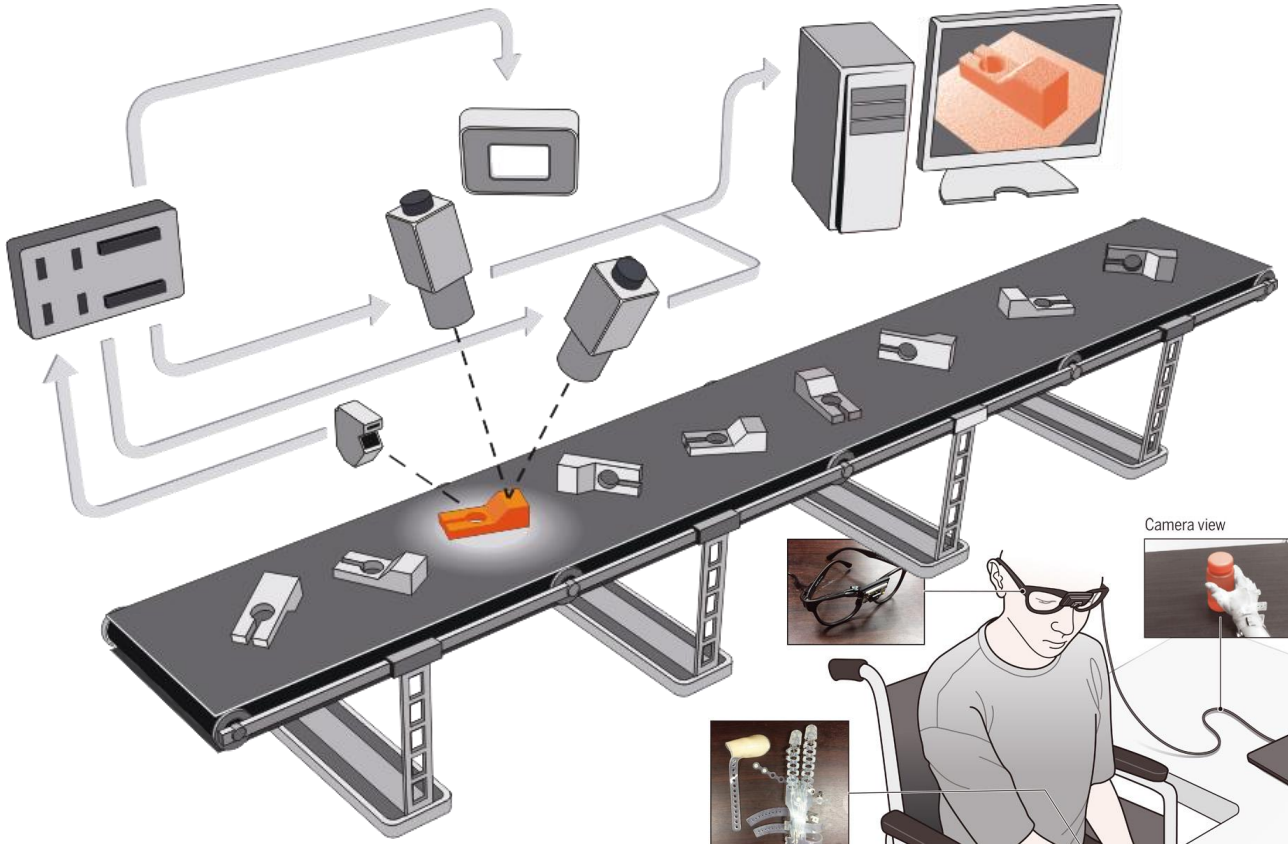
VILNIUS TECH
Faculty of Electronics

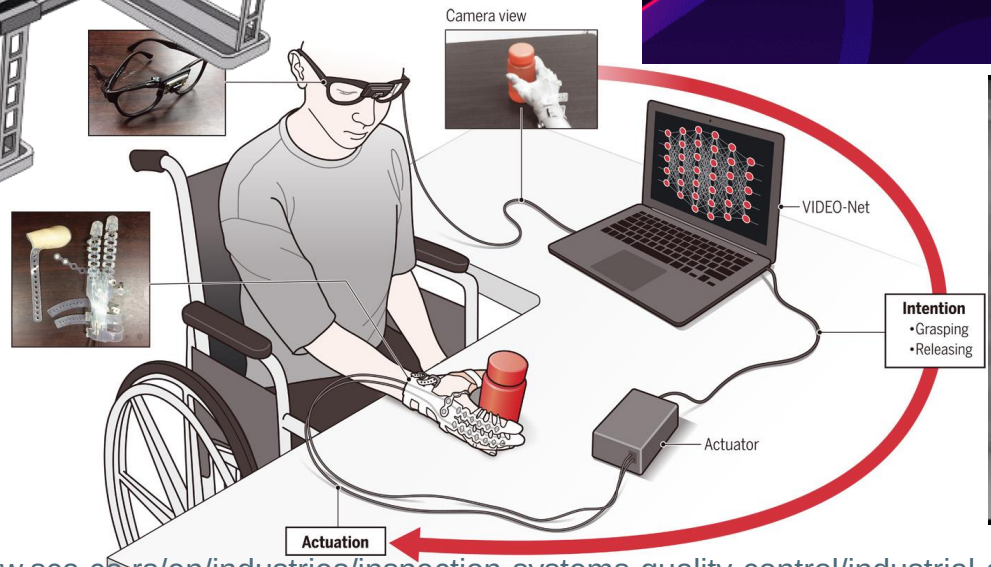
Dalius Matuzevičius, prof. dr.
Department of Electronic Systems
Faculty of Electronics
Vilnius Gediminas Technical University (VILNIUS TECH)
Vilnius, Lithuania

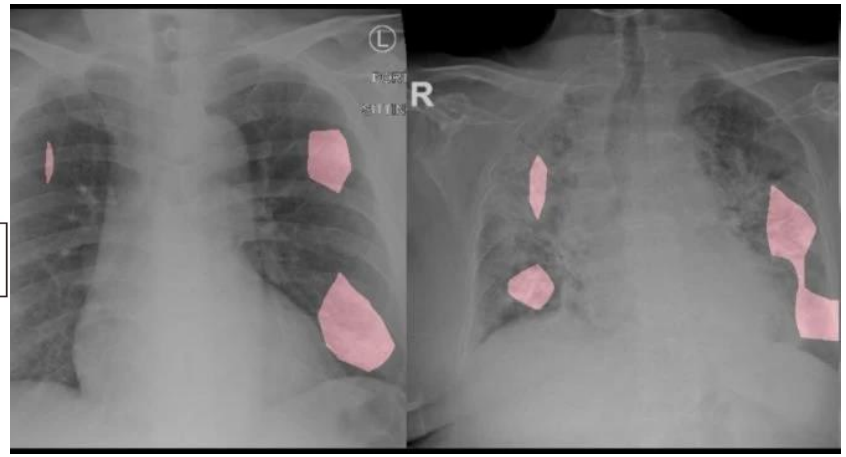
Deep Learning and Artificial Vision Systems

HMU
Chania, Crete
2023 05 15

Artificial Vision Systems







[*] https://www.sca.co.rs/en/industries/inspection-systems-quality-control/industrial-cameras/
[*] https://deeplobe.ai/howcomputer-vision-is-navigating-the-future-of-autonomous-vehicles/
[*] https://projects.iq.harvard.edu/visionwearablerobotics
[*] https://viso.ai/applications/computer-vision-in-healthcare/

Outline

Artificial Vision Systems

- Machine Vision [Part A]
- Deep Learning and Computer Vision [Part B]

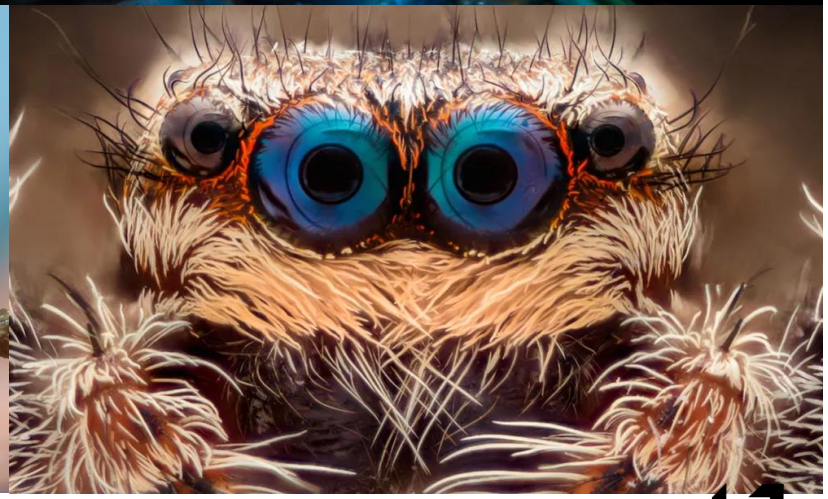
What can we learn from the Nature (Biological Vision Systems)?

Key Characteristic of Biological Vision Systems

– they are highly optimised/adapted





[*] https://www.livescience.com/62513-photos-amazing-animal-eyes.html

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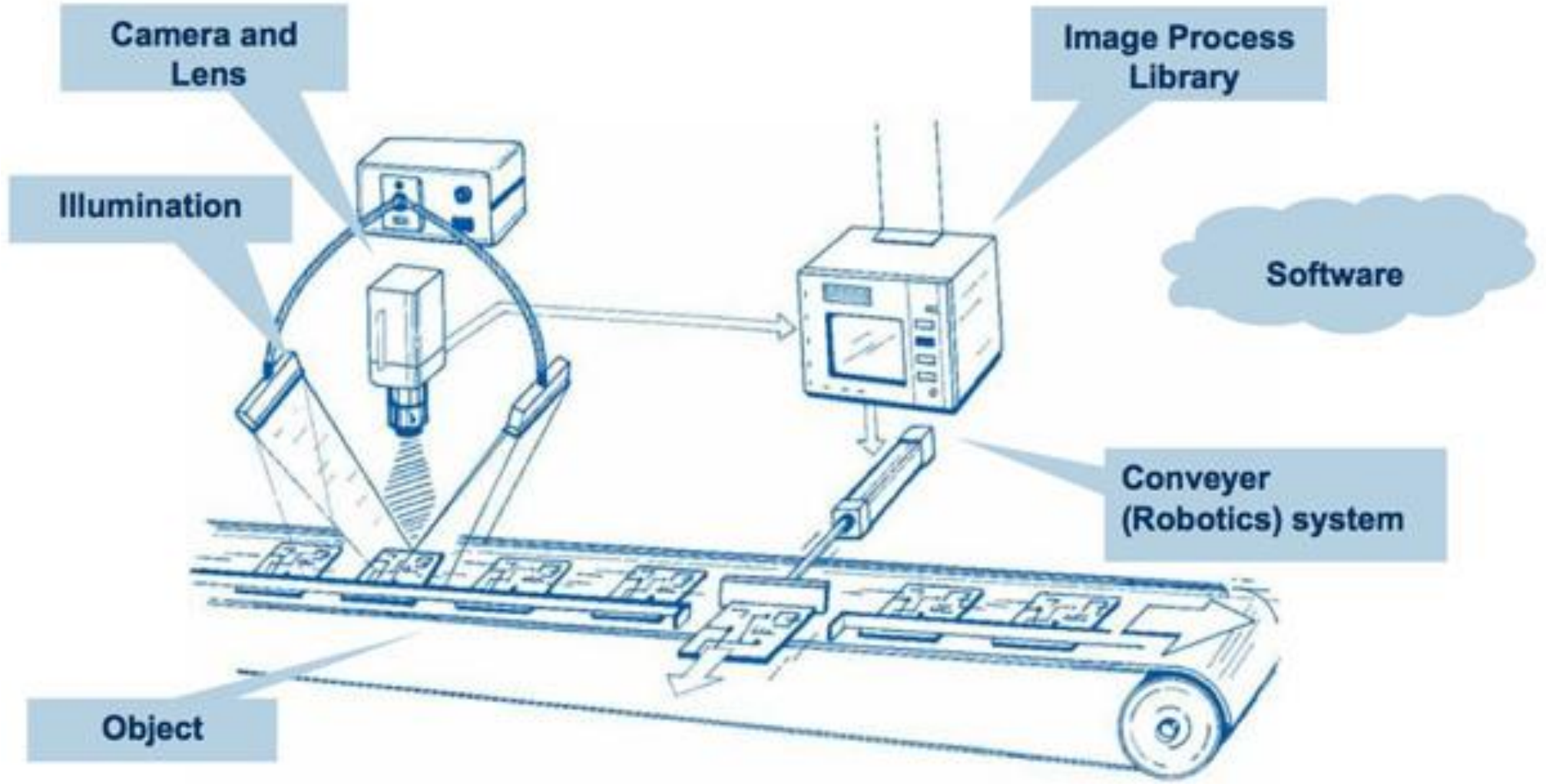
Part A:
Nature's Design Patterns for Vision Systems

Machine Vision Engineering Problem Overview

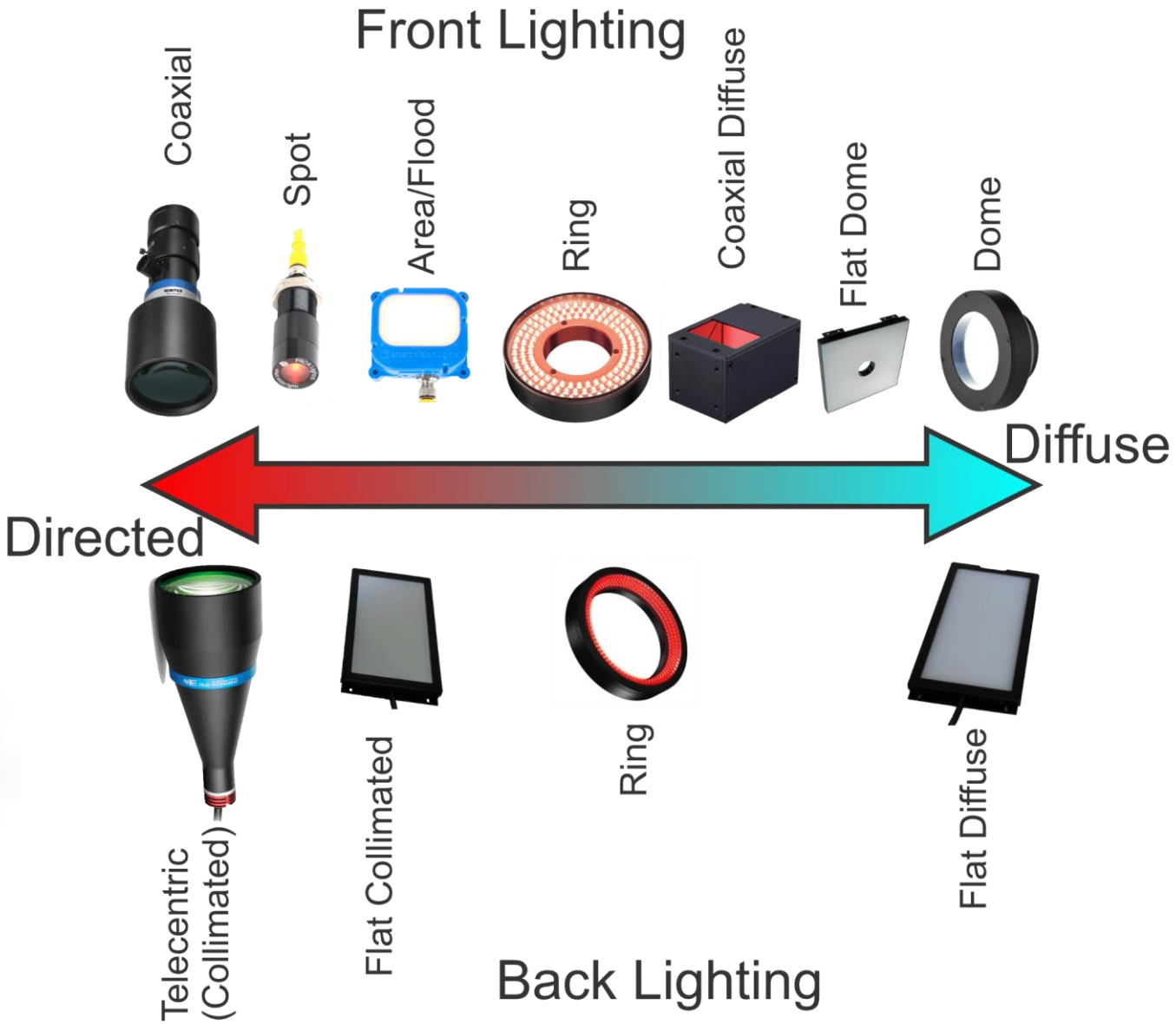


[*] https://aijourn.com/what-is-machine-vision-everything-you-need-to-know/

Cameras

Lenses

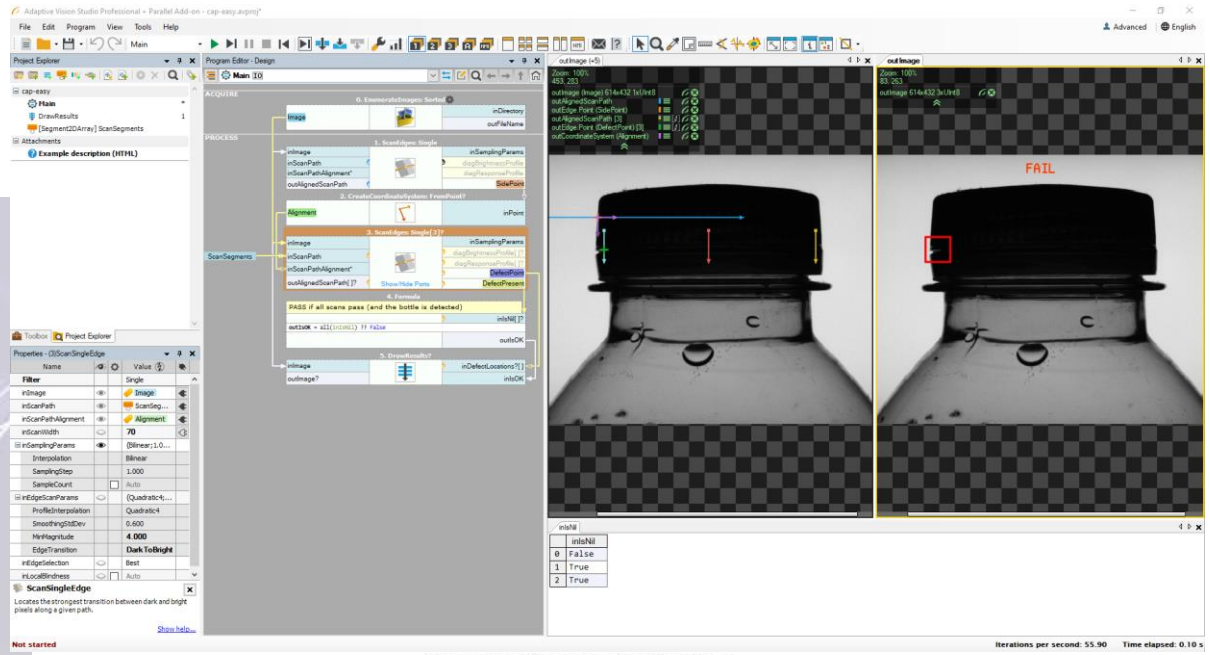
Illumination



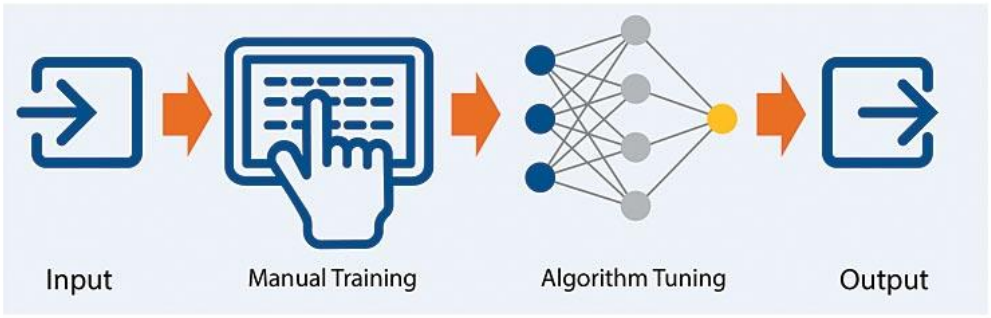
[*] https://digitaledition.qualitymag.com/march-2021/vs-machine-vision-101/

Computing

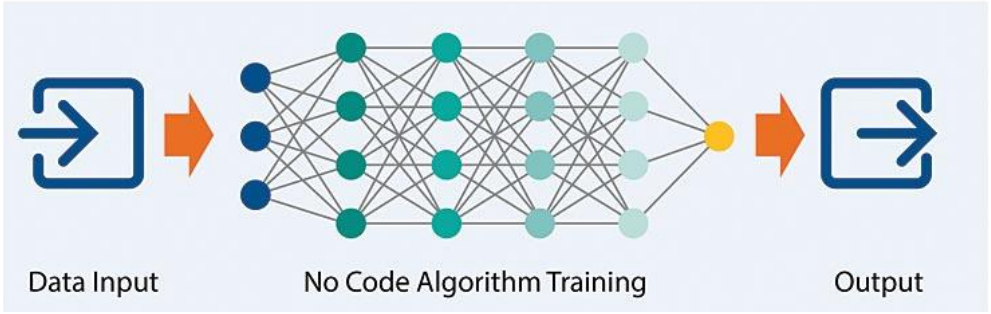
Software



Classic Computer Vision



Machine Learning



How Would Nature Solve the Problem?

