Images

University of Colorado Boulder

MCDB/BCHM 4312/5312
Fall 2020

Announcement

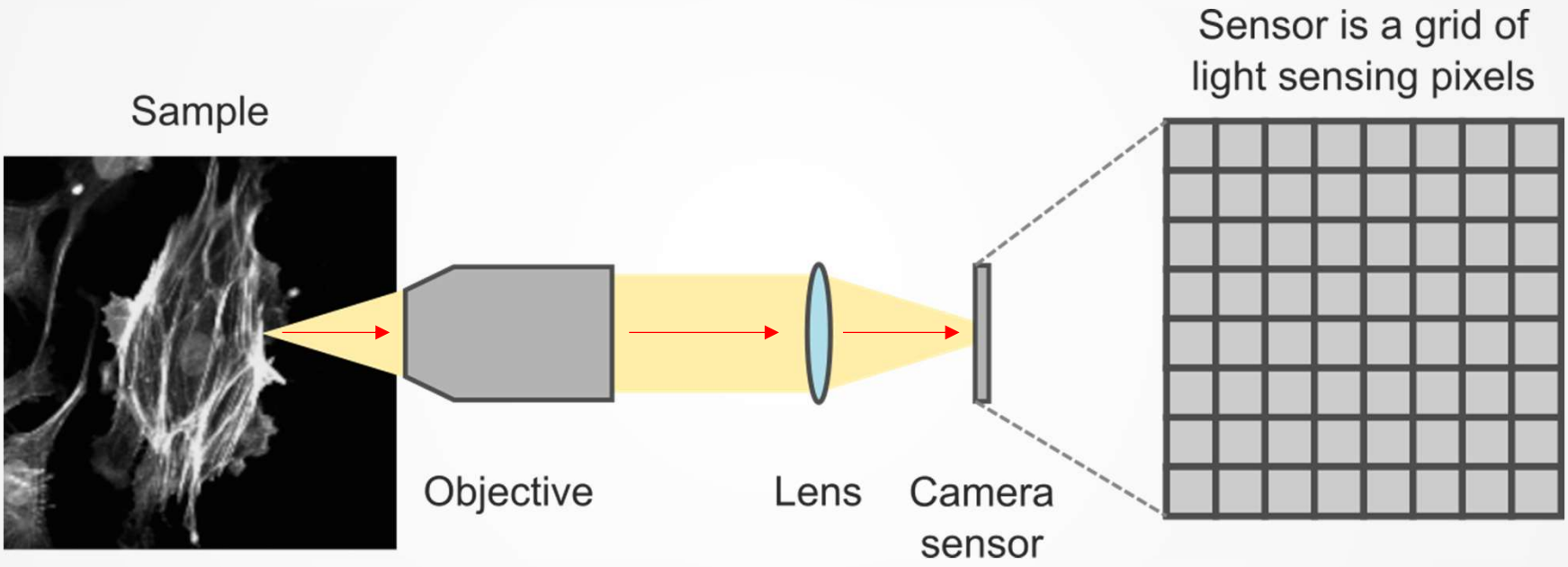
- Q1 of PS4 will be covered next week

Homework feedback

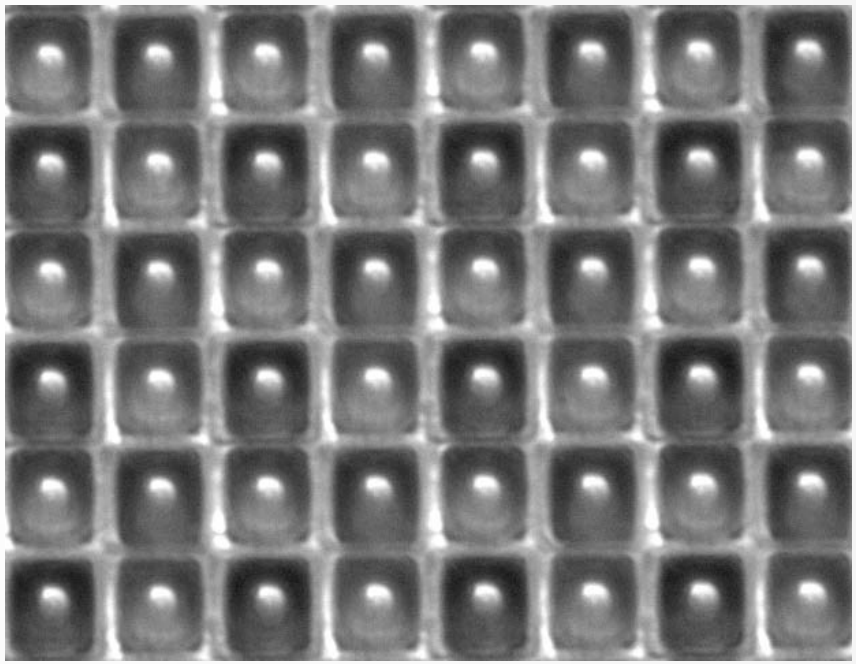
- Mean/std instead of by rows
- Try not to use for loops

