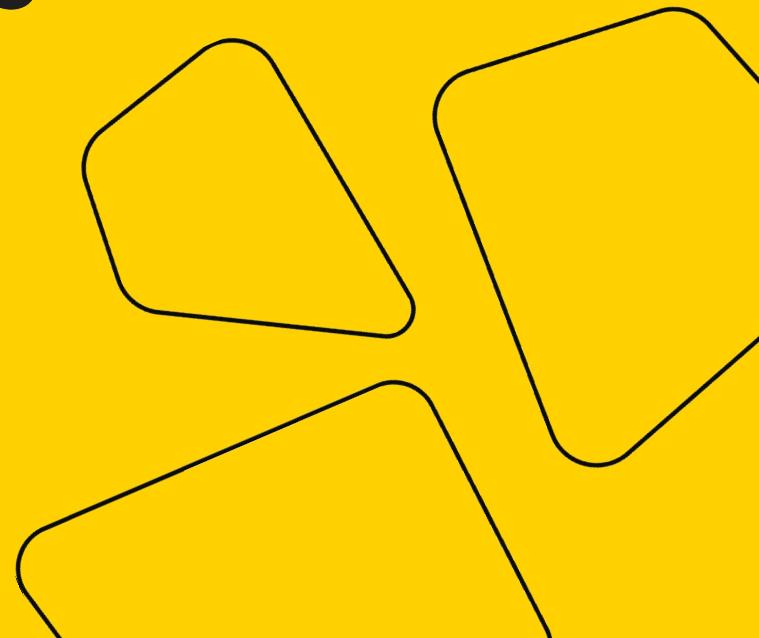


MSAI Computer Vision course

# Lecture 0

# Biological vision systems

Vladislav Goncharenko  
MIPT, 2021



# Outline

- Course information
- Eyes structure and types
- Human eye parameters
- Binocular vision
- Ways to improve eyes performance
- Applications in science and business

# Course info

---

girafe  
ai

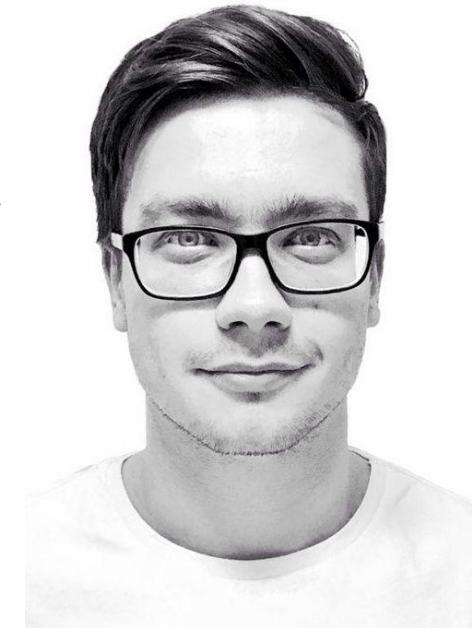
00

# Lecturer



Vladislav Goncharenko

- Head of perception at [Evocargo](#)
- PhD student an IITP, lab of Vision Systems
- Professor and course author at MIPT, Big data academy at mail.ru, Harbour Space and others
- Open source projects contributor



Telegram: @white\_pepper

Github: [v-goncharenko](#)

LinkedIn: [vladislav-goncharenko](#)

# Course plan



## Part I: Classical Computer Vision

- Image forming
- Representation in computer
- Colour theory
- Image processing
  - correction
  - denoising
- Morphologies
- Edges detectors
- Background subtractors
- Stereo vision, stereo matching
- Keypoints detection
- Histograms of gradients

## Part II: Neural Computer Vision

- CNNs
- Images classification architectures
- Object detection and tracking
- Semantic segmentation
- Style transfer
- Transformers in CV
- etc

# Biological vision systems

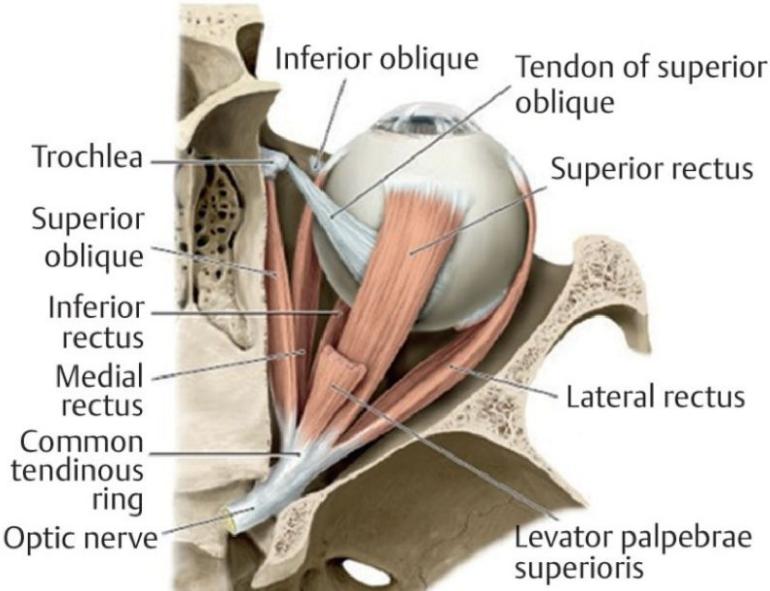
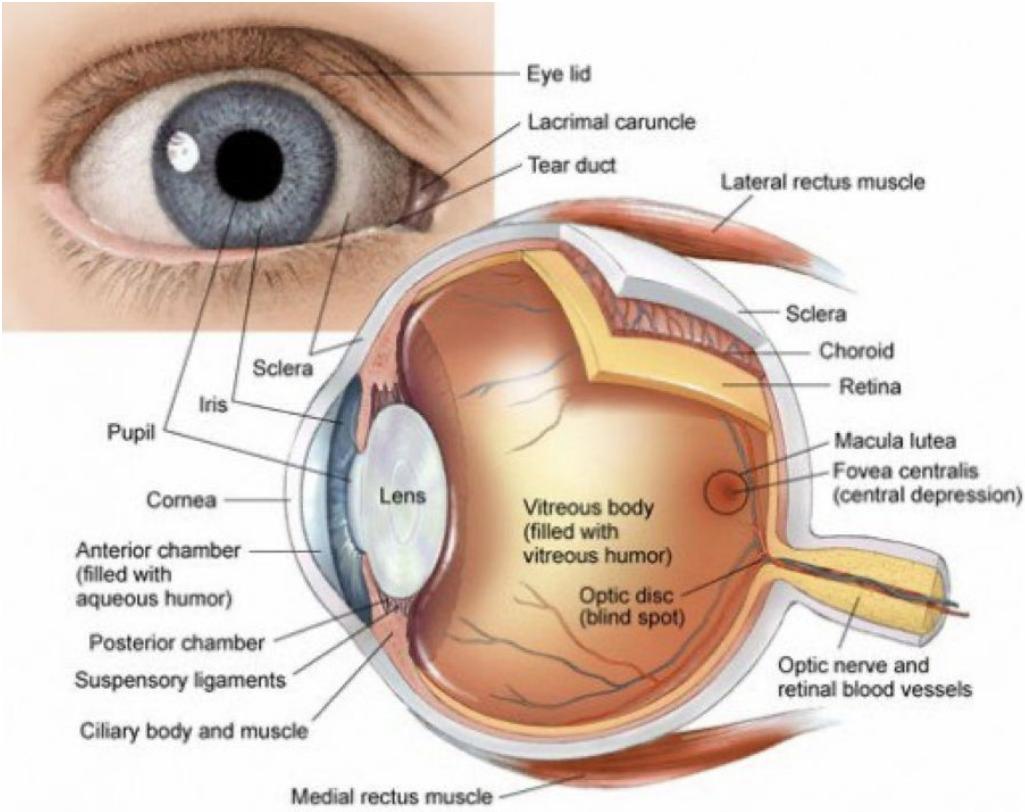
---

