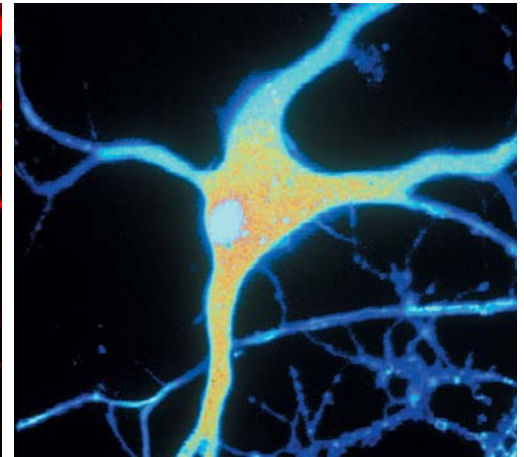
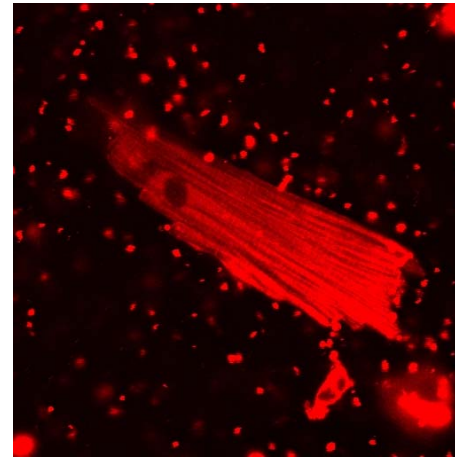
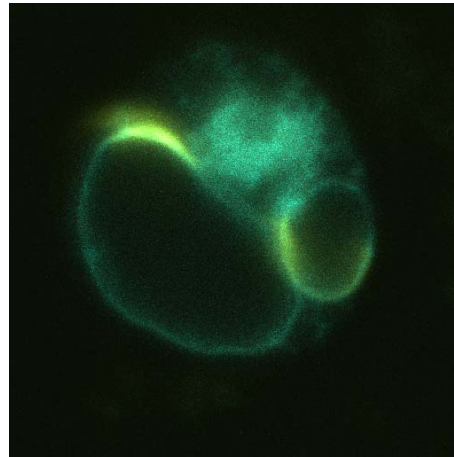
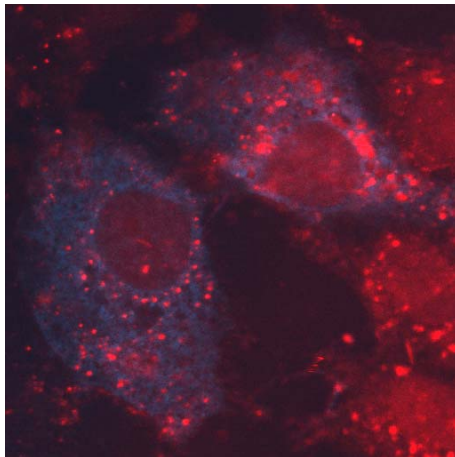


Image Processing II

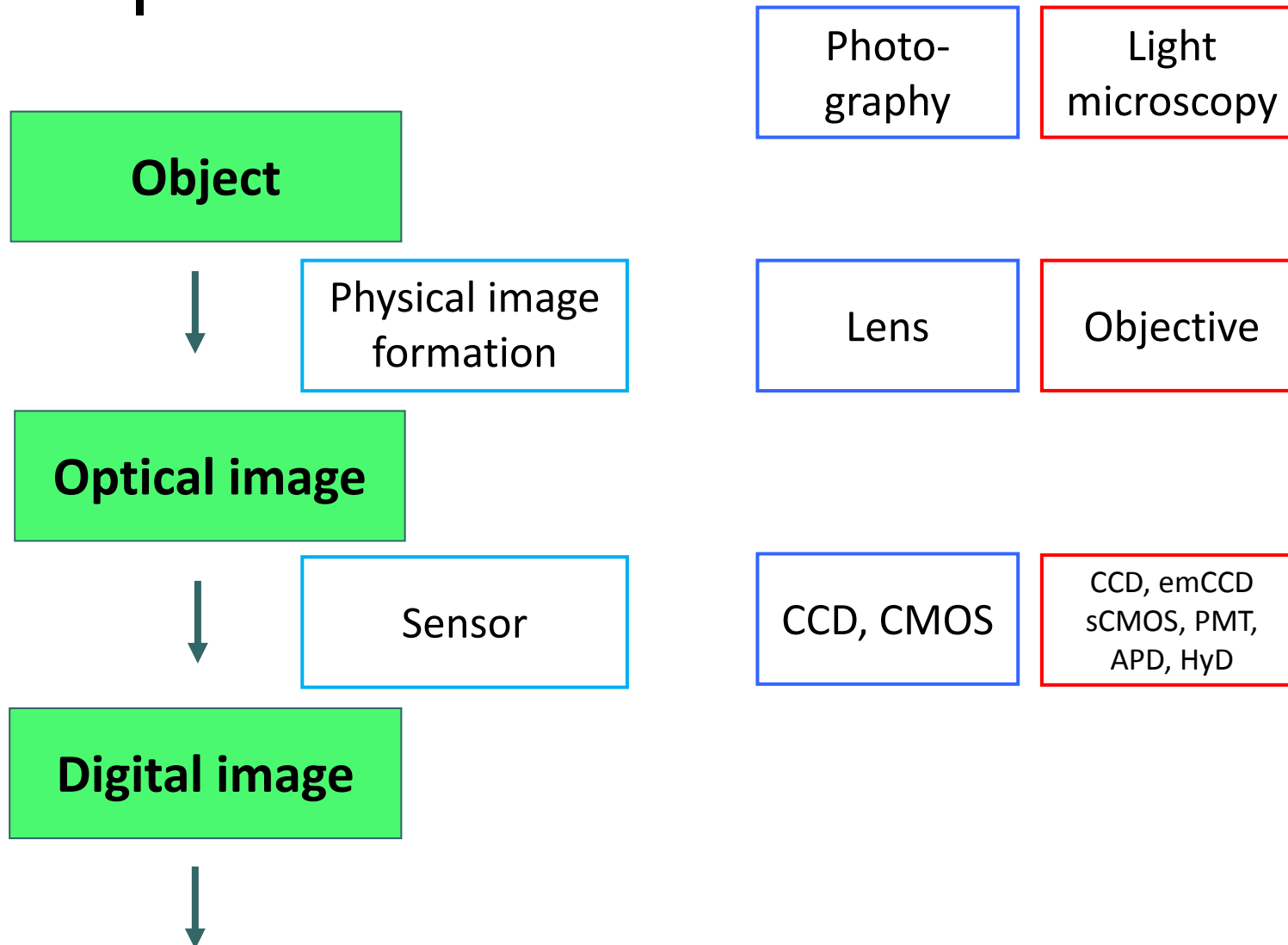
Introduction





Essential steps in image processing

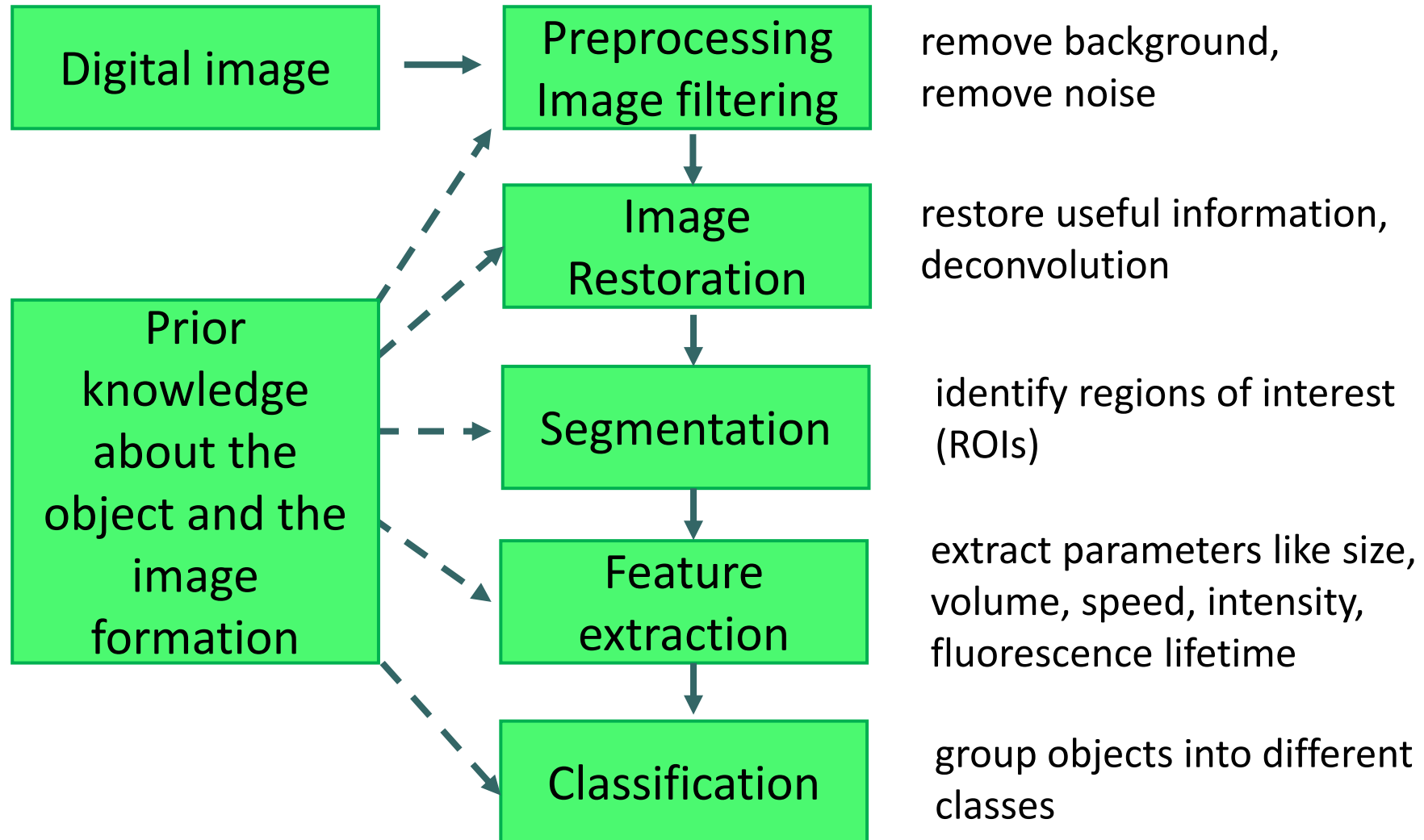
Image acquisition





Essential steps in image processing

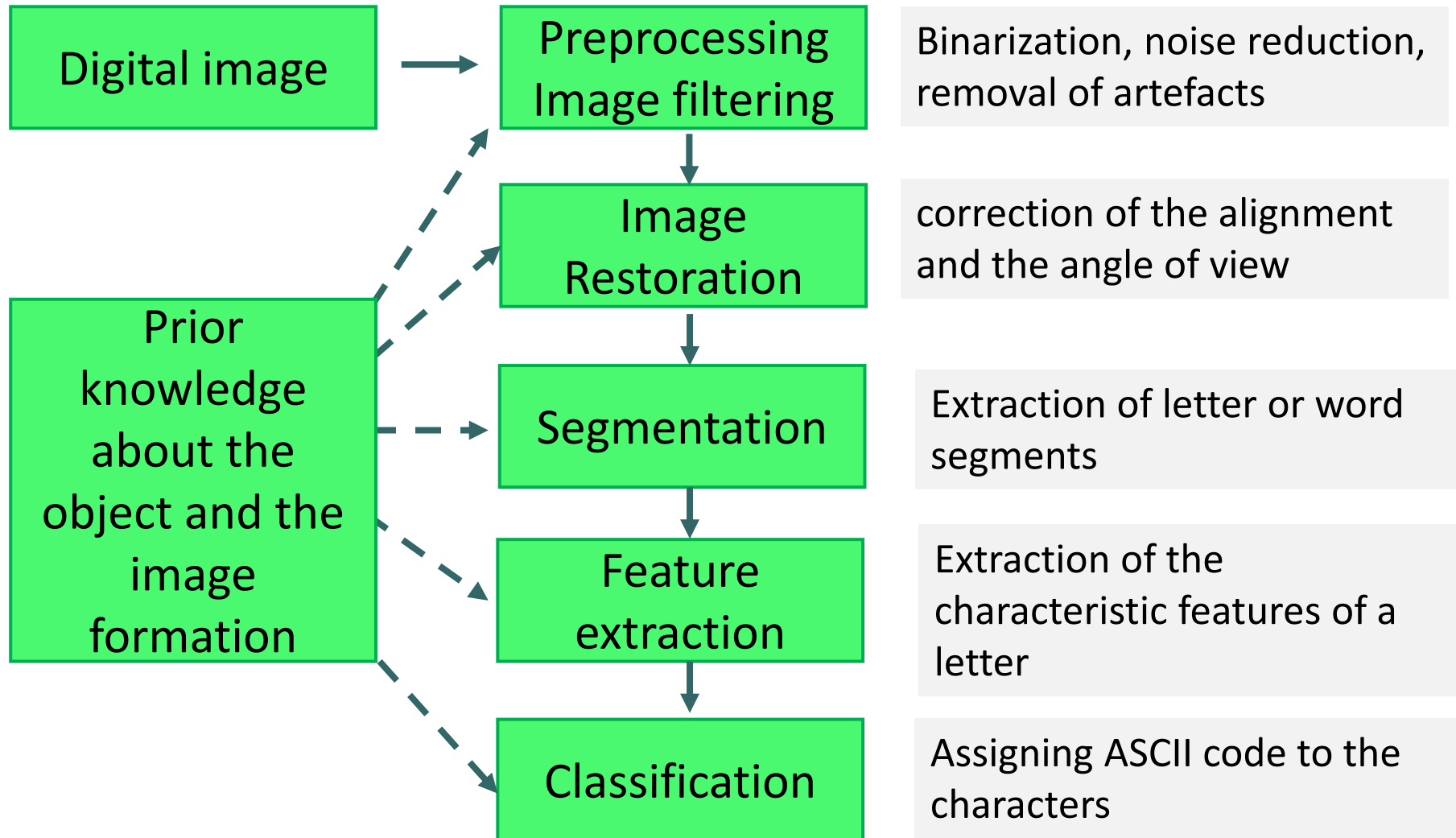
Low-level and mid-level processes in image processing