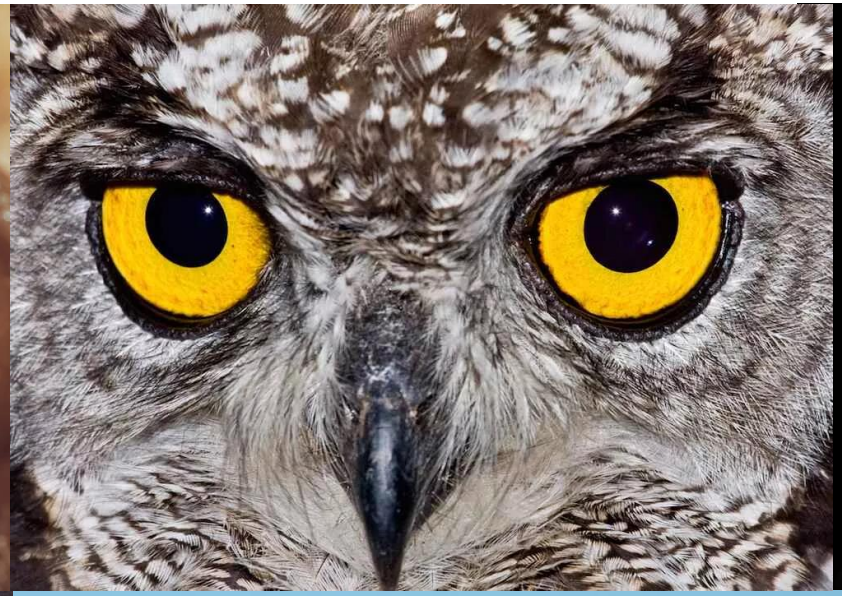
- The purpose of biological vision systems is to gain evolutionary advantage
- Biological vision systems are highly adapted to the image statistics of the natural world
- “Image statistics” depends on:
  - place an organism lives
  - function of organism in its environment

Setting the Goal

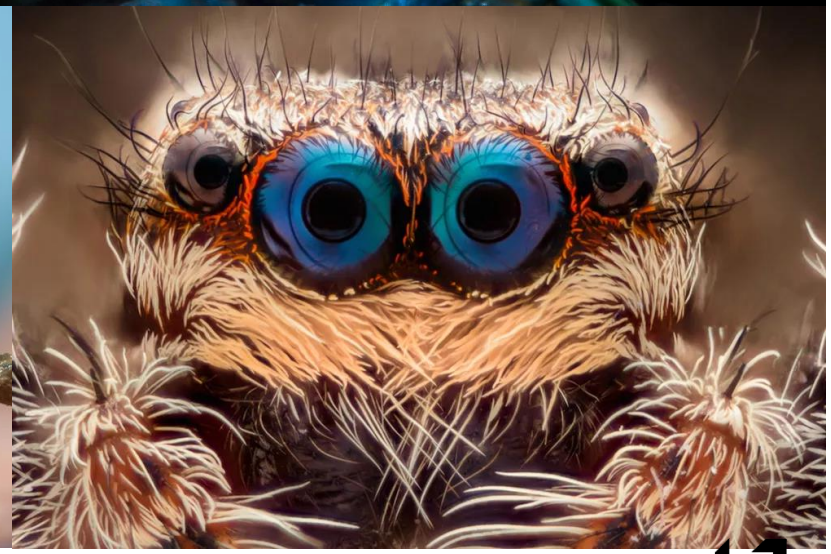
- The goal of nature is to survive and reproduce:
  - spot food, foes, and friendly-looking mates at some distance

- Nature’s way of adaption/optimization – natural selection

Variety of Eyes – Evidence of “Hardware” Adaptation

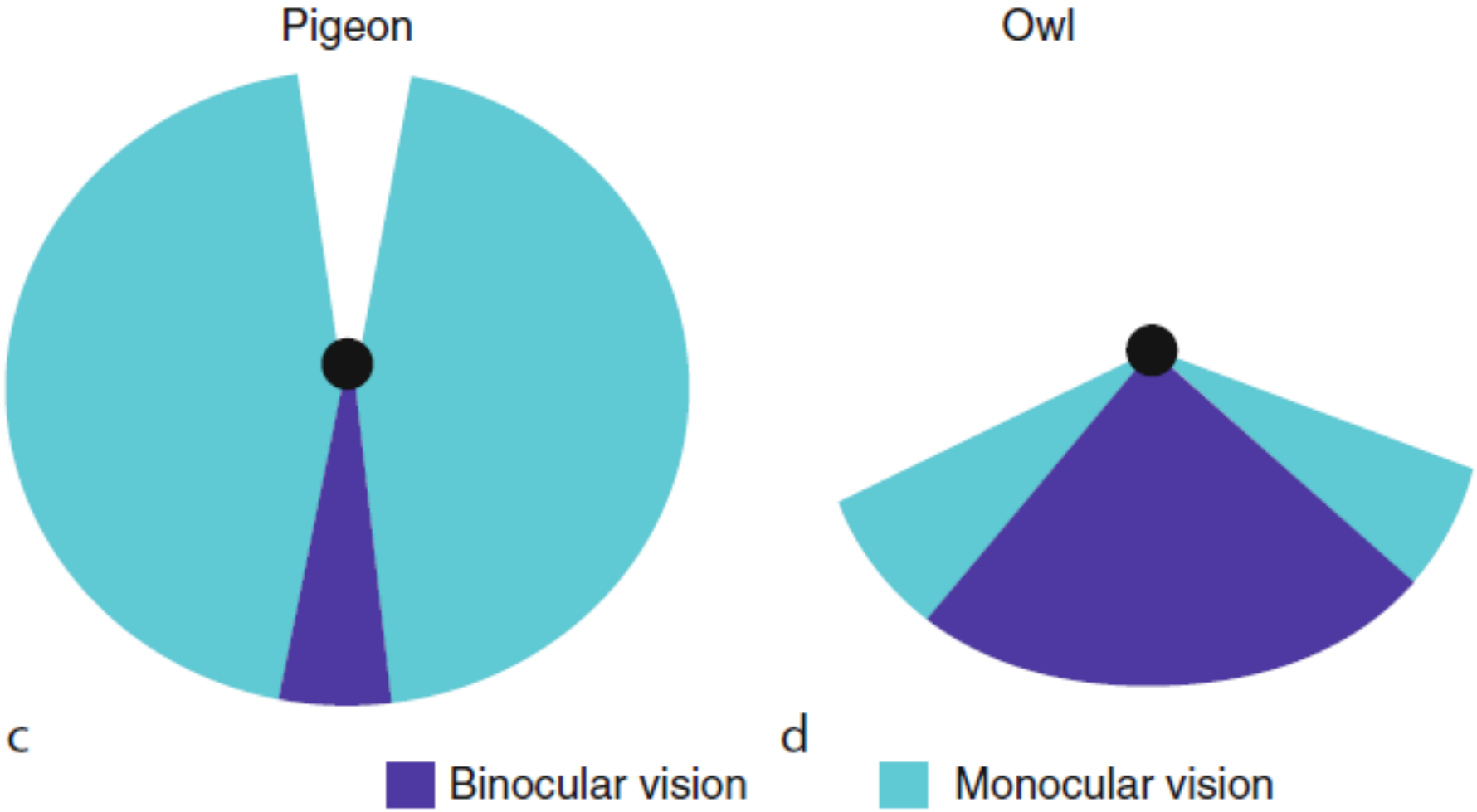







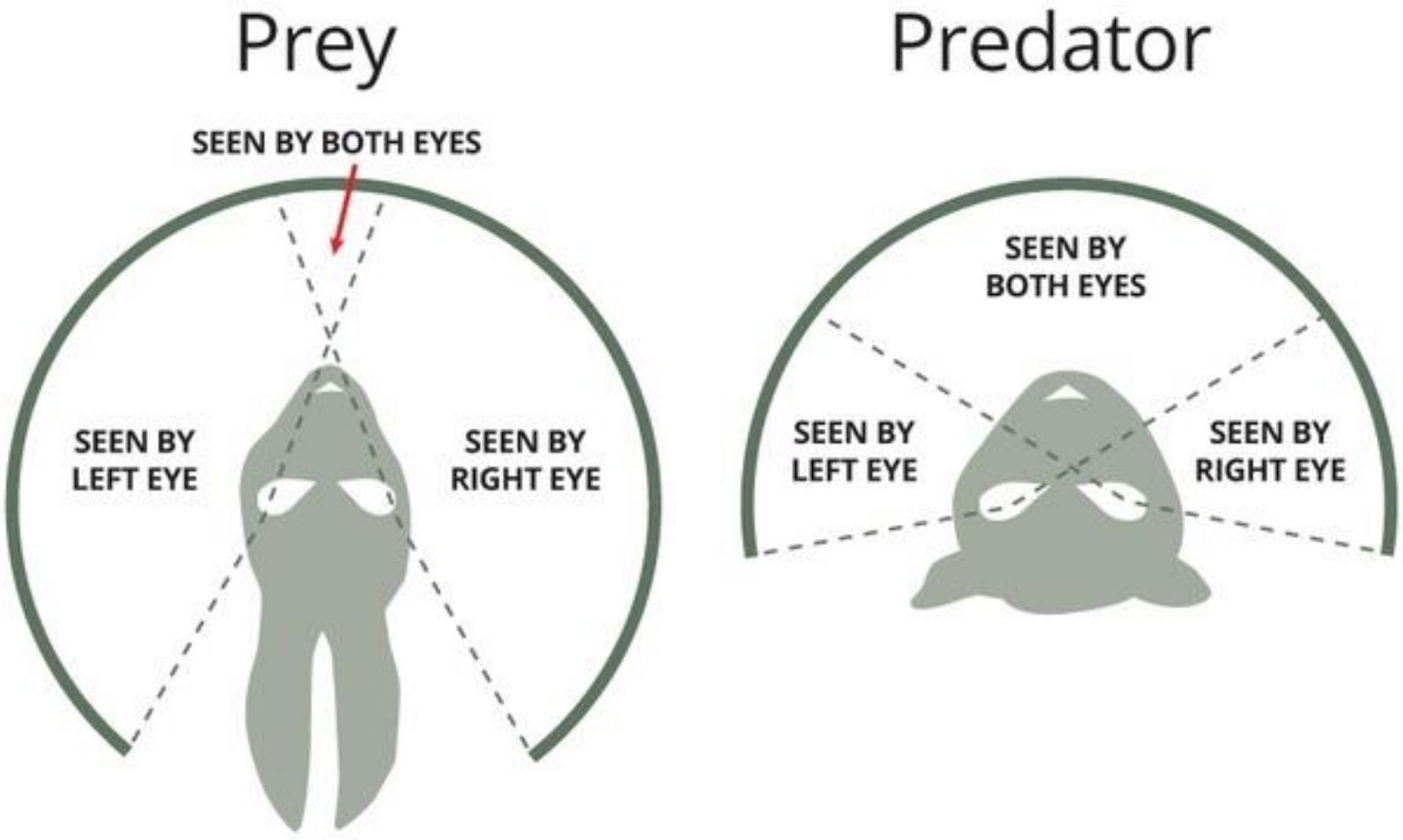
[*] https://www.livescience.com/62513-photos-amazing-animal-eyes.html

Variety of Eyes: Fields of View



[*] Machine Vision Handbook. Human and Animal Vision (cha3)

Variety of Eyes: Tendencies



[*] https://azretina.sites.arizona.edu/node/601

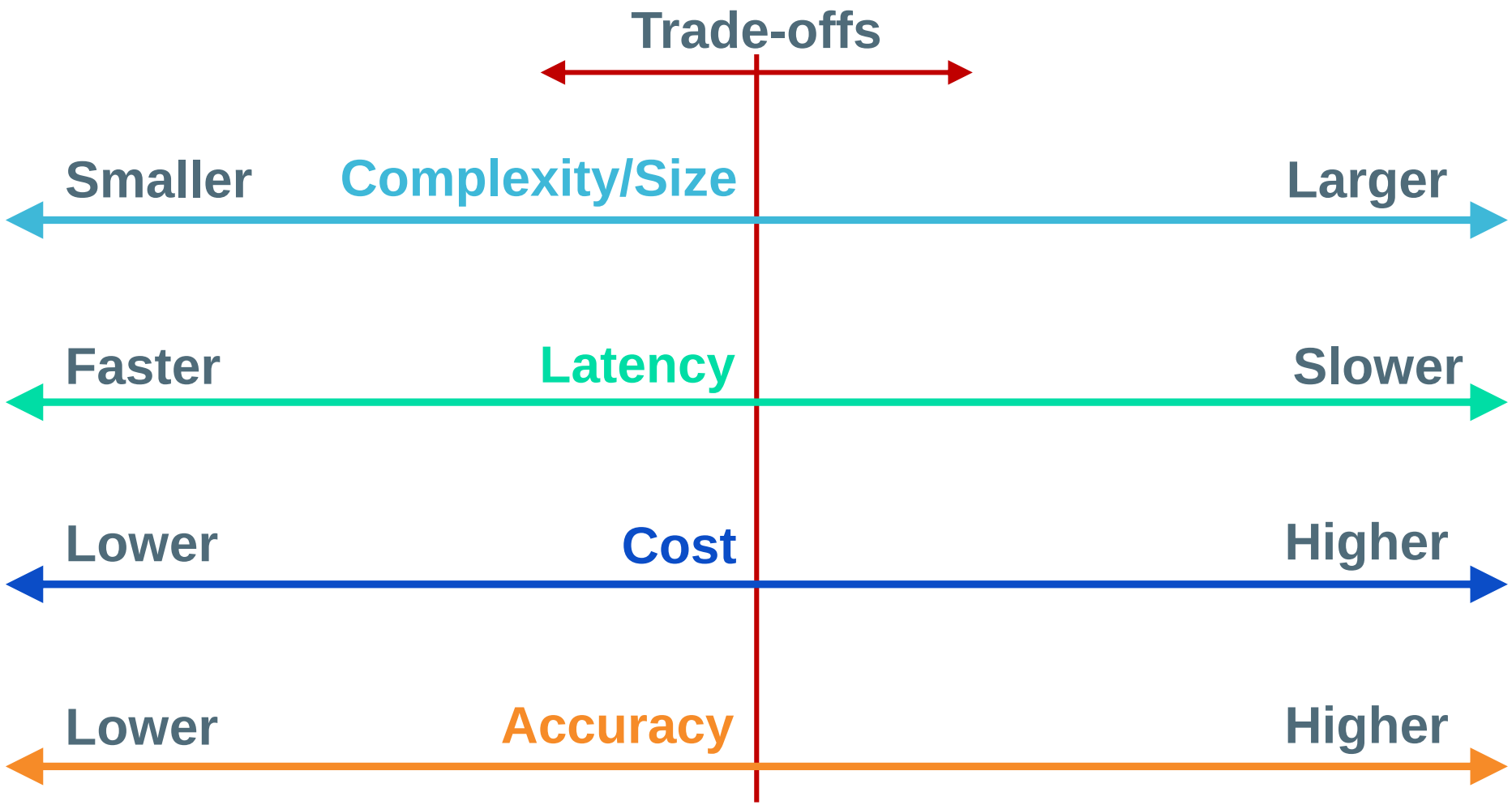
Variety of Pupils

[*] https://azretina.sites.arizona.edu/node/601
[*] https://www.iflscience.com/revealed-why-animals-pupils-come-different-shapes-and-sizes-29971

Setting the Goal

- The goal of nature is to survive and reproduce:
  - spot food, foes, and friendly-looking mates at some distance
- Nature’s way of adaption/optimization – natural selection
- What is the actual goal of artificial vision system beeing designed?

Achieving the Goal While Minimising Expenses



How Would Nature Solve the Problem?

