Algorithmic Evaluation of Escherichia Coli Bacteria Presence

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Systemized Escherichium Coli Bacteria Detection

German-Austrian pediatrician Theodor Escherich discovered bacteria in the feces of healthy individuals in 1885 and called it Bacterium coli commune because it is found in the colon.

Escherichia coli among other facultative anaerobe bacteria constitute about 0.1% of gut flora.

Escherichia coli normally colonizes an infant's gastrointestinal tract within 40 hours of birth.

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It can benefit their hosts by producing vitamin K2, and preventing colonization of the intestine with pathogenic bacteria.

It is expelled into the environment within fecal matter.

Fecal–oral transmission is the major route through which pathogenic strains of the bacterium cause disease.

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Escherichia coli are bacteria found in the environment, foods, and intestines of people and animals.

Although most types of Escherichia coli are harmless and even help keep our digestive tract healthy, others can make one sick.

Some types of Escherichia coli can cause diarrhea, pneumonia, breathing problems, and urinary tract infections.

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In fact, 75% to 95% of urinary tract infections are caused by this bacterium.

Some versions of Escherichia coli are very harmful by making a toxin called Shiga.

This toxin damages the lining of human intestine.

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One severe complication associated with Escherichia coli infection is hemolytic uremic syndrome which produces toxic substances that destroy red blood cells, causing kidney injury that can be life-threatening, especially for children and the elderly.

According to the Center for Disease Control and Prevention, about 5 to 10 percent of those who are infected develop hemolytic uremic syndrome.

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It is the leading cause of acute kidney failure in children.

It can also cause life-threatening symptoms such as: adult kidney failure, fever, bleeding, confusion and seizures.

Another Escherichia coli strain causes abdominal cramps, vomiting, and bloody diarrhea.

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Considering the importance of the Escherichia coli bacteria presence in the organism and its potential for causing of severe diseases, mathematical model that automatically detects and quantifies related indicators is developed.

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Systematized algorithm is meant for pictures of stained bacteria presented on slides with the possible focus on Escherichia coli bacteria presence and concentration as reflected in microscopic images.

The proposed algorithm performs as a visual weight tool expressed through detection and differentiation of the bacteria by marking it in a different color and numerical quantifier that enables quantification of the amount of detected bacteria by calculating its numerical content equivalent.

Systemized Escherichium Coli Bacteria Detection

A dedicated mathematical and simulation algorithm was developed in MATLAB for the purpose of systemized Escherichia coli bacteria detection in microscopic images that includes three steps:

1. The first step in the procedure is taking the raw data, which consists of the acquired images in JPEG format, and decomposing the color images into Hue, Saturation and Intensity color plane images.

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2. In the second step we calculate the average intensity values of Hue, Saturation and Intensity color planes.

If it is gray scale image Intensity plane average value is used as a threshold for generating binary image with the extracted tainted targeted bacteria.

In case of color image, which is in majority of the microscopic Escherichia coli bacteria images, a maximum between Hue plane average value and Saturation plane average value is taken as a threshold used for binary image generation.

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2. The following equation represents the mathematical model of the applied algorithm:

```
if ( (TH>=TS) & (TH>0) )
      Inew (x,y)( if HUE(x,y) >TH )=255;
end
if ( (TH<TS) & (TS>0) )
      Inew (x,y)( if SAT(x,y)>TS )=255;
end
if ( (TH==0) & (TS==0) )
      Inew (x,y)( if INT(x,y)>TI )=255;
end
```

I_{new} represents the new value of the pixel intensity in the generated mask binary image with the detected targeted areas.

The values HUE(i, j), SAT(i, j), INT(i, j) represent the intensity pixel values in the Hue, Saturation and Intensity color planes, respectively of the analyzed image.

Parameters TH, TS and TI are Hue, Saturation and Intensity plane average values respectively.

They are empirically obtained limit values in the respective Hue, Saturation and Intensity color planes.

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3. Results obtained with HSI color based segmentation method in step two are binary images that are applied on original Escherichia coli bacteria images with the colored marked areas of successfully detected bacteria.

The obtained images are binarized where the detected bacteria occupied region is marked as white and the rest of the image, called background, as black.

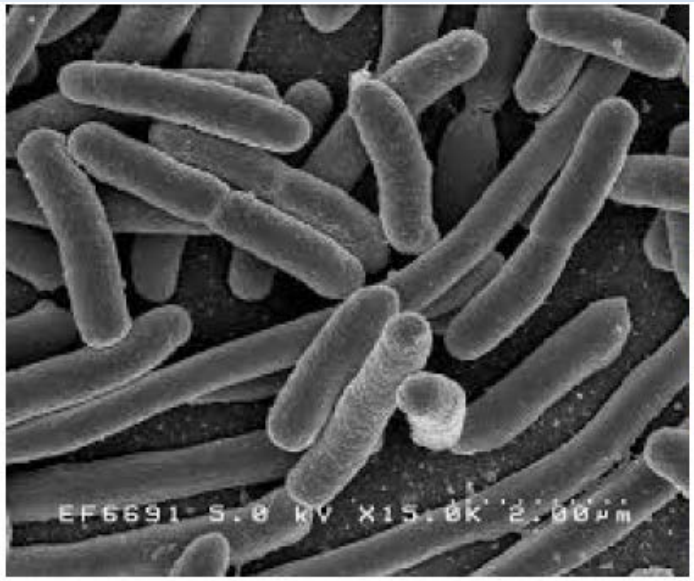
White pixels in the obtained mask of the binary image denote the detected targeted bacteria regions and the black pixels represent the background.

The advantage of the proposed method is that it is not iterative method but it takes just one span over the analyzed microscopic image taking benefit of the color of the dyed regions which makes it simple, fast and efficient.

Systemized Escherichium Coli Bacteria Detection

These images are taken under various clinical conditions, bacteria are tainted in many colors and microscopic images are of different resolutions.

This algorithm was tested using an independent database of 19 real Escherichia coli bacteria images



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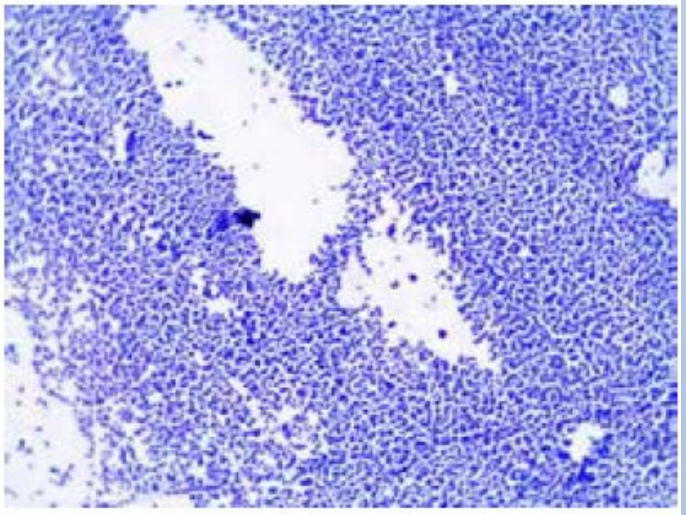

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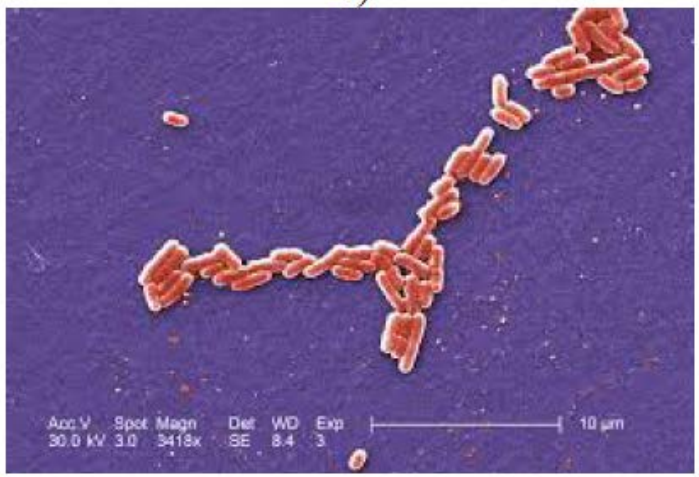

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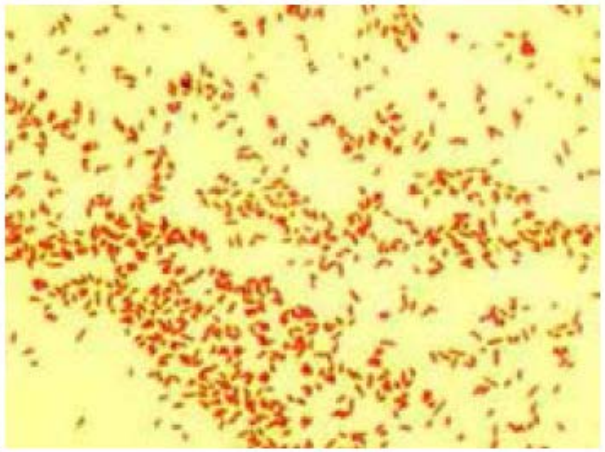

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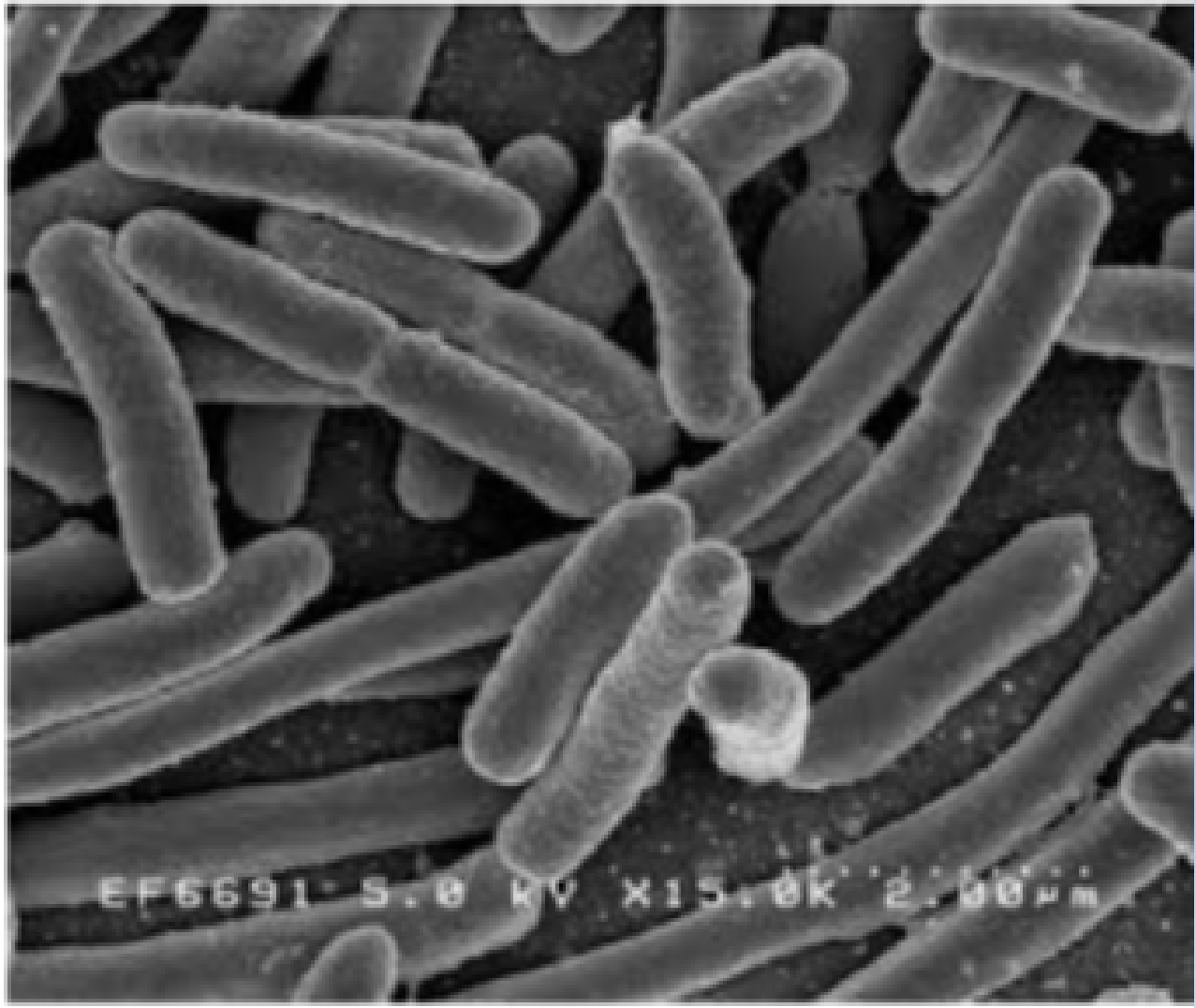