Essential steps in image processing

Just one example: Optical character recognition (OCR)





Essential steps in image processing

Image acquisition

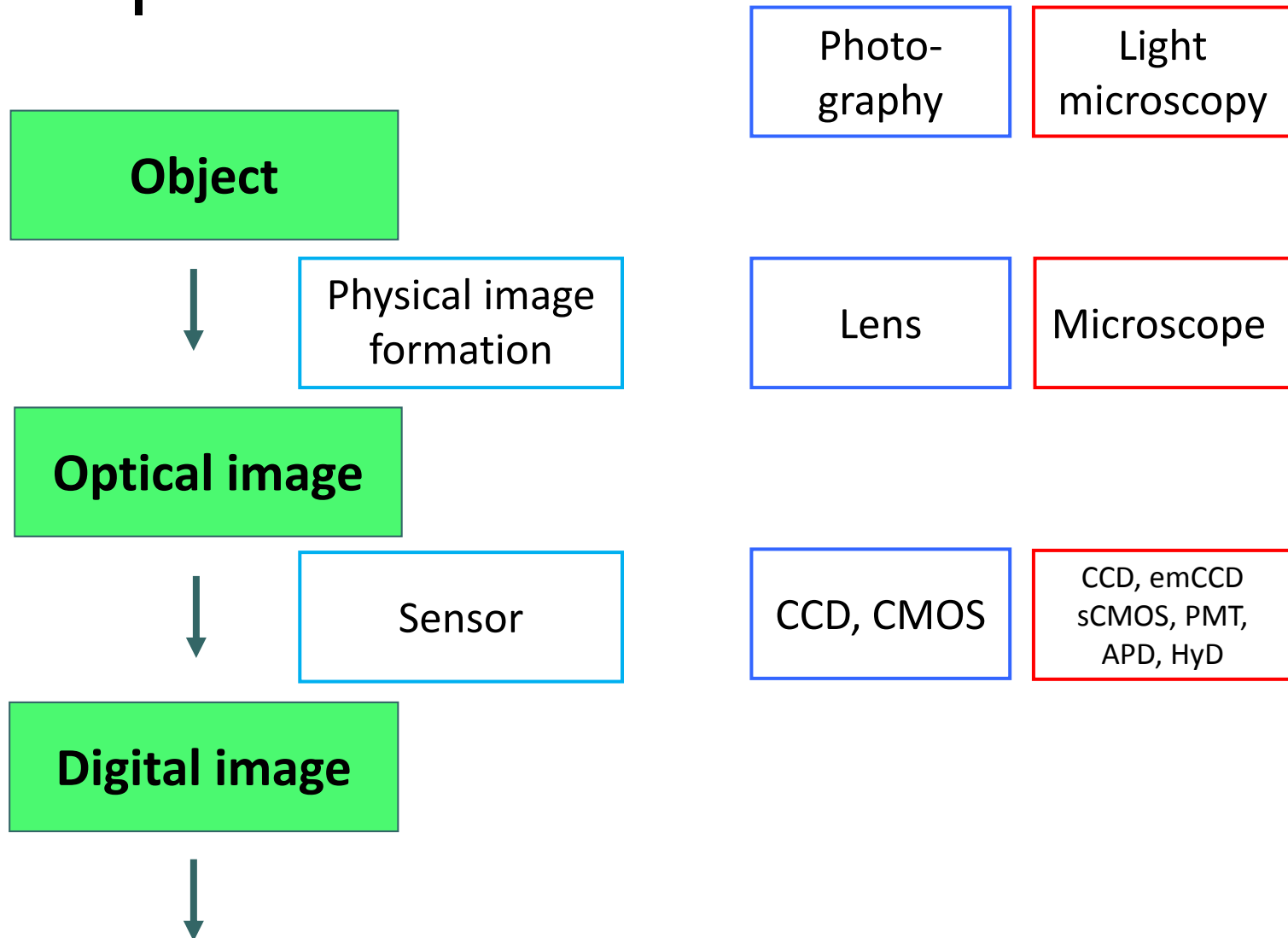




Image acquisition

Some examples





Image acquisition

Effects of optical image formation



Camera: Canon EOS 6D Mark II
Lens: LOREO 35 mm
Exposure time: $1/400\text{s} = 2.5\text{ ms}$
Aperture: 5.6
Gain: ISO200
Price: ~ 35 €



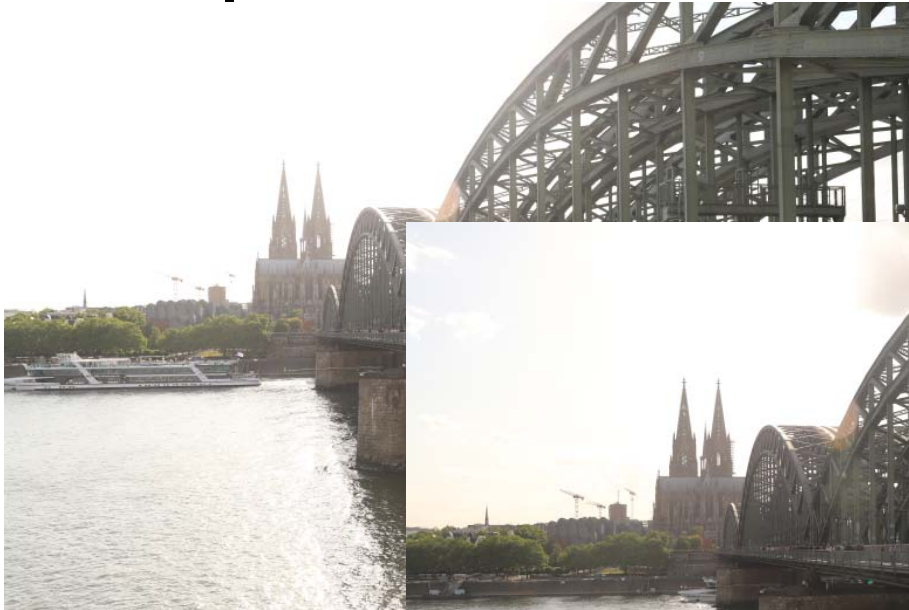
Camera: Canon EOS 6D Mark II
Lens: Canon EF 24-70 mm, 1:4L, IS USM, set to 35 mm
Exposure time: $1/1250\text{s} = 0.4\text{ms}$
Aperture: 5.6
Gain: ISO200
Price: ~ 830 €





Image acquisition

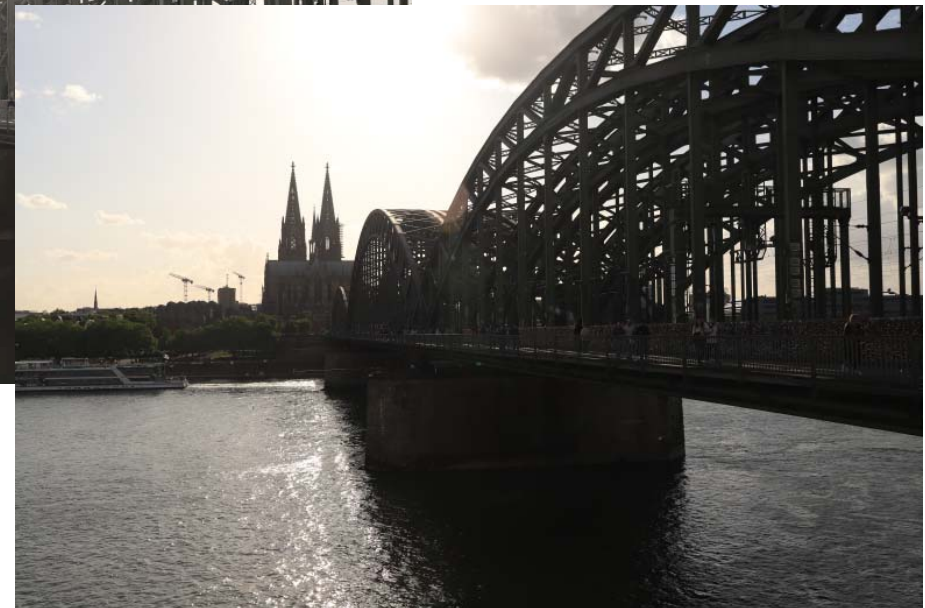
Effects of aperture and exposure time



Exposure time: 4 ms



Exposure time: 2 ms



Exposure time: 1 ms

Camera: Canon EOS 6D Mark II
Lens: Canon EF 24-70 mm, 1:4L, IS USM, set to 35 mm
Aperture: 8, Gain: ISO200



Image acquisition

Effect of Illumination





Image acquisition

Effect of Illumination

Exposure to daylight on a cloudy day



Exposure to room light (LEDs)



Illumination with a 85 W photo lamp (5500K)



