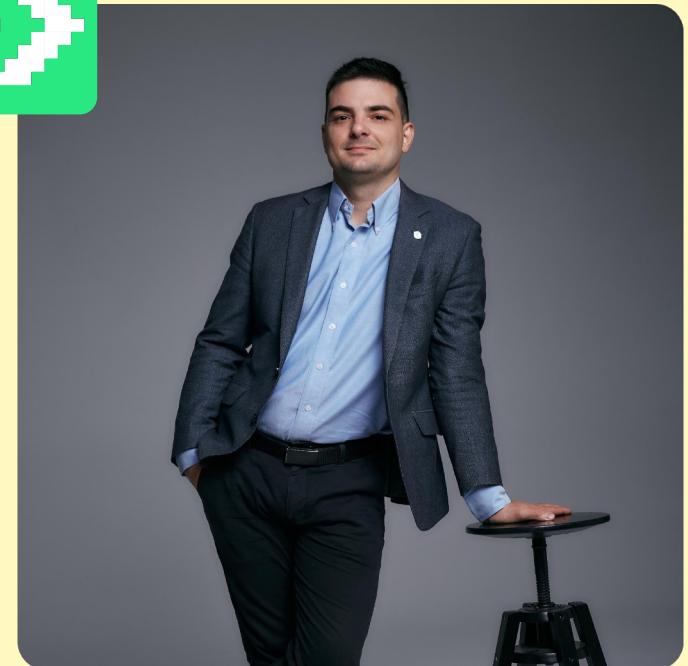
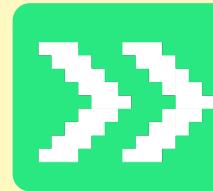


Biological vision and classic edge detection

YOUNG & YANDEX

Радослав Нейчев
Выпускник и преподаватель ШАД и МФТИ,
руководитель группы ML-разработки в Яндексе,
основатель  girafe



Outline

01 Convolution recap

02 Eyes structure and types

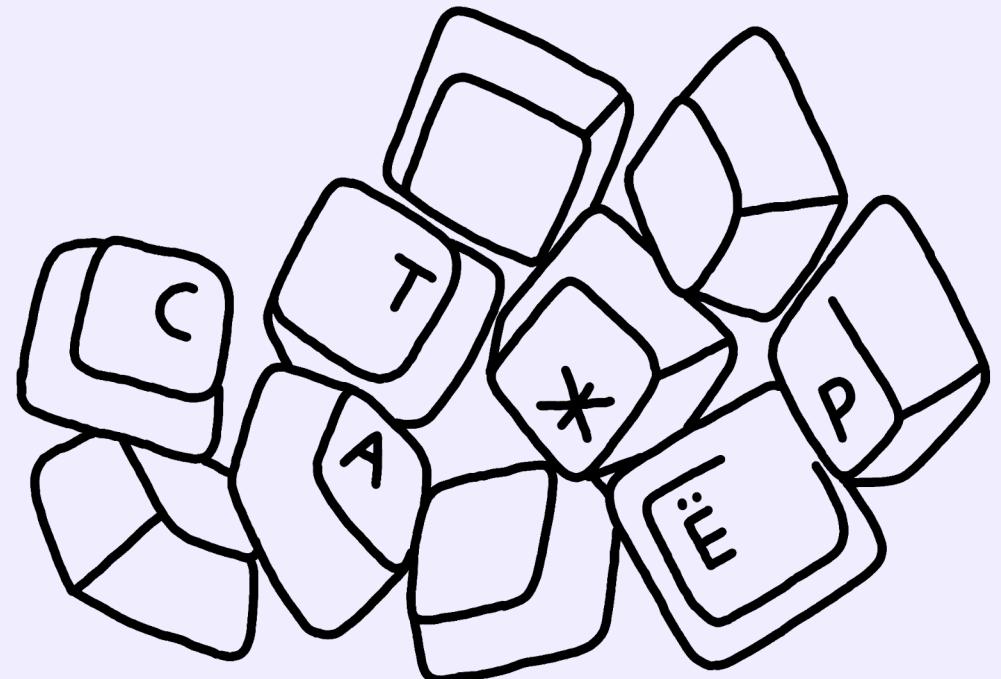
03 Sobel filtering

04 Canny filtering

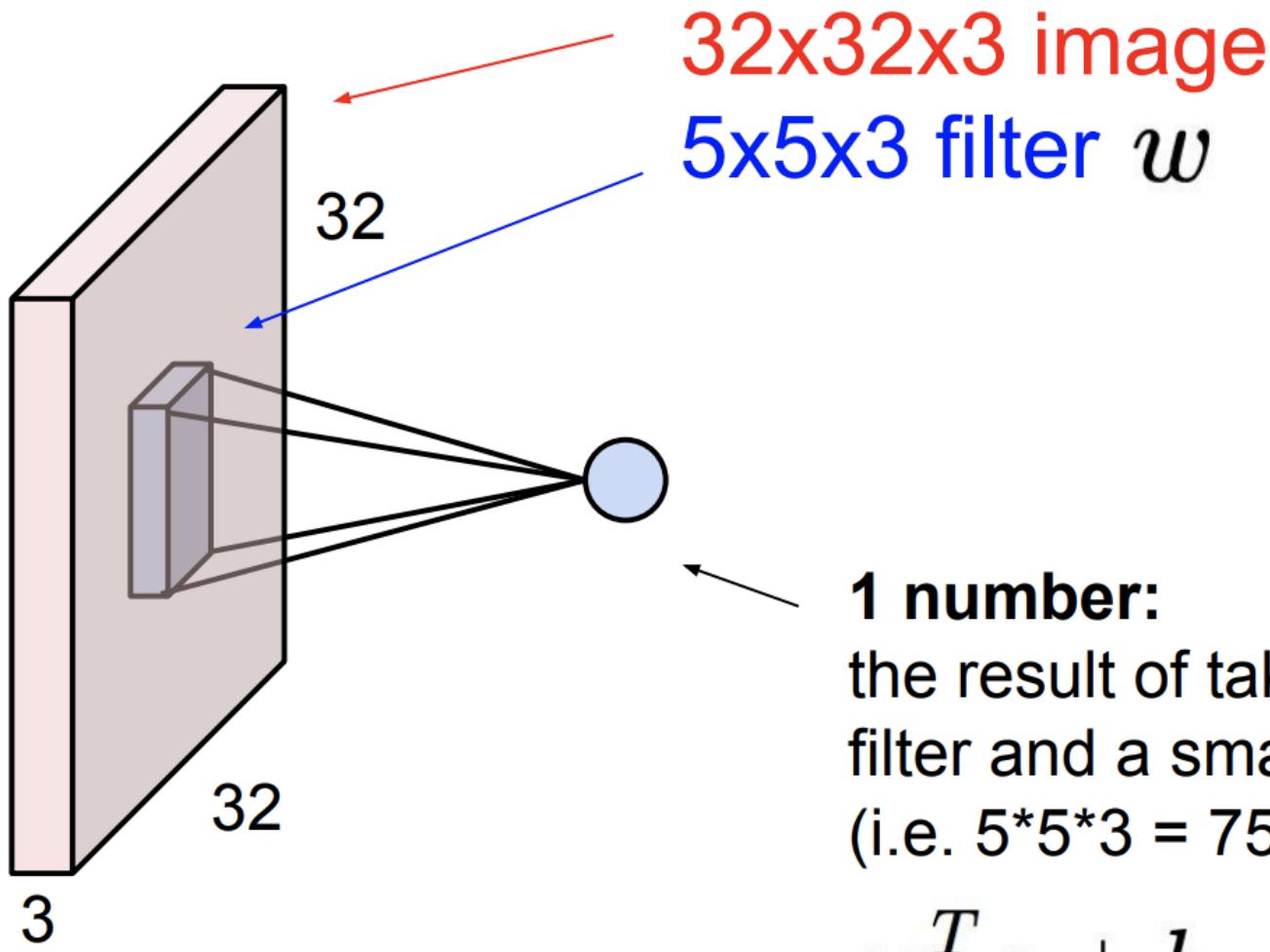
05 Histogram of oriented gradients (HoG)