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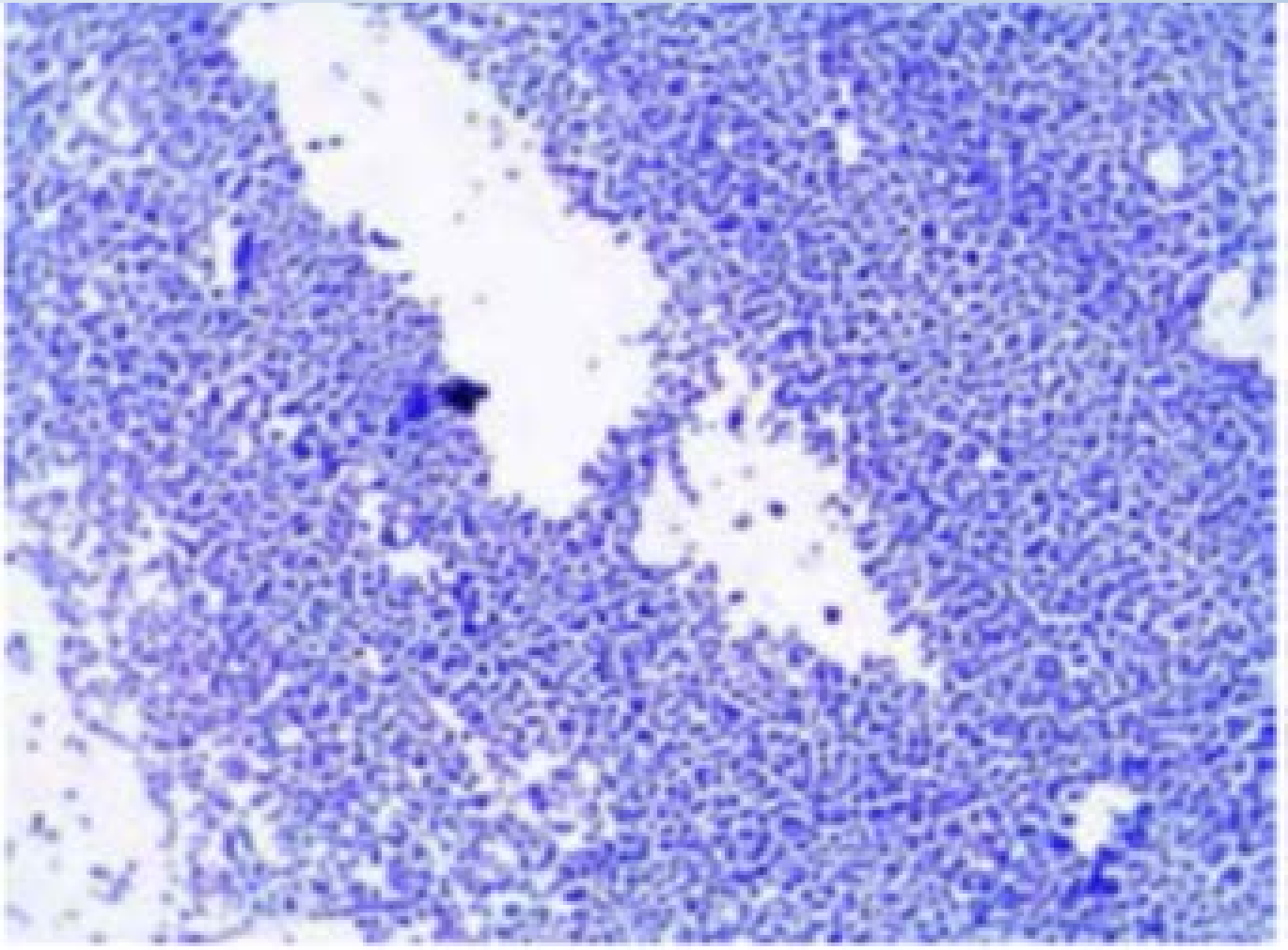

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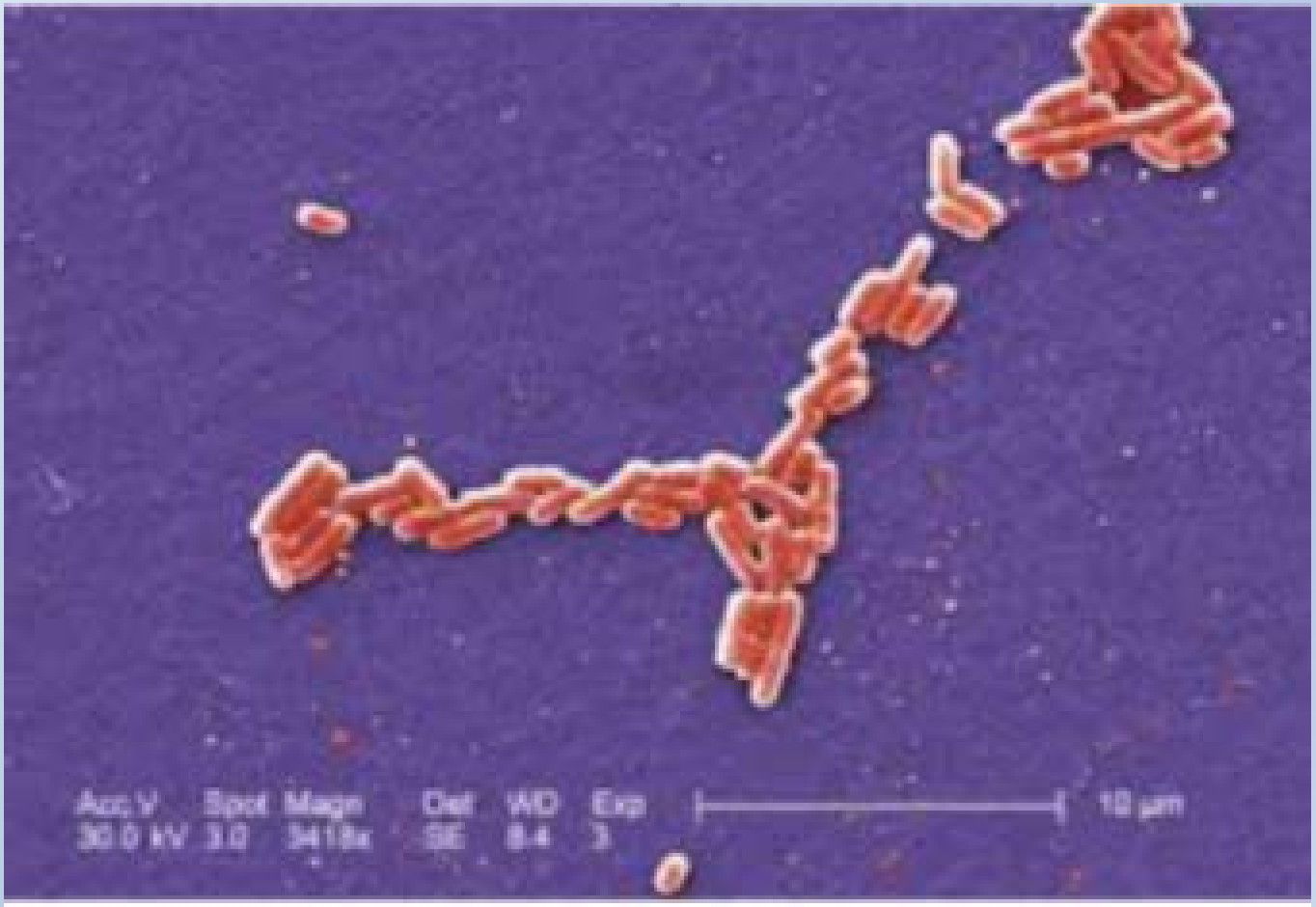

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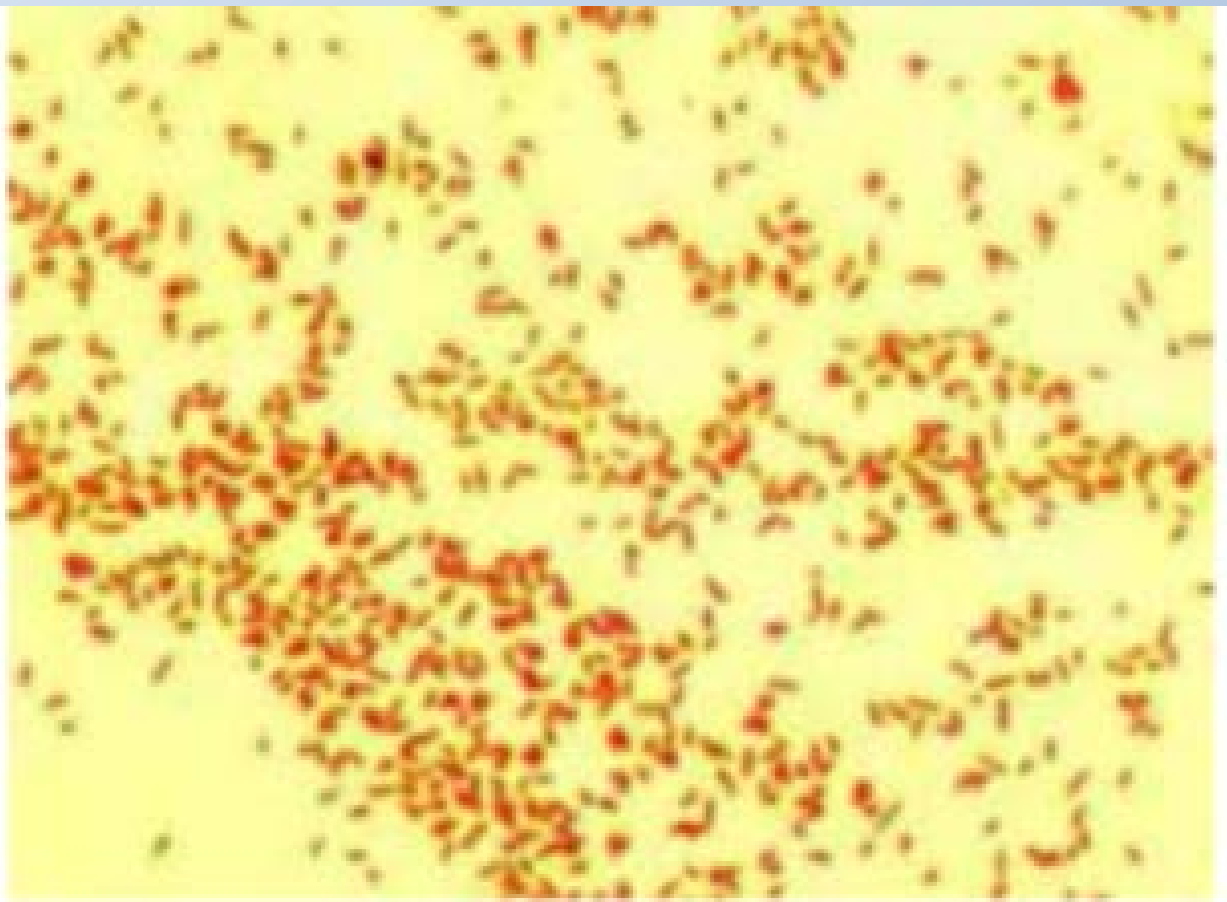

1. Step Hue color component of the selected images

Hue color plane of gray scale image

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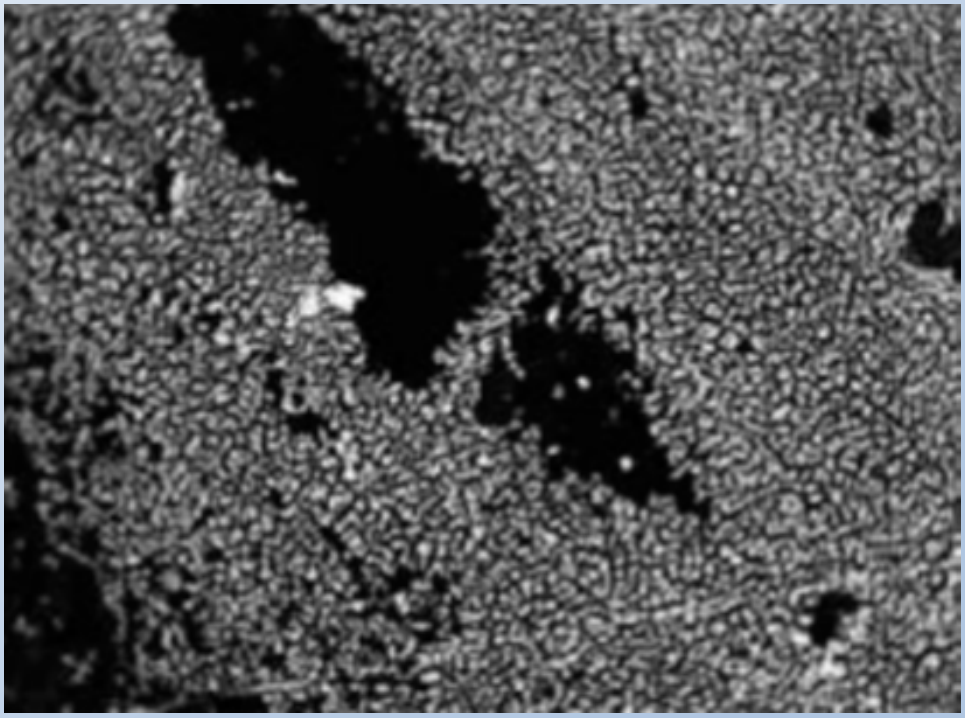