Illumination with a flash light





Image acquisition

Effects of sampling



Image sampled with 6240 x 4160 points

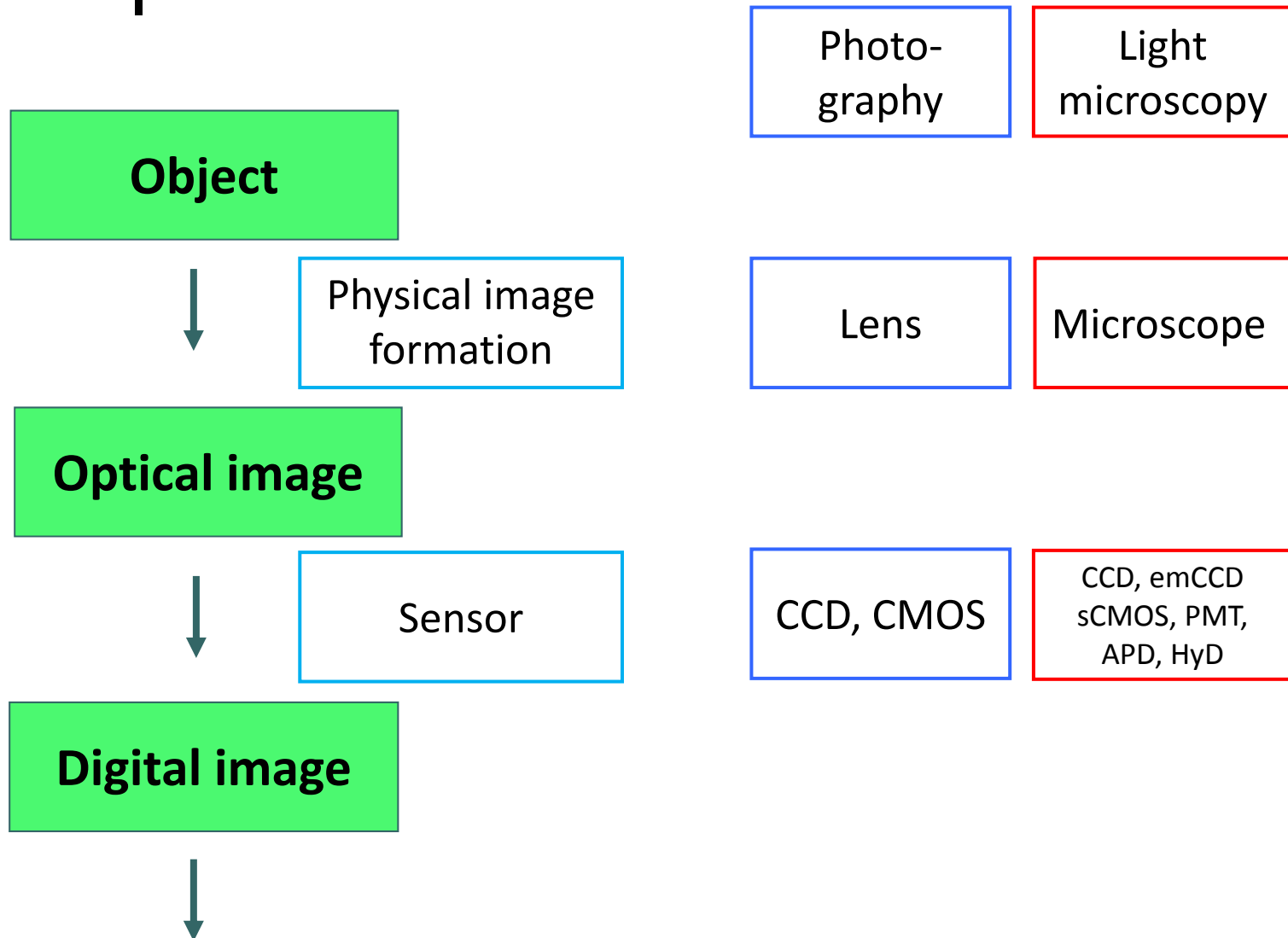


Image sampled with 780 x 520 points



Essential steps in image processing

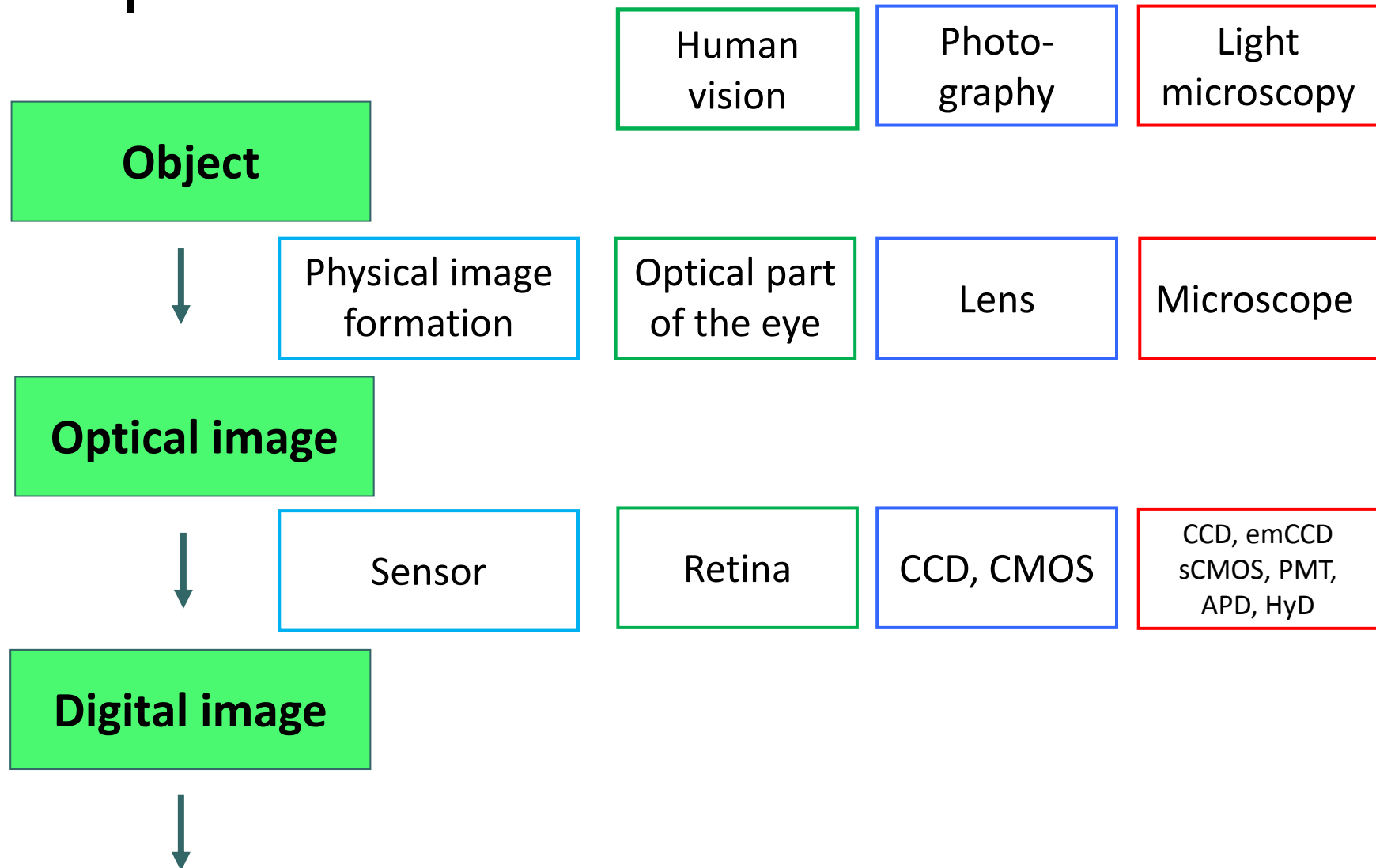
Image acquisition





Essential steps in image processing

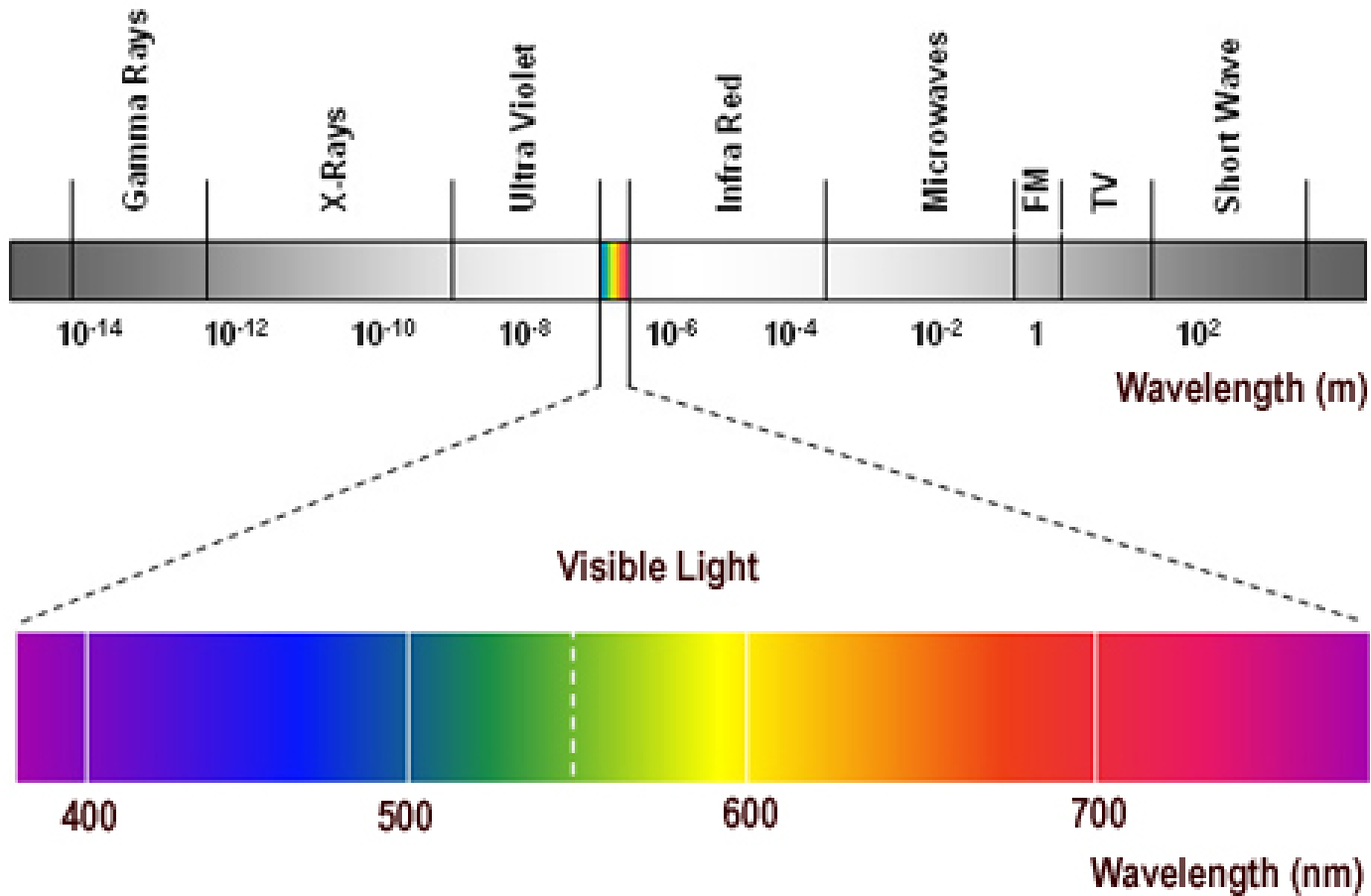
Image acquisition





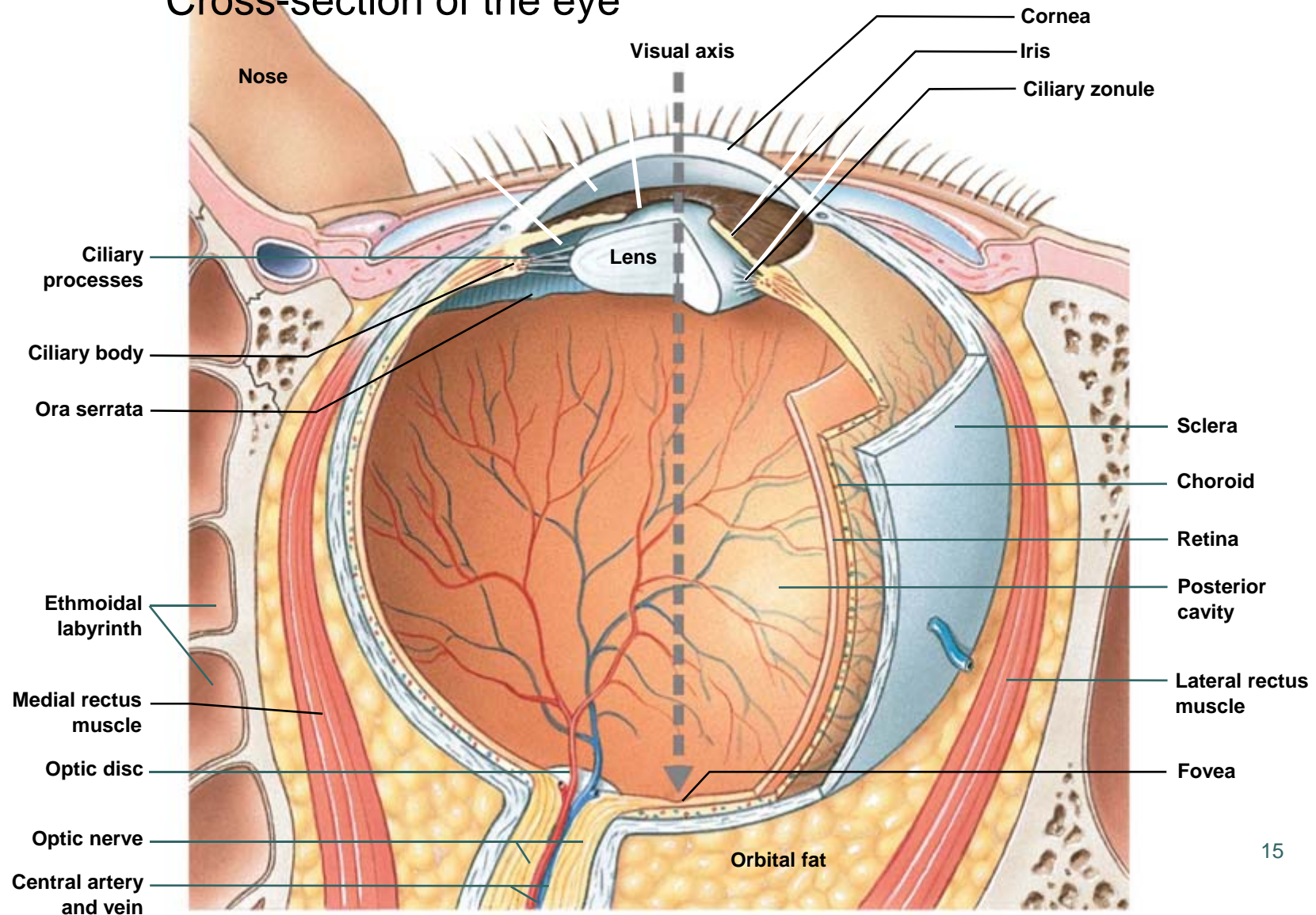
What is visible for humans?