How digital images are recorded

Image is projected onto camera sensor



Scientific-grade digital cameras

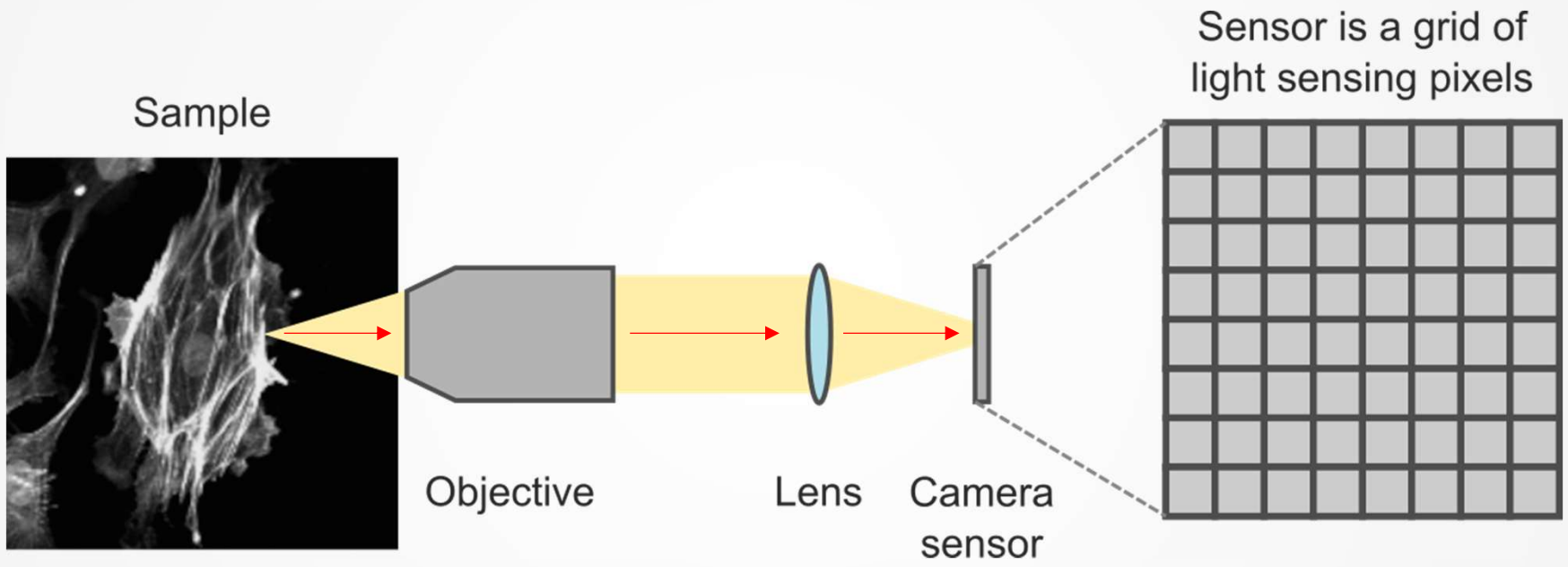


Question

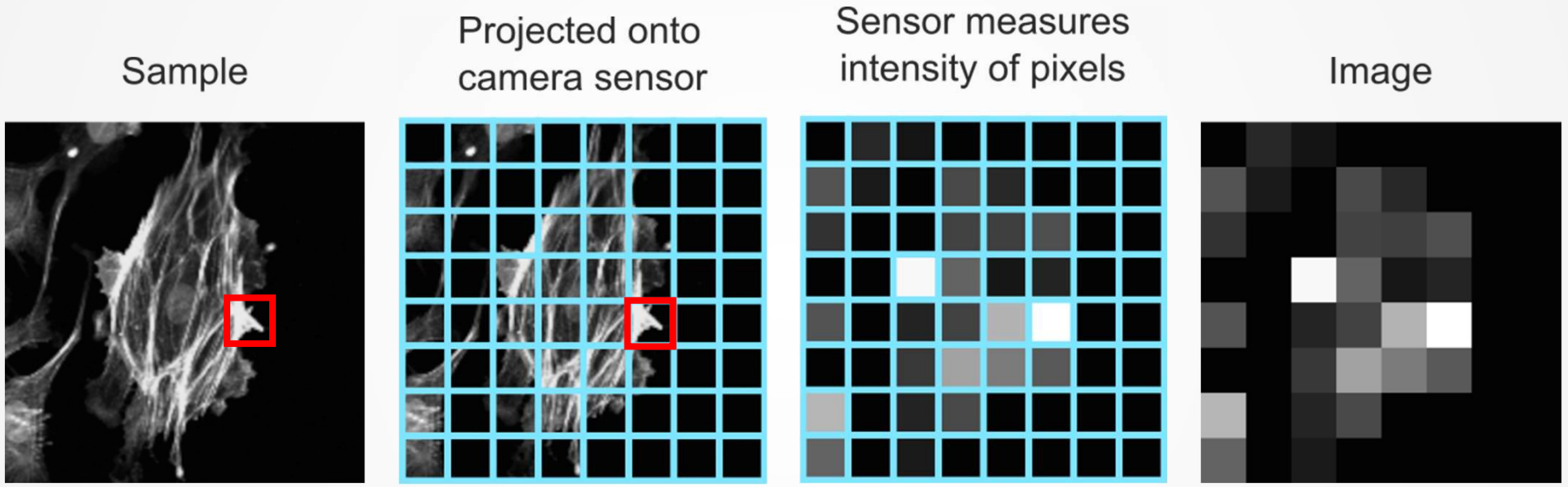
- For an image to be projected onto the camera sensor, it must be _____

A. Real
B. Imaginary

A real image is projected onto camera sensor



The sensor measures light falling on each pixel



What is the effective pixel size or image resolution?

A. The number of pixels illuminated by light
B. The size of the pixel of the camera
C. The number of pixels in an image
D. The region of the sample that is imaged onto a single camera pixel