- Biological vision systems are highly adapted to the image statistics of the natural world
- “Image statistics” depends on:
  - place an organism lives
  - function of organism in its environment
- Evidence of “software” part of biological vision systems being highly adapted/optimized – visual (optical) illusions

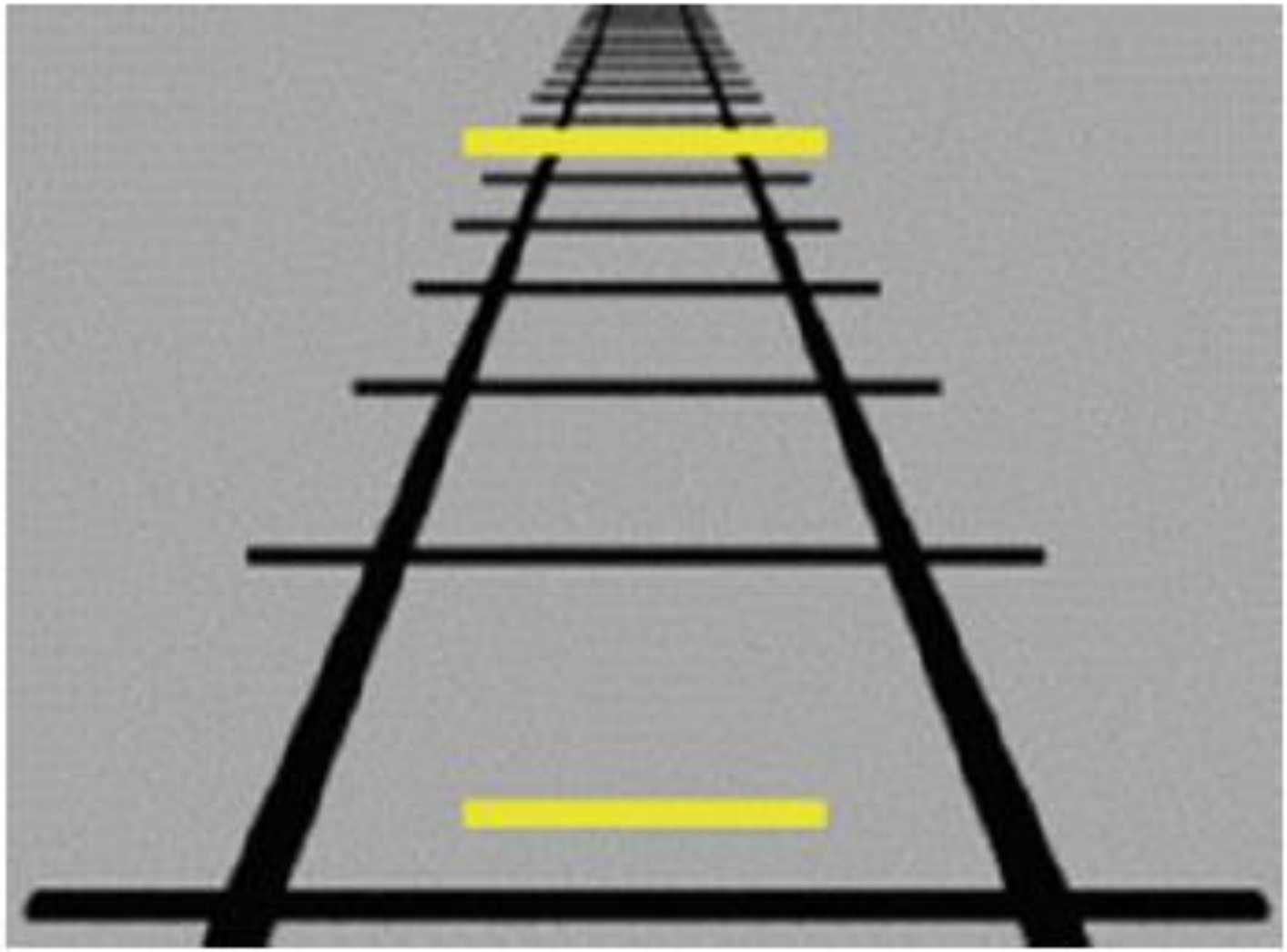
The Margaret Thatcher Illusion

[*] https://www.independent.co.uk/news/science/thatcher-effect-the-35yearold-optical-illusion-that-will-work-on-almost-anyone-a6875481.html

The Margaret Thatcher Illusion (2)

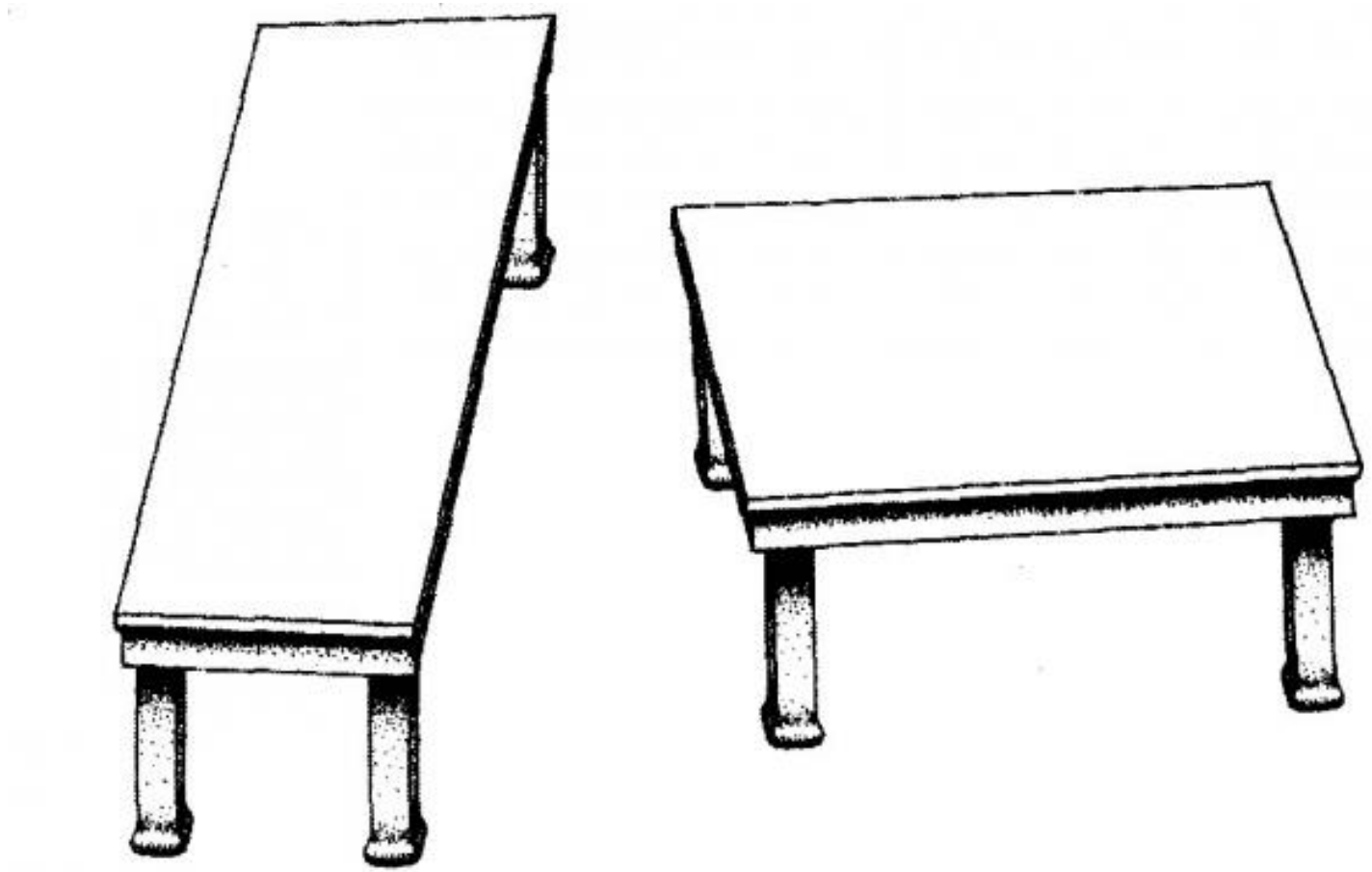
[*] https://www.independent.co.uk/news/science/thatcher-effect-the-35yearold-optical-illusion-that-will-work-on-almost-anyone-a6875481.html

Ponzo Illusion



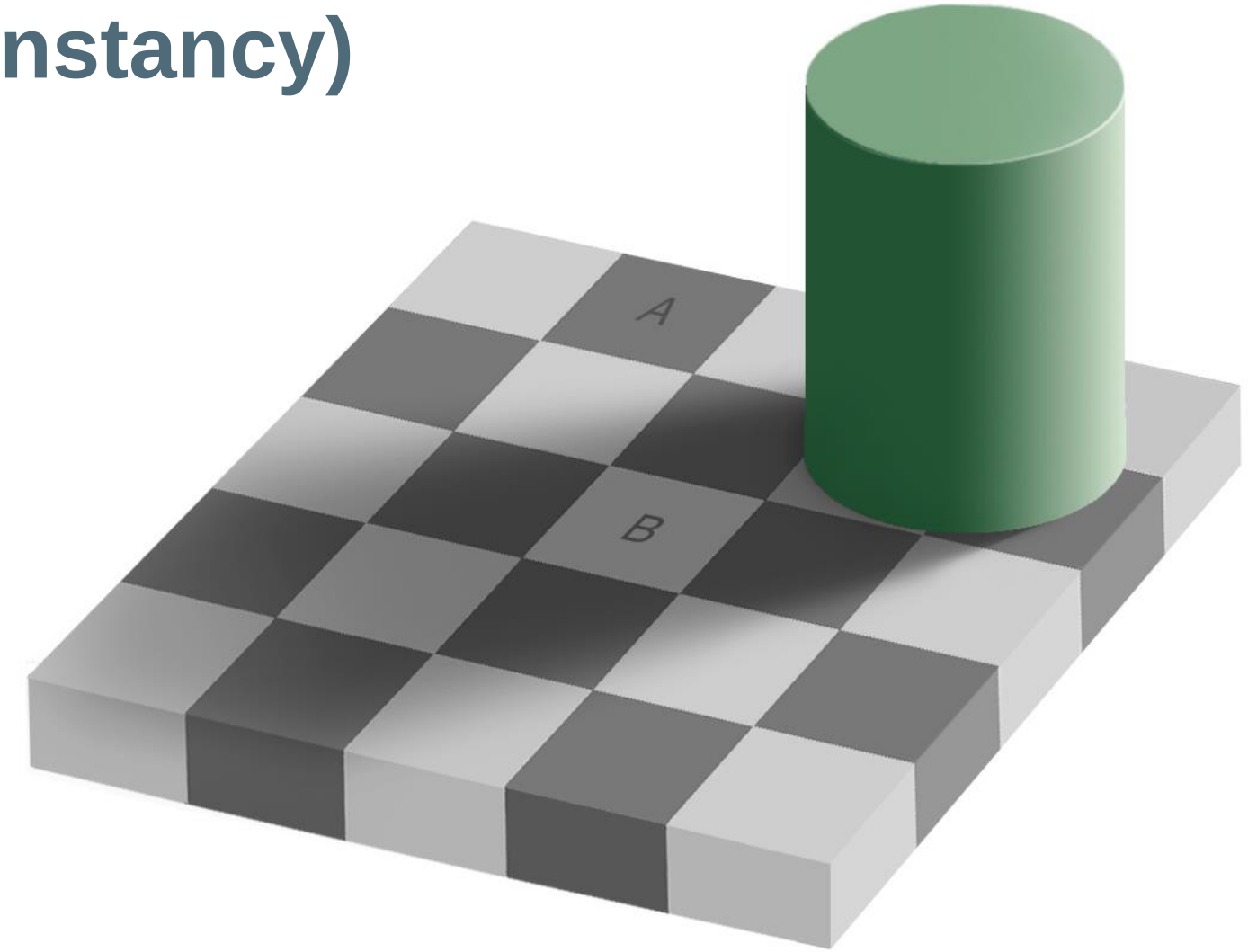
[*] https://en.wikipedia.org/wiki/Ponzo_illusion

Shepard Tabletop Illusion



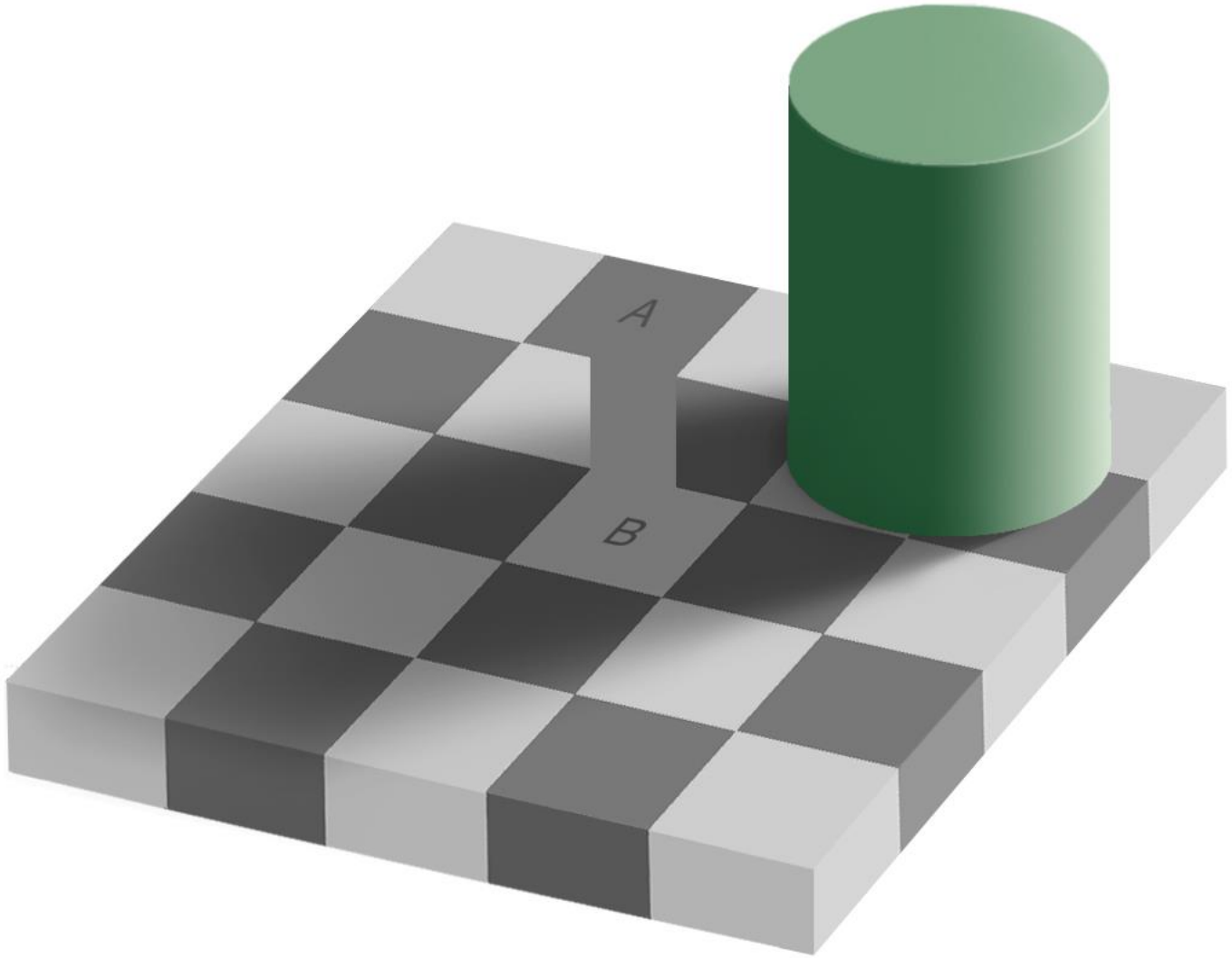
[*] https://en.wikipedia.org/wiki/Shepard_tables

Adelson’s Checkerboard Illusion (Color Constancy)



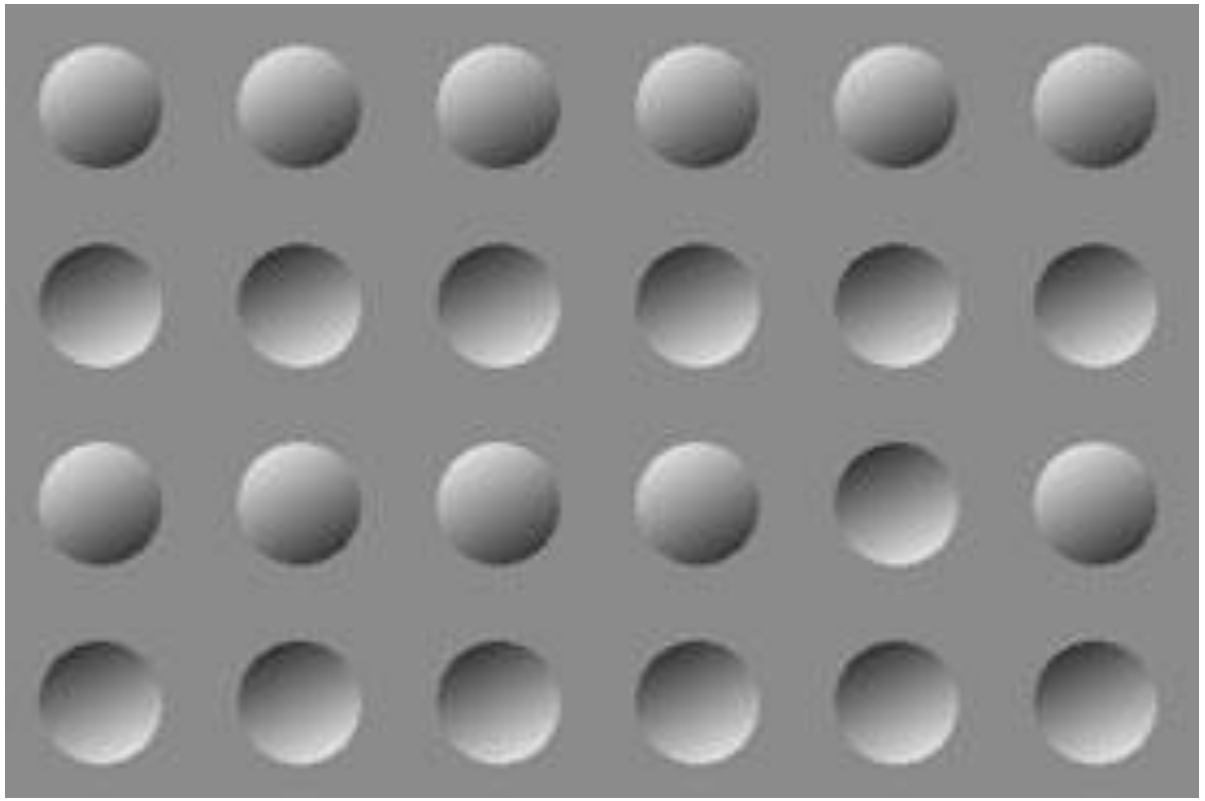
[*] https://en.wikipedia.org/wiki/Checker_shadow_illusion

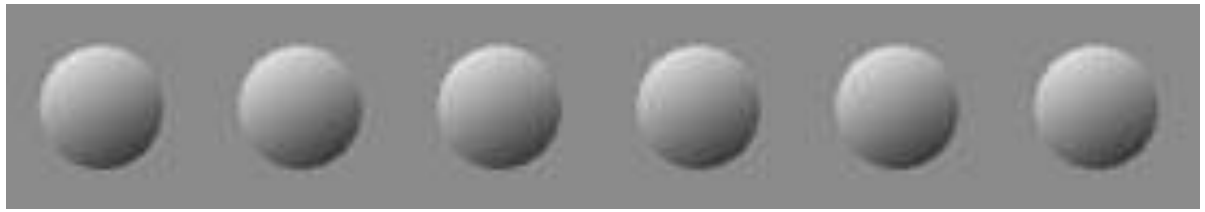
Adelson’s Checkerboard Illusion (2)



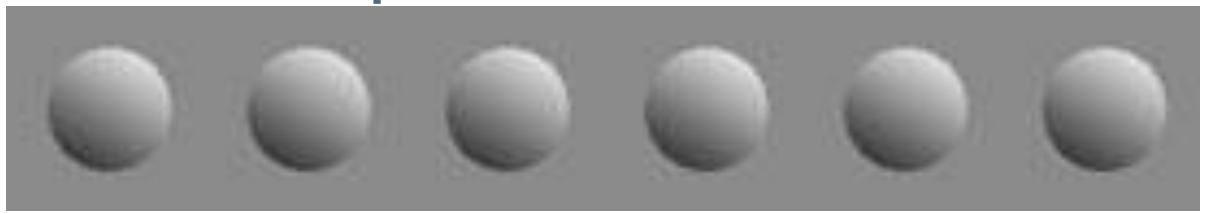
[*] https://en.wikipedia.org/wiki/Checker_shadow_illusion

Brains: Lighting Is Typically Coming from Above

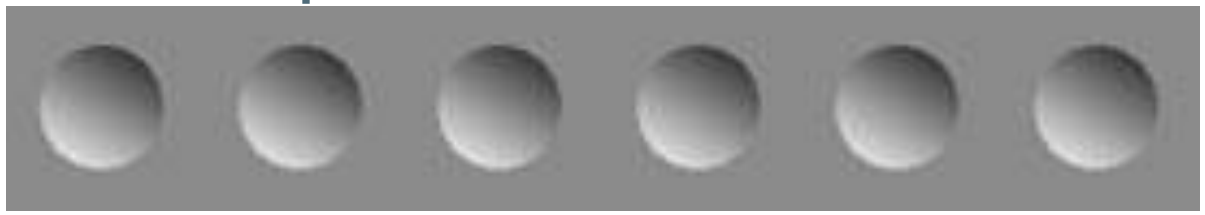




Horizontal flip:

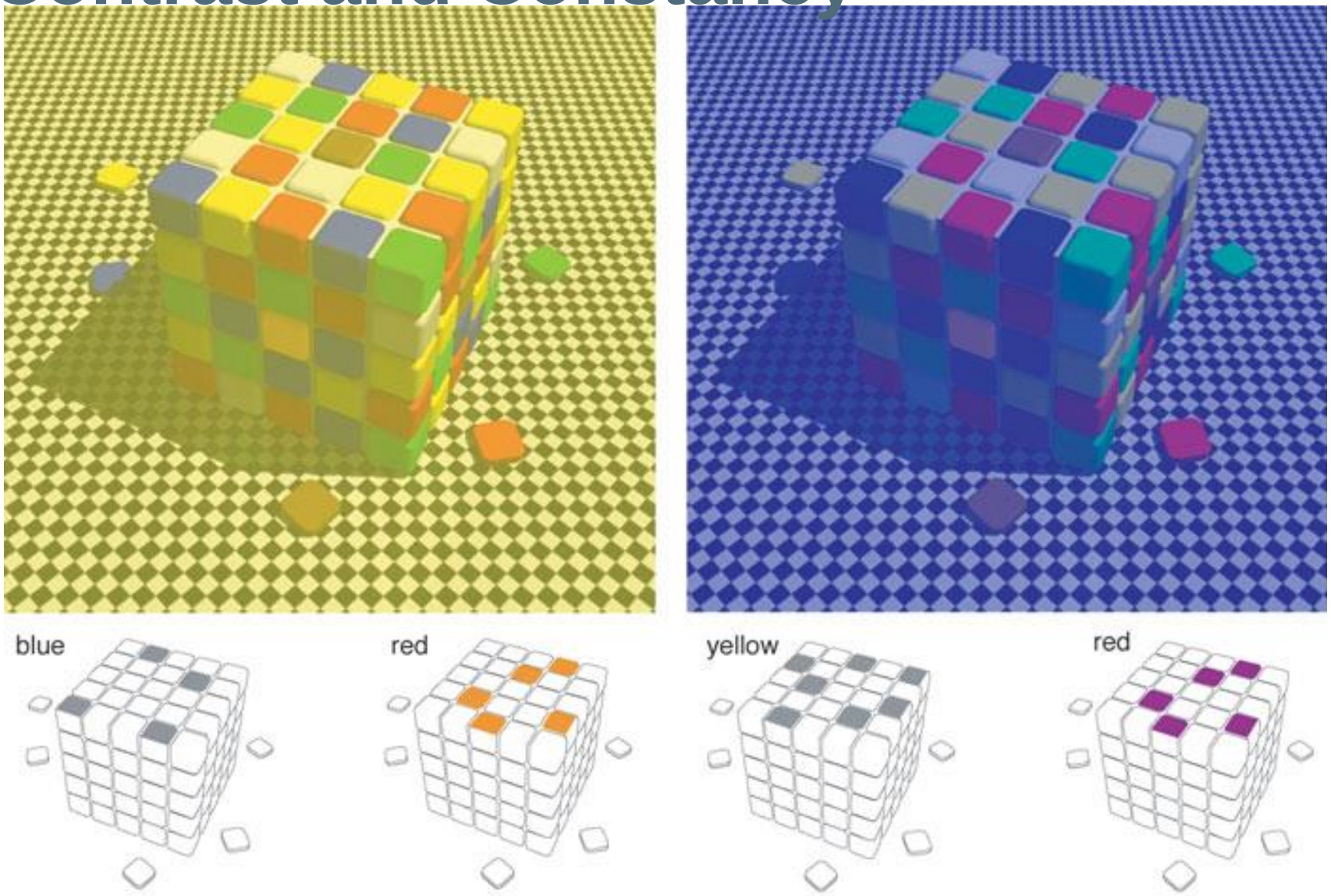


Vertical flip:



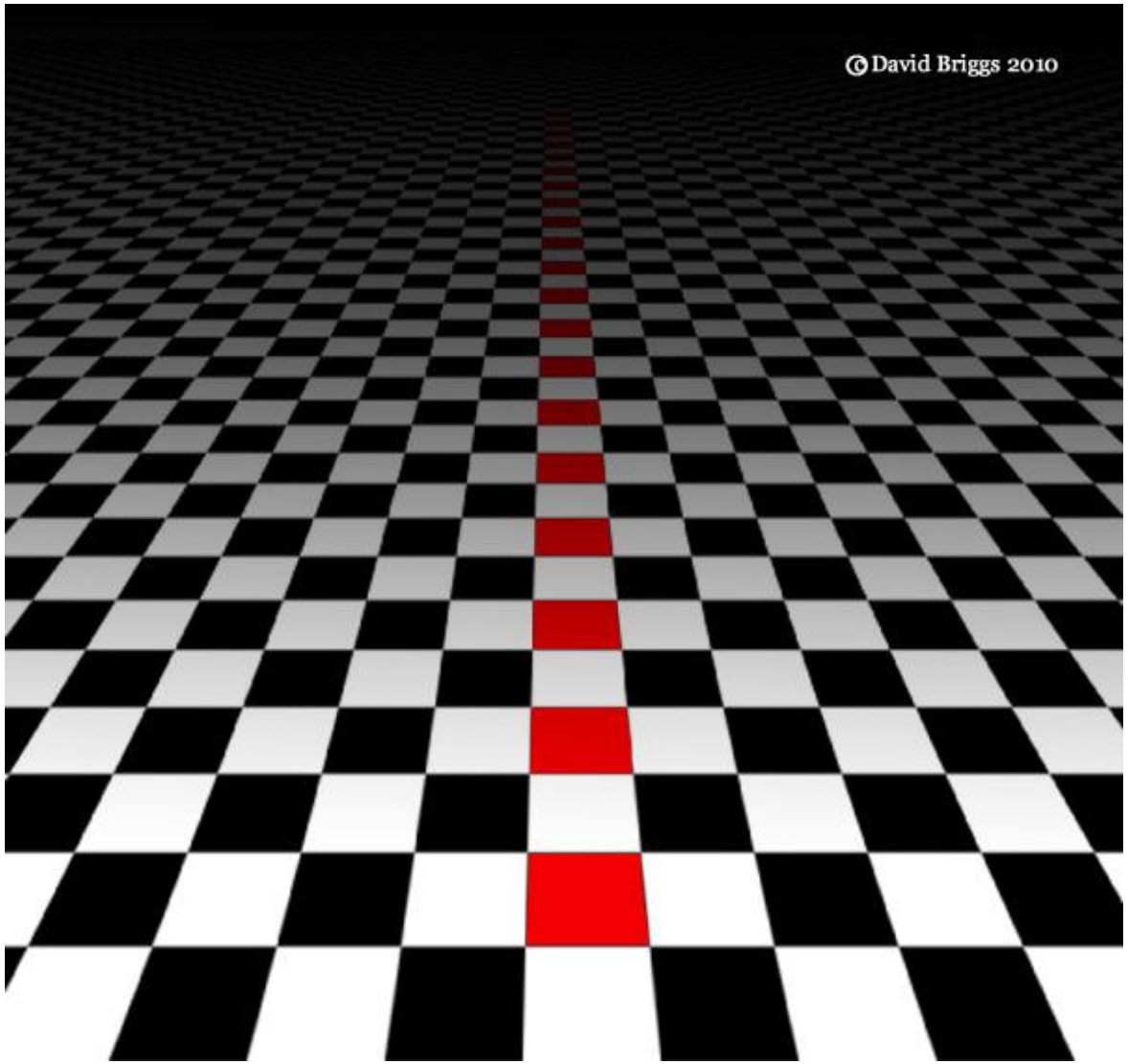
[*] https://thebrain.mcgill.ca/flash/a/a_02/a_02_p/a_02_p_vis/a_02_p_vis.html

Color Contrast and Constancy



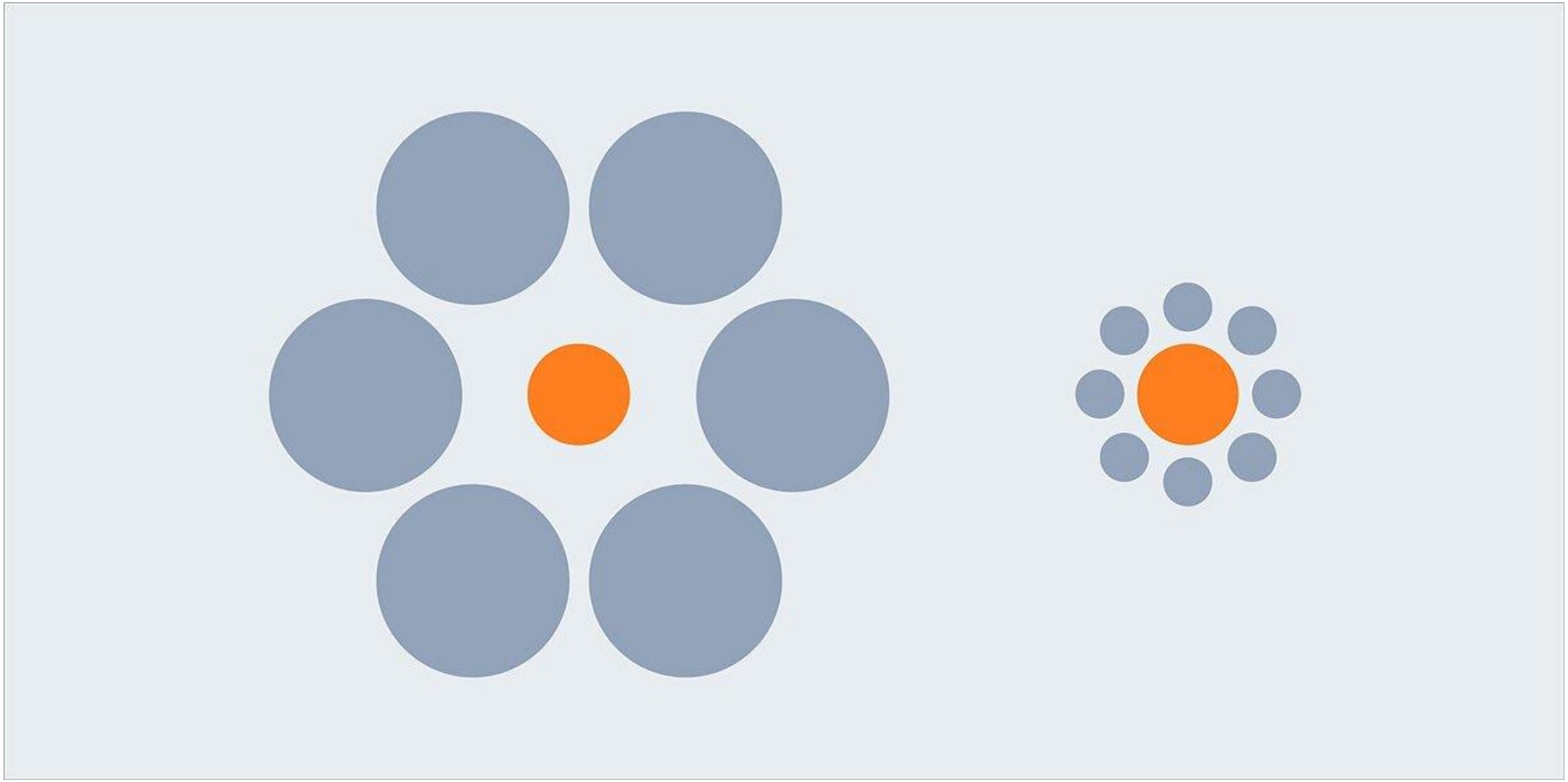
[*] https://engineering.purdue.edu/~bouman/ece637/notes/ColorConstancy/color/

Color, Shape and Size Constancy



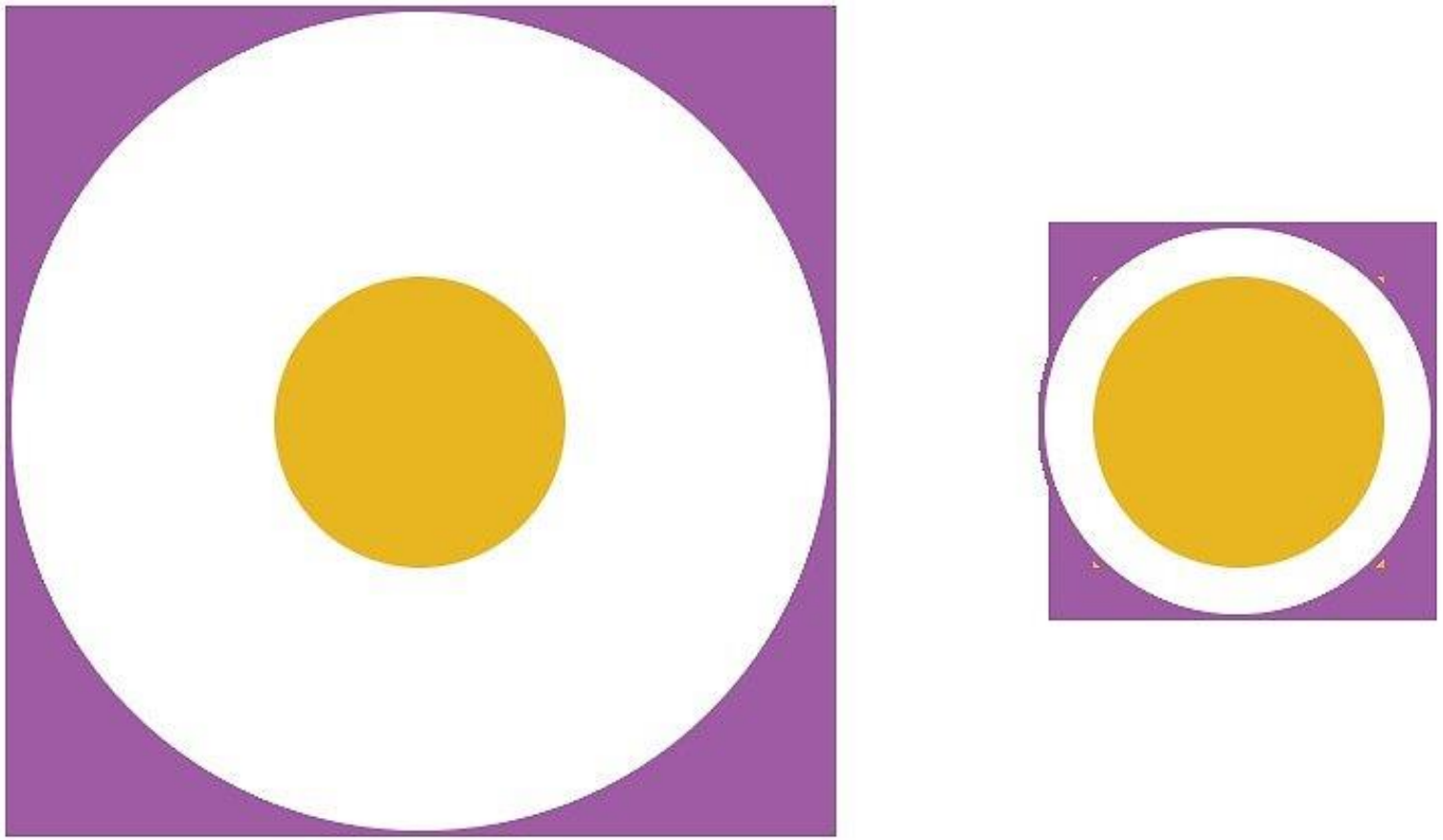
[*] http://www.huevaluechroma.com/034.php

Ebbinghaus Illusion



[*] https://en.wikipedia.org/wiki/Ebbinghaus_illusion

Delboeuf Illusion



[*] https://en.wikipedia.org/wiki/Delboeuf_illusion

Perception

- Perception is a guess
- Image has infinite interpretations, and brains must derive only one or two meaningful interpretations
- Vision is underconstrained and necessitates some form of guessing by the agent using prior knowledge
- Brains speed up perception by guessing what’s next

[*] Computer Vision: Statistical Models for Marr's Paradigm. Springer Nature, 2023
[*] https://www.quantamagazine.org/brains-speed-up-perception-by-guessing-whats-next-20190502/

Illusion

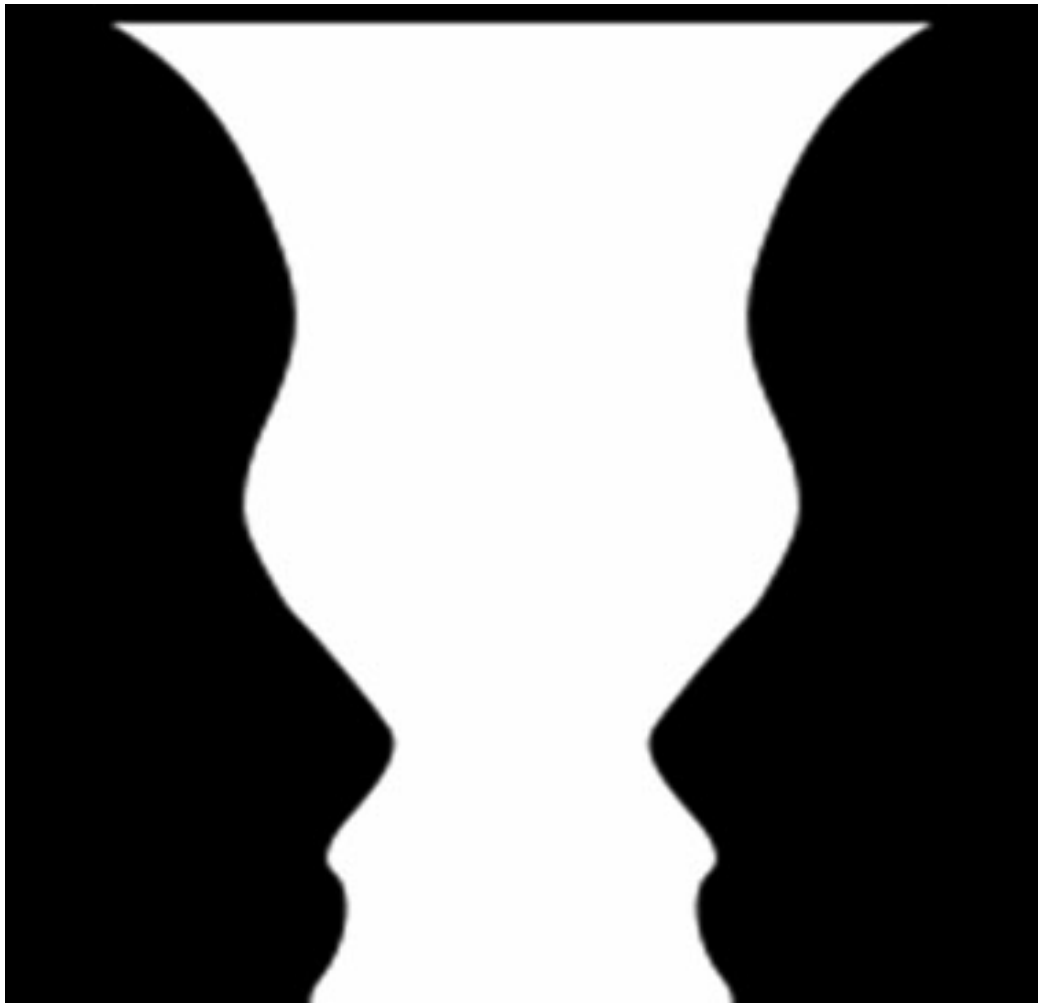
Dalmatian Illusion

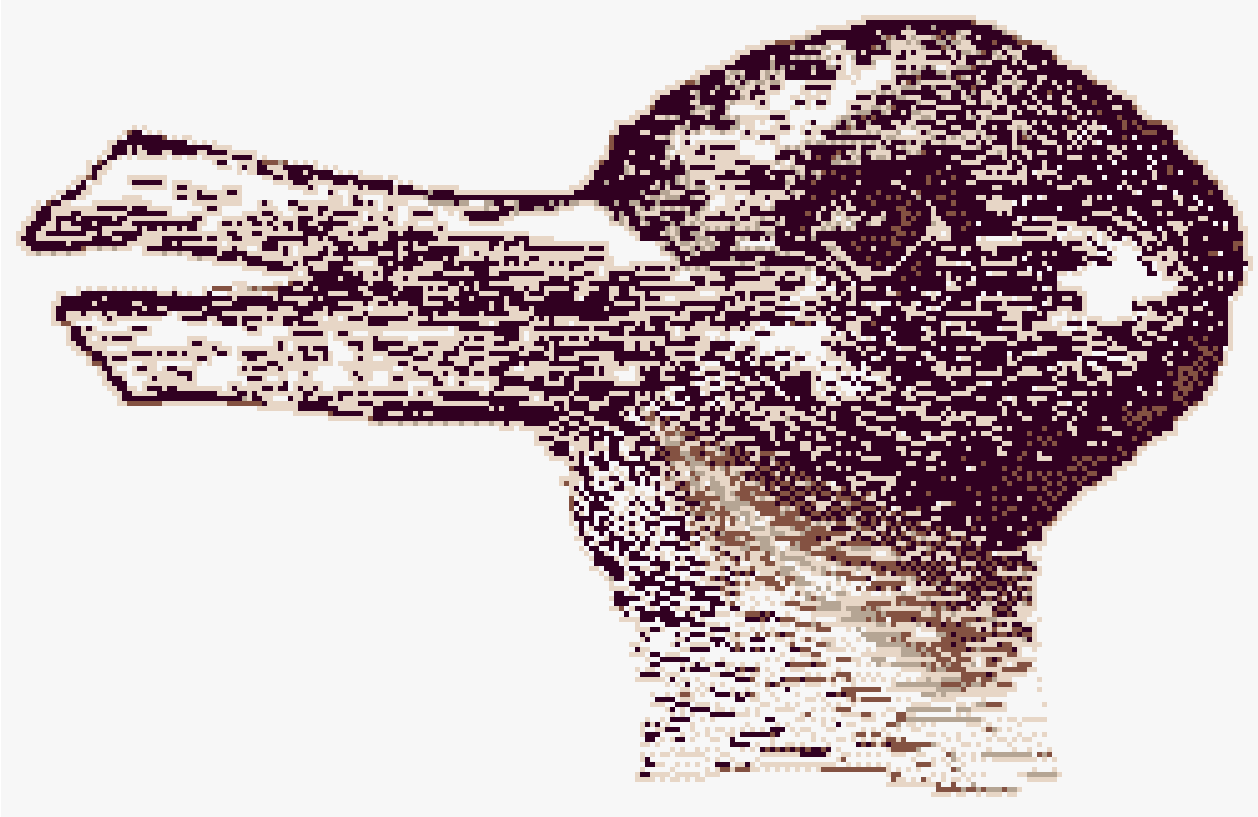
[*] https://www.popsci.com/story/diy/dalmatian-illusion/

