Image Processing: Filters

Till Korten

With material from

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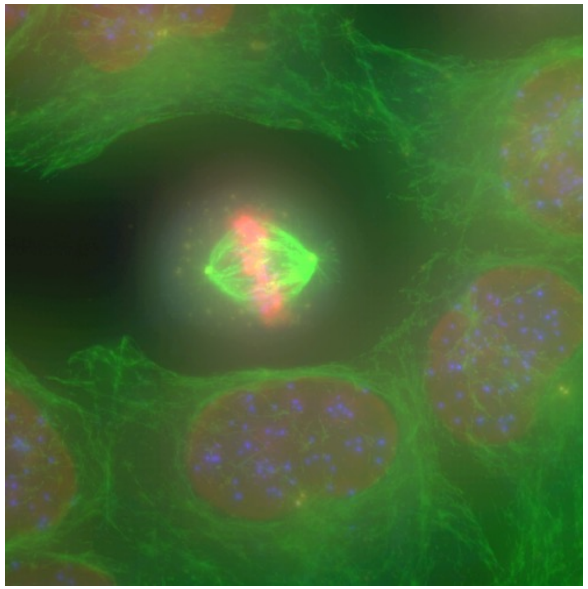
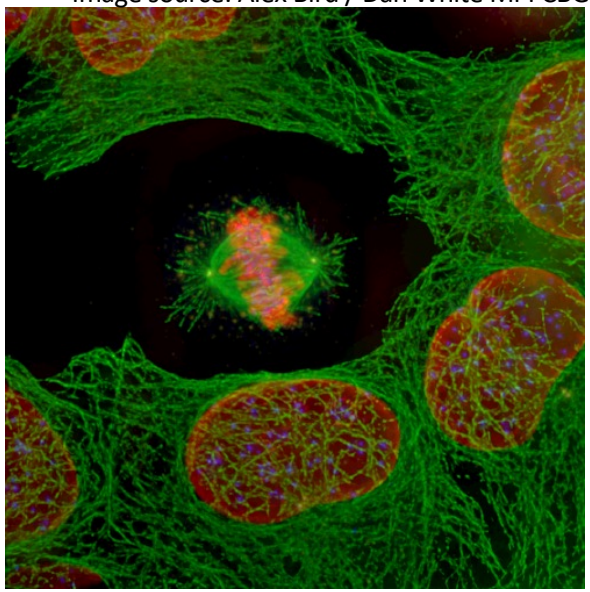
Filters are usually used to enhance features of interest

- An image processing filter is an operation on an image.
- It takes an image and produces a new image out of it.
- Filters change pixel values.
- There is no “best” filter. Which filter fits your needs, depends on the context.
- Filters do not do magic. They can not make things visible which are not in the image.



Filter

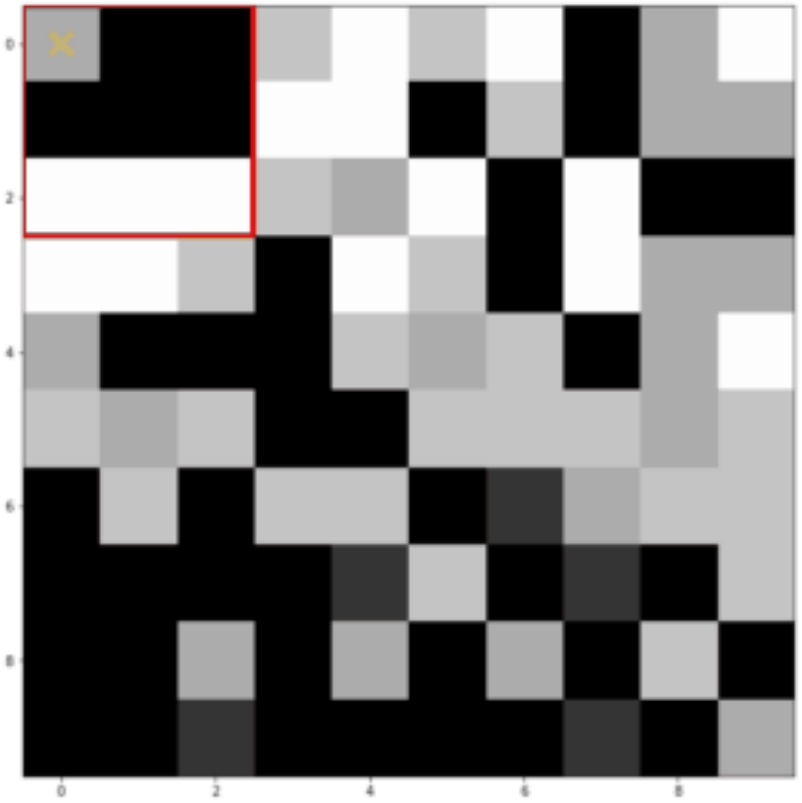
Image source: Alex Bird / Dan White MPI CBG



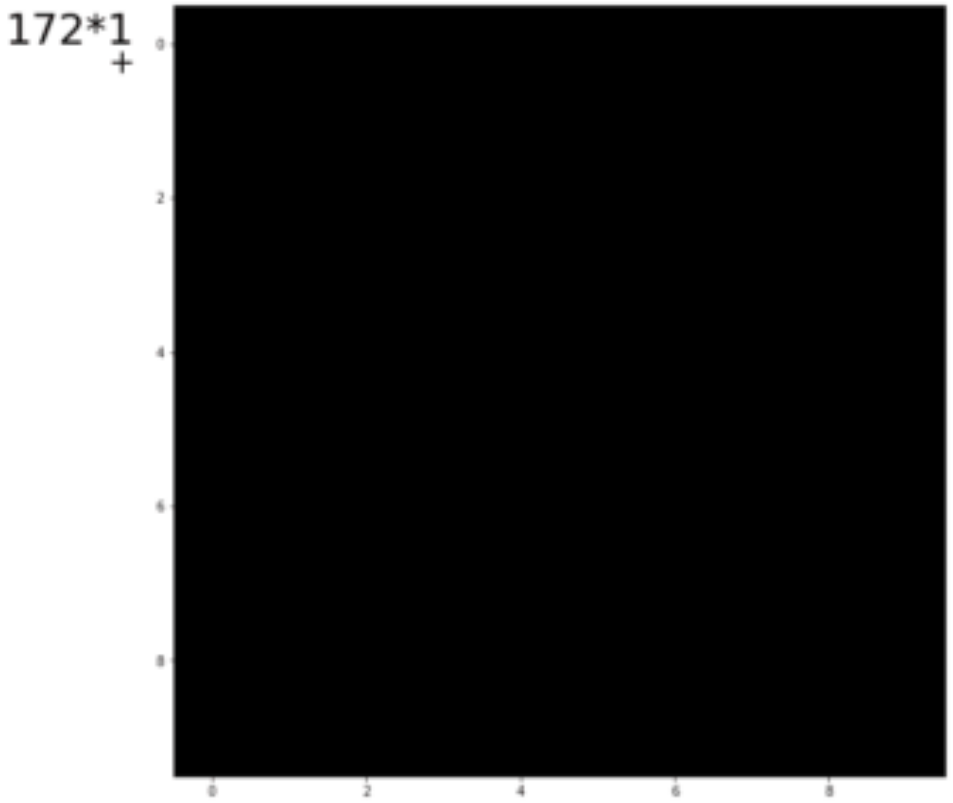
Filters apply an algorithm to each pixel of an image