girafe  
ai

01

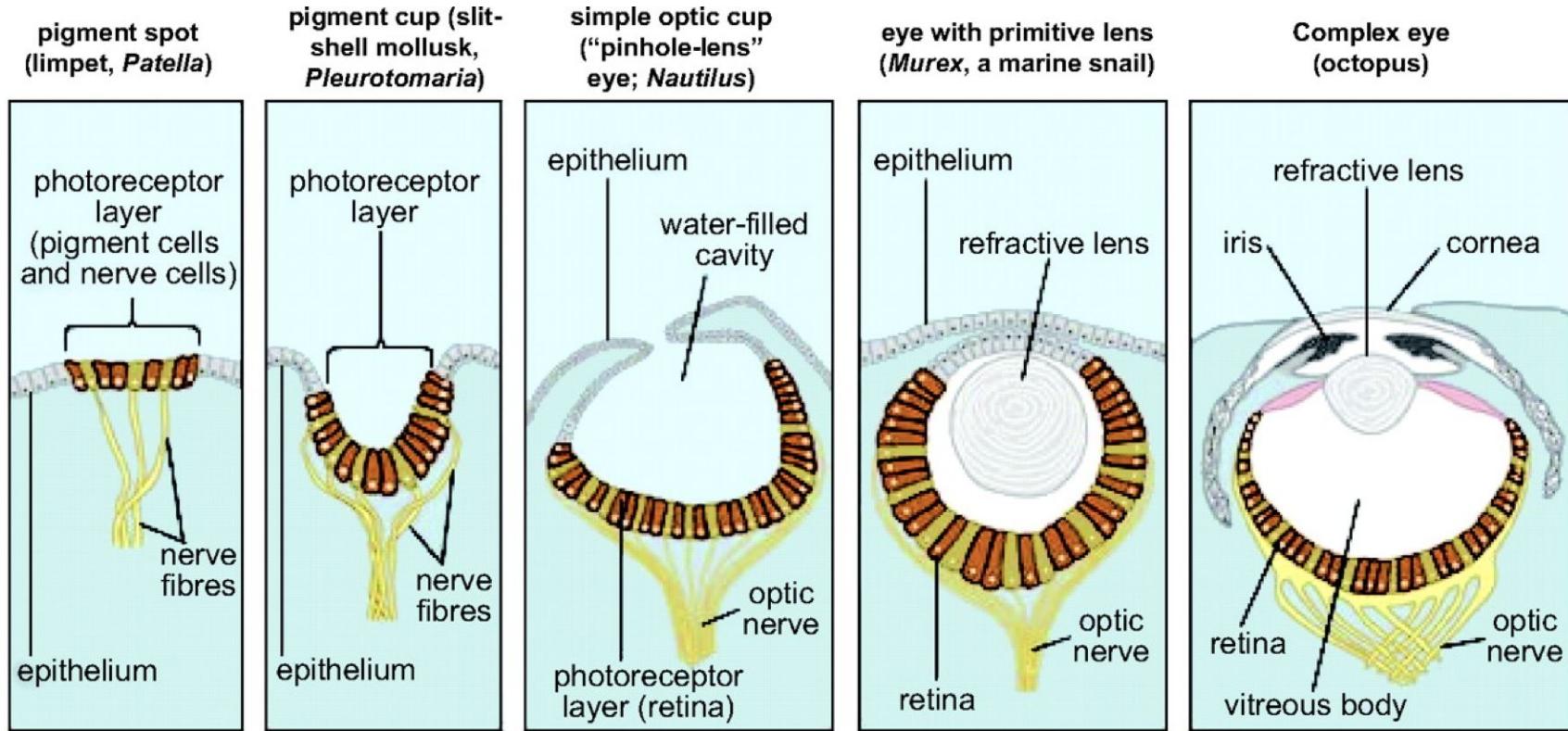


# Human eye



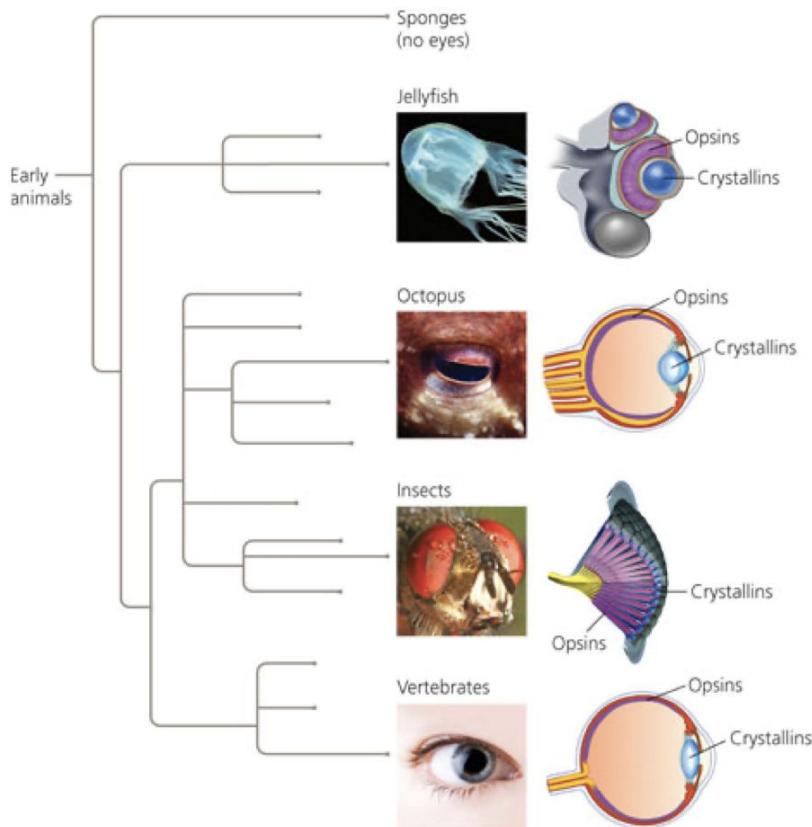


# Evolutionary development

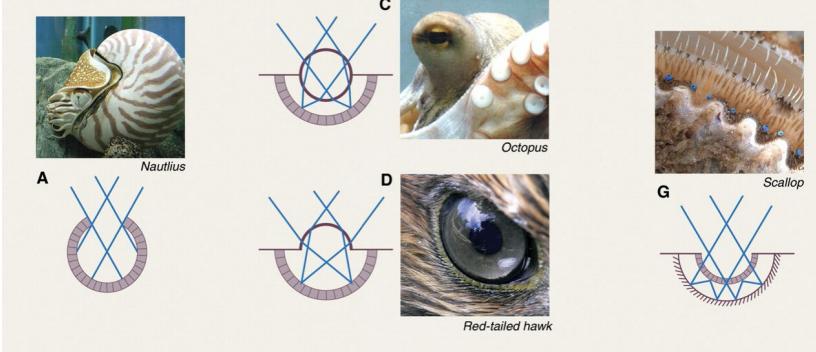




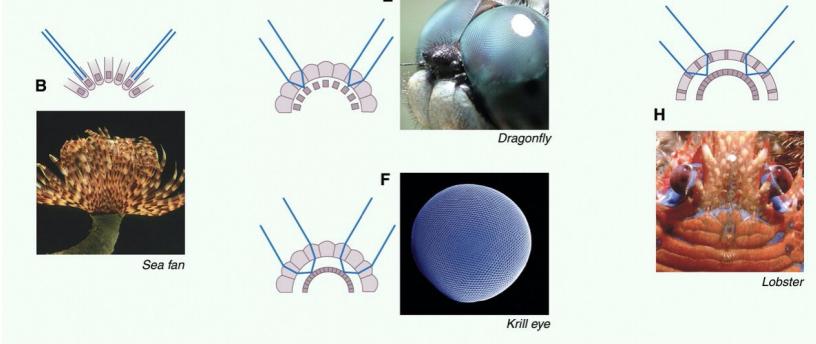
# Eye types



## Chambered eyes

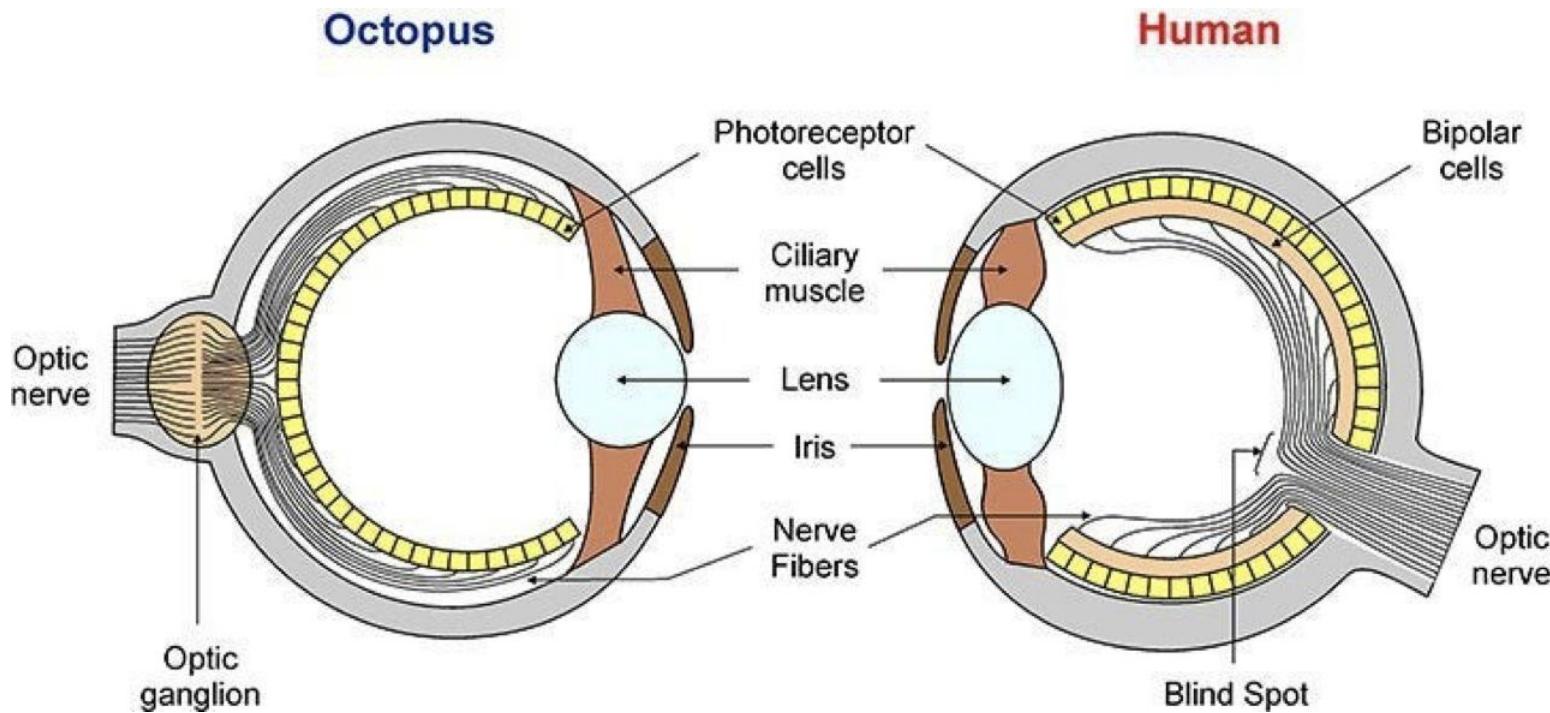


## Compound eyes





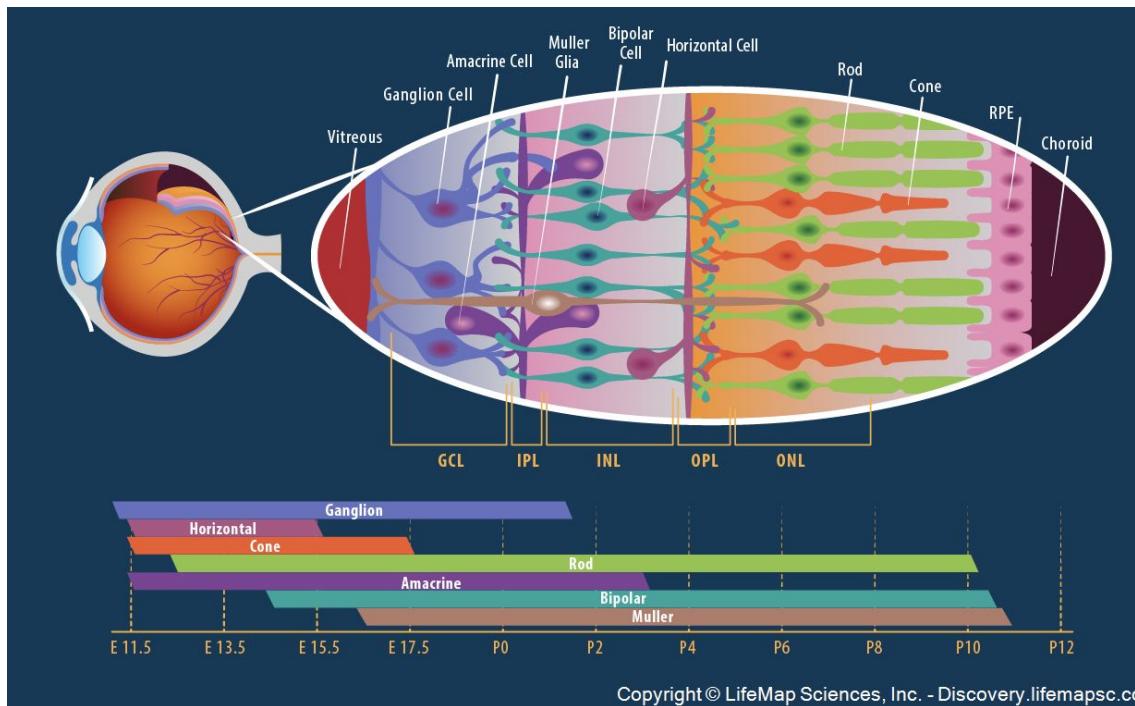
