Module # 3—Seeing Space

Visual Perception and the Brain

DUKE INSTITUTE *for* BRAIN SCIENCES

Topic 2. Seeing Distance and Depth

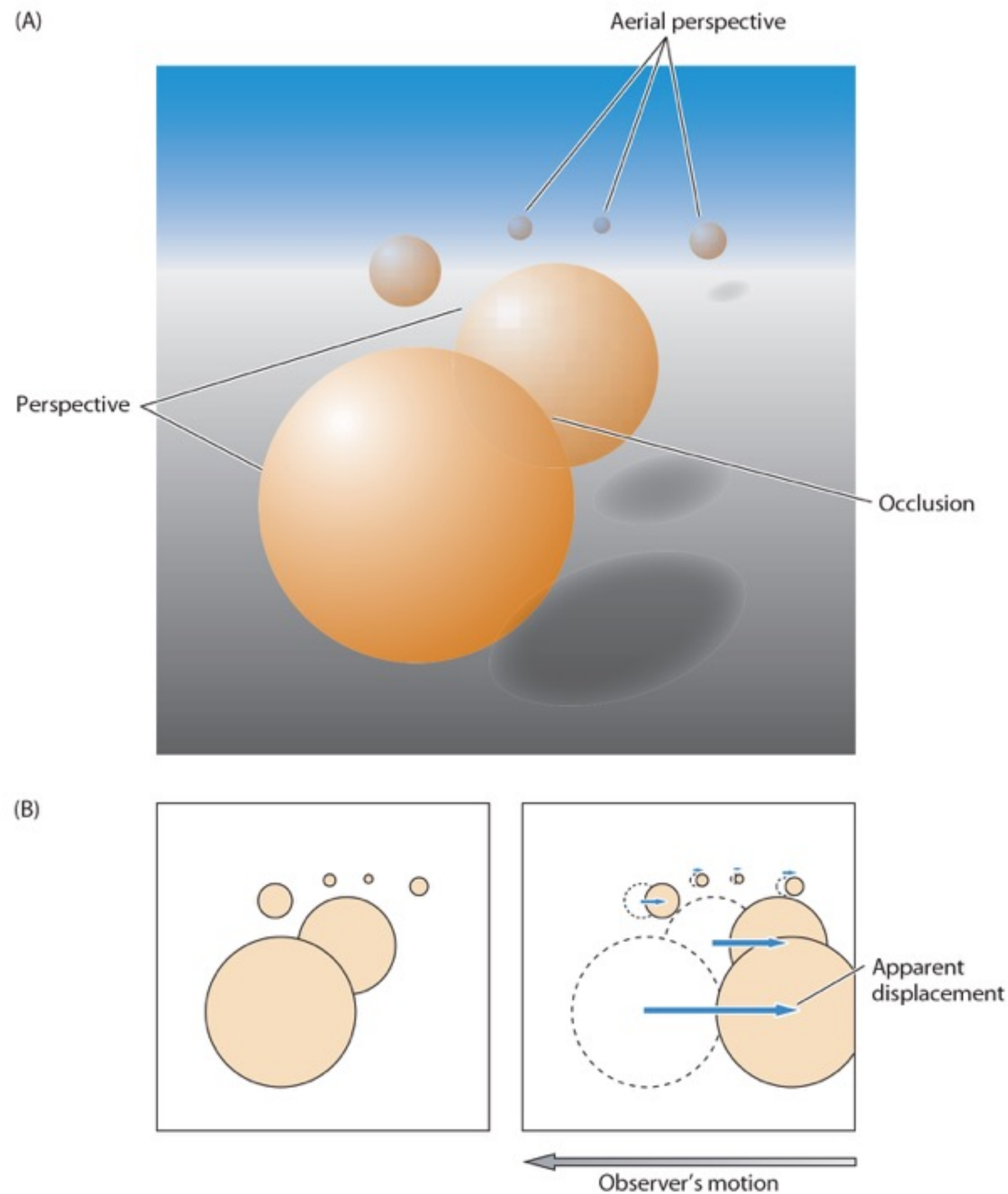
Lesson 1. Definitions

Definitions

