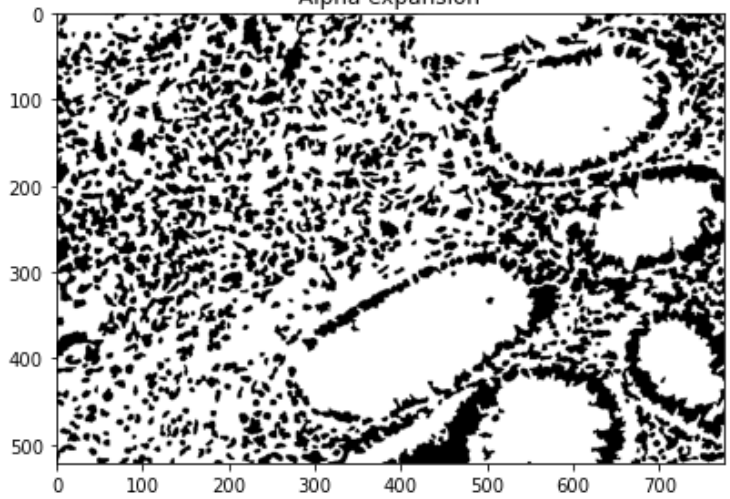
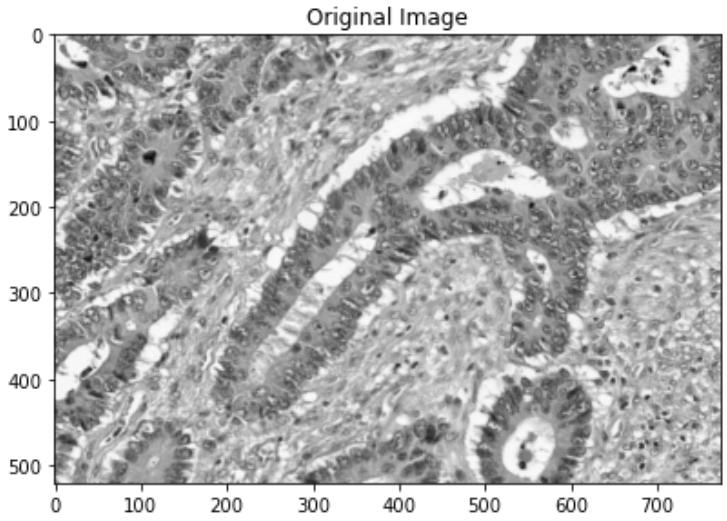
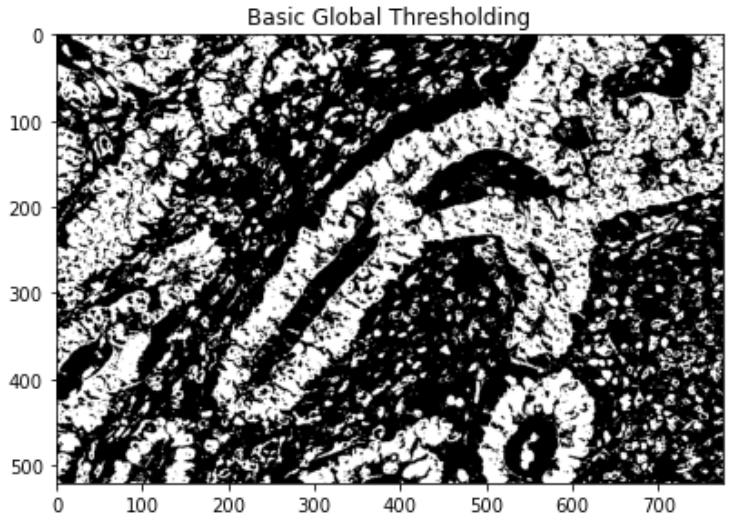