The electromagnetic spectrum



The eye as a spectral image sensor

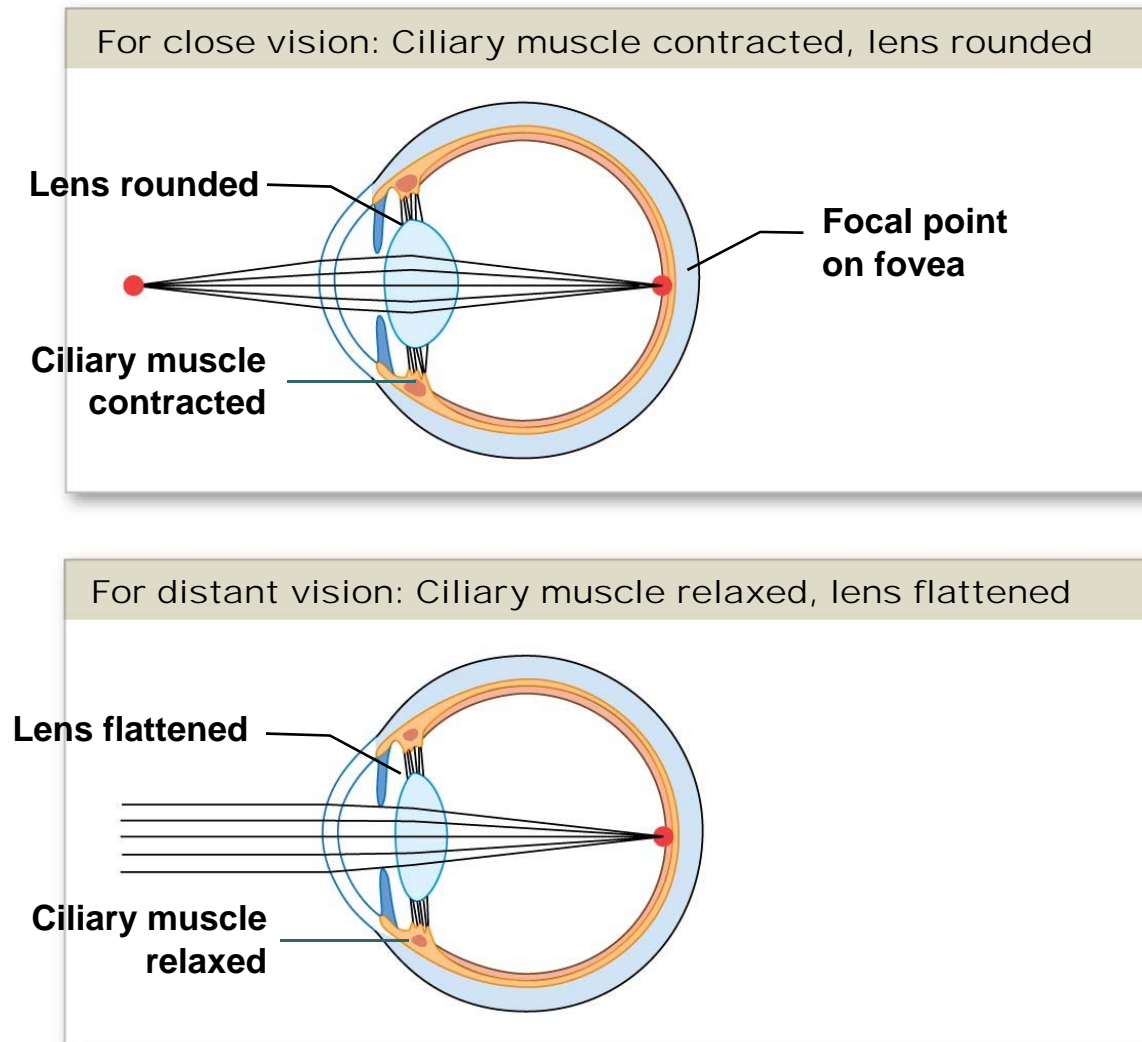
Cross-section of the eye





The eye as a spectral image sensor

The optical part - Accommodation



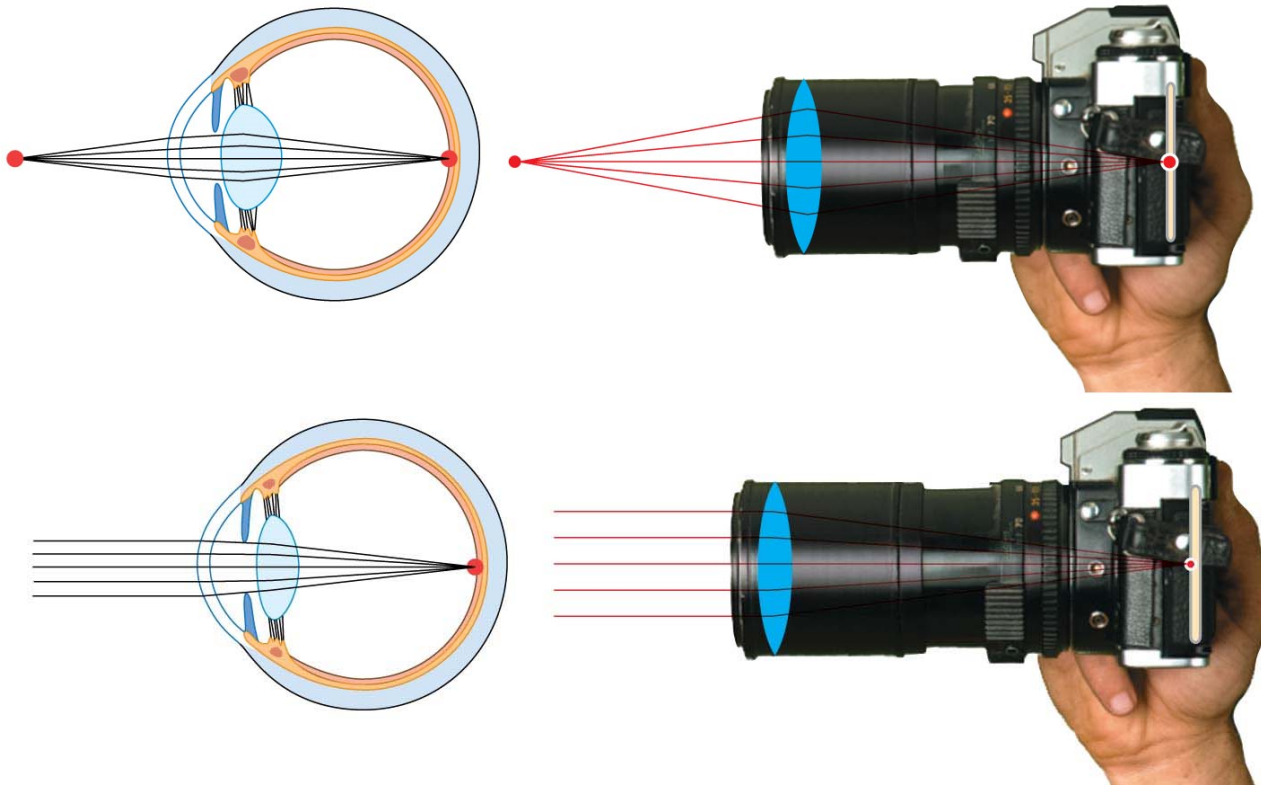


The eye as a spectral image sensor

The optical part

The eye has a fixed focal distance and focuses by varying the shape of the lens.

A camera lens has a fixed size and shape and focuses by varying the distance to the film.





The eye as a spectral image sensor

The fundus

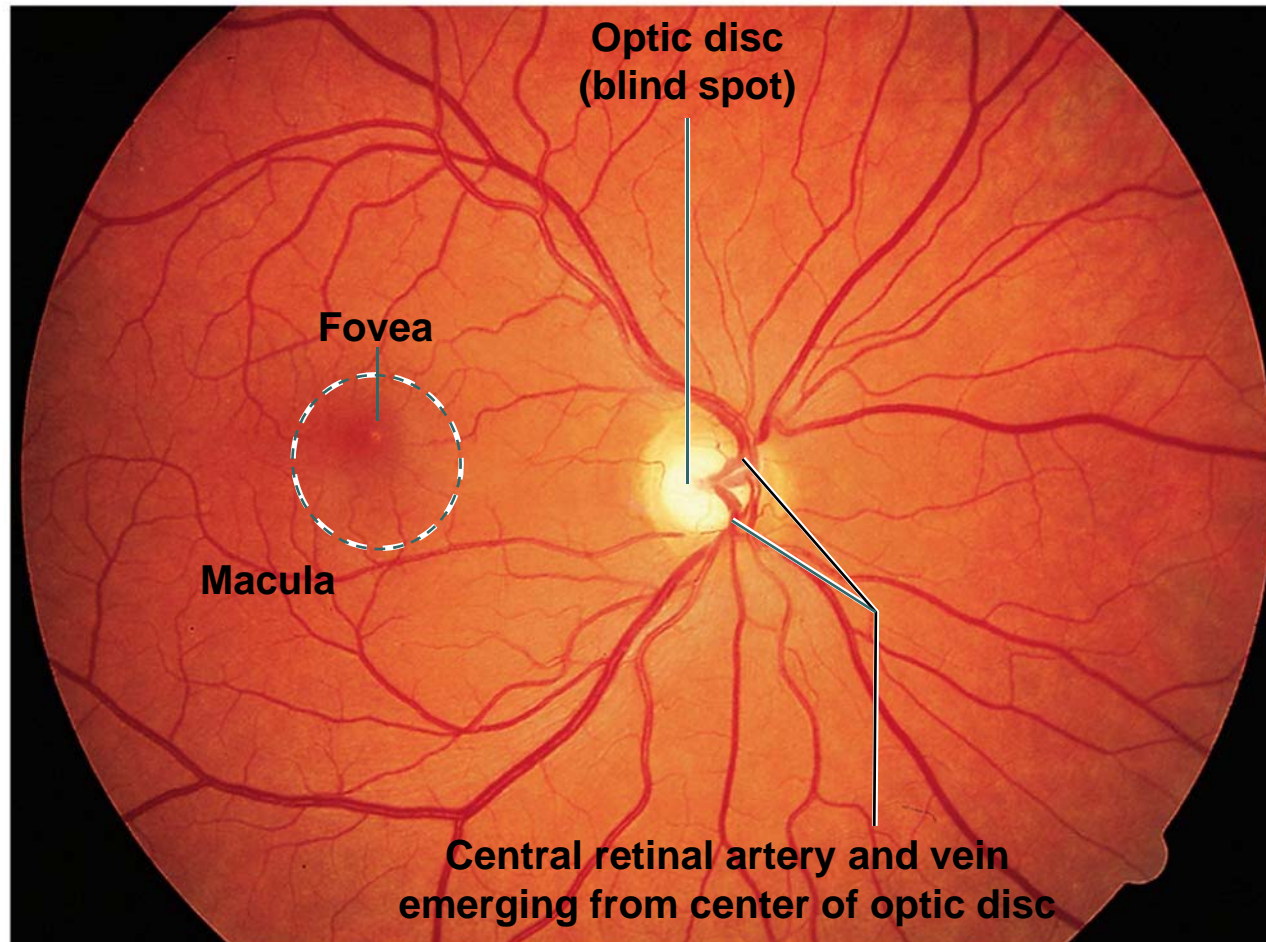


Fig. from: Martini, Nath, Bartholomew, Fundamentals of Anatomy & Physiology, 10th ed, Pearson (2015), p. 576.



The eye as a spectral image sensor

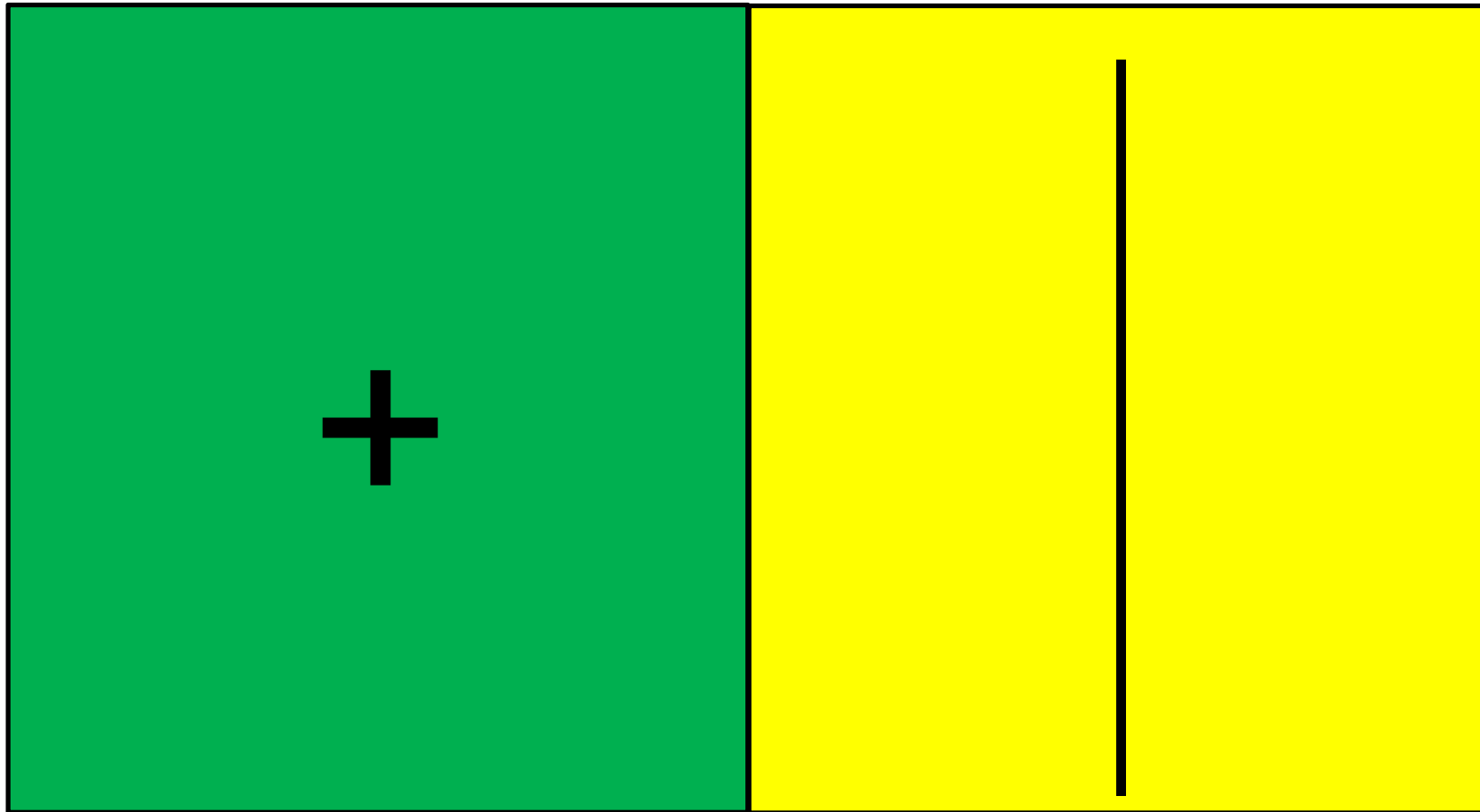
Demonstration of the presence of the blind spot