The sensor measures light falling on each pixel

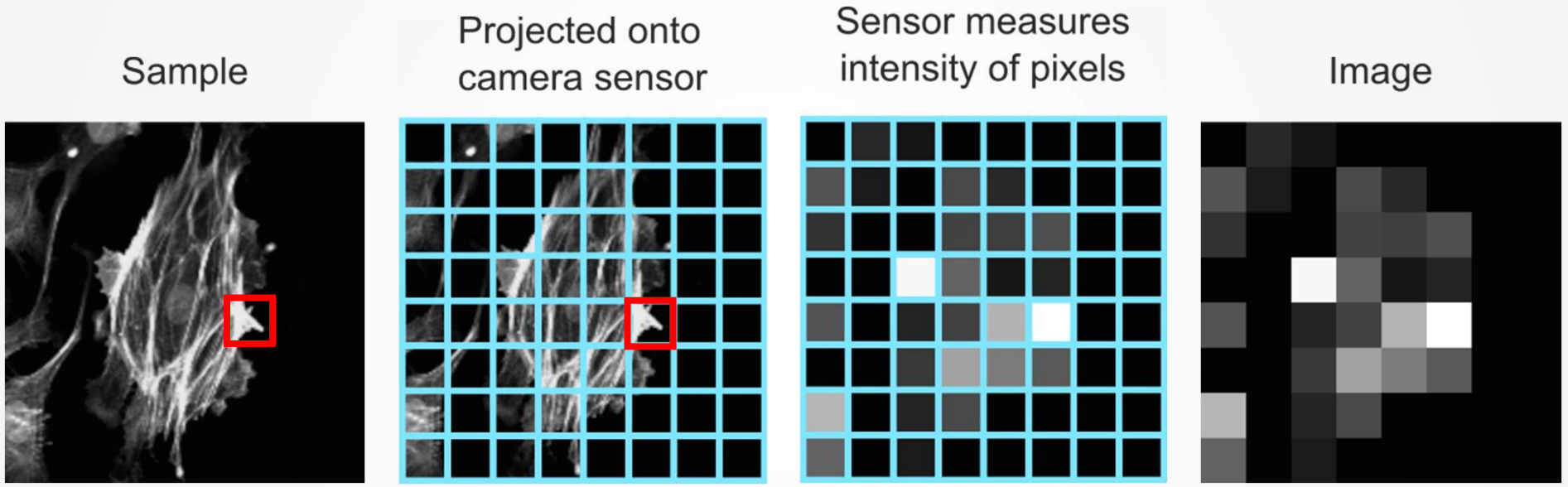
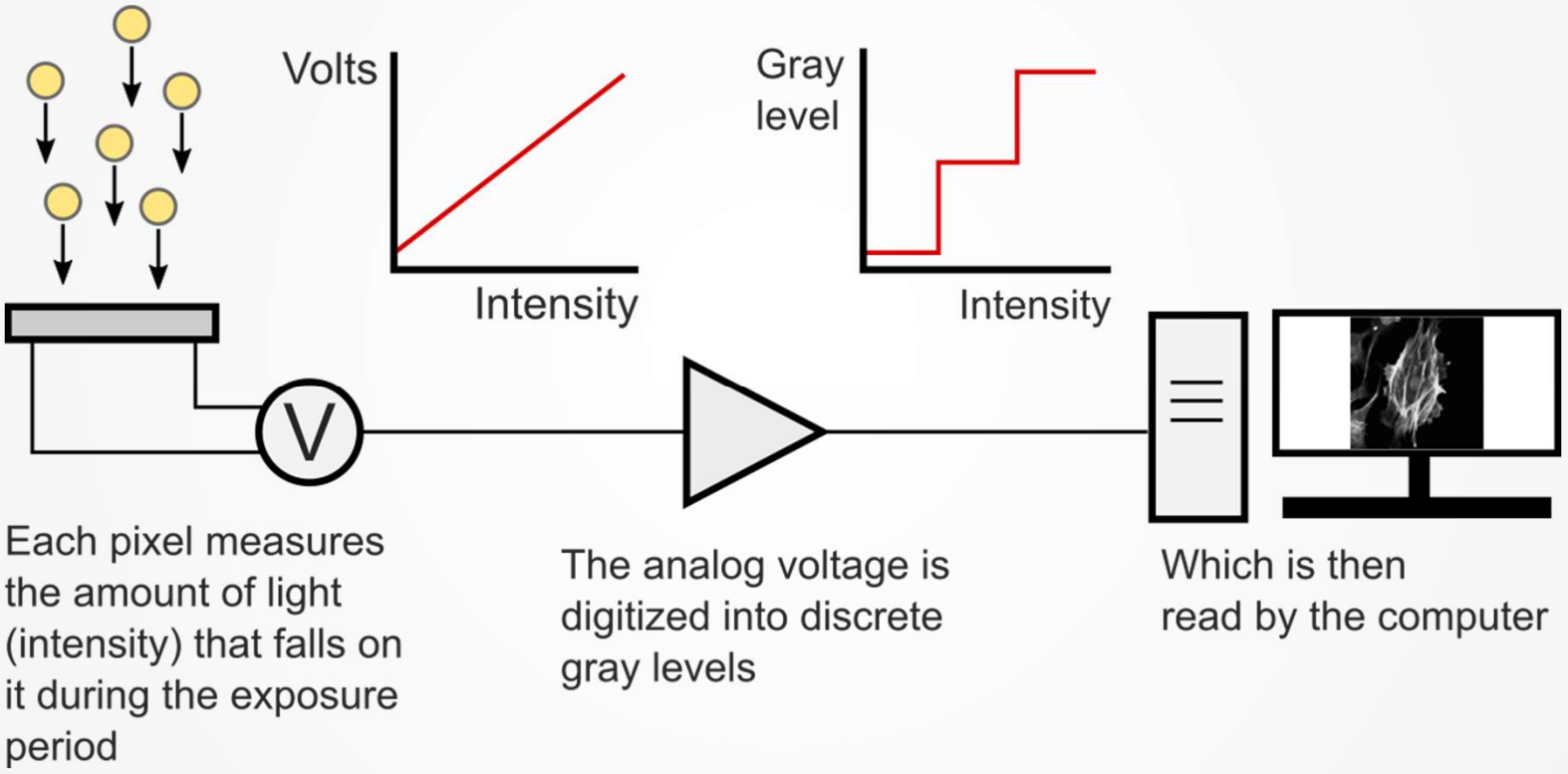


Image **resolution** or **effective pixel size** = Area of sample projected on to a pixel
Usually reported in units of µm/px
Calibrated by microscope company

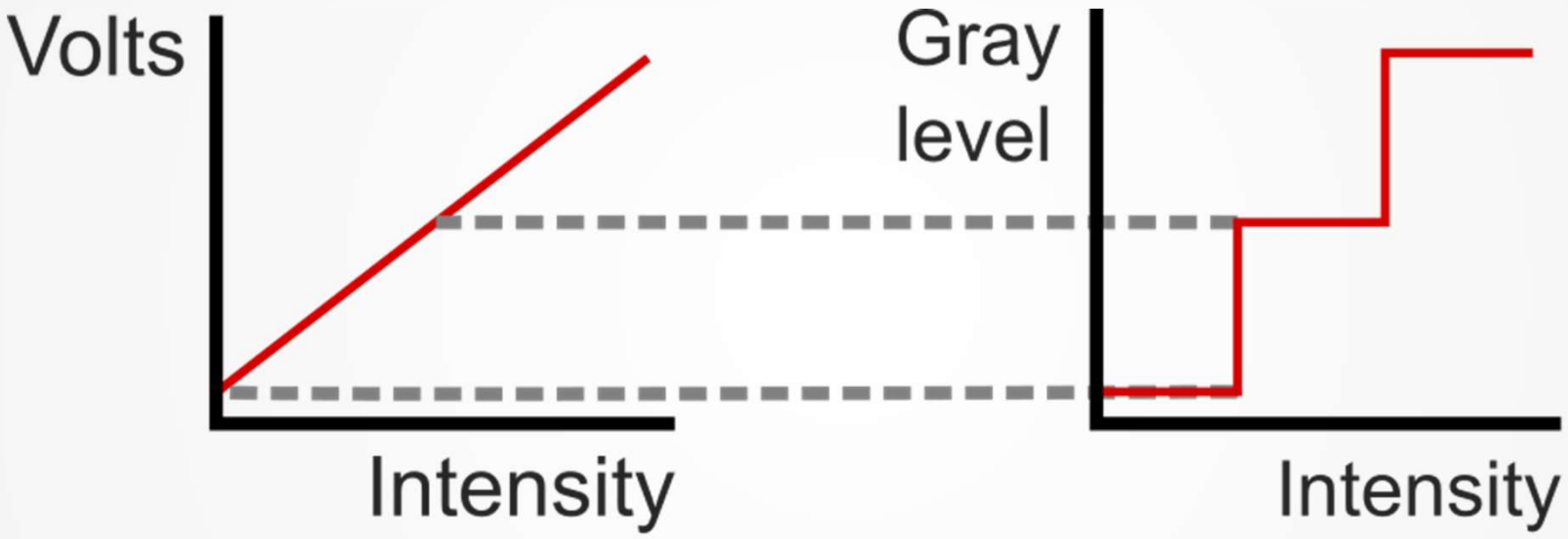
Which factors affect the effective pixel size?

