

Image Visualization

Marcelo Leomil Zoccoler

With material from

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Image Visualization

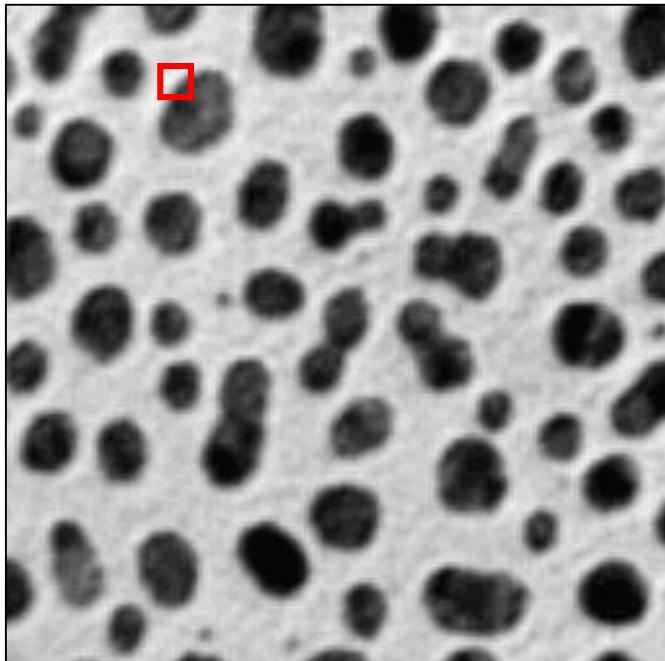
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With material from:

Robert Haase, PoL

Images and pixels

- An image is just a matrix of numbers
- Pixel: “picture element”
- The edges between pixels are an artefact. In reality, they don’t exist!

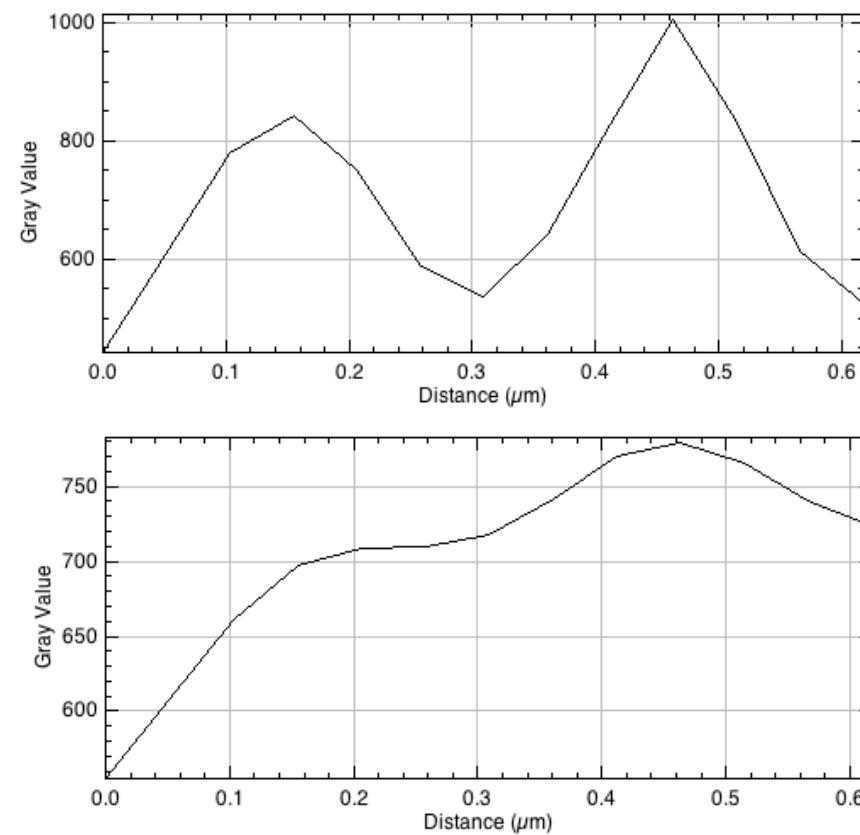
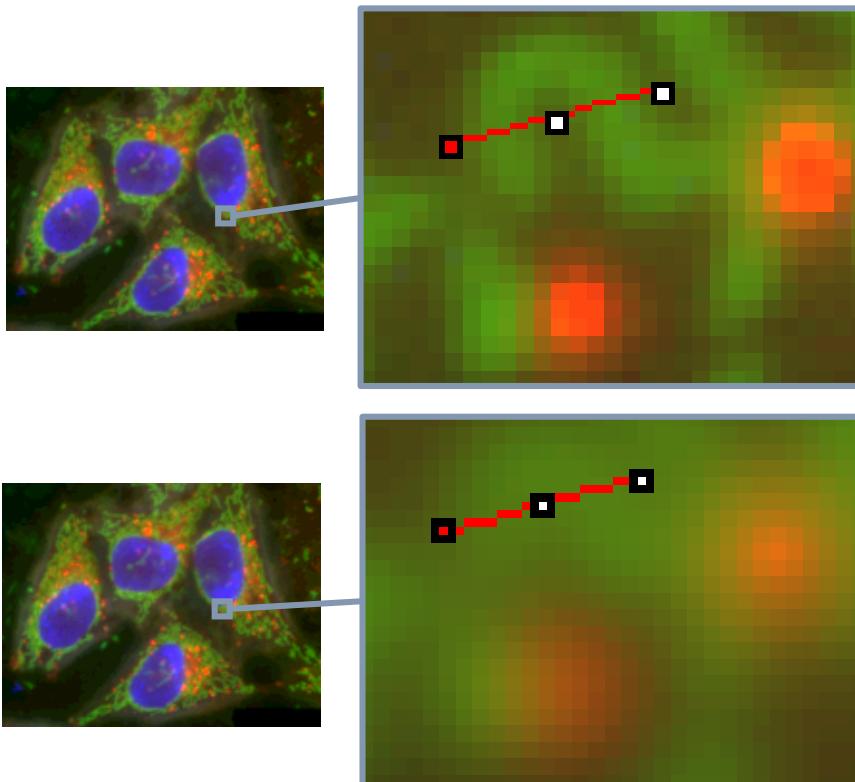


48	48	48	40	40	32	32	24	24	24	24	24	24	24	24
48	48	40	32	32	24	24	16	16	16	16	24	24	24	24
48	48	40	32	24	24	16	16	16	16	16	24	24	32	40
40	40	32	24	24	16	16	16	8	16	16	24	24	40	48
32	32	32	24	24	16	24	24	32	48	56	64	72	88	
24	24	24	16	16	16	24	32	56	72	88	96	112	120	
24	16	16	16	24	32	48	64	96	120	128	144	152	152	
16	8	16	16	32	40	72	96	128	160	176	184	184	184	
16	8	16	24	48	72	104	136	160	176	184	192	192	192	184
16	8	24	32	72	104	136	168	184	192	200	200	192	192	184
24	24	48	64	104	136	160	184	184	192	192	192	184	184	184
32	40	64	88	128	168	184	192	192	184	184	176	176	176	176
40	56	88	120	152	192	192	192	184	184	184	176	176	176	176
48	64	104	144	176	208	200	184	184	184	184	176	176	176	168



Pixel size versus resolution

- Resolution is a property of your imaging system.
- The measure of how close object can be in an image while still being differentiable, is called spatial resolution.



In epi-fluorescence microscopy:

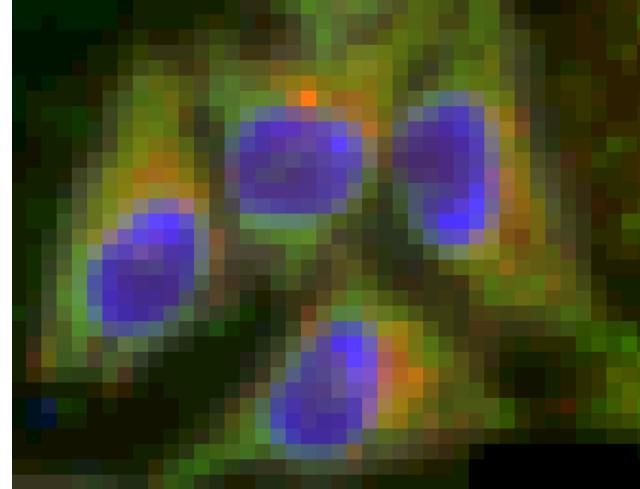
$$d = \frac{0.61\lambda}{NA}$$

Pixel size versus resolution

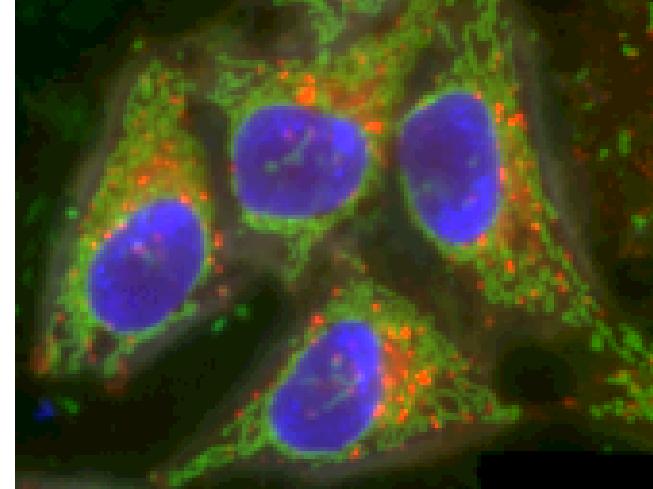
- Pixel size is a digital property of an image.
- You configure it during the imaging session at the microscope.



Pixel size: 3.3 μm



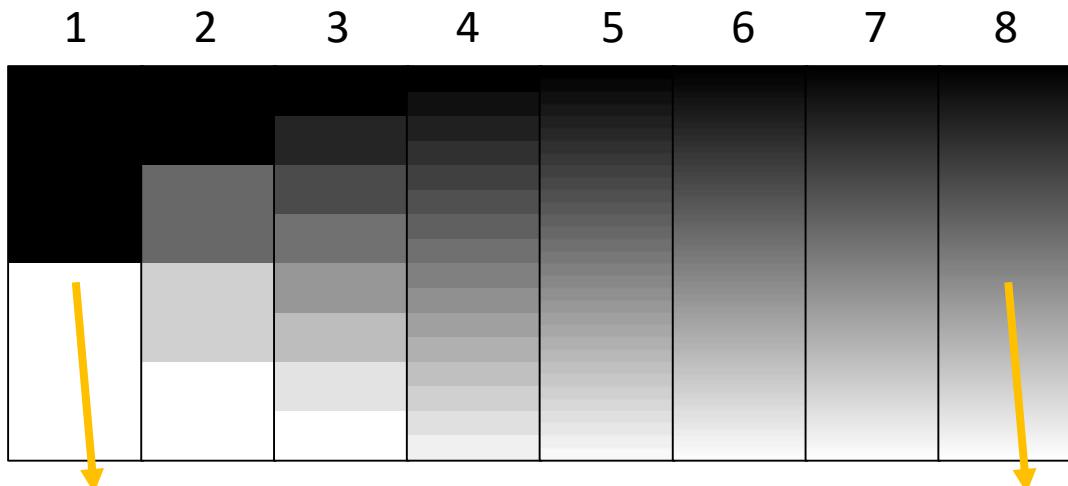
Pixel size: 0.8 μm



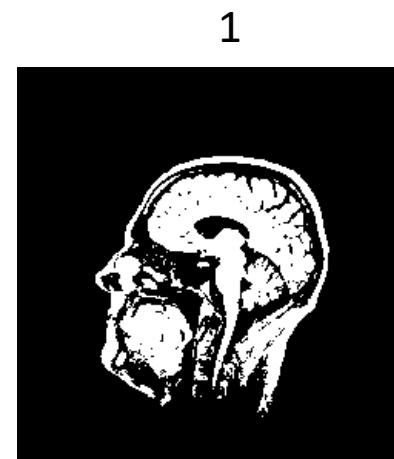
Pixel size: 0.05 μm

Bit-depth

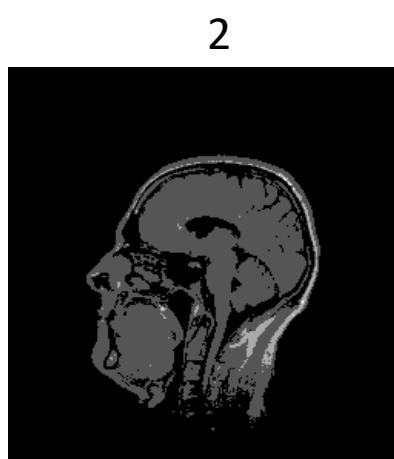
- A bits is the smallest memory unit in computers, *atomic data*.
- The bit-depth n enumerates how many different intensity values are present in an image:
 - 2^n grey values
- In microscopy, images are usually stored as 8, 12 or 16-bit images.



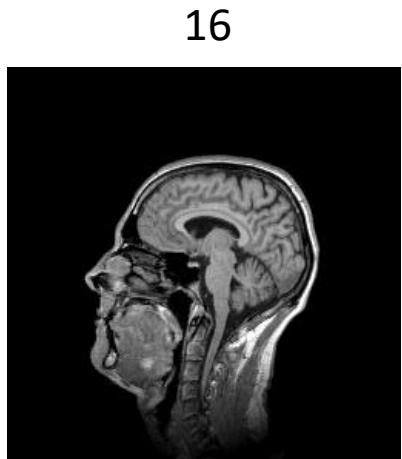
```
image.dtype  
dtype('bool')
```



```
image.dtype  
dtype('uint8')
```



```
image_16bit = image.astype('uint16')
```

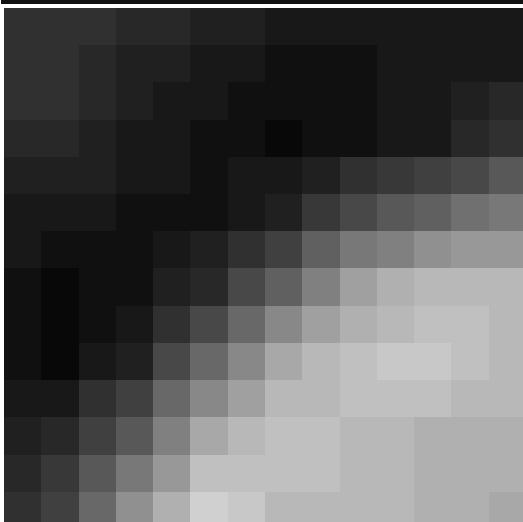


Lookup tables / Colormaps

- The lookup table decides how the image is displayed on screen.
- Applying a different lookup table doesn't change the image. All pixel values stay the same, they just appear differently

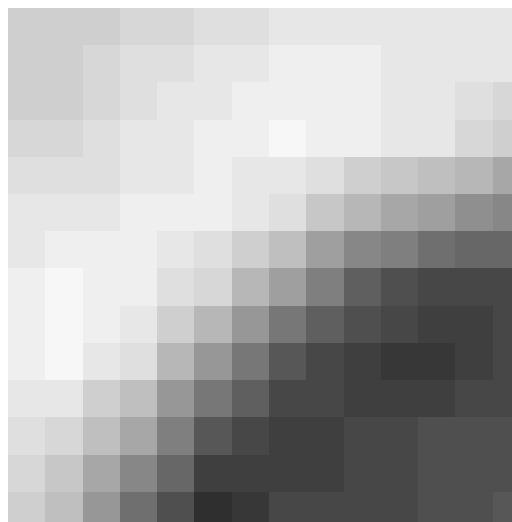
Pixel value	Display color
0	
1	
2	
...	
255	

```
plt.imshow(image, cmap='gray')
```



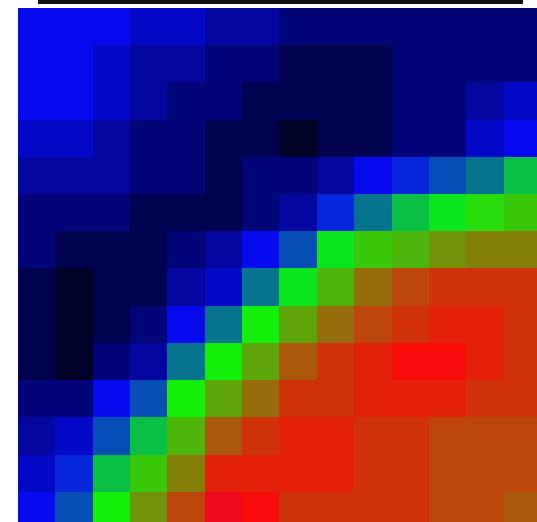
Pixel value	Display color
0	
1	
2	
...	
255	

```
plt.imshow(image, cmap='gray_r')
```



Pixel value	Display color
0	
1	
2	
...	
255	

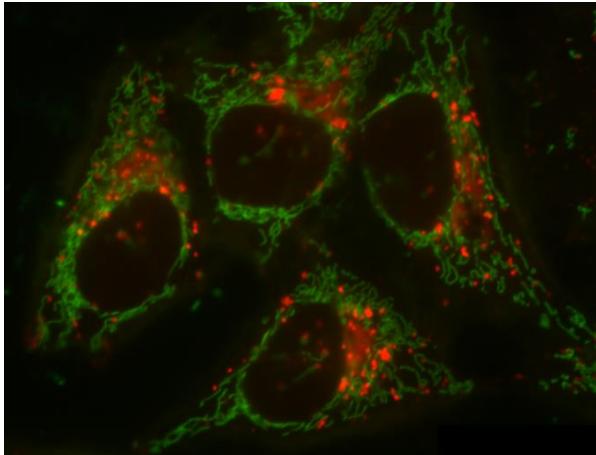
```
plt.imshow(image, cmap='jet')
```



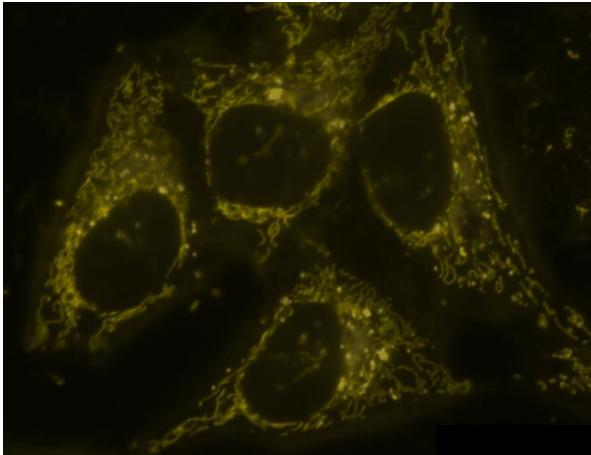
Lookup tables

- Choose visualization of your color tables wisely!
- Think of people with red/green blindness!