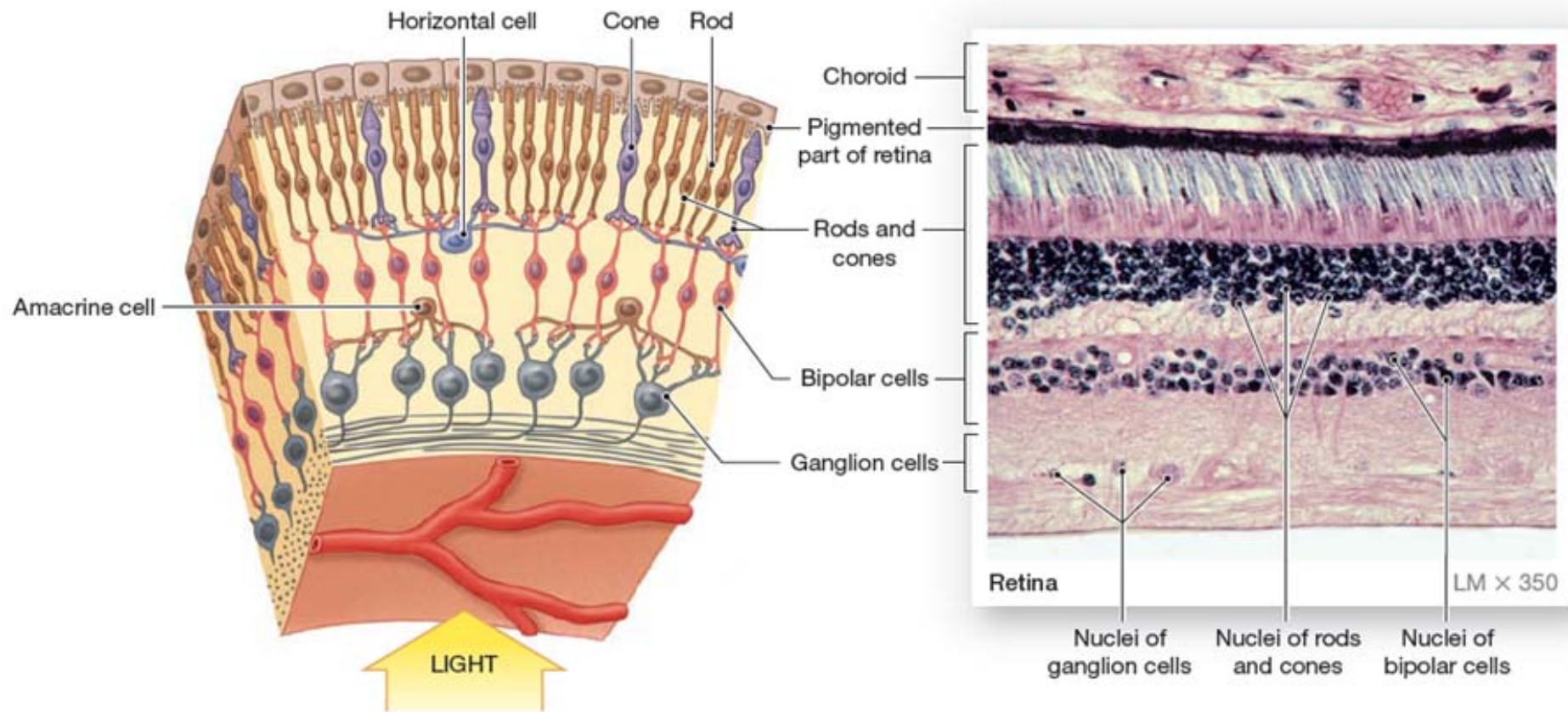
The eye as a spectral image sensor

Demonstration of the presence of the blind spot



The eye as a spectral image sensor

The retina





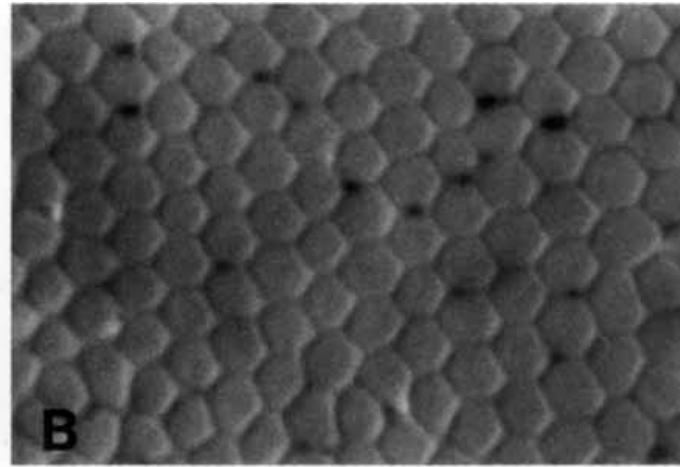
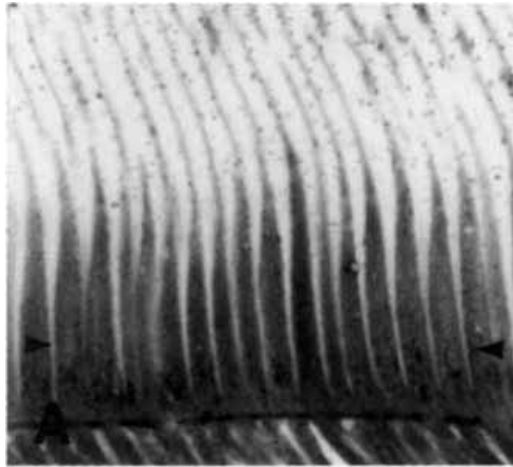
The eye as a spectral image sensor

Rod and cone density in the retina

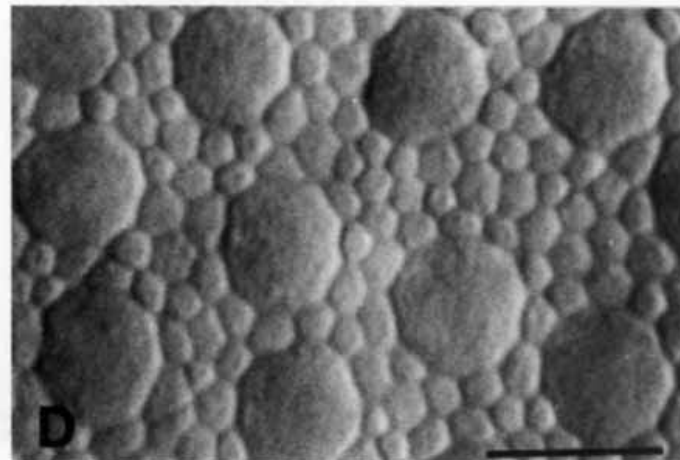
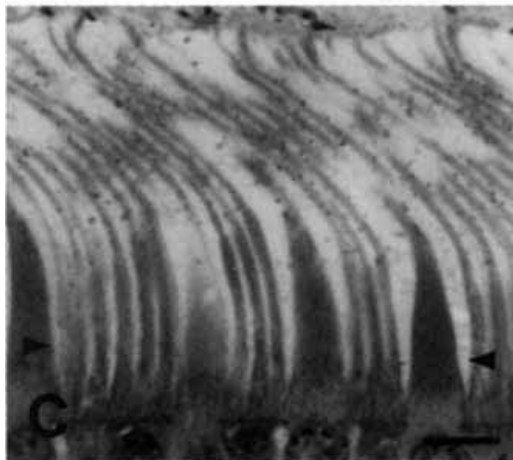
Vertical section

Horizontal section at position of
the arrowhead in panel A and C

Fovea centralis



Near periphery

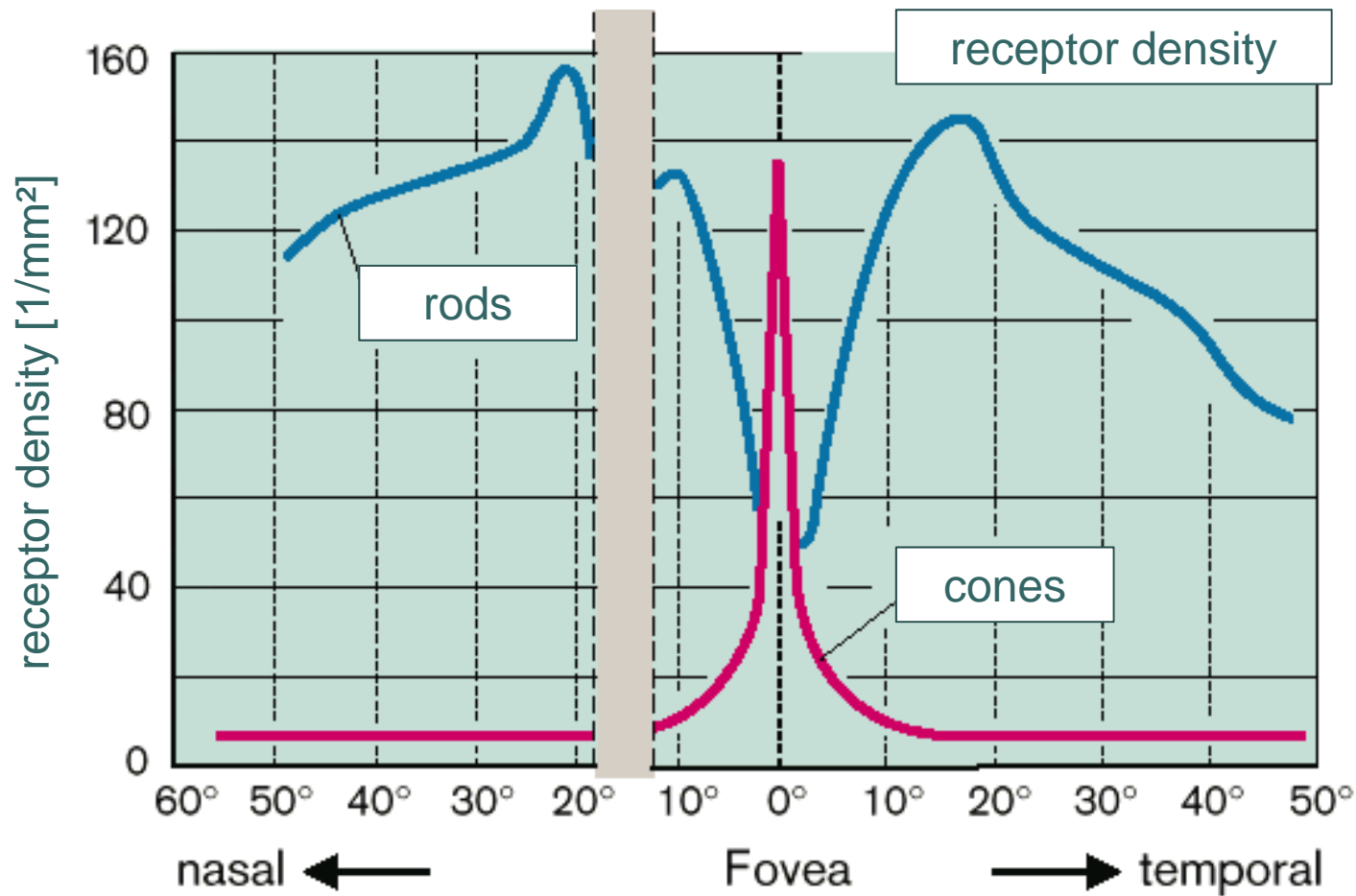


Scale bar = 10 μ m



The eye as a spectral image sensor

Rod and cone density in the retina





The eye as a spectral image sensor

Spectral sensitivity of the photoreceptors

	Human eye ¹	Full frame photo camera sensor ²
Number of receptors/pixels	Cones: $4.6 \cdot 10^6$ Rods: $91.7 \cdot 10^6$	$5472 * 3648$ $= 20 \cdot 10^6$
Sensor area [mm ²]	Retina: 1018.6 Fovea: 3.6	$35.8 * 23.9$ $= 855$
Receptor/pixel density [1000/mm ²]	Cones (peak int.): 199 Cones (mean int.): 5 Rods (peak int.): 176 Rods (mean int.): 95	23.3
Center-to-center spacing [μm]	2.1	6.5

Sources:

1) Curcio, J Comp Neurol 292, 497-523 (1990)

2) Canon-Website: <https://www.canon.de/cameras/eos-1d-x-mark-iii/specifications/>