Example: mean filter

Input image



Output image

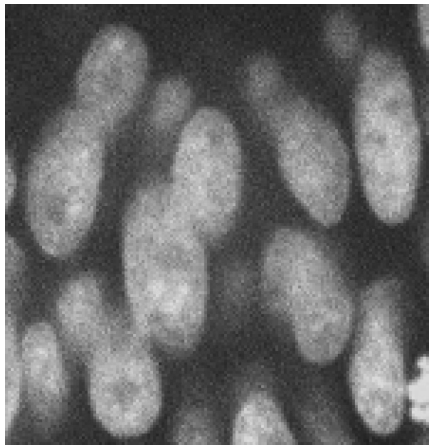


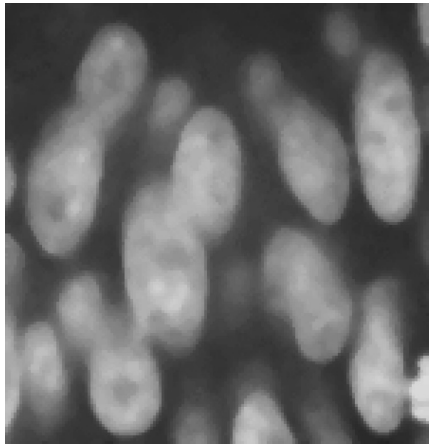
Animation source: Dominic Waithe, Oxford University
https://github.com/dwaithe/generalMacros/tree/master/convolution_ani

Common applications for image filters

PoL Physics of Life TU Dresden

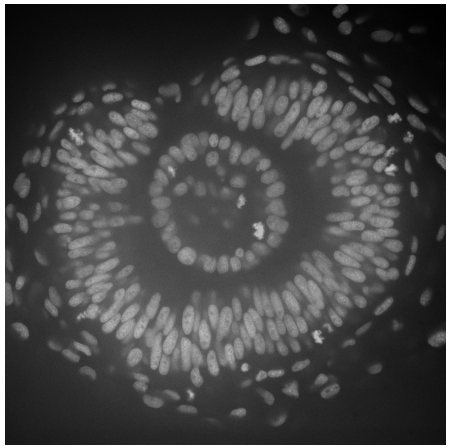
Noise reduction

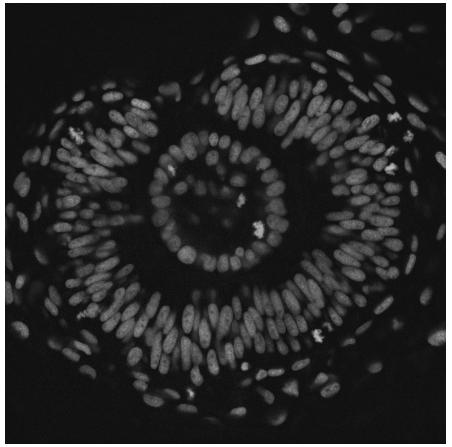




Mauricio Rocha Martins (Norden/Myers lab, MPI CBG)

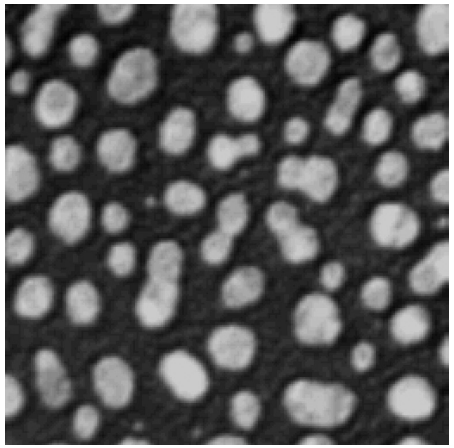
Background removal

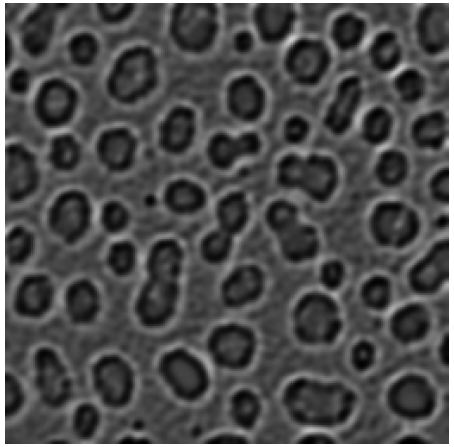




Mauricio Rocha Martins (Norden/Myers lab, MPI CBG)

Edge detection





https://imagej.nih.gov/ij/images/

De-convolution

Stub Mandrel, CC BY-SA 4.0, via Wikimedia Commons

Noise reduction

- In microscopy, noise is usually comprised of
  - shot noise: Statistical variation of the photons arriving at the camera
  - dark noise: noise produced by thermal fluctuations in the camera chip
  - read out noise: introduced by the electronics, especially the analog-digital-converter