Convolutions recap

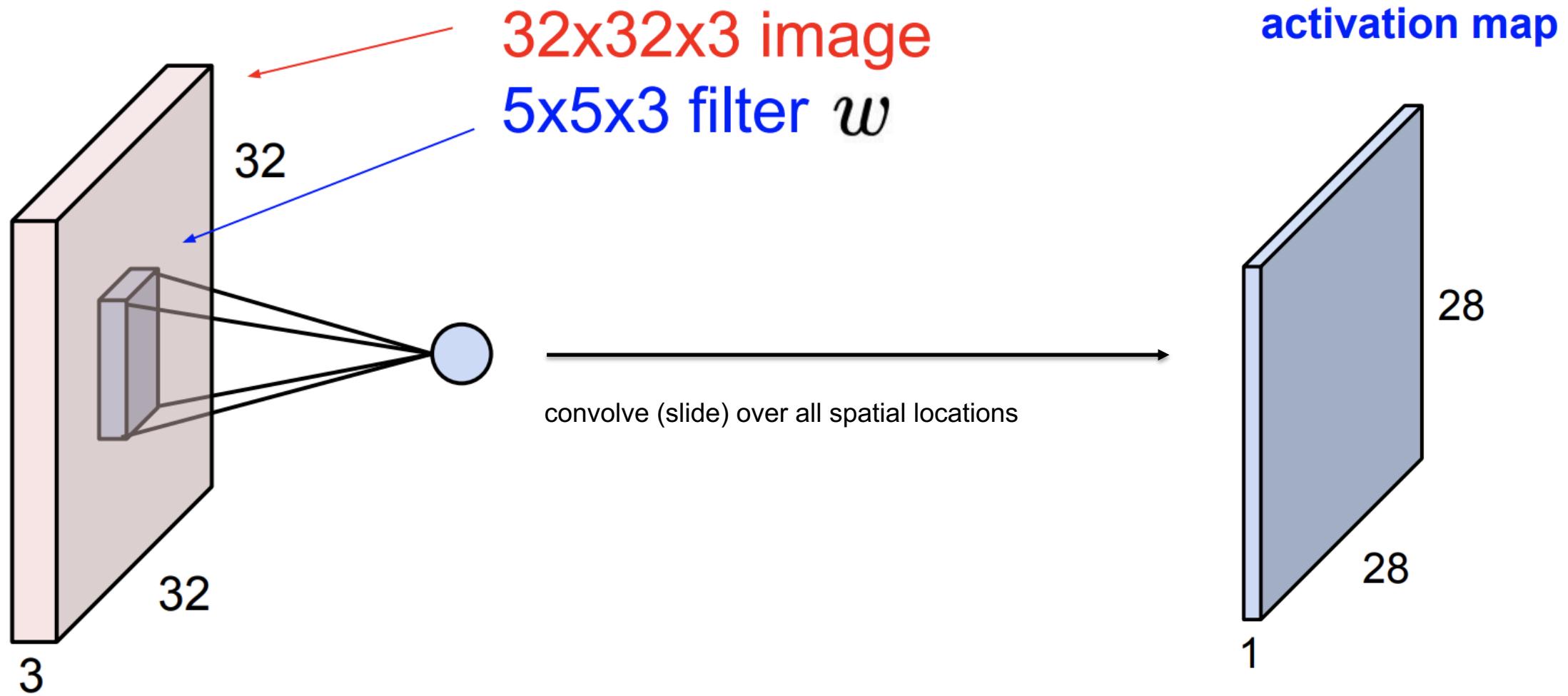
01



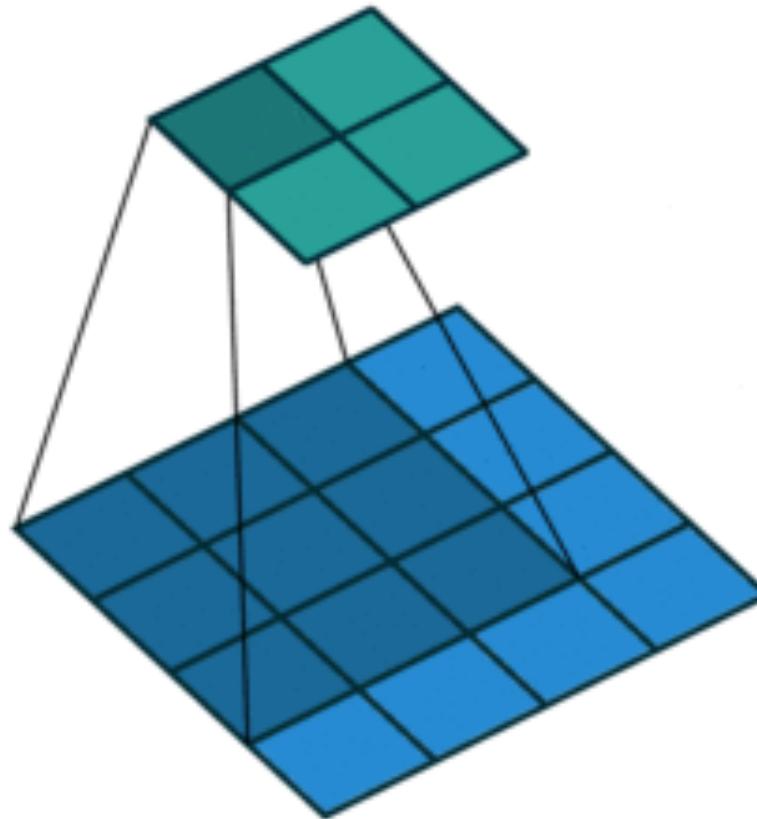
Convolutional layer



Convolutional layer



Convolution operation

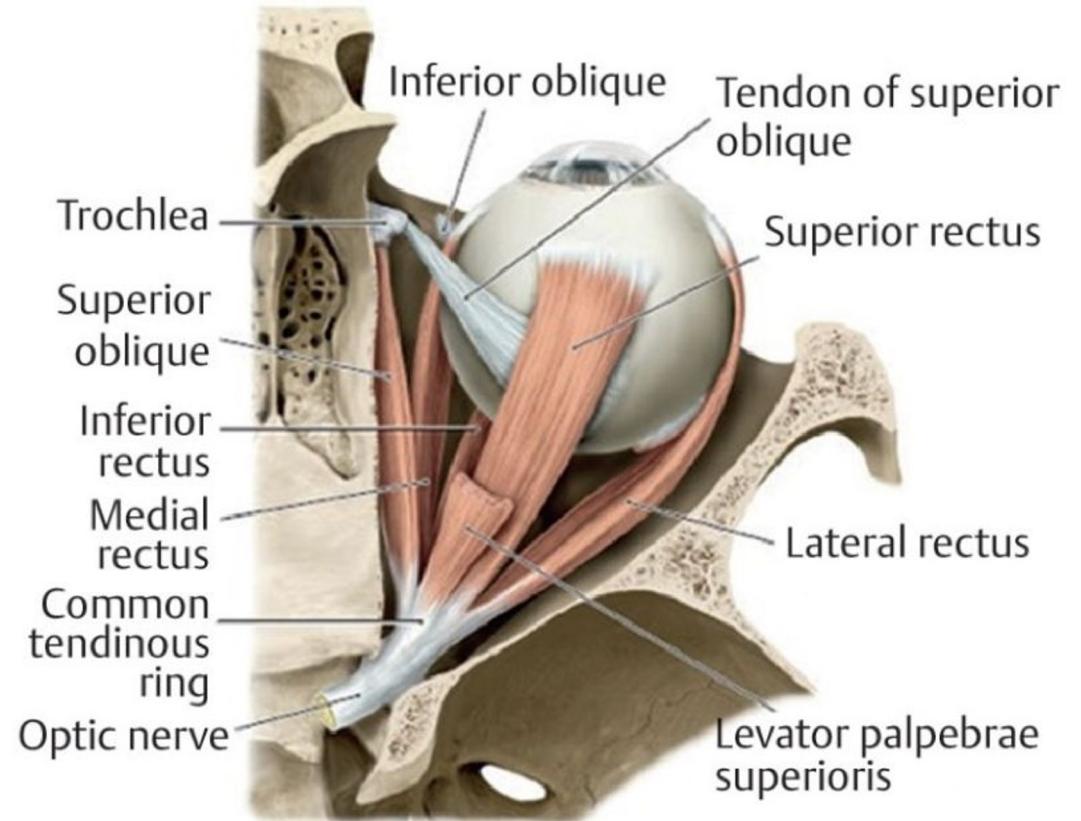
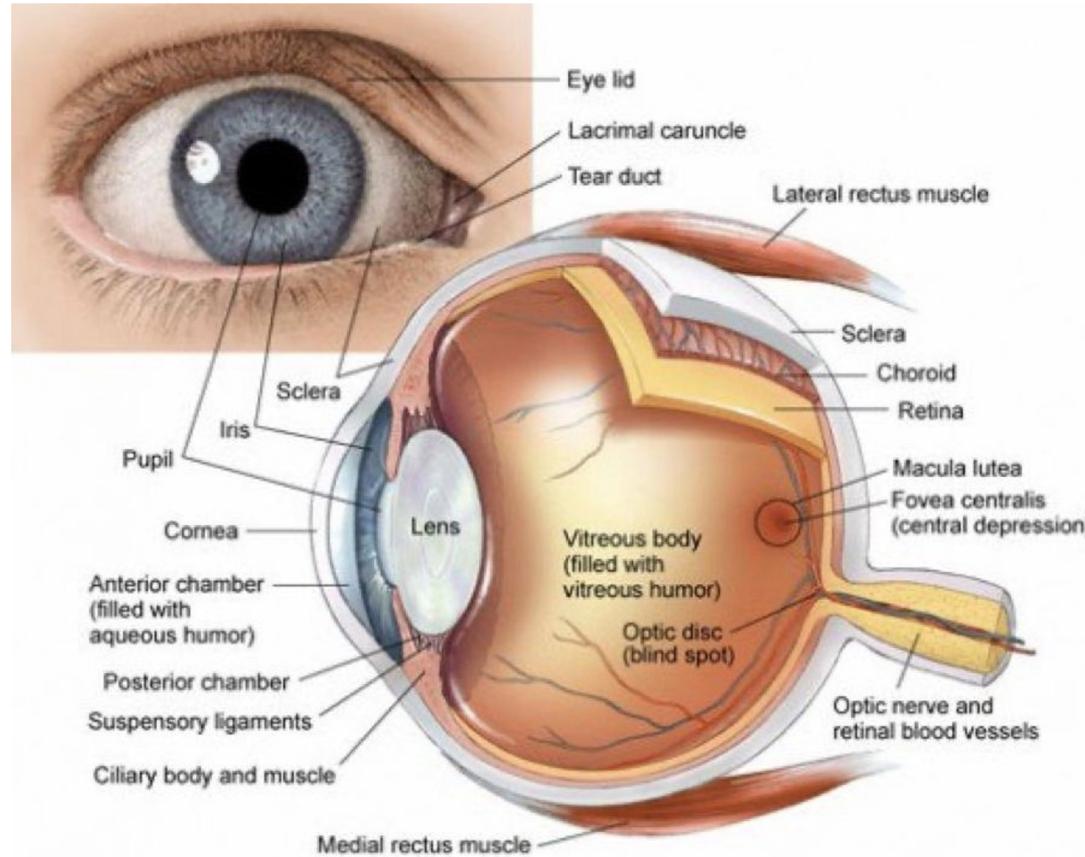