The eye as a spectral image sensor

Schematic of a photoreceptor

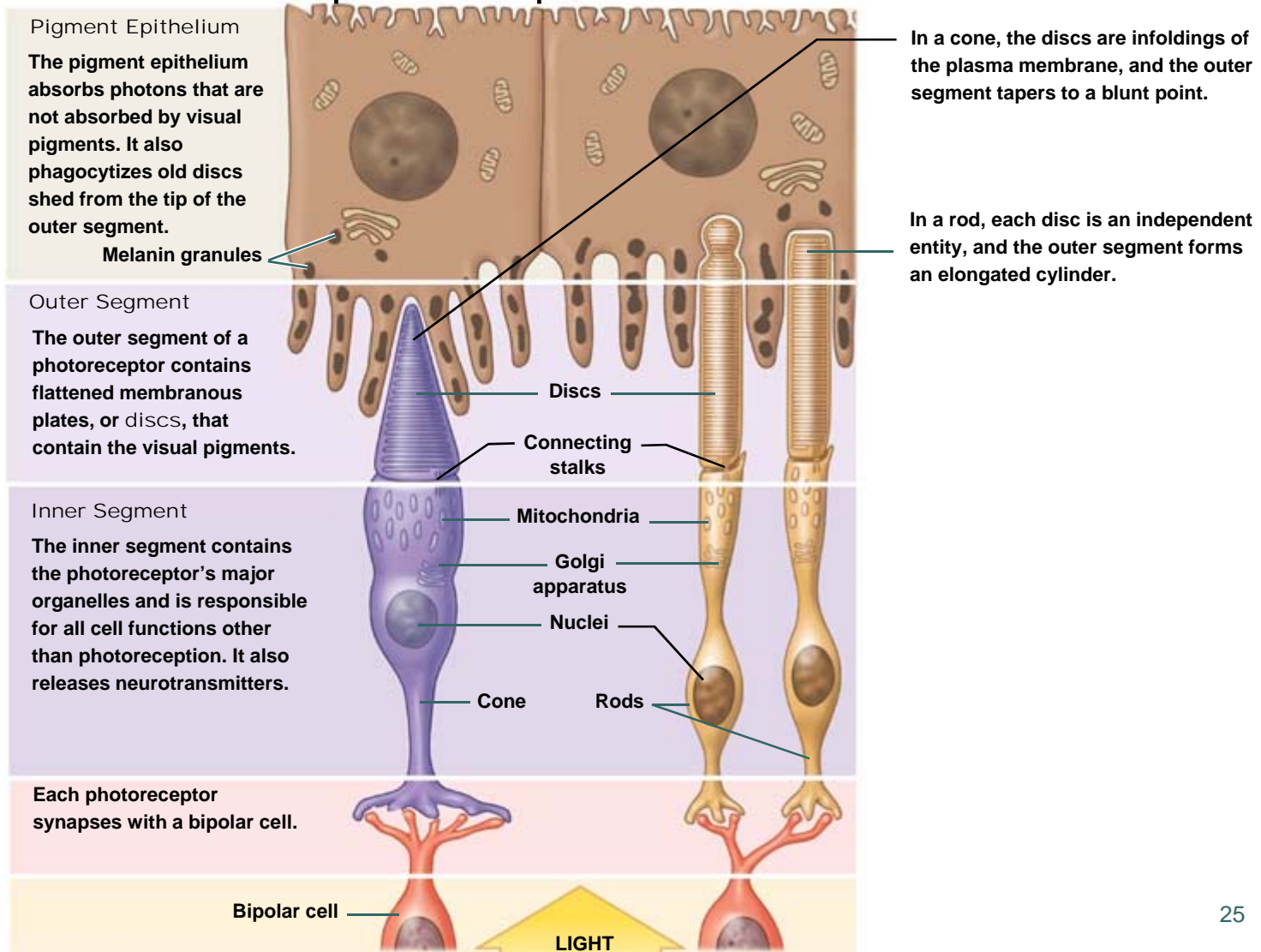


Fig. from: Martini, Nath, Bartholomew, Fundamentals of Anatomy & Physiology, 10th ed, Pearson (2015), p. 583..

The eye as a spectral image sensor

Signal transduction in the photoreceptor

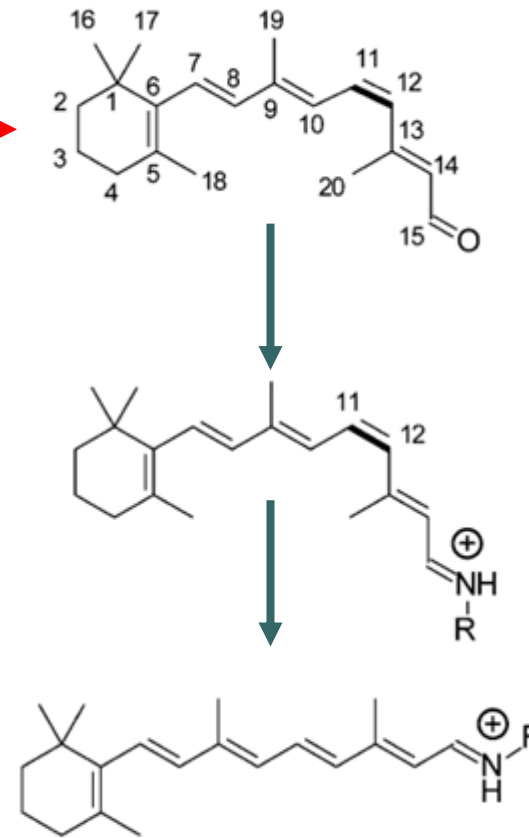
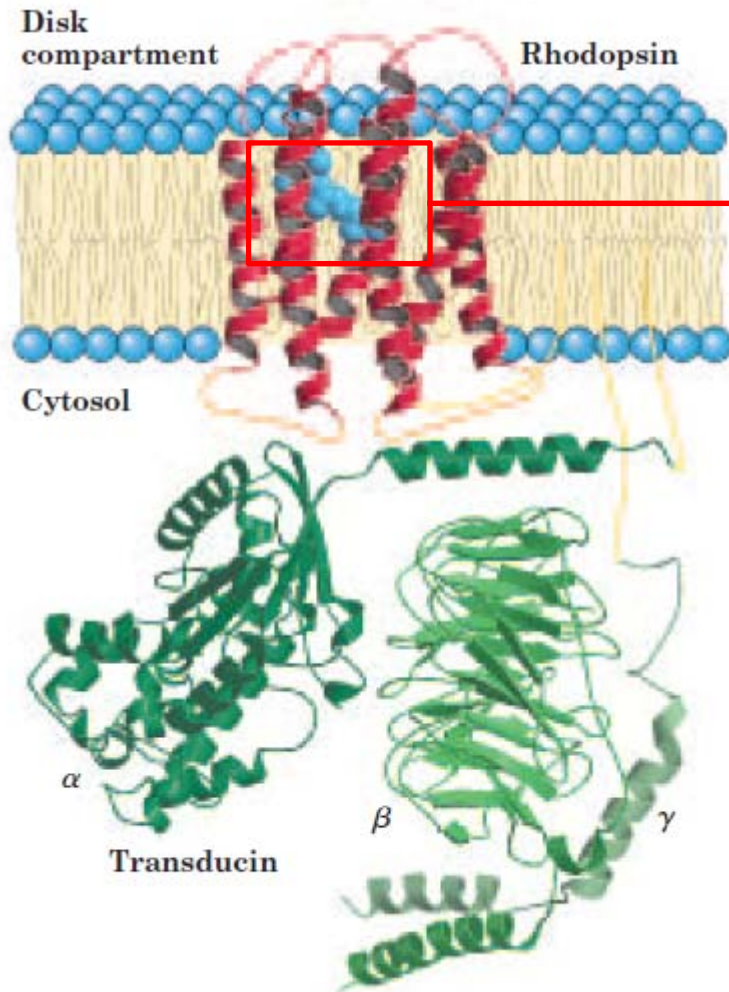
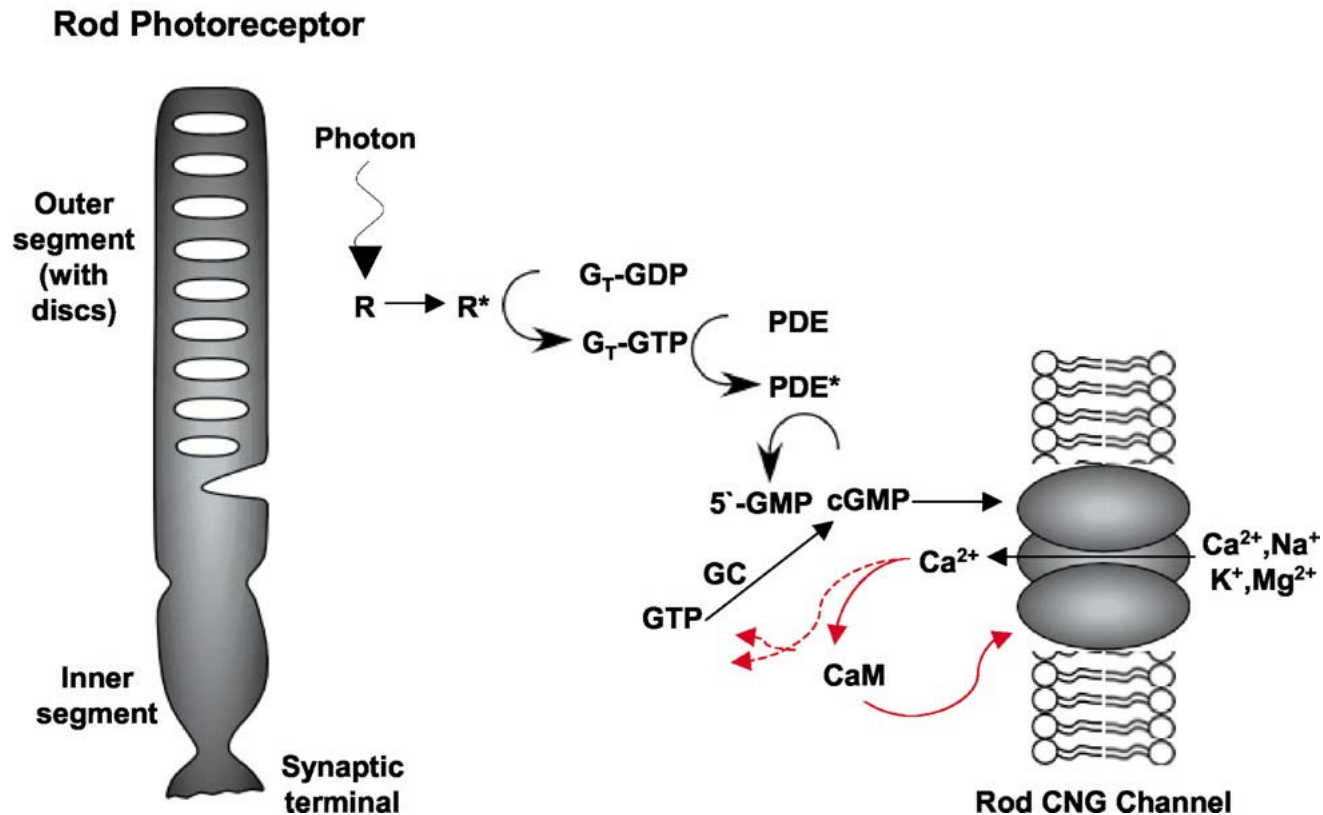


Fig. from: Nelson, Cox, Lehninger's principles of biochemistry 4th ed, Freeman (2004), p. 458.

Fig. from: Van Eps, Photochem Photobiol Sci 14, 1586-1597 (2015).