Alpha expansion
0
100
200
300
400
500
0
100
200
300
400
500
600
700

Image 5


Original Image
0
100
200
300
400
500
0
100
200
300
400
500
600
700


Basic Global Thresholding
0
100
200
300
400
500
0
100
200
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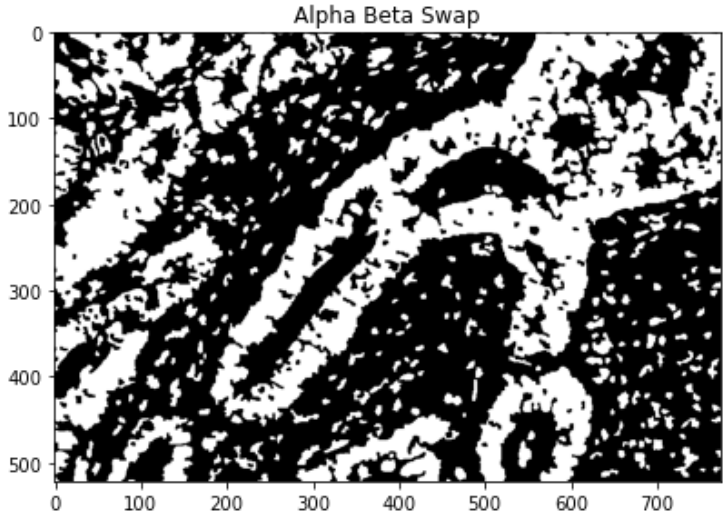
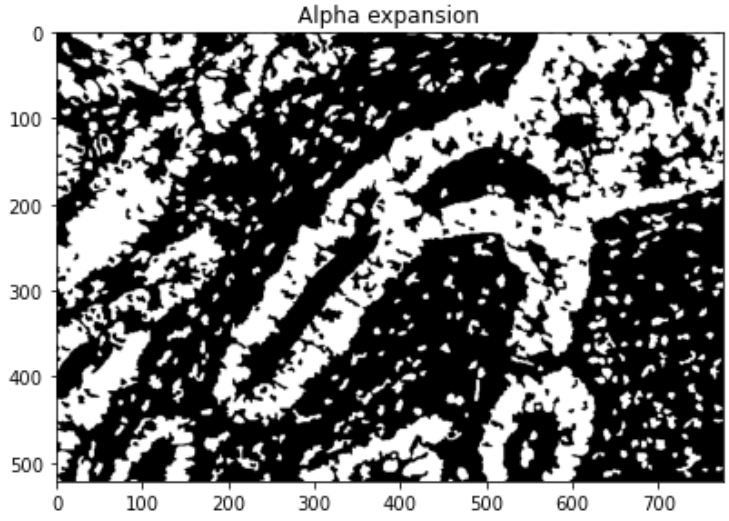
400
500
600
700


Alpha Beta Swap
0
100
200
300
400
500
0
100
200
300
400
500
600
700


Alpha expansion
0
100
200
300
400
500
0
100
200
300
400
500
600
700

Part 3

Image 1

	Global Histogram Thresholding	Alpha Beta Swapping	Alpha Expansion Performance
Jaccard Coefficient	0.4390982553072048	0.4545485176463541	0.45101593020066566
Dice Coefficient	0.6102408278070914	0.6250028955814714	0.6216553806384375
Accuracy	0.6245902855024101	0.6398591027067112	0.6338722036831047
Sensitivity	0.6887498551732129	0.7033599814621713	0.7049299038350133
Specificity	0.5768378390031476	0.5925969042383478	0.5809856422196352

Image 2

	Global Histogram Thresholding	Alpha Beta Swapping	Alpha Expansion Performance
Jaccard Coefficient	0.44451308487863067	0.45328990720636053	0.45503761205771004
Dice Coefficient	0.6154504095973338	0.6238120900154238	0.625465085282843
Accuracy	0.7421678408107774	0.7497985415894204	0.7534124335681621
Sensitivity	0.6805159228398585	0.6842255450291063	0.6791136041221648
Specificity	0.7689928200471096	0.7783295967307092	0.7857401311121832

Image 3

	Global Histogram Thresholding	Alpha Beta Swapping	Alpha Expansion Performance
Jaccard Coefficient	0.5317796817945558	0.45328990720636053	0.5351056424271331
Dice Coefficient	0.6943292016663252	0.6238120900154238	0.6971580686539403
Accuracy	0.6459522926708688	0.7497985415894204	0.6434235570386849
Sensitivity	0.8531159370886454	0.6842255450291063	0.8707684562174521
Specificity	0.46124964347334113	0.7783295967307092	0.4407277352023902

Image 4

	Global Histogram Thresholding	Alpha Beta Swapping	Alpha Expansion Performance
Jaccard Coefficient	0.31620834104183737	0.3193775256450109	0.31976751813804594
Dice Coefficient	0.4804837215839924	0.48413364550661897	0.48458158538282603
Accuracy	0.48836732171548636	0.4804152762328513	0.48735137807440365
Sensitivity	0.7392261353104727	0.76177015755329	0.36232958883193367
Specificity	0.46124964347334113	0.34797687861271676	0.4407277352023902

Image 5

	Global Histogram Thresholding	Alpha Beta Swapping	Alpha Expansion Performance
Jaccard Coefficient	**0.49643737377554403**	**0.5584545387386526**	**0.5470273960015227**
Dice Coefficient	**0.663492348527786**	**0.7166773554917324**	**0.707198072141942**
Accuracy	**0.7035422073909282**	**0.7488369793597824**	**0.744108268446422**
Sensitivity	**0.5877659574468085**	**0.6388496719029628**	**0.6214754424338835**
Specificity	**0.8180490682924431**	**0.8576183686513594**	**0.865396528836226**

Observations (Part 2 and 3)

- Since the initial labels are acquired from histogram thresholding, the quality of segmentation is highly variable depending on the histogram distribution of the image pixels.
- Alpha beta swapping works better than alpha expansion for images that contain similar concentration of black and white pixels in a particular region because the histogram based thresholding generates a lot of salt and pepper noise, which alpha beta swap reduces drastically since it minimizes the energy. Alpha expansion gets hindered here because of the background labels given by thresholding,

- On the other hand, alpha expansion works better on the images that contain skewed concentrations of pixels.
- Both alpha beta swapping and alpha expansion algorithm reduce the noise present in the histogram based segmented image by some margin.