Biological vision systems

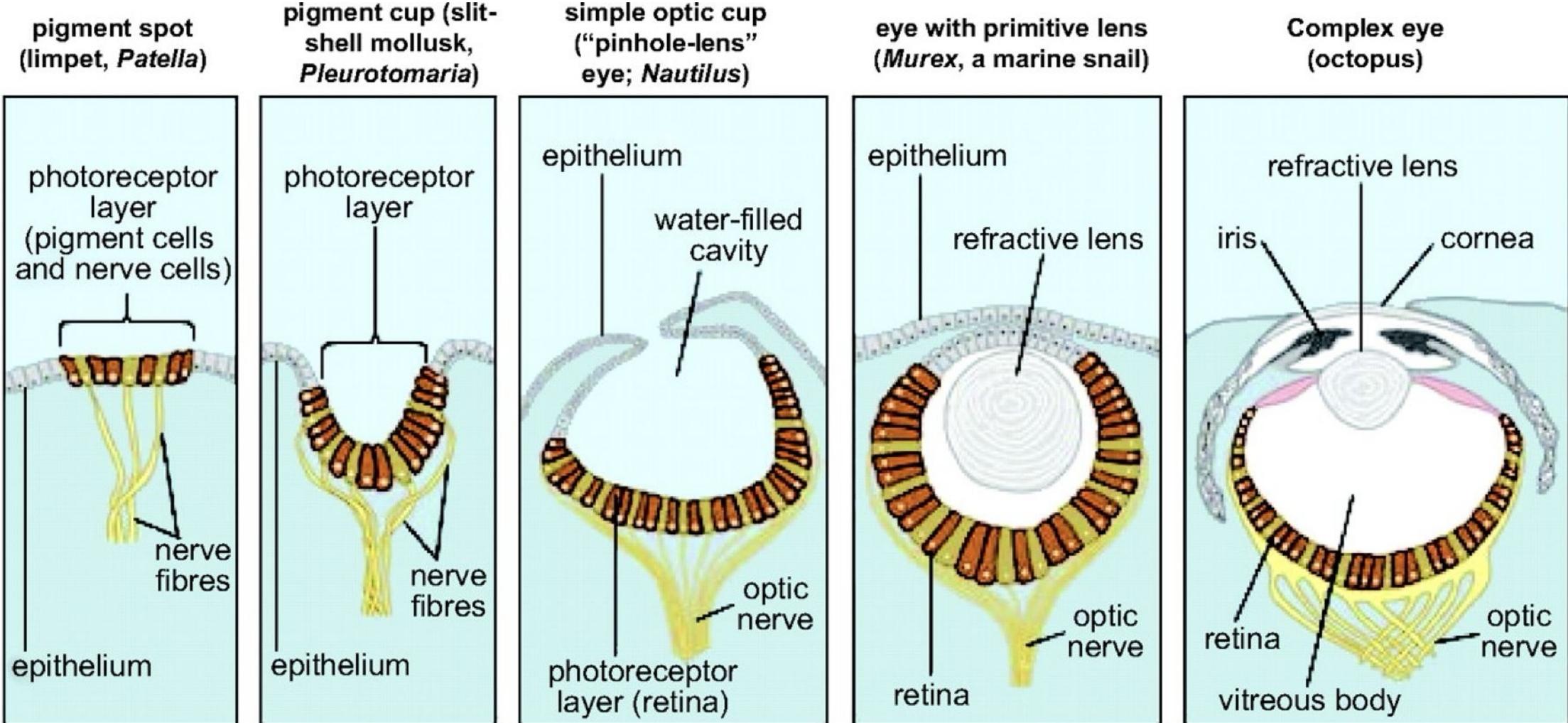
02



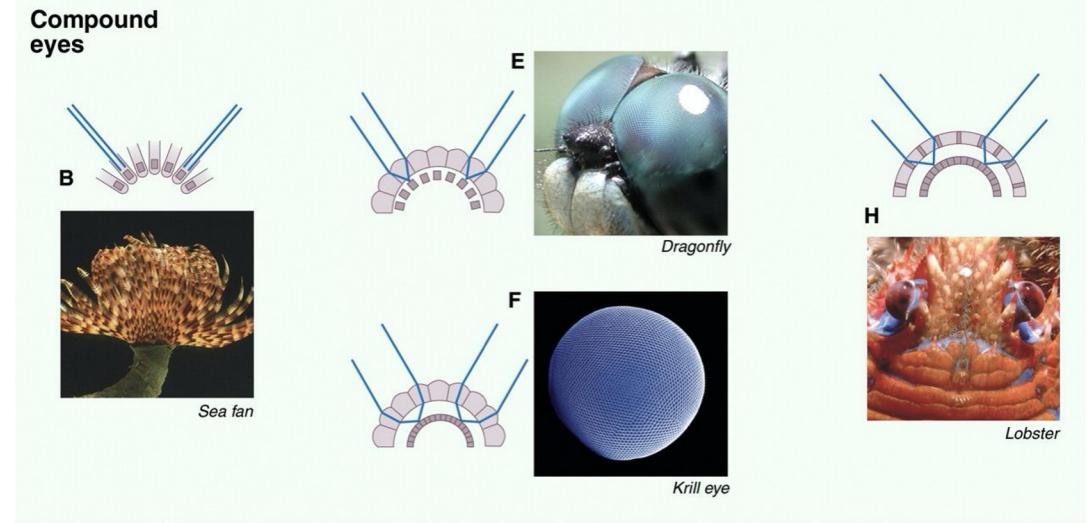
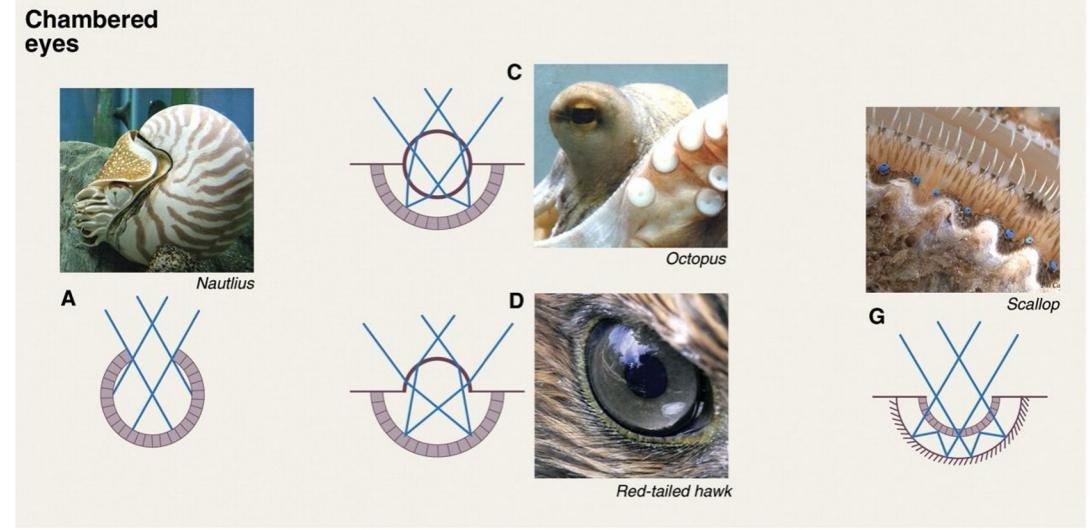
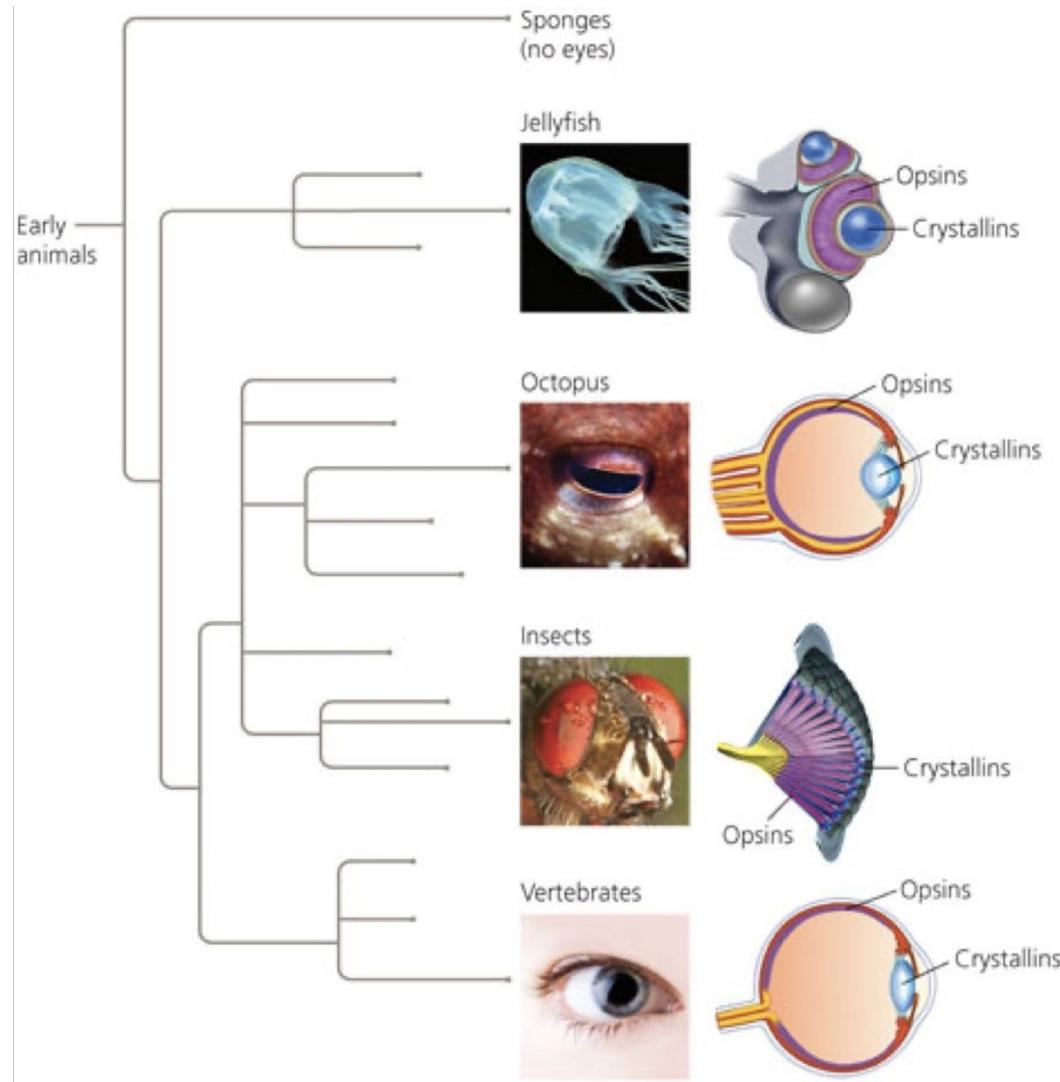
Biological eye



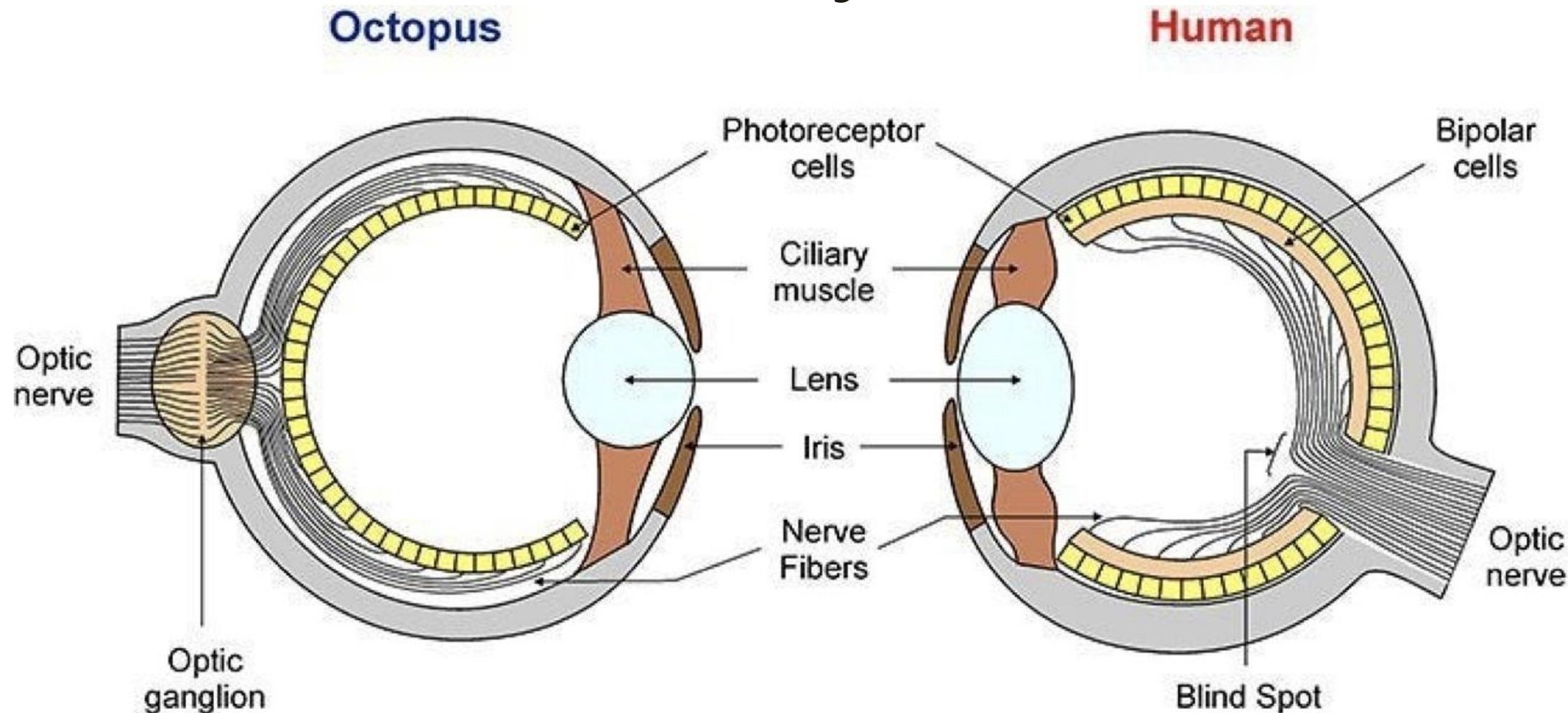
Evolutionary development



Eye types

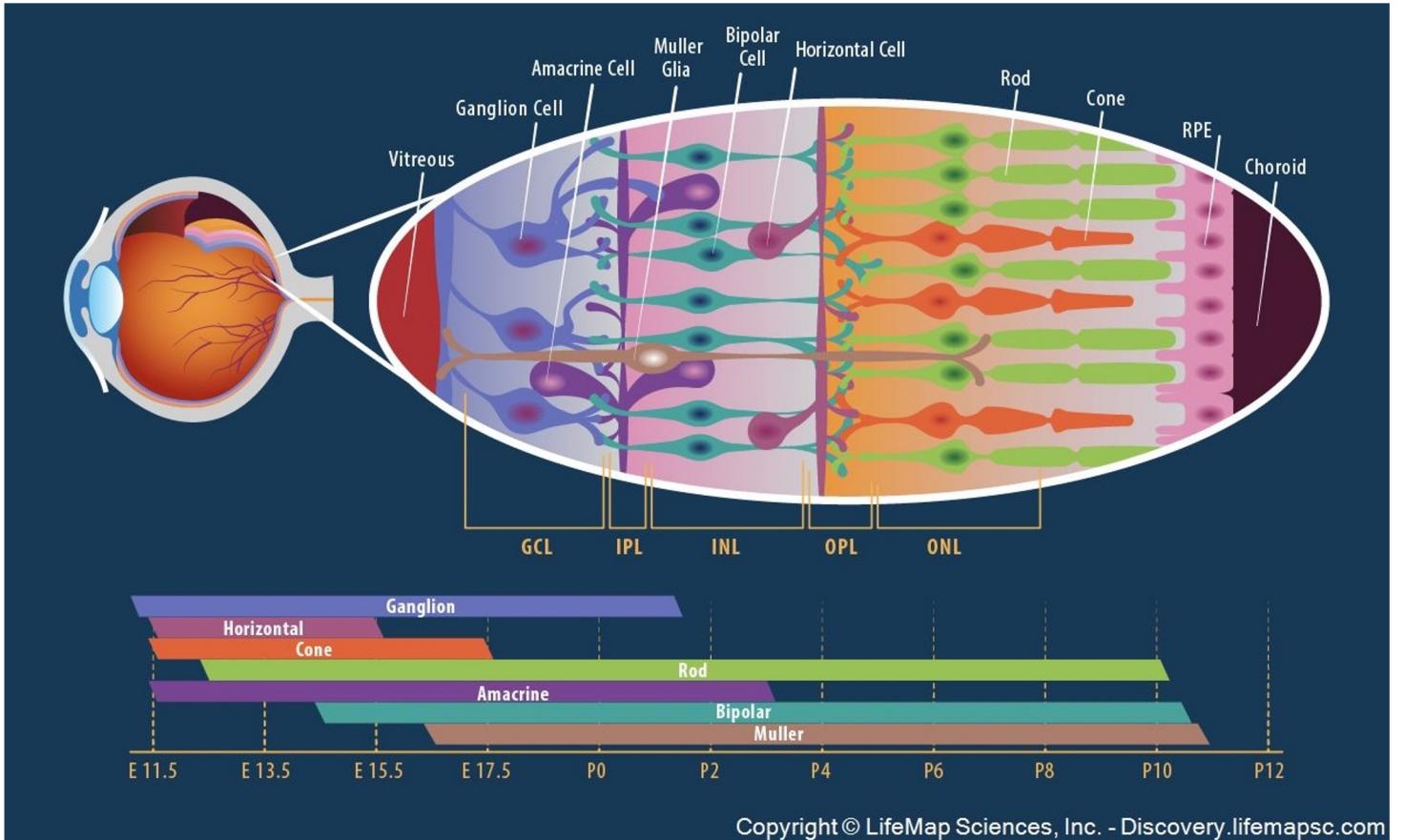
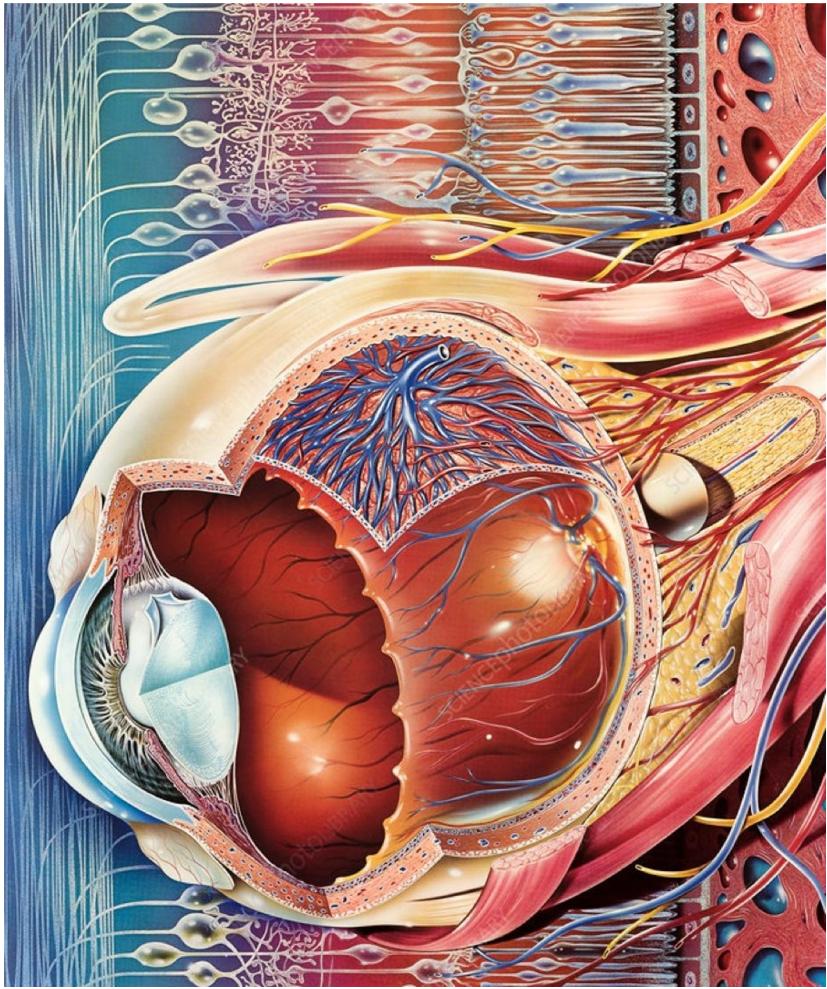


