Computational Optical Imaging

Lecture 1a

Reality is a construct

Outline for today

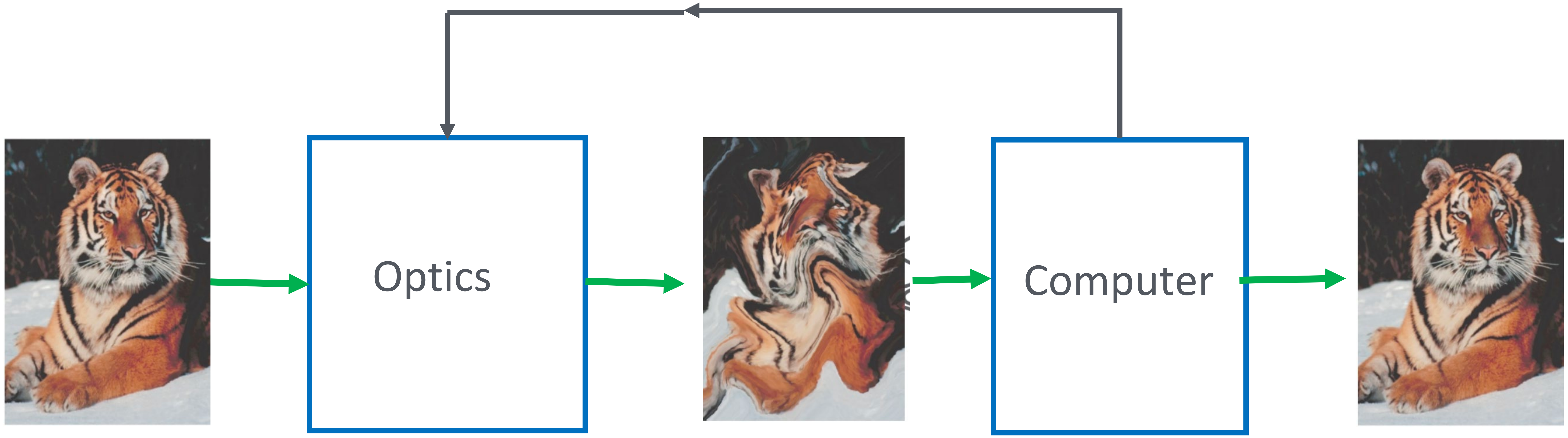
A few words about the course

The **best** example of computational imaging: Human visual system

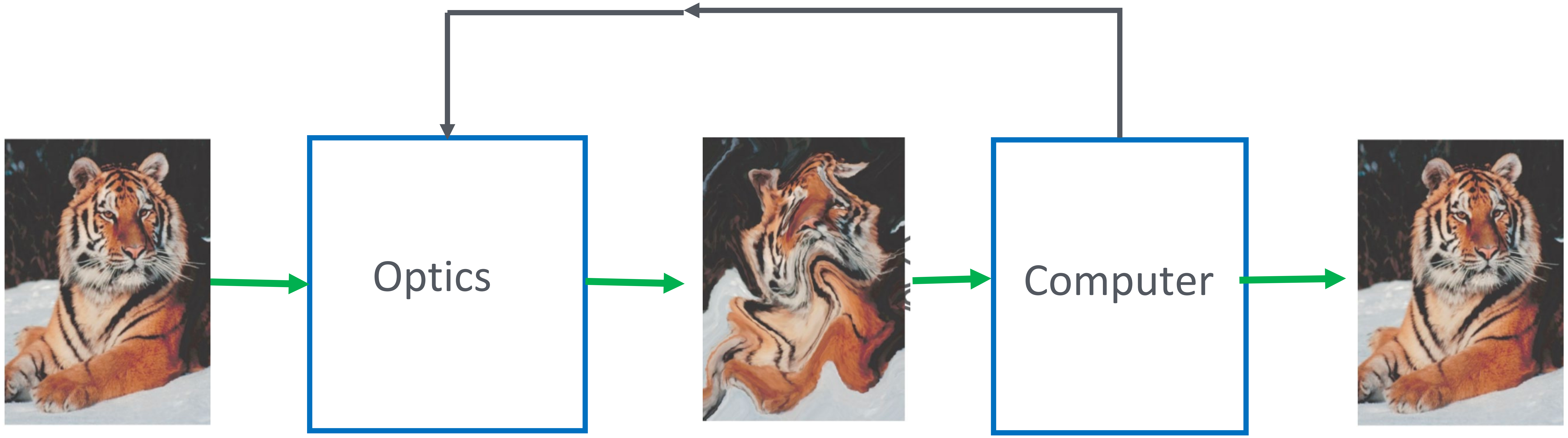
Computational Optical Imaging

A. Graded weekly exercise sessions (60% of the grade)
B. Final (40% of the grade)
C. No weekly homework
D. 4 hours per week, 13 weeks
    1. First hour (Friday 10:15 to 1100): Lecture introducing the topic
    2. Second hour (Friday 11:15 to 12:00) : Lecture and code on topic
    3. Third hour (Friday 12:15 to 13:00): In class exercise on topic
    4. Fourth hour (Wednesday 10:15 to 11:00): Graded exercise on topic (10 out of 13 will count)