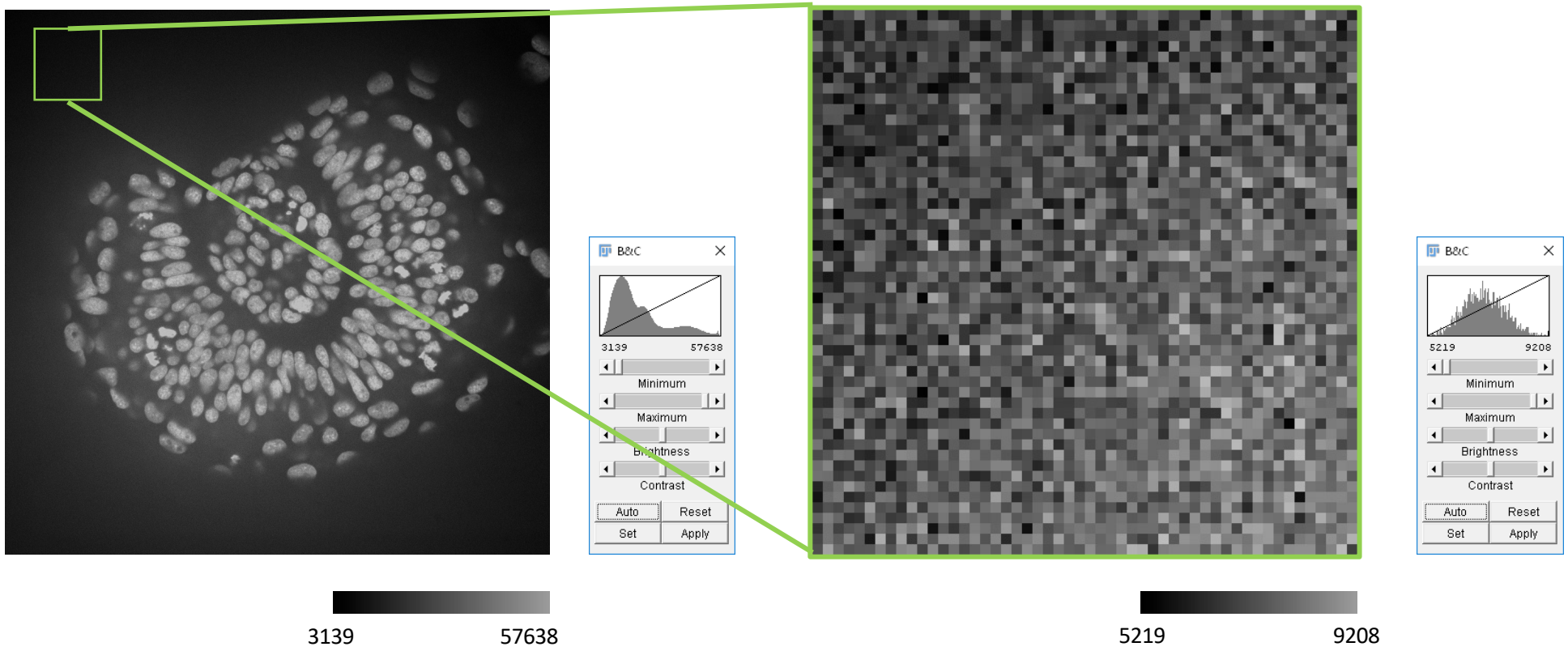


Image source: Mauricio Rocha Martins (Norden/Myers lab, MPI CBG)

Reducing noise by lightly blurring the image

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```
from skimage.filters import median, gaussian
from skimage.morphology import disk

zfish_gaussian = gaussian(cropped_zfish, sigma=2, preserve_range=True)
zfish_median = median(cropped_zfish, footprint=disk(4))
```

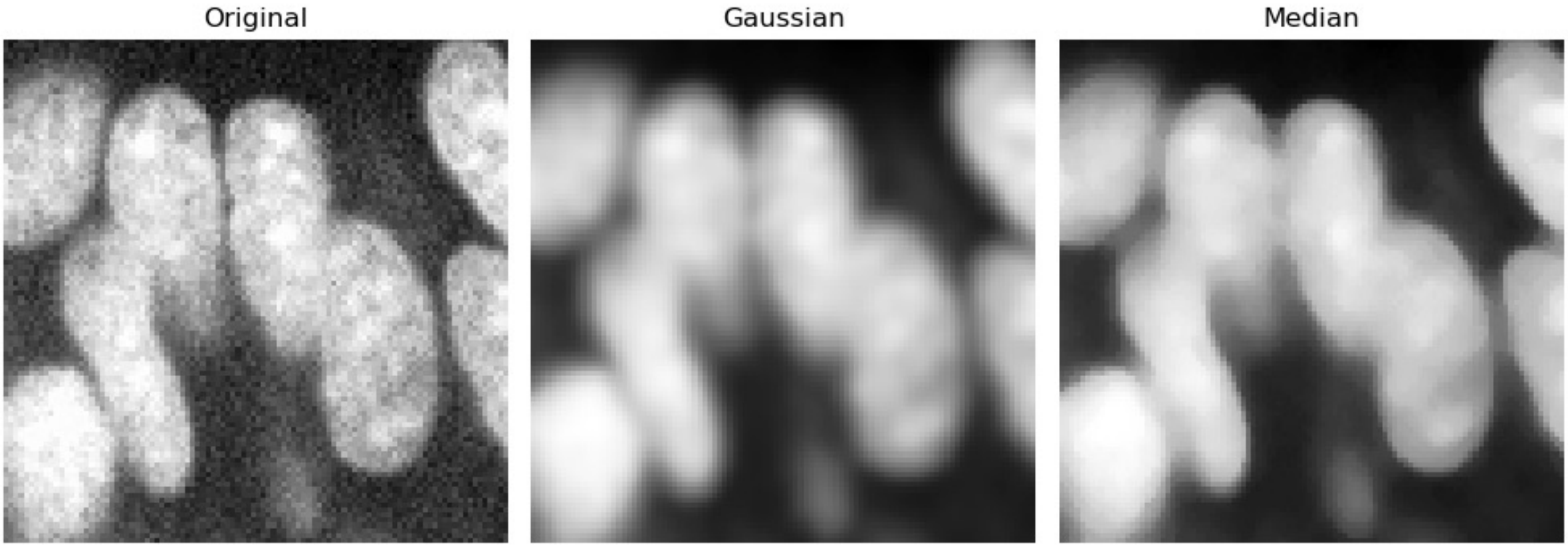
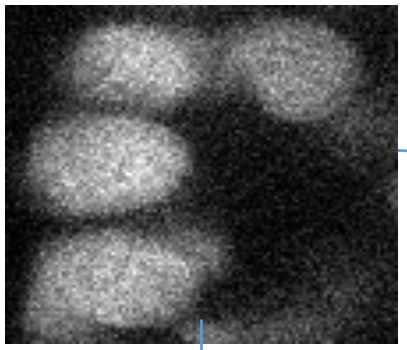


Image source: Mauricio Rocha Martins (Norden/Myers lab, MPI CBG)