A. Number of camera pixels
B. Size of the sample
C. Magnification of the objective
D. Physical size of the camera pixels

Analog intensity is converted to digital gray levels



Number of steps = bit depth

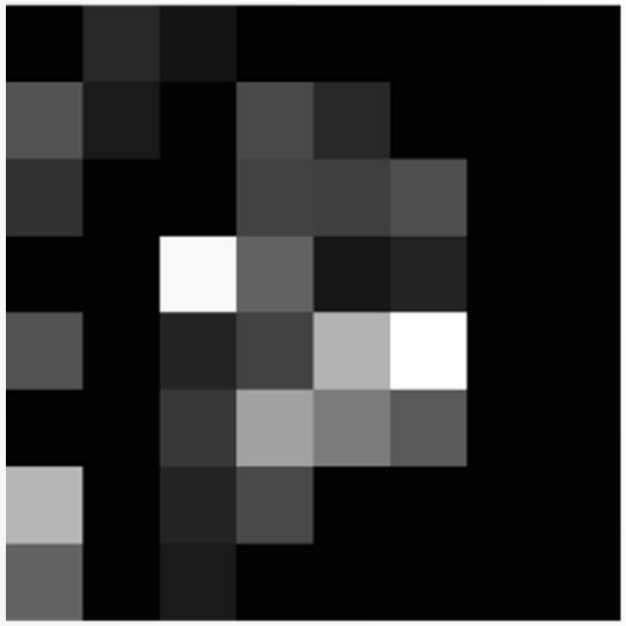


Each gray level represents a range of intensities

Units of gray level (intensity) = Counts/ A.U./ I.U.

Image data is stored as an array of numbers

Image



Data

3	40	20	3	3	3	3	3
83	26	3	70	40	3	3	3
50	3	3	66	63	79	3	3
3	3	248	99	23	36	3	3
83	3	36	66	179	255	3	3
3	3	56	162	123	89	3	3
182	3	36	73	3	3	3	3
99	3	26	3	3	3	3	3

What data type is used to store image data?

A. Signed integers

B. Character arrays

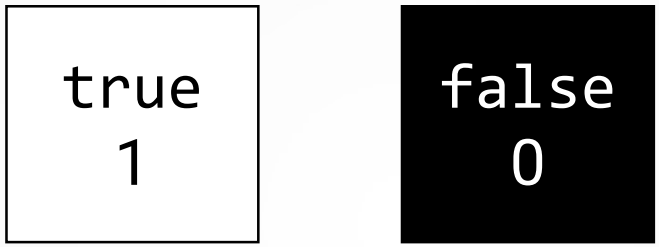
C. Unsigned integers

D. Double-precision floating-point format

E. What are data types?

Digital data is stored as bits

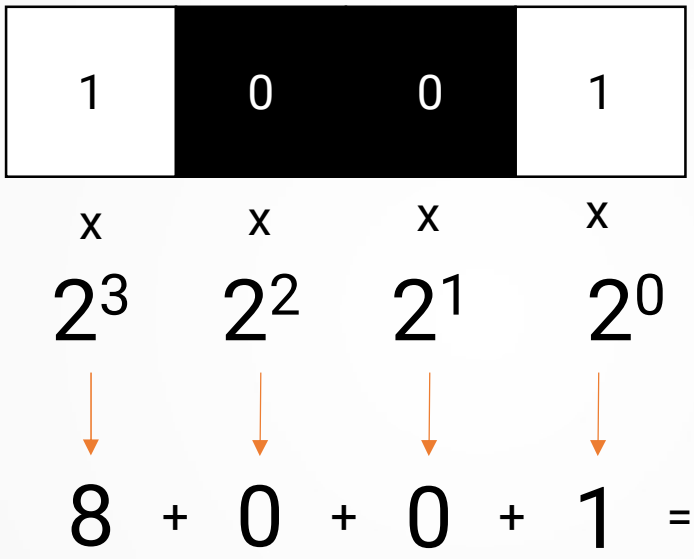
- A bit can only have one of two values



- How can we store different types of information (e.g. numbers and text) using just bits?