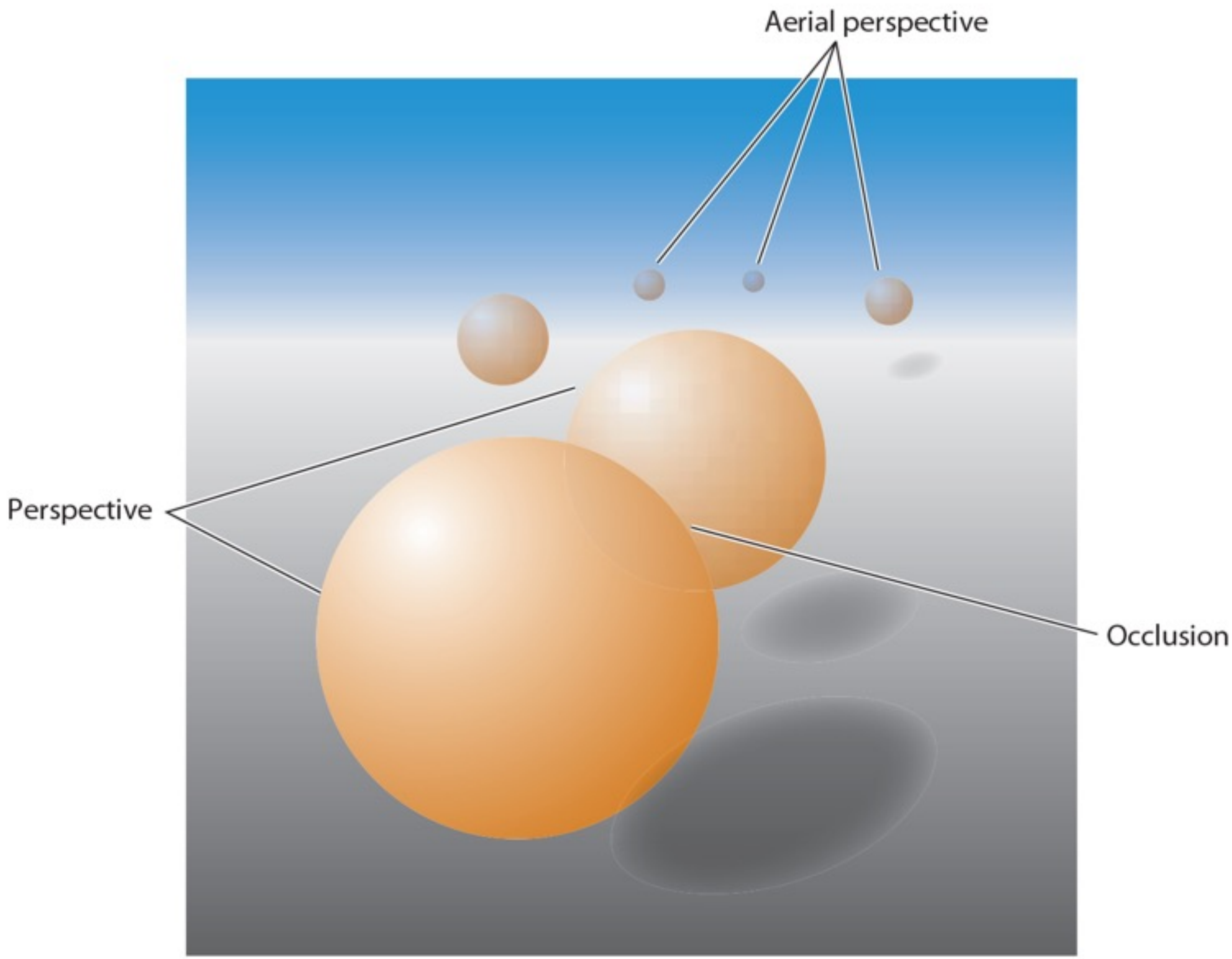
- Distance refers to the sense of how far away something is, and is mediated monocularly
- Depth refers to a special sense of three dimensionality (called stereopsis), and is mediated binocularly