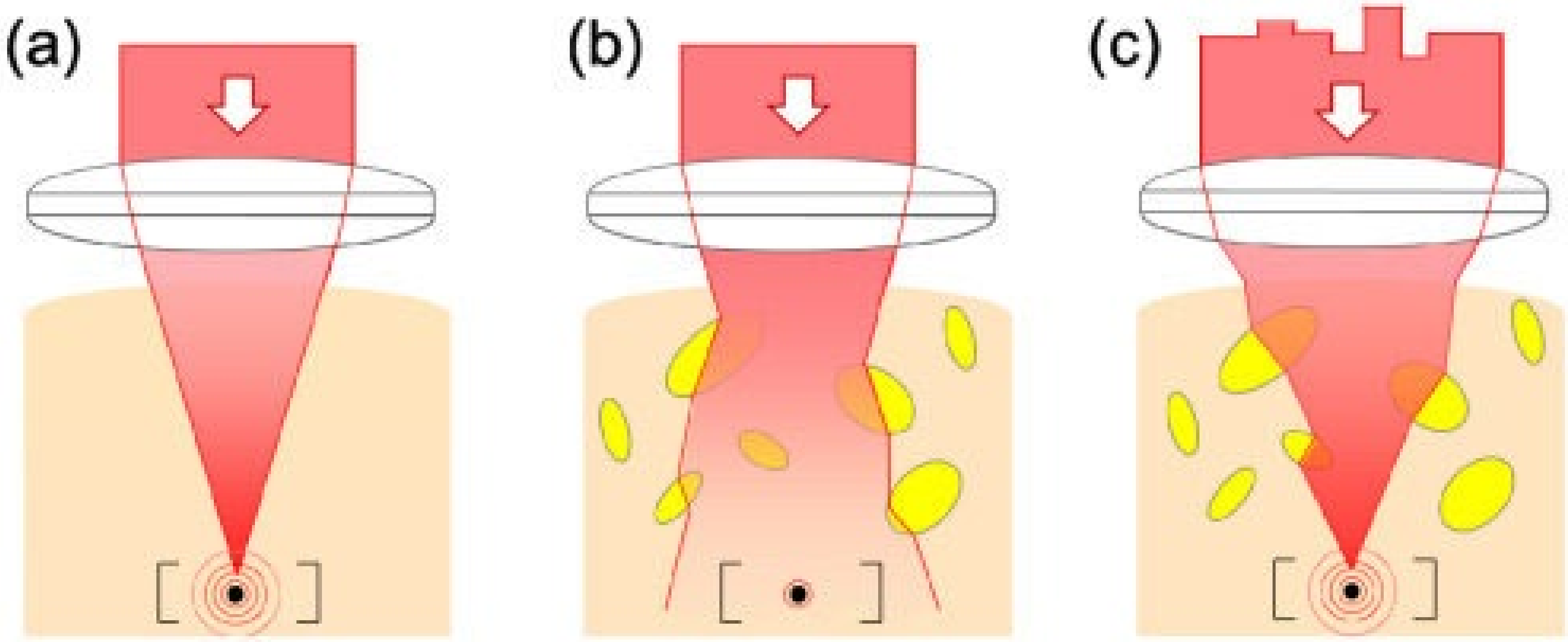
Computational Imaging



Computational Imaging



An Example: Focusing in scattering media



Early eyes

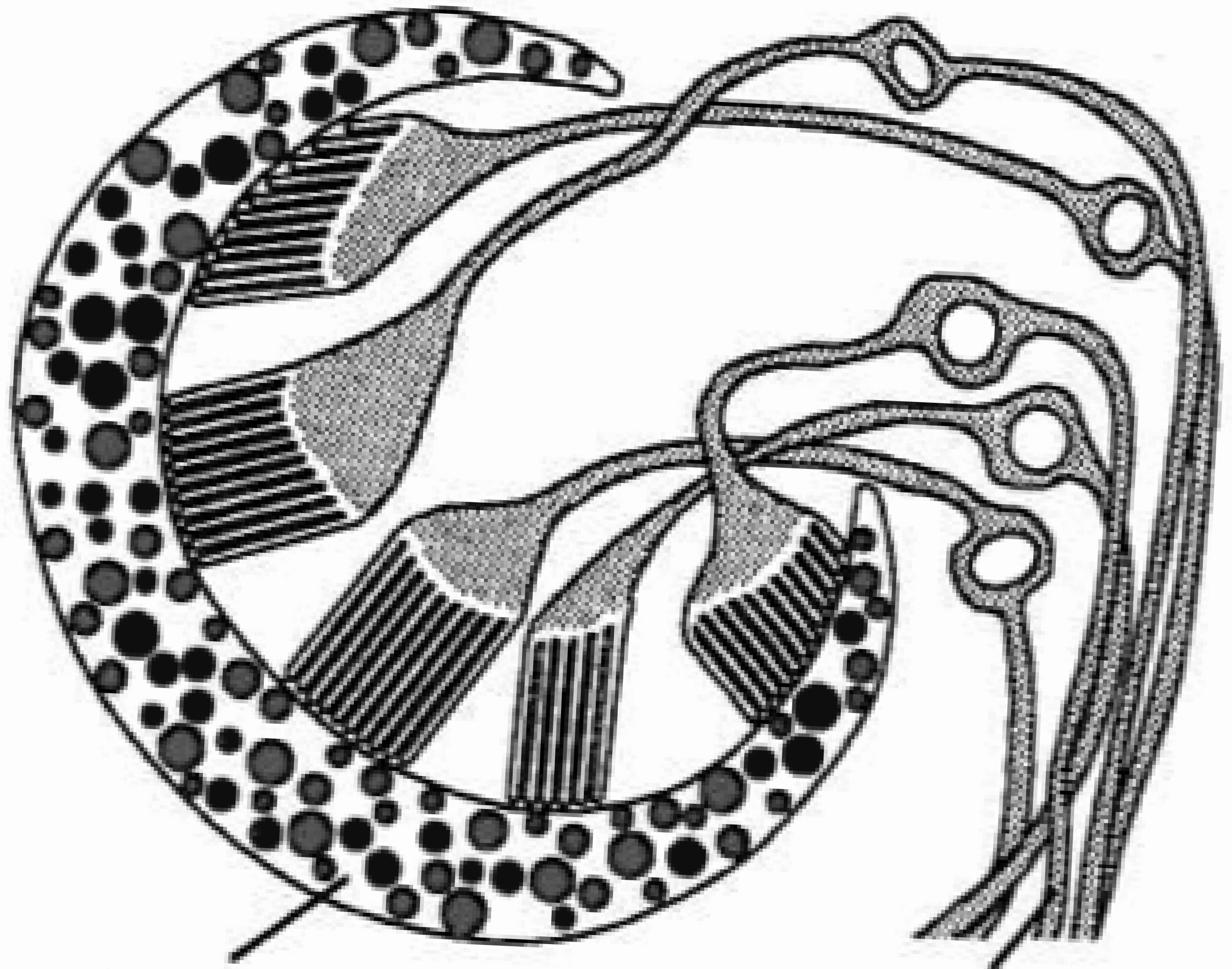


Fig. 1.3 Animals that are small and not very swift often make do with eyes of uncomplicated design. The eyes of turbellarian worms include many such examples. Here in the eye of *Bdellocephala brunnea* a small number of receptor cells share a pigment cup. The receptive segments (microvilli assembled into rhabdoms) occupy different positions in the pigment cup and thus receive light from different directions. This allows the animal to simultaneously discriminate between the brightness of different parts of a very crude image. Even though the amount of pictorial (spatial) information is minuscule compared to that of a human eye, the flatworm eye is clearly an organ capable of spatial vision. In terms of function there is only a gradual difference between the eyes of flatworms and humans. Redrawn from Kuchiiwa et al. (1991).

Eary eyes

Fig. 1.8 A group (a) of pigment-pit eyes from the clam, *Anadara notabilis*, illustrate the point of evolutionary branching of compound and single-chambered eyes. A section through two of the pit eyes (b) reveals a simple organization. Some of the epithelial cells in the pit are filled with screening pigment and others are receptors with microvillar plumes projecting into the cavity of the pit. The fact that there are many such eyes grouped together and that the pits are deep and narrow indicate that further evolution towards improved spatial vision would in this case lead to a compound eye. The closely-related ark clams do indeed have proper compound eyes. From Nilsson (1994).

Single chamber and compound eyes

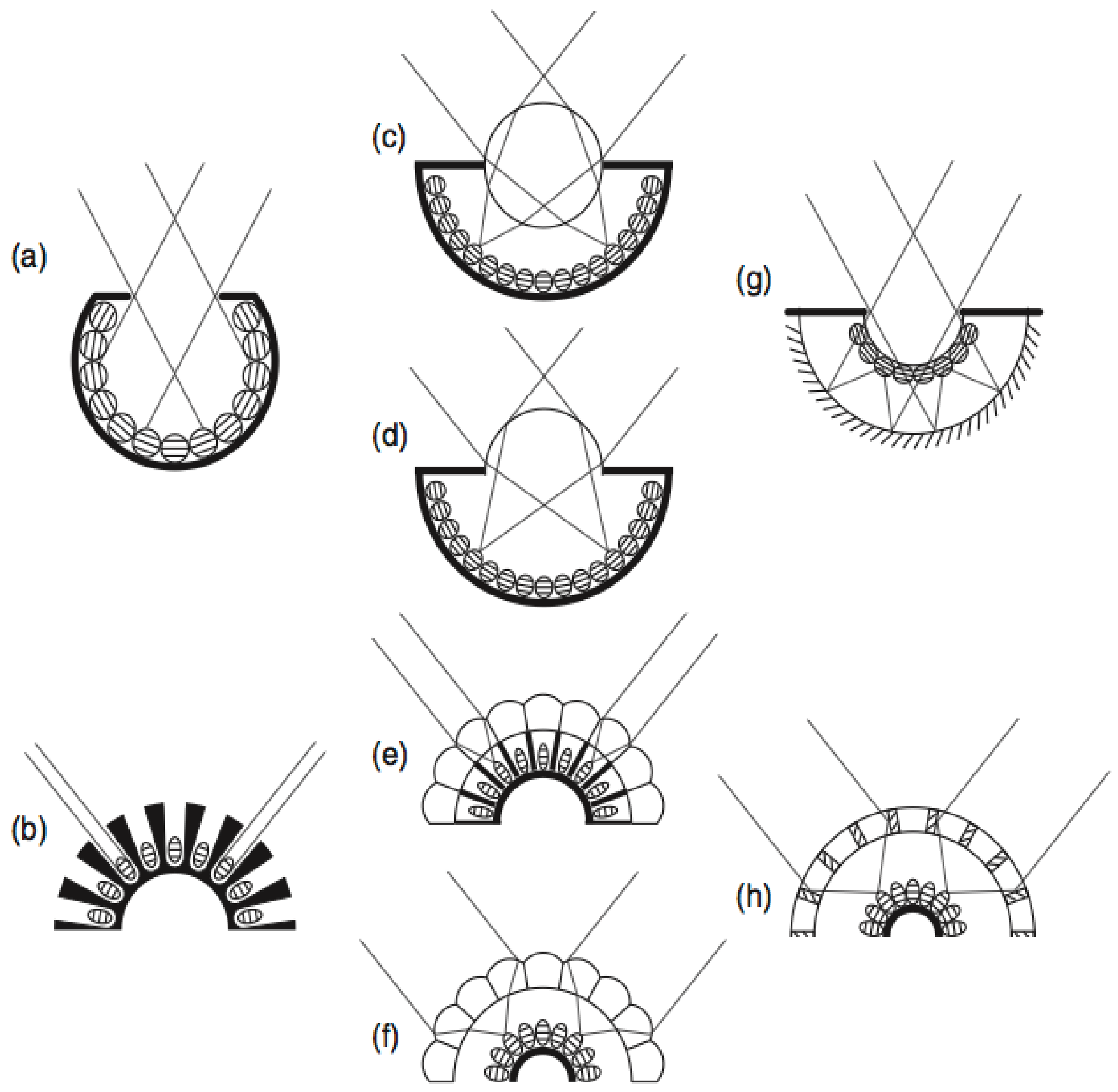


Fig. 1.7 Diagram of the evolutionary relationships of major animal groups. For clarity, a number of minor phyla have been excluded. Grey fields indicate branches that have at least ocelli with directional photoreception. Photoreceptors with associated screening pigment are thus not present in Placozoa, Ctenophora (comb jellies), or Porifera (sponges). Sophisticated visual systems with multi-purpose eyes (filled circles) have evolved in four groups only: spiders, insects/crustaceans, cephalopods, and vertebrates (Land and Nilsson 2006). Interestingly, there is at least one of these groups in each of the three major branches of bilaterian animals. The presence of imaging eyes, and their main optical types are indicated by letters a–h, which refer to the schematic diagrams below (a–h), modified from Land (1981a). Intermediates between (a) and (c) are indicated by a+ in the phylogenetic tree. The schematic diagrams of eye types are arranged in three columns, after the mechanisms used to form images: shadow (a, b), refracting devices (c–f), and reflectors (g, h). The upper four eyes are single-chambered eyes, and the lower four are compound eyes. The receptor cells are represented by striped ovals. The eye types are: (a) pigment cup eye, (b) compound pigment pit eye, (c) aquatic camera-type eye, (d) terrestrial camera-type eye, (e) apposition compound eye, (f) refracting superposition compound eye, (g) concave-mirror eye, (h) reflecting superposition compound eye. The different eye types and their function are explained in detail in Chapters 4–8. Because single-chambered and compound eyes are fundamentally different solutions to spatial vision, the distribution of eyes suggests that Urbilateria possessed pigmented photoreceptor cells, but no imaging eyes. Molecular similarities between cnidarian and bilaterian eyes suggest that non-directional photoreceptors predated Urbilateria. Note that many of the eyes indicated in the phylogenetic tree are extracephalic, and clearly not homologous to paired cephalic eyes. Molecular and embryological cues also suggest that vertebrate eyes have a complex evolutionary history, distinct from that of cephalic eyes in other bilaterians.