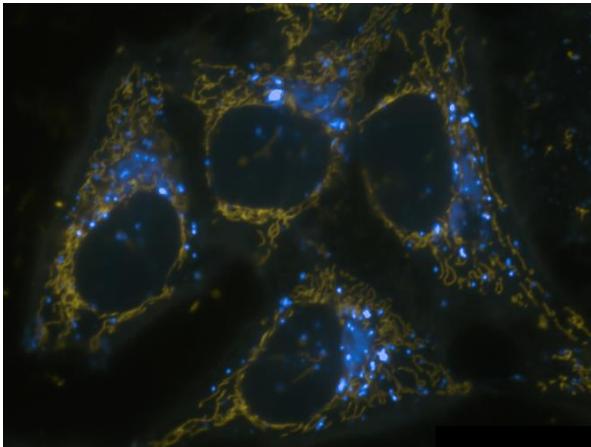
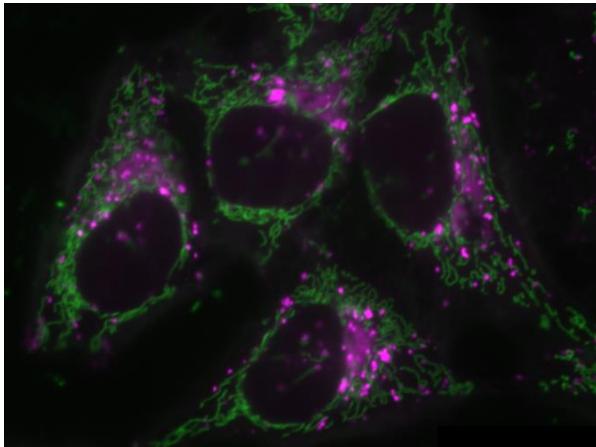
Default view



Red/green blind people see it like this



Replace red with
magenta!

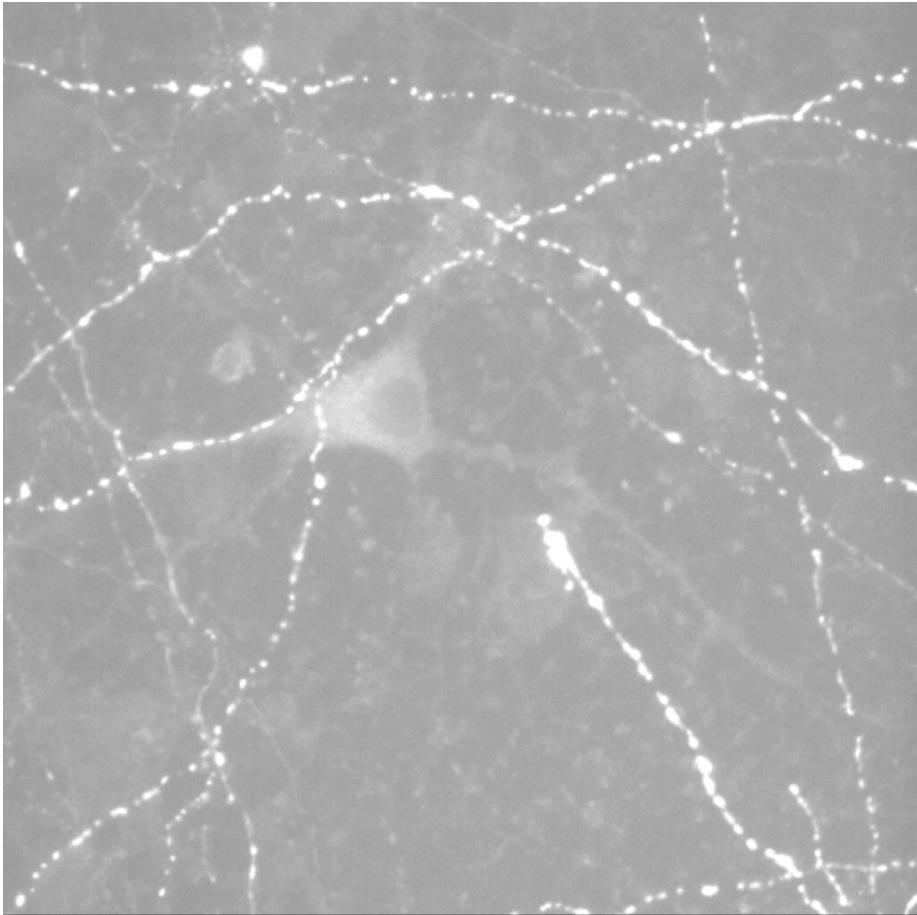


Visualisation: brightness / contrast

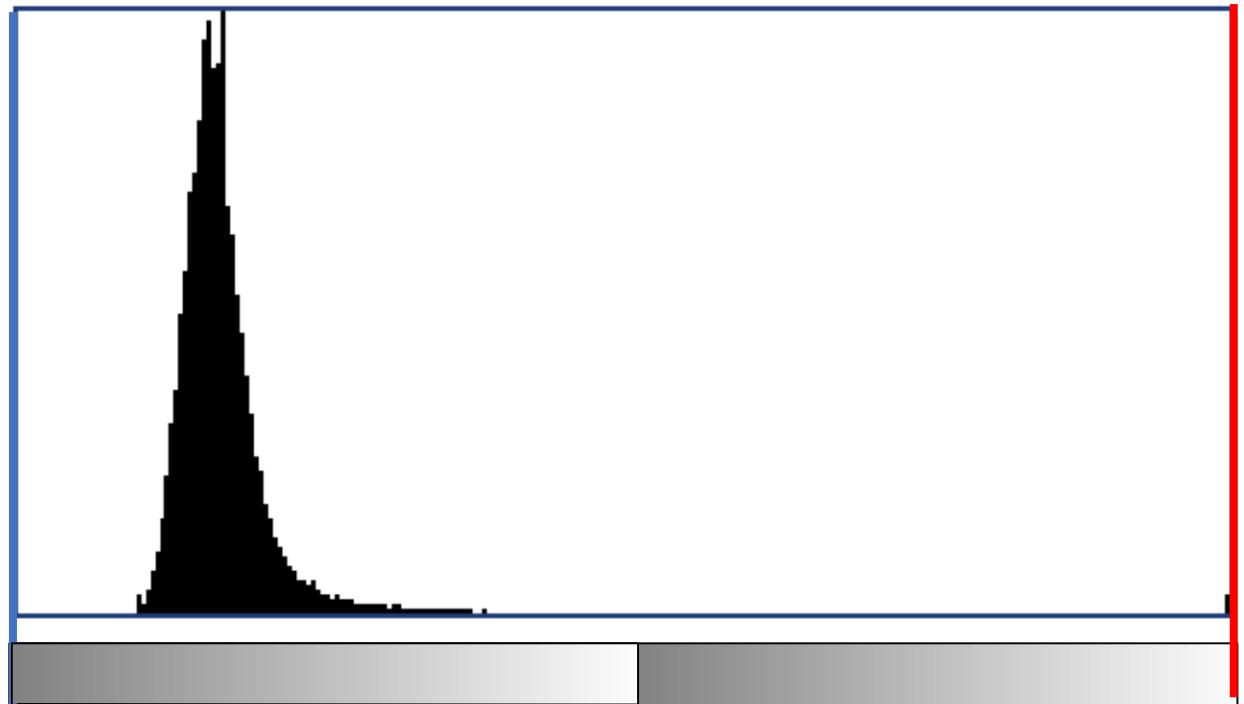
Brightness: a relative attribute that represents how much light a source is emitting.

Contrast: refers to the amount of color or grayscale differentiation that exists between various image features.

- Is this image bright?
- Does it have good contrast?



Decrease vmin and vmax:
Brightness Increased



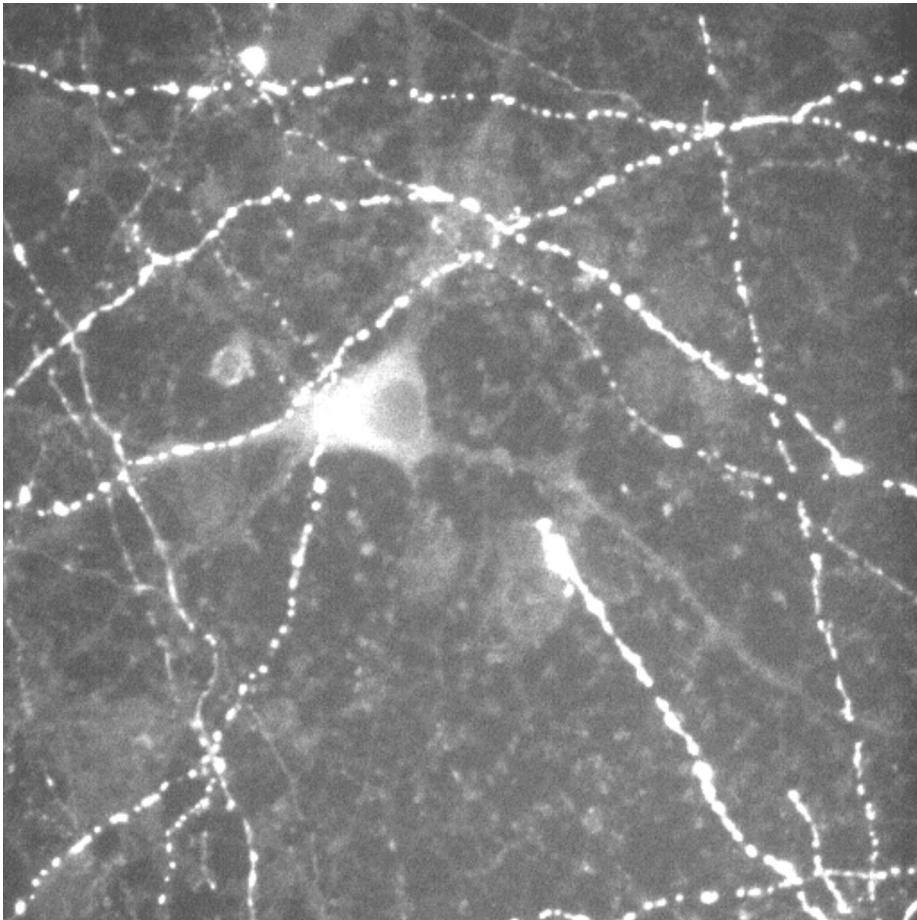
```
plt.imshow(image, cmap='gray', vmin=0, vmax=255)
```

Visualisation: brightness / contrast

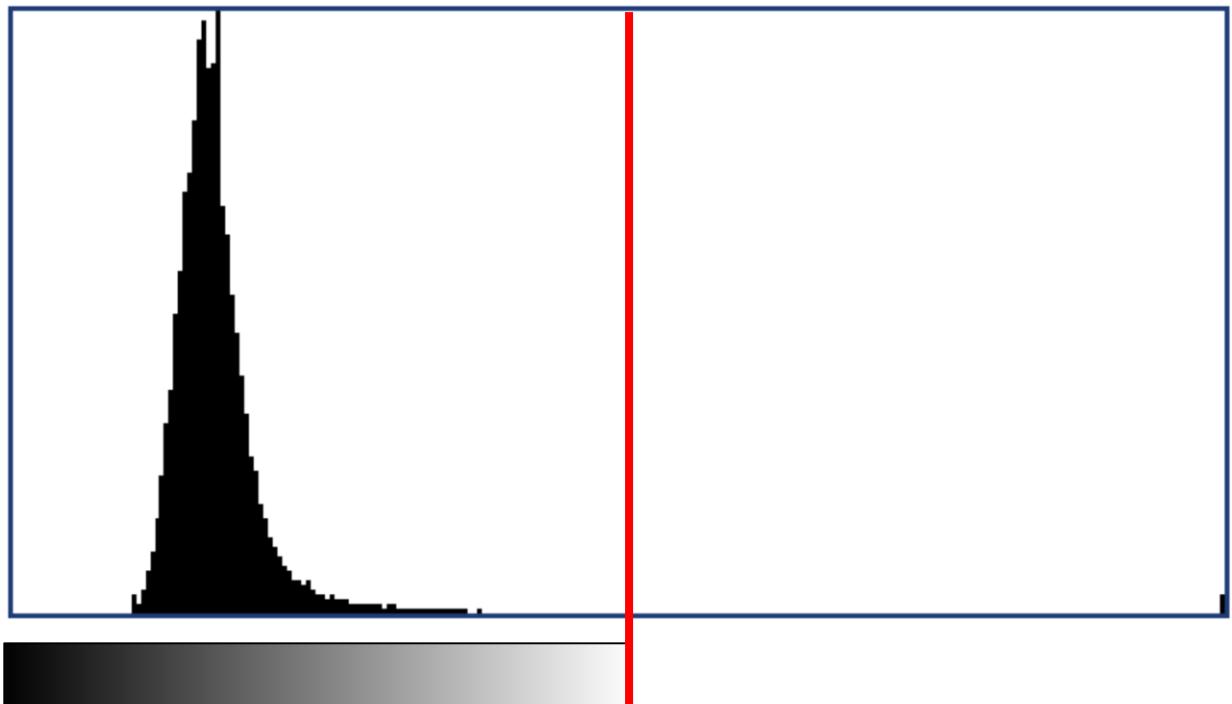
Brightness: a relative attribute that represents how much light a source is emitting.

Contrast: refers to the amount of color or grayscale differentiation that exists between various image features.

- Is this image bright?
- Does it have good contrast?