Data type or class in MATLAB

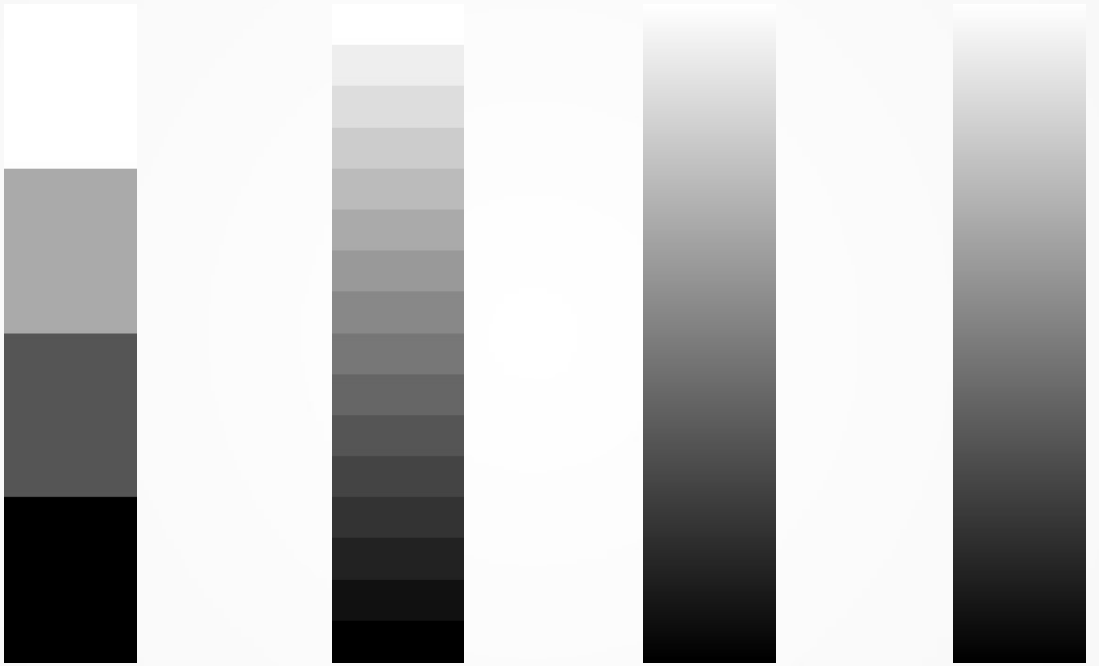
Unsigned integer



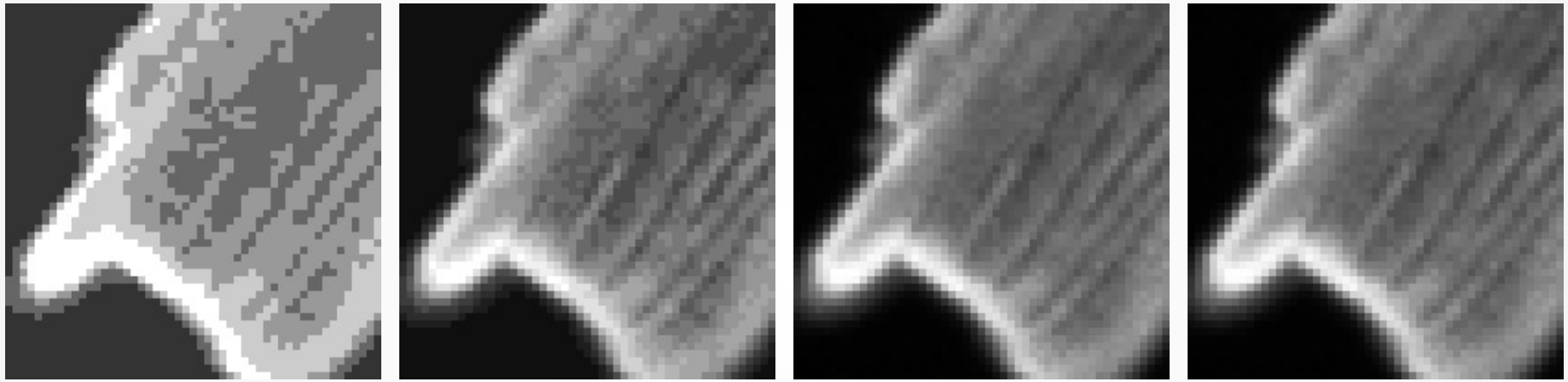
4-bit unsigned integer

The position of the bit indicates its value as a power of 2

Bit depth is the number of bits used to digitize the intensity



Bit depth

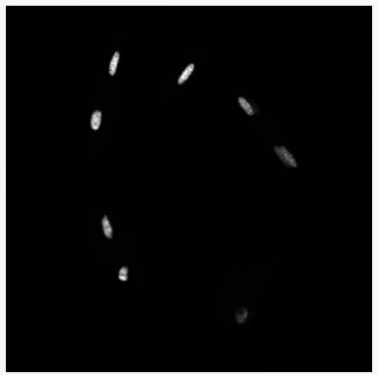


2 bit 4 bit 8 bit 16 bit

Glossary of terms

- **Pixel:** Sampled data point, element in matrix
- **Pixel value/intensity:** Numerical value of a pixel in image
- **Physical pixel size/effective pixel size/image resolution:** the region of the original sample projected on a pixel
- **Bit depth:** Number of bits used to quantize the intensity

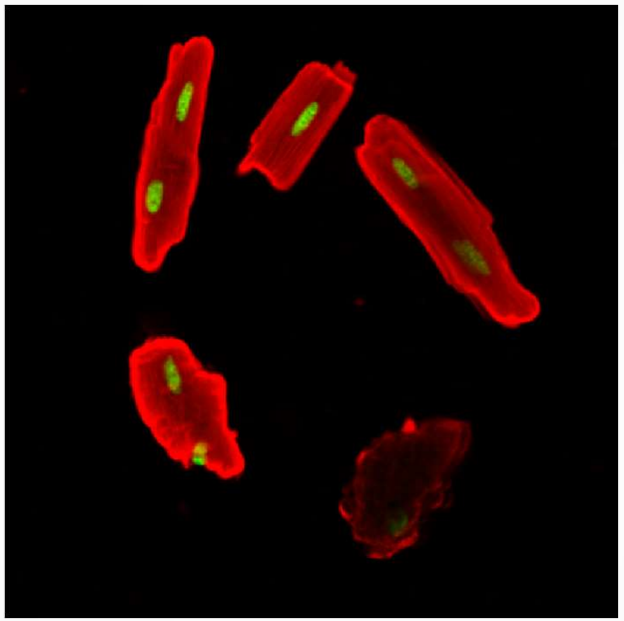
Grayscale



Matrix size 100x100

Data type `uint16`

Color (RGB)