The human eye

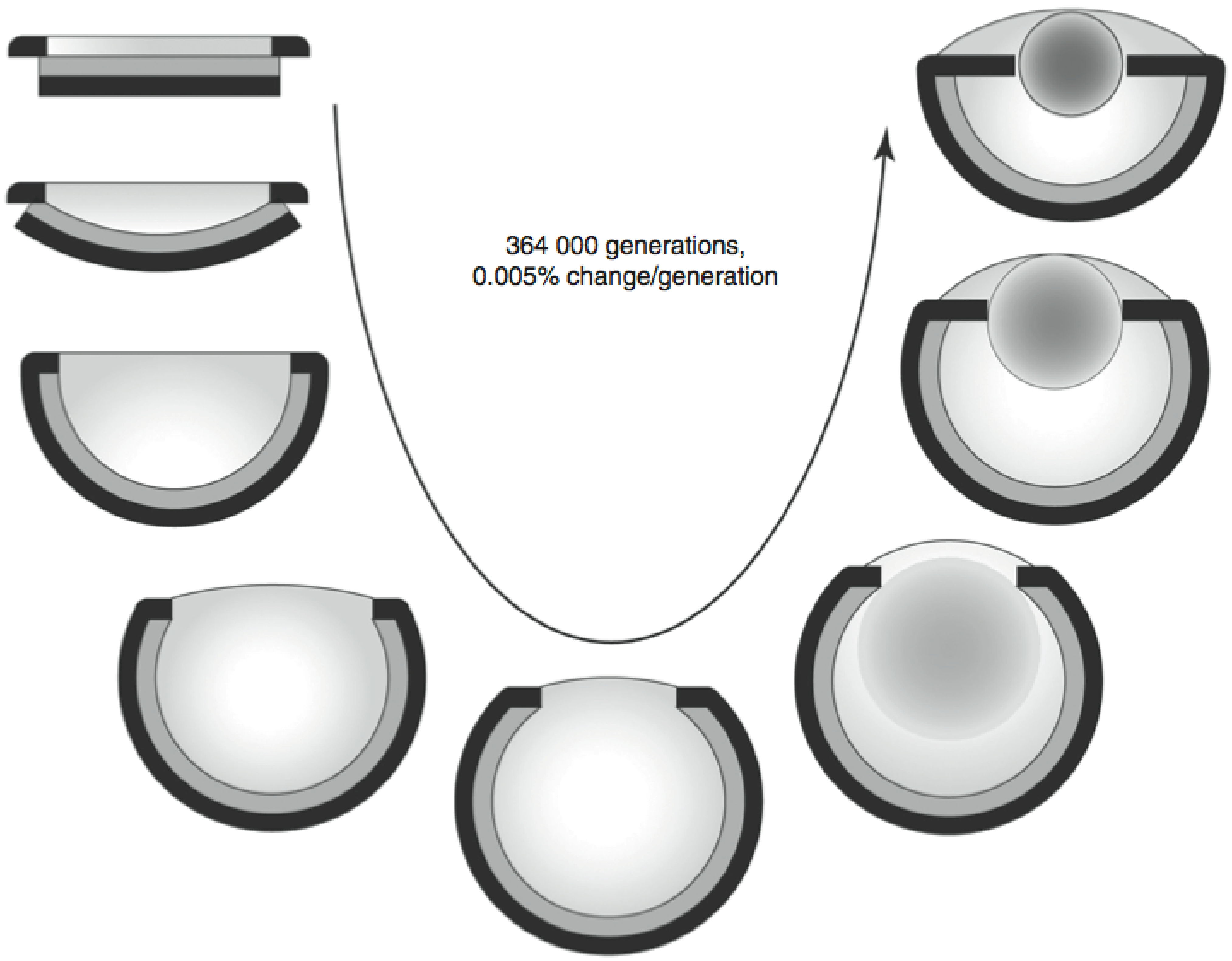
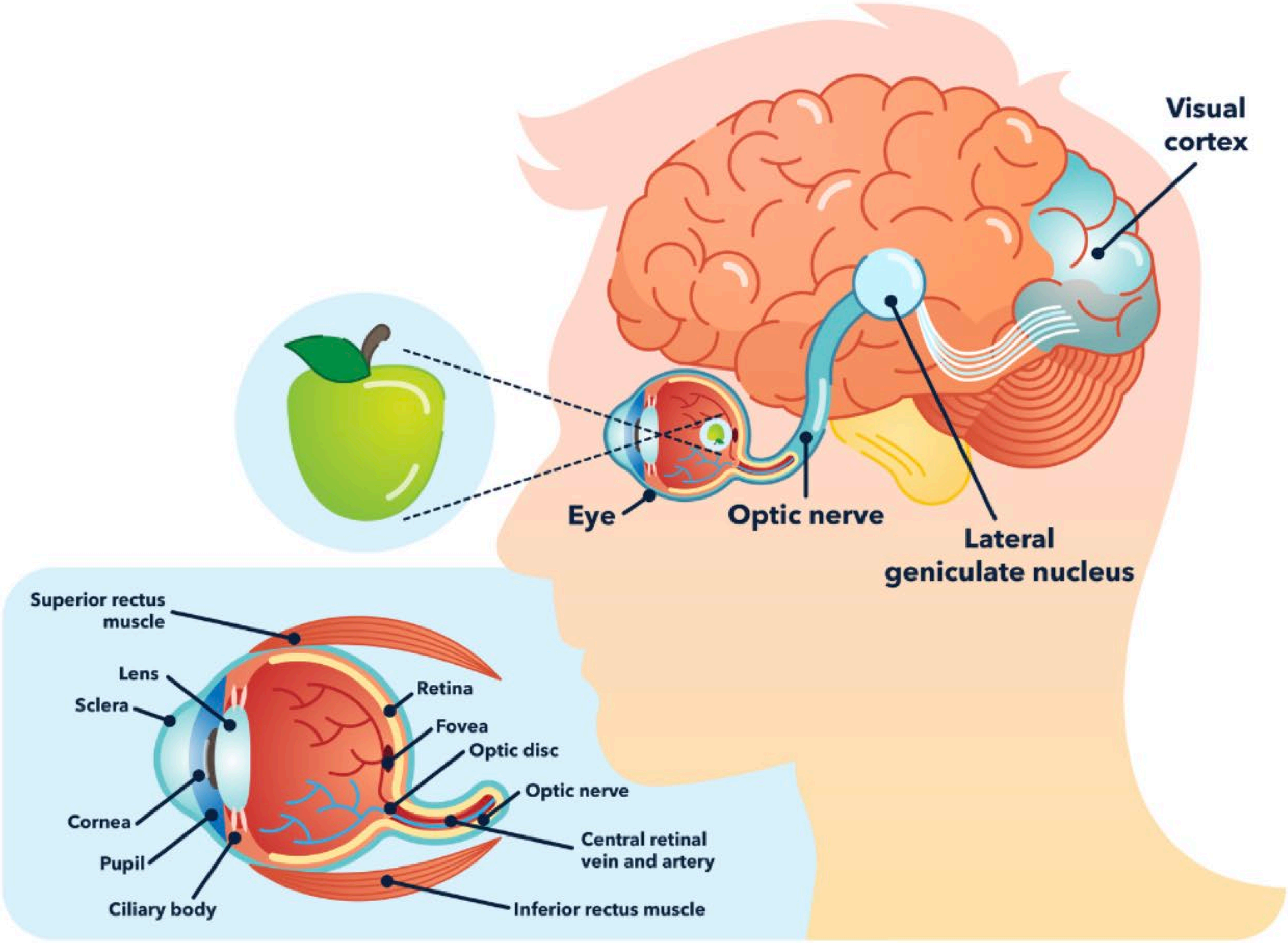