Decrease only vmax:
Contrast Increased

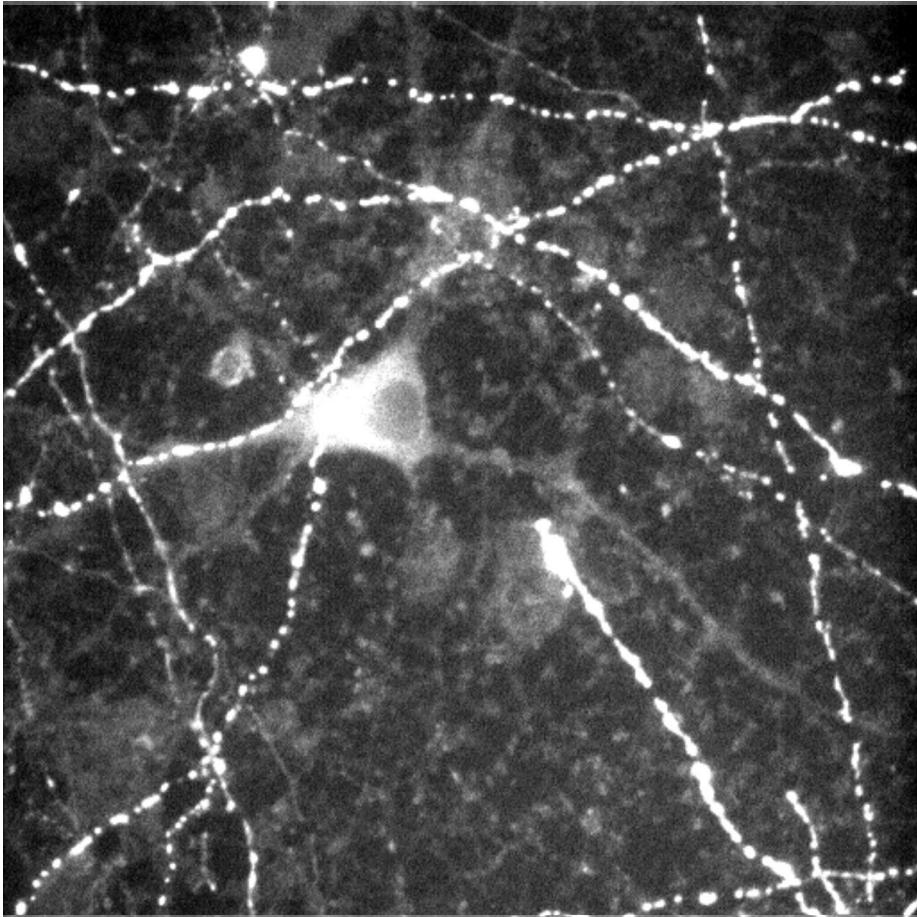


Visualisation: brightness / contrast

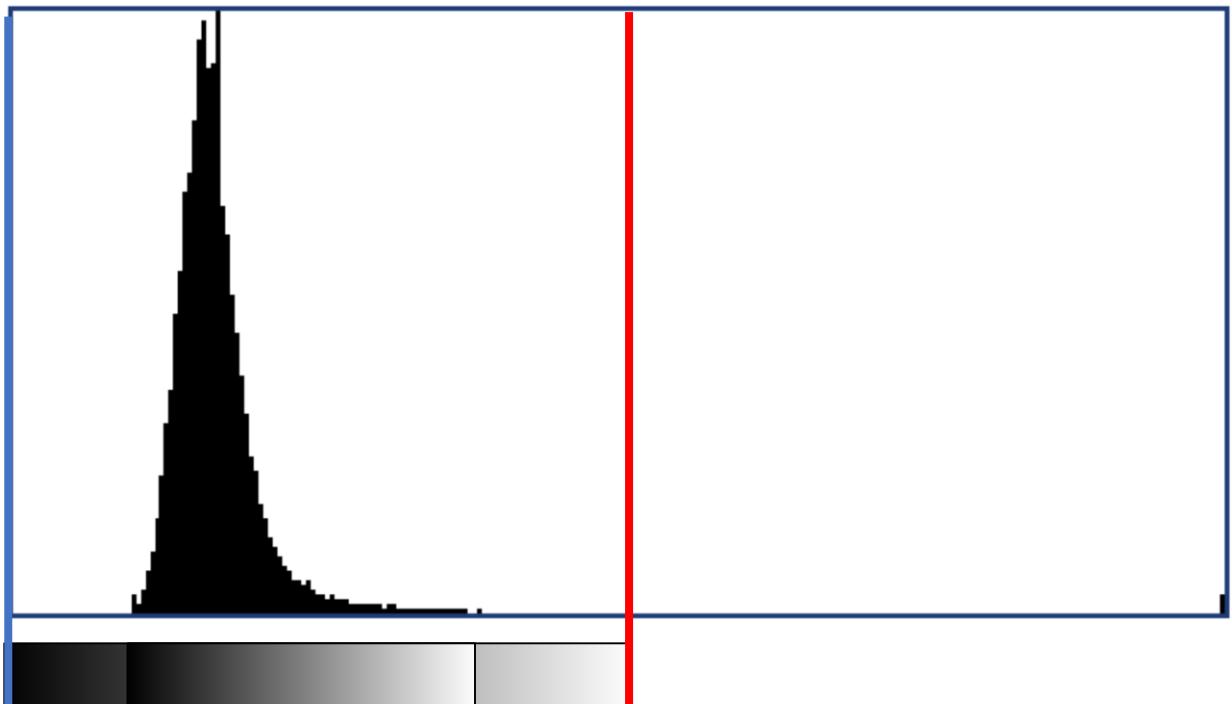
Brightness: a relative attribute that represents how much light a source is emitting.

Contrast: refers to the amount of color or grayscale differentiation that exists between various image features.

- Is this image bright?
- Does it have good contrast?



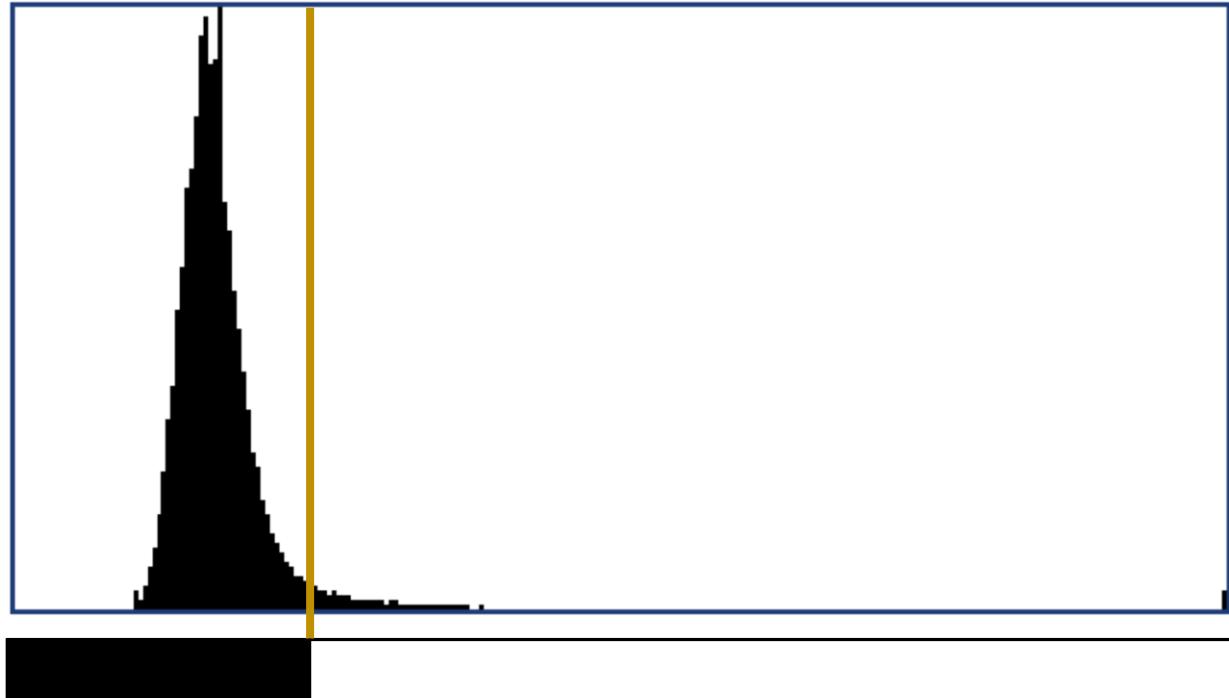
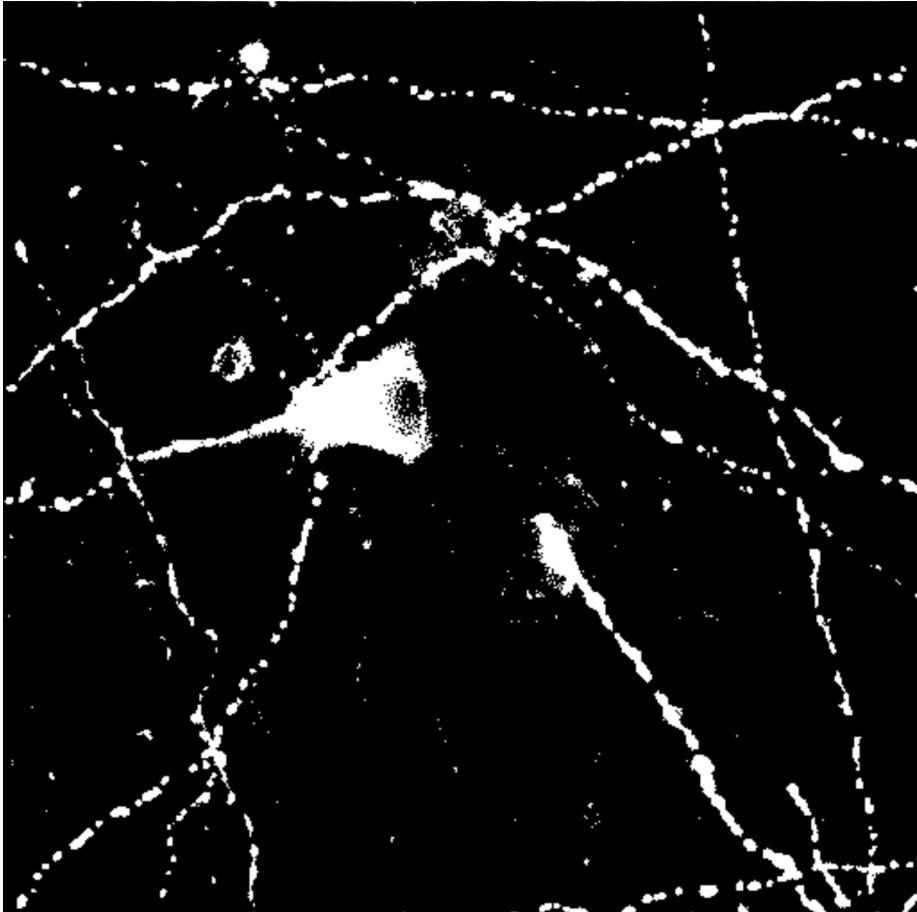
Window vmin and vmax around histogram:
Contrast Increased



Don't do such a narrow window right before acquisition!
If your signal changes over time/sample, you will lose information.

Binarization: a quick peek

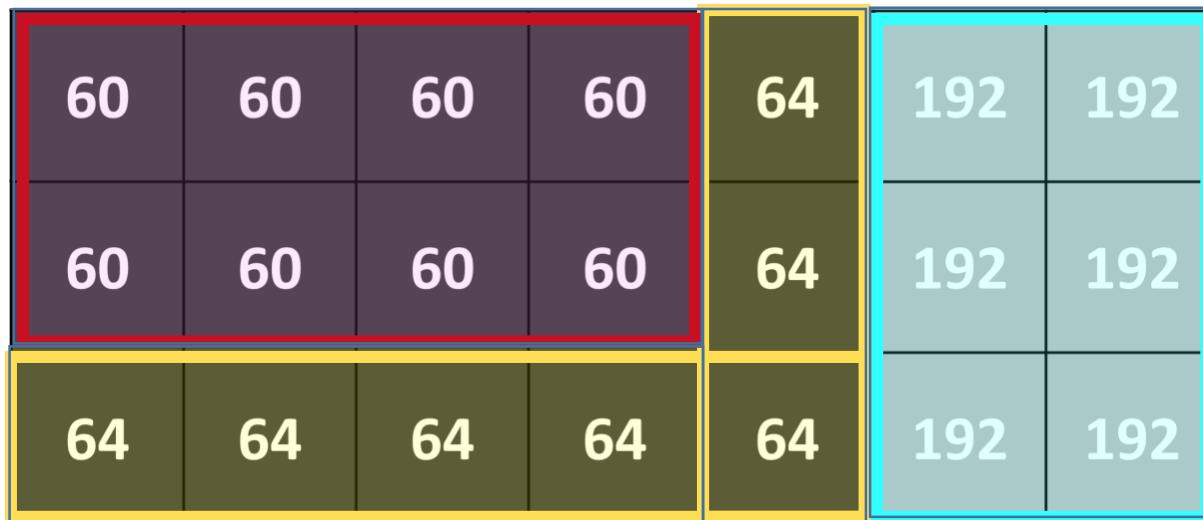
Values above a threshold value are replaced by 1 (or True).
Values below or equal threshold are replaced by 0 (or False)



```
image_binary = image > value
```

Histogram

Consider the following image:



How many elements does it have?

Which pixel value occurs more often?

If we may be mistaken in such a small image,
imagine for big images!

The histogram answers these questions at a glance!

Histogram: a graph that shows how frequent values are in an array/image

```
from skimage.exposure import histogram  
  
pixel_counts, pixel_values = histogram(array)  
  
plt.bar(pixel_values, pixel_counts)
```