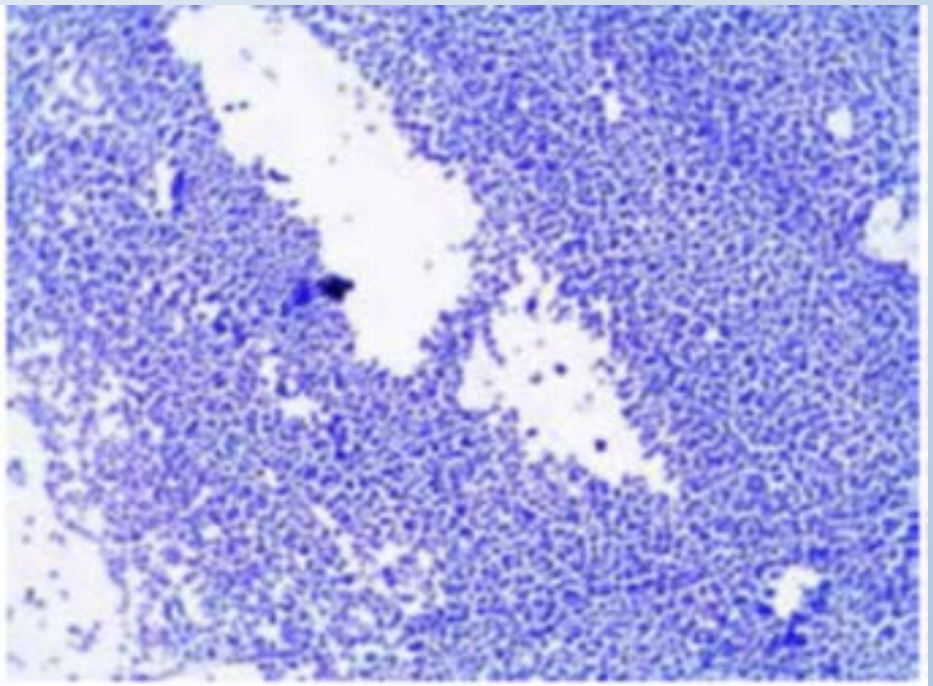

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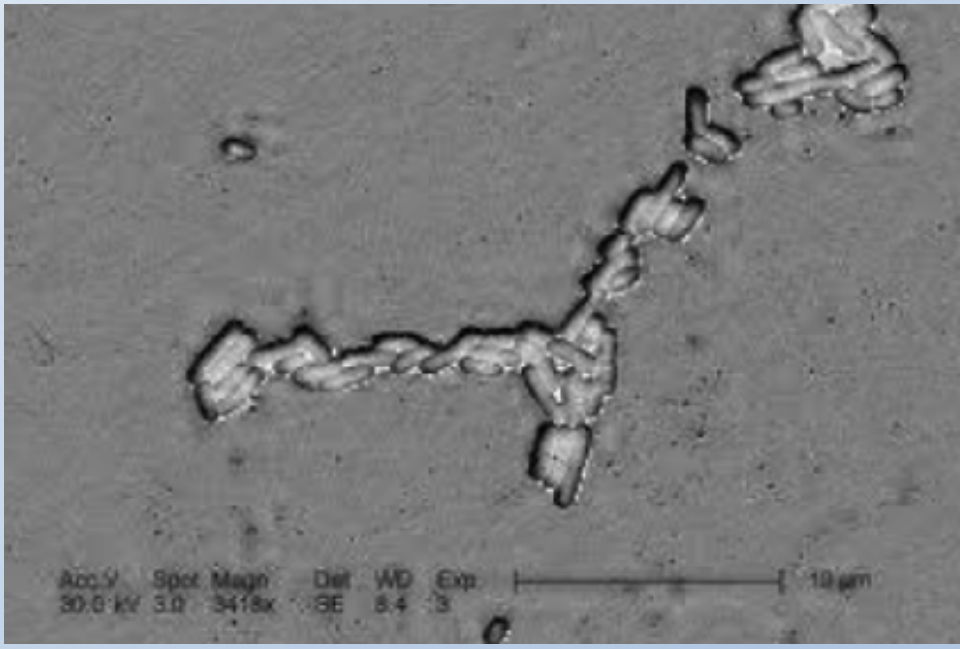

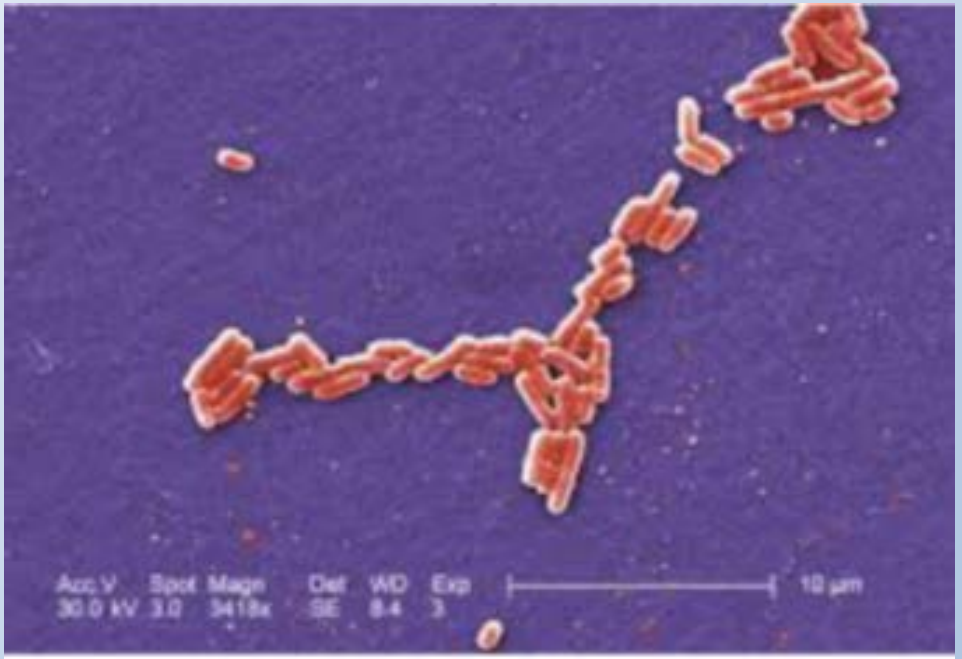

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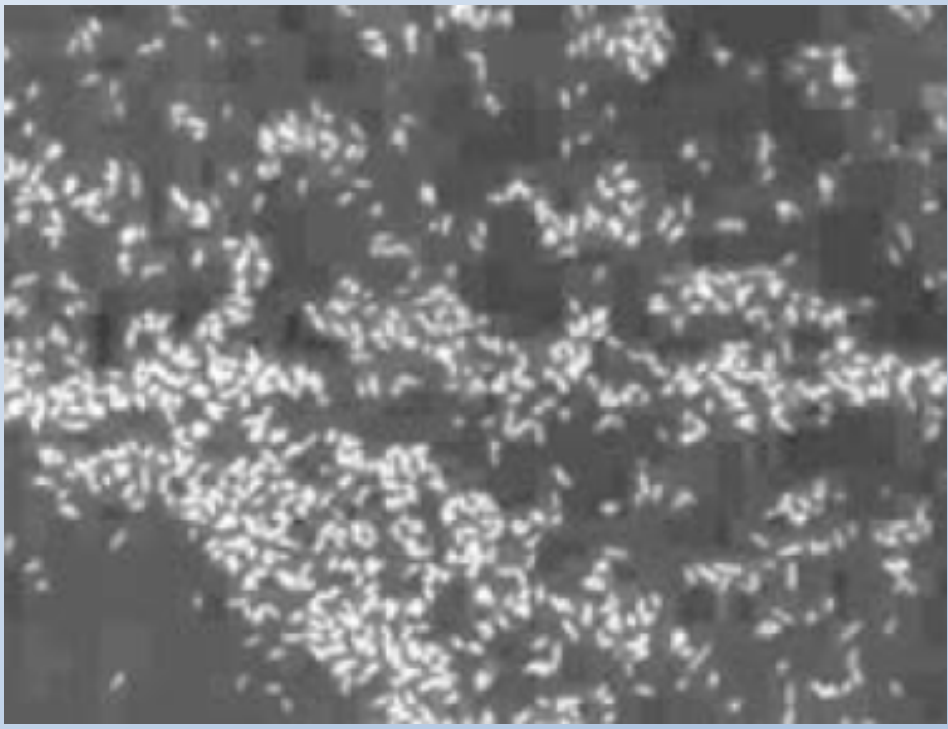

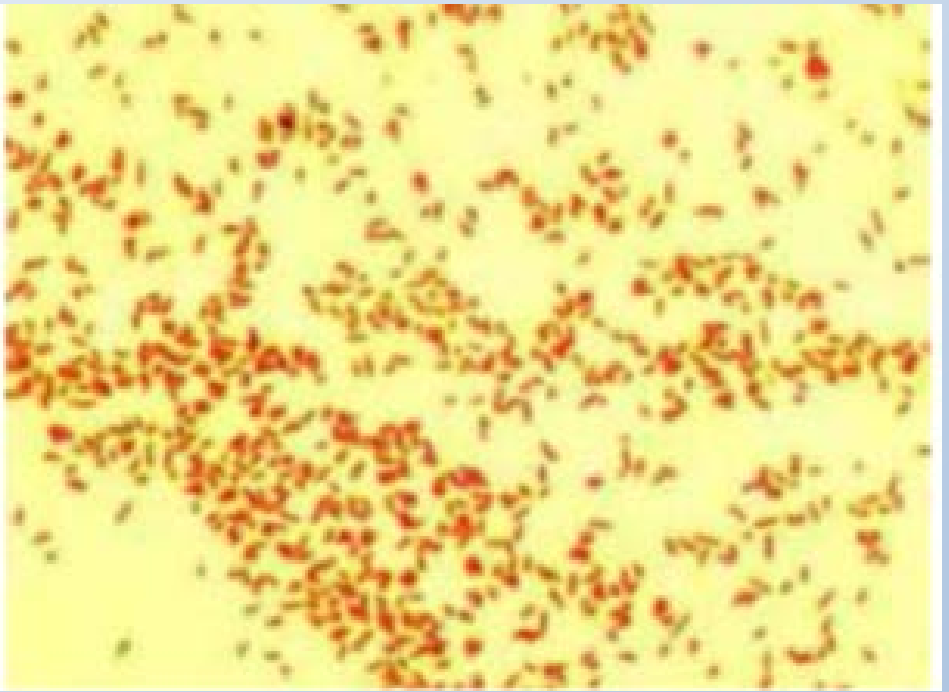

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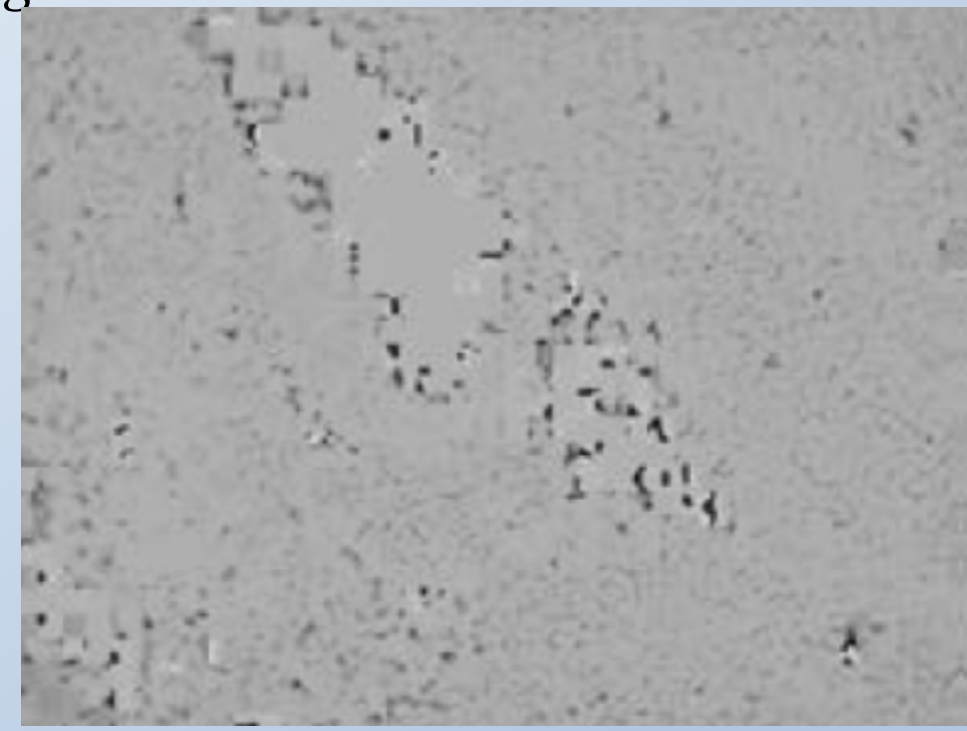
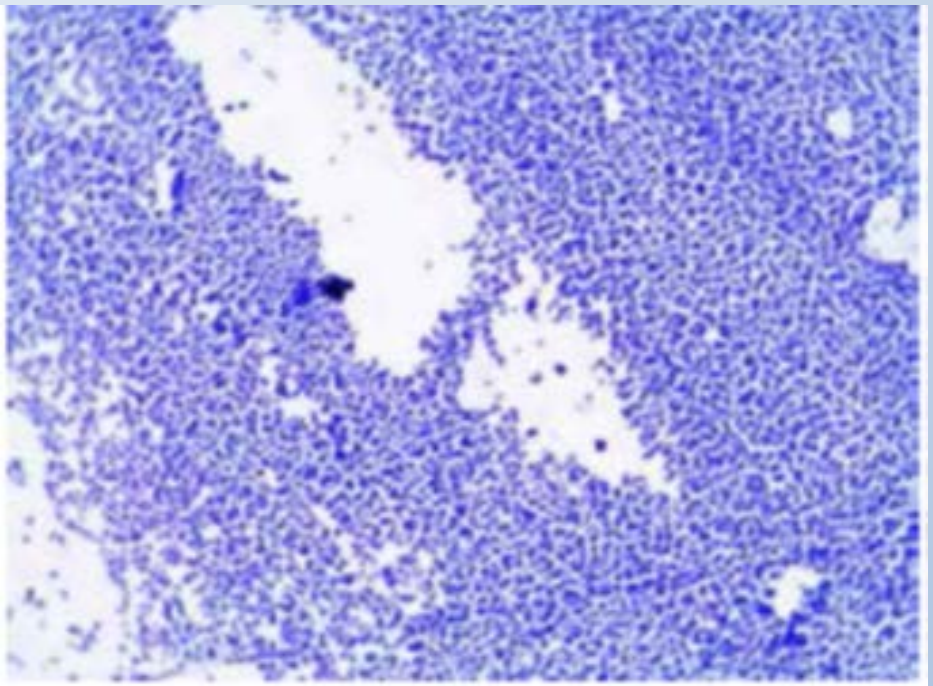
Hue color plane of gray scale