Lens and corneal eyes



[More on eyes classification](#)

Photosensitive cells layers



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Eyes functioning research

[Yarbus, A.L. \(1967\) Eye Movements and Vision. Plenum Press, New York.](#)

This work was conducted at IITP (see later slides for current state of our lab)

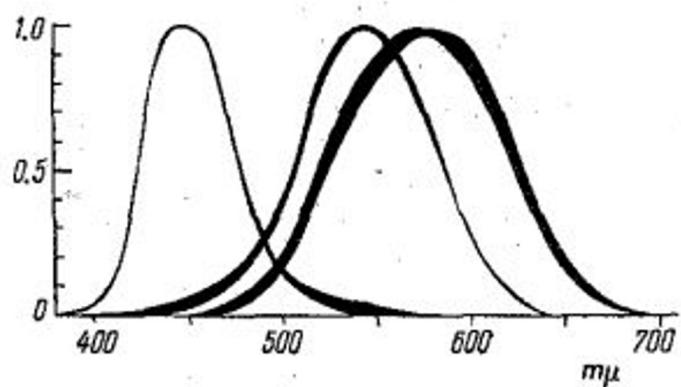


Fig. 3. Curves of sensitivity of human daylight receptors—cones (Bongard and Smirnov, 1955).

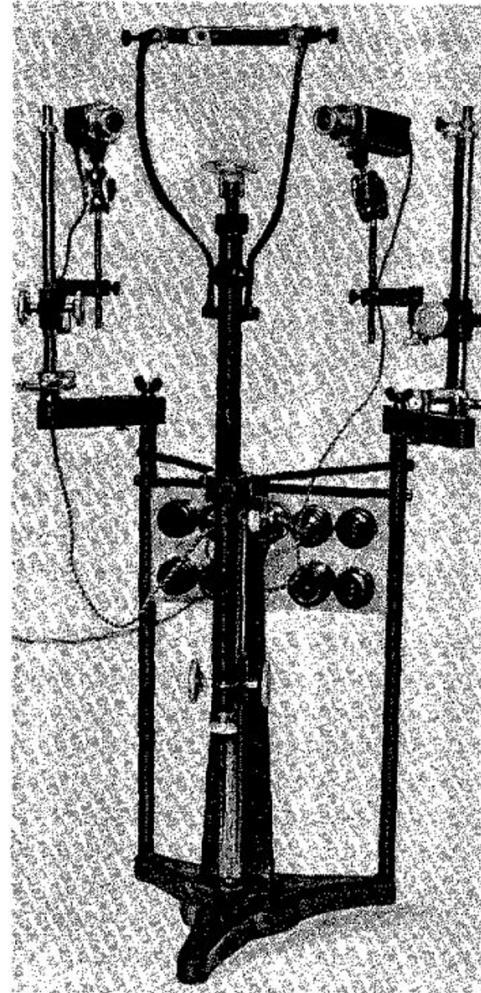
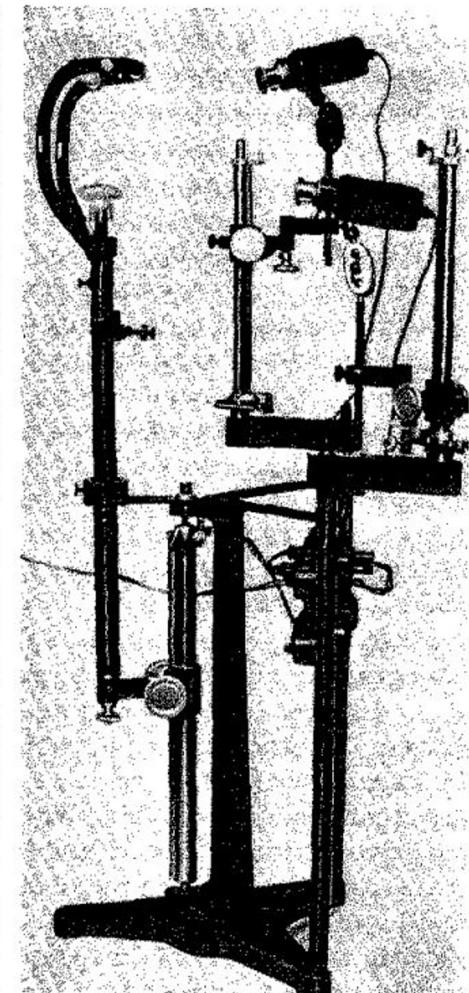
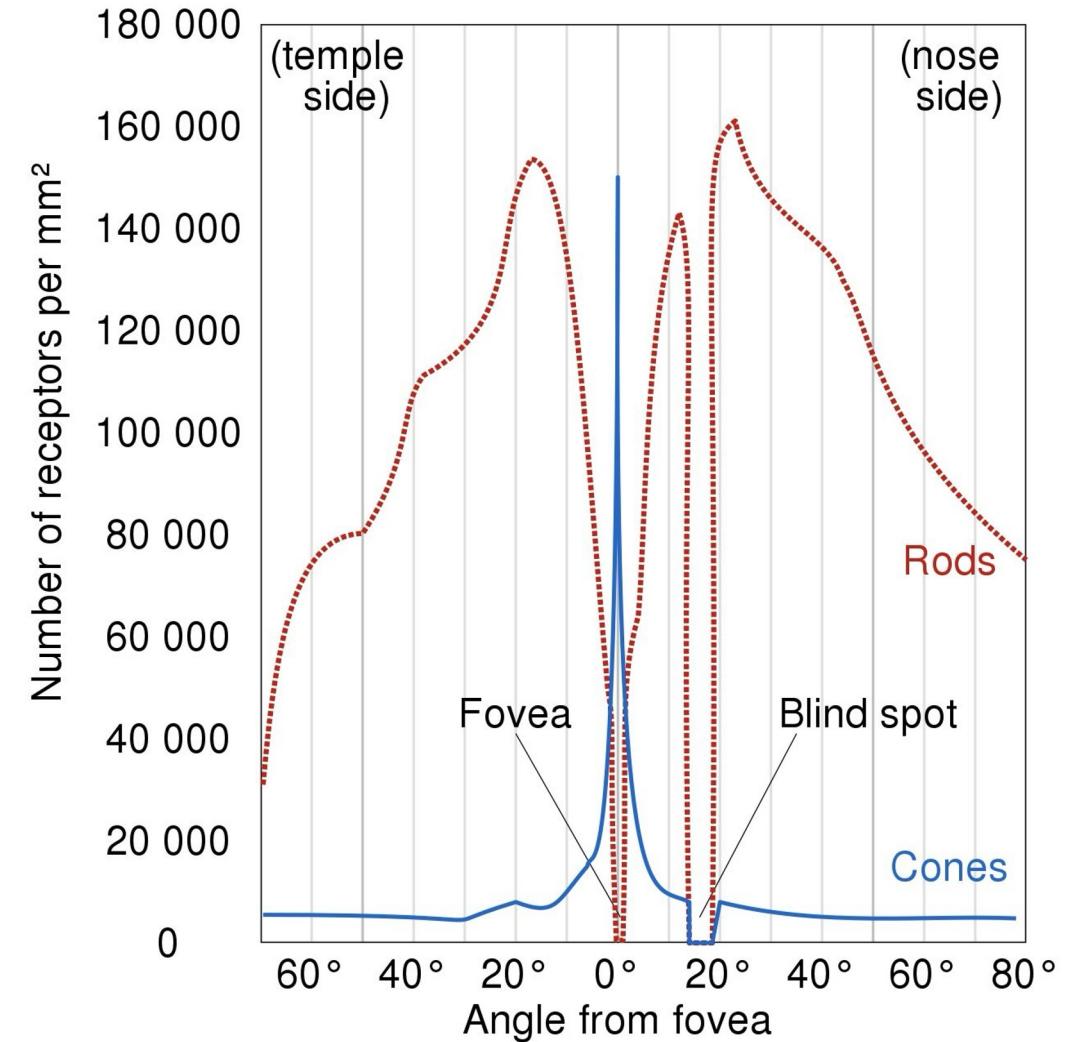
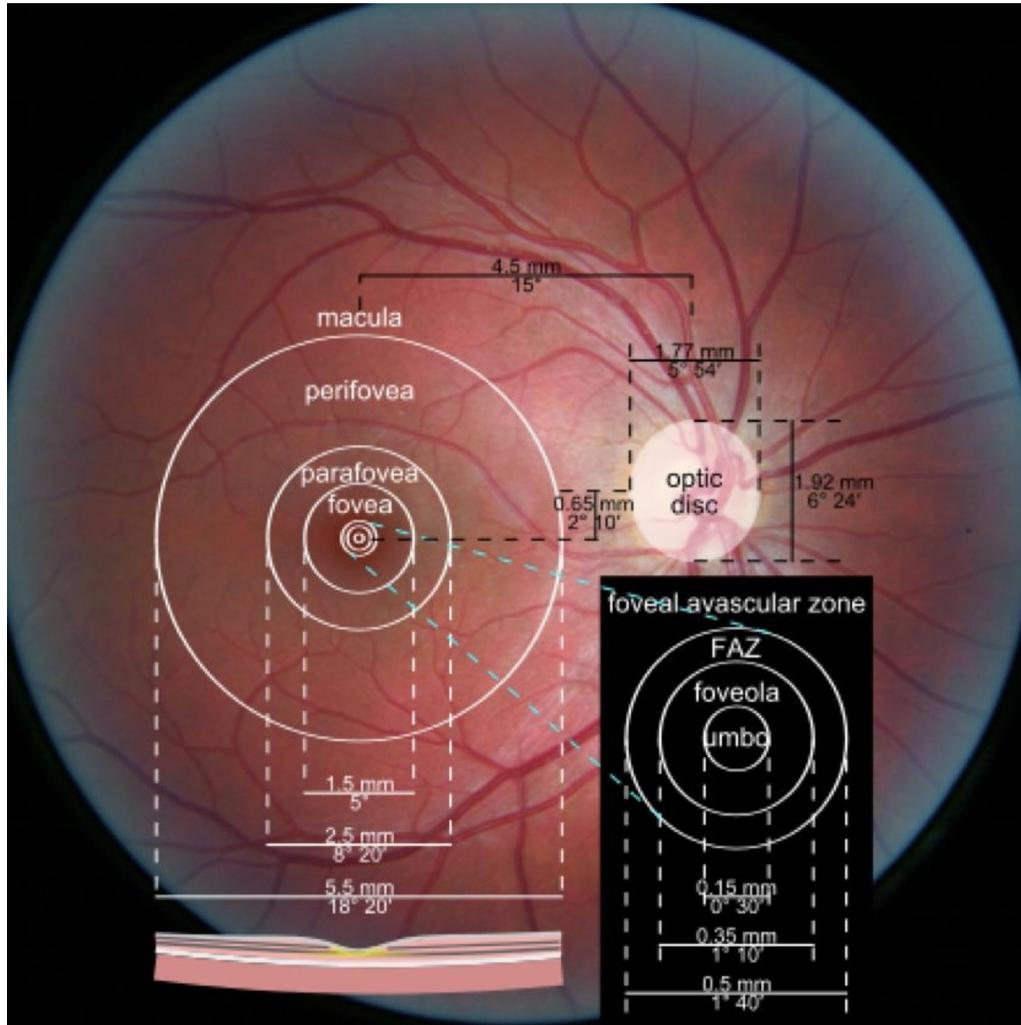