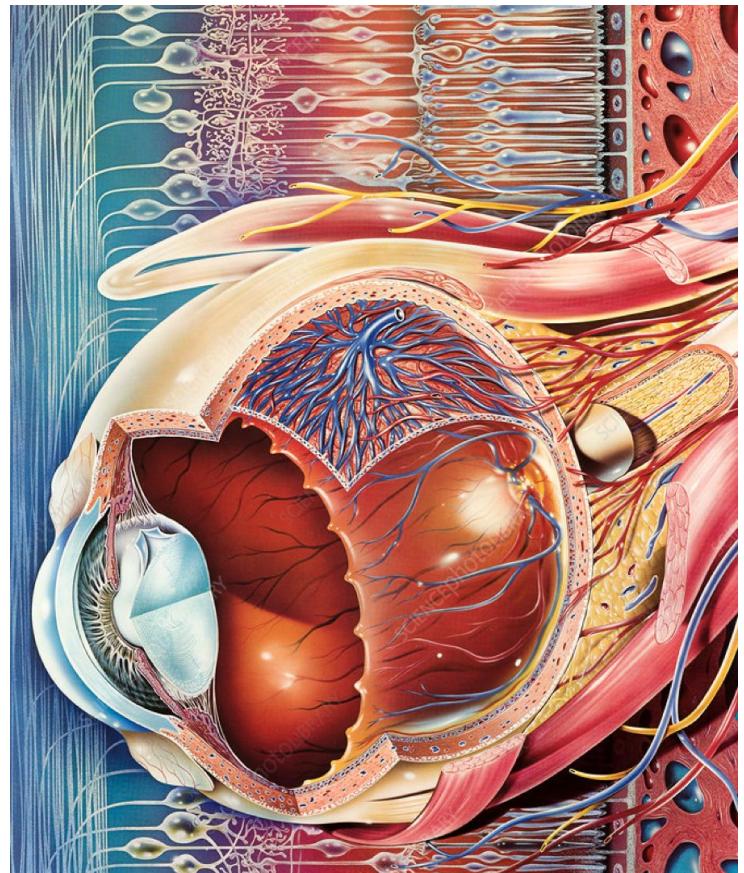
# Lens and corneal eyes



More on eyes classification



# Photosensitive cells layers





# 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)

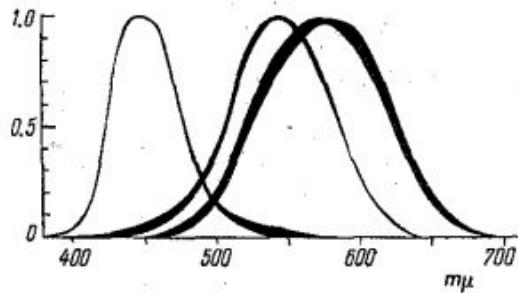


Fig. 3. Curves of sensitivity of human daylight receptors—cones (Bongard and Smirnov, 1955).