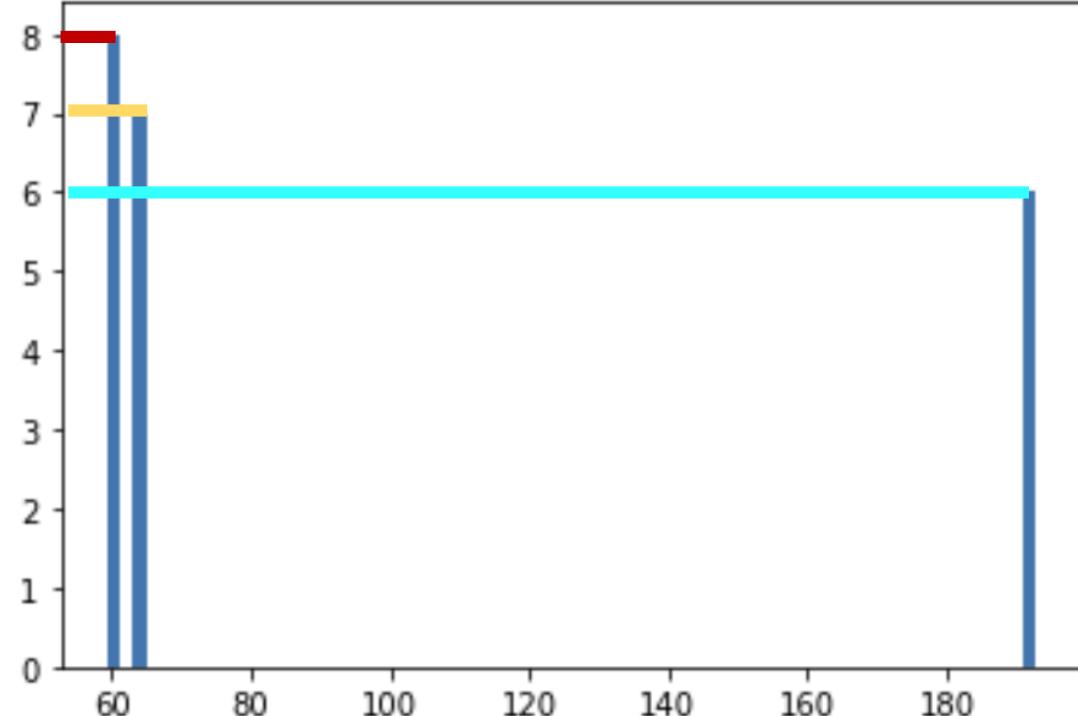
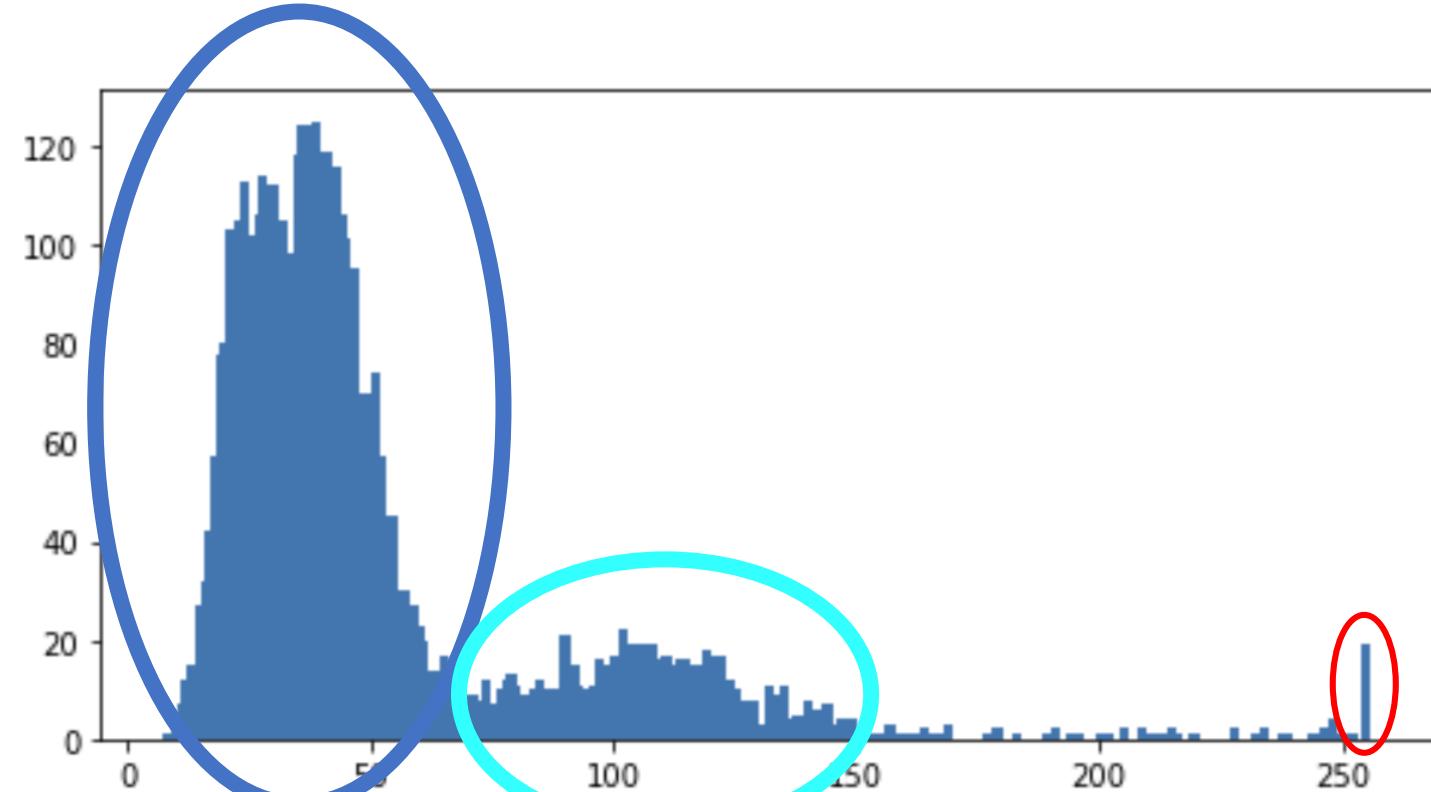
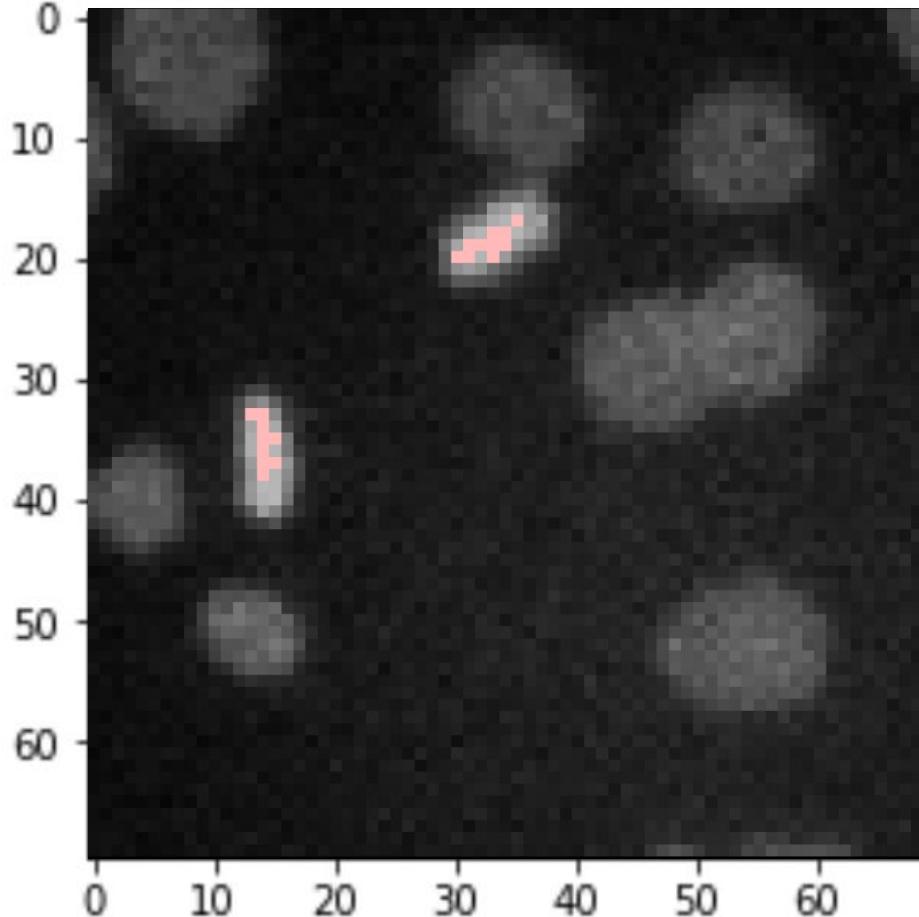


Image Histogram

Example with a slightly larger image:

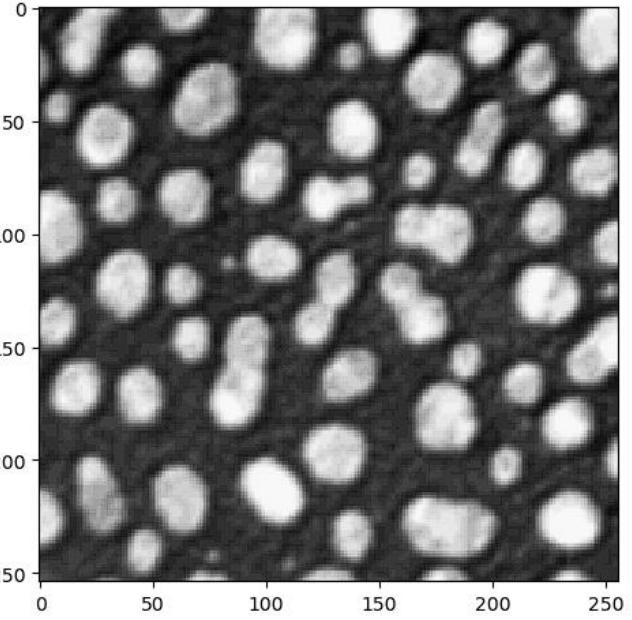


Plotting images in Jupyter notebooks

Many Python libraries usually have a “imshow” function to display images.

scikit-image

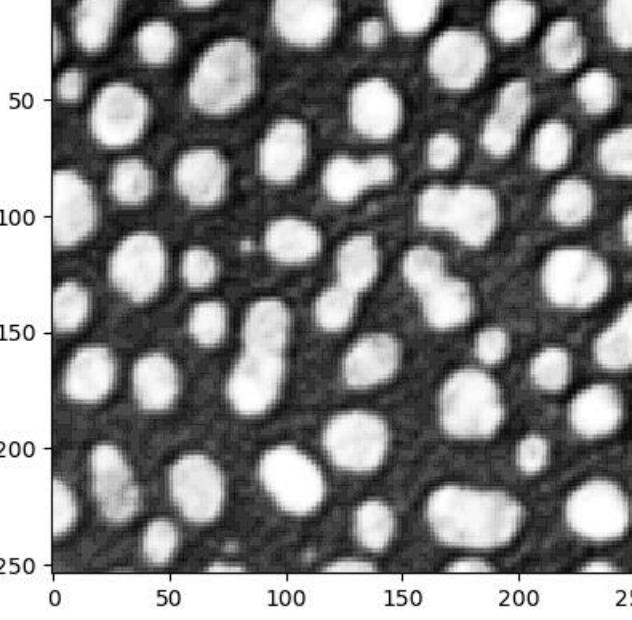
```
from skimage.io import imshow
imshow(image)
<matplotlib.image.AxesImage at 0x2d0adef0e50>
```



A grayscale image showing a collection of white, irregularly shaped objects against a black background. The image is displayed in a coordinate system where both axes range from 0 to 250.

pyclesperanto

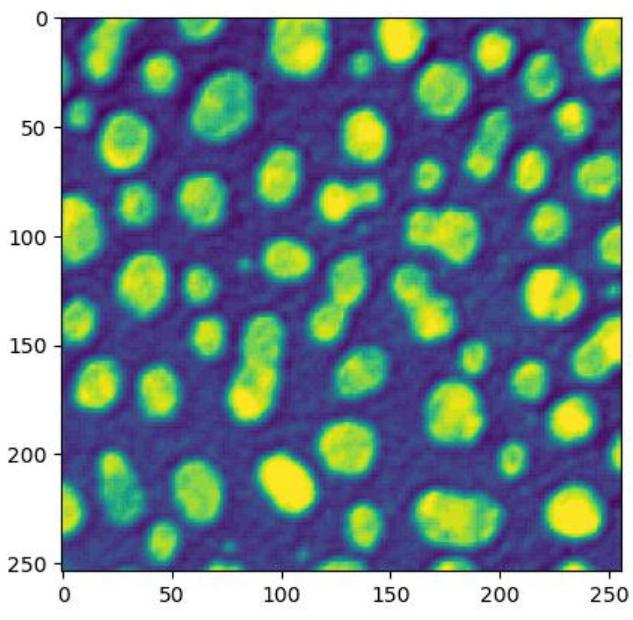
```
import pyclesperanto_prototype as cle
cle.imshow(image)
```



A grayscale image showing a collection of white, irregularly shaped objects against a black background. The image is displayed in a coordinate system where both axes range from 0 to 250.

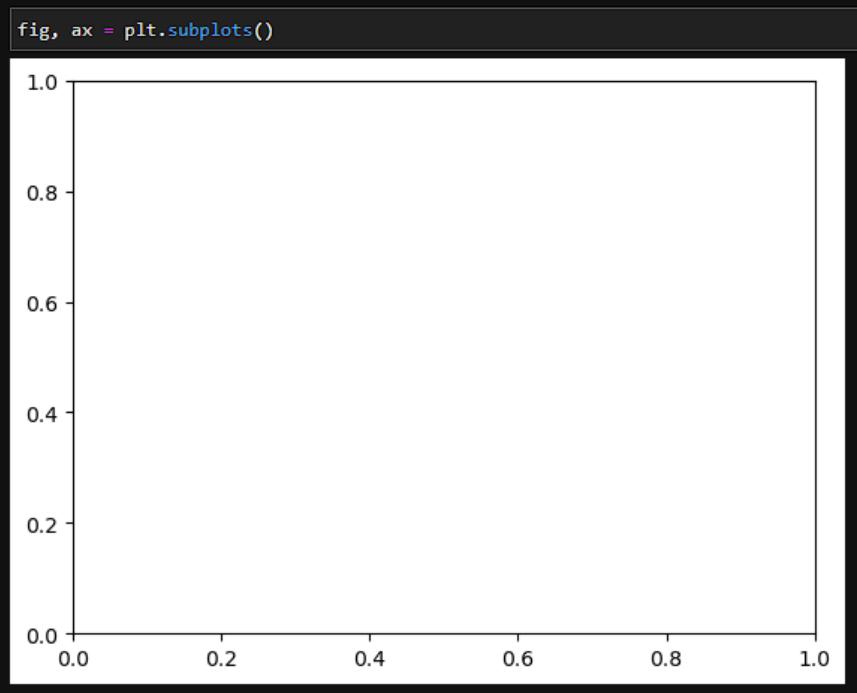
matplotlib

```
import matplotlib.pyplot as plt
plt.imshow(image)
<matplotlib.image.AxesImage at 0x2d0adf3e6a0>
```



A heatmap showing a collection of bright, yellow-green spots of varying sizes against a dark blue background. The image is displayed in a coordinate system where both axes range from 0 to 250.

Plotting with matplotlib



The 'subplots' method creates a Figure and 1 or more Axes Artists

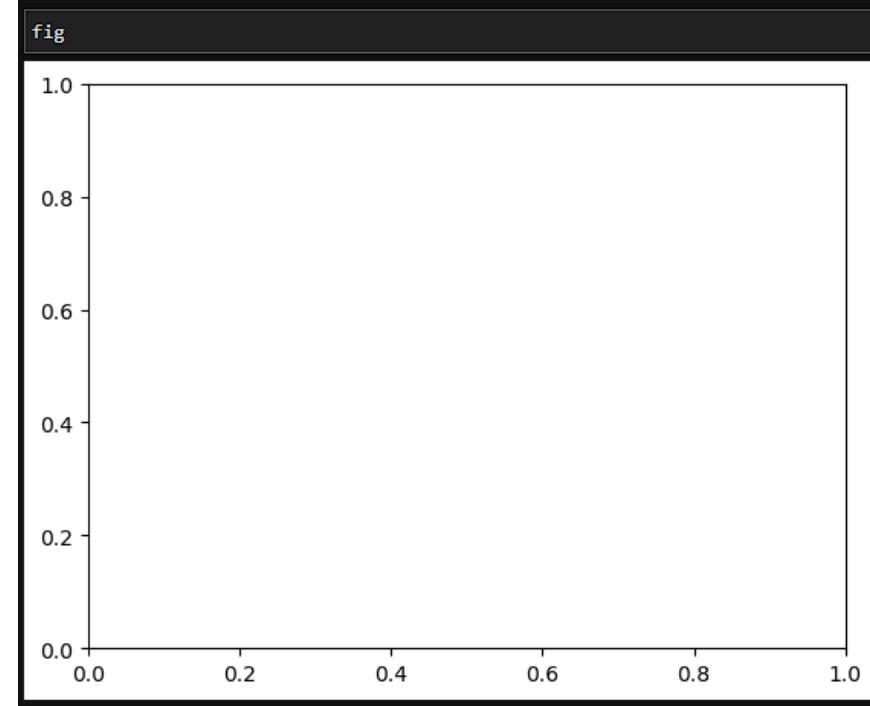


Figure: the whole figure, where many 'Artist' objects go inside

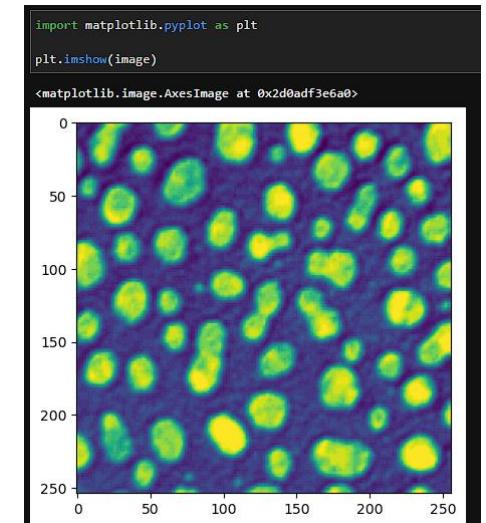
Calling imshow automatically creates a Figure and an Axes Artists under the hood.

```
ax
```



```
<AxesSubplot: >
```

An Axes is an Artist attached to a Figure that contains a region for plotting data