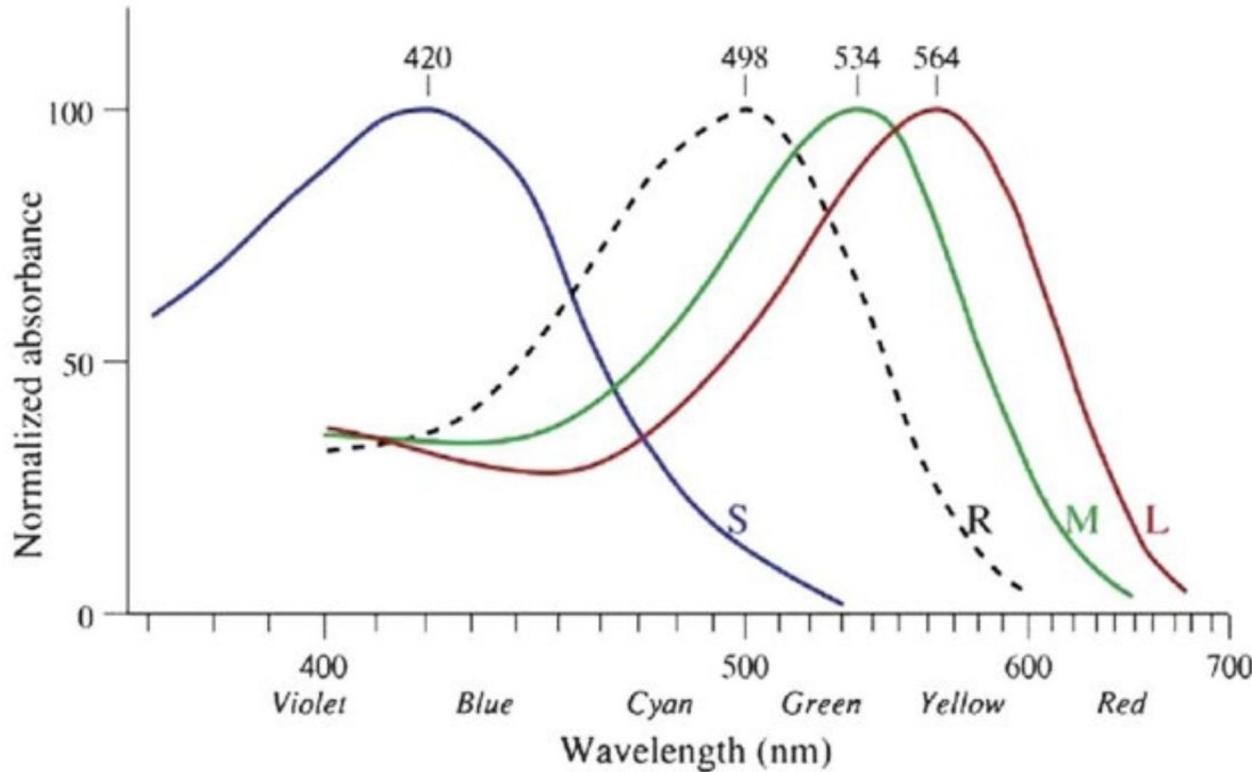
Fig. 21. The apparatus used in recording eye movements.



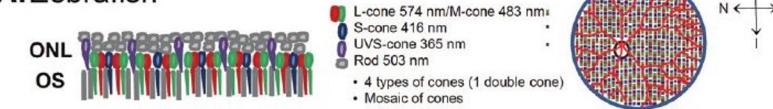
Retina spatial sensitivity



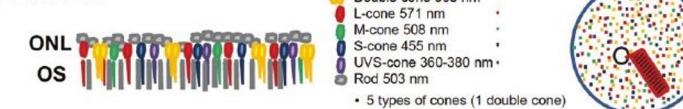
Retina spectral sensitivity



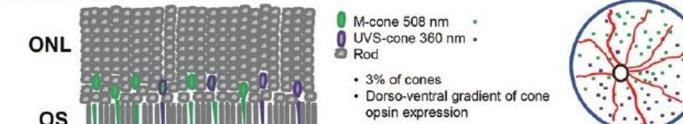
A. Zebrafish



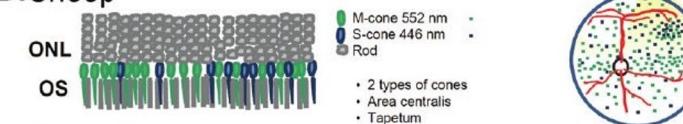
B. Chick



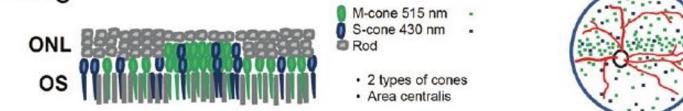
C. Mouse



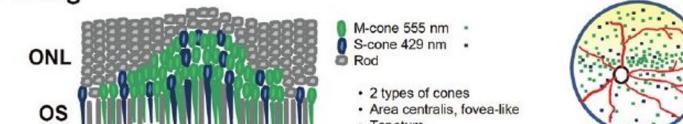
D. Sheep



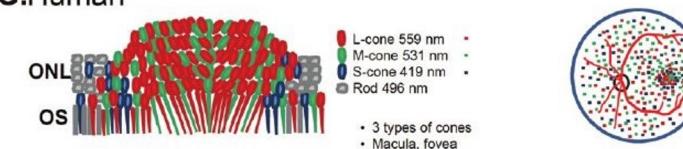
E. Pig



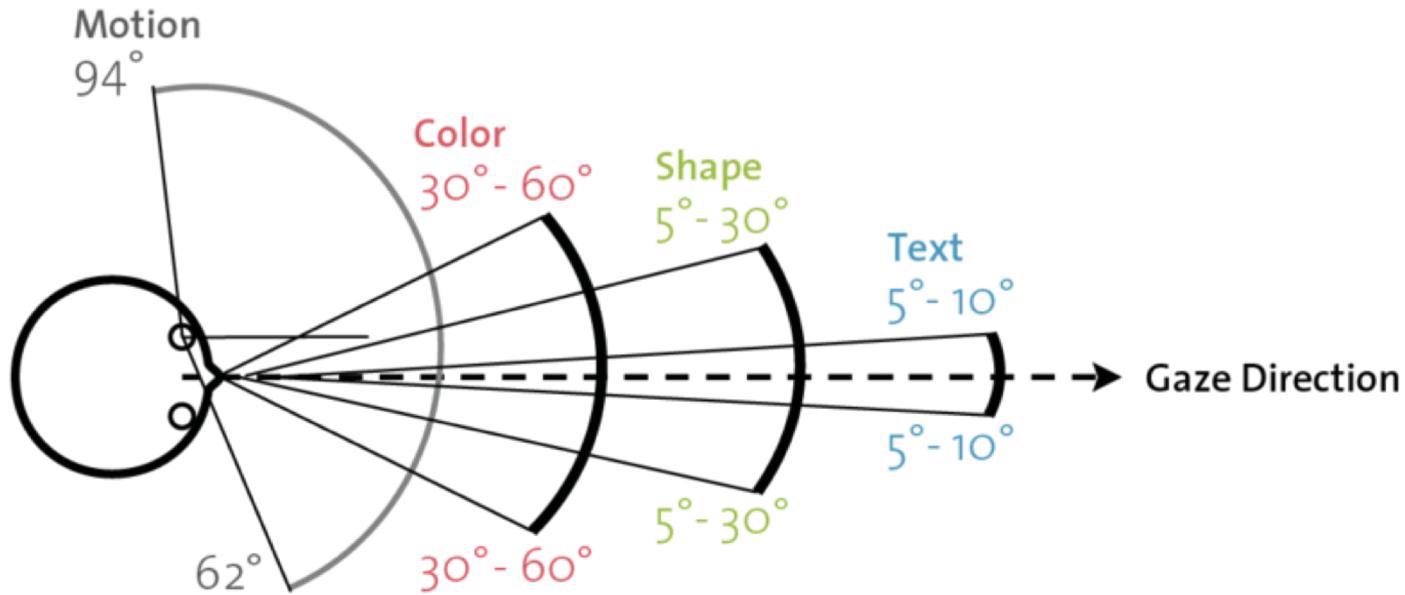
F. Dog



G. Human



Angle of view and resolution



7 megapixels in the fovea
1 megapixel in other areas

16.67 to 500 ms processing speed

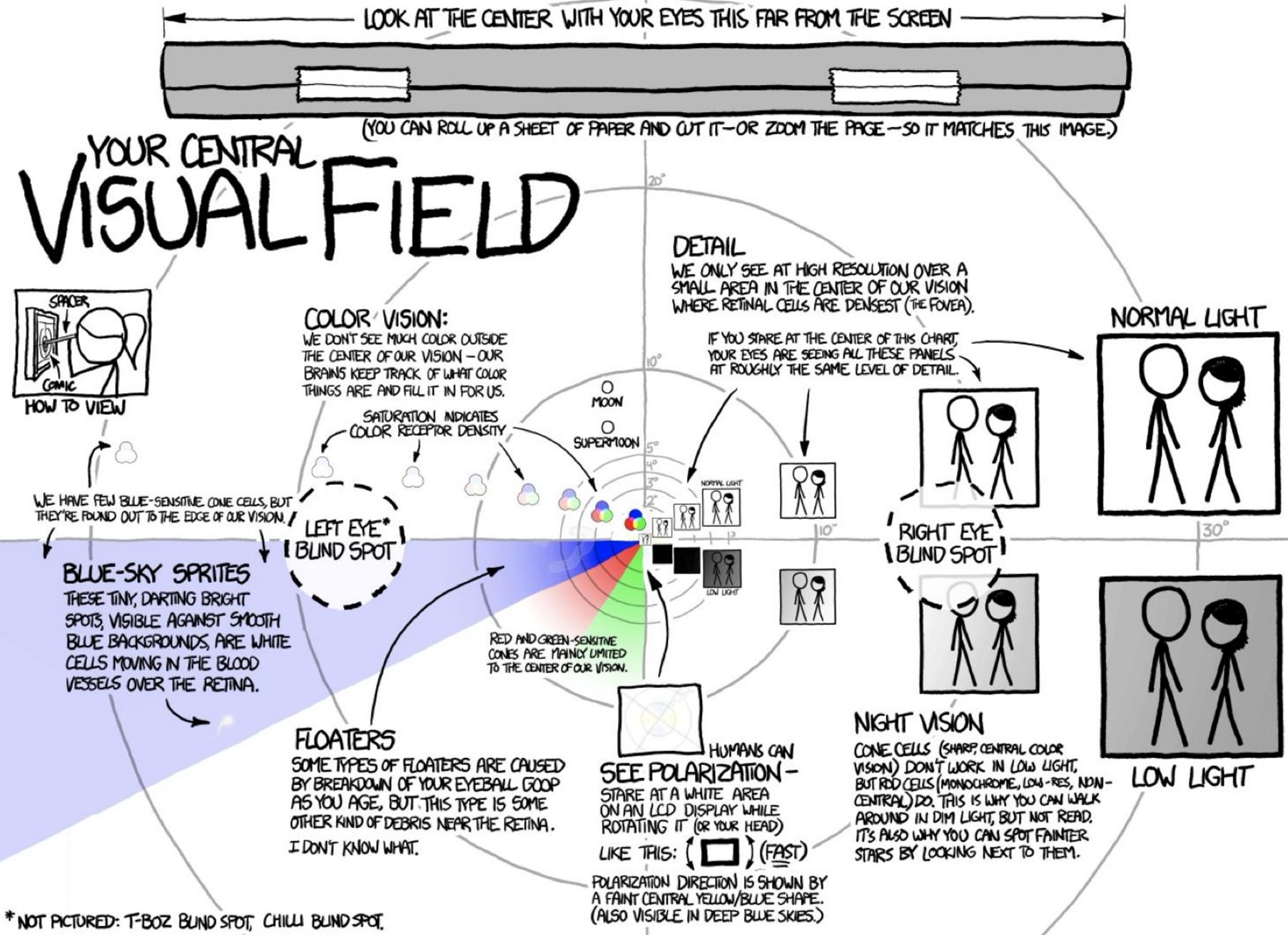
What do we really see with our eyes?