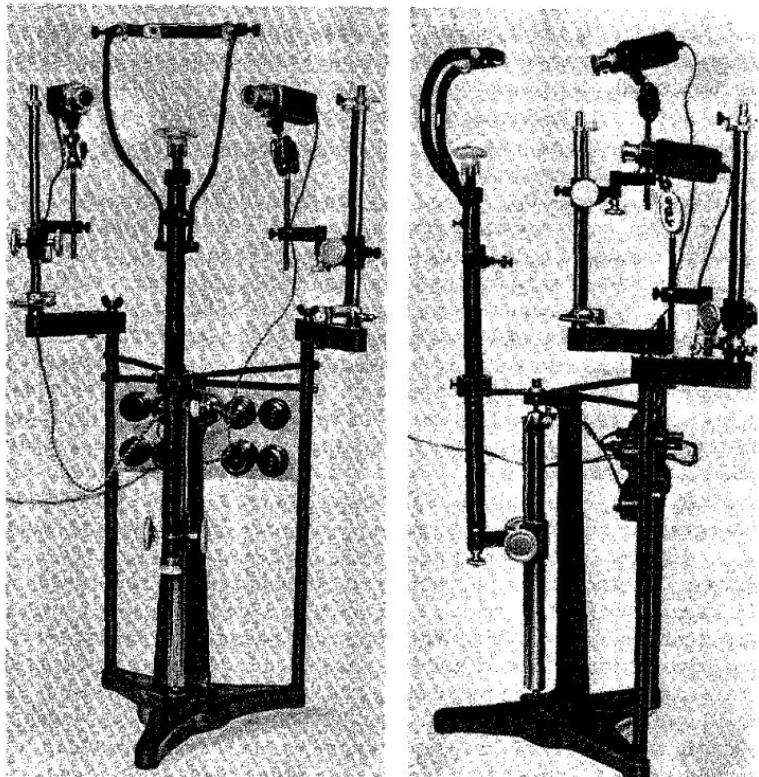
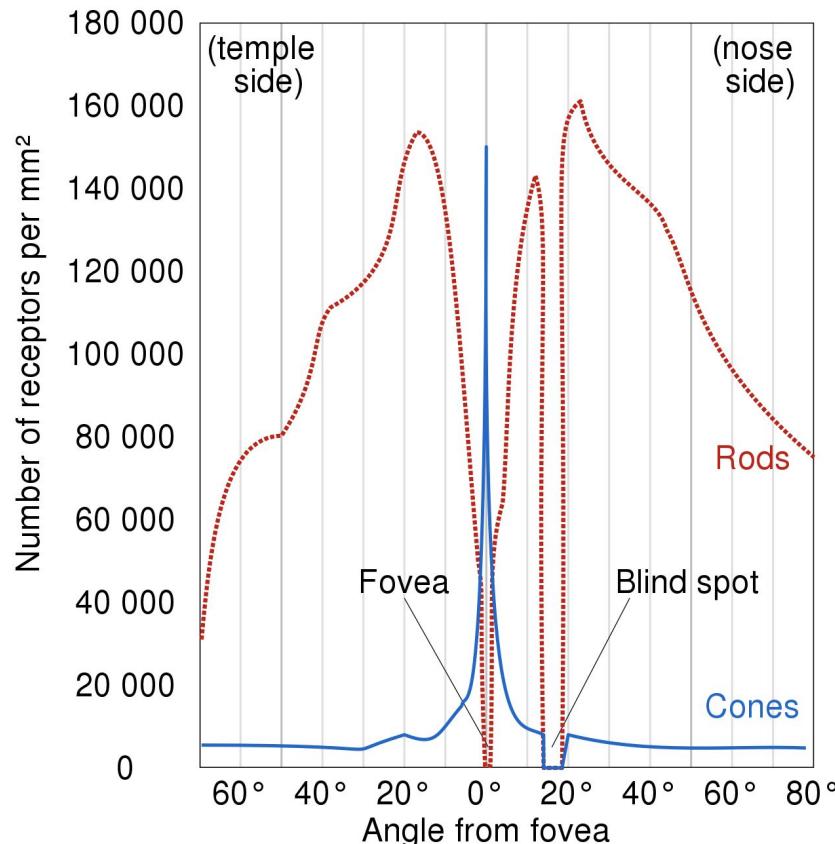
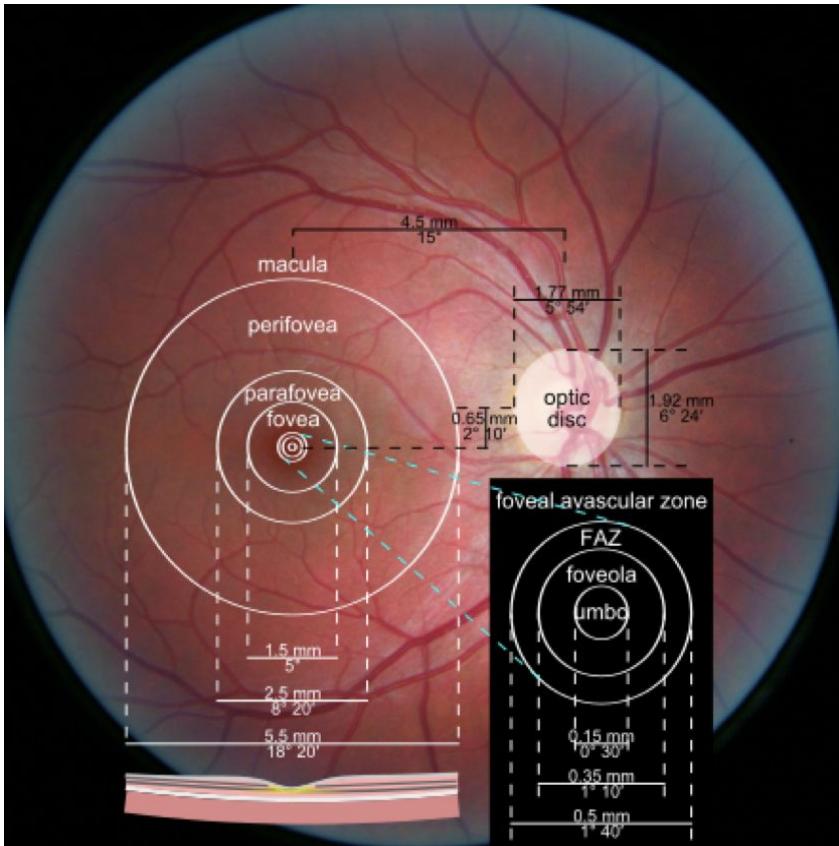


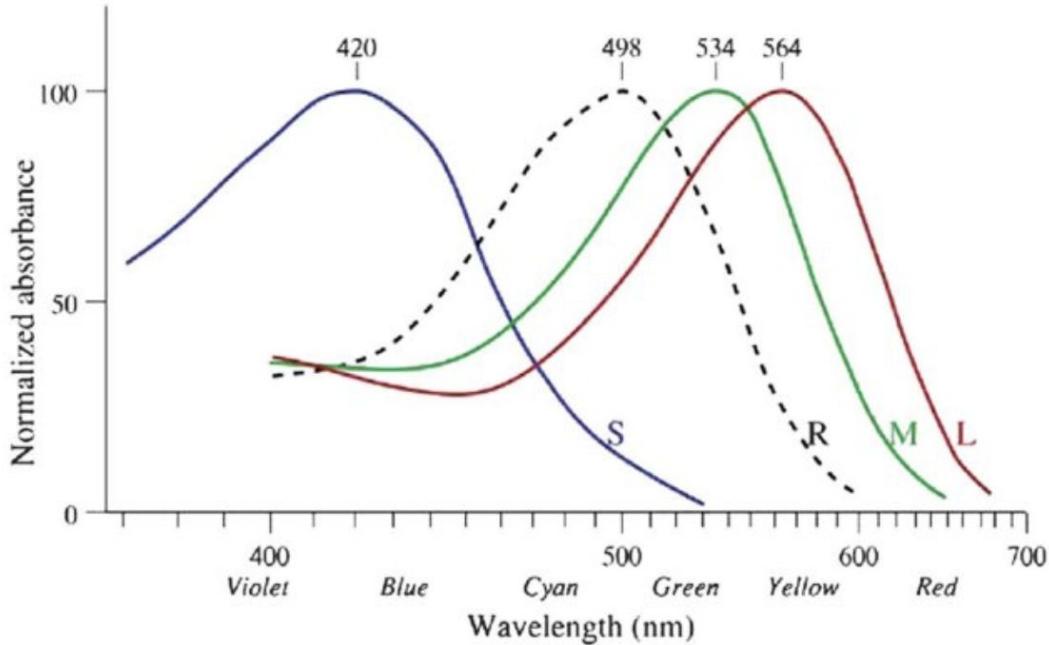
Fig. 21. The apparatus used in recording eye movements.