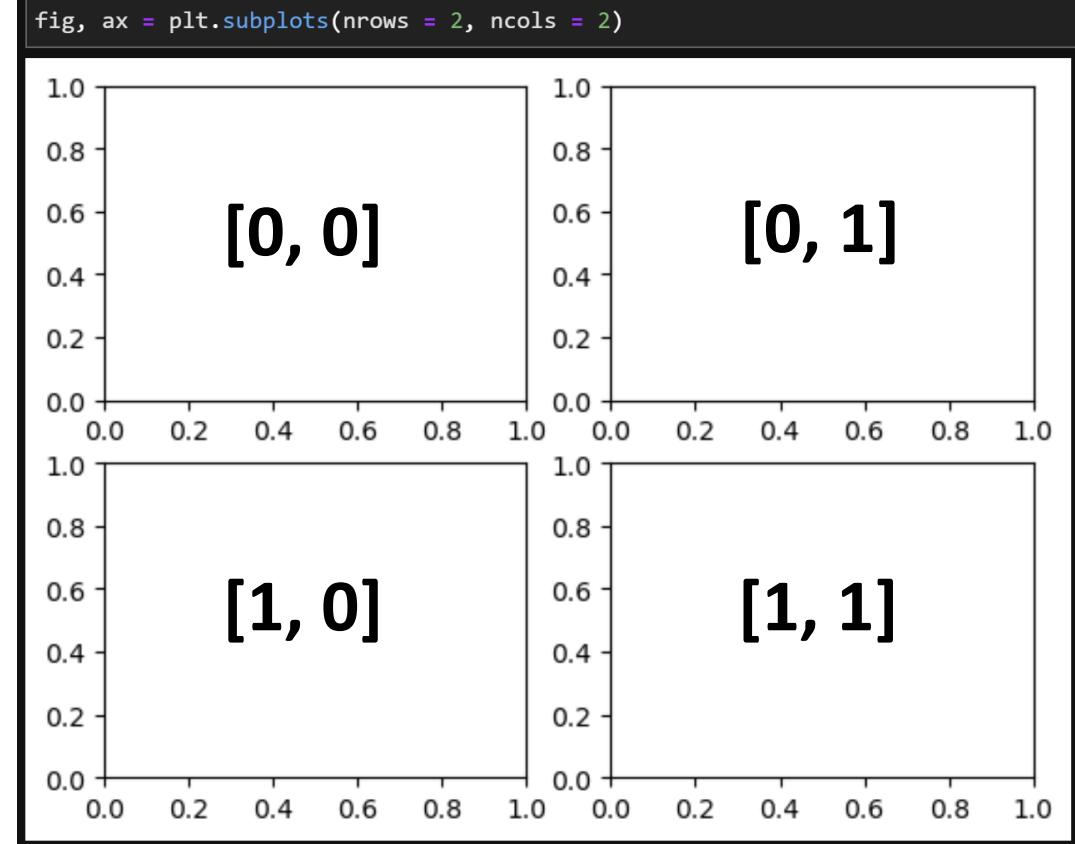


Plotting with matplotlib

- Use matplotlib to put images side-by-side

Columns 0 1

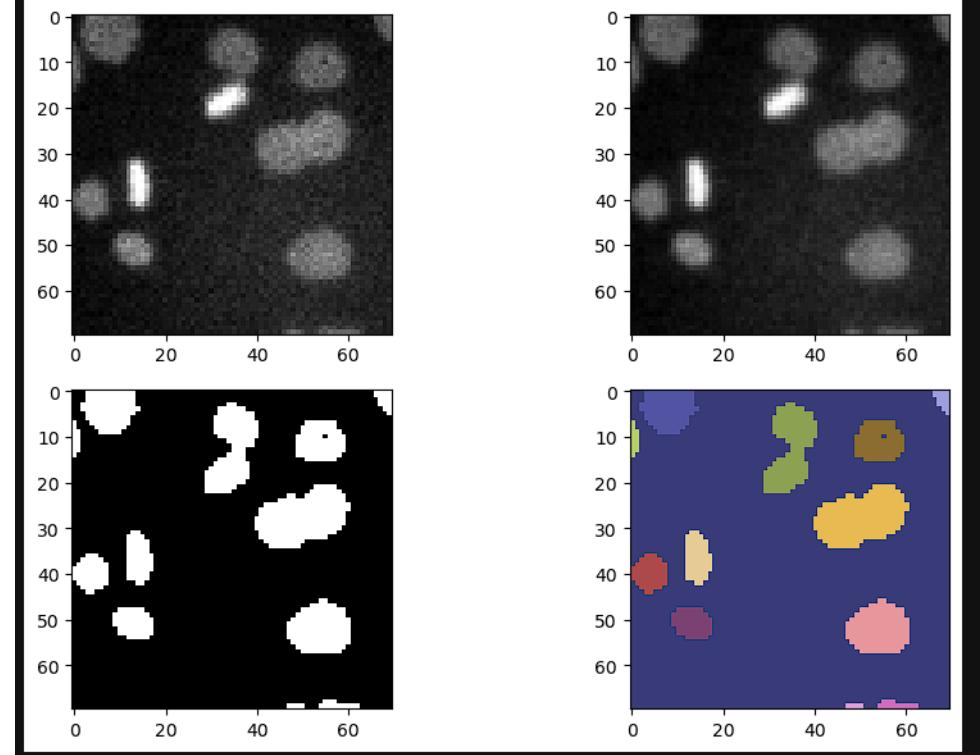
Rows



```
fig, ax = plt.subplots(nrows = 2, ncols = 2, figsize = (10,6))

ax[0, 0].imshow(image_cells, cmap = 'gray')
ax[0, 1].imshow(image_filtered, cmap = 'gray')
ax[1, 0].imshow(binary_image, cmap = 'gray')
ax[1, 1].imshow(label_image, cmap = 'tab20b')

# Handy function to avoid overlap of axes labels
plt.tight_layout()
```



https://matplotlib.org/stable/api/_as_gen/matplotlib.pyplot.subplots.html

Reading Images and Folder Structures

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Reading Images in Python

In Python, images can often be read by providing a path to a “imread” function. The path can be a relative path or an absolute path.

```
from skimage.io import imread  
  
image = imread('.../..data/blobs.tif')
```

Relative path to image

```
from skimage.io import imread  
  
image = imread("C:\Users\mazo260d\Quantitative_Bio_Image_Analysis_with_Python_2022\data\blobs.tif")
```

Absolute path to image

Backslash ('\') is a special character. In Windows, this may lead to errors.

```
OSError: [Errno 22] Invalid argument:
```

Replace backslashes ('\') by forward slashes ('/')

```
from skimage.io import imread  
  
image = imread("C:/Users/mazo260d/Quantitative_Image_Analysis_with_Python_2022/data/blobs.tif")
```

Reading Multidimensional Images in Python

- 2D images
 - Some libraries return an array in a standardized fashion

```
image.shape  
(254, 256)
```

```
image.shape  
(1, 1, 1, 80, 520, 692, 1)
```

- 3D images

```
image.shape  
(36, 254, 256)
```

- Multichannel images

```
image.shape  
(512, 672, 3)
```

```
channel1 = image[:, :, 0]  
channel2 = image[:, :, 1]  
channel3 = image[:, :, 2]
```

Check image metadata to know which dimension corresponds to what.
Check library documentation.

Reading Images in Python

The path can also be a variable.

```
from skimage.io import imread  
  
image = imread(path_to_image)
```

Two popular libraries to handle paths are 'os' and 'pathlib'.

pathlib

```
from pathlib import Path  
  
image_path = Path('.../..../data/blobs.tif')  
image_path  
  
WindowsPath('.../..../data/blobs.tif')
```

name with extension

```
image_path.name  
  
'blobs.tif'
```

name

```
image_path.stem  
  
'blobs'
```

extension

```
image_path.suffix  
  
.tif'
```

parent directory

```
image_path.parent  
  
WindowsPath('.../..../data')
```

os

```
import os  
  
image_path = r'.../..../data/blobs.tif'  
image_path  
  
'.../..../data/blobs.tif'
```

parent directory +
name with extension

```
os.path.split(image_path)  
  
(.../..../data', 'blobs.tif')
```

parent directory with
name + extension

```
os.path.splitext(image_path)  
  
(.../..../data/blobs', '.tif')
```

Reading Images from Folders in Python

pathlib

```
folder_path = Path('.../..../data')
folder_path

WindowsPath('.../..../data')
```

Iterating over a folder:

```
image_list = []
for path in folder_path.iterdir():
    image = imread(path)
    image_list.append(image)
    UL.csv
    UL.csv
...\\data\\BBBC007_analysis.csv
...\\data\\BBBC007_batch
```

```
image_path_list = []
for path in folder_path.iterdir():
    image_path_list.append(path)
```

```
for image_path in image_path_list:
    image = imread(image_path)
    process_image(image)
```

OS

```
folder_path = r'.../..../data'
folder_path

'.../..../data'
```

Iterating over a folder:

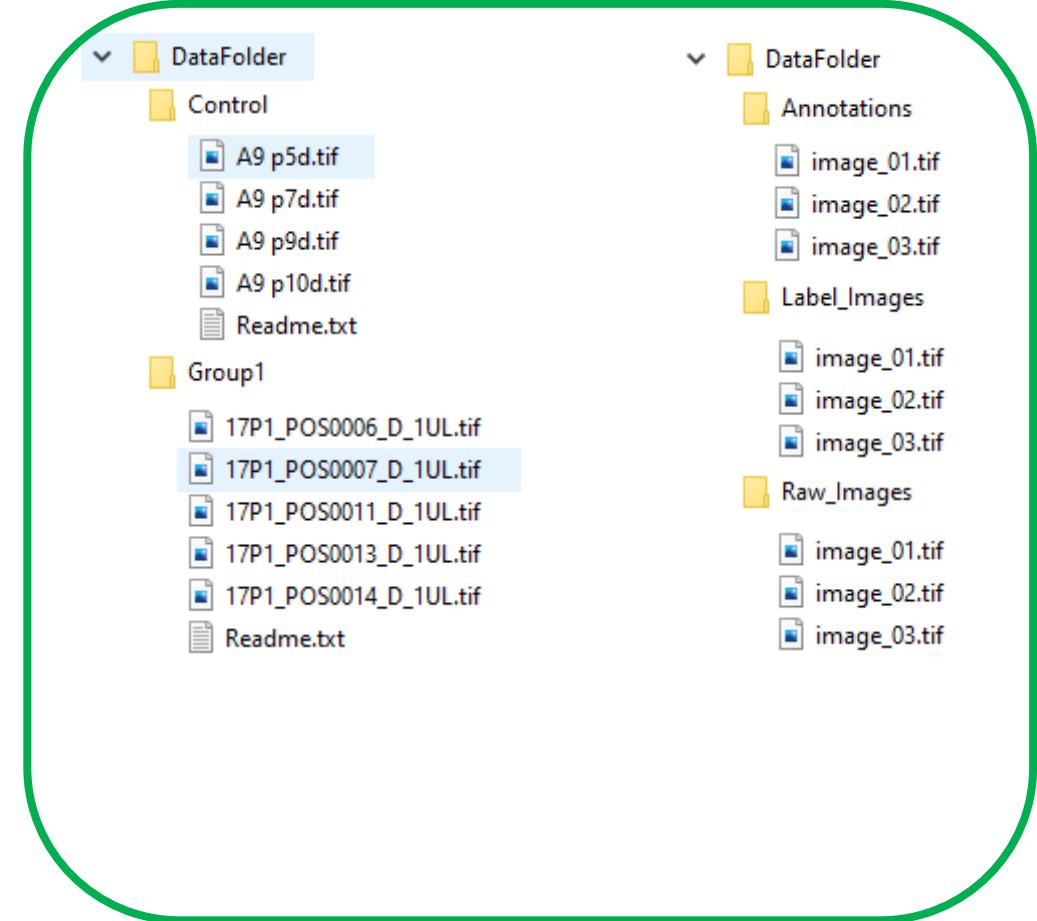
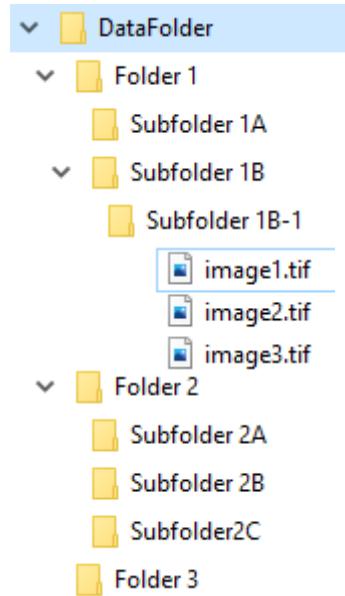
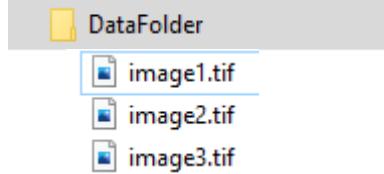
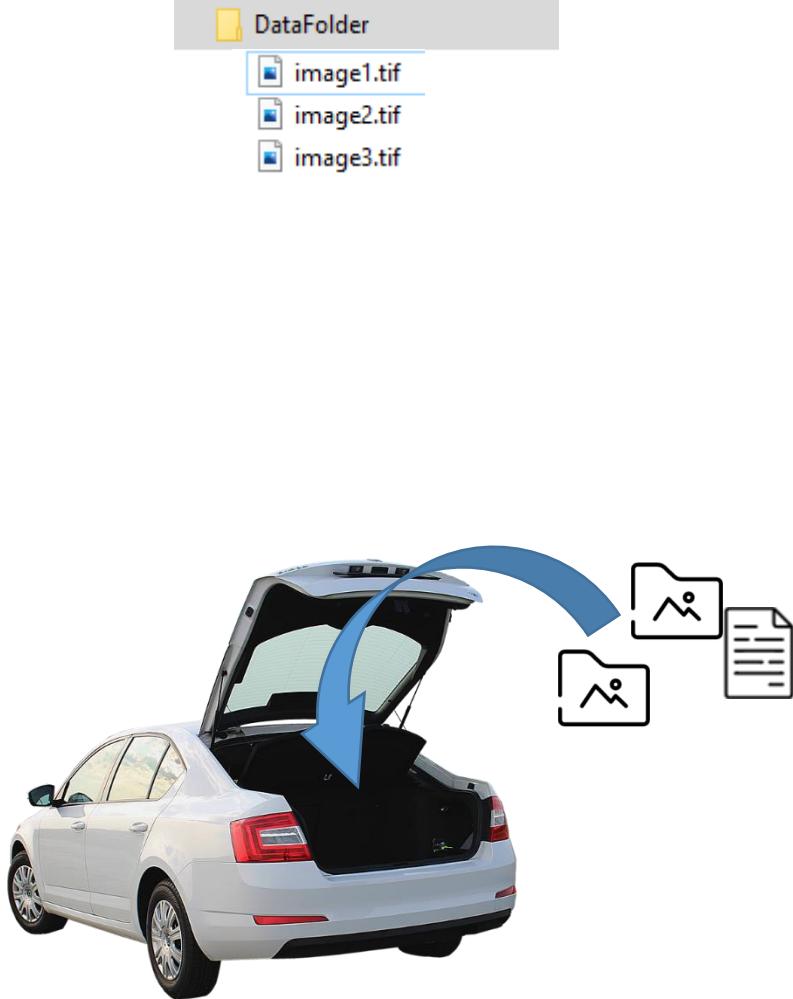
```
file_names = os.listdir(folder_path)
file_names

['BBBC007_20P1_POS0007_D_1UL.csv',
 'BBBC007_20P1_POS0010_D_1UL.csv',
 'BBBC007_analysis.csv',
 'BBBC007_batch',
```

```
for file_name in file_names:
    full_path = os.path.join(folder_path, file_name)
    print(full_path)

...\\data\\BBBC007_20P1_POS0007_D_1UL.csv
...\\data\\BBBC007_20P1_POS0010_D_1UL.csv
...\\data\\BBBC007_analysis.csv
...\\data\\BBBC007_batch
```

Folder Structures



A few general advice:

- Avoid too many levels
- Add “Readme” files as soon as you create a folder (you will forget later)
- Consider using a data management platform
- Talk to a data management experts to find the best structure to your needs