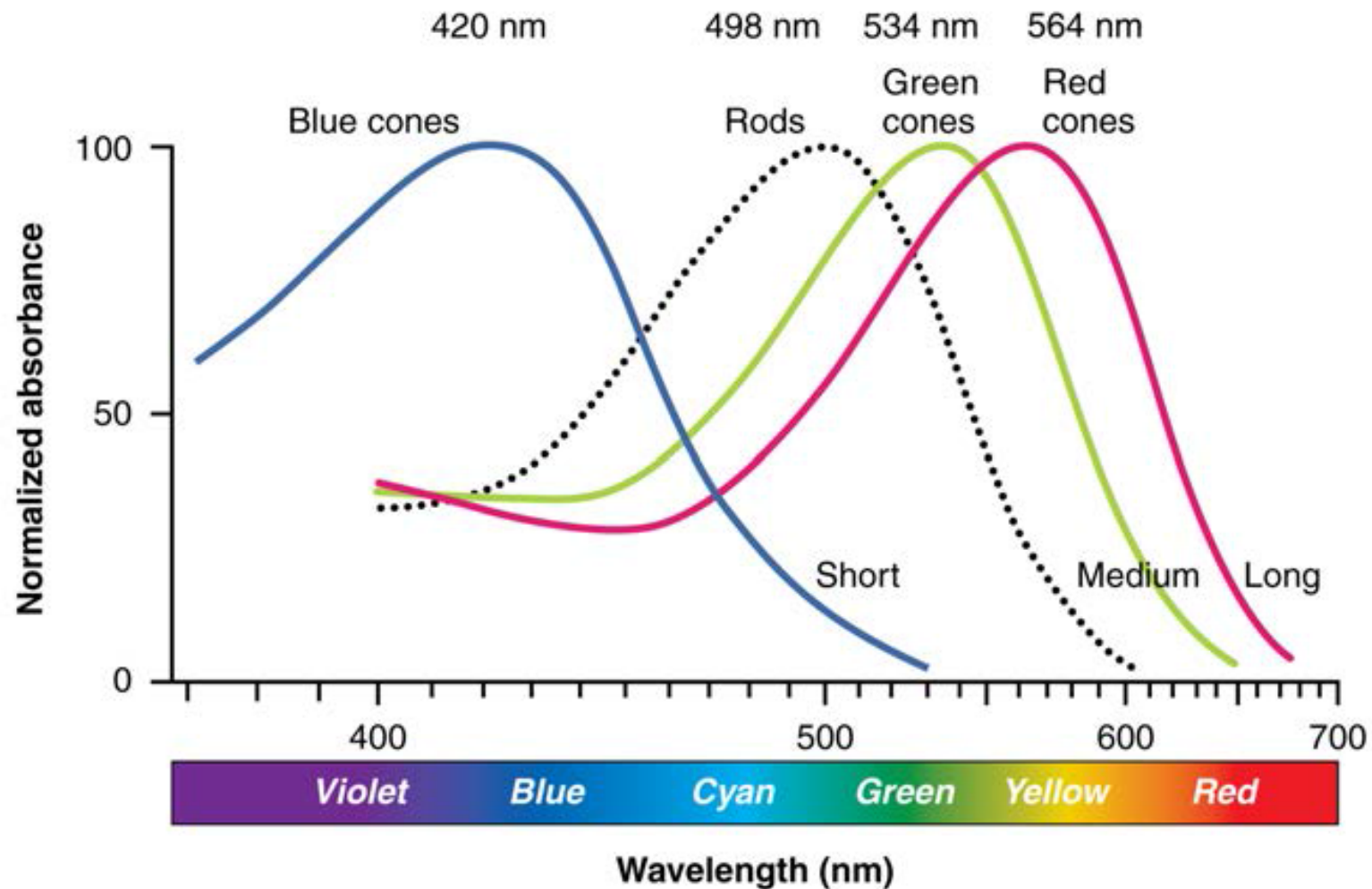
The eye as a spectral image sensor

Signal transduction in the photoreceptor



The eye as a spectral image sensor

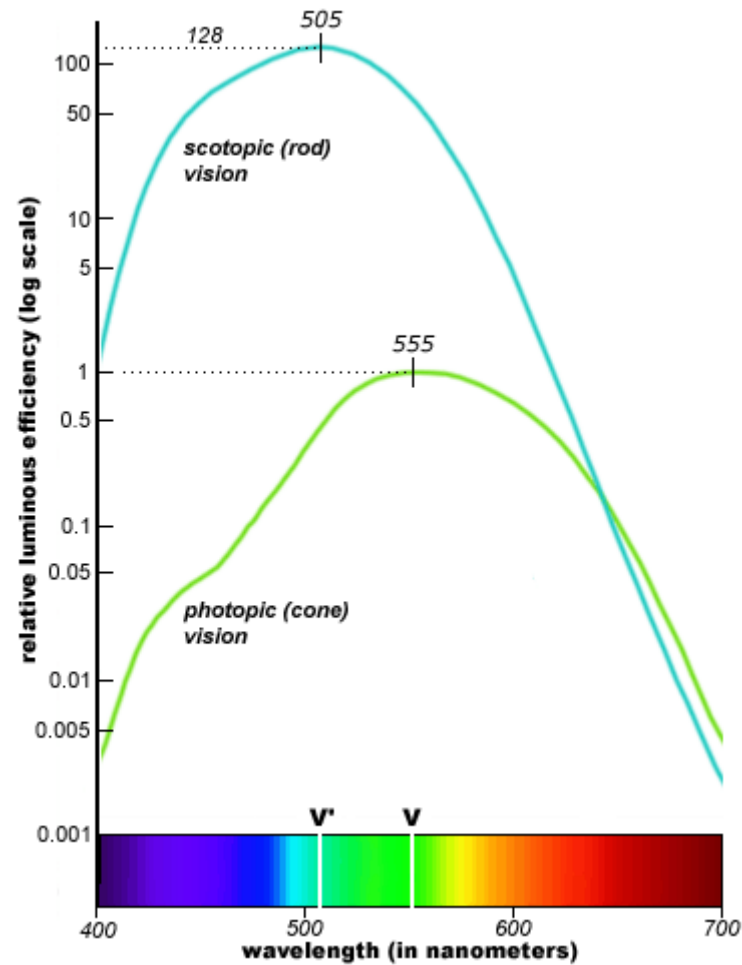
Spectral sensitivity of the photoreceptors





The eye as a spectral image sensor

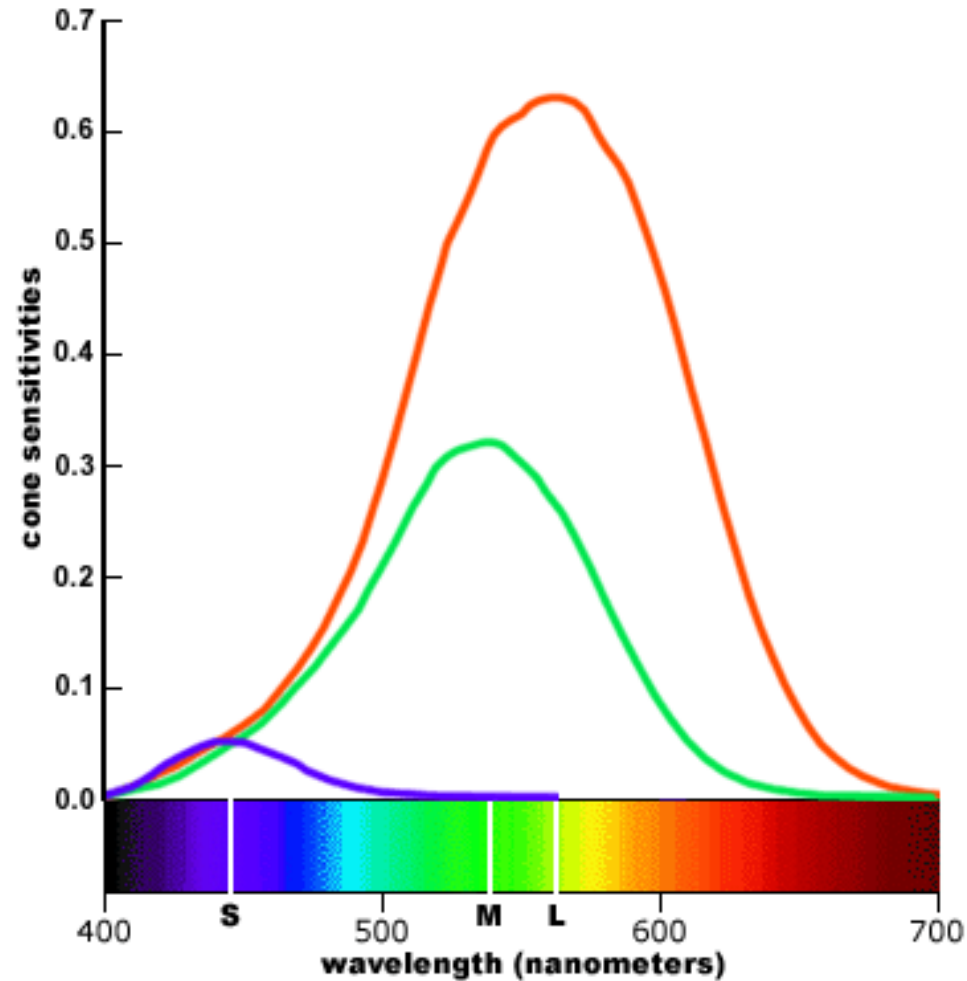
Sensitivity of the cone and rod photoreceptors





The eye as a spectral image sensor

Population weighted linear cone sensitivity functions



The eye as a spectral image sensor

Spectral sensitivity of the photoreceptors

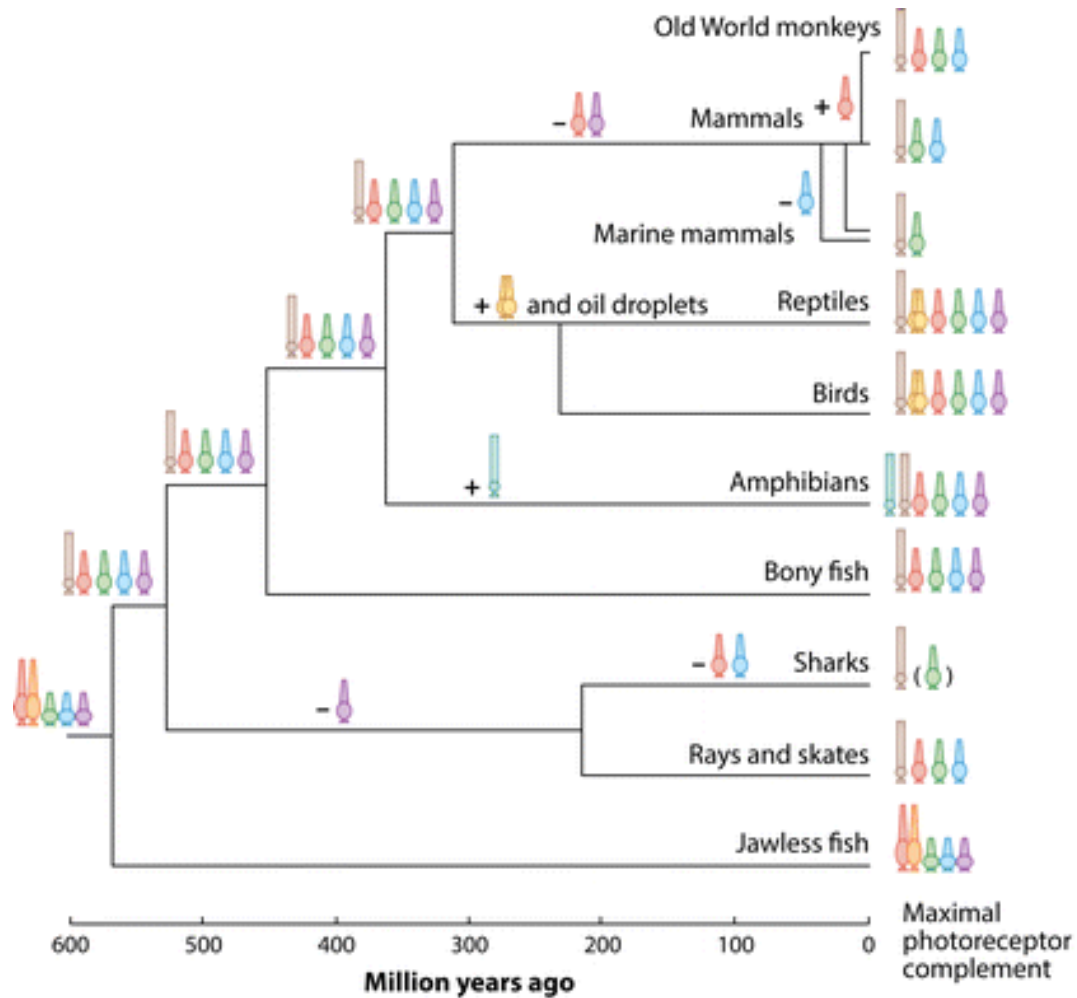
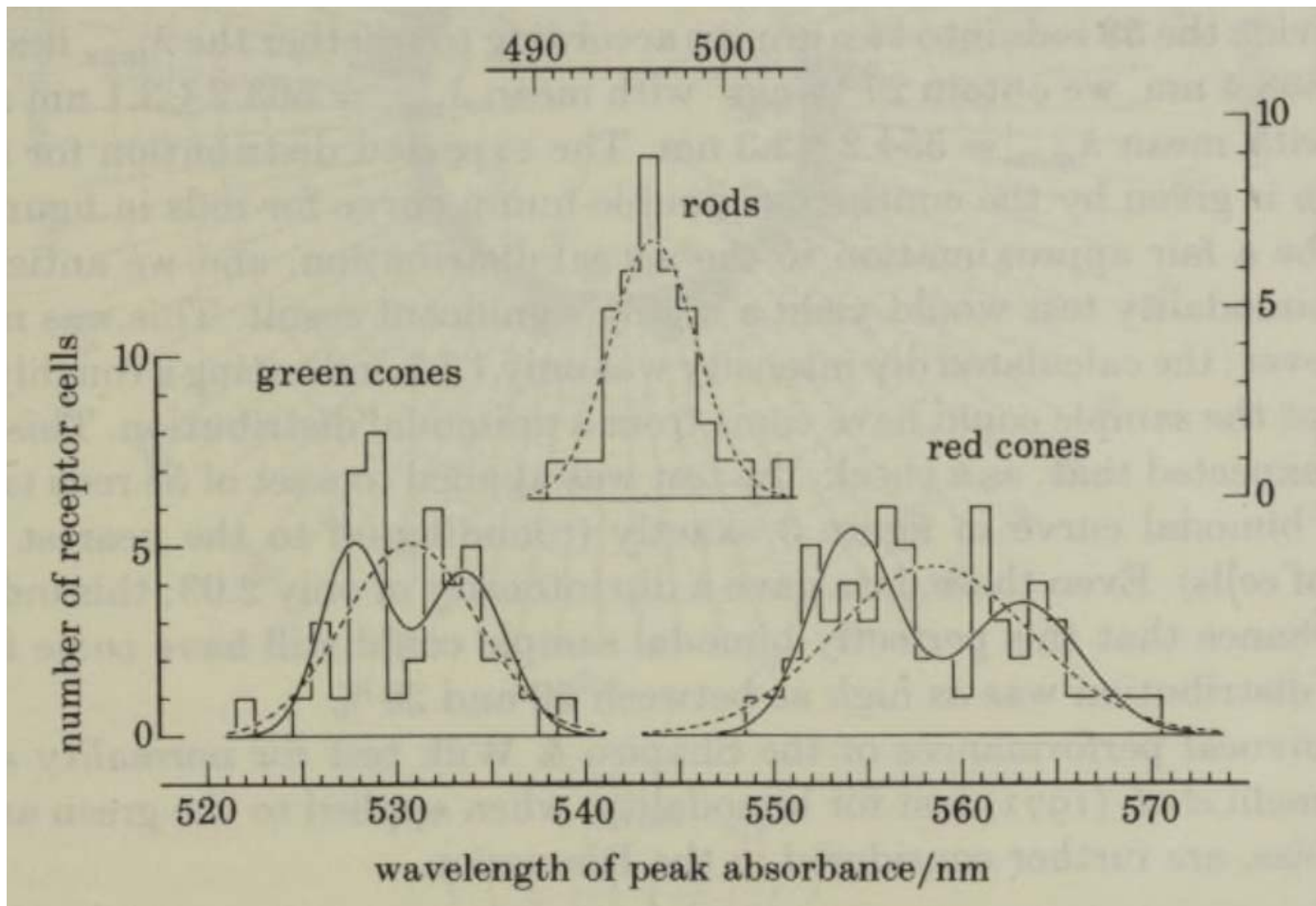


Fig. from: Baden, Annu Rev Vis Sci, 5, 177–200 (2019)