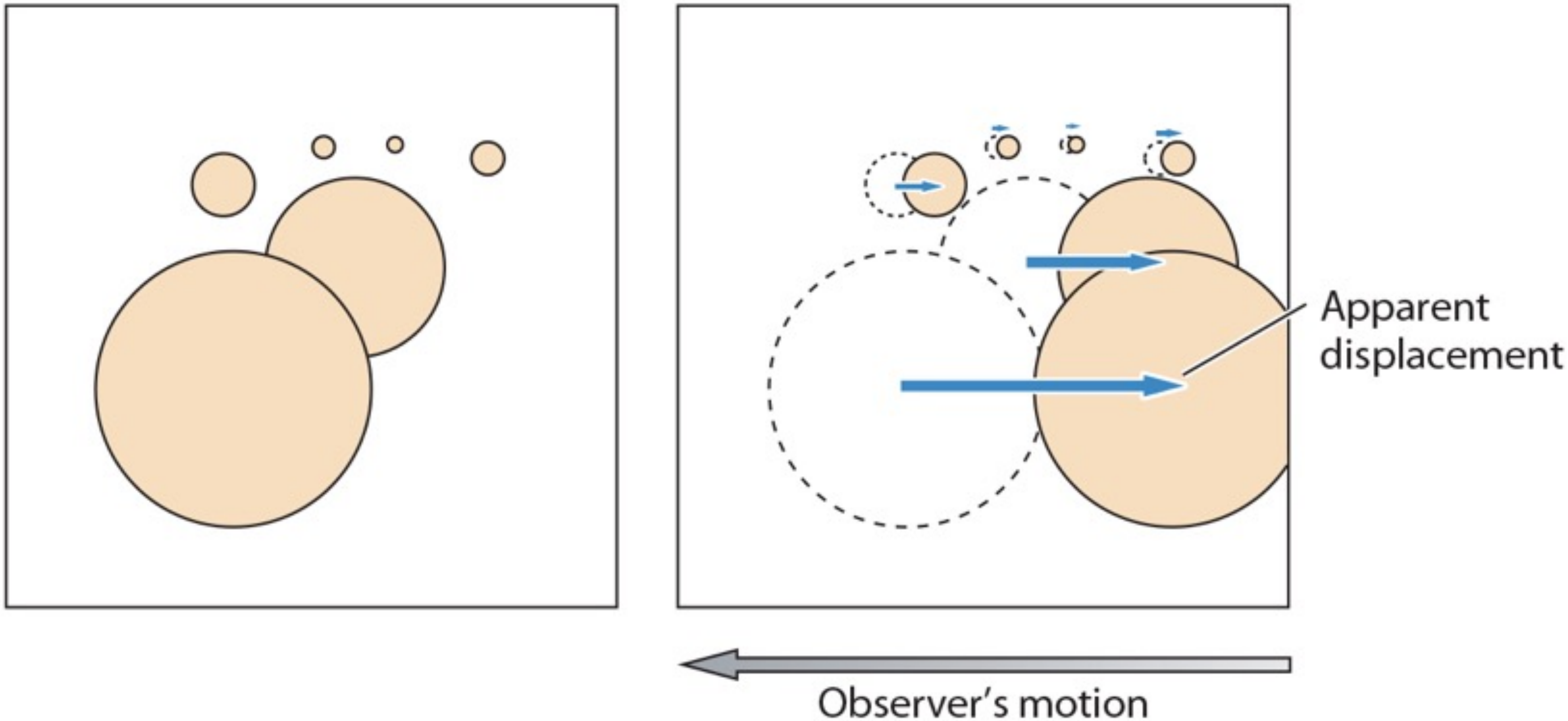
Lesson 2. Seeing Distance with One Eye

Cues to a Monocular Sense of Distance