1. Step Saturation color component of the selected images

Saturation color plane of gray scale image





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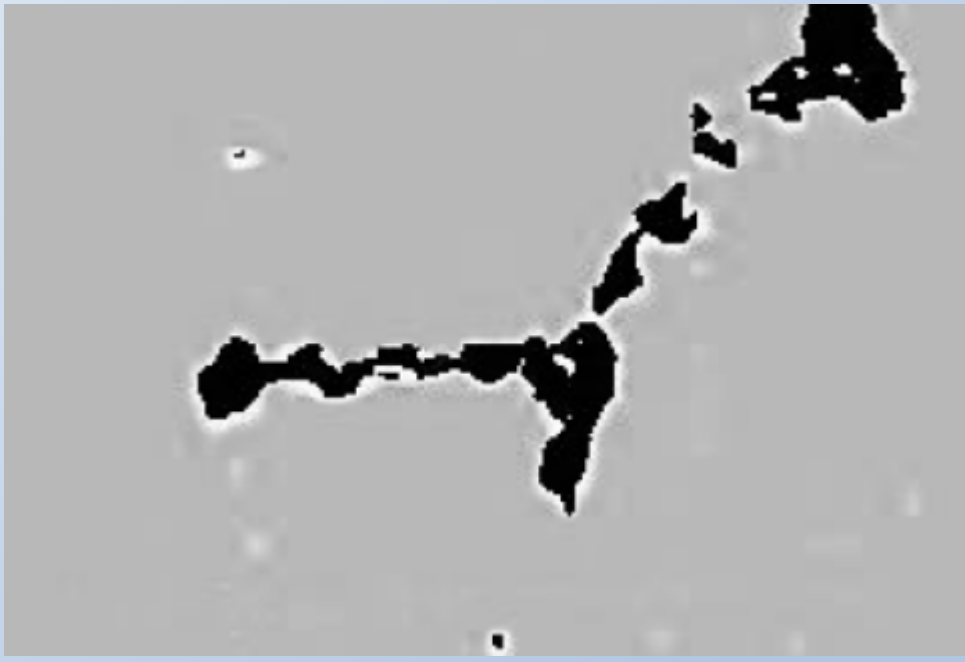

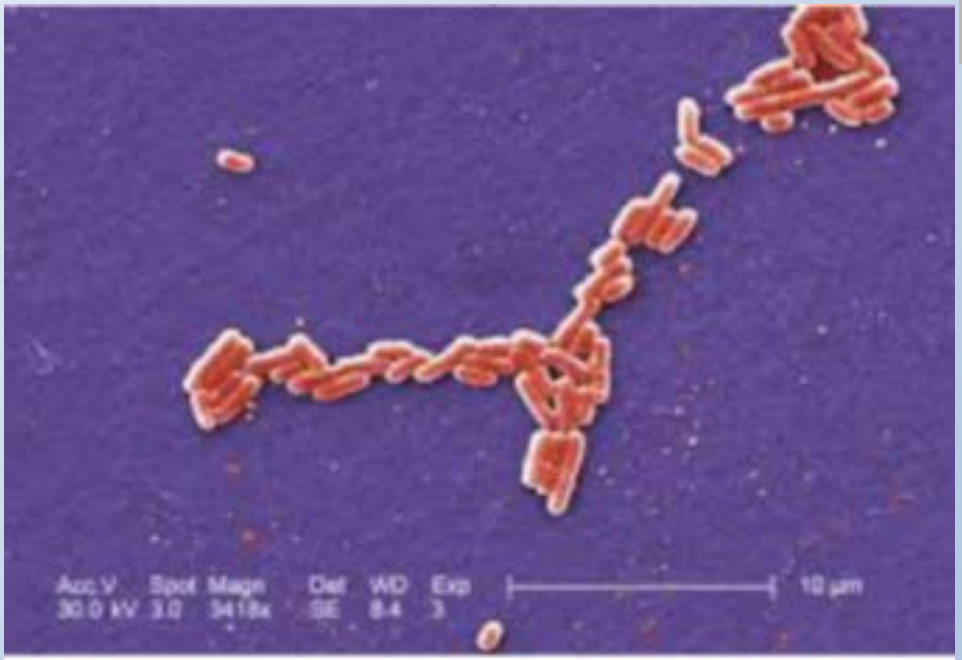

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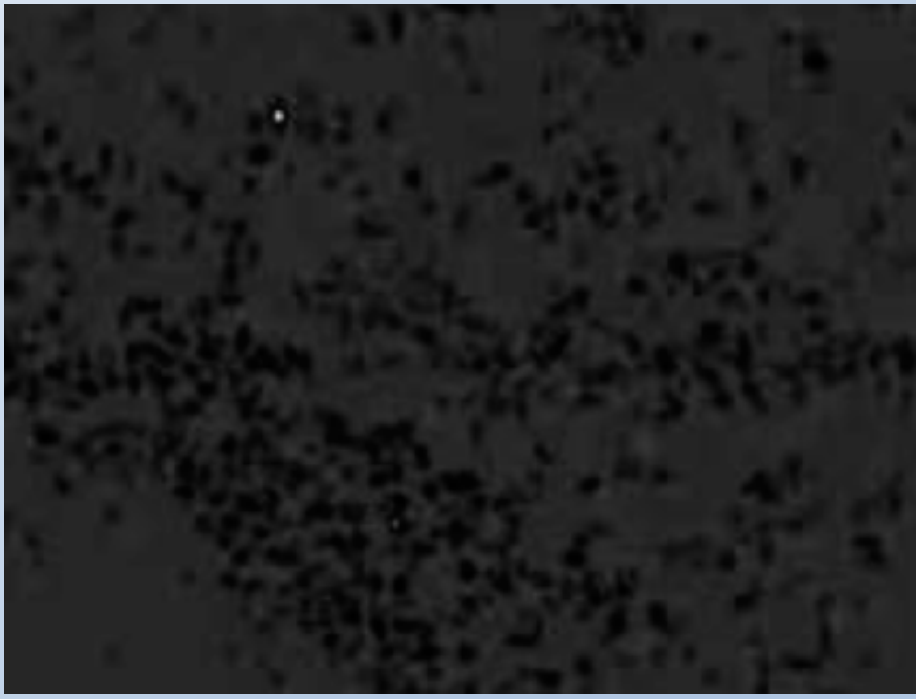

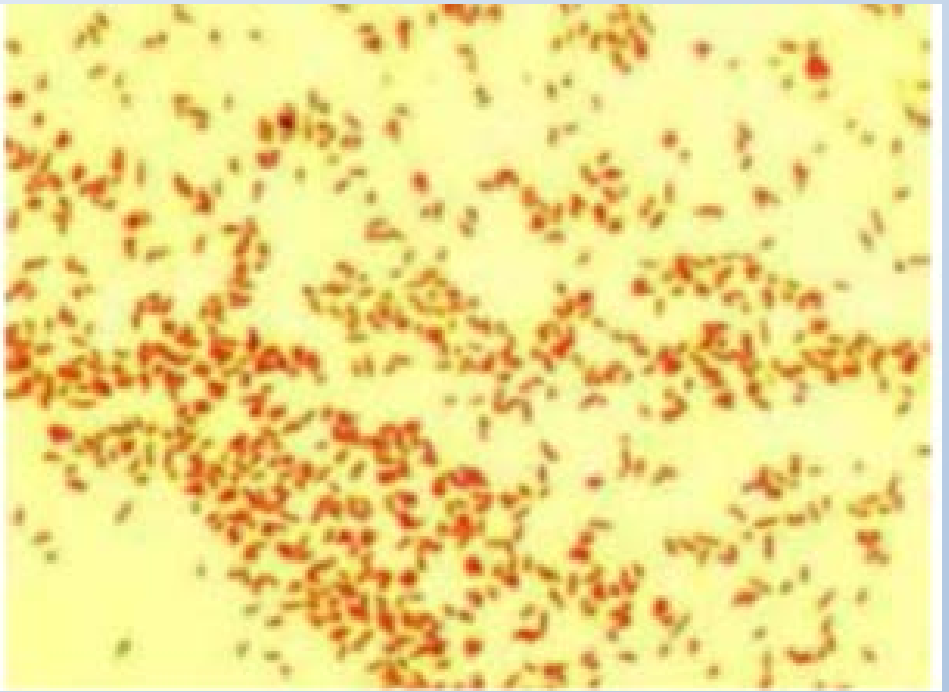

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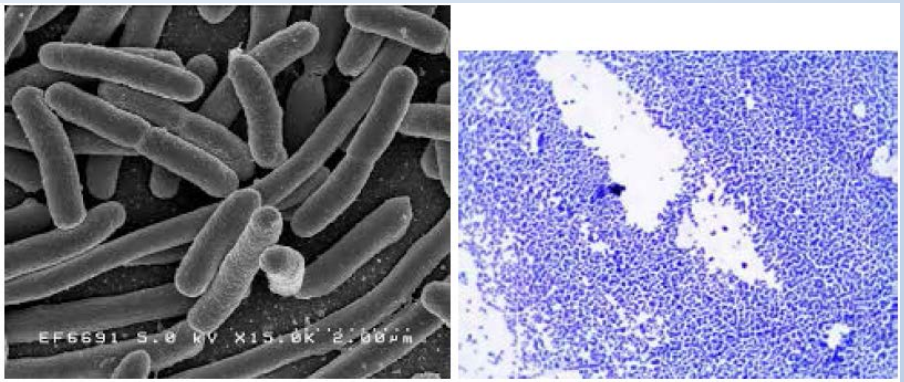

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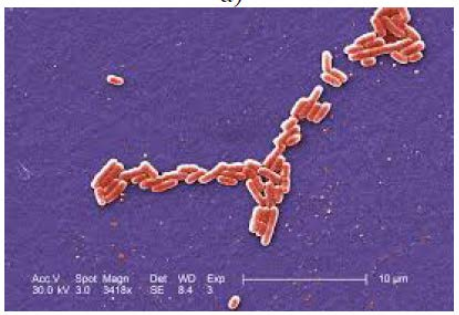

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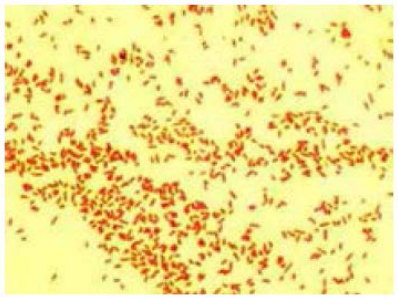

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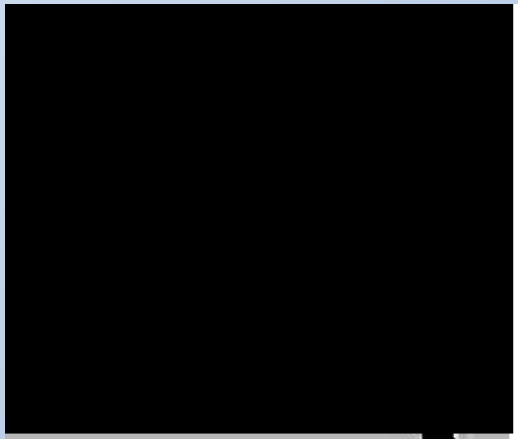

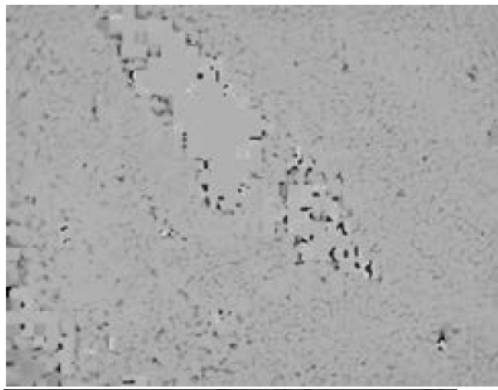

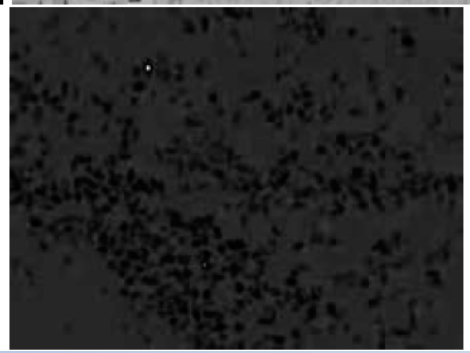

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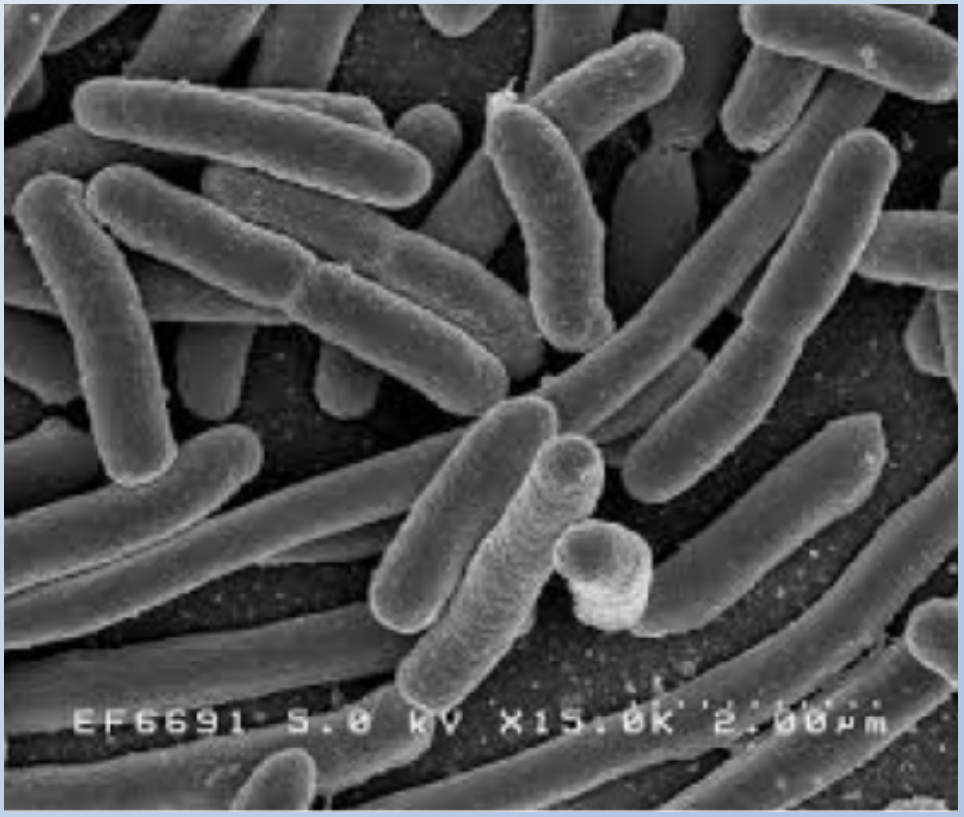