100x100x3

`uint16`

Logical

100x100

`logical`

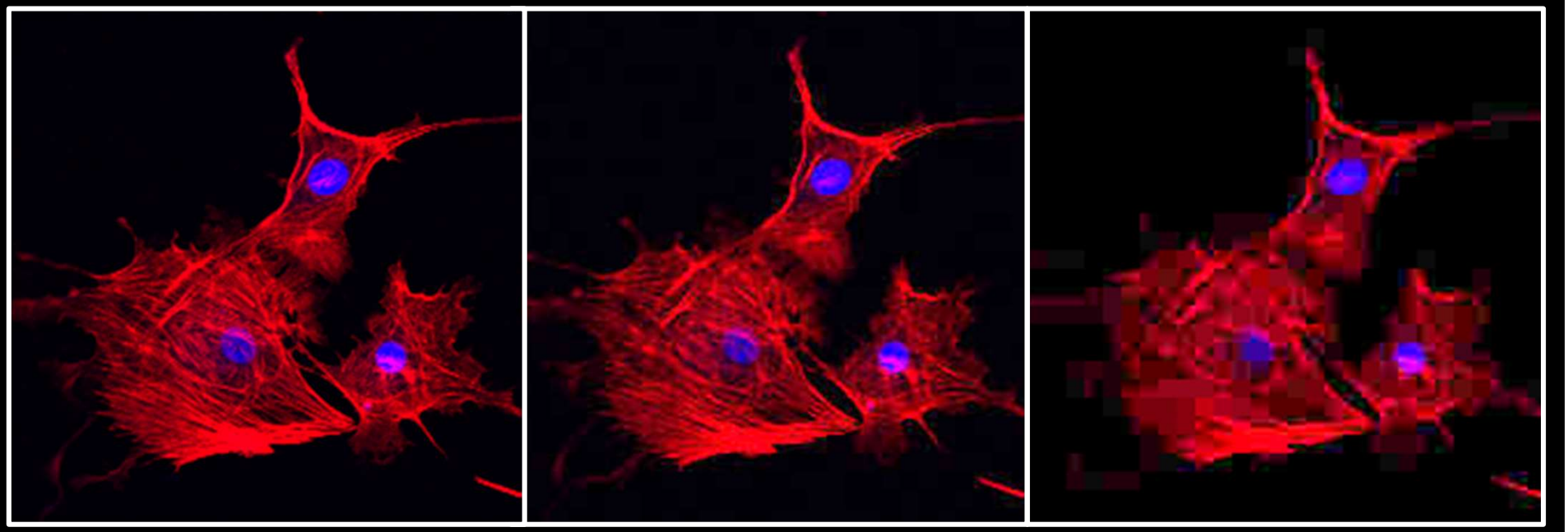
Key functions

- `imread`
- `imshow`
- `imwrite`

Common file formats

- JPG , JPEG – Often used in digital cameras, web images
- GIF – Often used for animated web images
- PNG – Now often used in web images
- TIFF, TIF – Often used for scientific imaging, must be saved uncompressed

Image compression is used to reduce file size

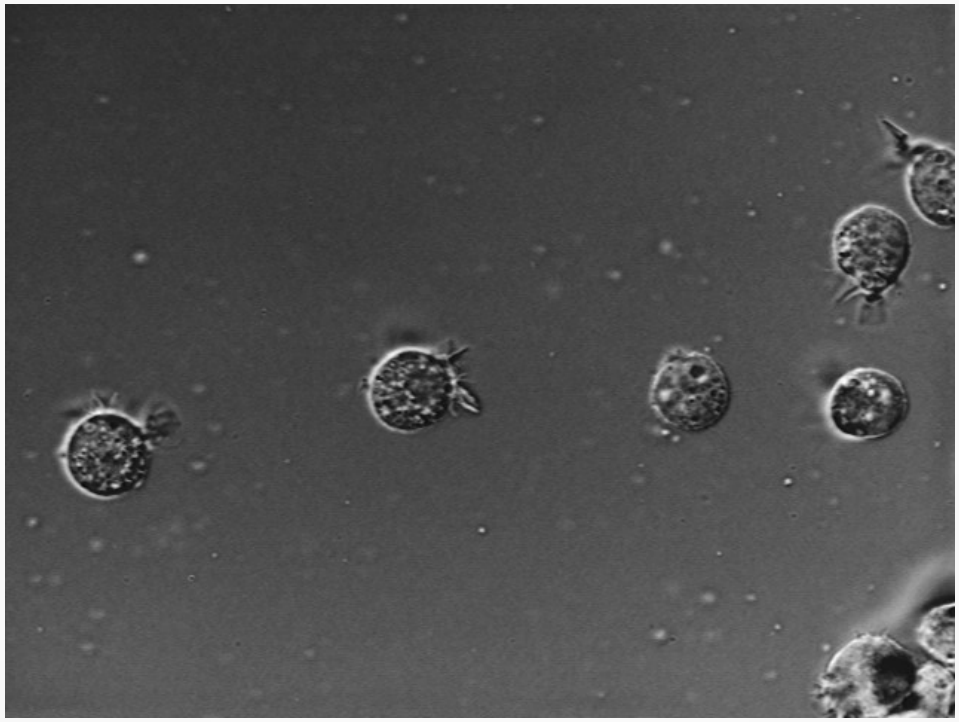


Original Uncompressed TIFF	50% JPEG compression	90% JPEG compression
336 kB	12.6 kB	9.02 kB

```
I = imread('filename')
```