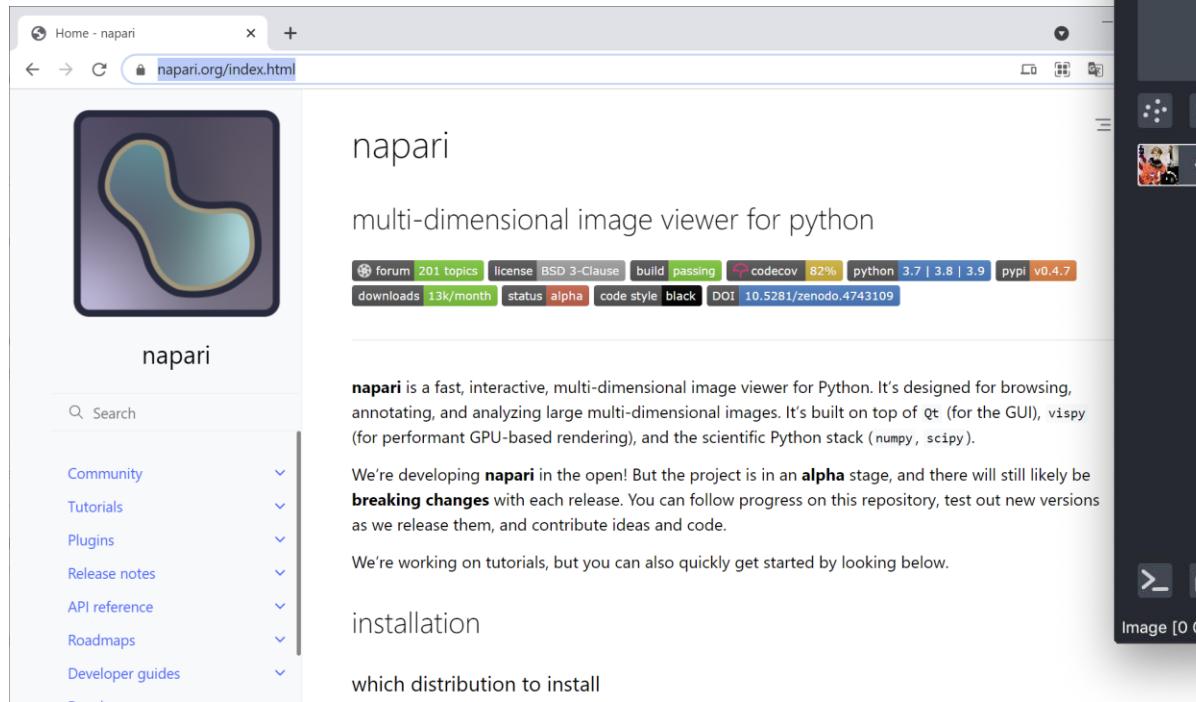
Napari

Marcelo L. Zoccoler

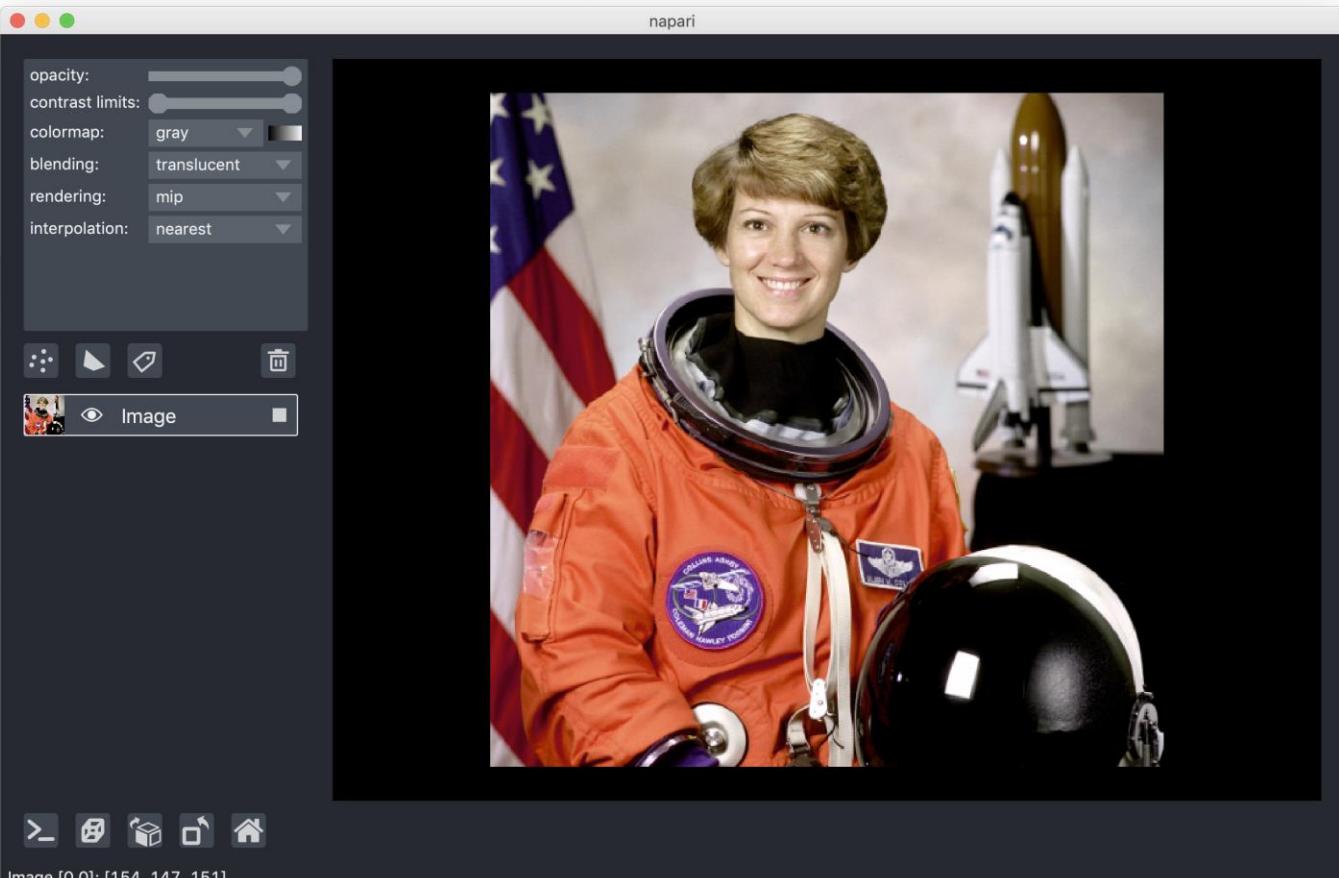
With material from:

Robert Haase, PoL; Guillaume Witz, Universität Bern

- Multi-dimensional image
- <https://napari.org/>



The screenshot shows the official website for Napari. At the top, there's a header with a logo, a search bar, and navigation links. Below the header, there's a main content area with a sidebar containing links for Community, Tutorials, Plugins, Release notes, API reference, Roadmaps, and Developer guides. The main content area features a large image of a multi-dimensional image, a search bar, and several buttons for navigating through the data.

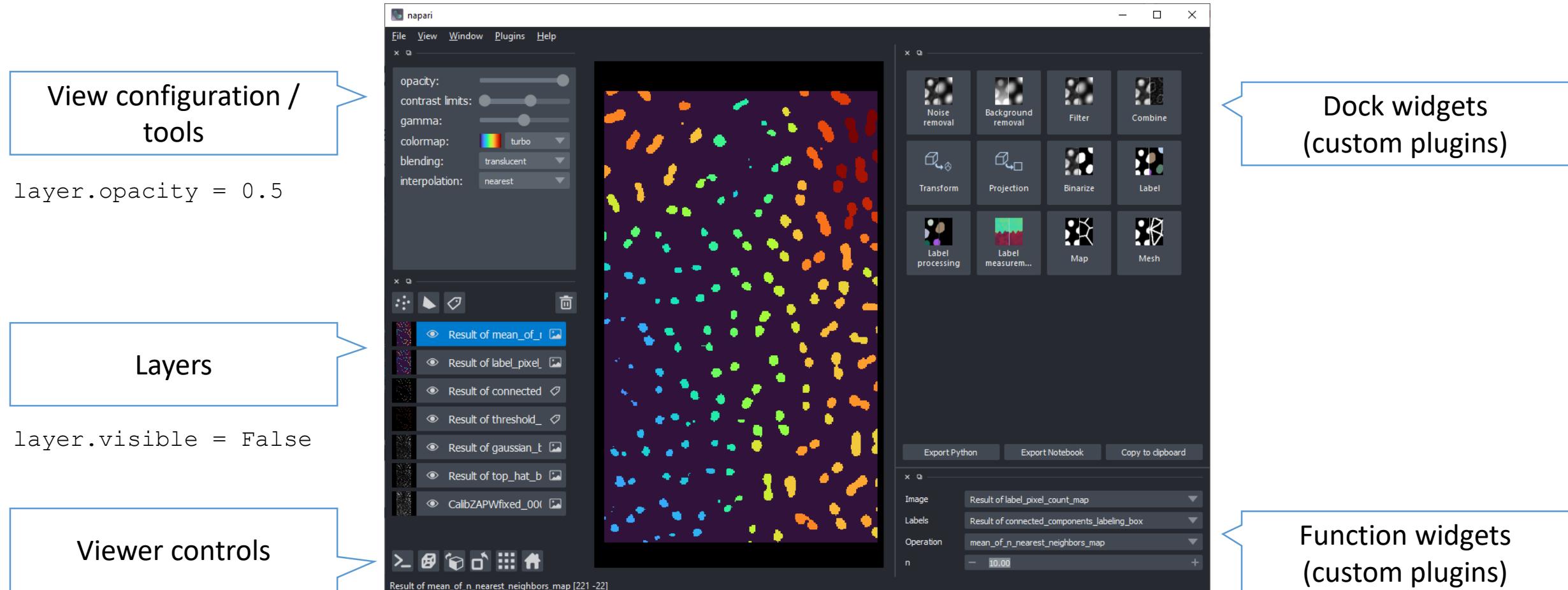


Napari: 3D viewer for Python



Image data source: Daniela Vorkel, Myers lab, MPI-CBG/CSBD

Napari user interface



<https://napari.org/tutorials/fundamentals/viewer.html>

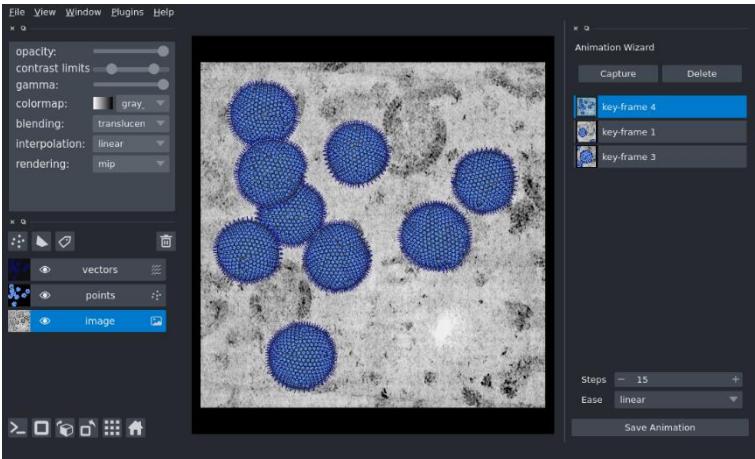
napari plugins

clusters-plotter



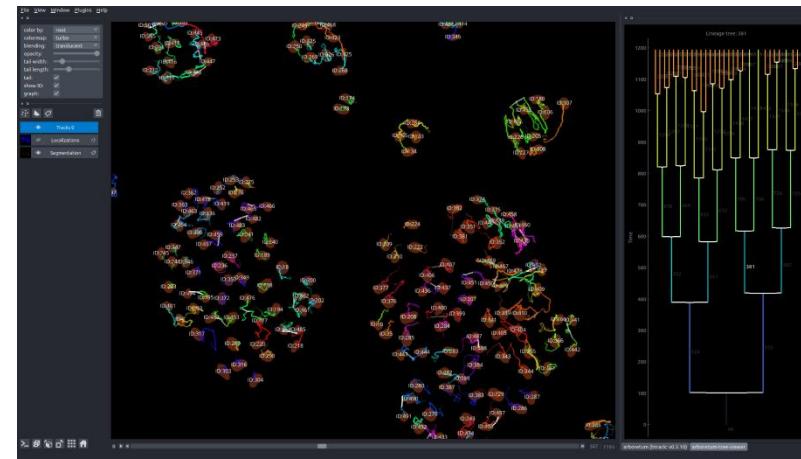
<https://github.com/BiAPoL/napari-clusters-plotter>

animation



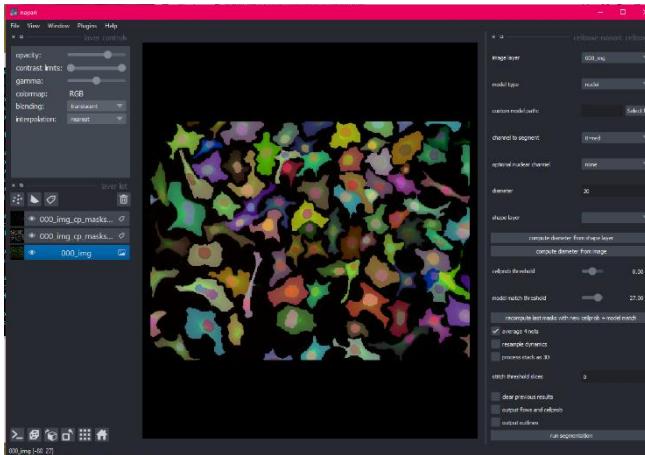
<https://github.com/napari/napari-animation>

arboretum



<https://github.com/quantumjot/arboretum>

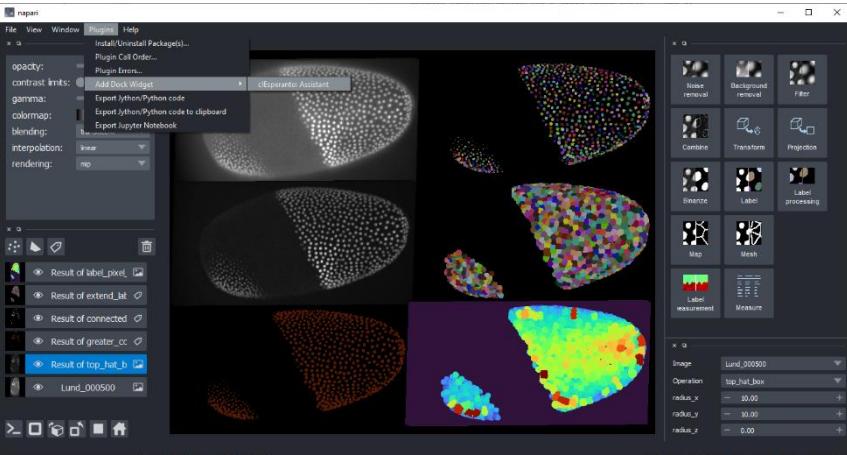
cellpose



<https://cellpose-napari.readthedocs.io/en/latest/>

In development: <https://github.com/topics/napari-plugin>
Released: <https://pypi.org/search/?q=&o=&c=Framework+%3A%3A+napari>

clesperanto



https://github.com/c1Esperanto/napari_pyclesperanto_assistant

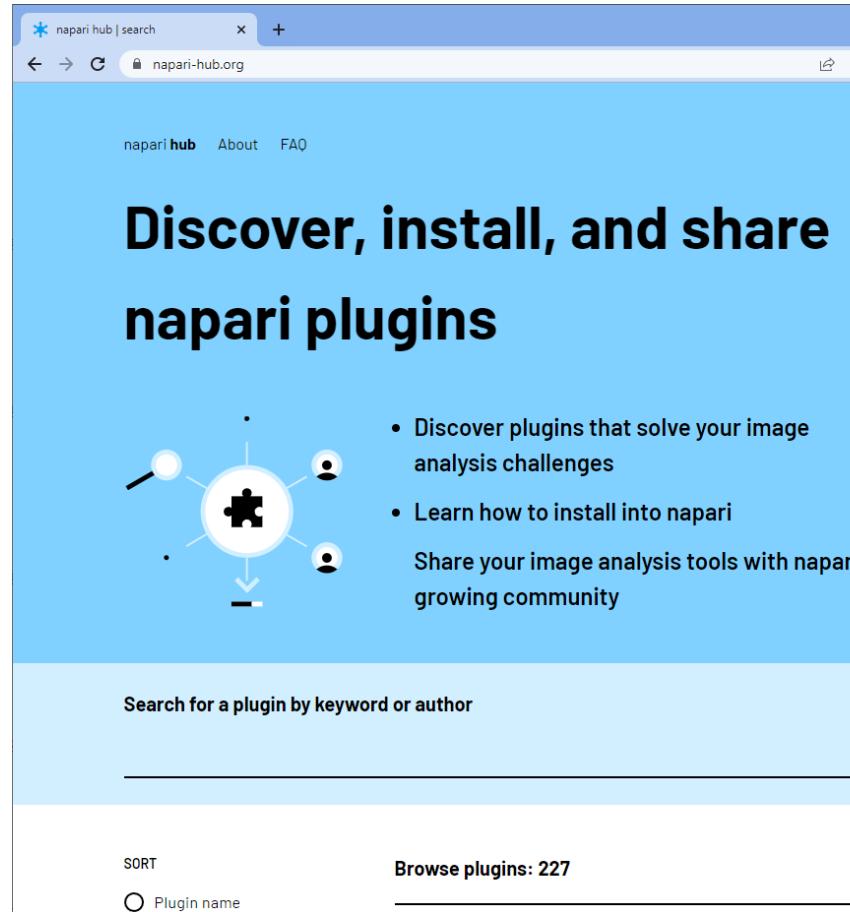


PoL
Physics of Life
TU Dresden



The Napari Hub

- Search engine for napari plugins



napari hub | search napari-hub.org

Discover, install, and share napari plugins

Discover plugins that solve your image analysis challenges

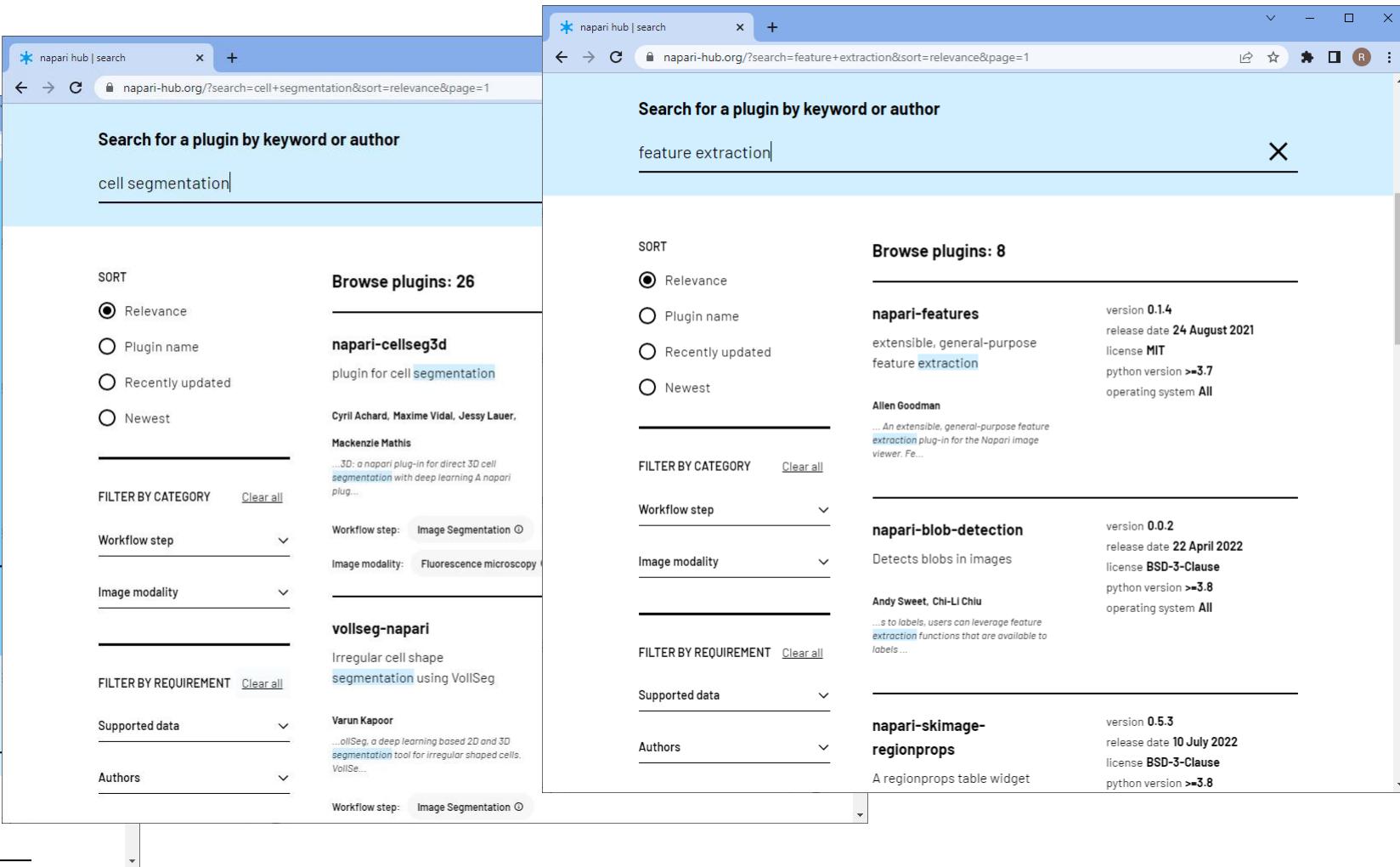
Learn how to install into napari

Share your image analysis tools with napari's growing community

Search for a plugin by keyword or author

SORT Plugin name

Browse plugins: 227



napari hub | search napari-hub.org/?search=cell+segmentation&sort=relevance&page=1