Dalmatian Illusion

[*] https://www.popsci.com/story/diy/dalmatian-illusion/

Ambiguous Images





[*] https://en.wikipedia.org/wiki/Figure%E2%80%93ground_(perception)
[*] https://en.wikipedia.org/wiki/Rabbit%E2%80%93duck_illusion

Ambiguous Animation

[*] https://www.anopticalillusion.com/2014/11/moving-train-optical-illusion/

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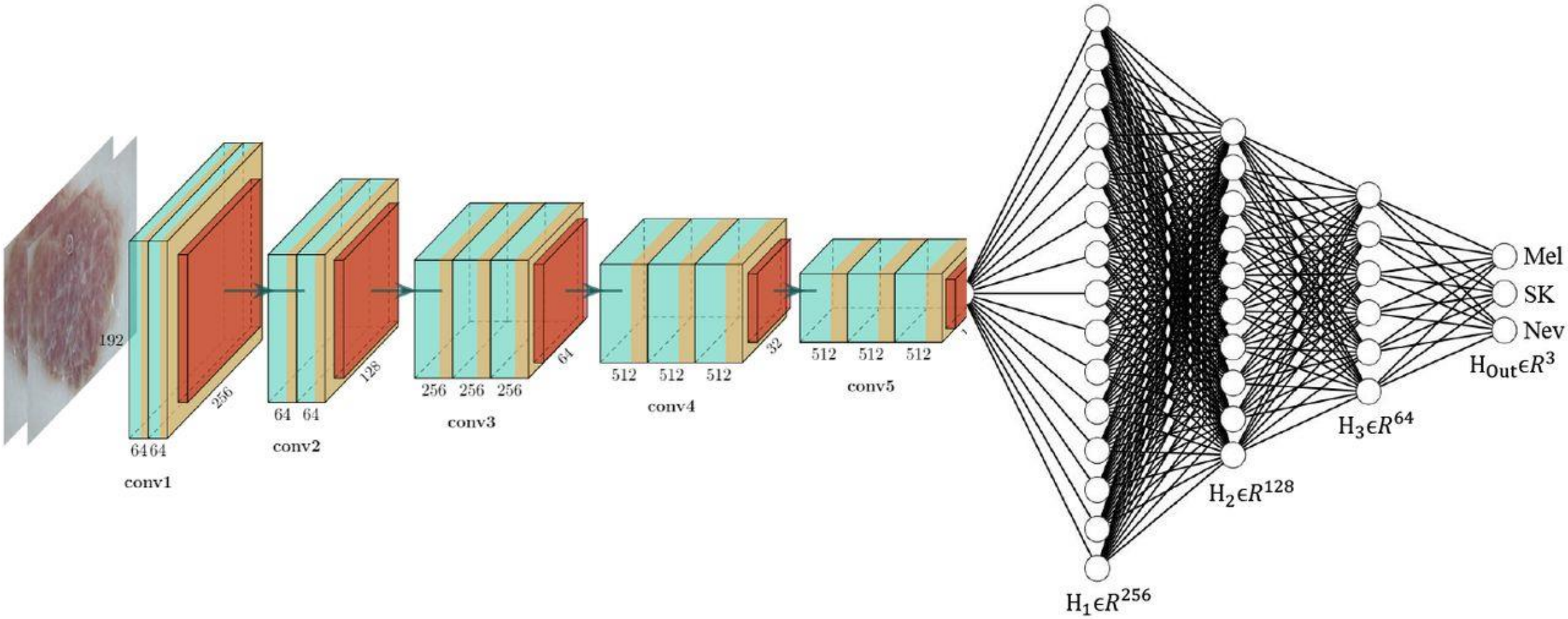
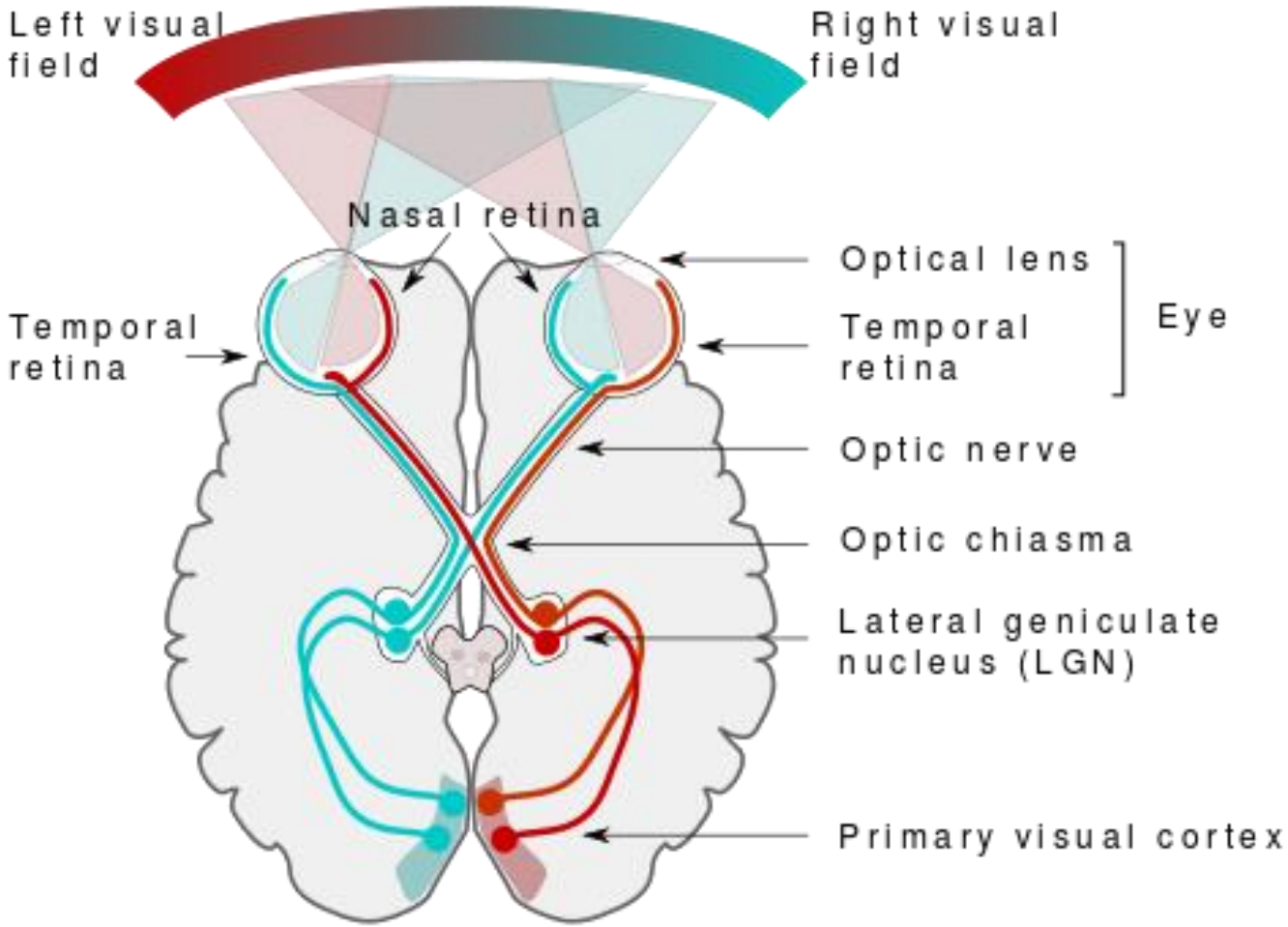
Part B:
Deep Learning-Based and Biological Vision

Convolutional Neural Network, CNN



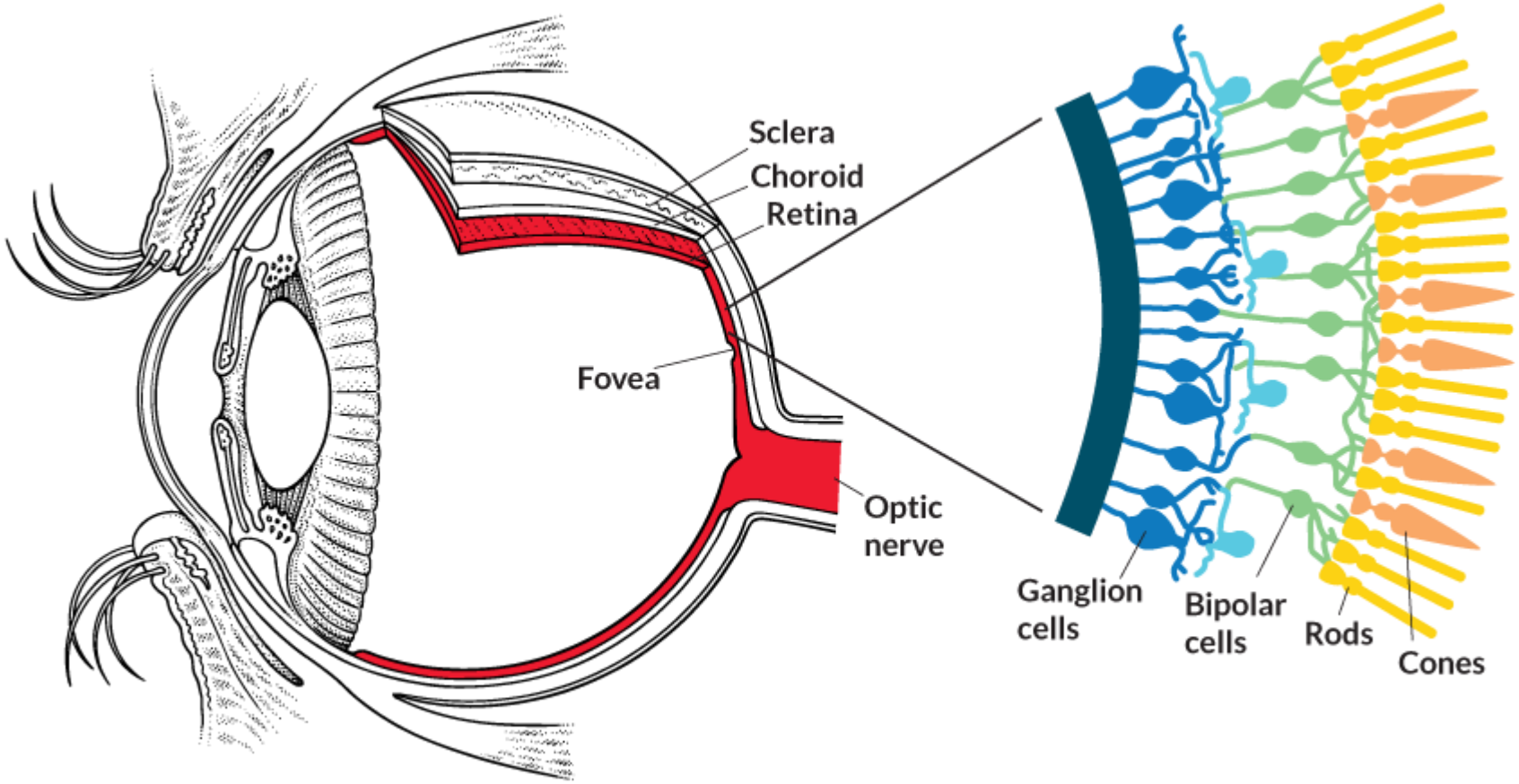
[*] https://www.medrxiv.org/content/10.1101/2020.11.24.20238246v1.full

Human Visual System



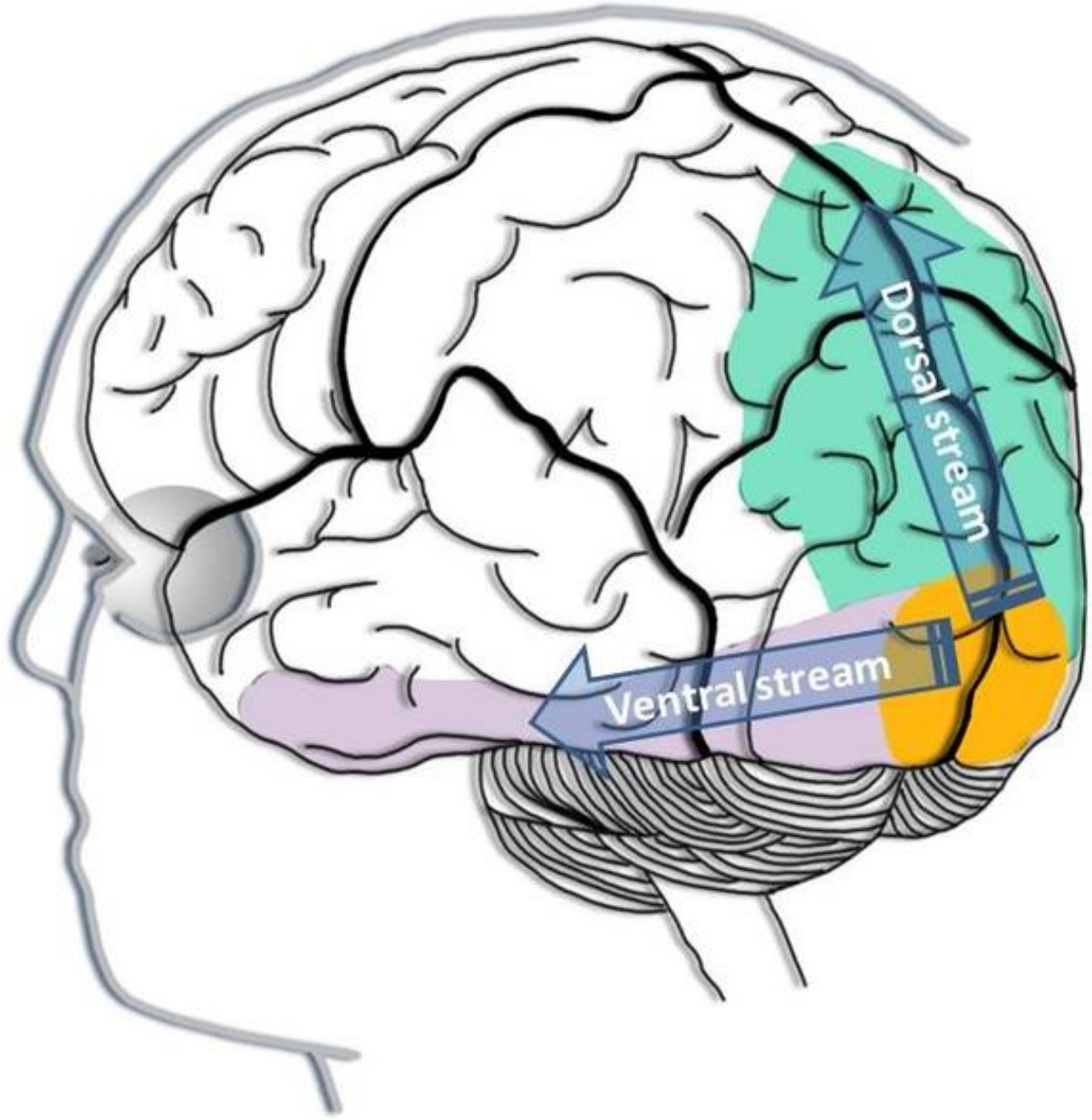
[*] https://commons.wikimedia.org/wiki/File:Human_visual_pathway.svg

Human Eye



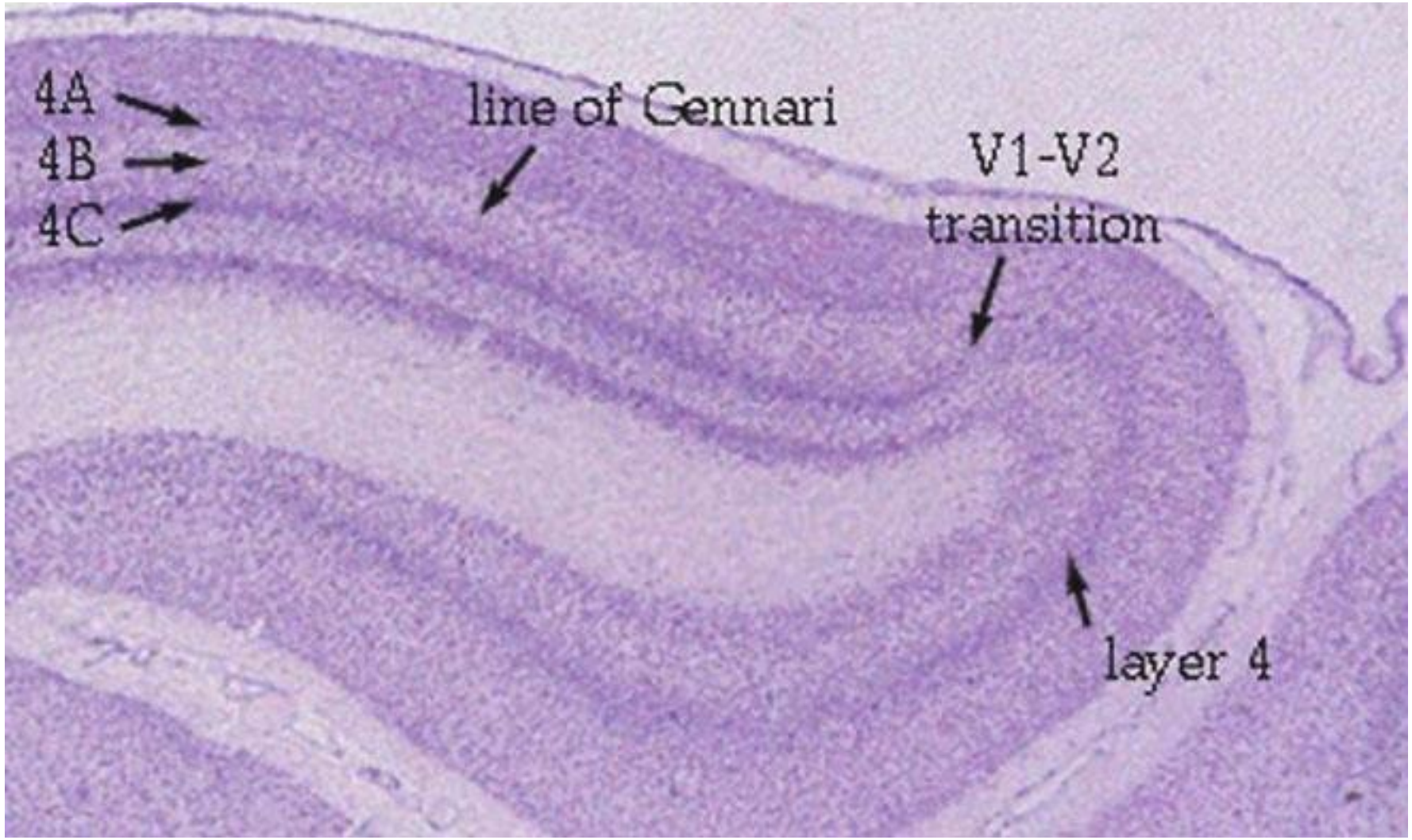
[*] https://universiestmentalis.wordpress.com/2015/05/24/how-to-rewire-the-eye-biology/