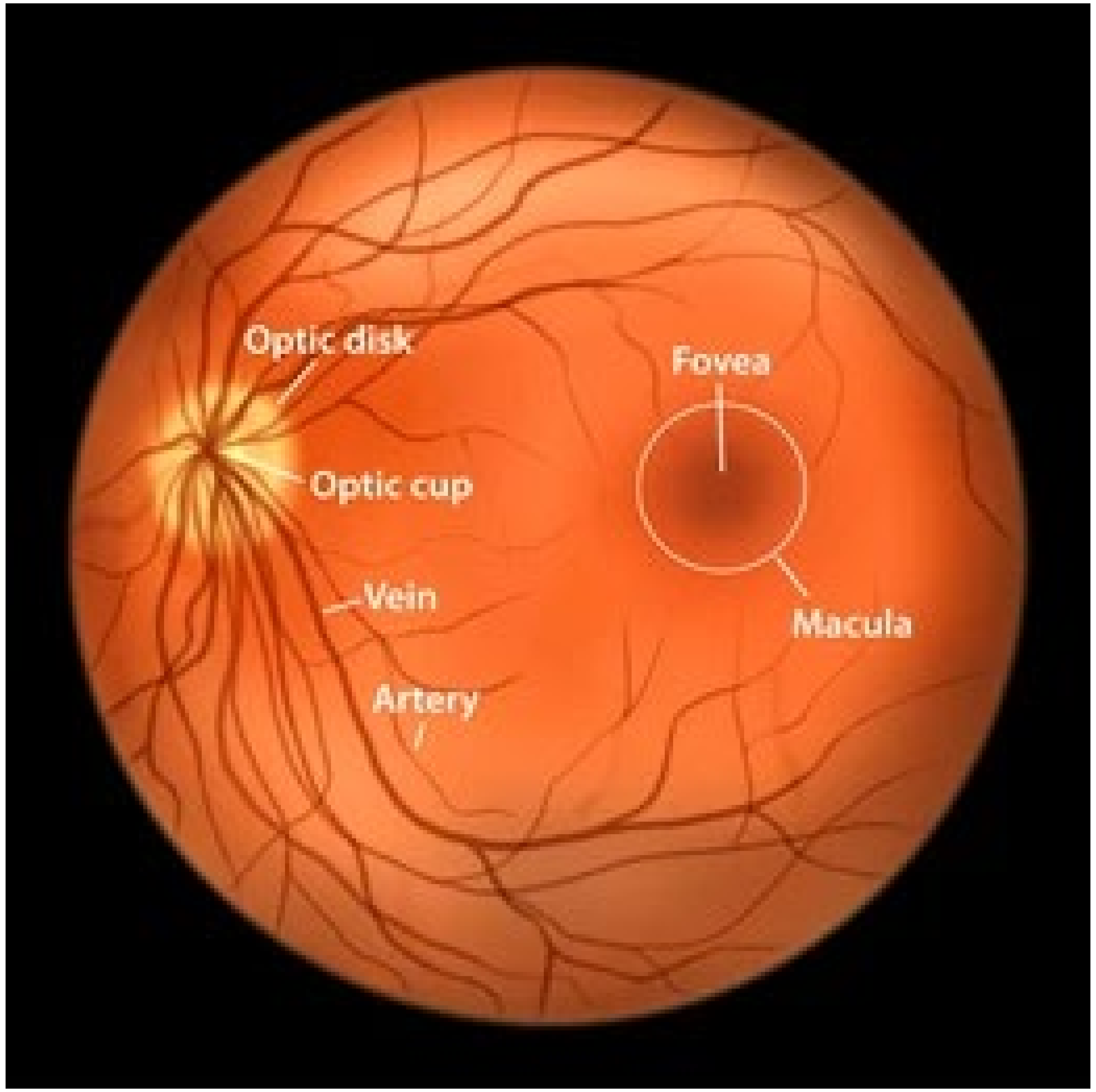
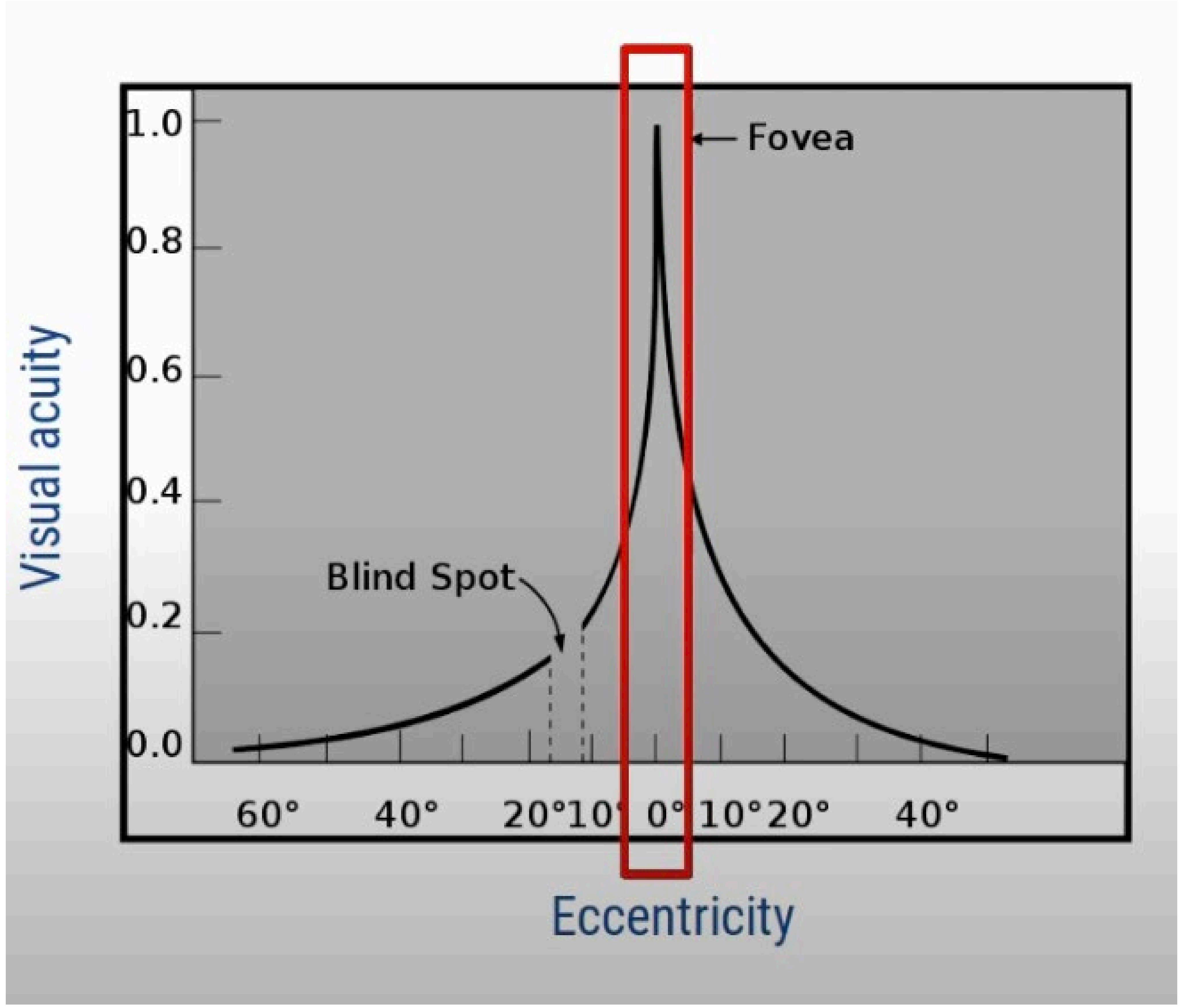