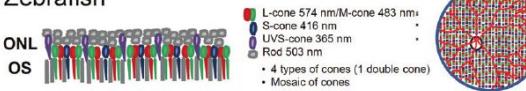
# Retina spatial sensitivity



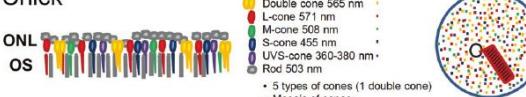
# Retina spectral sensitivity



A. Zebrafish



B. Chick



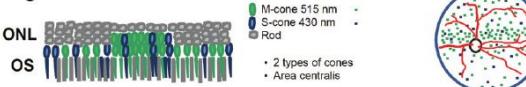
C. Mouse



D. Sheep



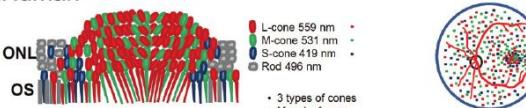
E. Pig



F. Dog

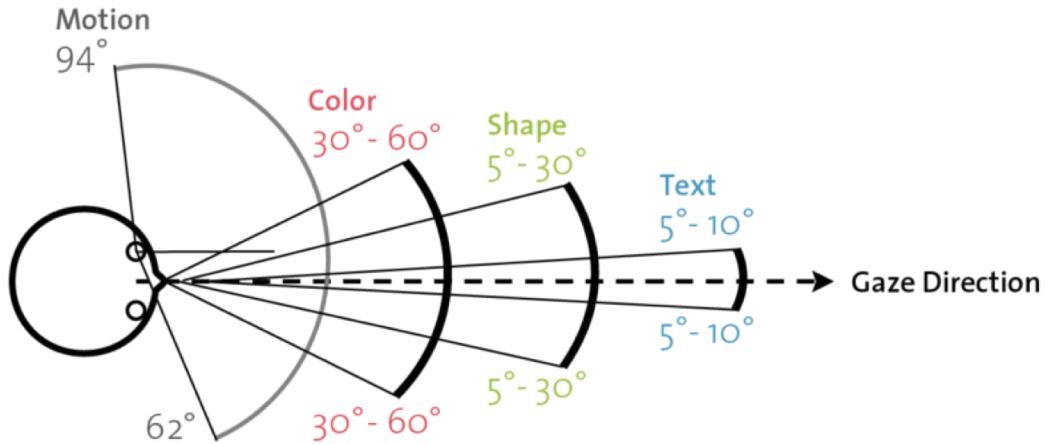


G. Human





# 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







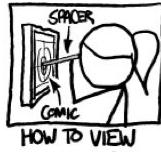


LOOK AT THE CENTER WITH YOUR EYES THIS FAR FROM THE SCREEN



(YOU CAN ROLL UP A SHEET OF PAPER AND CUT IT - OR ZOOM THE PAGE - SO IT MATCHES THIS IMAGE.)

# YOUR CENTRAL VISUAL FIELD



HOW TO VIEW

WE HAVE FEW BLUE-SENSITIVE CONE CELLS, BUT THEY'RE FOUND OUT TO THE EDGE OF OUR VISION.

## BLUE-SKY SPRITES

THESE TINY, DARTING BRIGHT SPOTS, VISIBLE AGAINST SMOOTH BLUE BACKGROUNDS, ARE WHITE CELLS MOVING IN THE BLOOD VESSELS OVER THE RETINA.

## FLOATERS

SOME TYPES OF FLOATERS ARE CAUSED BY BREAKDOWN OF YOUR EYEBALL GOOP AS YOU AGE, BUT THIS TYPE IS SOME OTHER KIND OF DEBRIS NEAR THE RETINA.  
I DON'T KNOW WHAT.

SATURATION INDICATES COLOR RECEPTOR DENSITY  
LEFT EYE\* BLIND SPOT

RED AND GREEN-SENSITIVE CONES ARE MAINLY LIMITED TO THE CENTER OF OUR VISION.

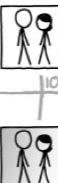
HUMANS CAN SEE POLARIZATION - STARE AT A WHITE AREA ON AN LCD DISPLAY WHILE ROTATING IT (OR YOUR HEAD) LIKE THIS: ( ) (FAST)

POLARIZATION DIRECTION IS SHOWN BY A FAINT CENTRAL YELLOW/BLUE SHAPE. (ALSO VISIBLE IN DEEP BLUE SKIES.)

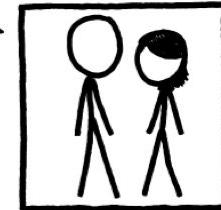
## DETAIL

WE ONLY SEE AT HIGH RESOLUTION OVER A SMALL AREA IN THE CENTER OF OUR VISION WHERE RETINAL CELLS ARE DENSEST (THE FOVEA).

IF YOU STARE AT THE CENTER OF THIS CHART, YOUR EYES ARE SEEING ALL THESE PANELS AT ROUGHLY THE SAME LEVEL OF DETAIL.



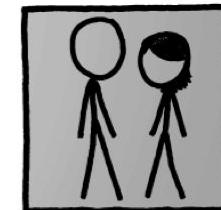
## NORMAL LIGHT



30°



RIGHT EYE BLIND SPOT



LOW LIGHT

## NIGHT VISION

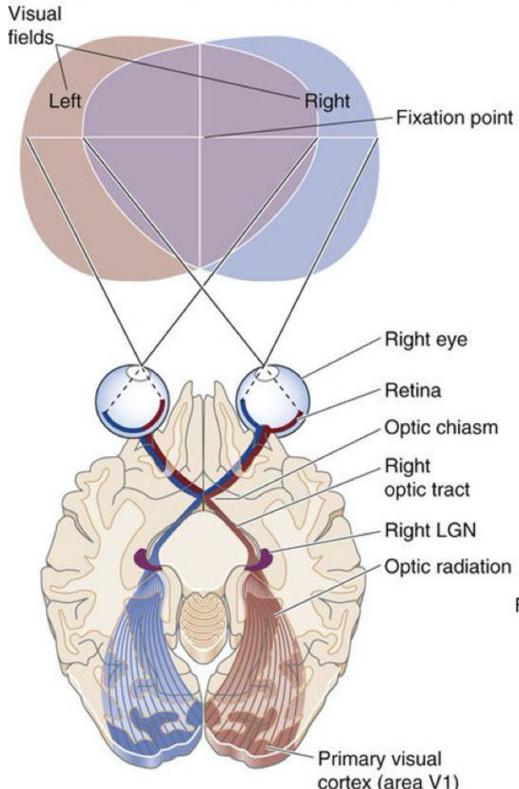
CONE CELLS (SHARP, CENTRAL COLOR VISION) DON'T WORK IN LOW LIGHT, BUT ROD CELLS (MONOCHROME, LOW-RES, NON-CENTRAL) DO. THIS IS WHY YOU CAN WALK AROUND IN DIM LIGHT, BUT NOT READ. IT'S ALSO WHY YOU CAN SPOT FAINTER STARS BY LOOKING NEXT TO THEM.

\* NOT PICTURED: T-BOZ BLIND SPOT, CHILLI BLIND SPOT.