Visual Information Pathways



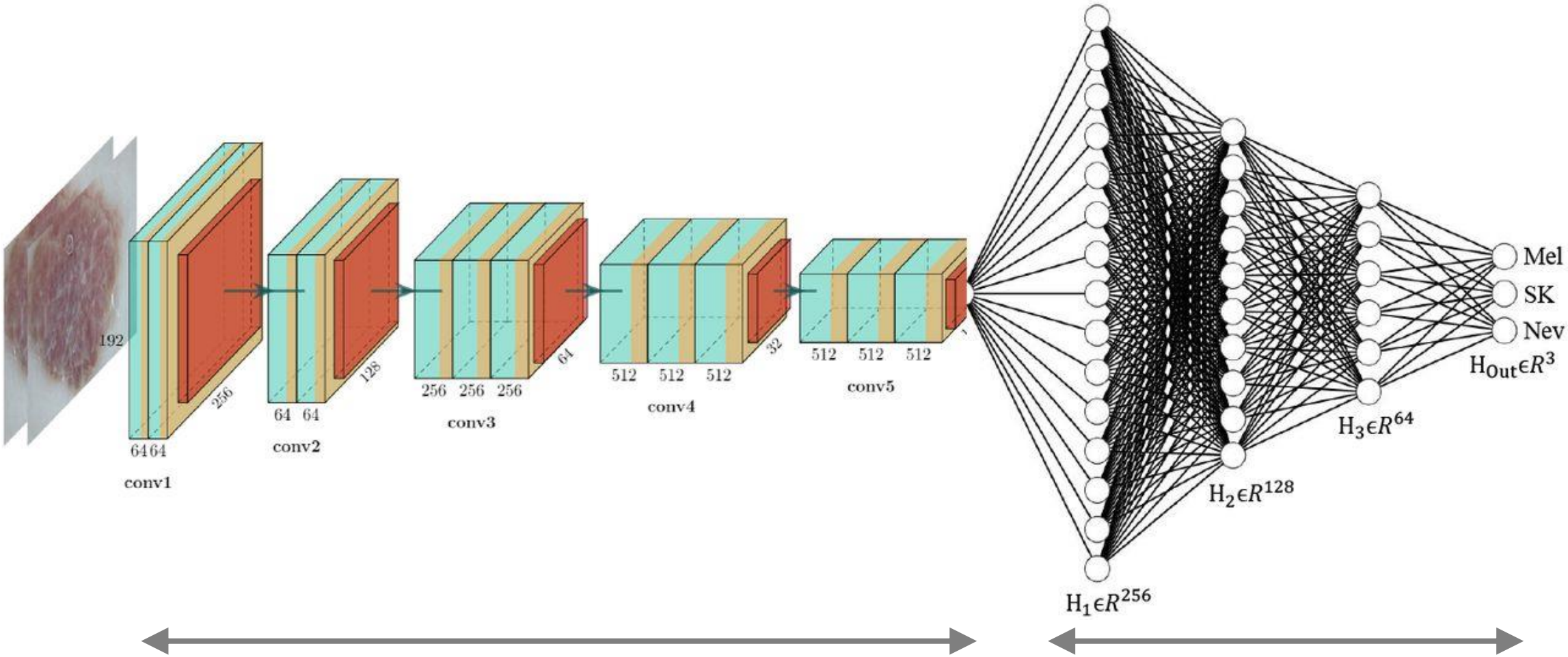
[*] https://commons.wikimedia.org/wiki/File:Ventral_and_dorsal_stream_in_visual_information_processing.png

Cortical Layers



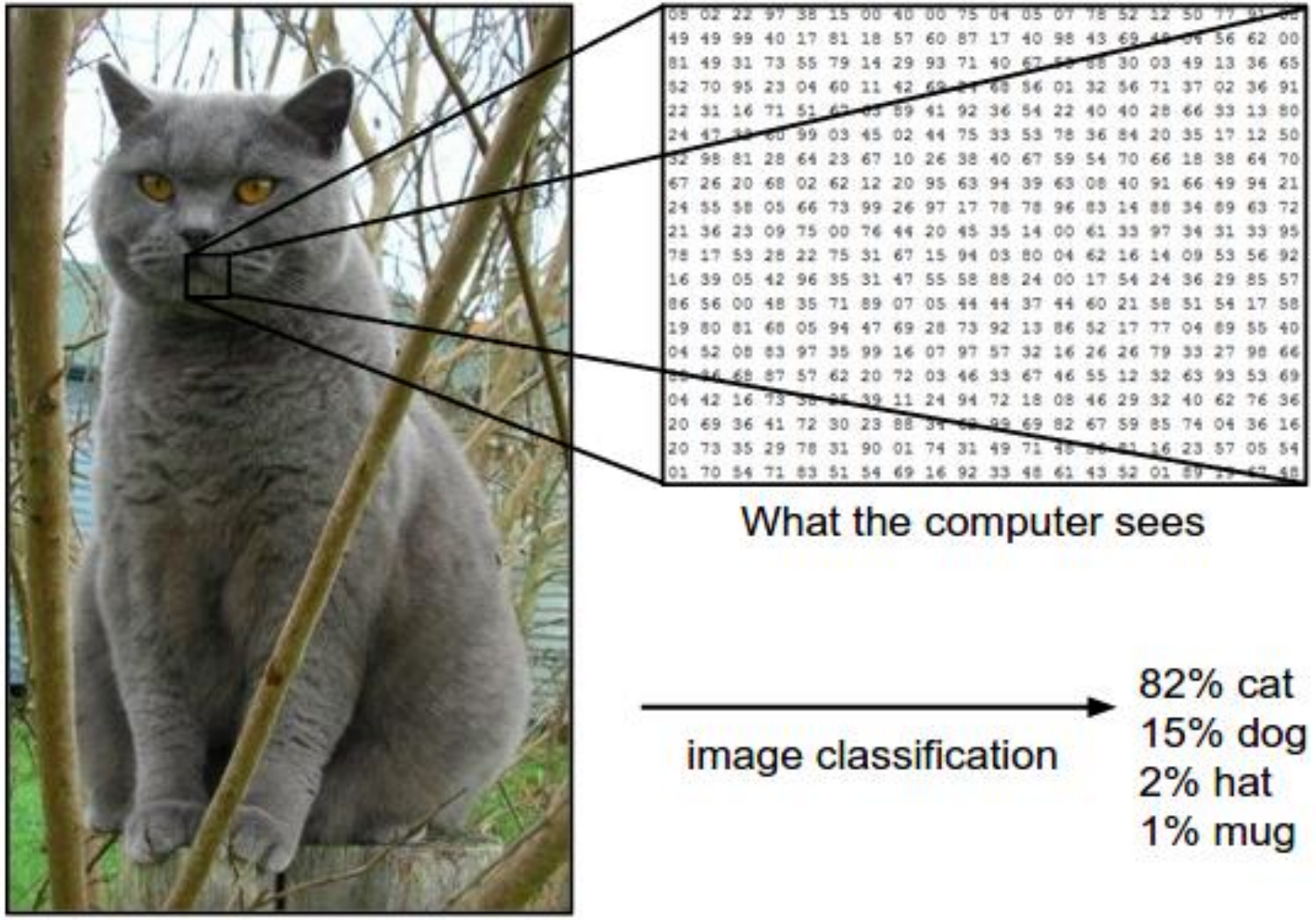
[*] https://webvision.med.utah.edu/book/part-ix-brain-visual-areas/the-primary-visual-cortex/

Convolutional Neural Network, CNN



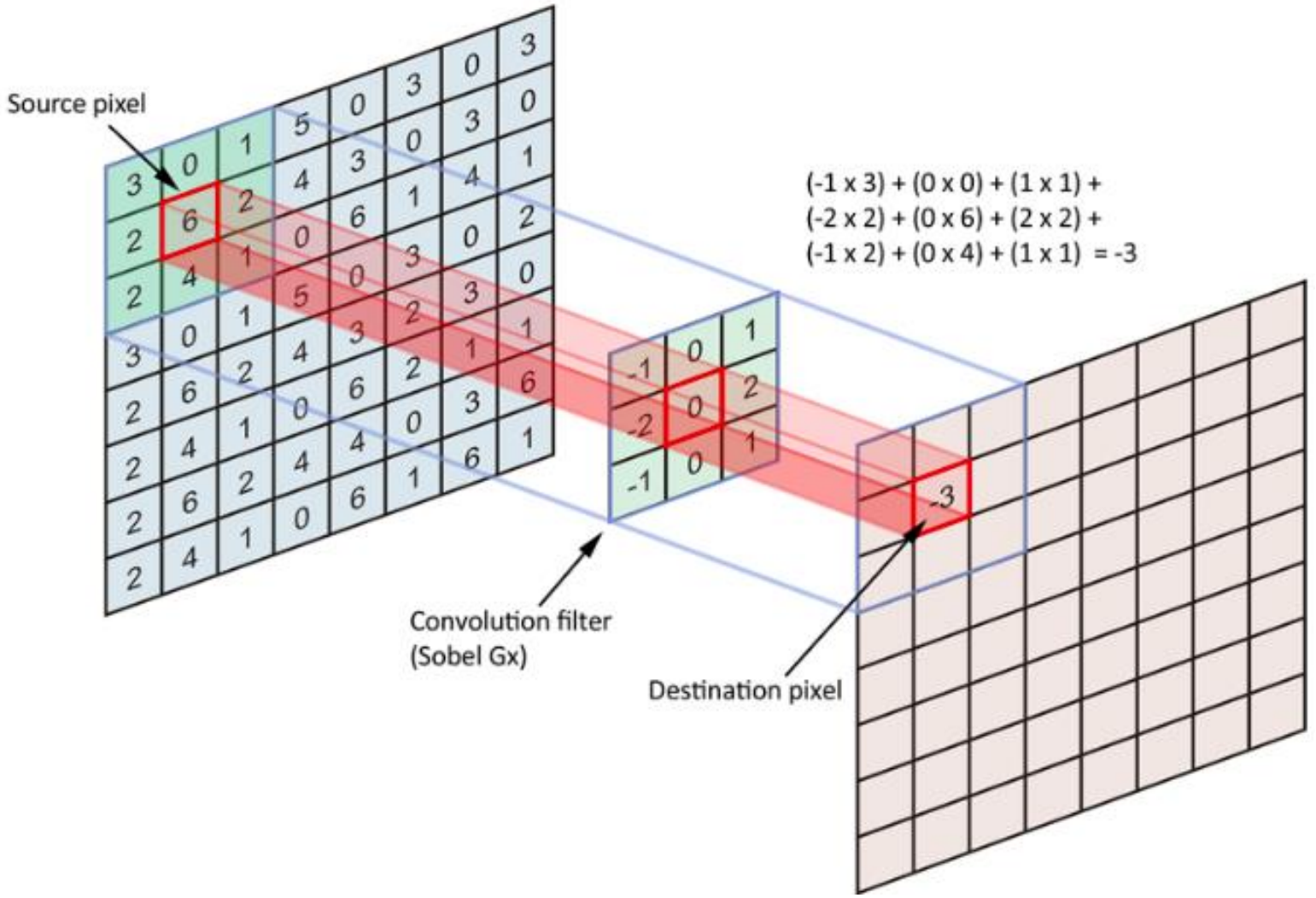
[*] https://www.medrxiv.org/content/10.1101/2020.11.24.20238246v1.full

How Computer/Algorithm Sees



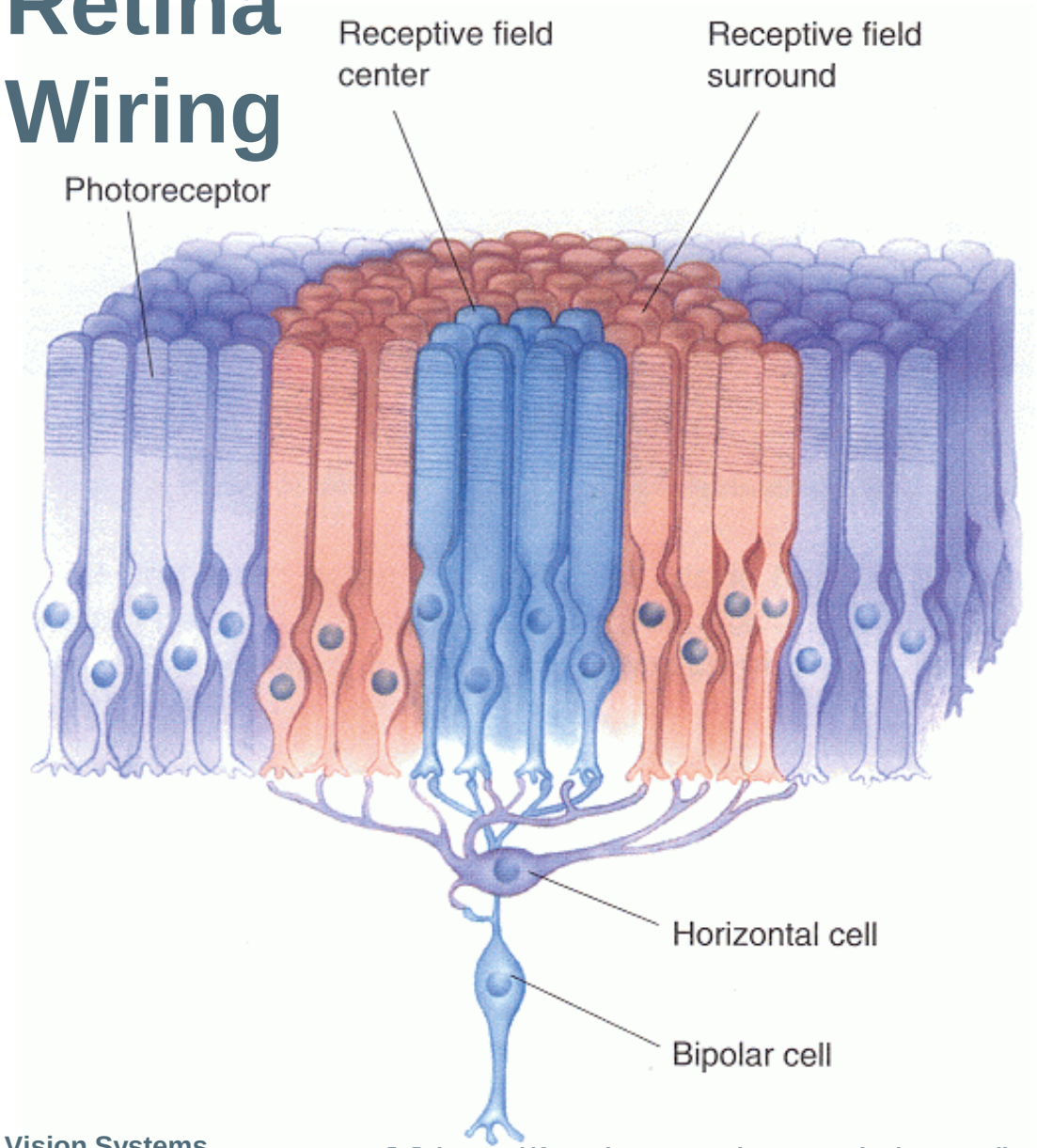
[*] http://cs231n.github.io/classification/

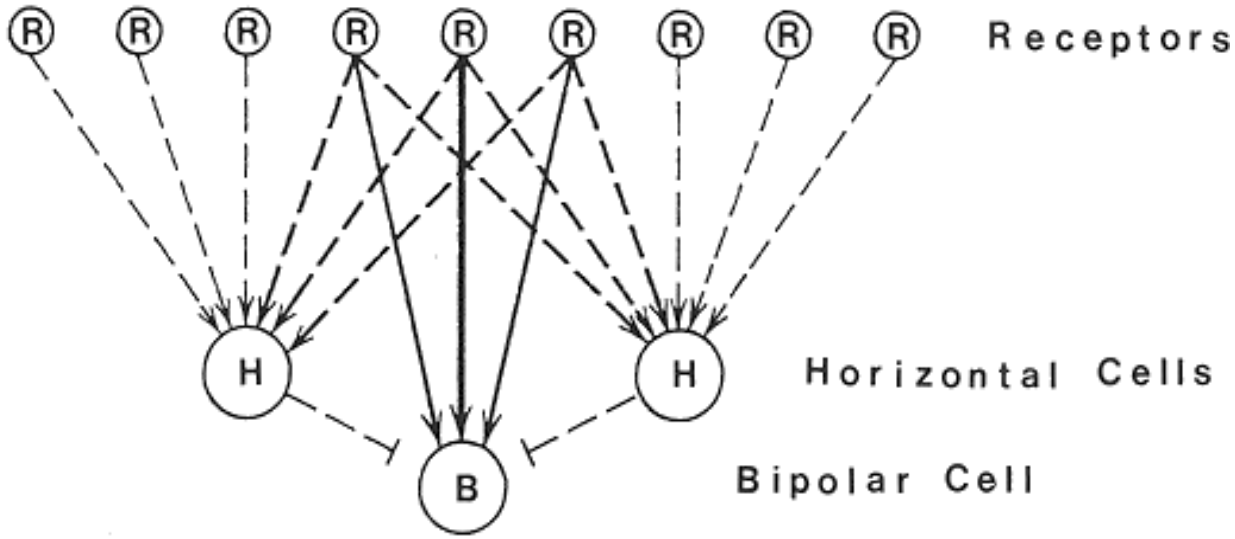
Convolution (Digital Signal Processing)



[*] https://towardsdatascience.com/applied-deep-learning-part-4-convolutional-neural-networks-584bc134c1e2