Search for a plugin by keyword or author

cell segmentation

SORT Relevance Plugin name Recently updated Newest

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napari-cellseg3d
plugin for cell segmentation
Cyril Achard, Maxime Vidal, Jessy Lauer, Mackenzie Mathis
...3D: a napari plug-in for direct 3D cell segmentation with deep learning A napari plug...

vollseg-napari
Irregular cell shape segmentation using VollSeg
Varun Kapoor
...ollSeg: a deep learning based 2D and 3D segmentation tool for irregular shaped cells. VollSe...

FILTER BY CATEGORY Workflow step: Image Segmentation Image modality: Fluorescence microscopy

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Workflow step: Image Segmentation

napari-hub | search napari-hub.org/?search=feature+extraction&sort=relevance&page=1

Search for a plugin by keyword or author

feature extraction

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Browse plugins: 8

napari-features
version 0.1.4
release date 24 August 2021
license MIT
python version >=3.7
operating system All
extensible, general-purpose feature extraction
Allen Goodman
...An extensible, general-purpose feature extraction plug-in for the Napari image viewer. Fe...

napari-blob-detection
version 0.0.2
release date 22 April 2022
license BSD-3-Clause
python version >=3.8
operating system All
Detects blobs in images
Andy Sweet, Chi-Li Chiu
...s to labels, users can leverage feature extraction functions that are available to labels ...

napari-skimage-regionprops
version 0.5.3
release date 10 July 2022
license BSD-3-Clause
python version >=3.8
A regionprops table widget

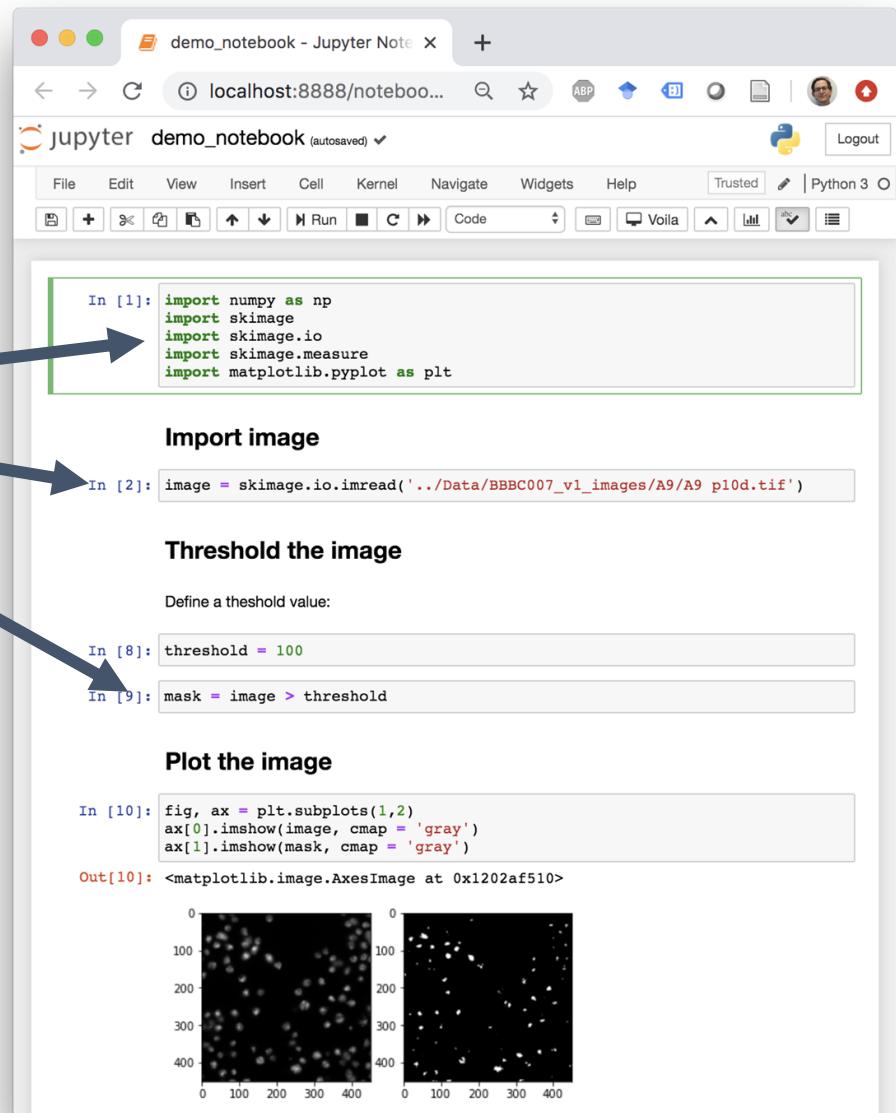
<https://www.napari-hub.org/>

What is a jupyter notebook?

A text file (easily sent around)

Rendered by Jupyter in the browser

Split into sections called cells



The screenshot shows a Jupyter Notebook interface running in a browser window titled "demo_notebook - Jupyter Note". The notebook contains several code cells and their corresponding outputs:

- In [1]:**

```
import numpy as np
import skimage
import skimage.io
import skimage.measure
import matplotlib.pyplot as plt
```

Import image
- In [2]:**

```
image = skimage.io.imread('../Data/BBBC007_v1_images/A9/A9_p10d.tif')
```

Threshold the image
- In [8]:**

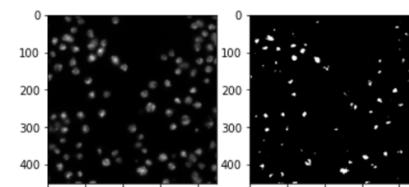
```
threshold = 100
```
- In [9]:**

```
mask = image > threshold
```

Plot the image
- In [10]:**

```
fig, ax = plt.subplots(1,2)
ax[0].imshow(image, cmap = 'gray')
ax[1].imshow(mask, cmap = 'gray')
```

Out[10]: <matplotlib.image.AxesImage at 0x1202af510>



Napari from jupyter notebooks

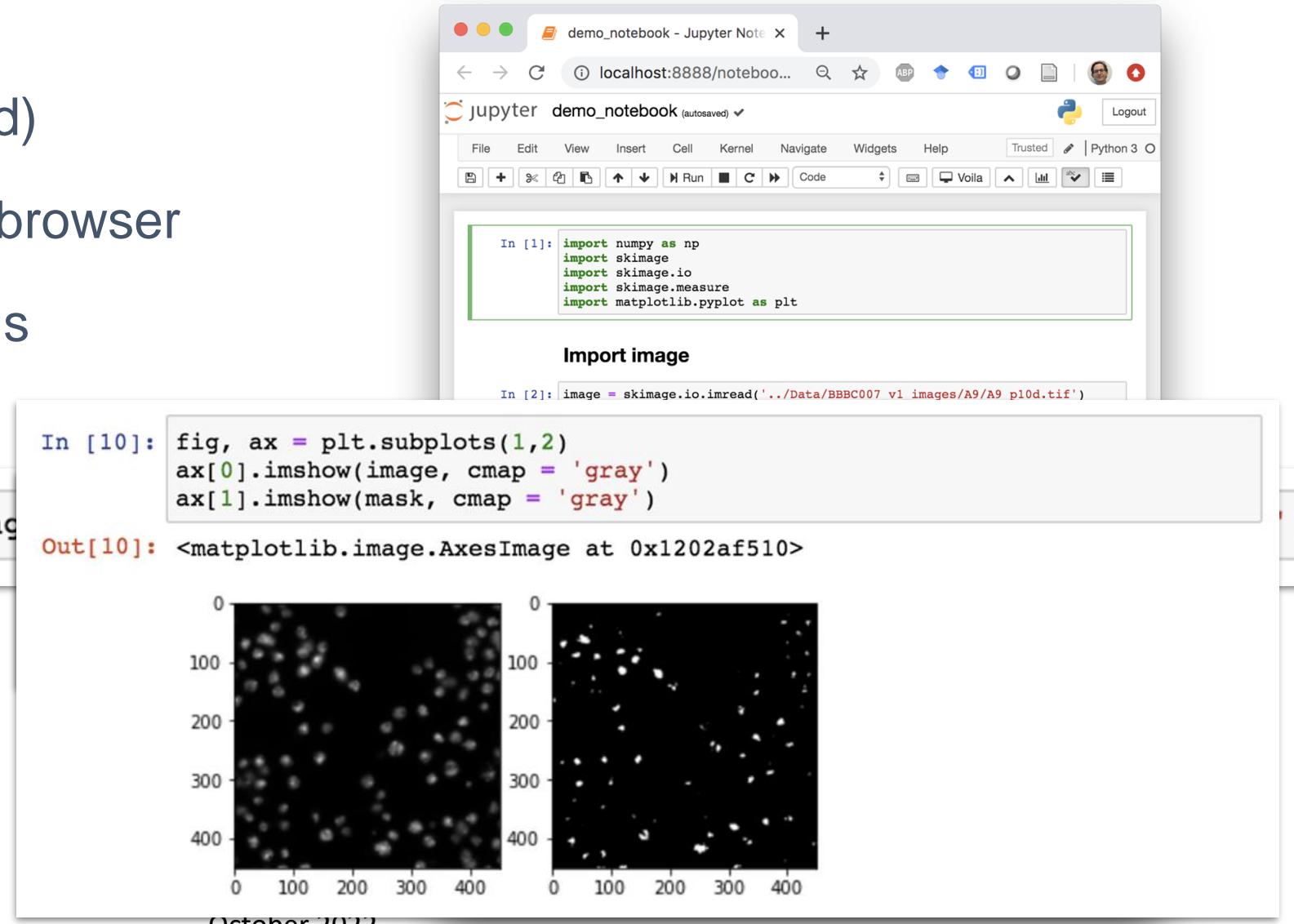
A text file (easily sent around)

Rendered by Jupyter in the browser

Split into sections called cells

Cells can contain:

- Code
- Formatted text
- Rich output



The screenshot shows a Jupyter Notebook interface running in a browser window titled "demo_notebook - Jupyter Note". The notebook has two cells visible:

- In [1]:** A code cell containing:

```
import numpy as np
import skimage
import skimage.io
import skimage.measure
import matplotlib.pyplot as plt
```

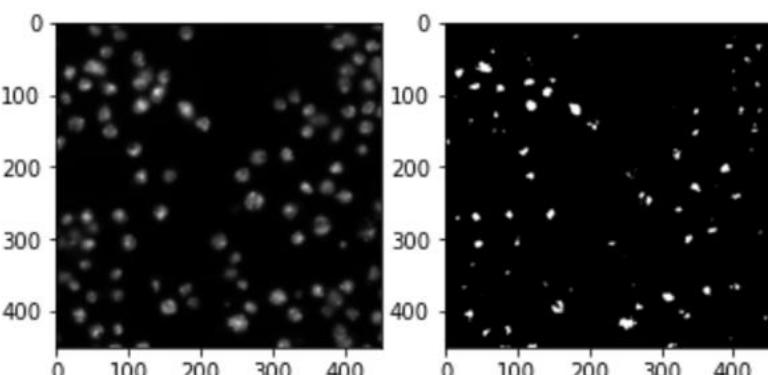
This cell is labeled "Import image".
- In [2]:** A code cell containing:

```
image = skimage.io.imread('../Data/BBBC007_v1_images/A9/A9_p10d.tif')
```

This cell is labeled "Import image".

Below the cells, the output of the second cell is shown:

Out[10]: <matplotlib.image.AxesImage at 0x1202af510>



Two square plots are displayed side-by-side. Both plots show a collection of small, bright, roughly circular spots against a dark background. The axes for both plots range from 0 to 400, with major ticks at 0, 100, 200, 300, and 400. The left plot's y-axis is labeled from top to bottom, while the right plot's y-axis is labeled from bottom to top.

Why using notebooks with napari?

- Easy data interaction and visualization with napari:
 - Call functions from code and visualize results in napari
 - Great for visualizing 3D (and more) data
 - Each processing step result can be displayed as a separate layer
- Data annotation

Scripting napari in notebooks

- Add layers to napari to visualize intermediate processing results on top of each other or side by side.
- Change layer visualization within napari...