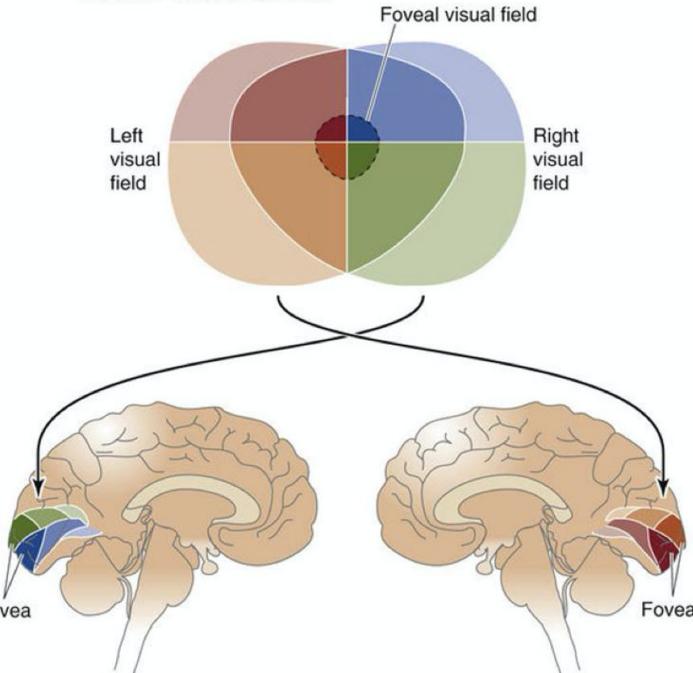


# Projection to brain

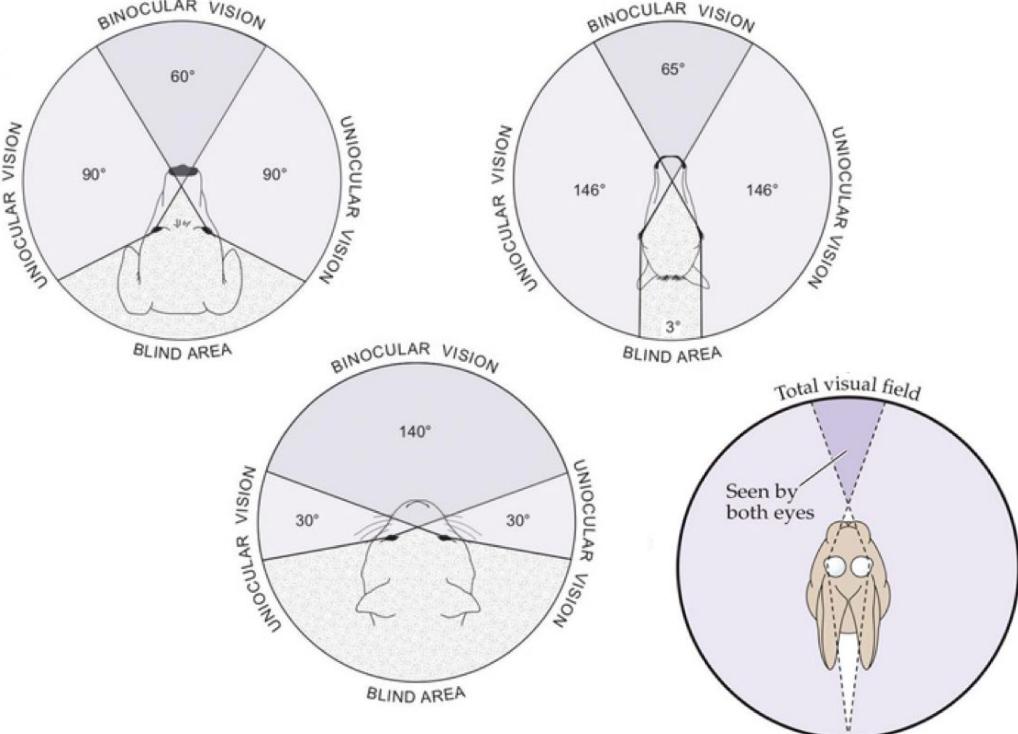
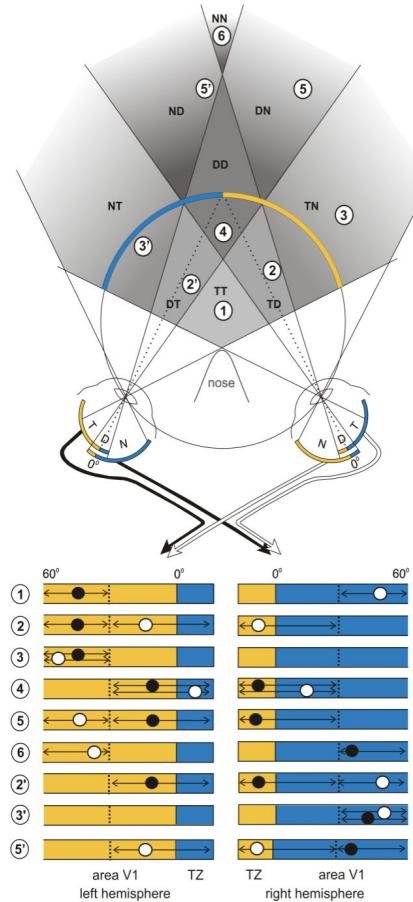
A CORONAL SECTION SHOWING PROJECTION OF THE RETINA TO THE PRIMARY VISUAL CORTEX



B SAGITTAL SECTIONS SHOWING VISUOTOPY OF THE PRIMARY VISUAL CORTEX

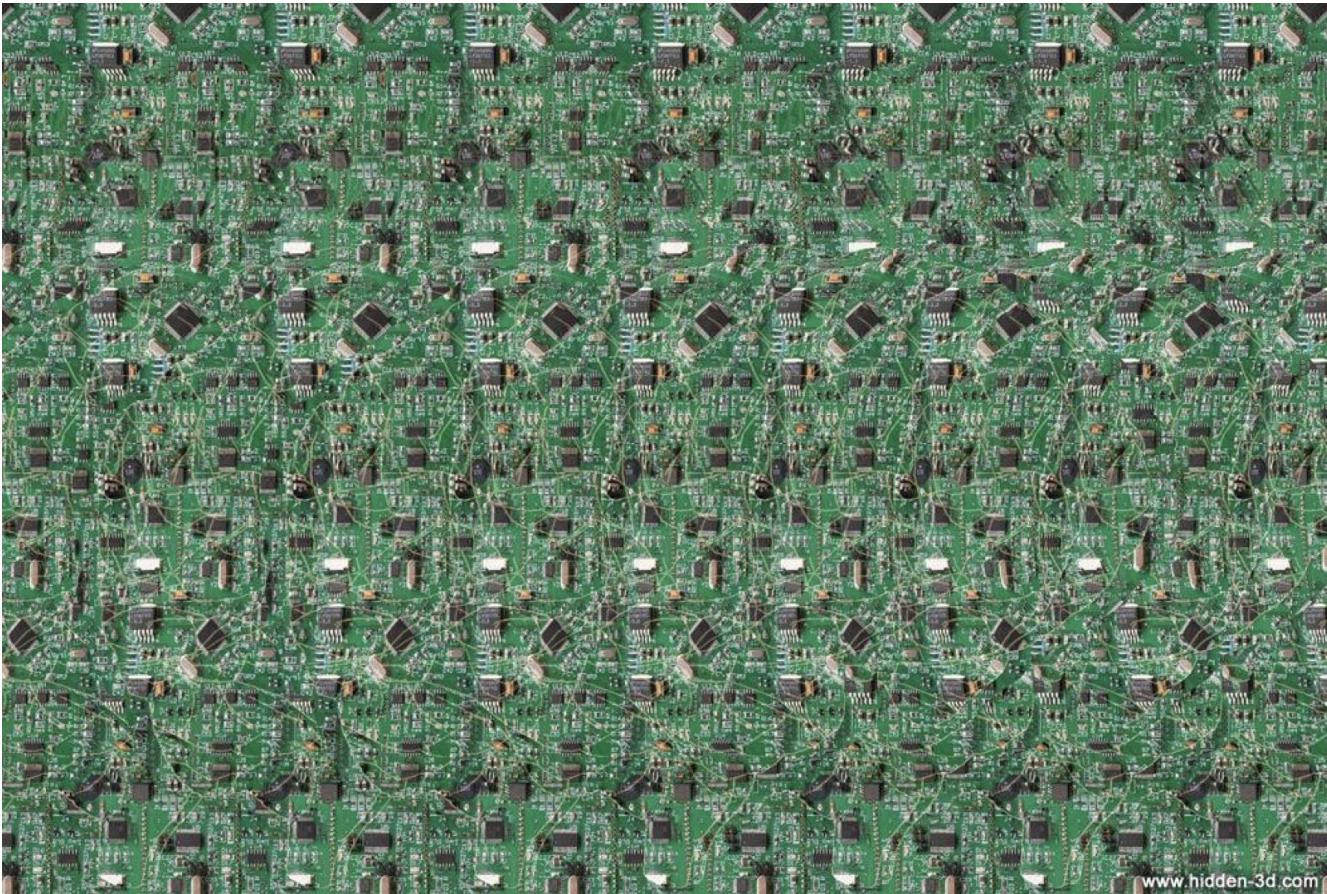


# Binocular vision





# Autostereogram phenomenon





# Ways to deal with eye restrictions

- Improve eye
- Move head or torso
- Move eye



# Improve eye

- Golden Eagle eye
- Color vision with resolution and clarity are the most prominent features of eagles' eyes
- Eagles can identify five distinctly colored squirrels and locate their prey even if hidden
- In the eagle, the retina's fovea has one 1,000,000 cells per mm<sup>2</sup> as compared to 200,000 per mm<sup>2</sup> in humans.
- An eagle able to spot a rabbit 3.2 km (~2 miles) away