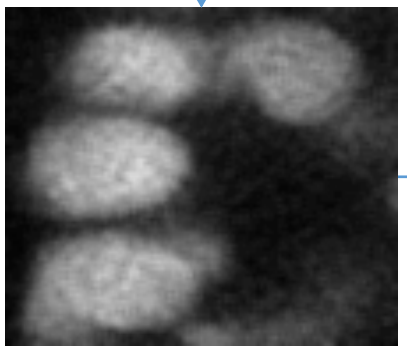
Removing noise helps the computer *interpret* the image



Thresholding

Oh no! I see thousands of tiny white objects!

Blurring



Thresholding

Ok, it's just 4 objects.

Background removal

- Differentiating objects is easier if their background intensity is equal.

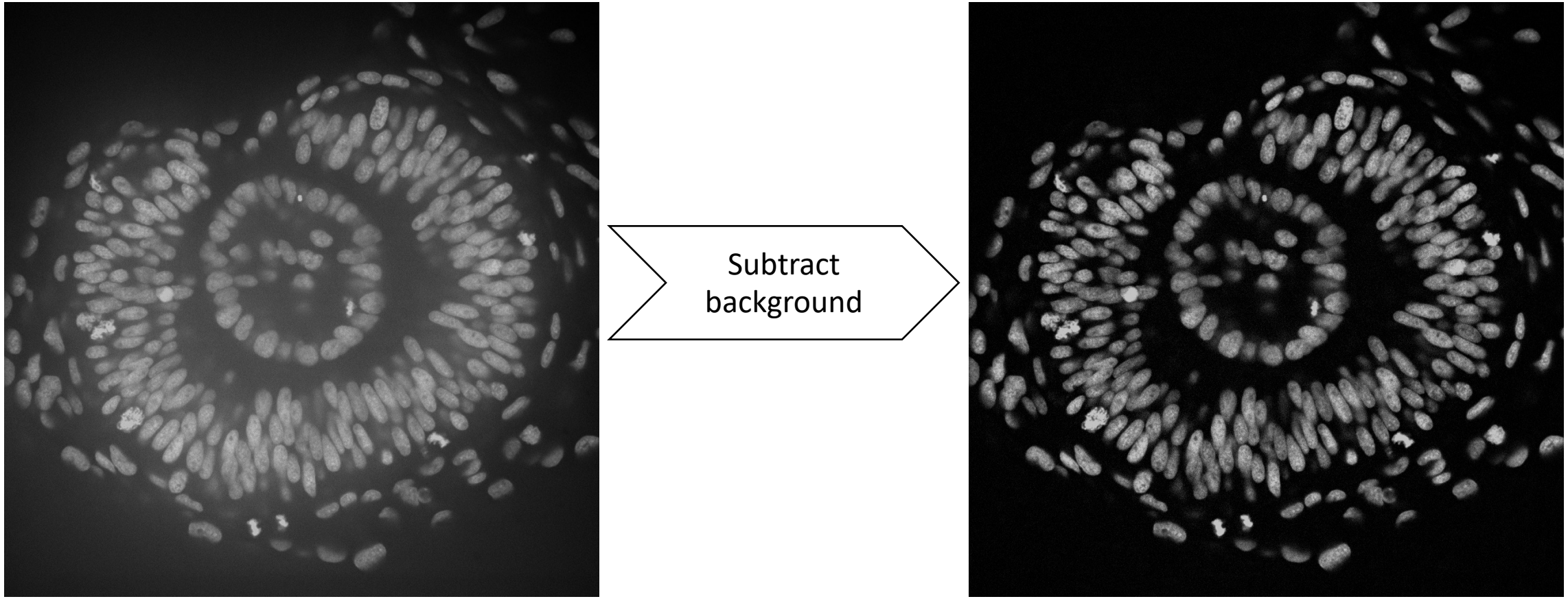


Image source: Mauricio Rocha Martins (Norden/Myers lab, MPI CBG)

Removing background with the white_tophat filter

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TU Dresden