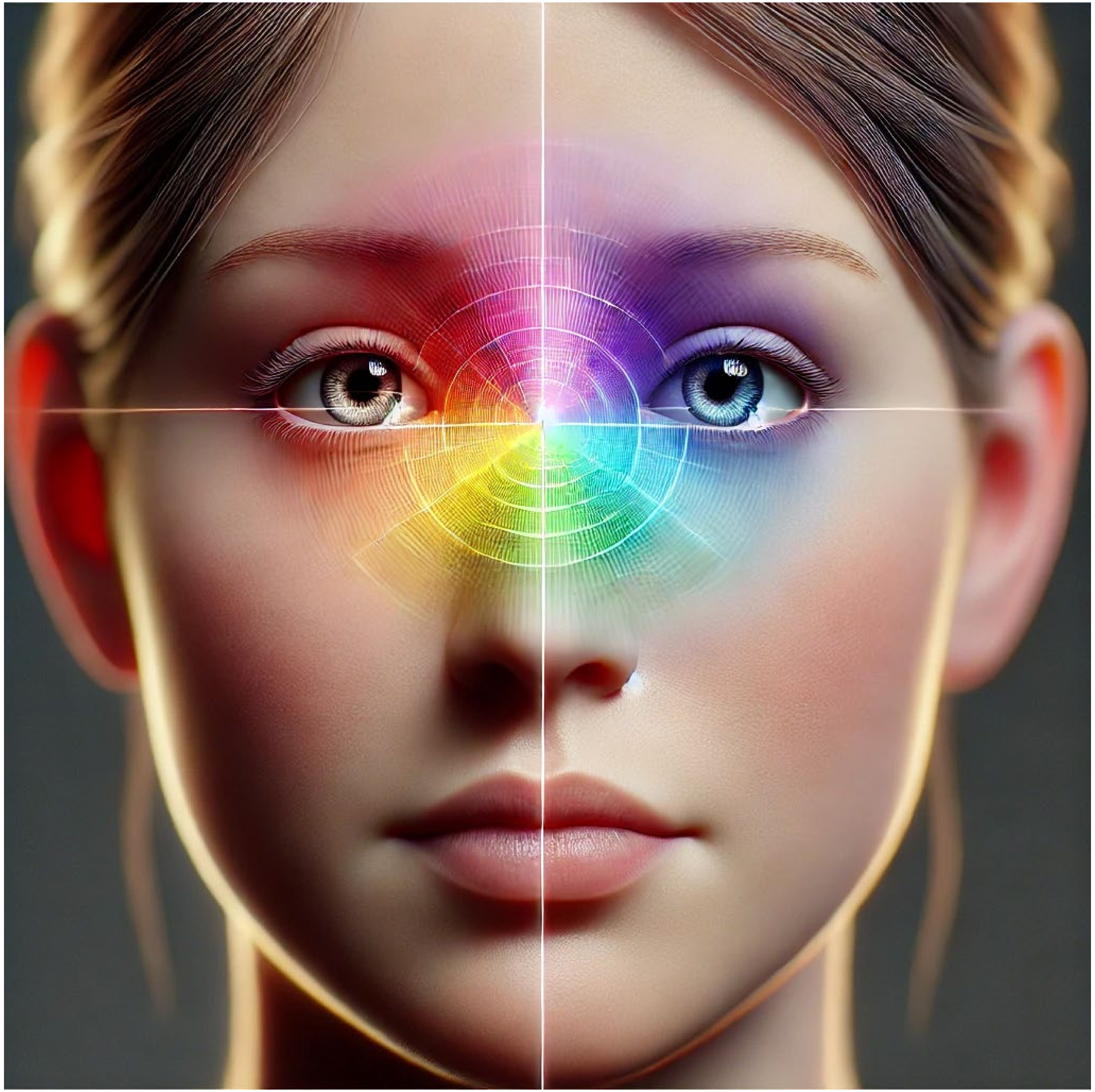
Fig. 1.6 A patch of light-sensitive epithelium can be gradually turned into a perfectly focused camera-type eye if there is a continuous selection for improved spatial resolution. A theoretical model based on conservative assumptions about selection pressure and the amount of variation in natural populations suggest that the whole sequence can be accomplished amazingly fast, in less than 400 000 generations. The number of generations between each of the consecutive intermediates is indicated in the figure. The starting point is a flat piece of epithelium with an outer protective layer, an intermediate layer of receptor cells, and a bottom layer of pigment cells. The first half of the sequence is the formation of a pigment cup eye. When this principle cannot be improved any further, a lens gradually evolves. Modified from Nilsson and Pelger (1994).


Visual cortex
Eye
Optic nerve
Lateral geniculate nucleus
Superior rectus muscle
Lens
Sclera
Retina
Fovea
Optic disc
Optic nerve
Cornea
Pupil
Ciliary body
Central retinal vein and artery
Inferior rectus muscle