# Improve eye: the price

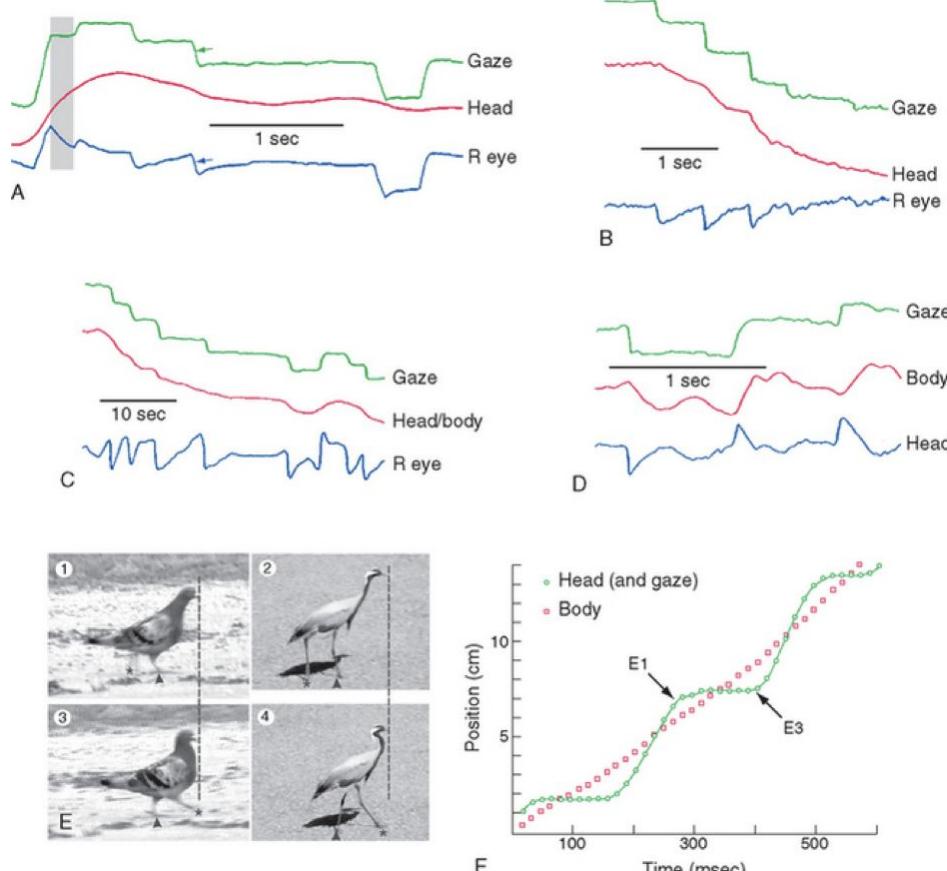


- Although the size of the eagle eye is about the same as of a human being
- Their eyes are stated to be larger in size than their brain, by weight

# Move head or torso



- A. Human standing at a sink and filling a kettle, getting ready to prepare a cup of tea
- B. Goldfish, as it turns while swimming in a tank of water
- C. A rock crab uses the same strategy as it walks around
- D. The eyes of flies are fixed in their heads and cannot move independently



From Nolte's The Human Brain: An Introduction to its Functional Anatomy 8th Edition by Todd Vanderah, Douglas Gould

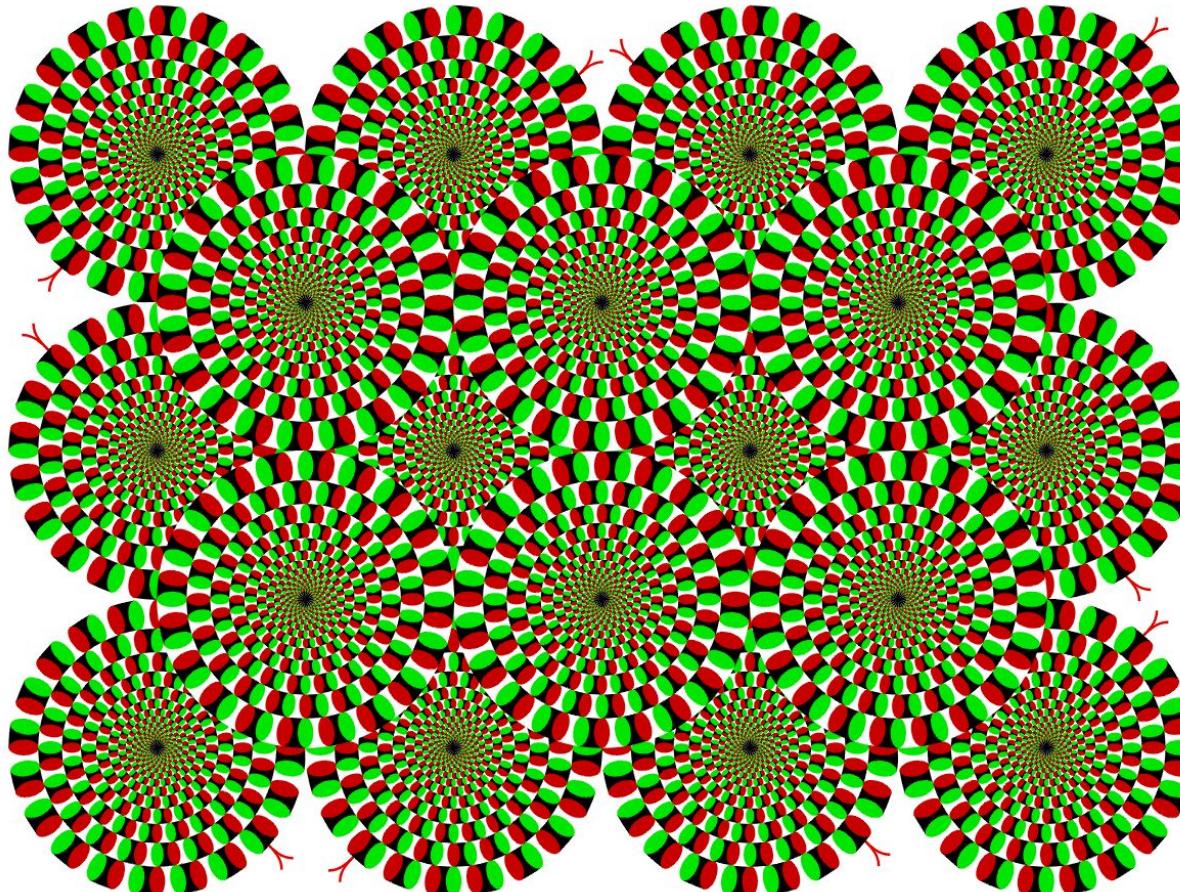


# Head stabilization by falcon





# Move eye



[List of many other illusions](#)

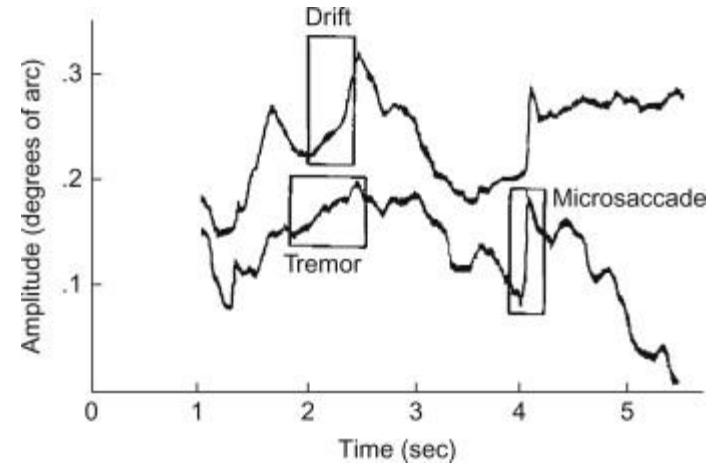
(not only caused by eye movement)

# Move eye



Types of eye movements:

- Fixations
- Microsaccades
- Pursuit
- Saccades
- Tremor



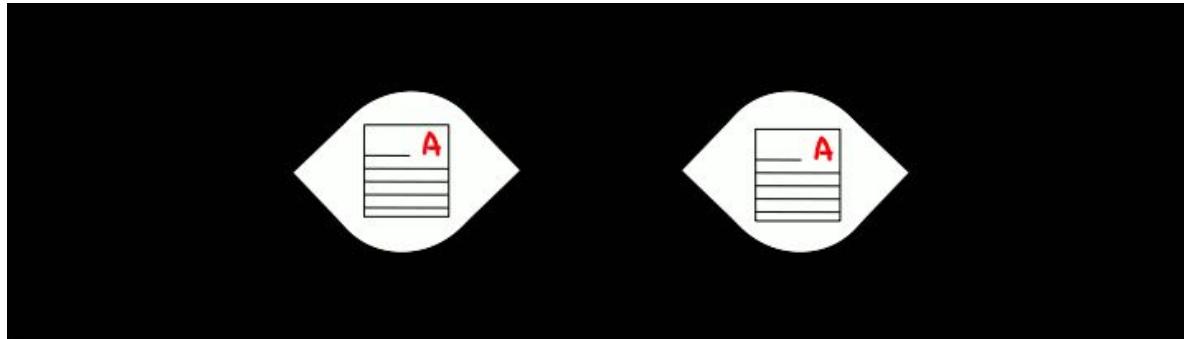


# Saccadic masking phenomenon





# Chronostasis



Student observing his work

Sensation



Perception

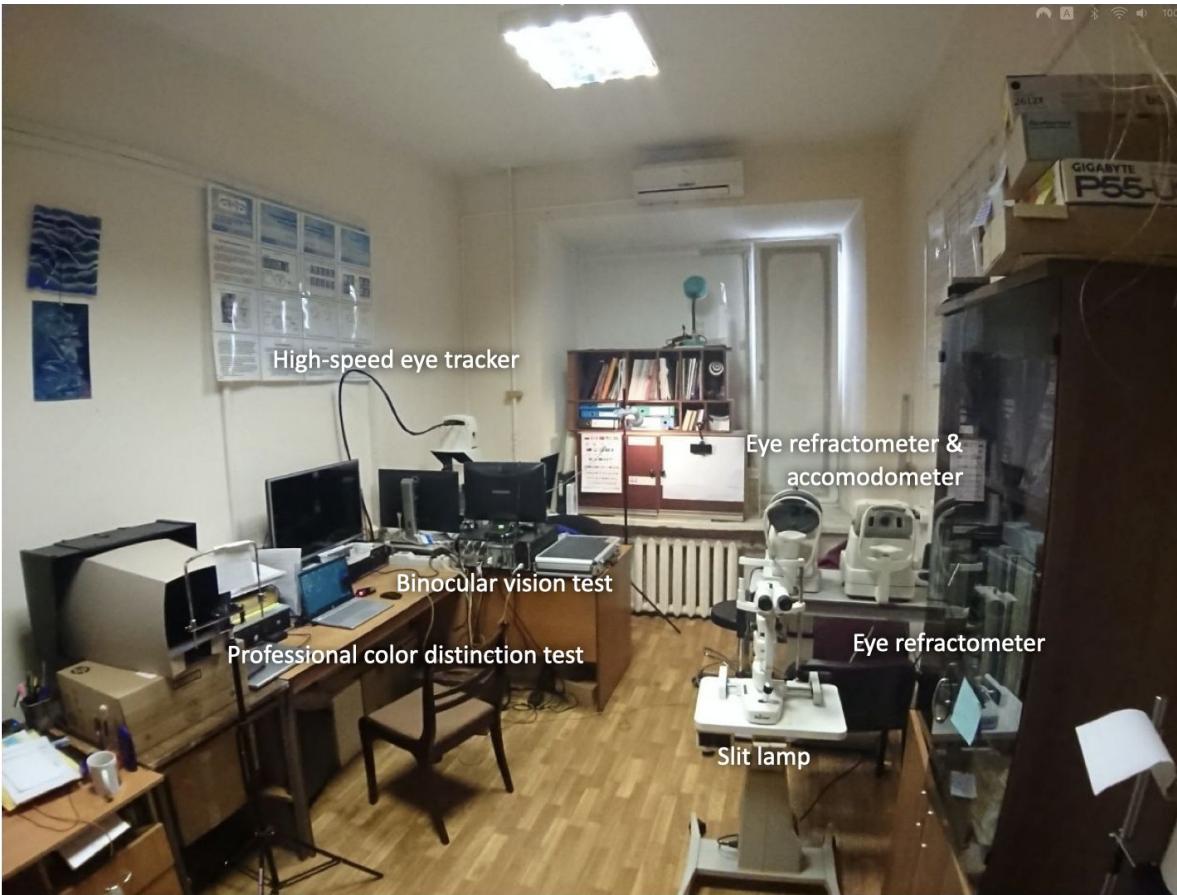


# Chronostasis: practice





# Eye research equipment at IITP



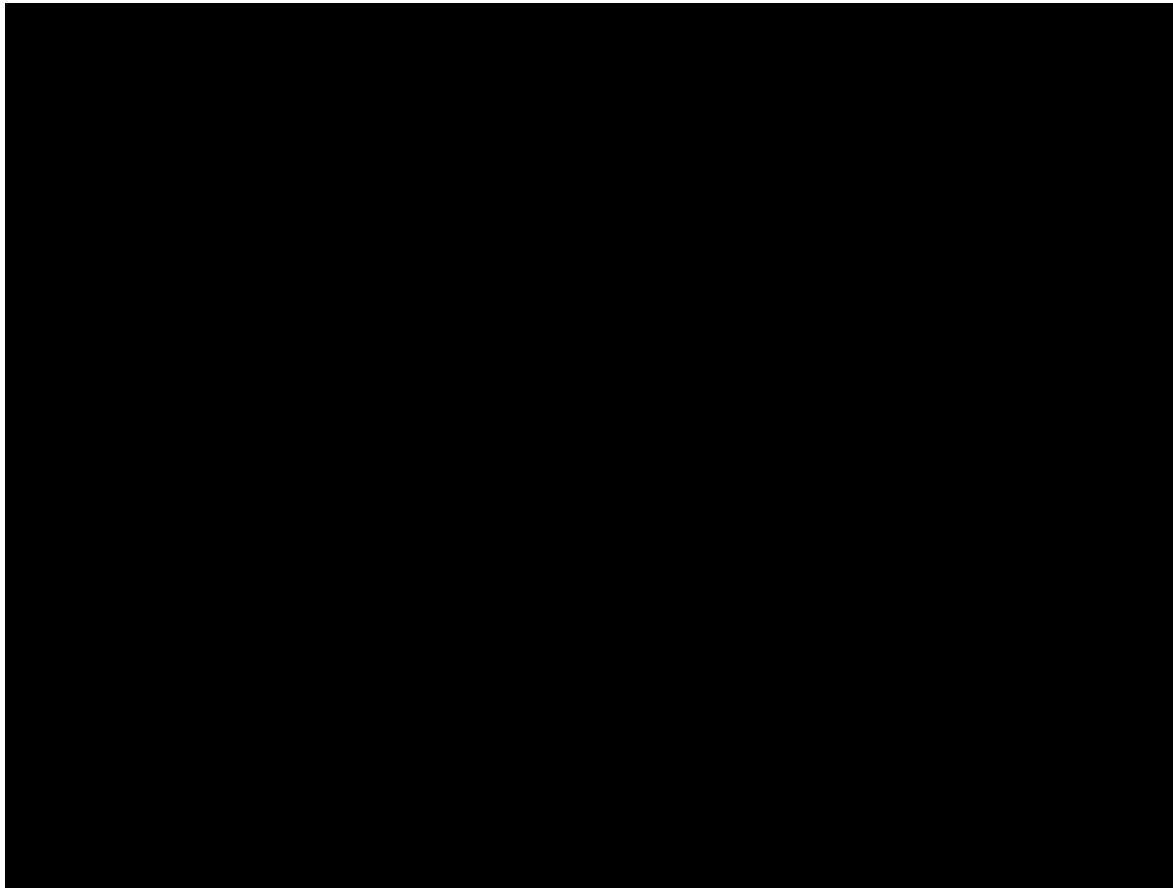


# Eyes movement record





# Usage in marketing



# Saliency-based video compression



Article: [Semiautomatic Visual-Attention Modeling and Its Application to Video Compression](#)

# Thanks for attention!

Questions?

---

girafe  
ai