```
from skimage.morphology import disk, white_tophat

zfish_tophat = white_tophat(zfish_image, footprint=disk(50))

background_tophat = zfish_image - zfish_tophat
```

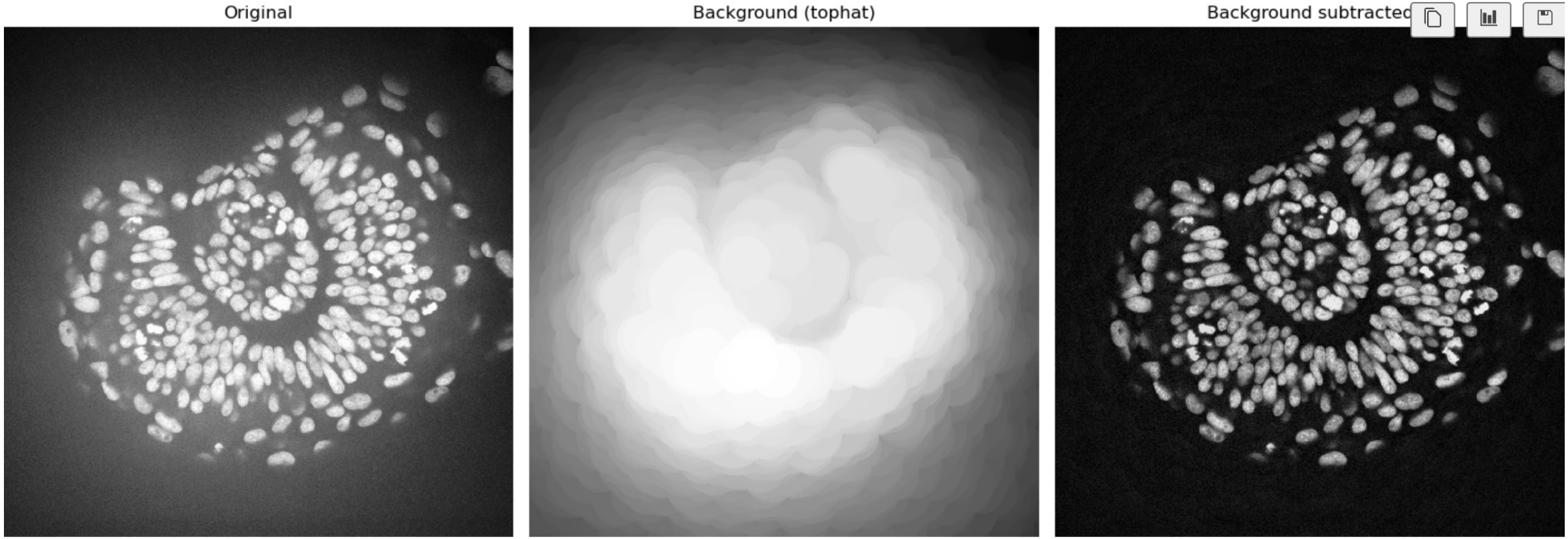
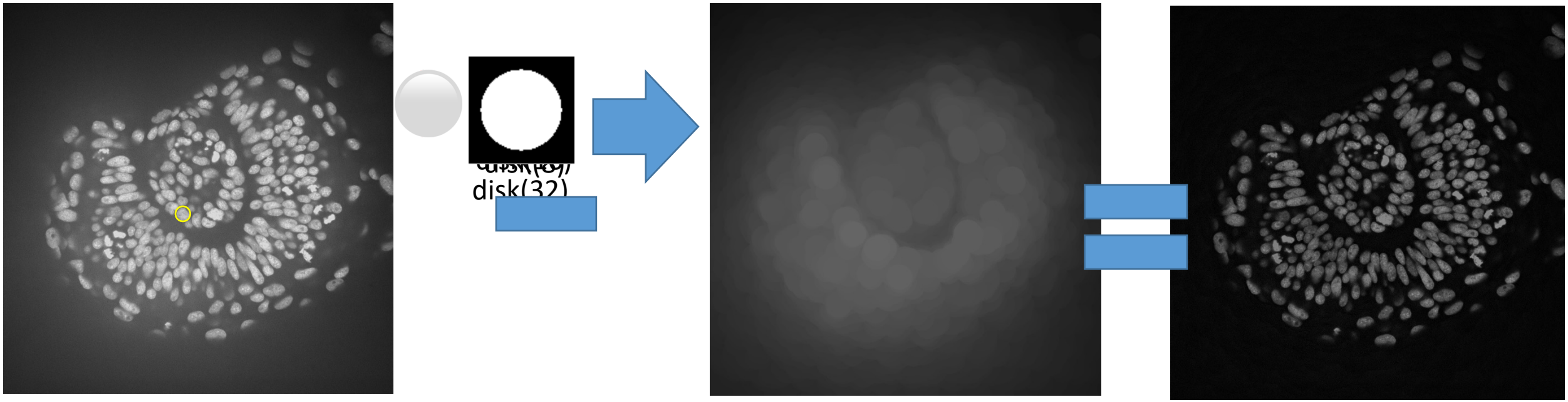


Image source: Mauricio Rocha Martins (Norden/Myers lab, MPI CBG)

The effect of footprint size

white_tophat



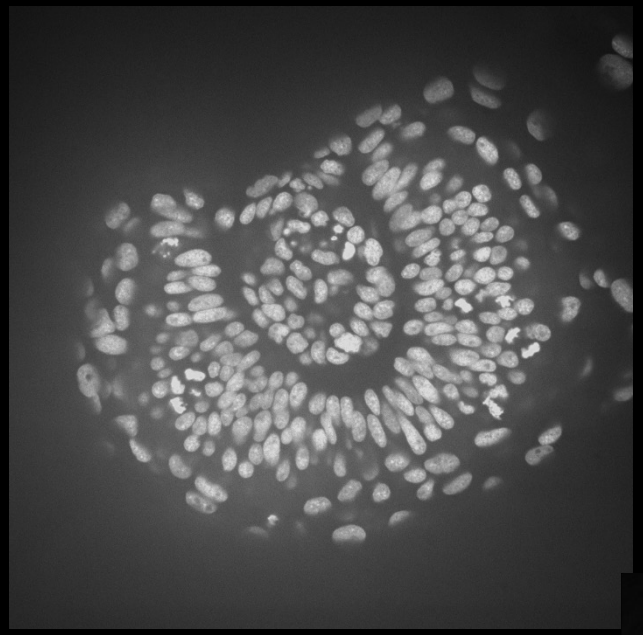
Original image

This is a good estimation of the background

Structures have a radius ≈ 12

Image source: Mauricio Rocha Martins (Norden/Myers lab, MPI CBG)