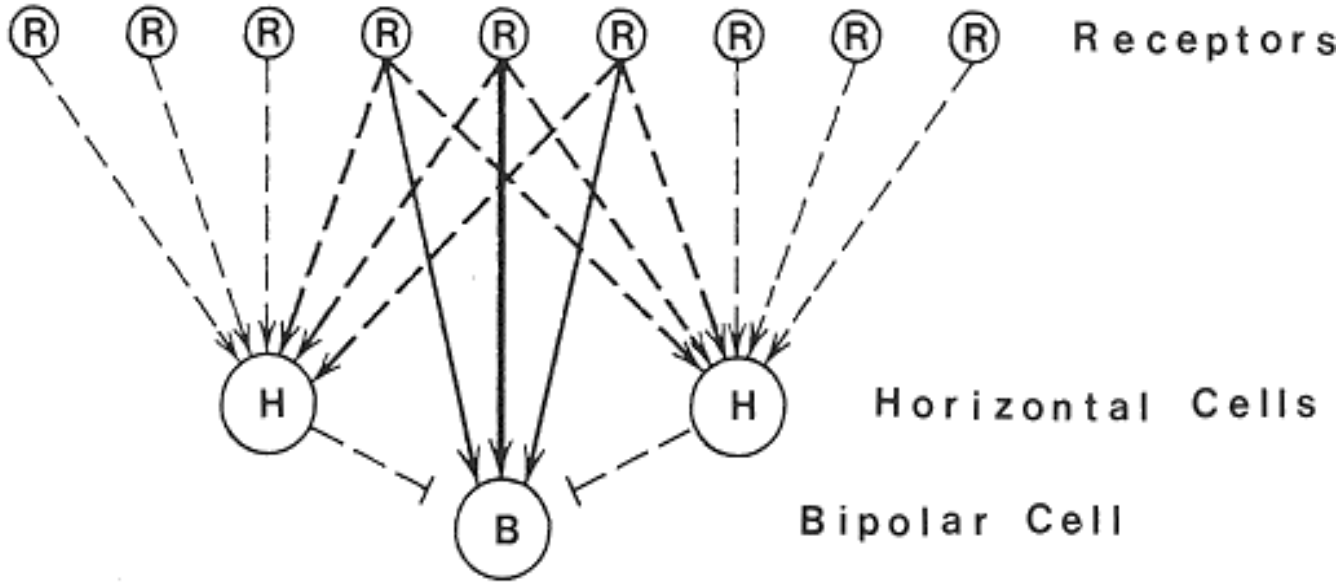
Retina Wiring

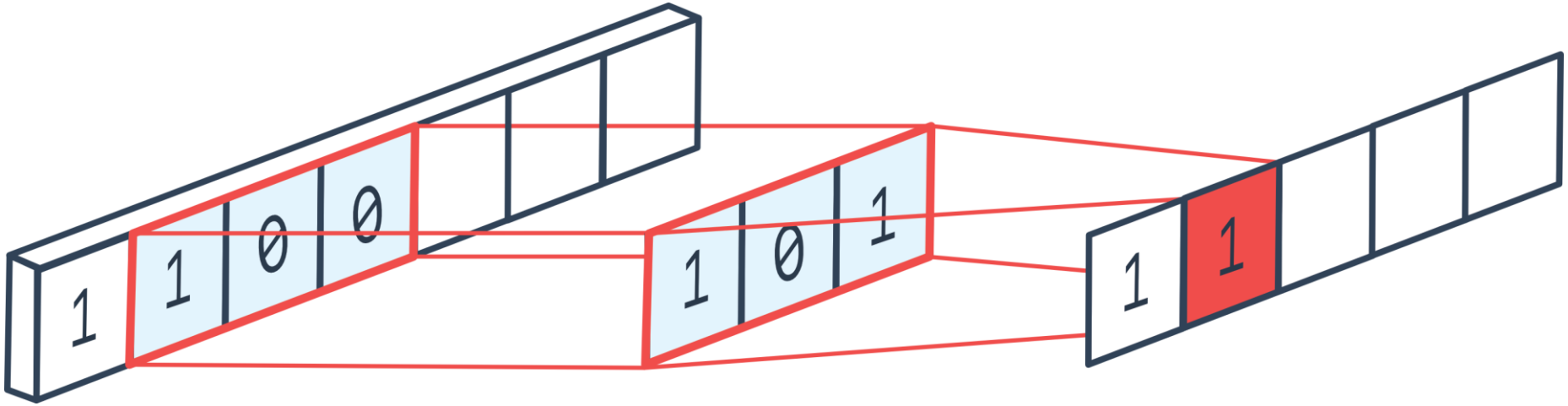




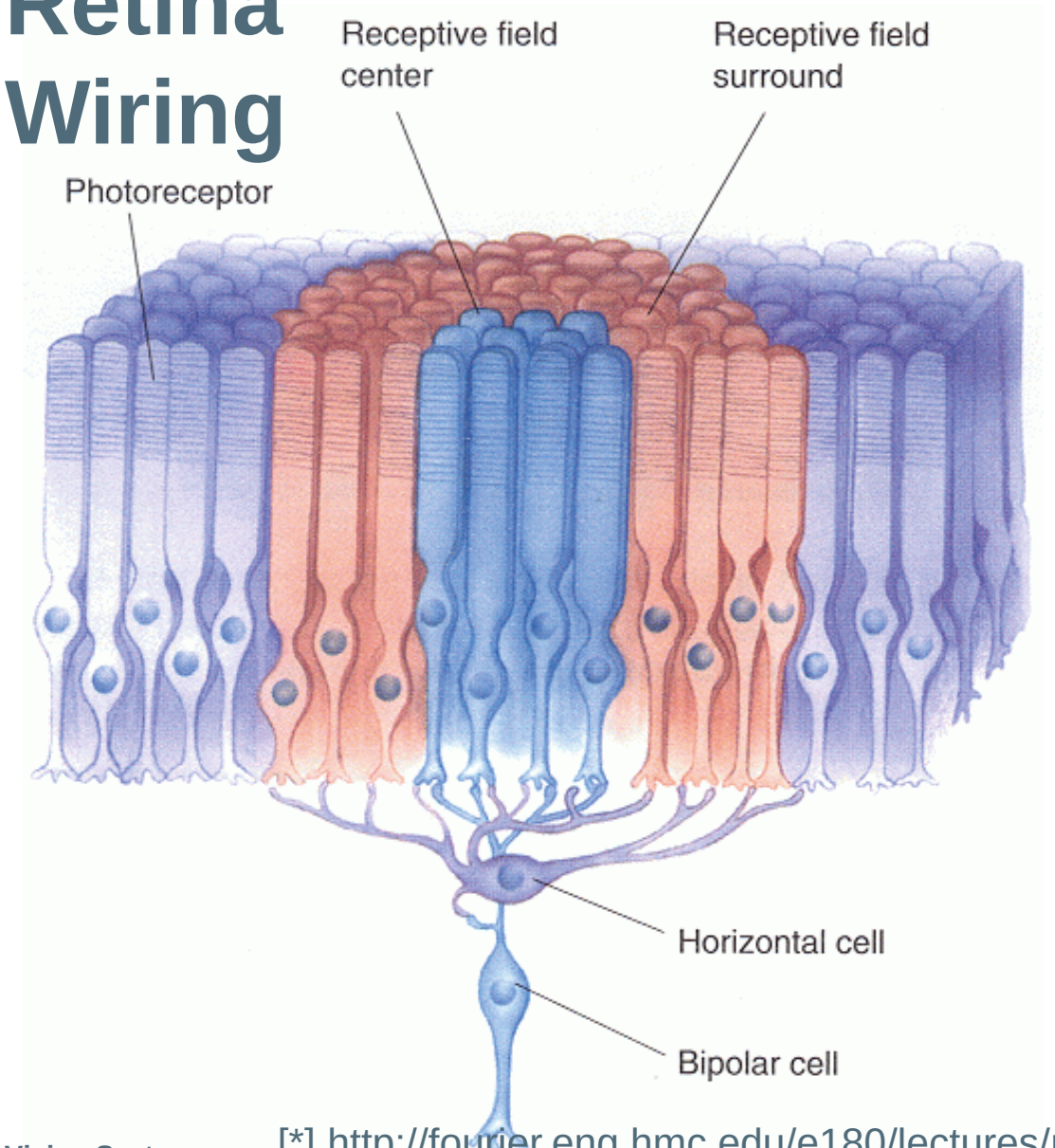
[*] http://fourier.eng.hmc.edu/e180/lectures/retina/node6.html

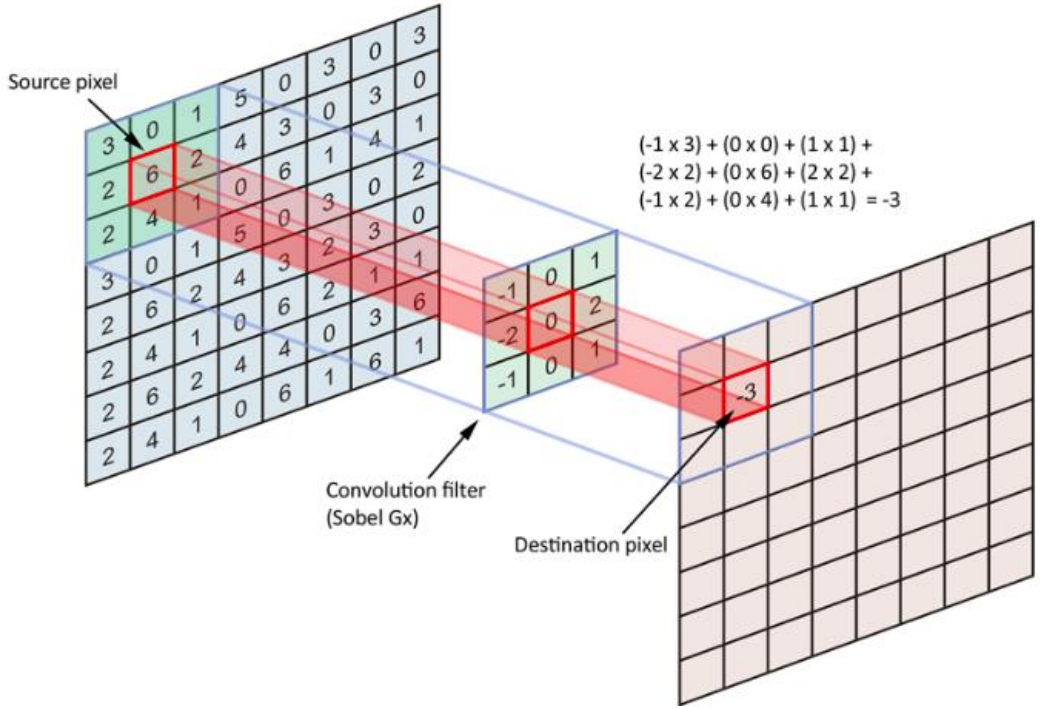
Retina Wiring





Retina Wiring





[*] http://fourier.eng.hmc.edu/e180/lectures/retina/node6.html
[*] https://towardsdatascience.com/applied-deep-learning-part-4-convolutional-neural-networks-584bc134c1e2

2D Receptive Field

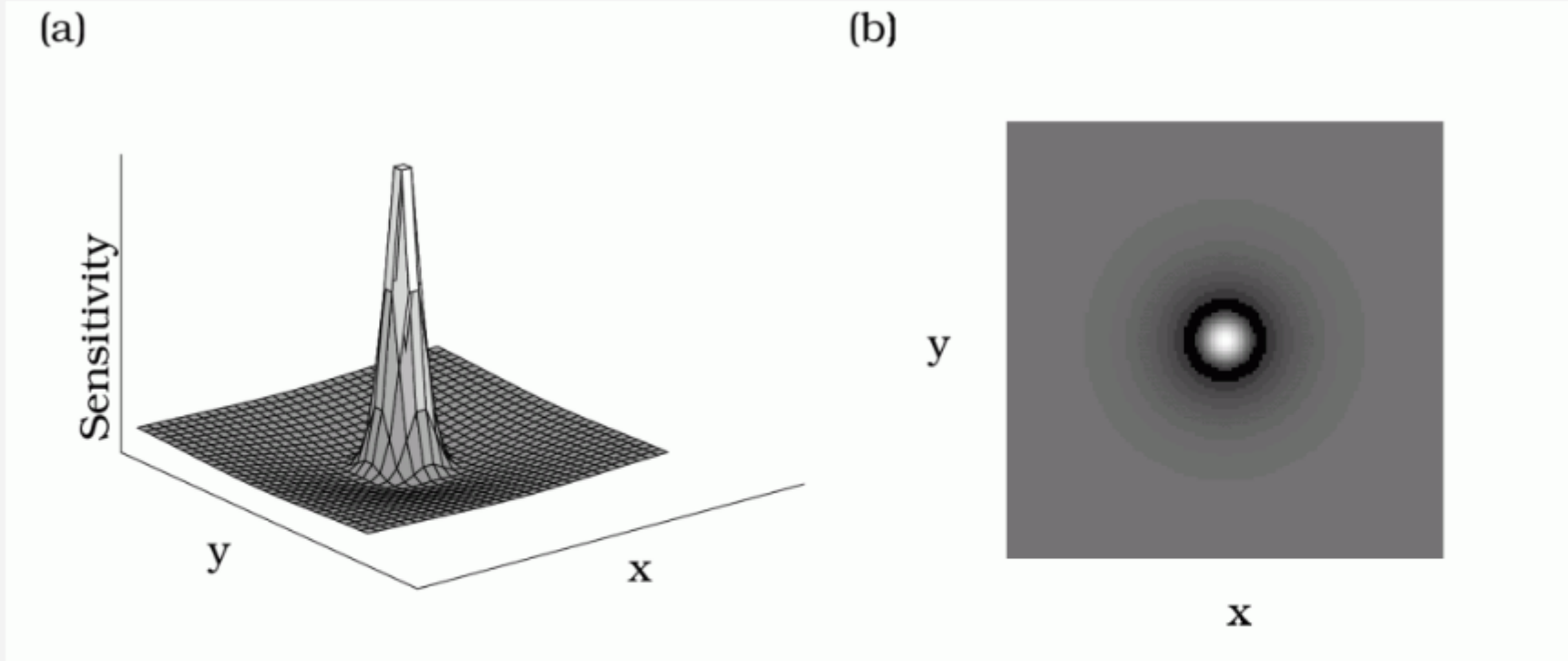
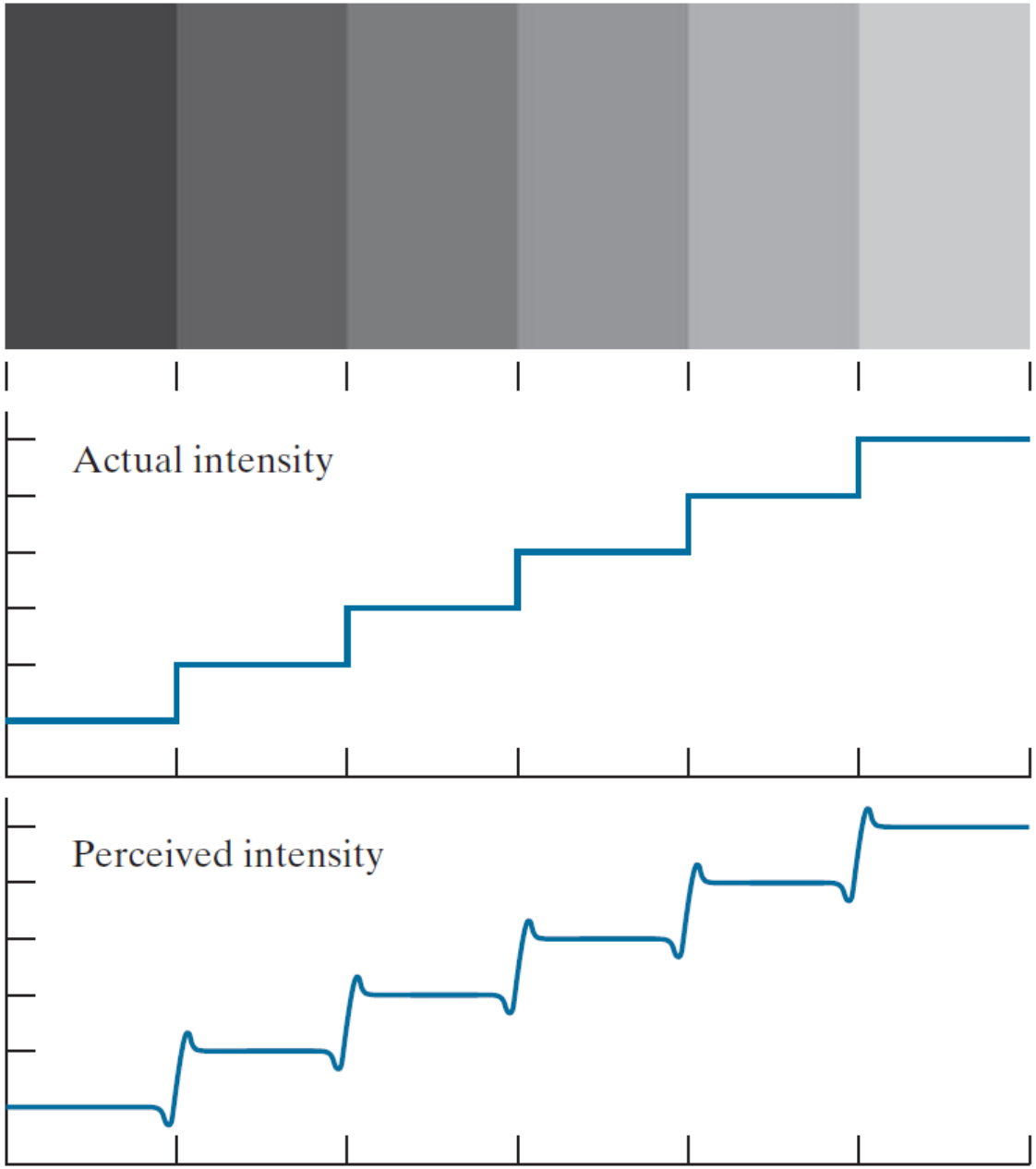


Figure 5.17: The two-dimensional steady-state receptive field} of an on-center off-surround retinal ganglion cell is represented in two different ways. (a) A surface plot shows the spatial sensitivity by the height of the surface. The inhibitory surround covers a large area compared to the center, but its general effect on the neuron's response is small compared to the center. (b) An image shows the spatial sensitivity of the receptive field by the image intensity. A light color denotes a retinal location where light excites the neuron, a dark color is a location where light inhibits the neuron, and gray locations are places where light has no influence on the neuron's response.

[*] https://foundationsofvision.stanford.edu/chapter-5-the-retinal-representation/

Mach Band Effect



[*] Gonzalez, R. C. Digital image processing 4th ed. 2018.