reads image data into matrix `I`

AT3_1m4_01.tif

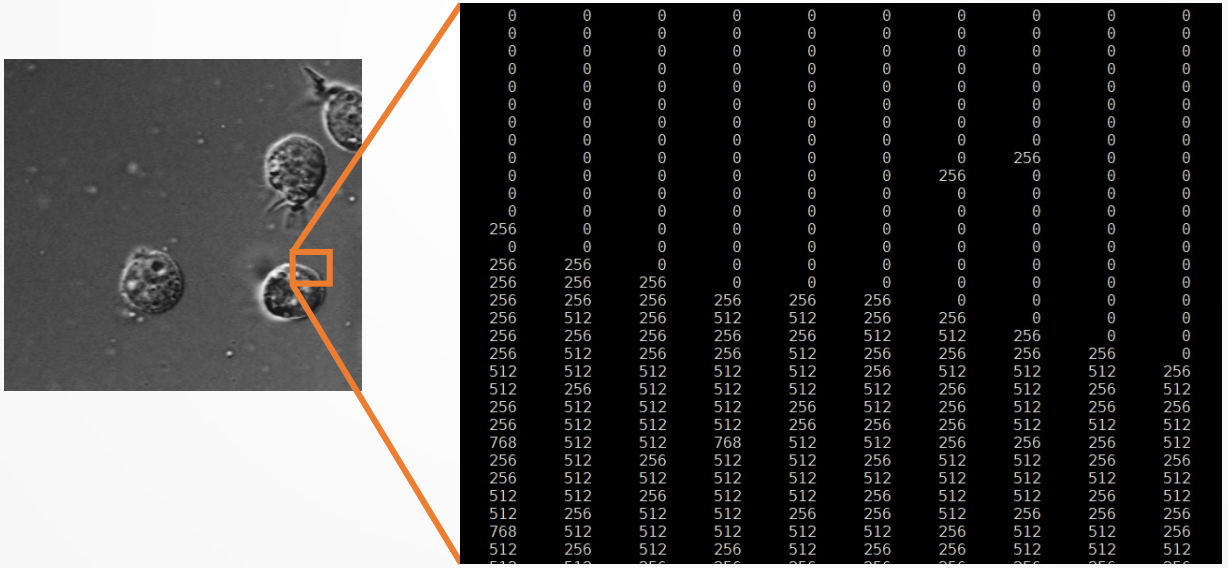


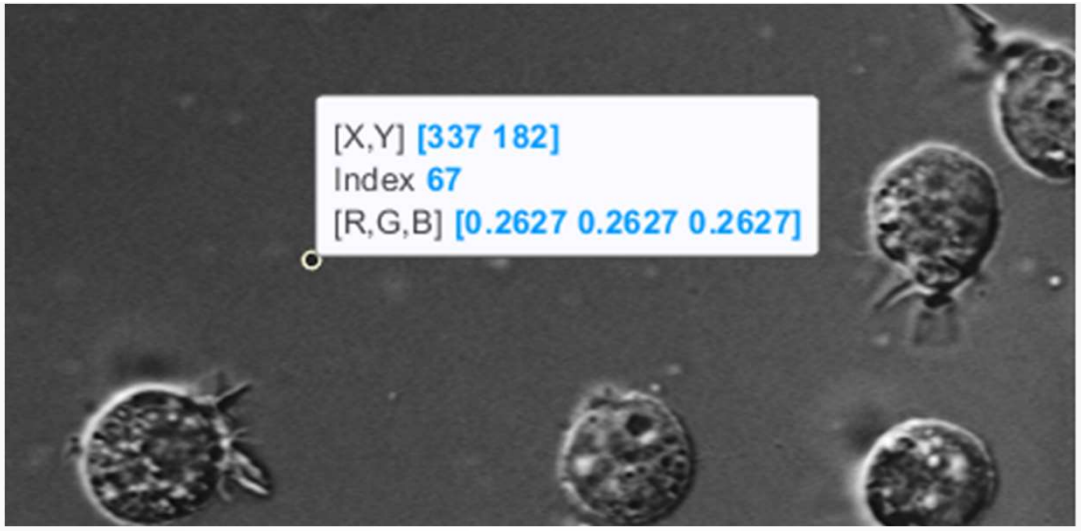
`imshow(I)`

displays image in matrix `I`

Image data is proportional to intensity

- **RAW** image data is the intensity of light arriving at the camera
- Higher pixel values = more light detected by camera pixel
- Orientation of image matches matrix

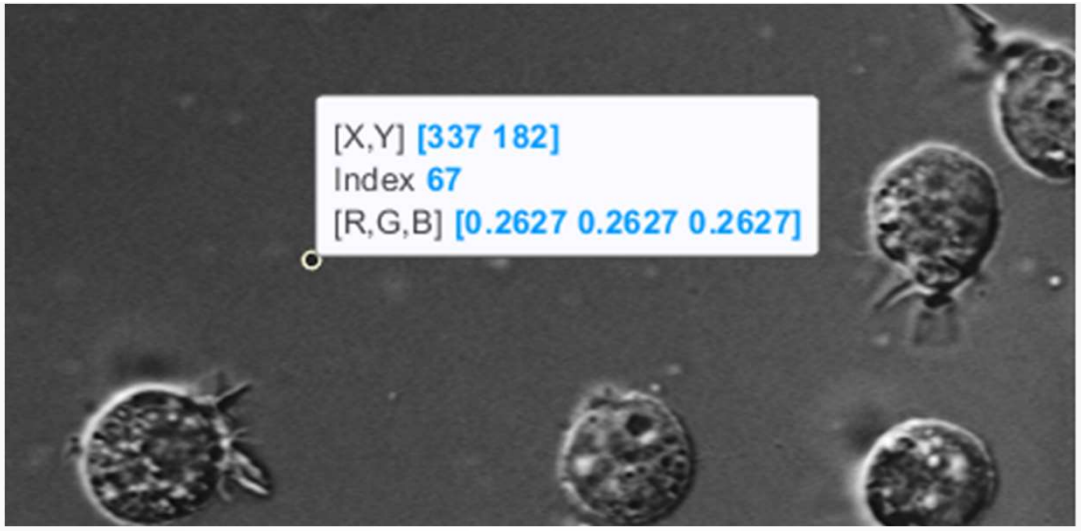




Which of the following statements correspond to the pixel with the (x, y) coordinates shown above?

A. I(182, 337)

B. I(337, 182)



Which of the following statements correspond to the pixel with the (x, y) coordinates shown above?

A. I(182, 337)

B. I(337, 182)

Changing how bright images appear

```
>> I = imread('mri.tif');
>> imshow(I)
```

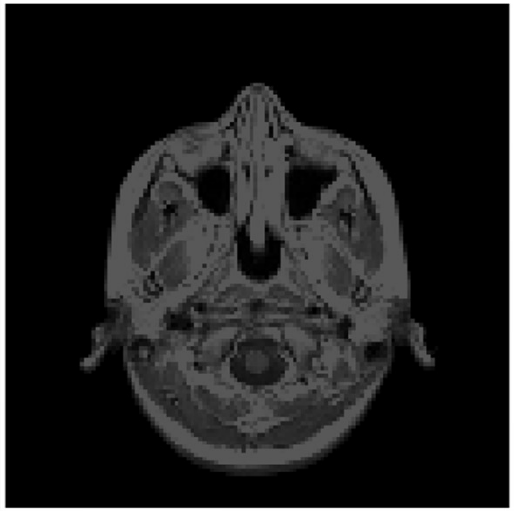


Image looks dark… why?

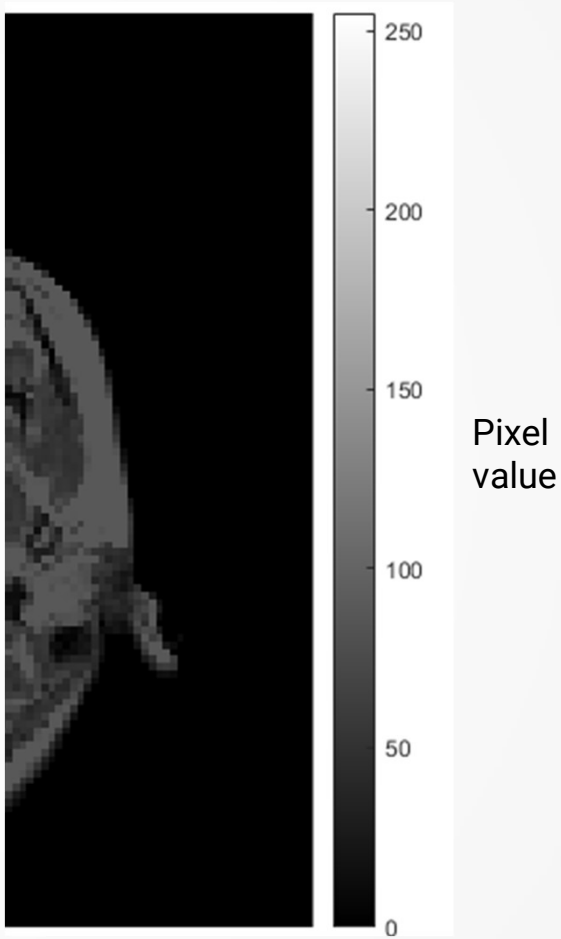
What is the highest pixel value in the image?