The effect of footprint size



What happens for a small structuring element (e.g., disk (2))?

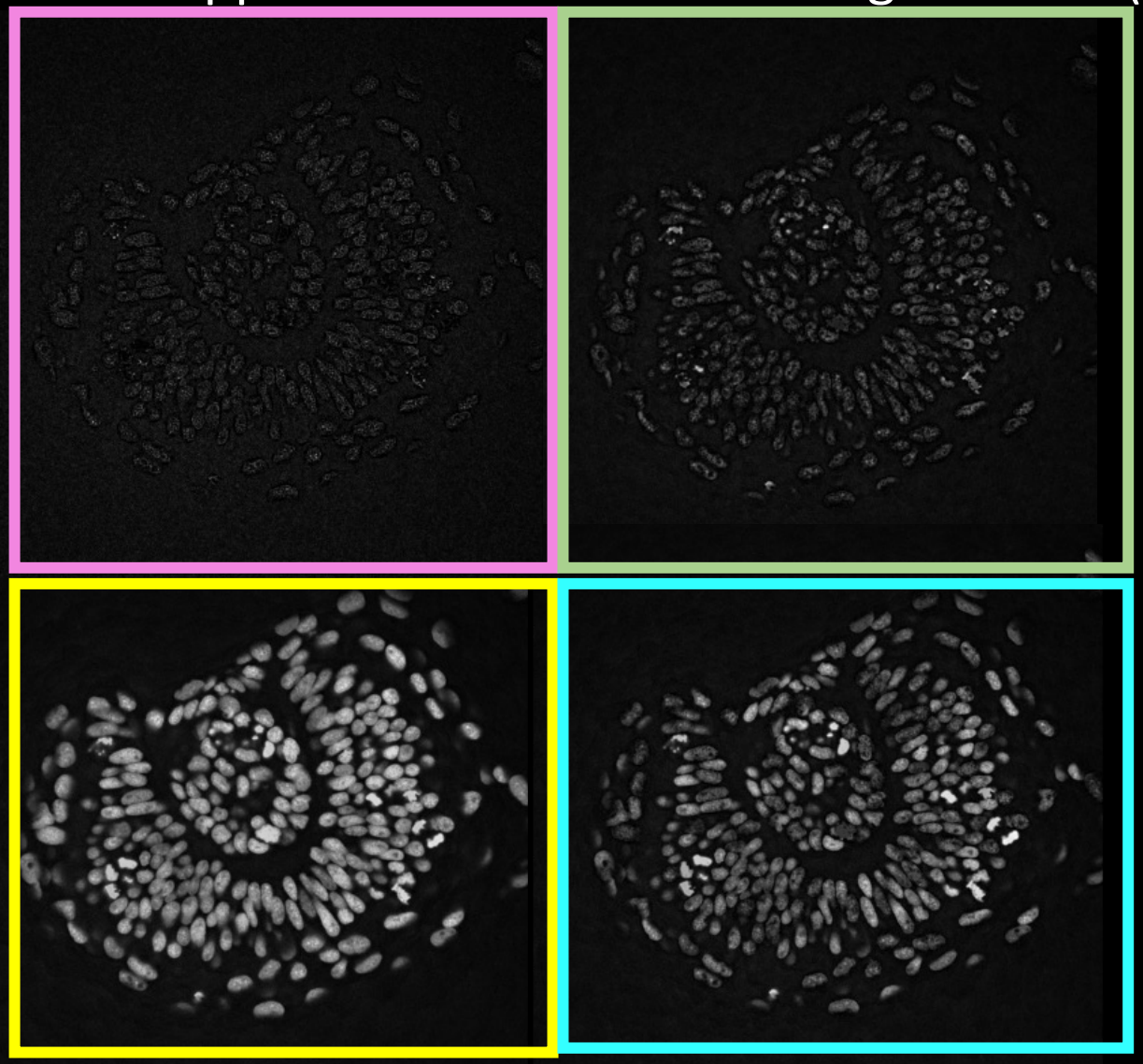
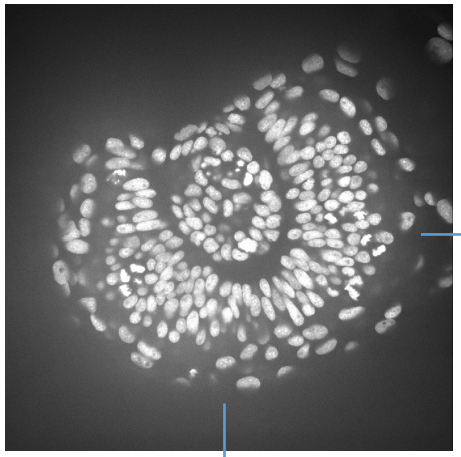
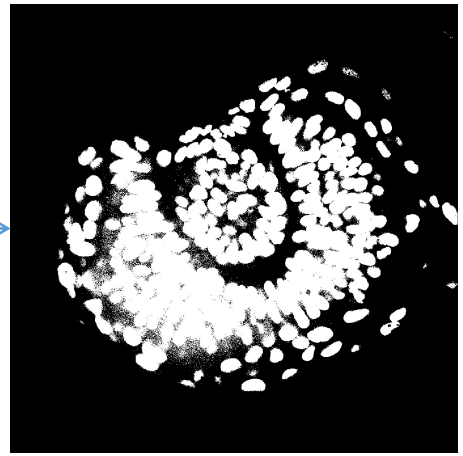


Image source: Mauricio Rocha Martins (Norden/Myers lab, MPI CBG)

Removing background helps the computer *interpret* the image

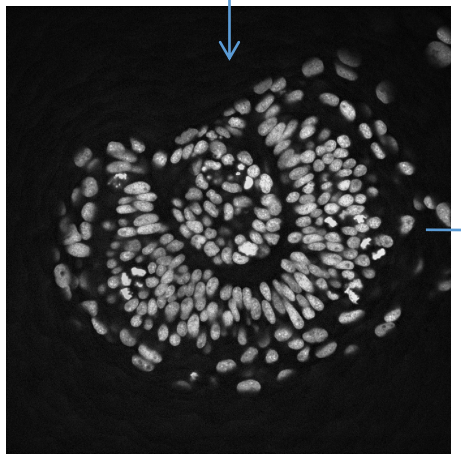


Thresholding

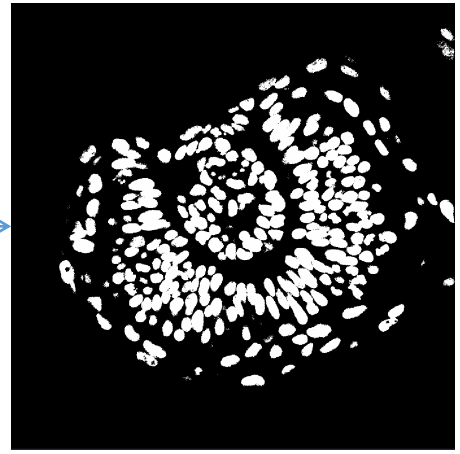


Oh no! I cannot distinguish some objects!

Background removal



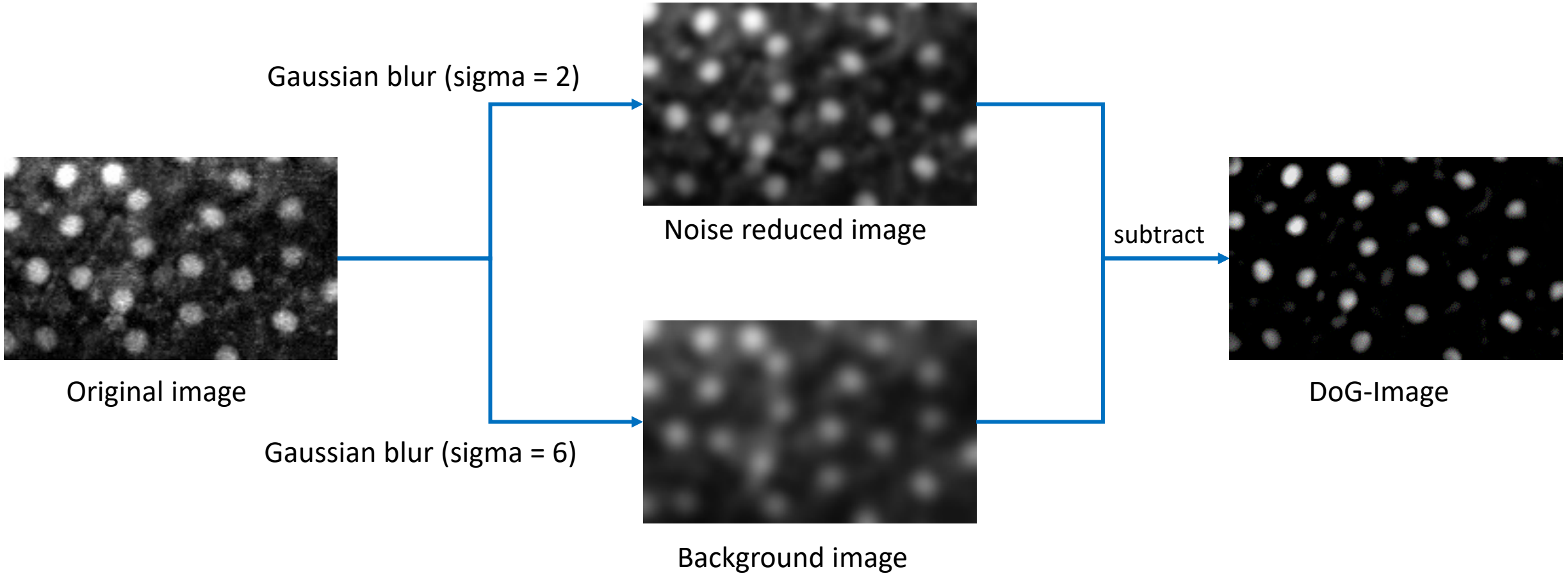
Thresholding