If we receive instant signal from an optic nerve

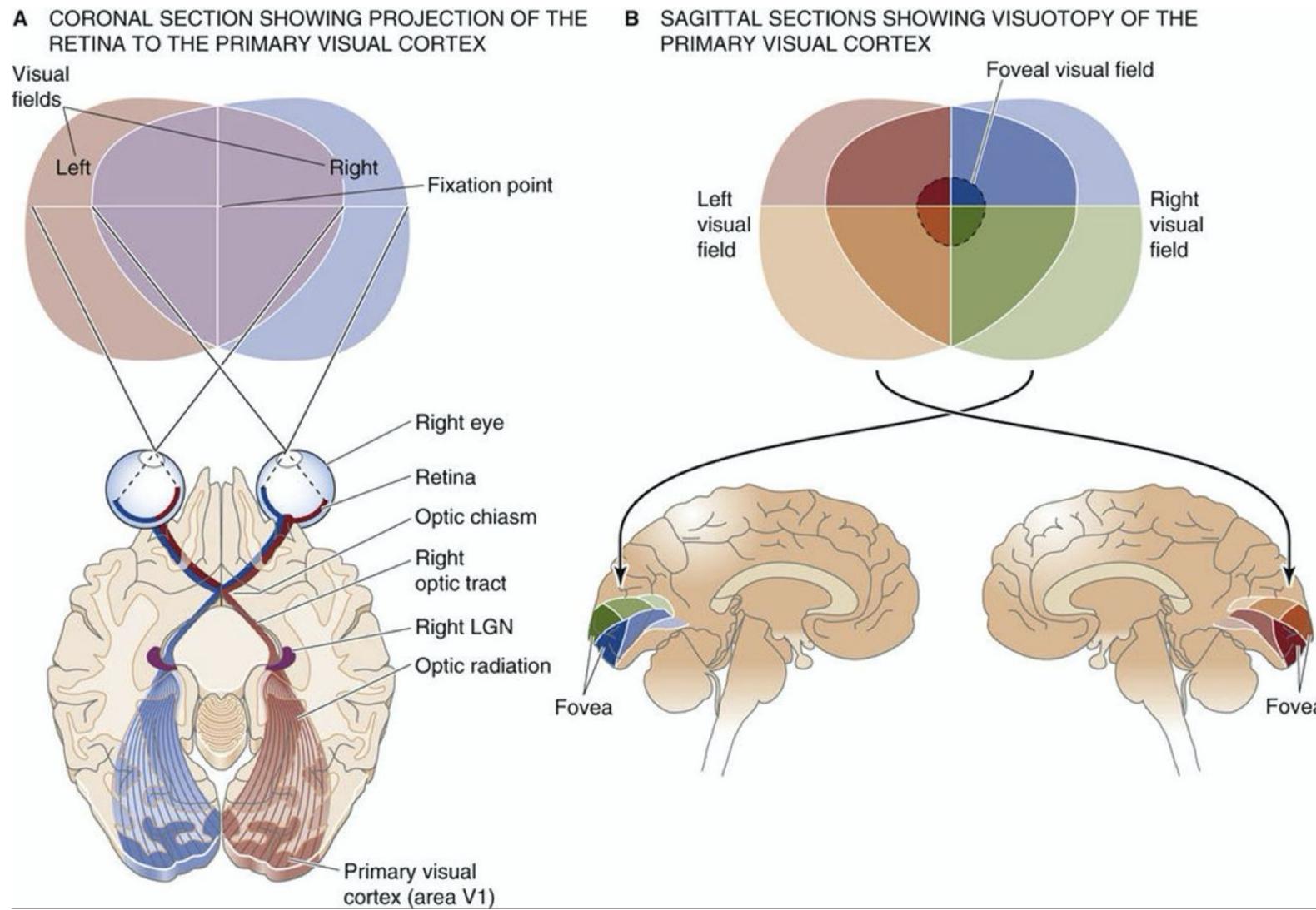




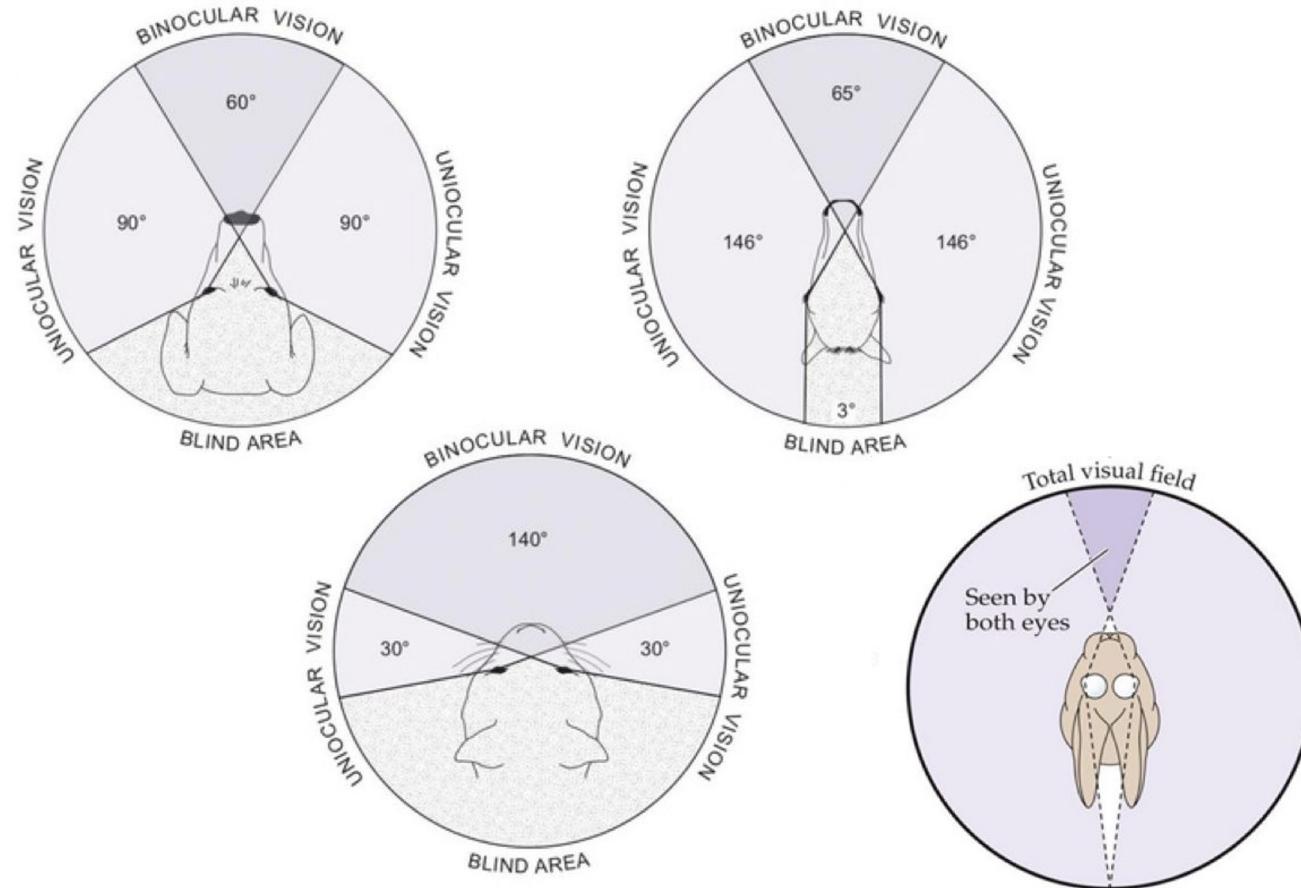
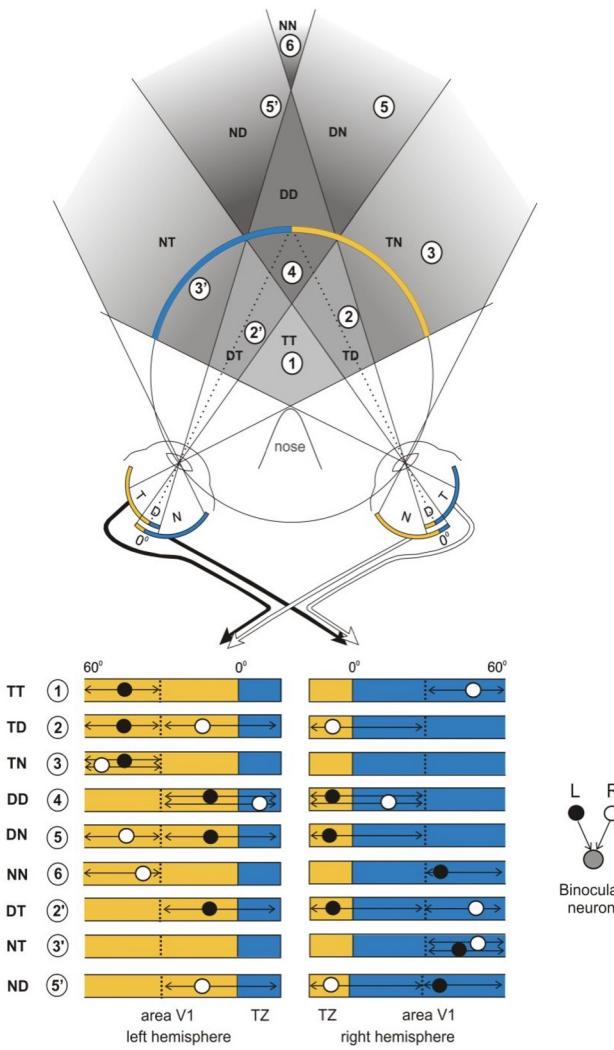