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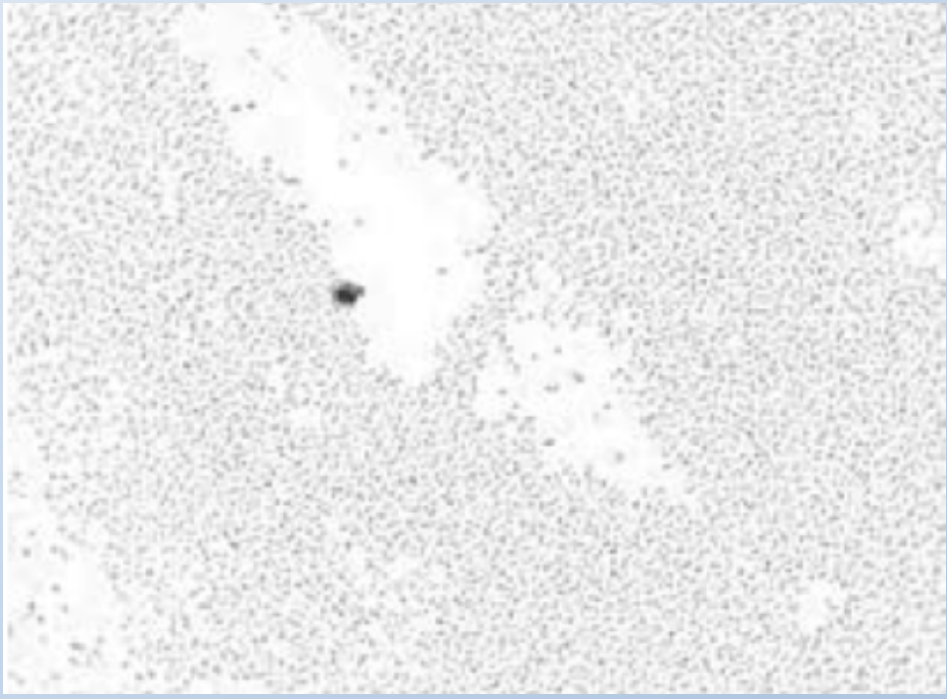

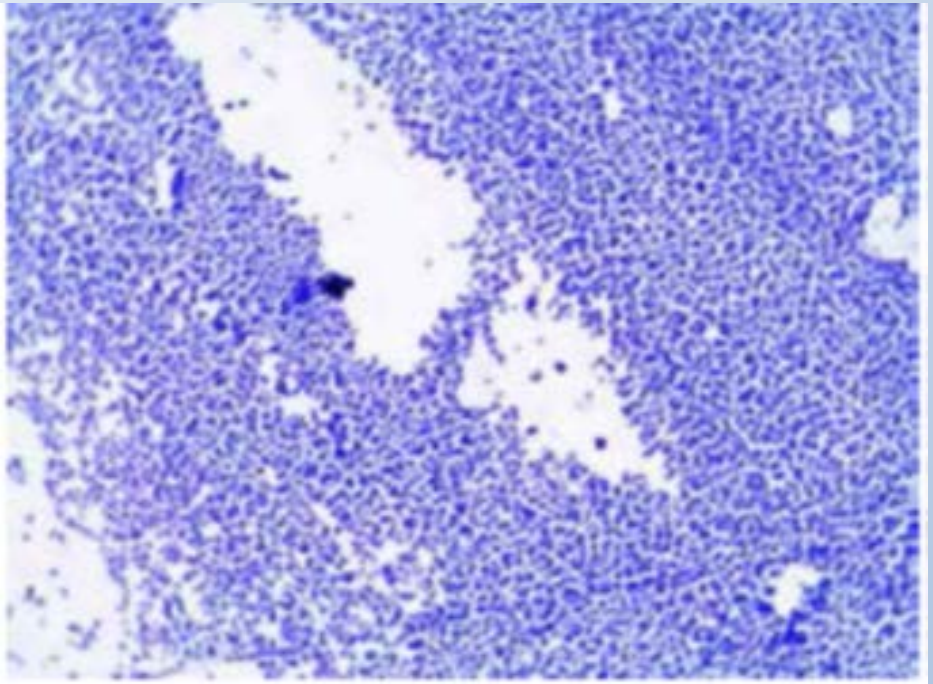

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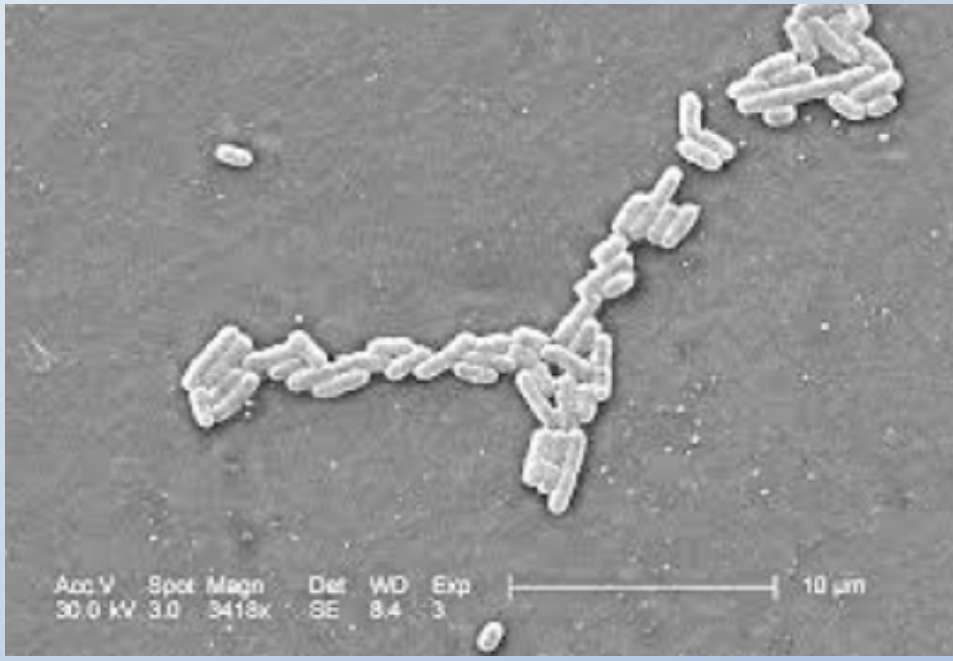

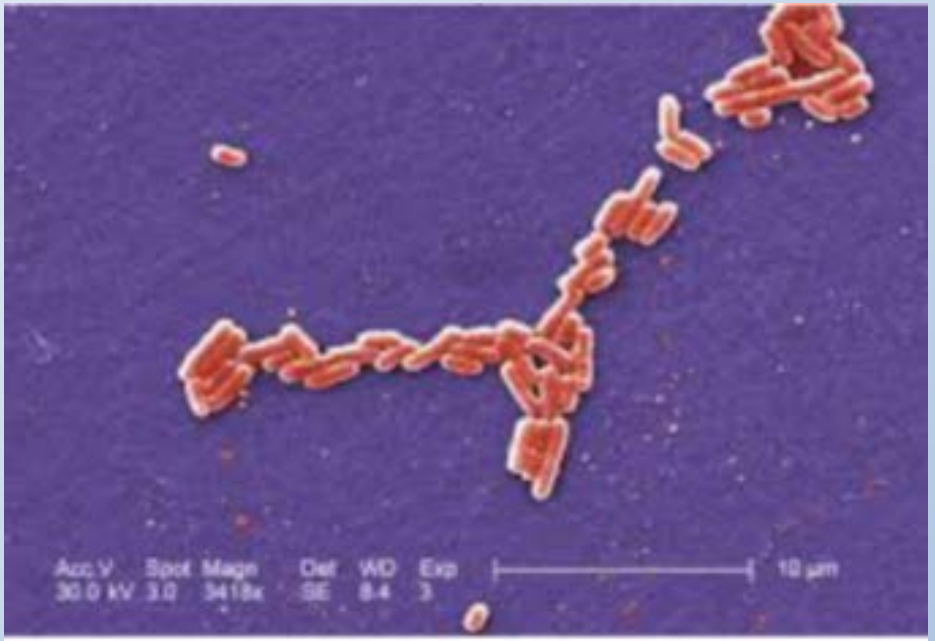

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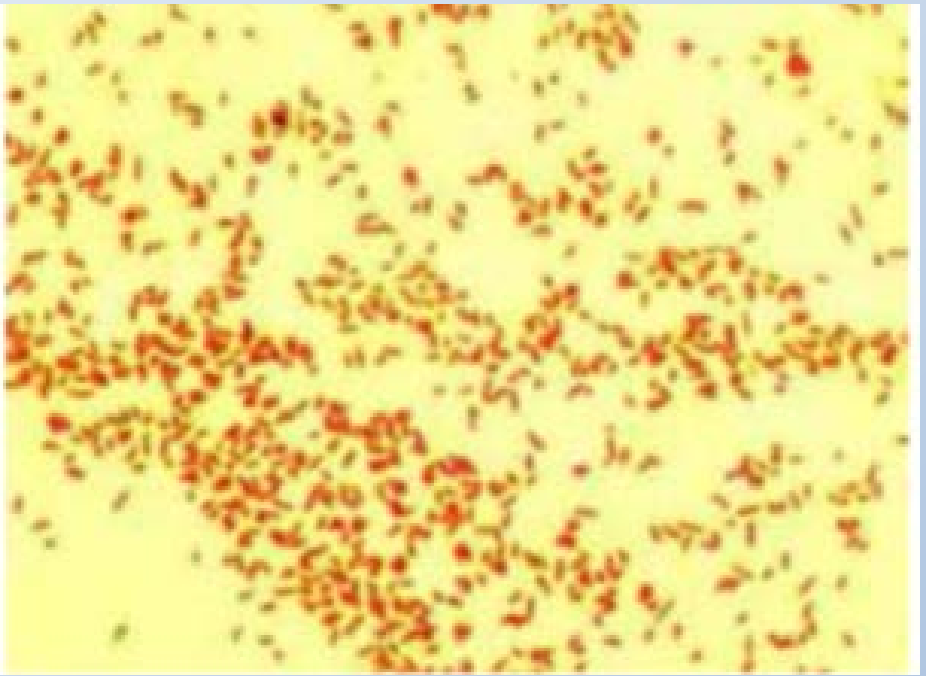

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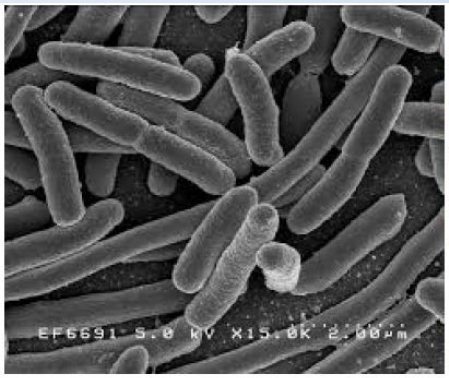

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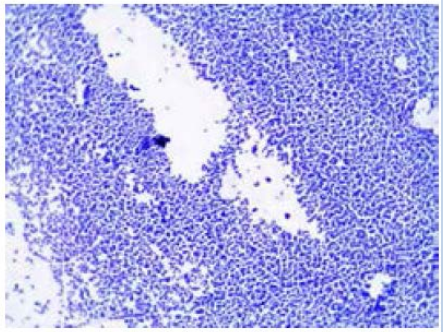

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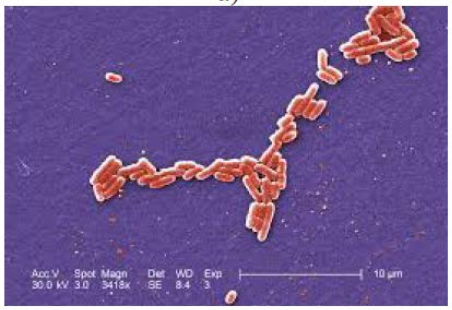

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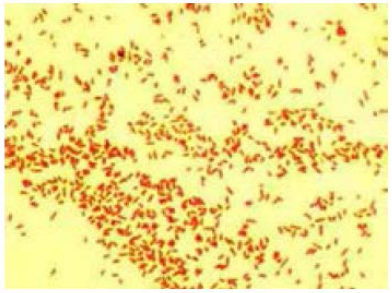

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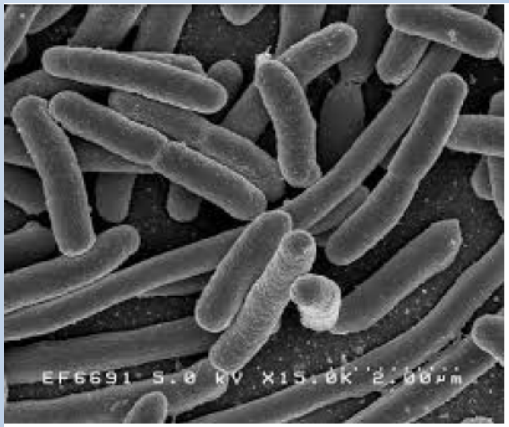

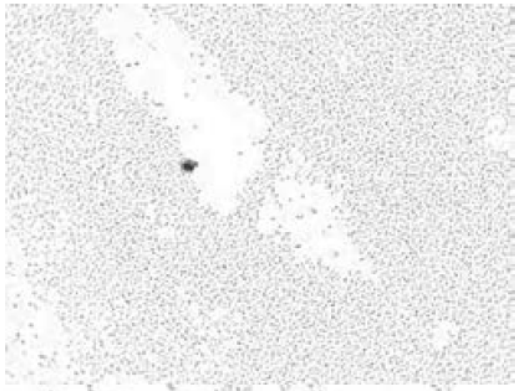

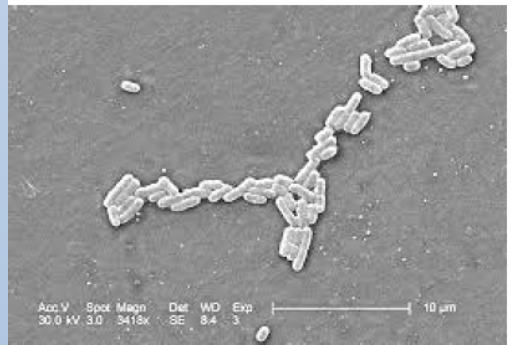

2. Step Systemized Escherichium Coli Bacteria Detection

Binary images obtained by the proposed mathematical model where white areas represent successfully detected Escherichia coli bacteria and black is representing background.