Ok, now I can distinguish most objects.

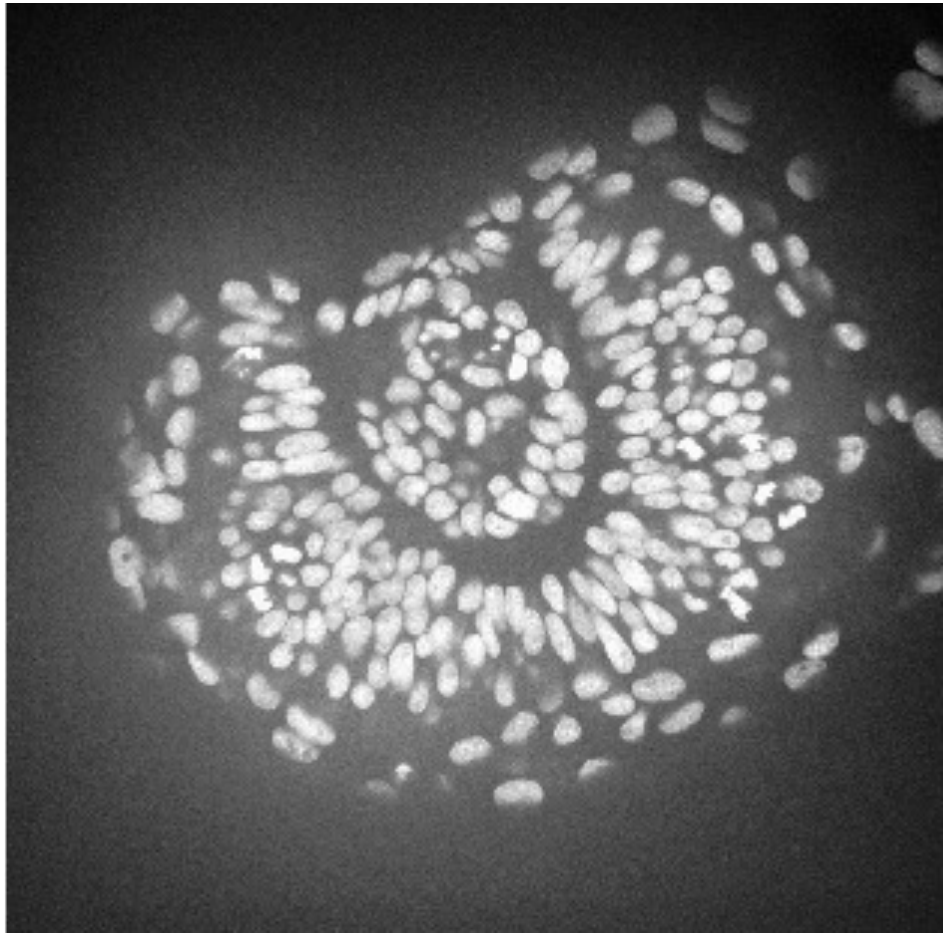
Difference-of-Gaussian (DoG)

- Combine noise reduction with background removal.

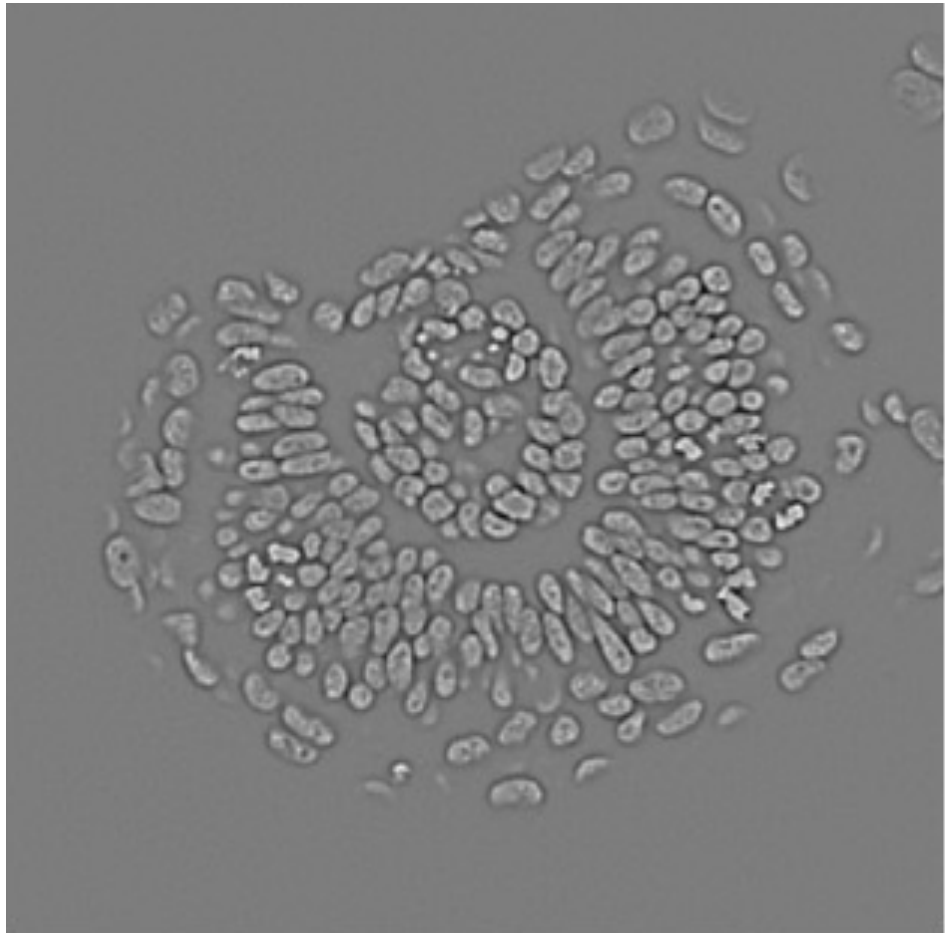


Edge detection

- Detecting the edges of objects can be useful in identifying object boundaries



Detect edges

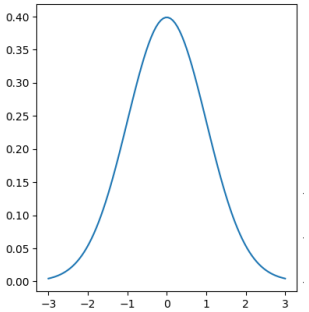


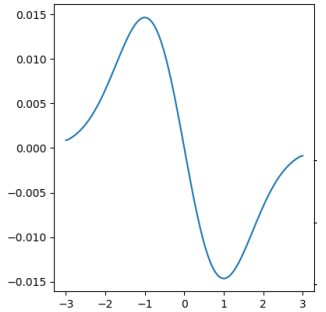
The Laplace-filter is frequently used to detect edges

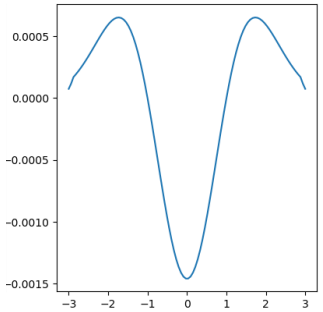
- *Second derivative of a Gaussian blur filter*
- Used for edge-detection and edge enhanc