Contrast Sensitivity

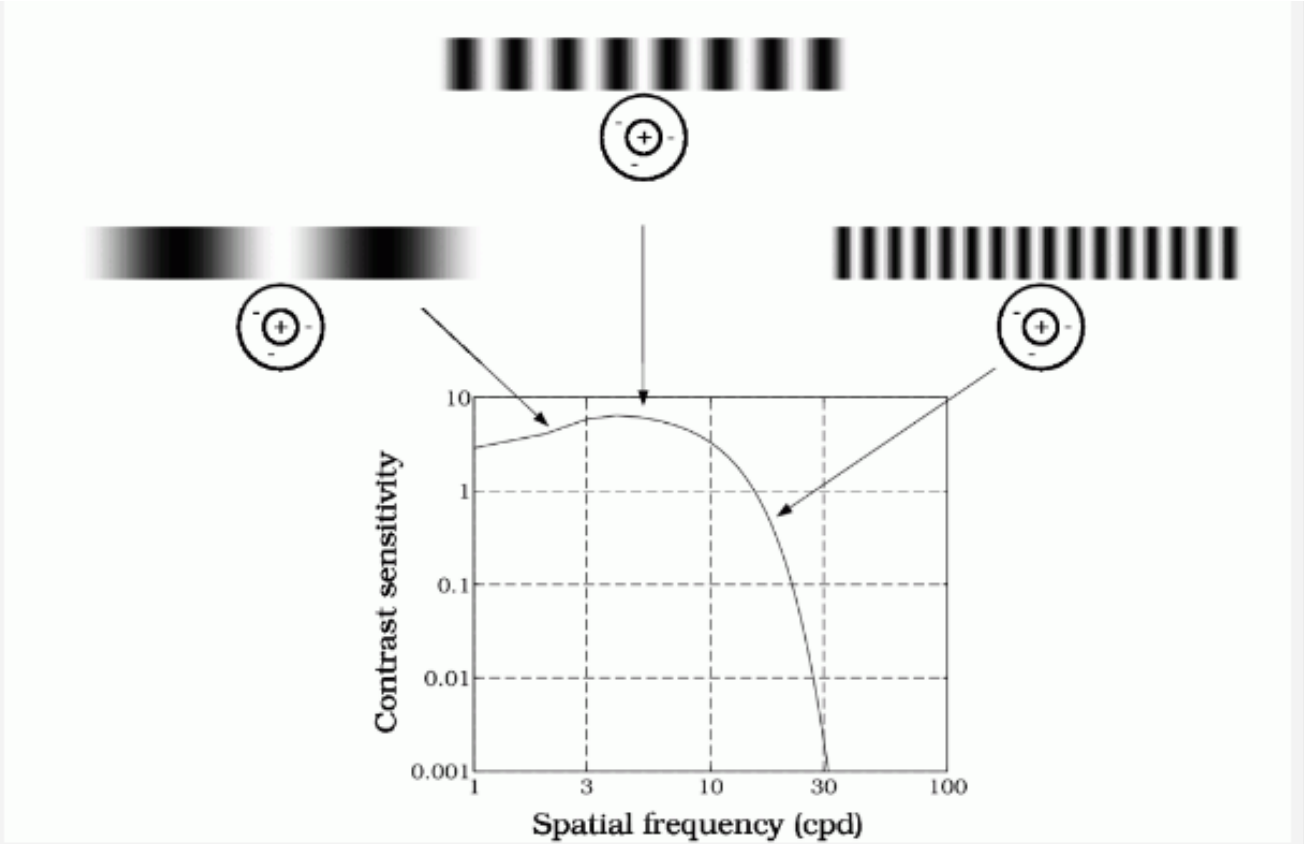
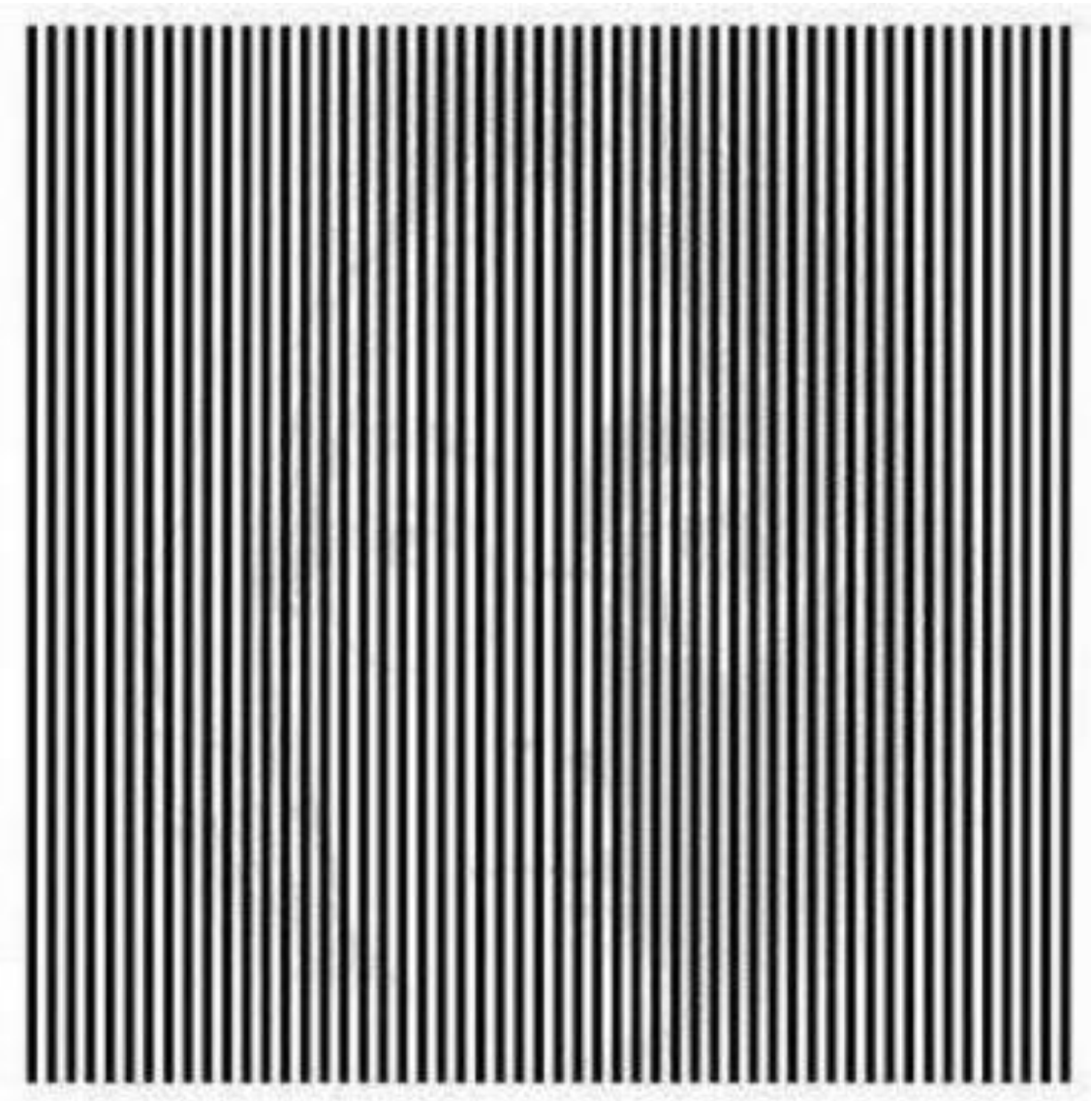


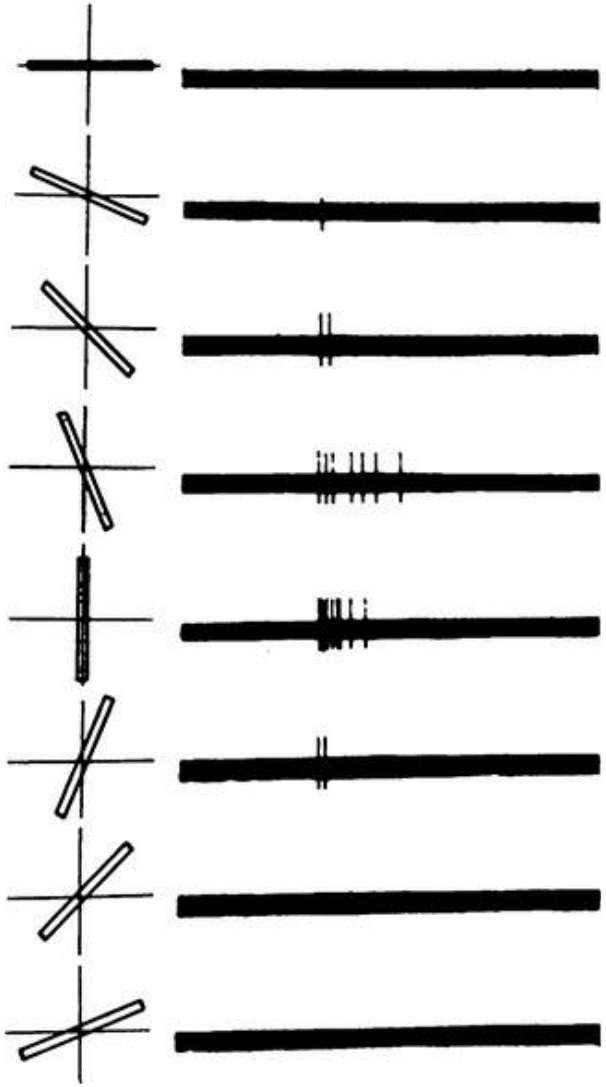
Figure 5.18: The contrast sensitivity function} describes a neuron's sensitivity to harmonic stimuli. In the example illustrated, a linear on-center neuron responds best to an intermediate spatial frequency whose bright bars fall over the on-center and whose dark barks fall over the opposing surround. When the spatial frequency is low, the signals from the center and surround oppose one another thus diminishing sensitivity. When the spatial frequency is high, the stimulus is averaged by the center again diminishing the response. From the response to harmonic stimuli, one can derive the spatial structure of the receptive field.

[*] https://foundationsofvision.stanford.edu/chapter-5-the-retinal-representation/

John Lennon Optical Illusion

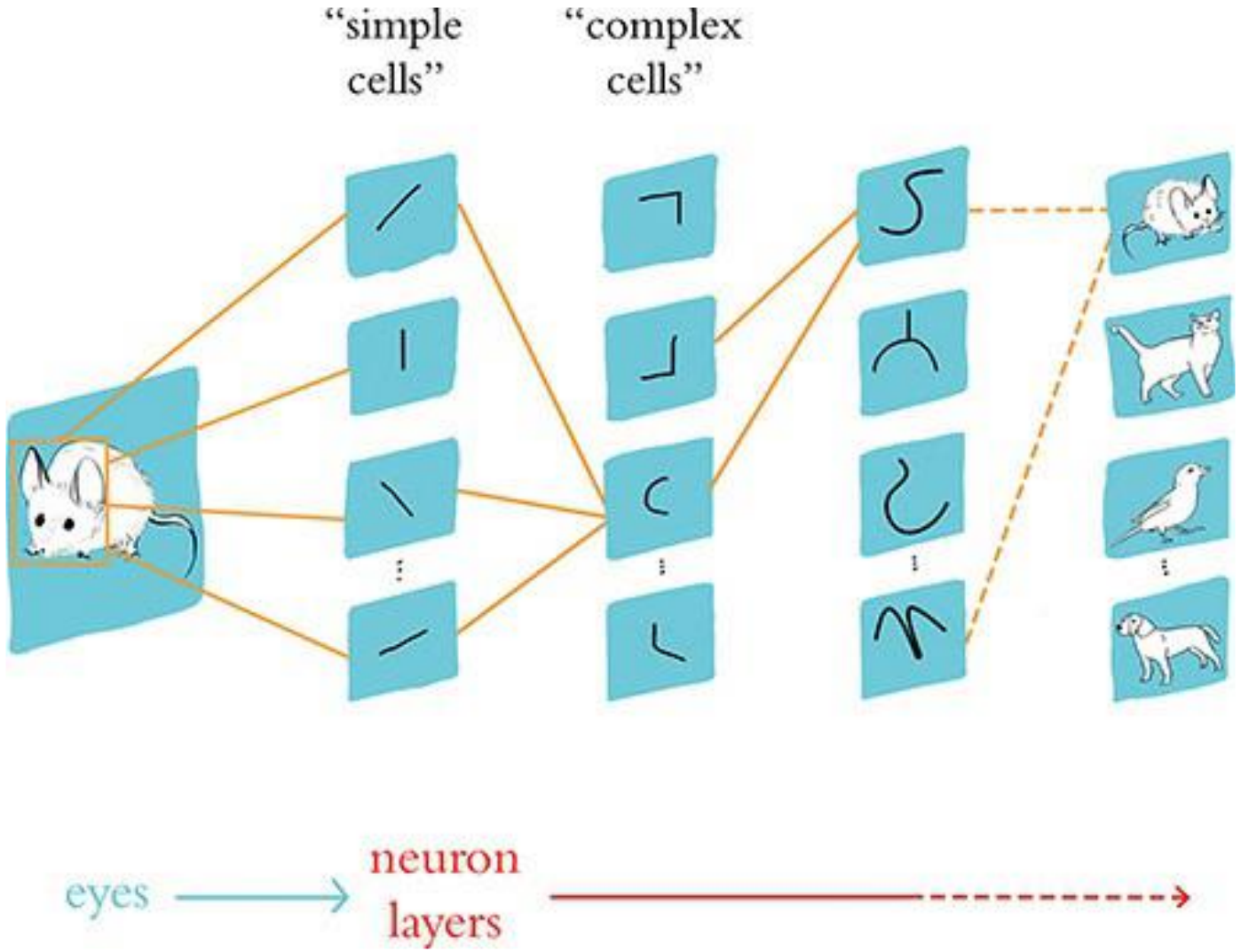


Response of the Simple Cell in V1



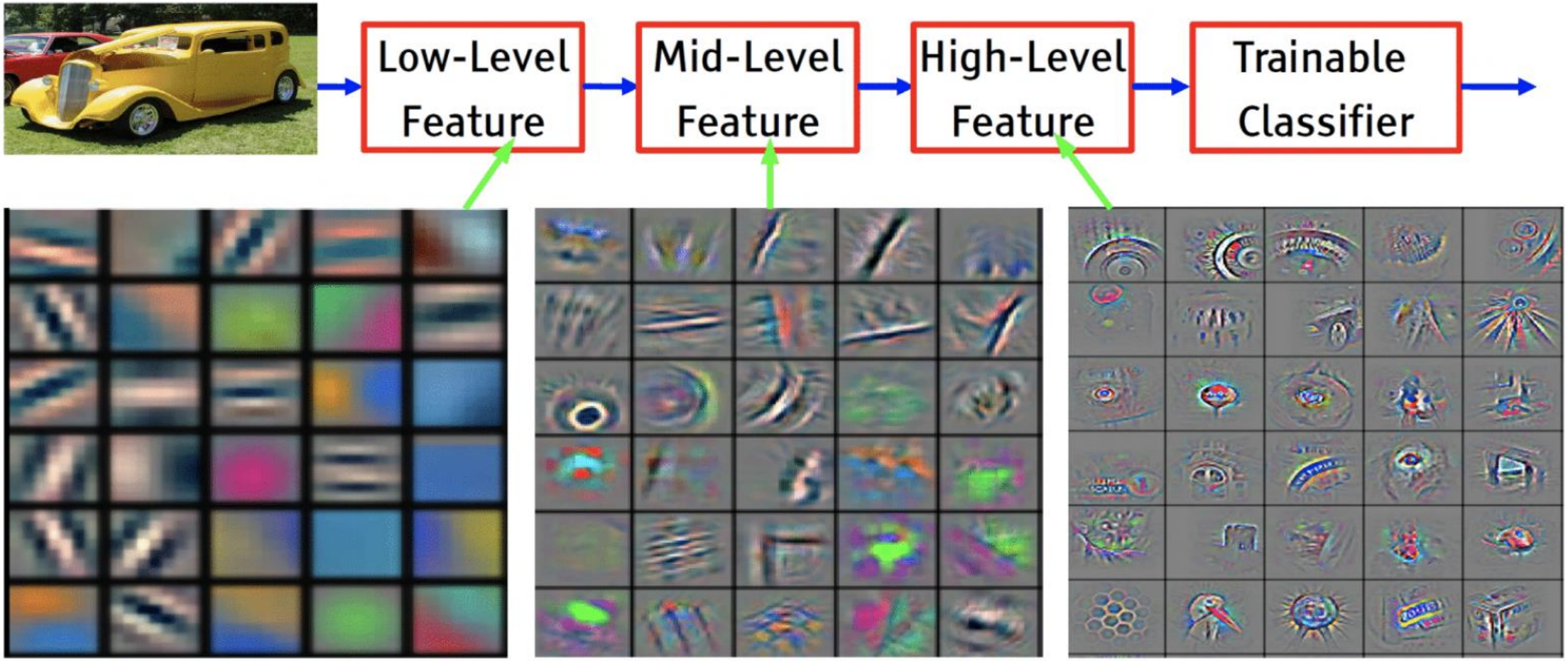
[*] Krohn, J., Beyleveld, G., & Bassens, A. Deep Learning Illustrated: A Visual, Interactive Guide to Artificial Intelligence. 2019

Visual Information Representation in the Brain



[*] Krohn, J., Beyleveld, G., & Bassens, A. Deep Learning Illustrated: A Visual, Interactive Guide to Artificial Intelligence. 2019

Hierarchy of Features in CNNs



[*] https://sailinglab.github.io/pgm-spring-2019/notes/lecture-16/

Decision Making

Apophenia is the tendency to perceive meaningful connections between unrelated things

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- **56 in QS Emerging Europe & Central Asia Rankings 2023**

FACTS AND FIGURES

- Established in **1956**
- **8 200** students
- **18%** of them are international students from over **80** countries
- **940** academic staff members
- **9:1** student / academic staff ratio
- **88 000** alumni
- Around **300** business partners
- **460** partner universities in **62** countries globally
- Member of **ATHENA** European University Alliance

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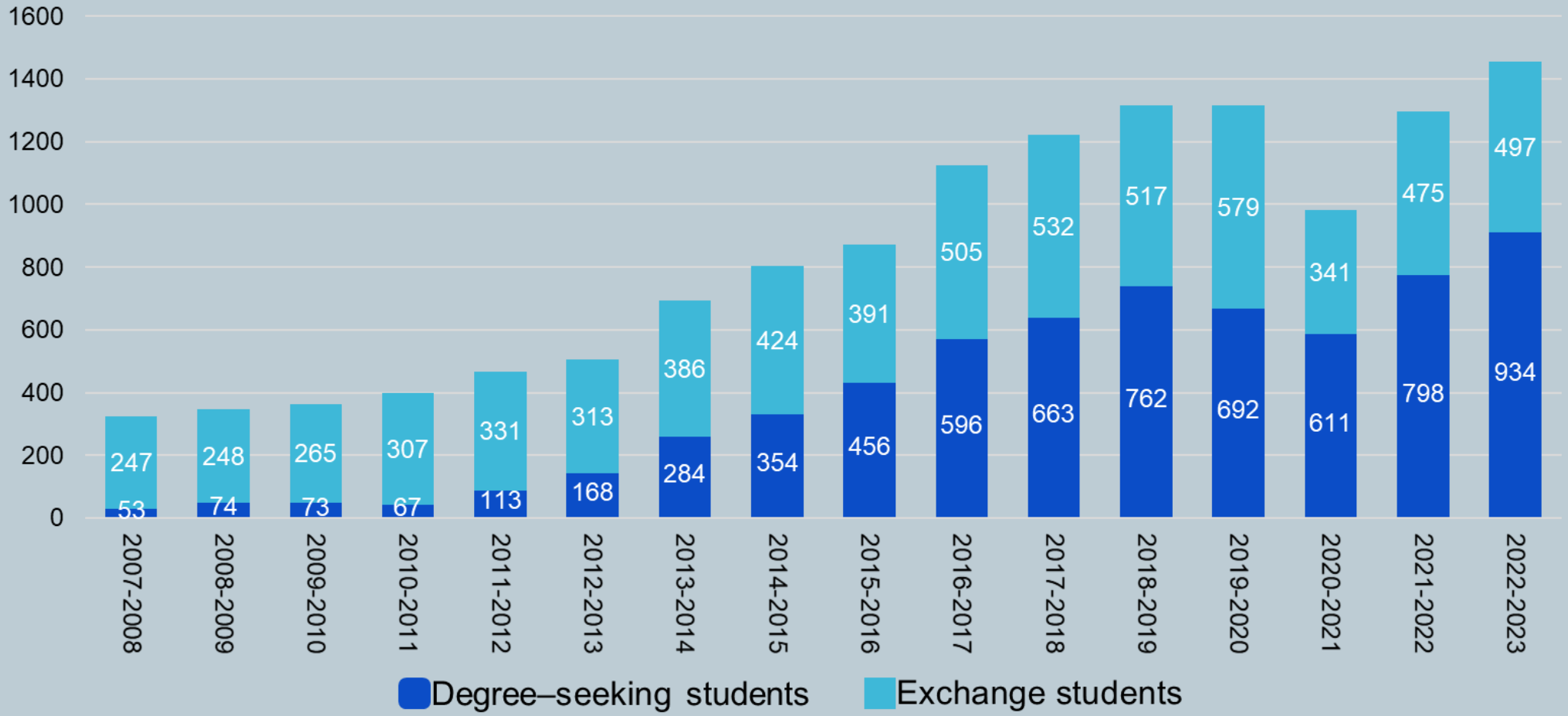
- Architecture
- Business Management
- Civil Engineering
- Creative Industries
- Electronics
- Environmental Engineering
- Fundamental Sciences
- Mechanics
- Transport Engineering

VILNIUS TECH INTERNATIONAL STUDENTS
(from 81 country in 2022–2023)



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