The colorbar

```
>> colorbar
```

Shows how pixel values are mapped to color

Important to show when displaying quantitative data



imshow scales displayed colors depending on data type

- For unsigned integer

  0 to maximum value of integer
  (e.g. 8-bit image: 0 and 255)

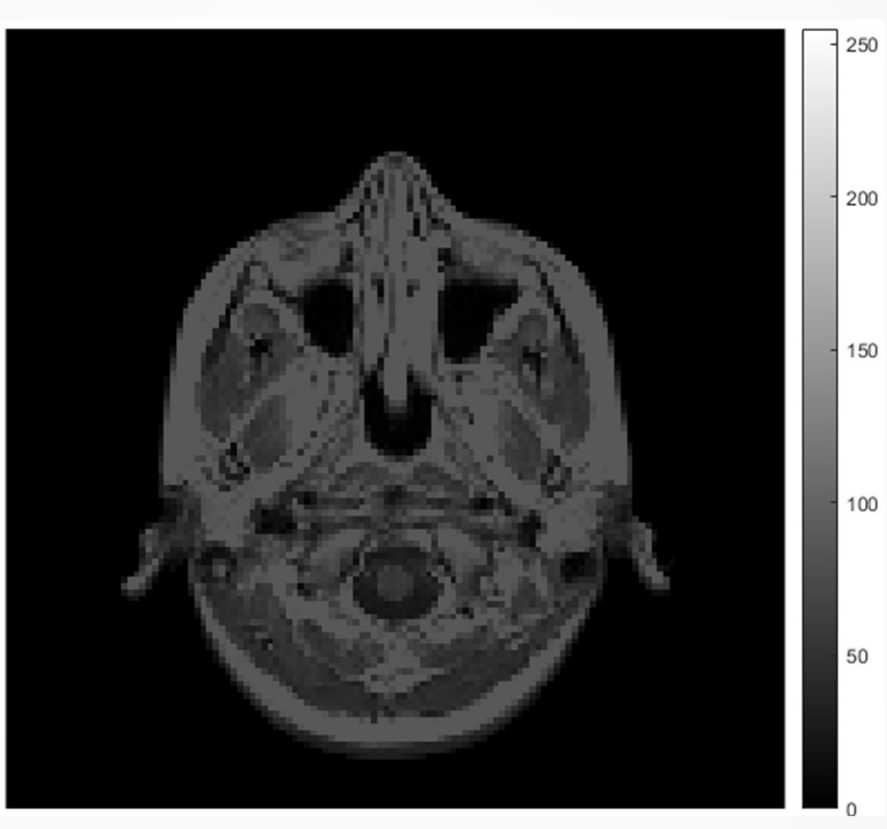
- For double

  0 to 1

- For logical

  0 and 1

Default scaling using imshow



255

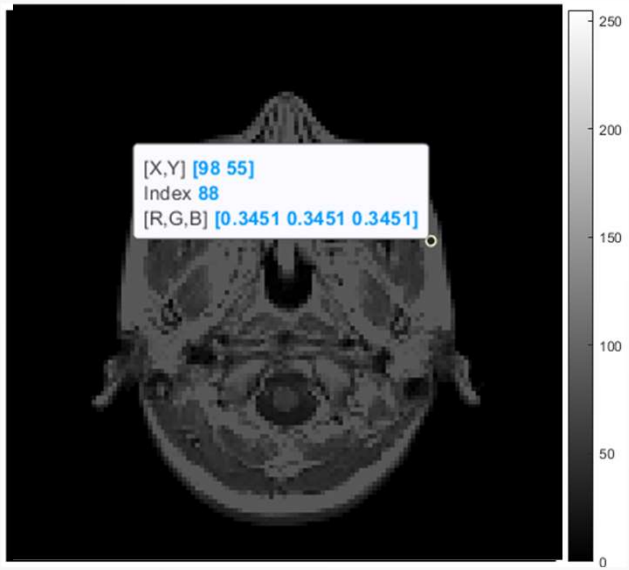
0

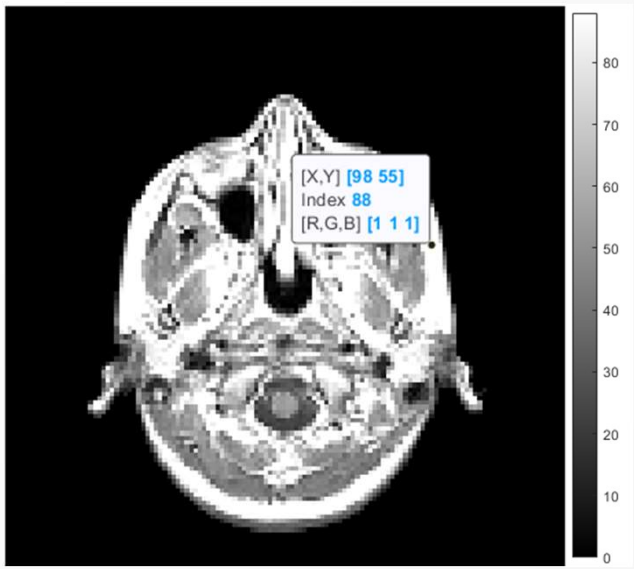
uint8 image

Changing the displayed color scale

```
imshow(image, [low, high])
>> imshow(I, [0, 88])
>> colorbar
```

Original intensity values have not been changed



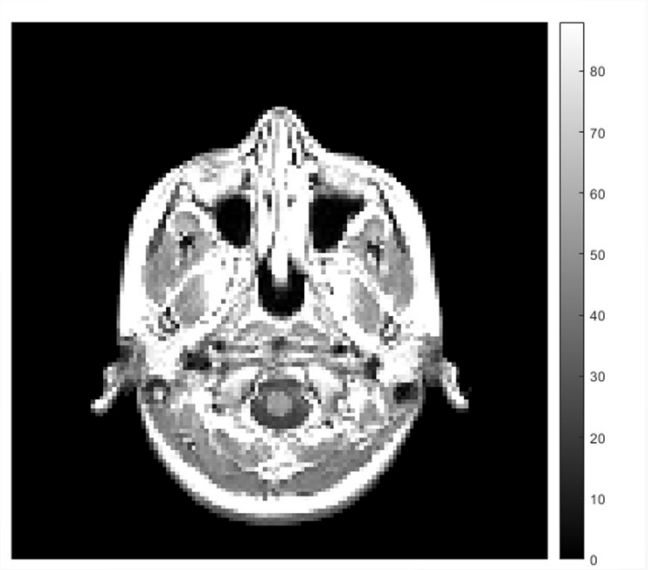


Automatic display scaling

```
imshow(I, [])
```

is equivalent to

```
imshow(I, [min(I(:)), max(I(:))]
```



- Download image demo16bit.tiff
- Convert to jpeg and save as uncompressed tiff
- Explain differences