Projection to brain



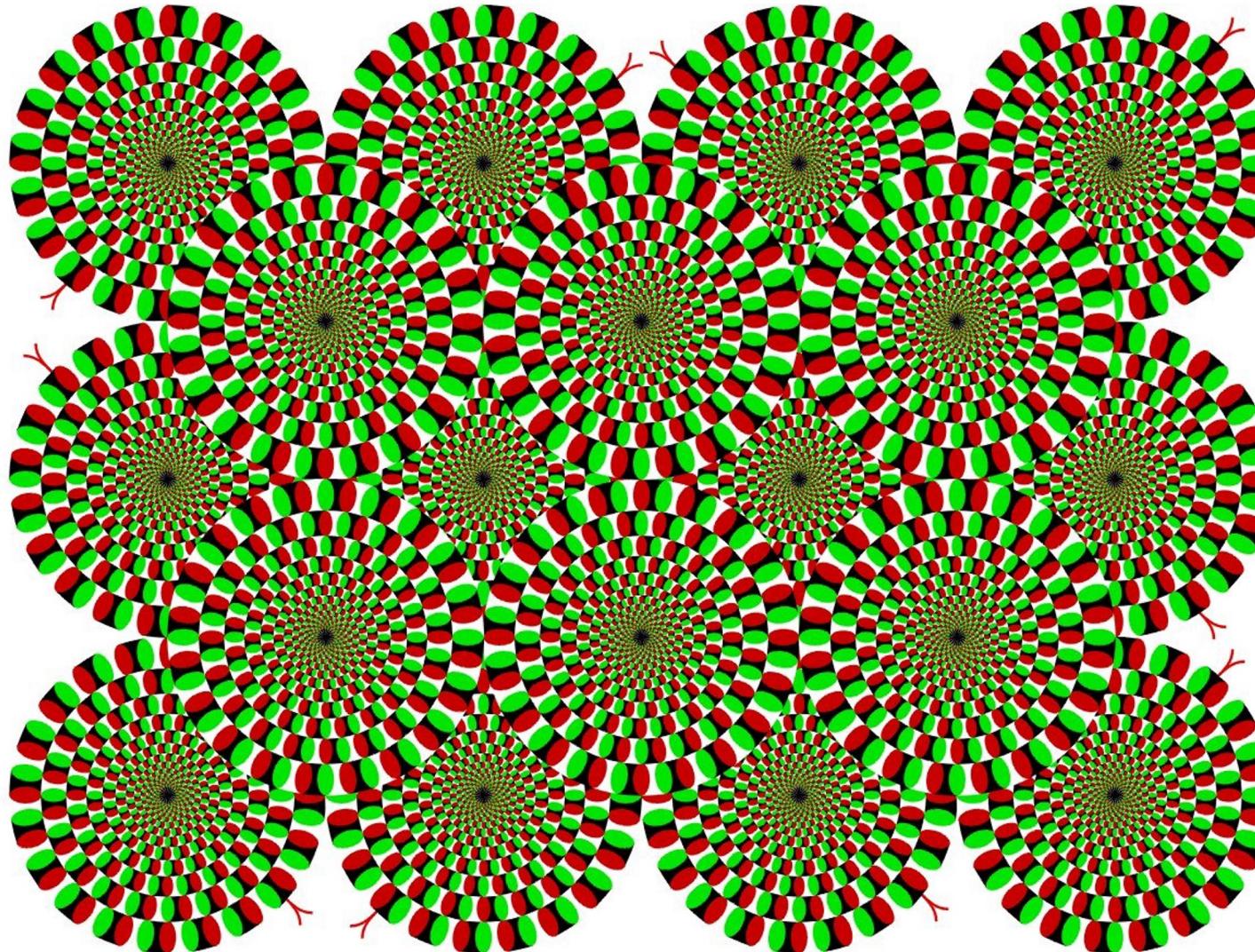
Binocular vision



Autostereogram phenomenon



Move eye



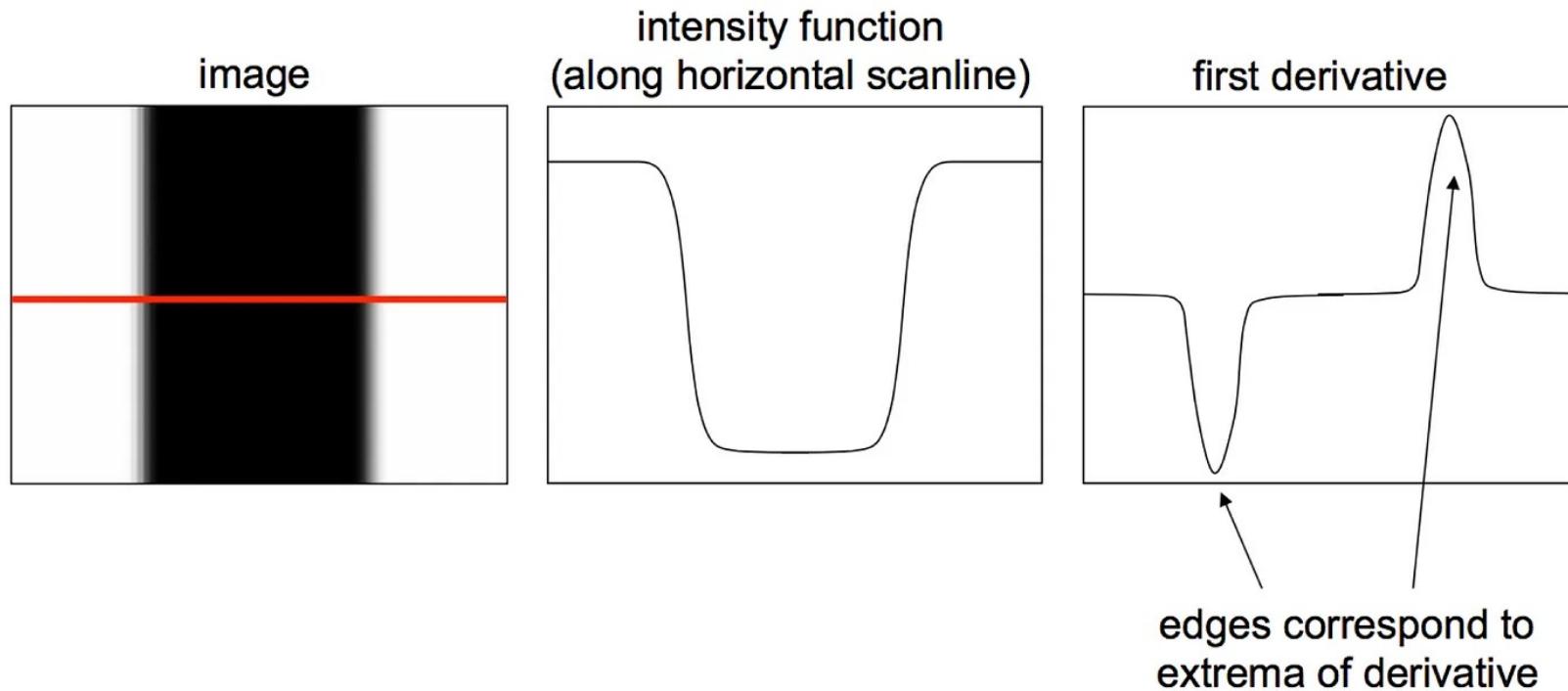
[List of many other illusions](#)
(not only caused by eye
movement)

Edge detection

03



Sobel filtering



Sobel filtering

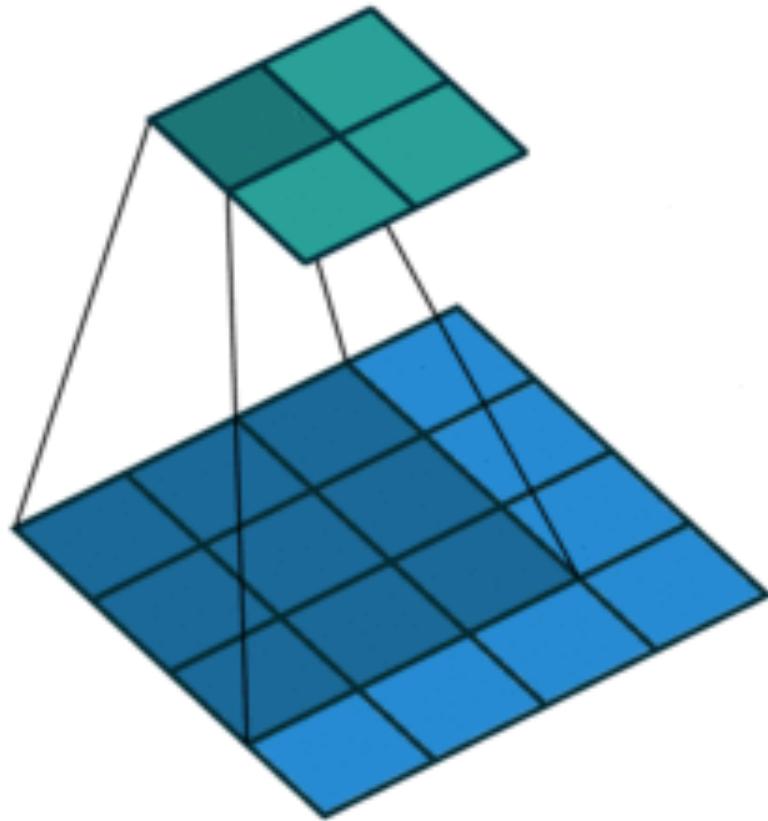
X – Direction Kernel

-1	0	1
-2	0	2
-1	0	1

Y – Direction Kernel

-1	-2	-1
0	0	0
1	2	1

We convolve two fixed filters



X – Direction Kernel

-1	0	1
-2	0	2
-1	0	1

Y – Direction Kernel

-1	-2	-1
0	0	0
1	2	1

Original



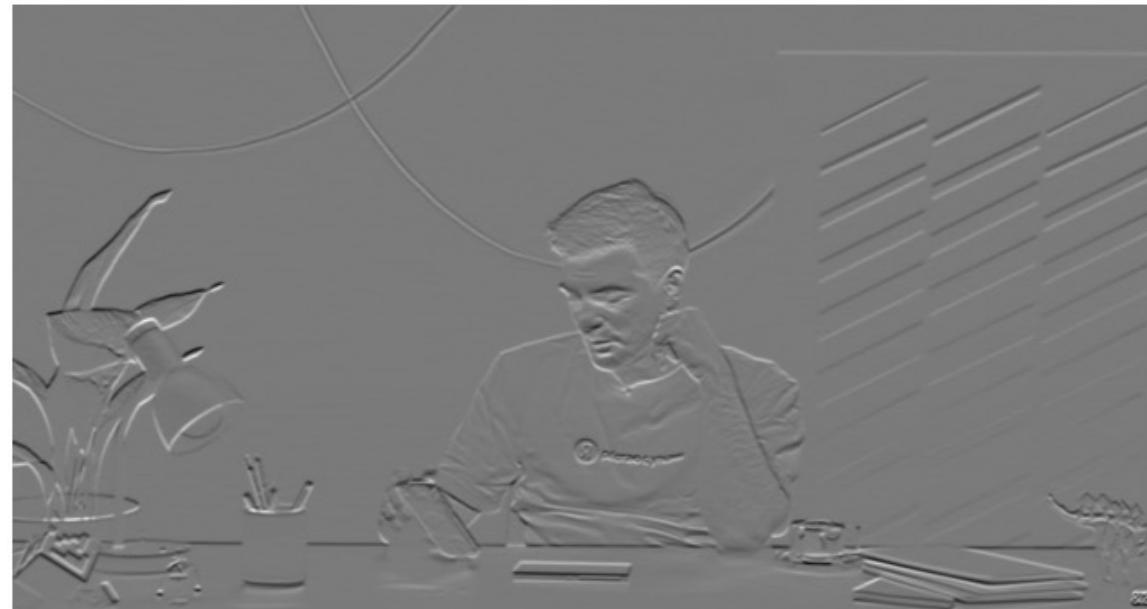
Sobel X Y



Sobel X



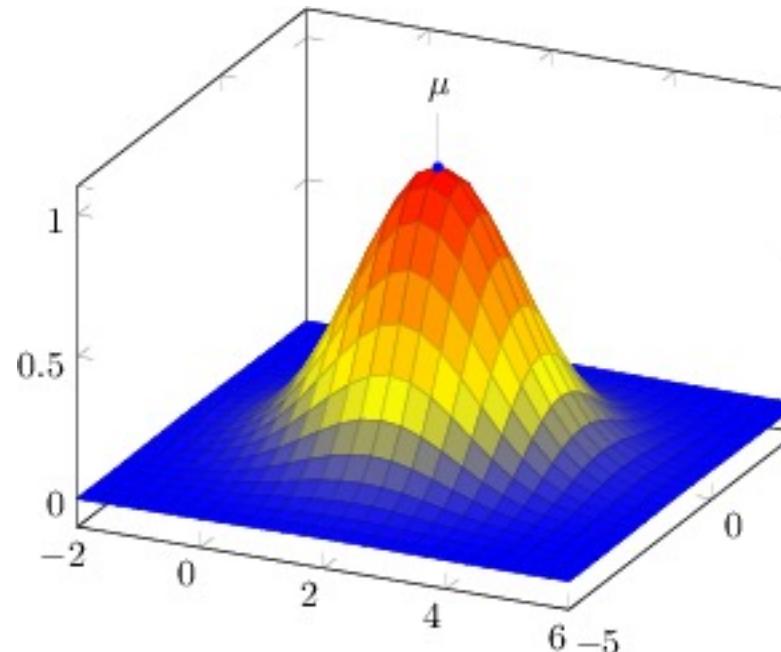
Sobel Y



Canny edge detector

$$G = (0.299 * I_{red}) + (0.587 * I_{green}) + (0.114 * I_{blue})$$

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-(\frac{x^2+y^2}{2\sigma^2})}$$



Canny edge detector

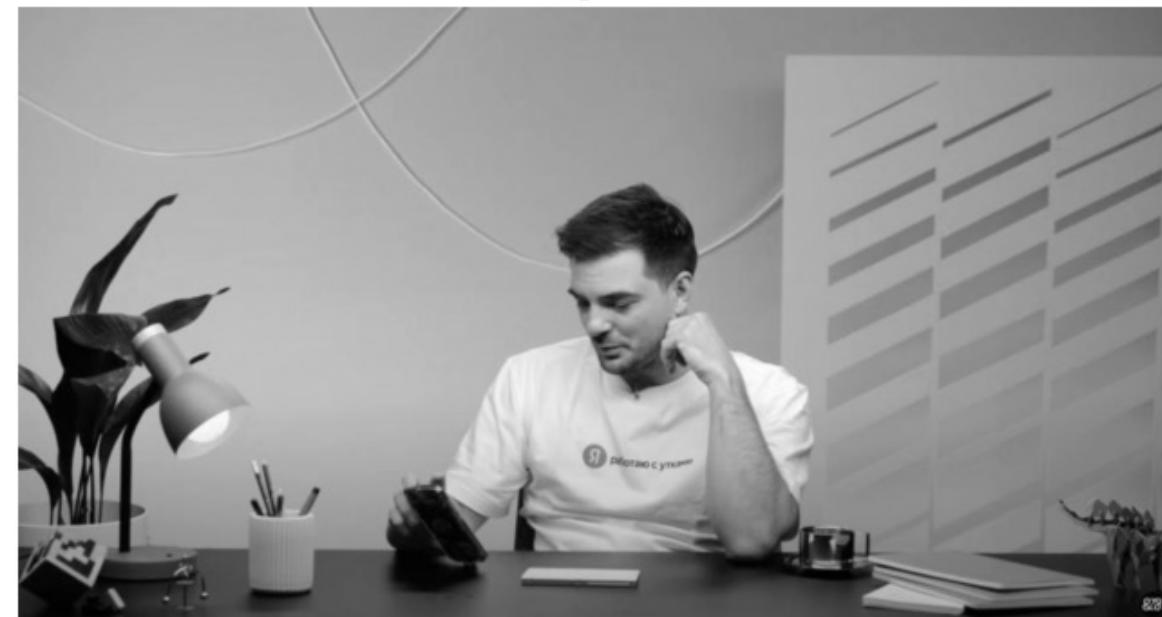
$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$G_m(x, y) = \sqrt{G_x(x, y)^2 + G_y(x, y)^2}$$