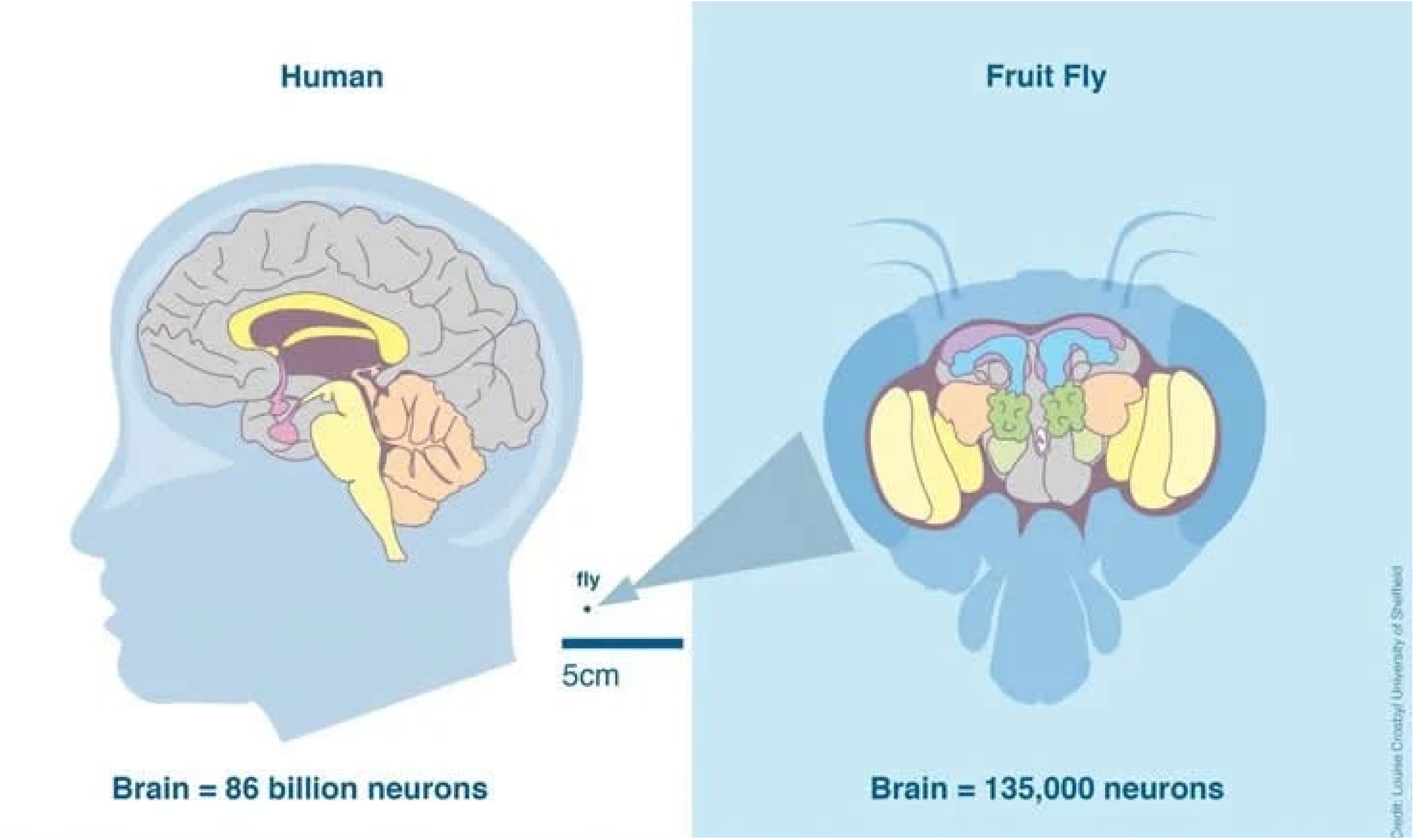

Optic disk
Optic cup
Vein
Artery
Fovea
Macula



https://www.youtube.com/watch?v=00eRYdljesQ

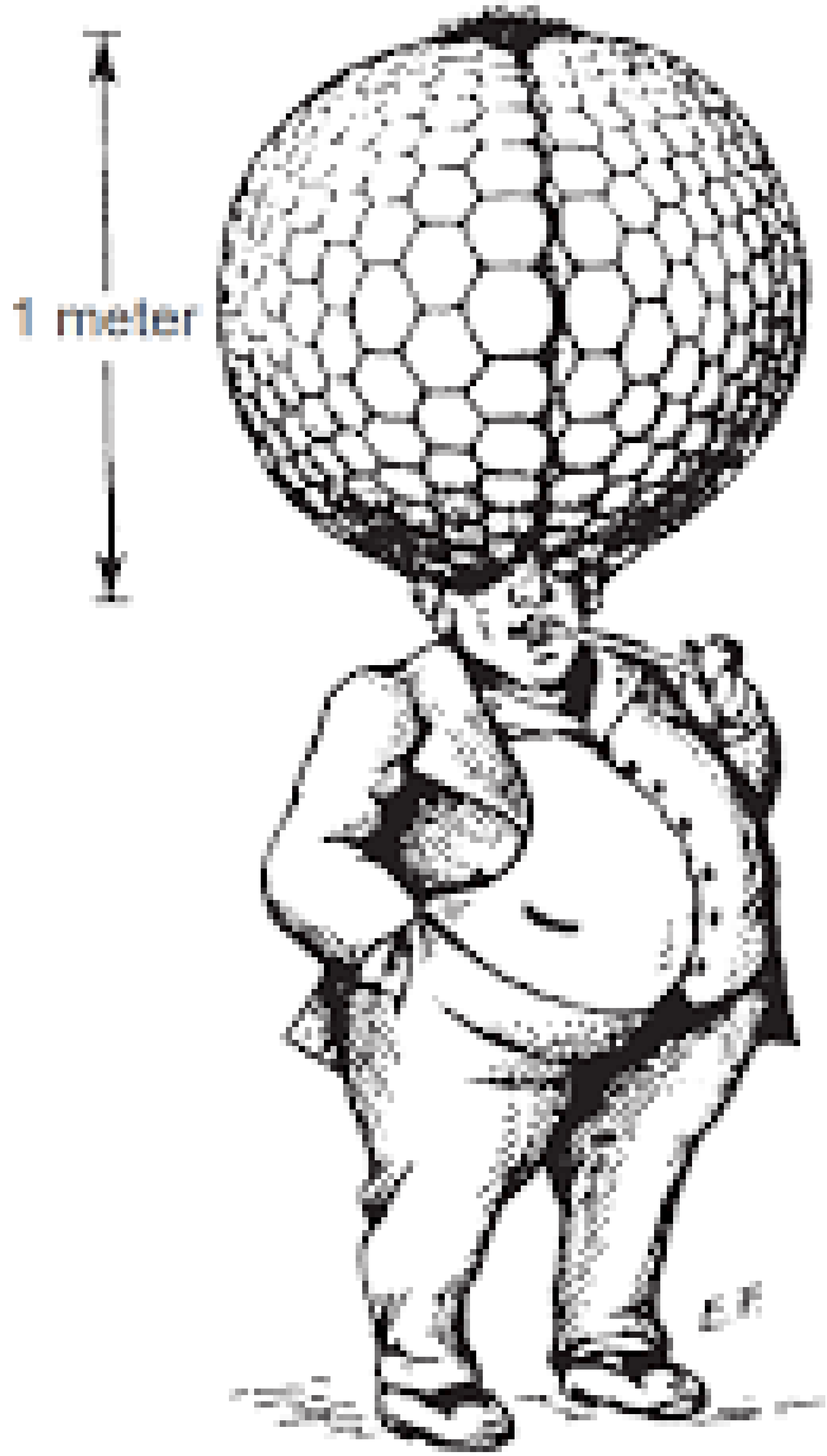


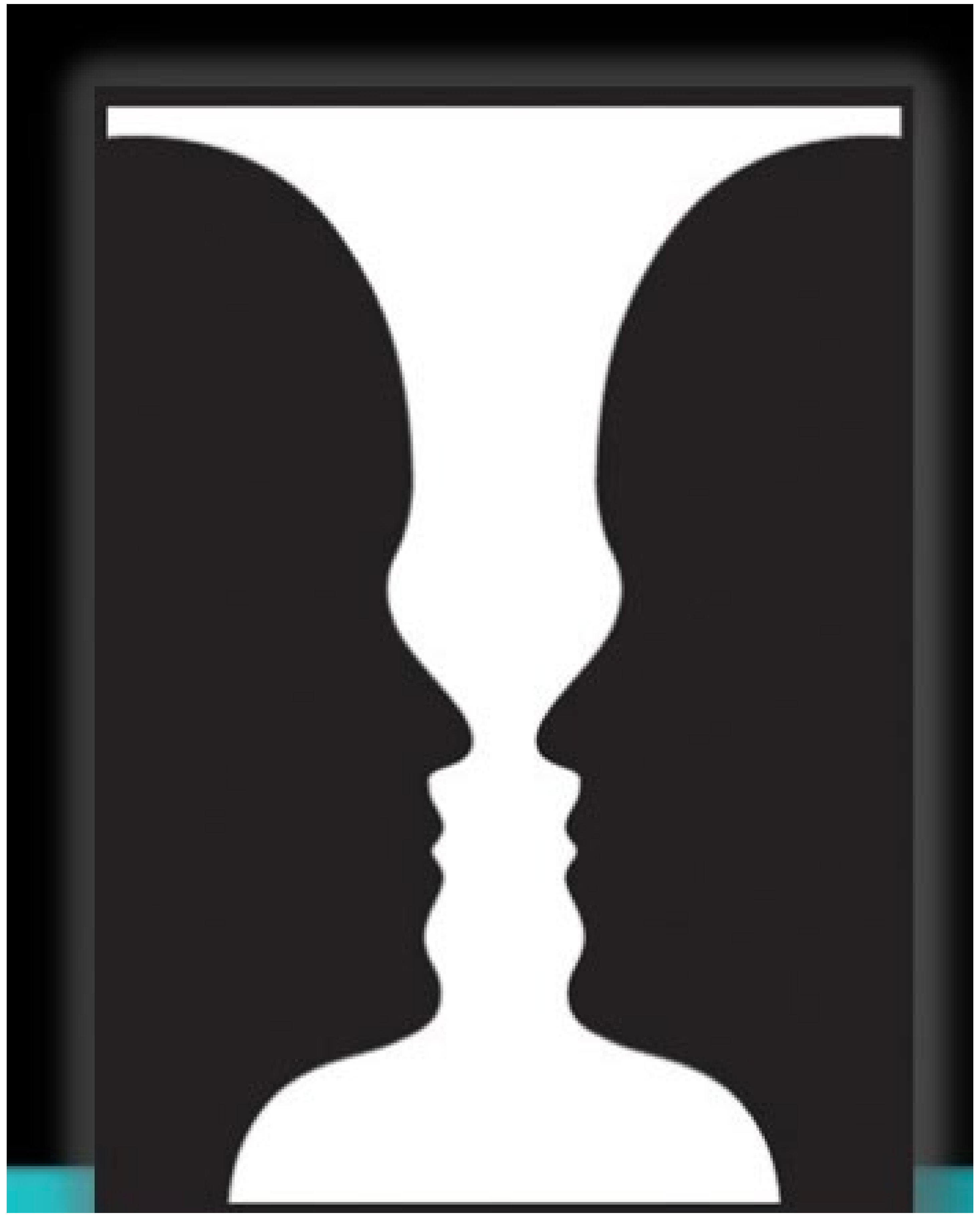
The human brain

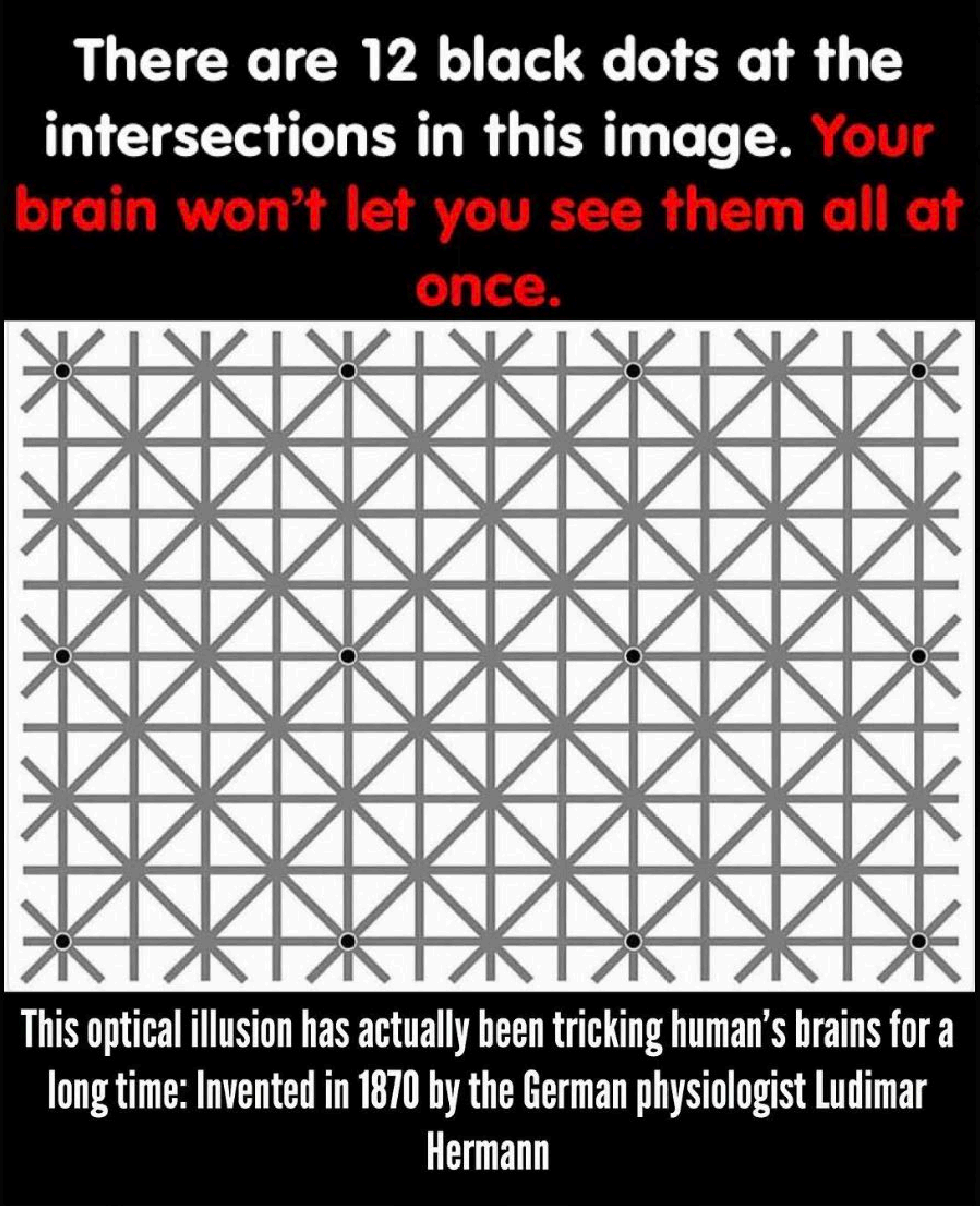


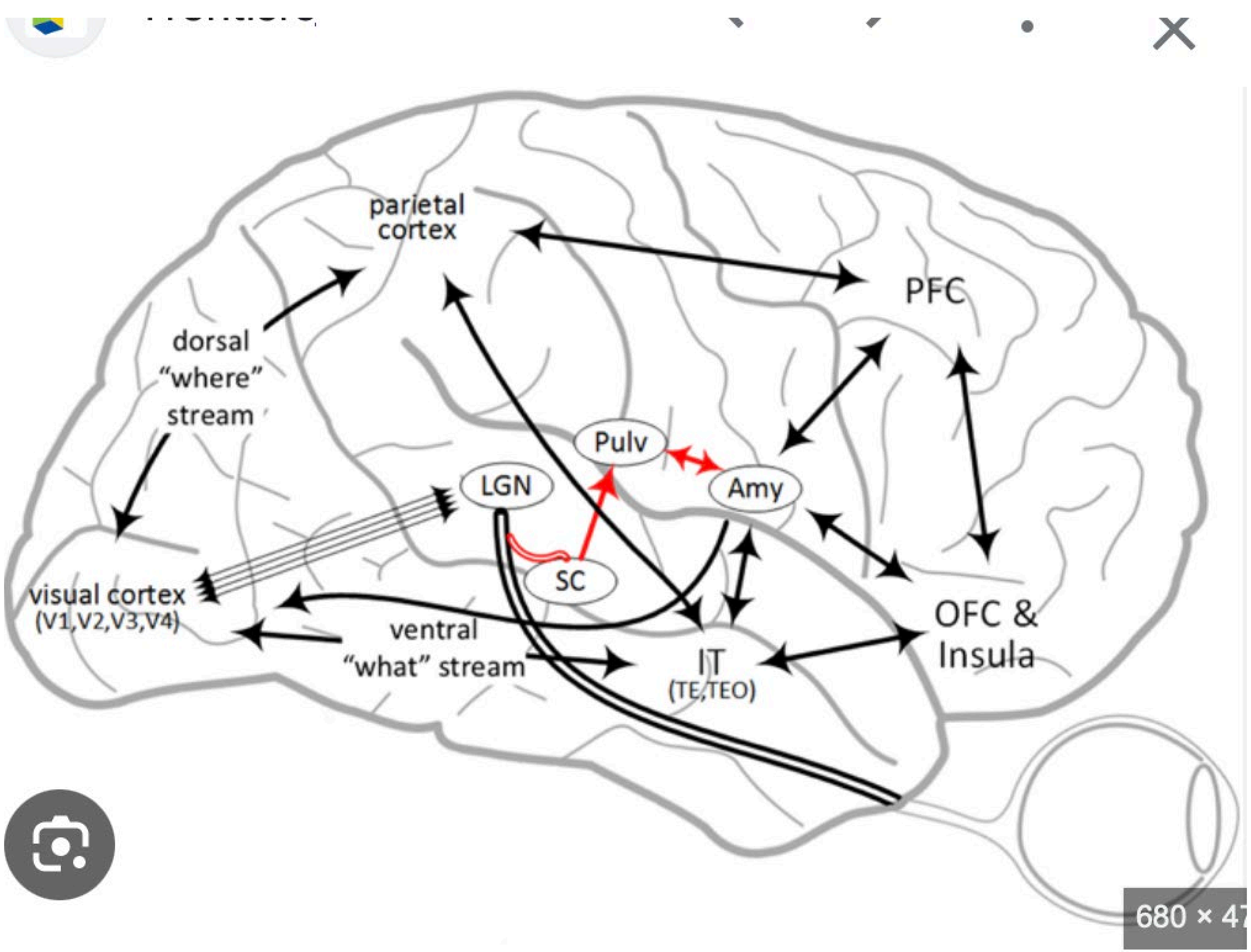
Eye movements

- Gaze stabilization