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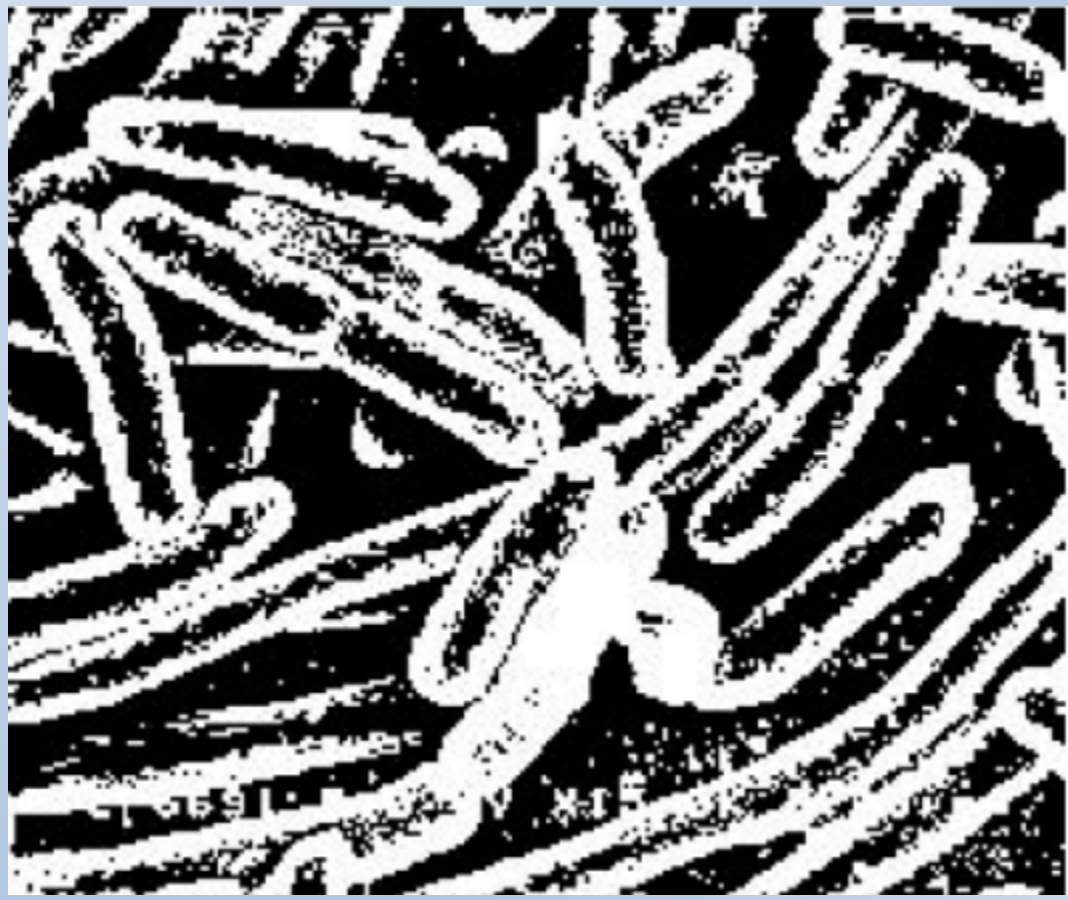

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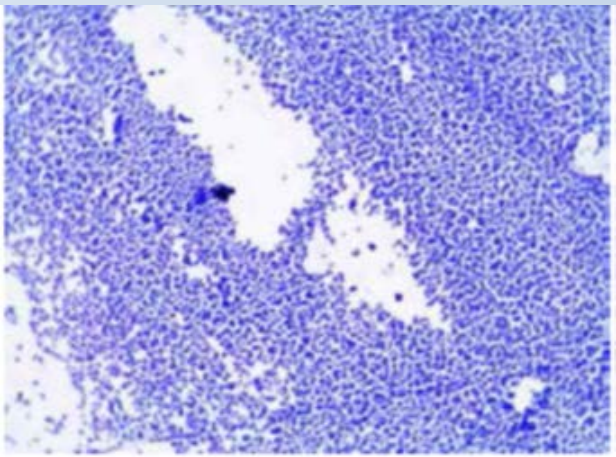

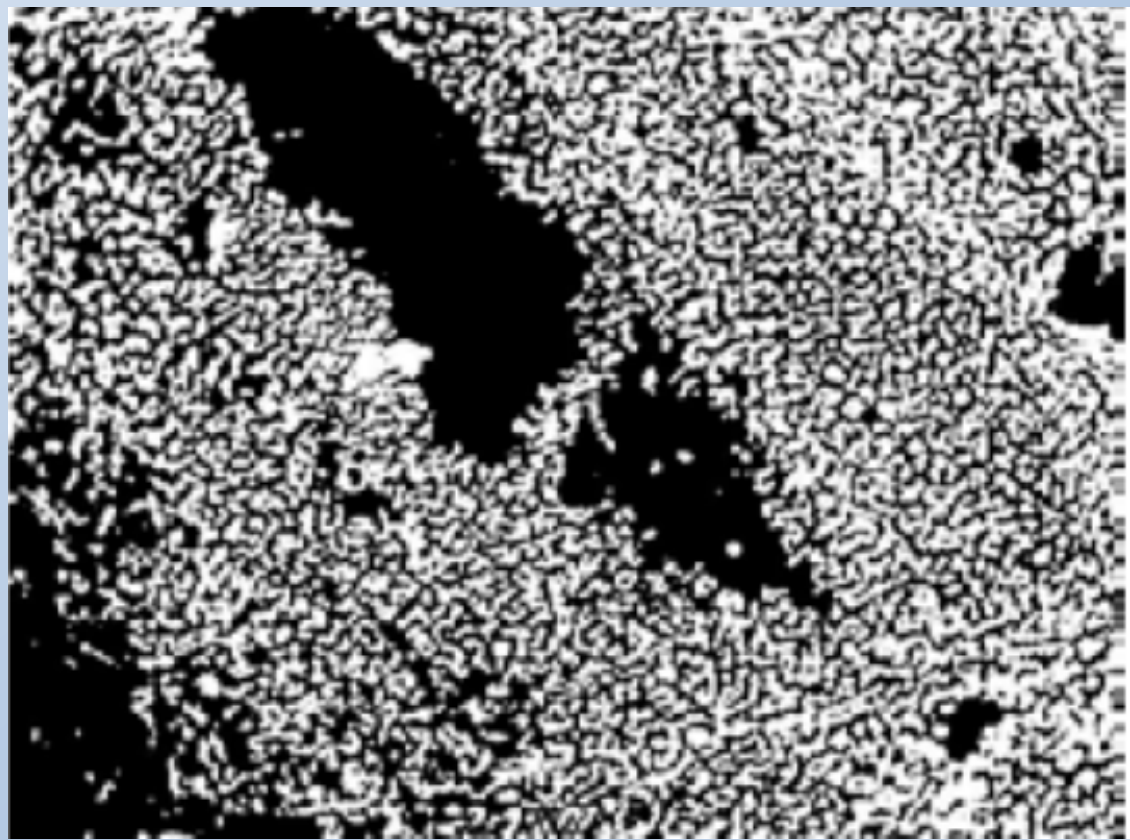

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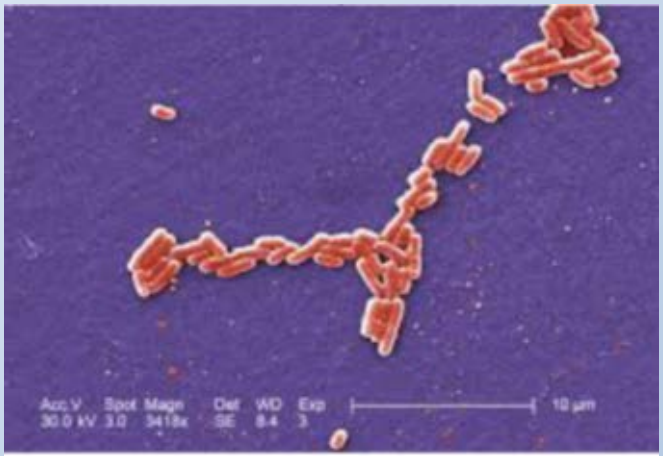