The eye as a spectral image sensor

Spectral sensitivity of the photoreceptors





The eye as a spectral image sensor

Spectral sensitivity of the photoreceptors

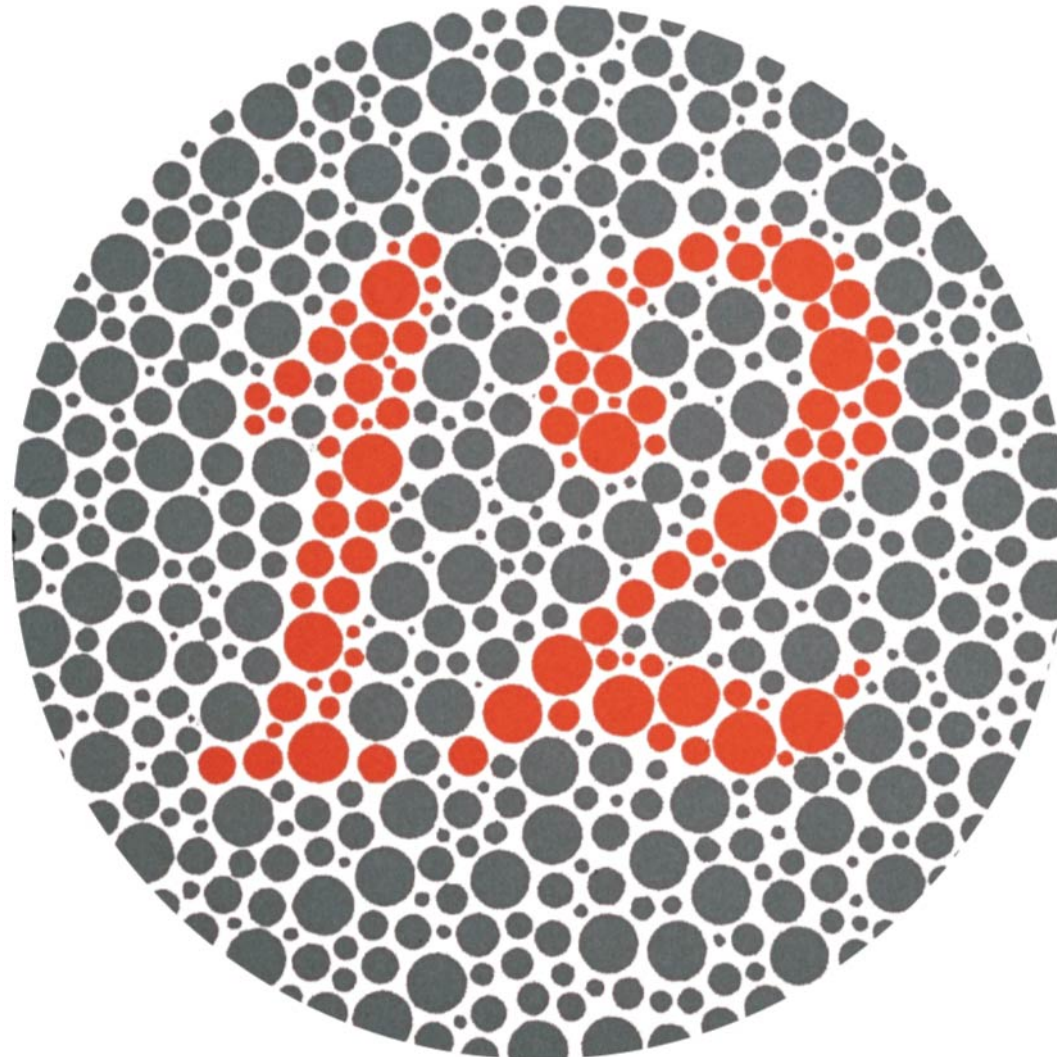


Image processing in human vision

The retina

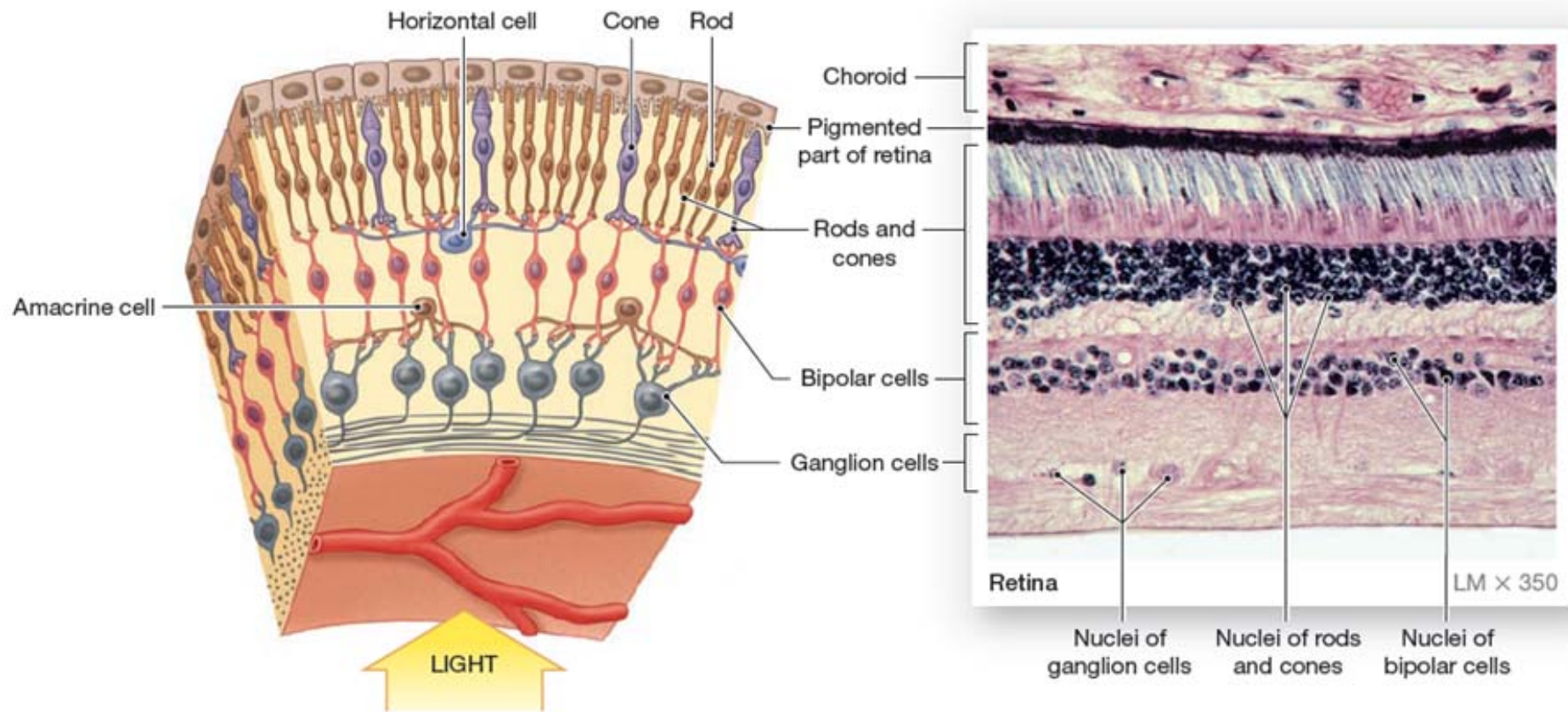


Image processing in human vision

Spectral sensitivity of the photoreceptors

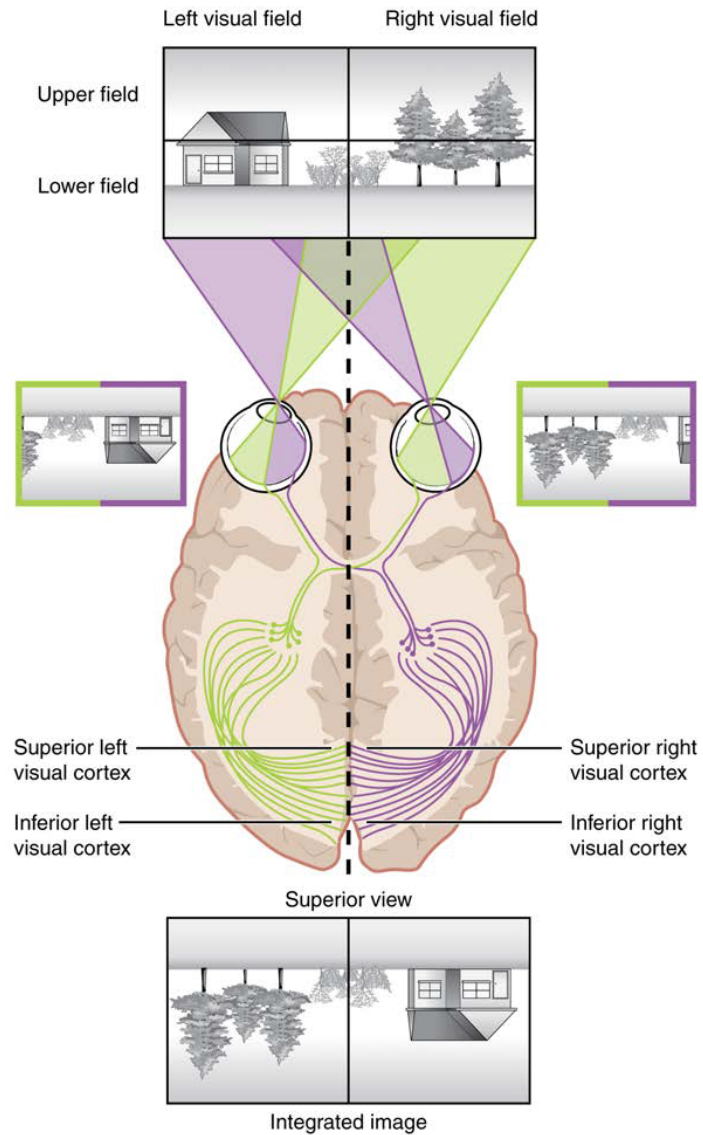


Fig. from: OpenStax
College, Anatomy &
Physiology.
<https://openstax.org/details/books/anatomy-and-physiology>, p.630,



Image processing in human vision

Spectral sensitivity of the photoreceptors

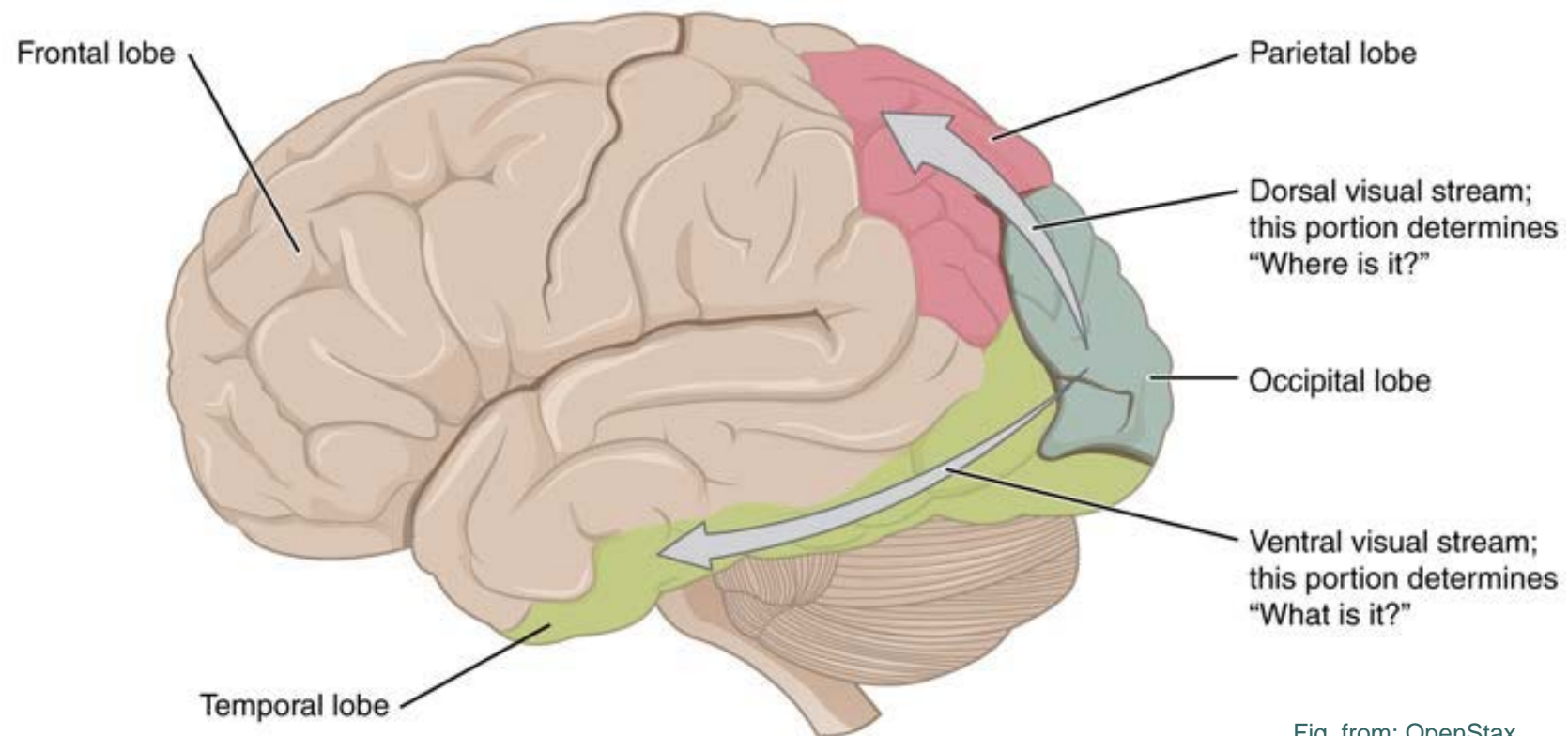


Fig. from: OpenStax
College, Anatomy &
Physiology.
[https://openstax.org/details/
books/anatomy-and-
physiology](https://openstax.org/details/books/anatomy-and-physiology), p.634,



Essential steps in image processing

Image acquisition and processing in human vision