- Also known as the Mexican-hat-filter

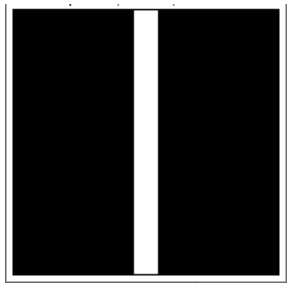
1st derivative

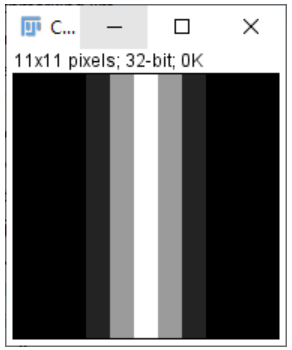
2nd derivative

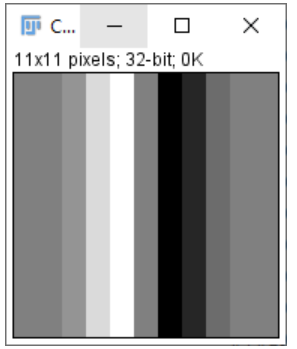


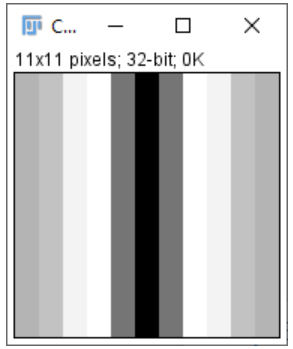


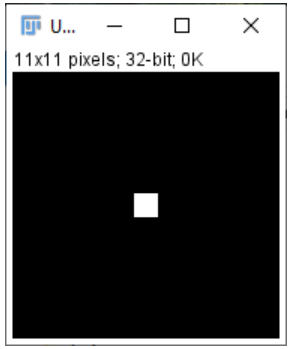


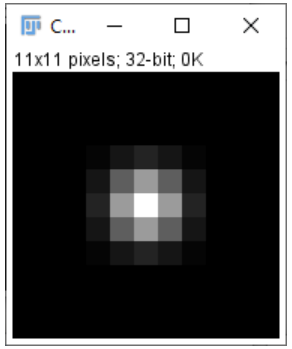


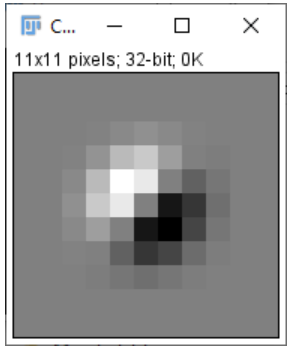


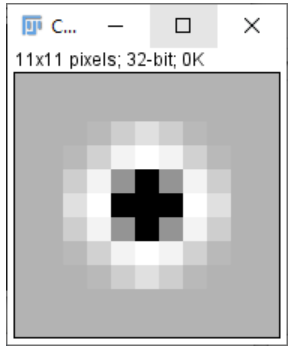




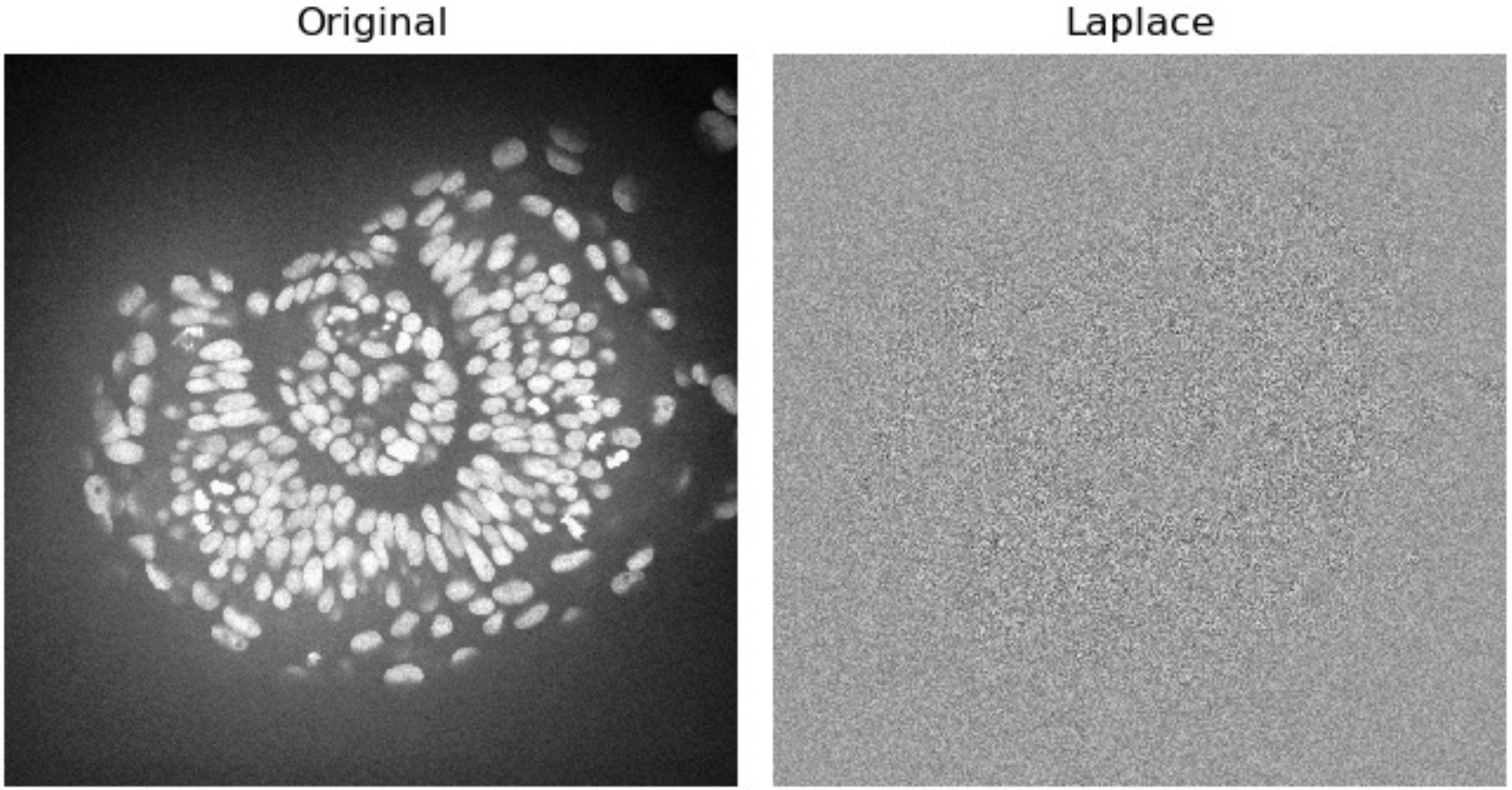








The Laplace filter does not work well on noisy data



Reducing noise improves the output of the Laplace filter