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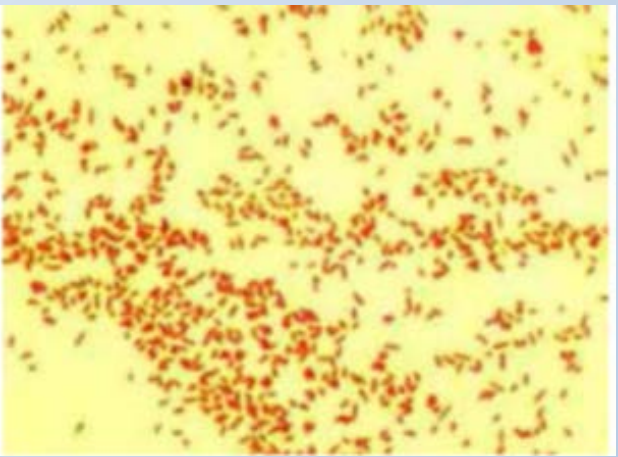
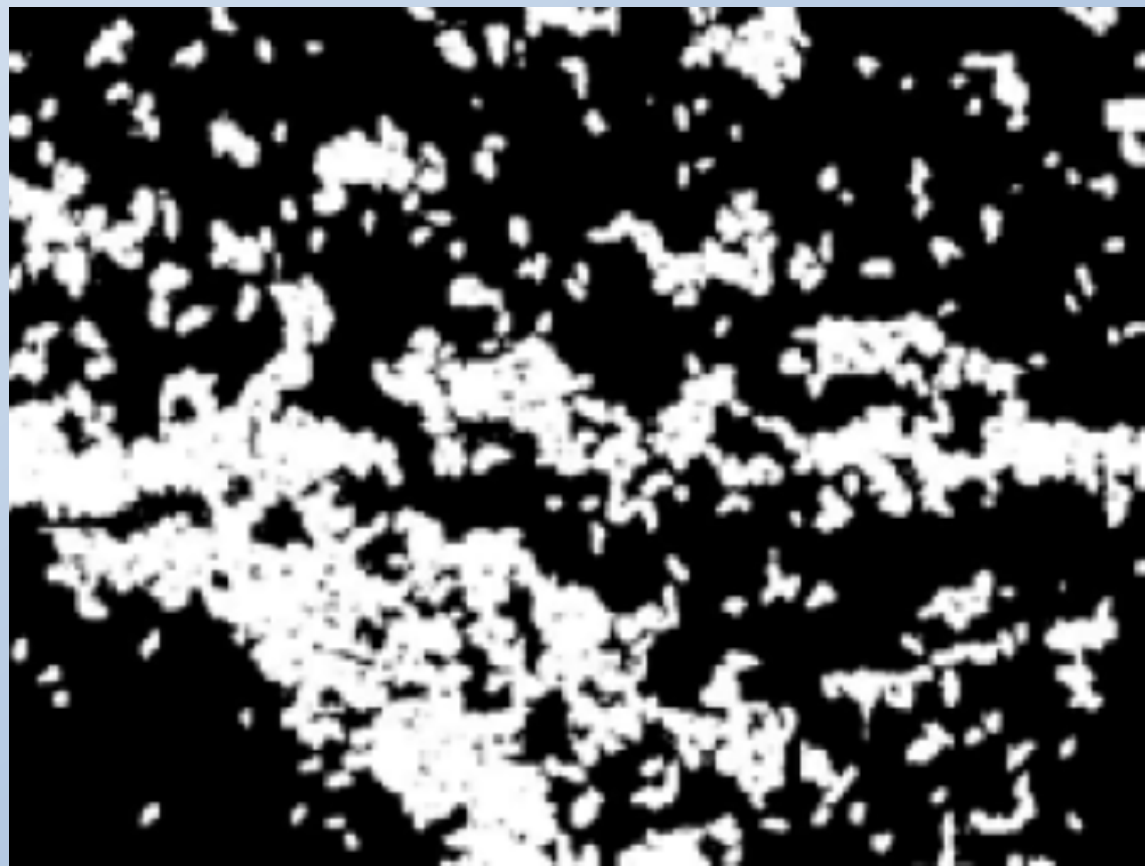
end
```

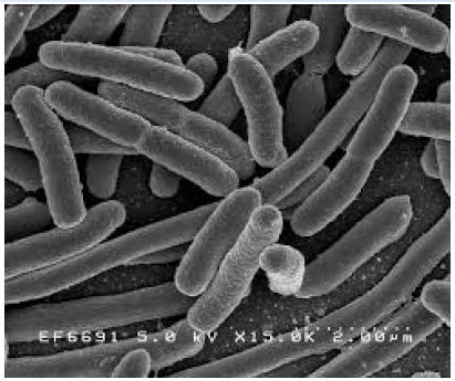




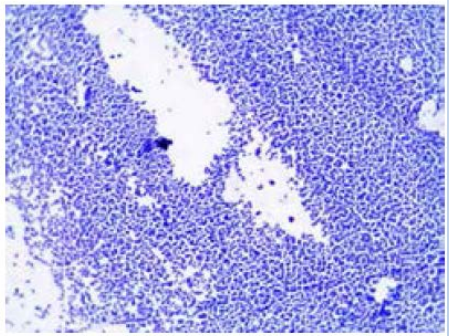
2. Step Systemized Escherichium Coli Bacteria Detection

Binary images obtained by the proposed mathematical model where white areas represent successfully detected Escherichia coli bacteria and black is representing background.

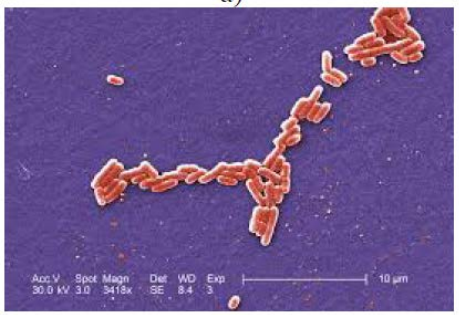
```
if ( (TH>=TS) & (TH>0) )
      Inew (x,y)( if HUE(x,y) >TH )=255;
end
if ( (TH<TS) & (TS>0) )
      Inew (x,y)( if SAT(x,y)>TS )=255;
end
if ( (TH==0) & (TS==0) )
      Inew (x,y)( if INT(x,y)>TI )=255;
end
```



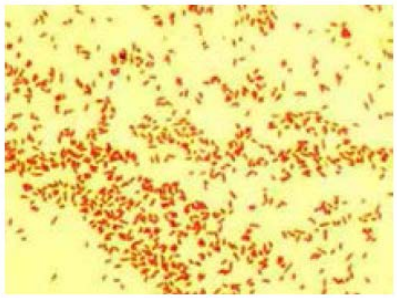
a)



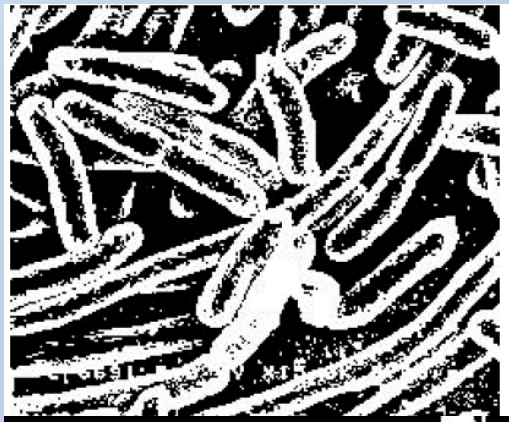
b)

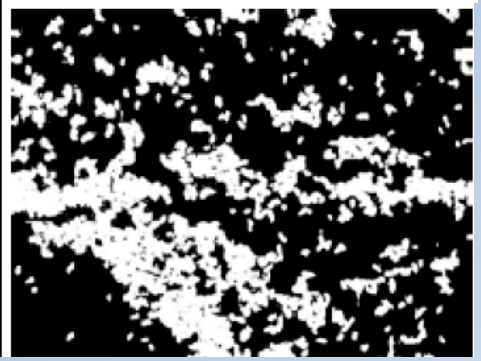


c)



d)





3. Step Systemized Escherichium Coli Bacteria Detection

Original Escherichia coli bacteria images with the colored marked areas of successfully detected bacteria with the proposed color based segmentation method.

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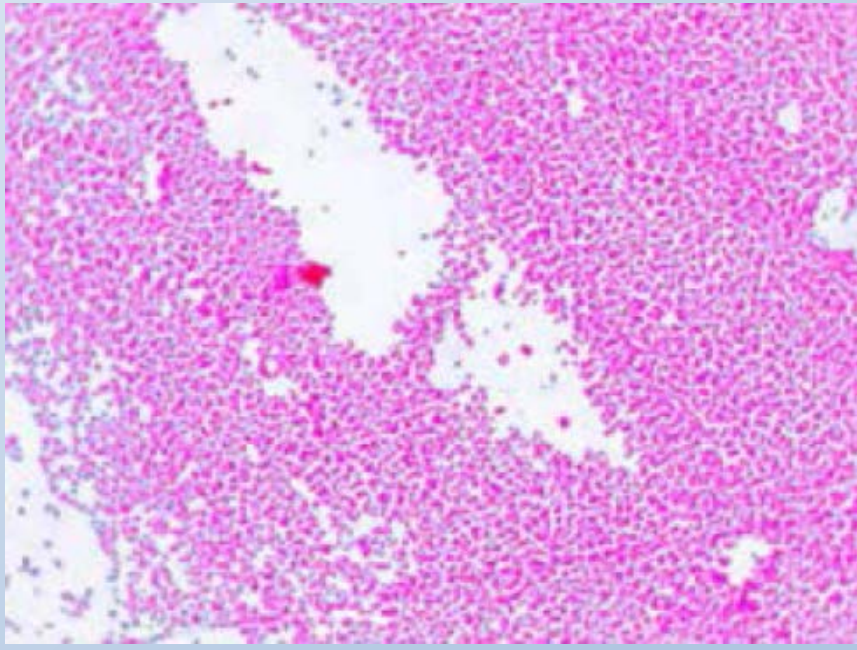

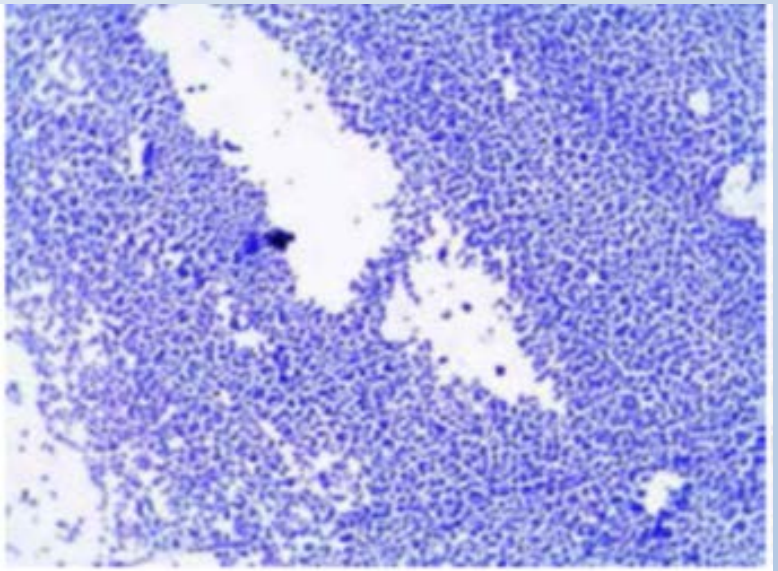

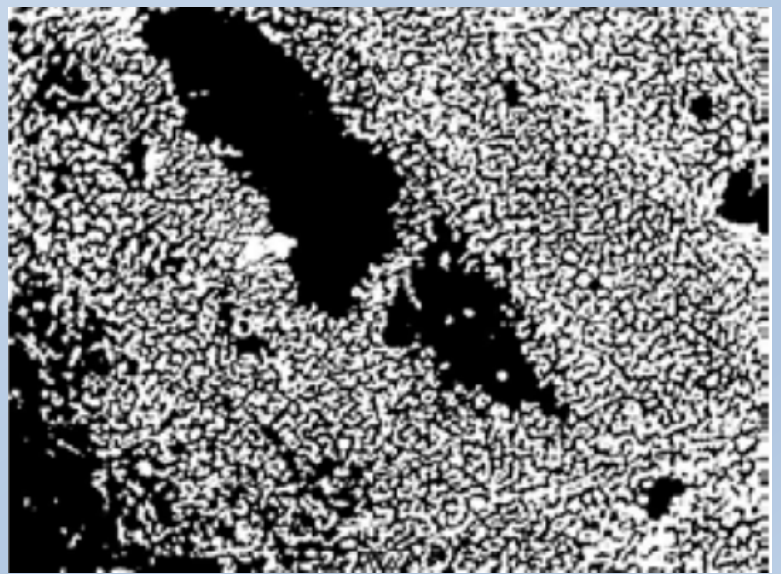

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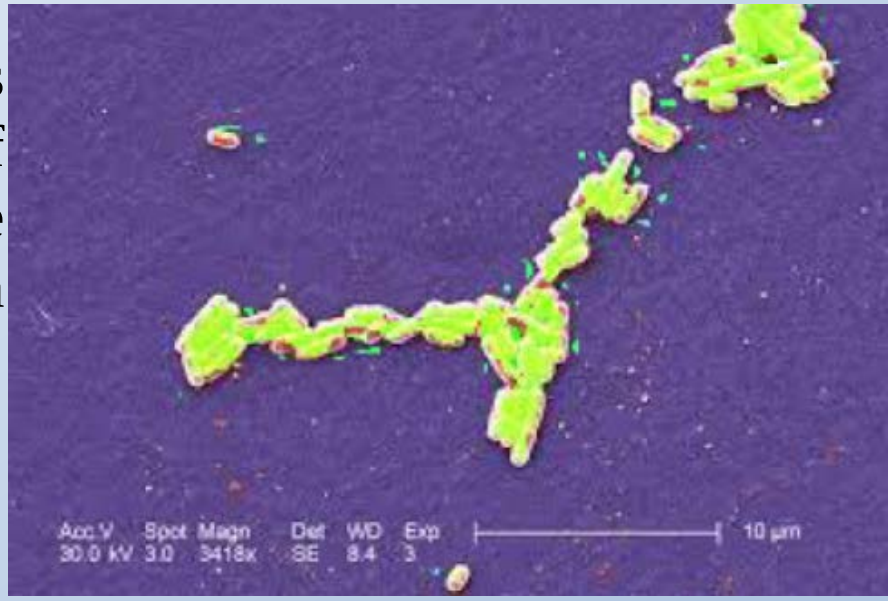
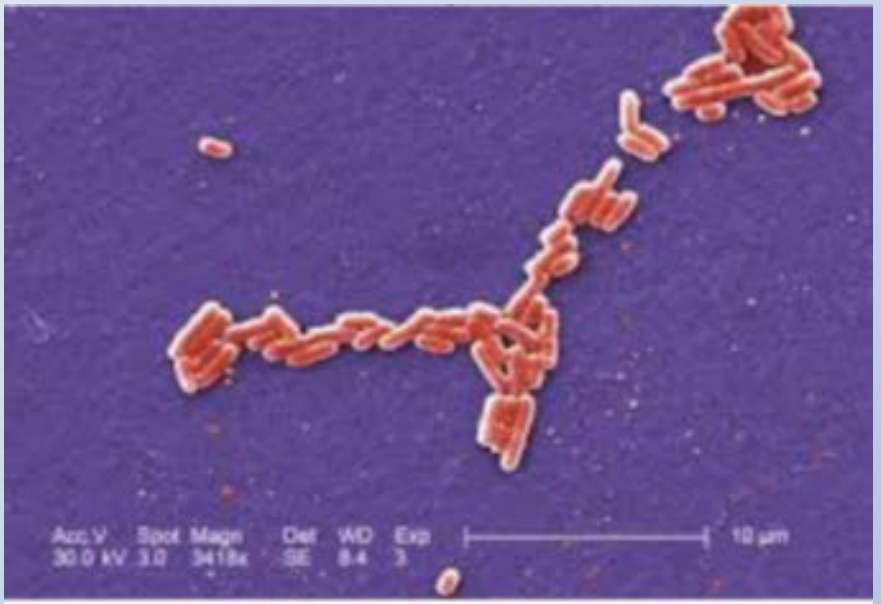
Original Escherichia coli bacteria images with the colored marked areas of successfully detected bacteria with the proposed color based segmentation method.





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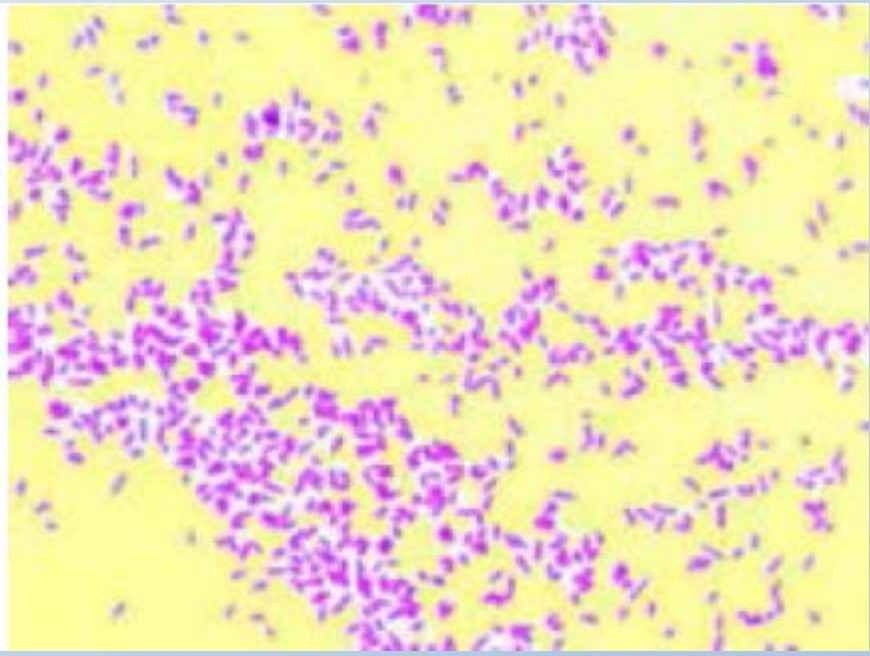
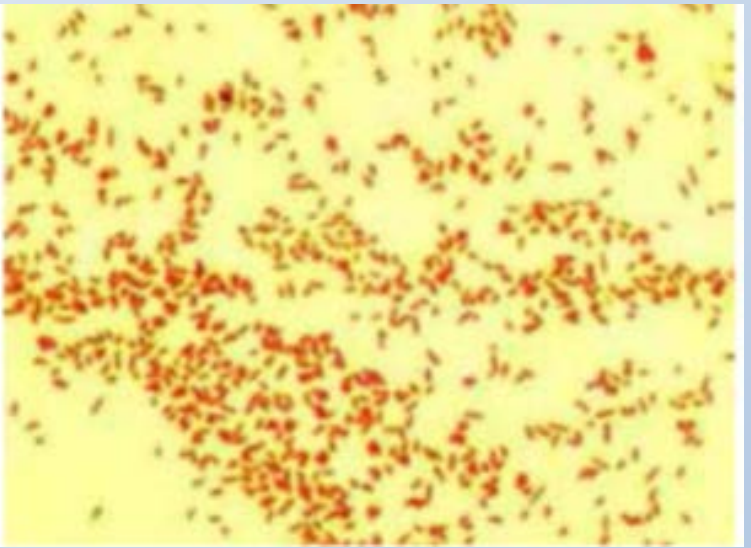
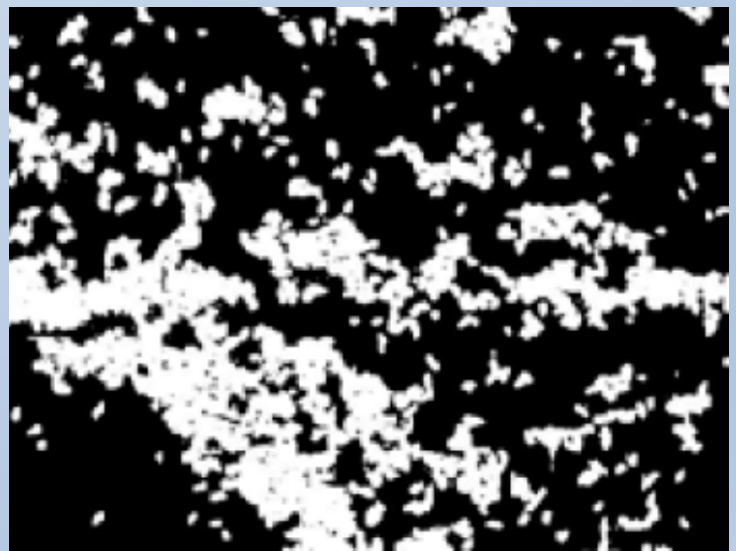
Original Escherichia coli bacteria images with the colored marked areas of successfully detected bacteria with the proposed color based segmentation method.





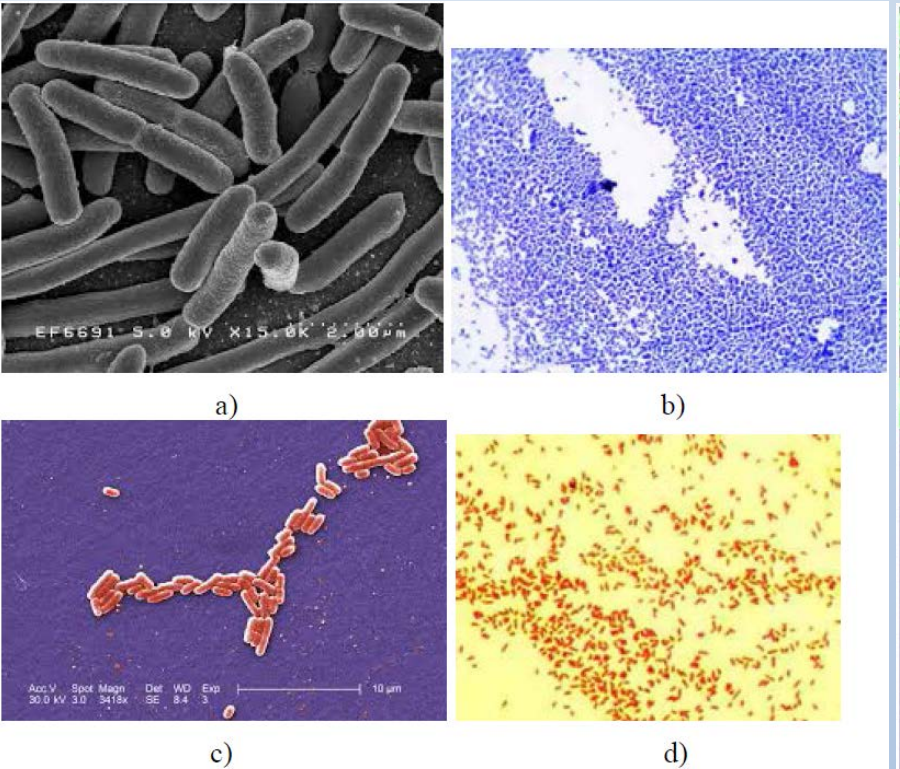


Systemized Escherichium Coli Bacteria Detection

Original Escherichia coli bacteria images with the colored marked areas of successfully detected bacteria with the proposed color based segmentation method.

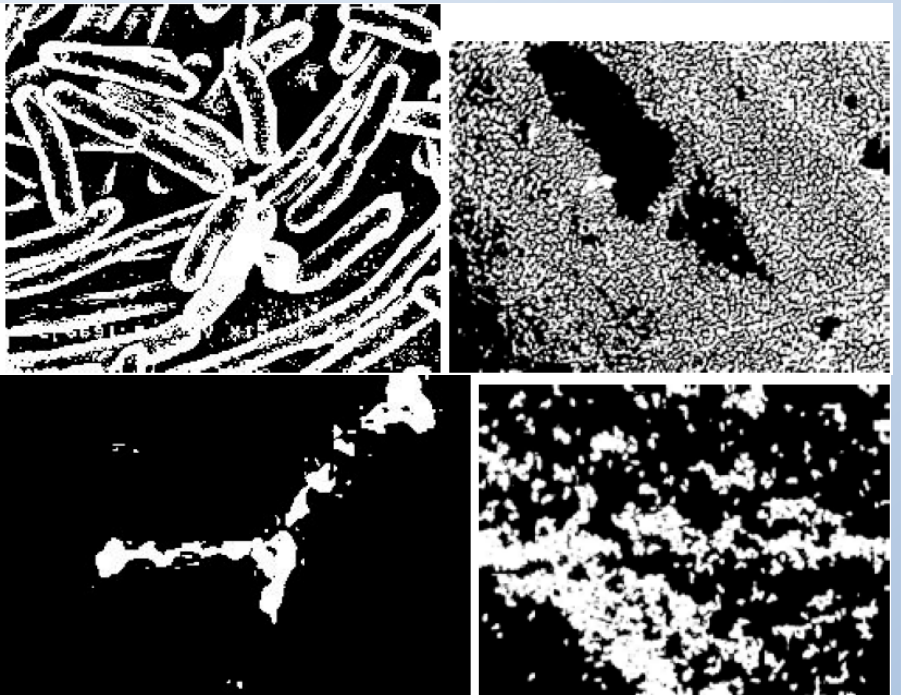
Original images

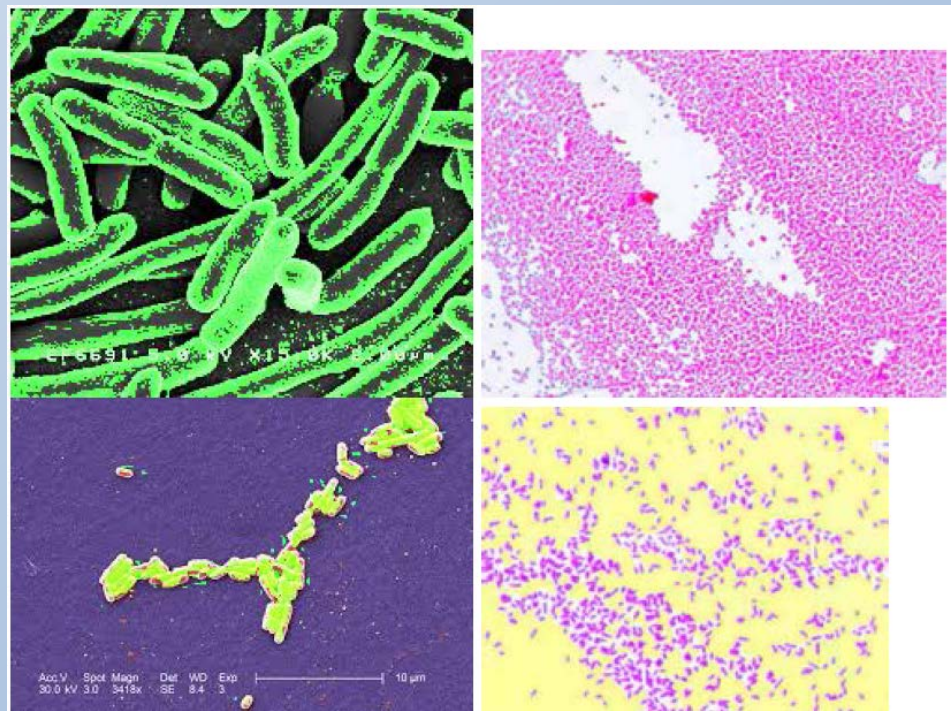