$$G_o(x, y) = \arctan 2 \frac{G_y(x, y)}{G_x(x, y)}$$

Canny edge detector

Original

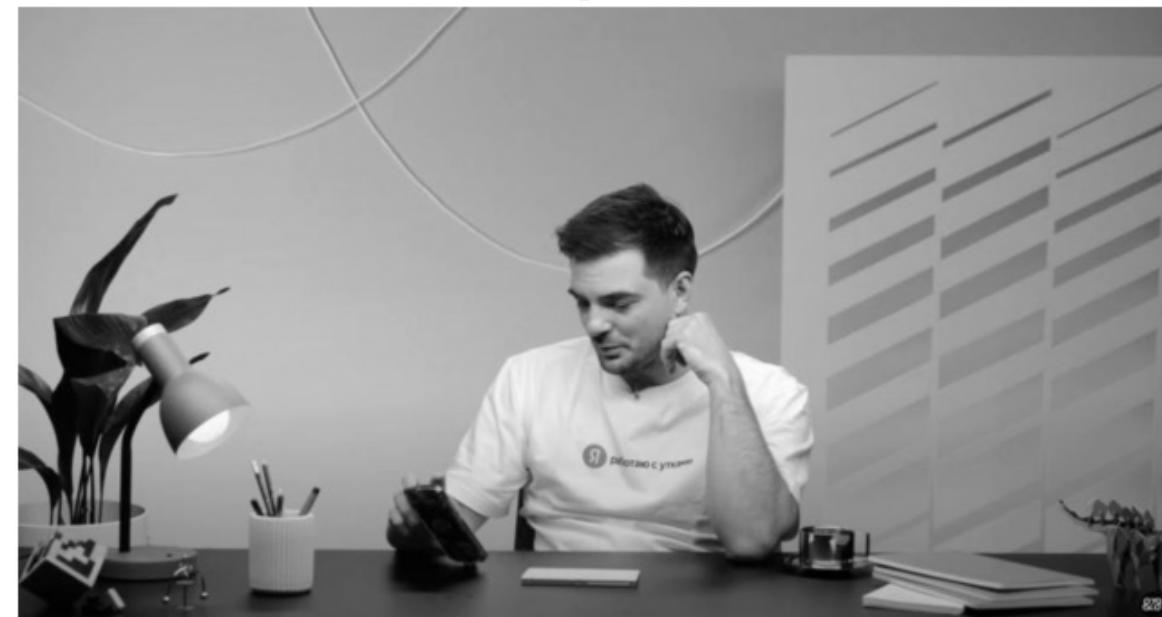


Edge image



Canny edge detector

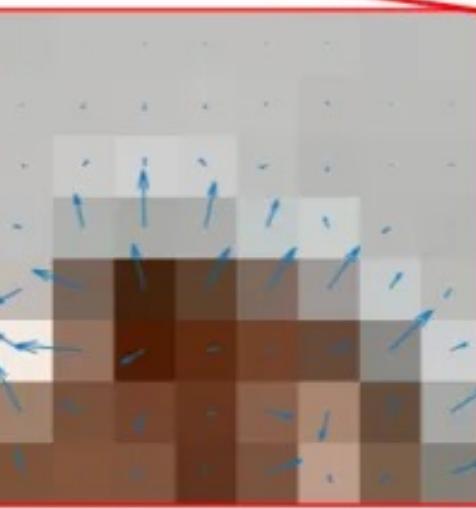
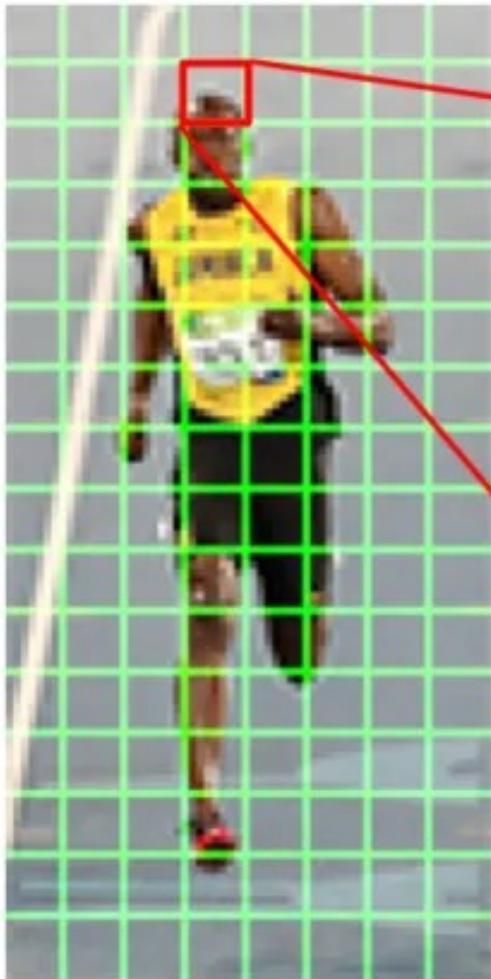
Original



Edge image



Histogram of oriented gradients (HoG)



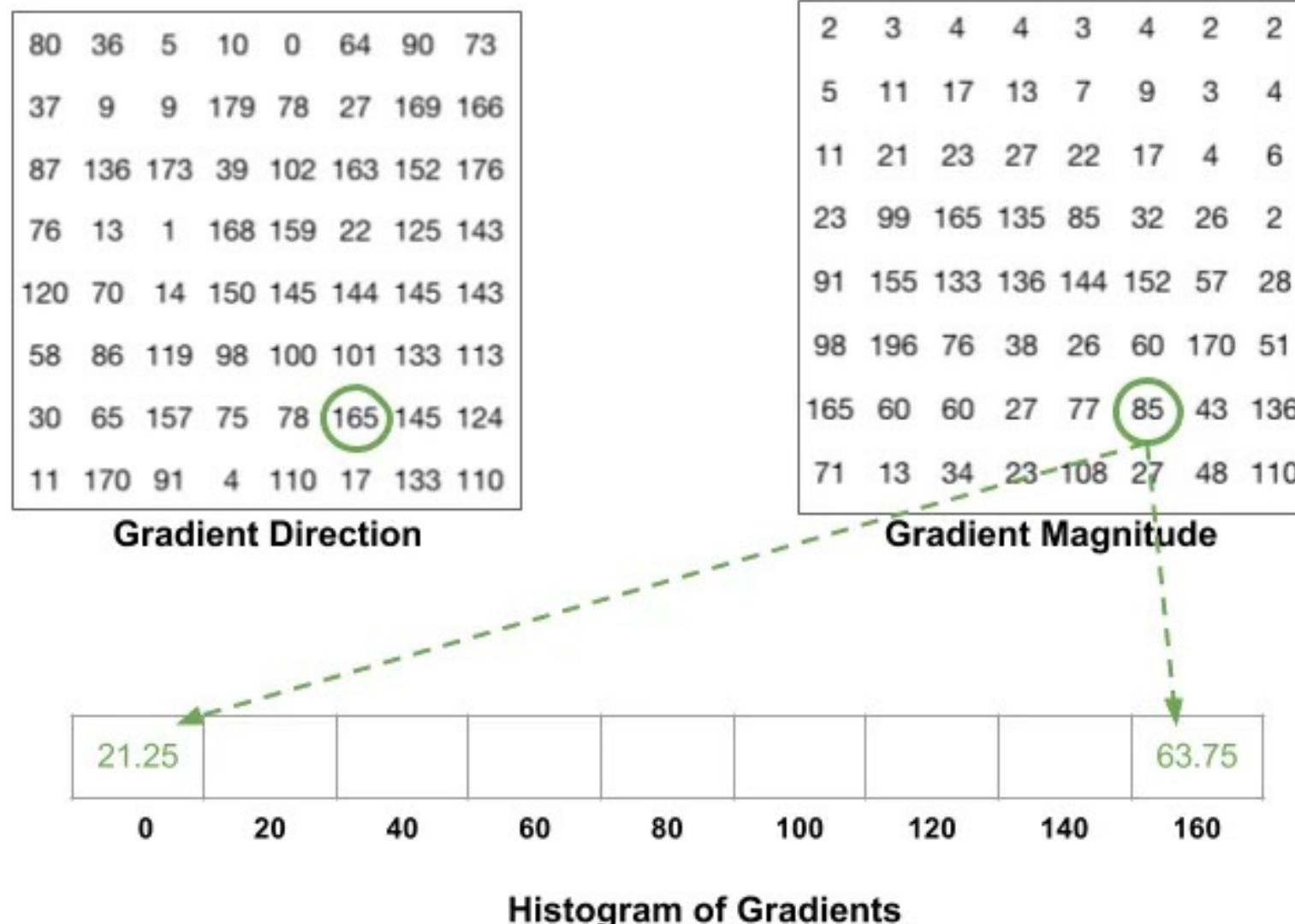
2	3	4	4	3	4	2	2
5	11	17	13	7	9	3	4
11	21	23	27	22	17	4	6
23	99	165	135	85	32	26	2
91	155	133	136	144	152	57	28
98	196	76	38	26	60	170	51
165	60	60	27	77	85	43	136
71	13	34	23	108	27	48	110

Gradient Magnitude

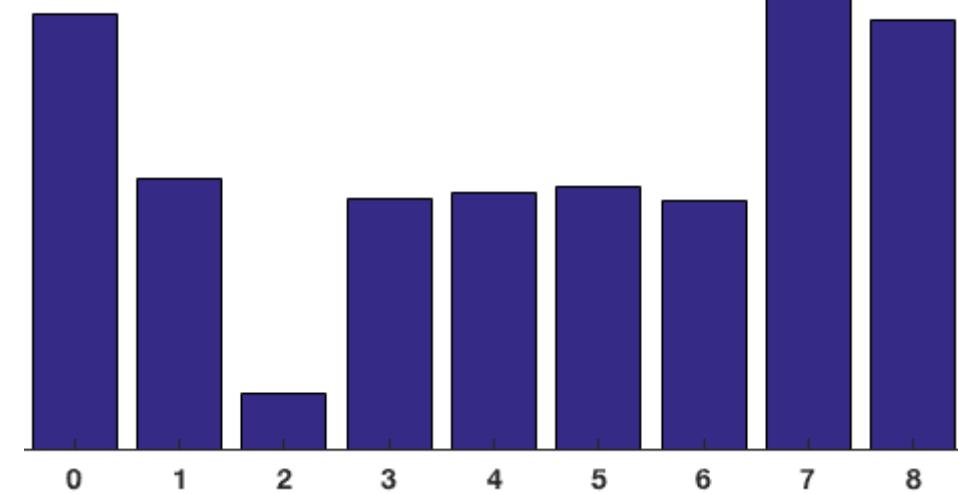
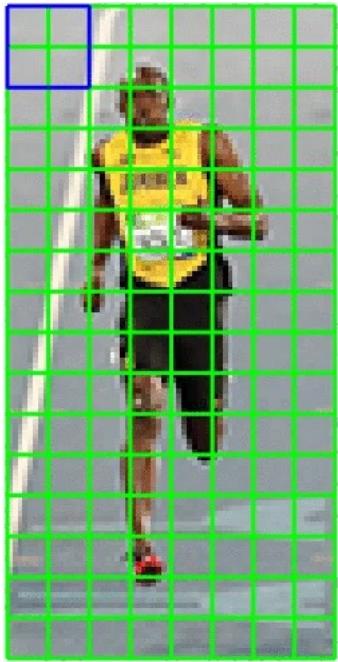
80	36	5	10	0	64	90	73
37	9	9	179	78	27	169	166
87	136	173	39	102	163	152	176
76	13	1	168	159	22	125	143
120	70	14	150	145	144	145	143
58	86	119	98	100	101	133	113
30	65	157	75	78	165	145	124
11	170	91	4	110	17	133	110

Gradient Direction

Histogram of oriented gradients (HoG)



Histogram of oriented gradients (HoG)

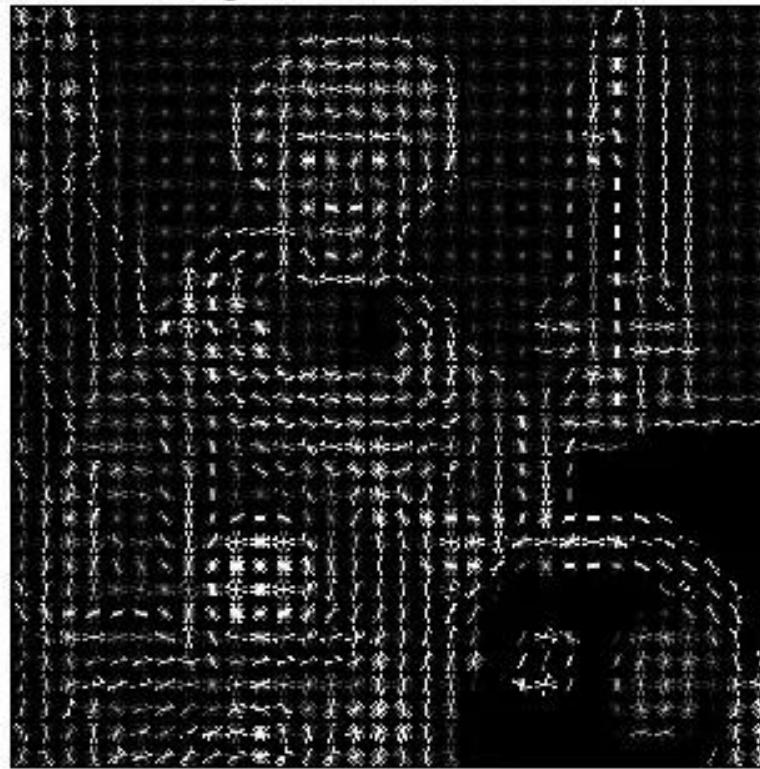


Histogram of oriented gradients (HoG)

Input image



Histogram of Oriented Gradients



Спасибо за внимание



Доп. материалы



УРОВЕНЬ