- Smooth pursuit
- Saccadic eye movements

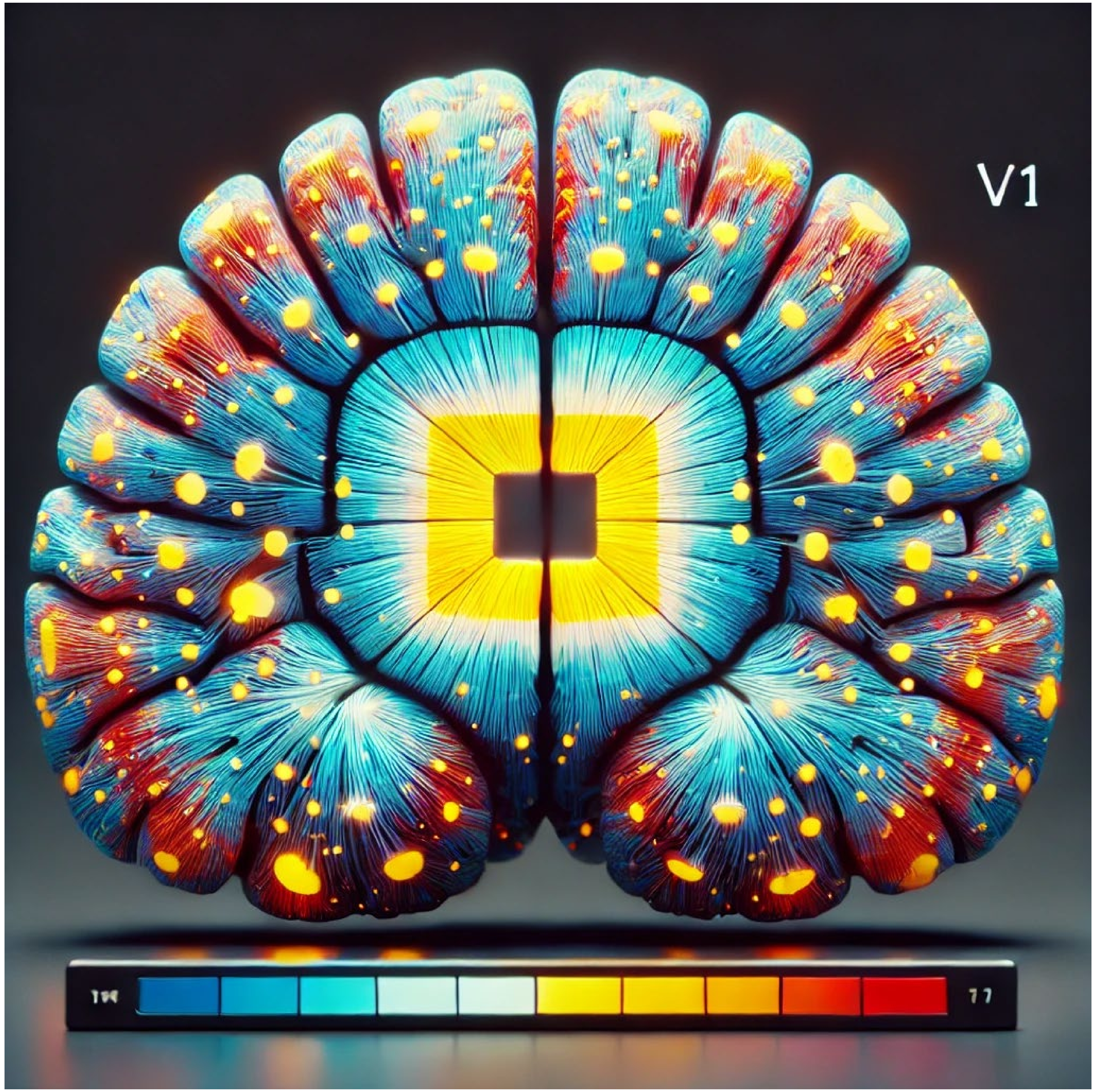

1 meter




There are 12 black dots at the intersections in this image. Your brain won't let you see them all at once.
This optical illusion has actually been tricking human's brains for a long time: Invented in 1870 by the German physiologist Ludimar Hermann