Processed images



Systemized Escherichium Coli Bacteria Detection

It is visually obvious from Figures that the proposed algorithm shows high precision in bacteria detection, successfully omitting similar color pixels detection that belong to non-targeted areas of the analyzed images.





Systemized Escherichium Coli Bacteria Detection

Table 1 shows the classification results of the proposed method and the percentage of the correctly classified Escherichia coli bacteria areas in microscopic images shown in Fig. 1.

The percentage of the classification is calculated as the ratio between the correctly detected pixels within the bacteria area and the total of all the pixels within the analyzed image.

TABLE I
SUMMARY OF THE OBTAINED RESULTS OF THE CLASSIFICATION OF ESCHERICHIA COLI BACTERIA IMAGES SHOWN IN FIGURE 1

Image	Area [%]
a)	46.58
b)	46.23
c)	6.03
d)	31.11

Systemized Escherichium Coli Bacteria Detection

Table 1 illustrates numerical equivalent of images shown in Figures.

TABLE I
SUMMARY OF THE OBTAINED RESULTS OF THE CLASSIFICATION OF ESCHERICHIA COLI BACTERIA IMAGES SHOWN IN FIGURE 1

Image	Area [%]
a)	46.58
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c)	6.03
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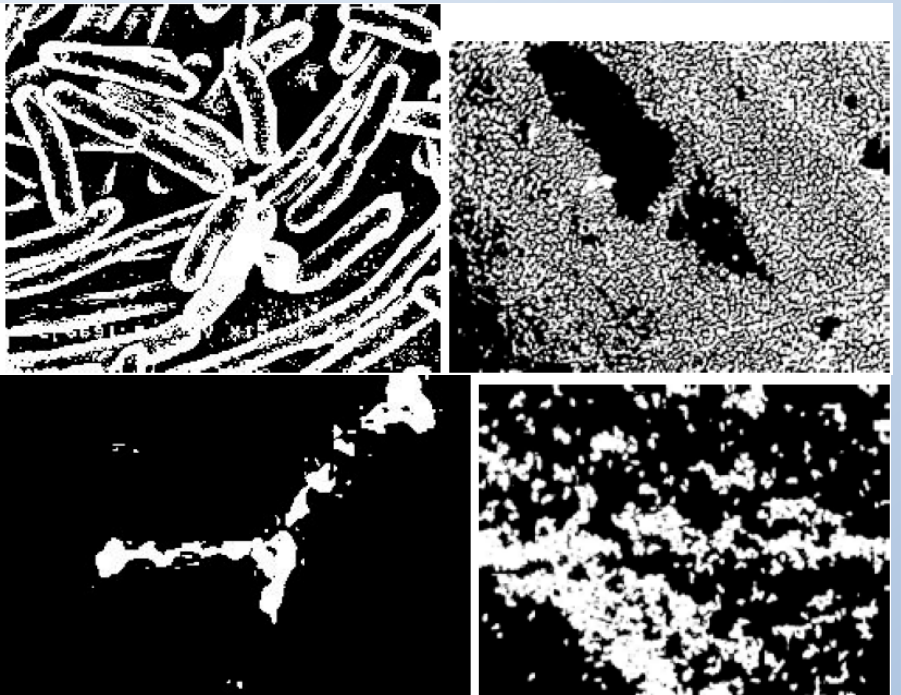

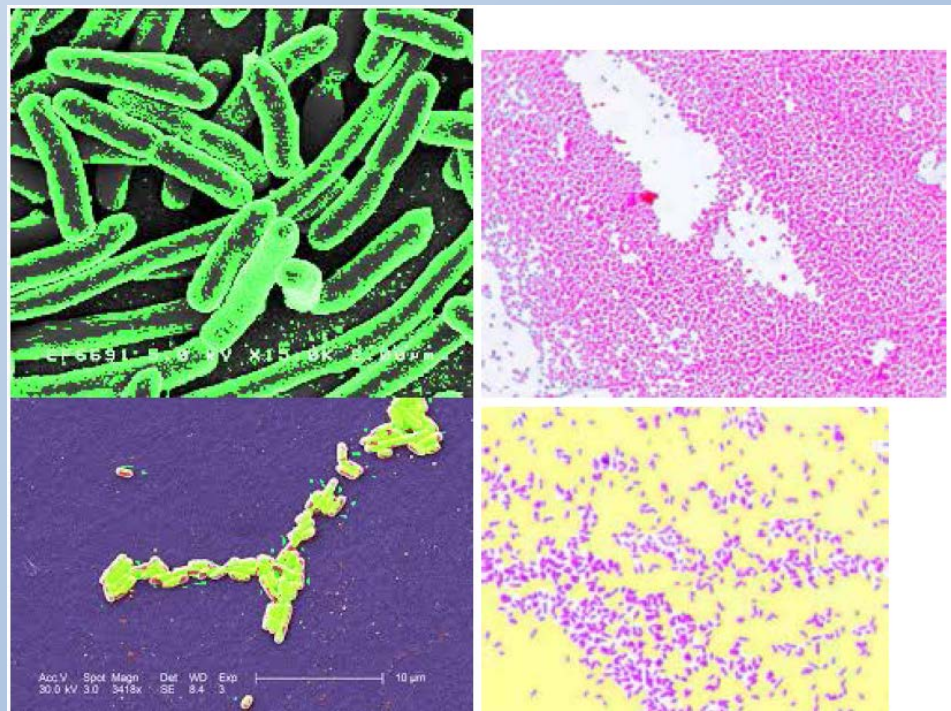

Conclusion

Escherichia coli are bacteria found in the environment, various food and intestines of people and animals.

Although most strains of Escherichia coli are harmless, others can make one sick causing diarrhea, urinary tract infections, respiratory illness, pneumonia and other illnesses.

Microscopy is an excellent technique in capturing the concentration of these bacteria showing the potential infection.

Conclusion

As it is difficult to evaluate its concentration simply by observation of the microscopy data, it is critical to expand capabilities of existing tools focusing on automated bacteria detection.

This is why computer assisted tool is developed for the purpose of facilitated bacteria detection and its concentration evaluation that successfully extracts and detects the areas of interest while rejecting the rest of the content of the analyzed image.