... or via code in a jupyter notebook:

```
viewer.layers[0].contrast_limits
```

[0, 255]

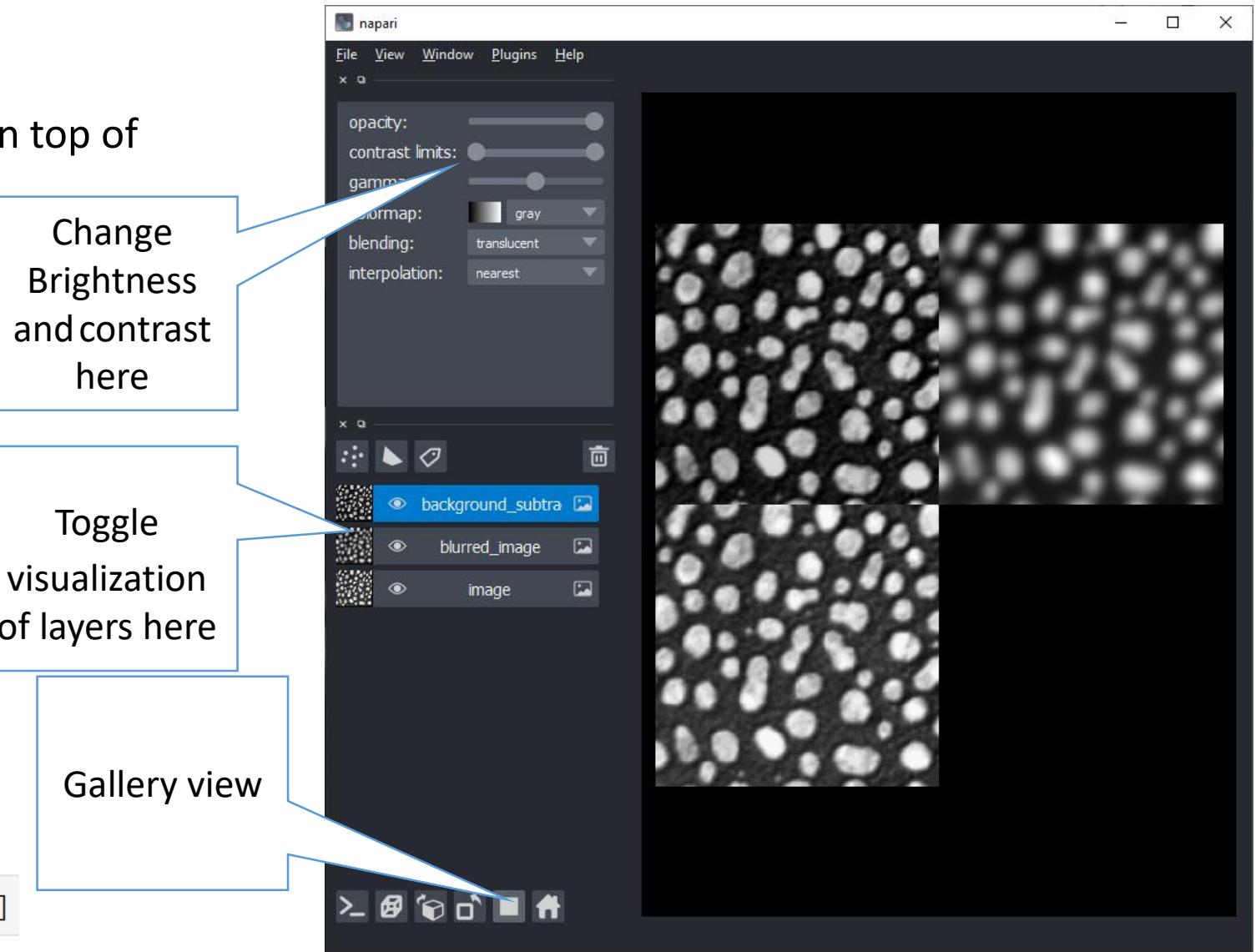
1. Access the viewer

2. Access the layers

3. Choose a layer (by index or name)

4. "Press TAB" and check out available properties

```
viewer.layers[0].contrast_limits = [30,170]
```



Visualizing image segmentation

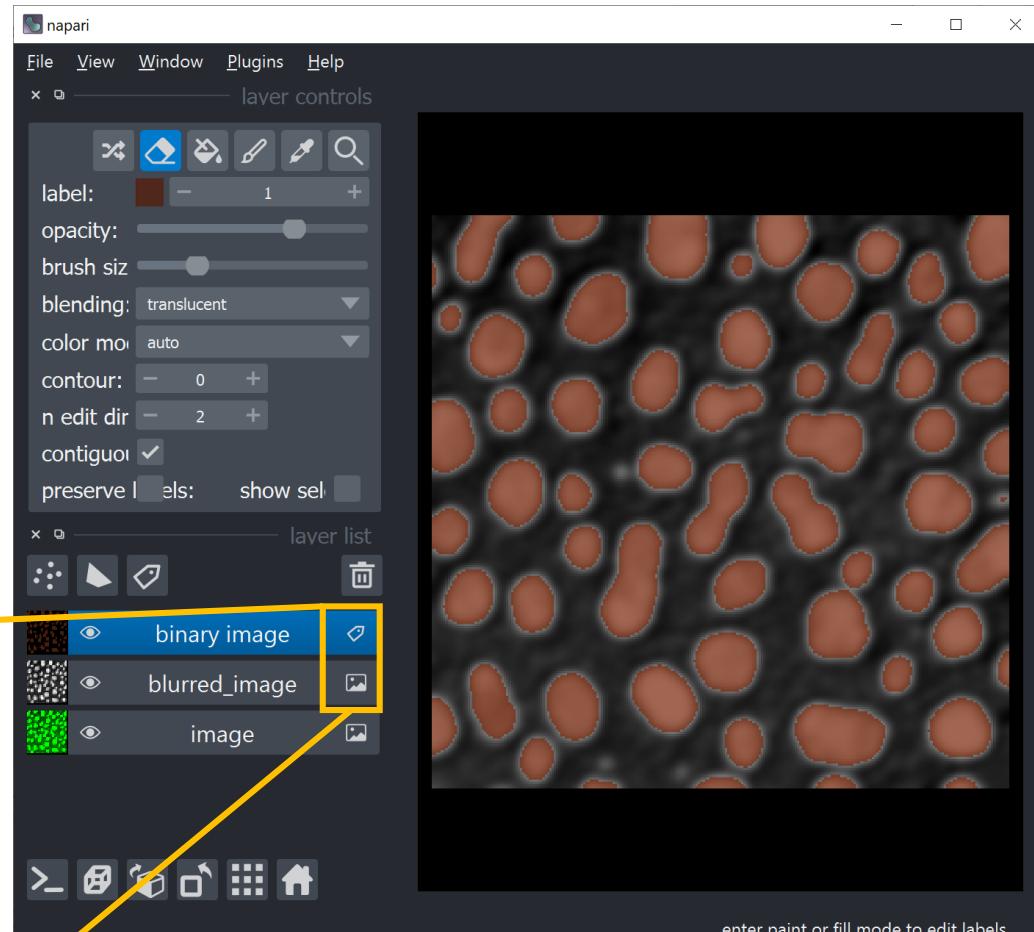
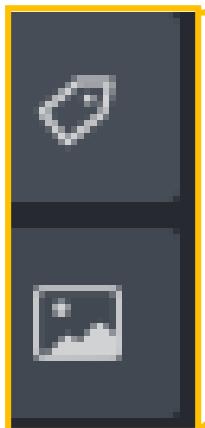
- Binary images and `label` images visualized as label layers

- `# Add a new labels layer containing an image`
- `viewer.add_labels(binary_image,`
- `name="binary image")`

Name your layers to keep track of what they contain

Labels Layer

Image Layer



enter paint or fill mode to edit labels

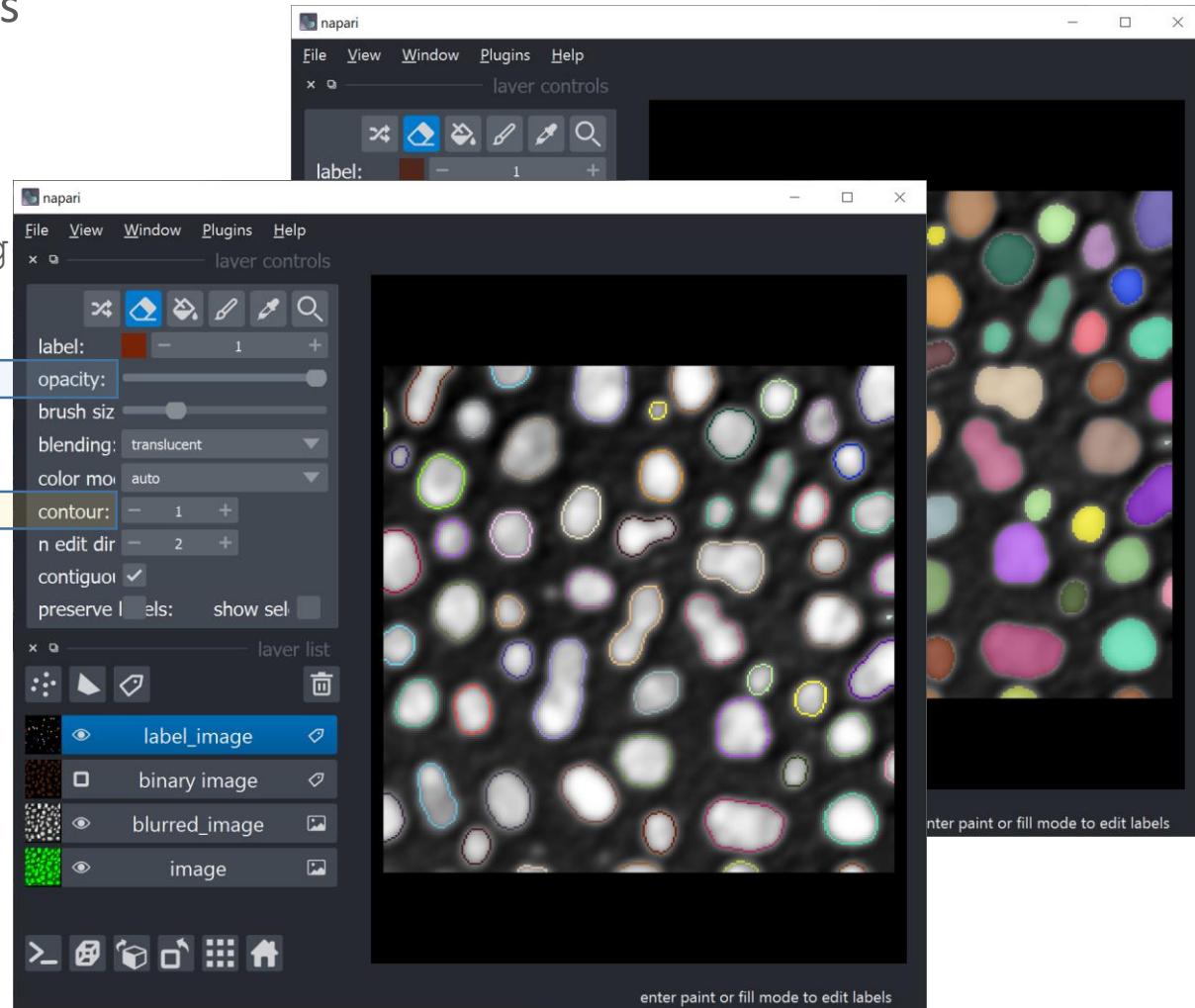
Visualizing image segmentation

- Binary images and label images visualized as label layers

- ```
add labels to viewer
```
- ```
label_layer = viewer.add_labels(label_image)
```

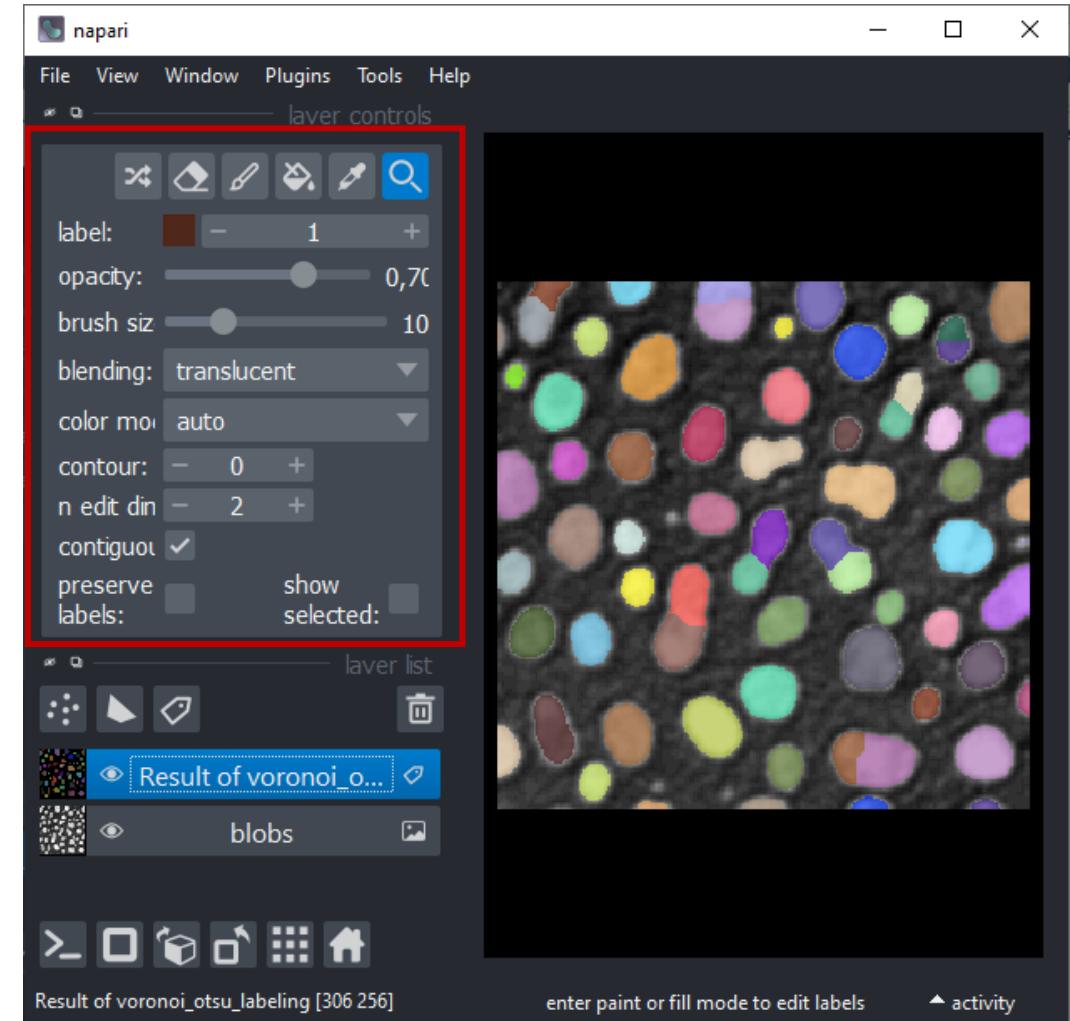
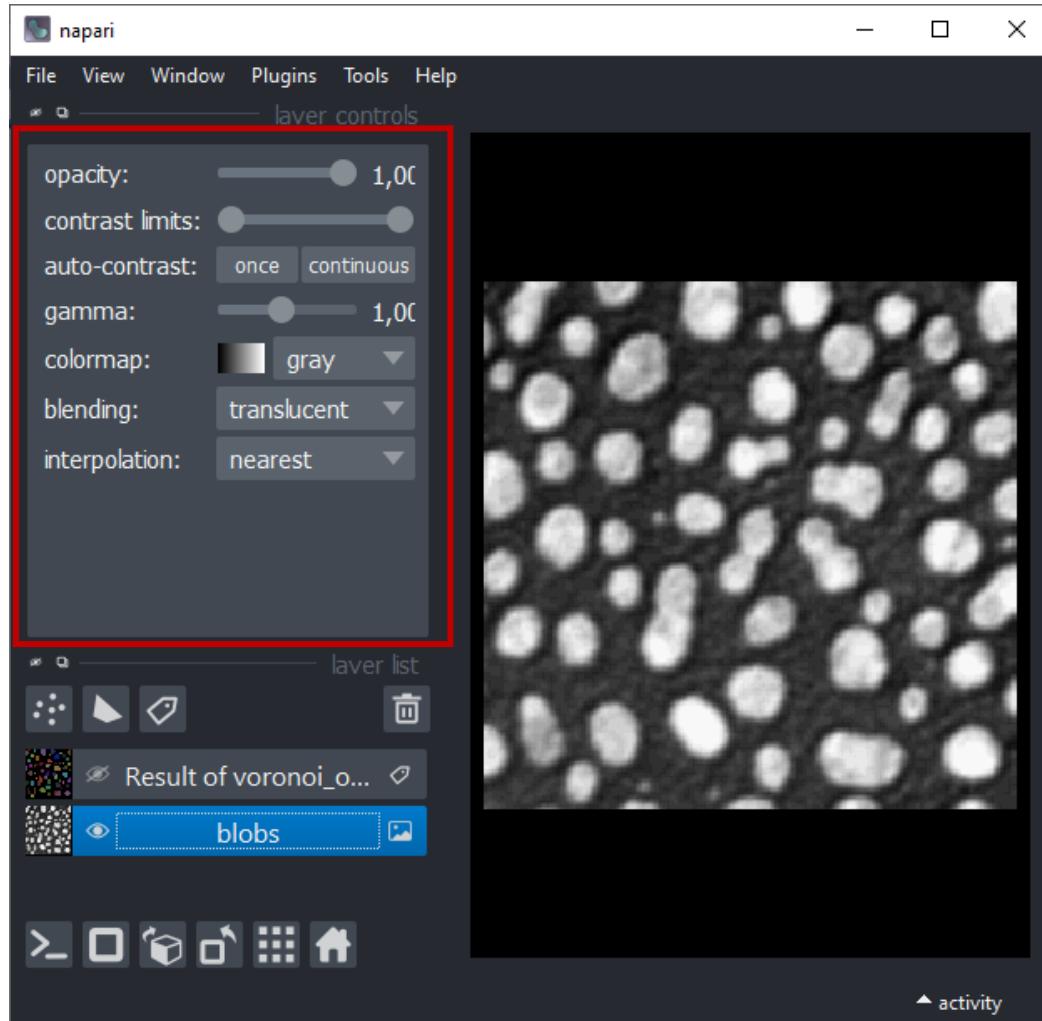
- Visualize contours instead of the overlay

- ```
label_layer.contour = 1
```
- ```
label_layer.opacity = 1
```



Visualizing image segmentation

Different layers have different configurations



Points layers

- There is also other layer types

- Shapes
- Points
- Surfaces
- Tracks
- Vectors

```
# add points to viewer
label_layer = viewer.add_points(points,
    face_color='green', symbol='cross', size=5)
```