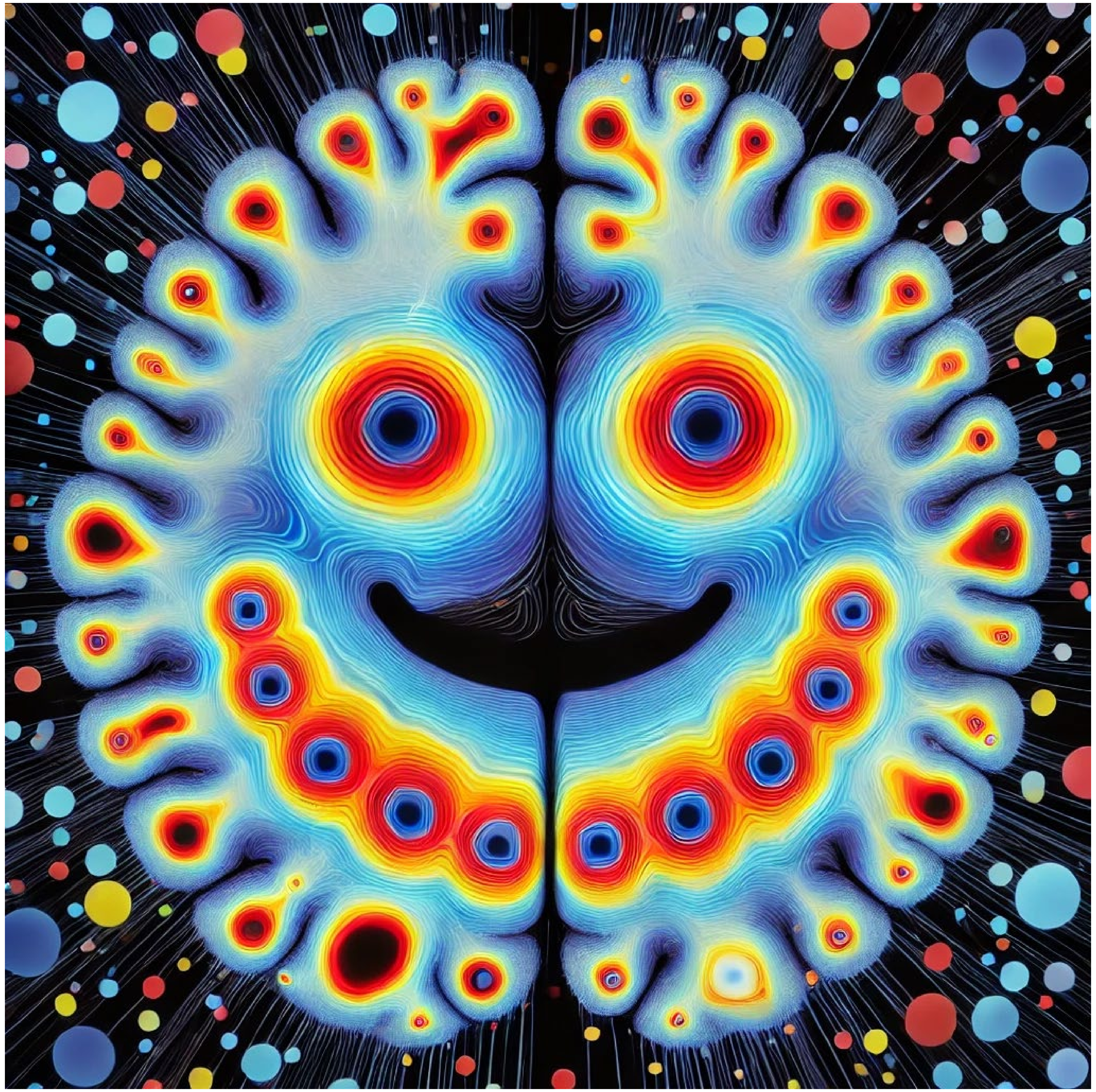

parietal cortex
PFC
dorsal "where" stream
Pulv
LGN
Amy
SC
visual cortex
(V1,V2,V3,V4)
ventral "what" stream
IT
(TE,TEO)
OFC & Insula
680 × 47

Activation in V1 (early visual area) for a rectanngle on the retina



chatgpt

Activation in V1 (early visual area) for a smiley face on the retina



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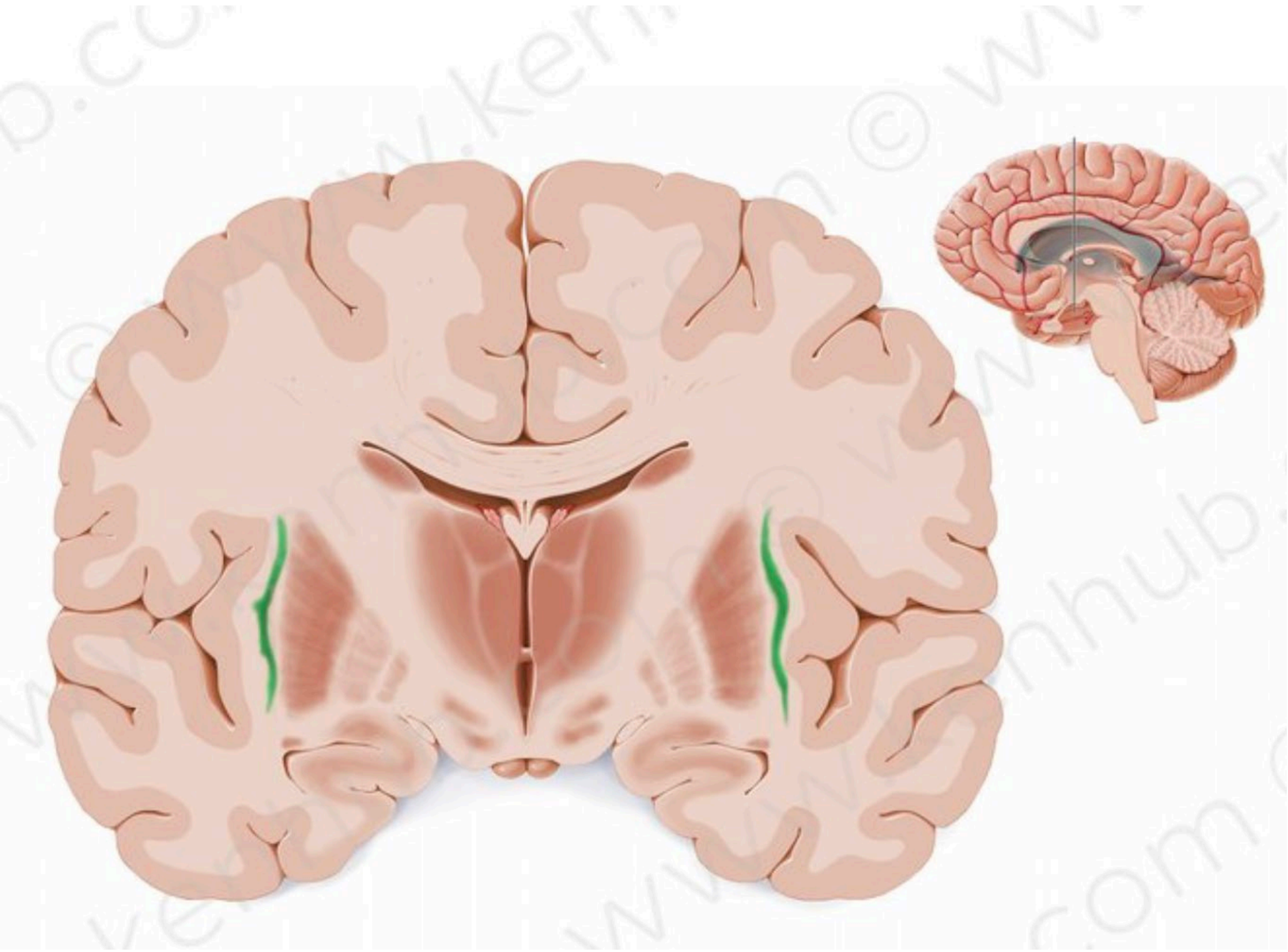
Claustrum

Through interhemispheric connections, the **claustrum** is believed to play a role in synchronizing activity in widely separated, but functionally related, parts of the brain such as between frontal eye fields and the visual cortex.[1][10][11] As such, the claustrum is thought to play a role in combining different information modalities, potentially to support consciousness itself.[10][12] Another proposed function of the claustrum is to differentiate between relevant and irrelevant information so that the latter can be ignored.[5][12][13]



Chatgpt prompt;

image of a student in Psaltis' course

reality is a construct

Top-down influences on visual processing

•Charles D. Gilbert &

•Wu Li

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Reconstructing feedback representations in the ventral visual pathway with a generative adversarial autoencoder

Haider Al-Tahan [1,2], **Yalda Mohsenzadeh** [1,2]*

1 Department of Computer Science, The University of Western Ontario, London, Ontario, Canada, **2** Brain

and Mind Institute, The University of Western Ontario, London, Ontario, Canada