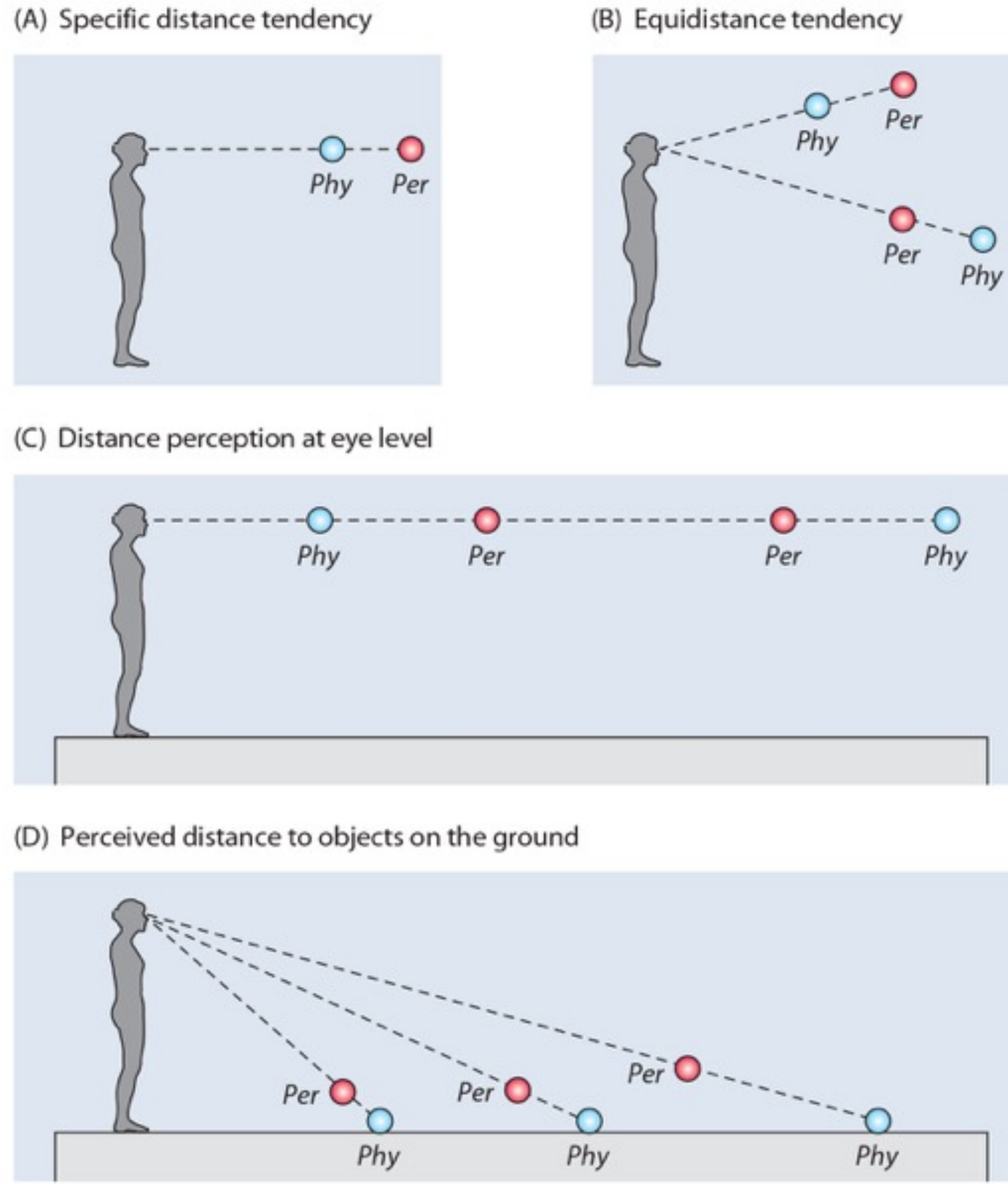
Motion parallax

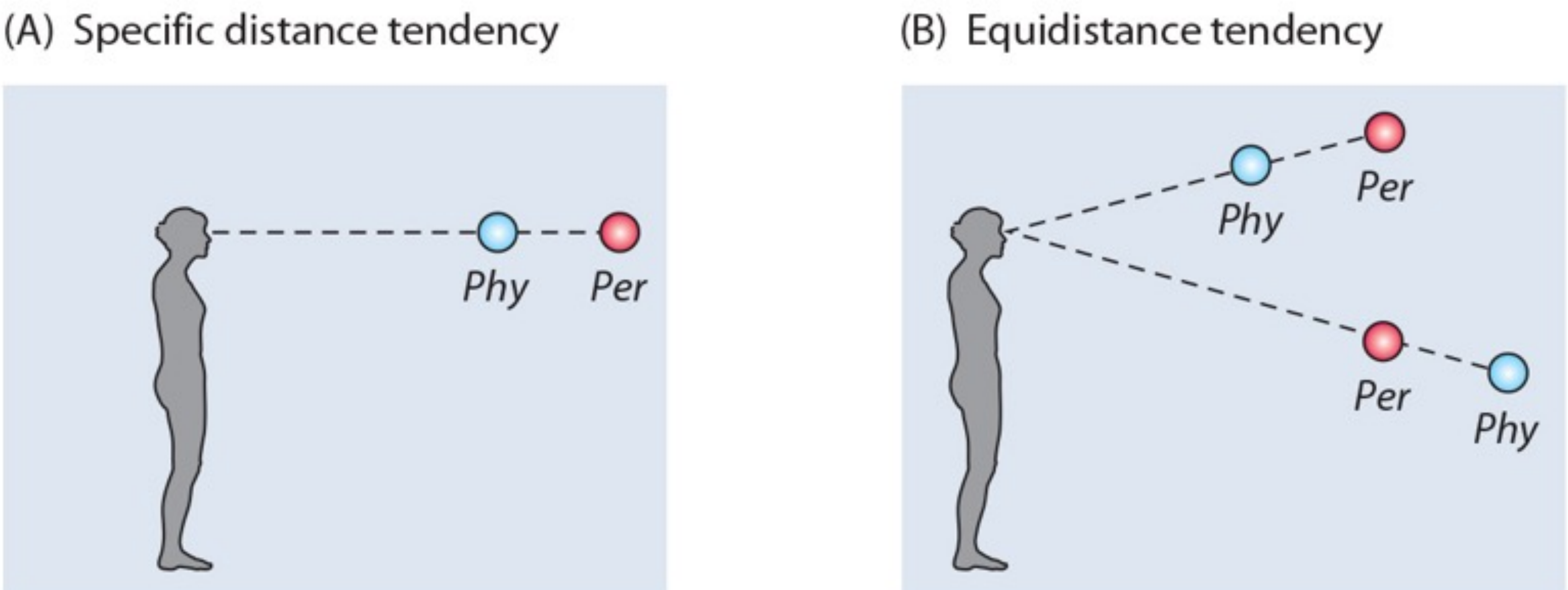

Aerial perspective
Perspective
Occlusion



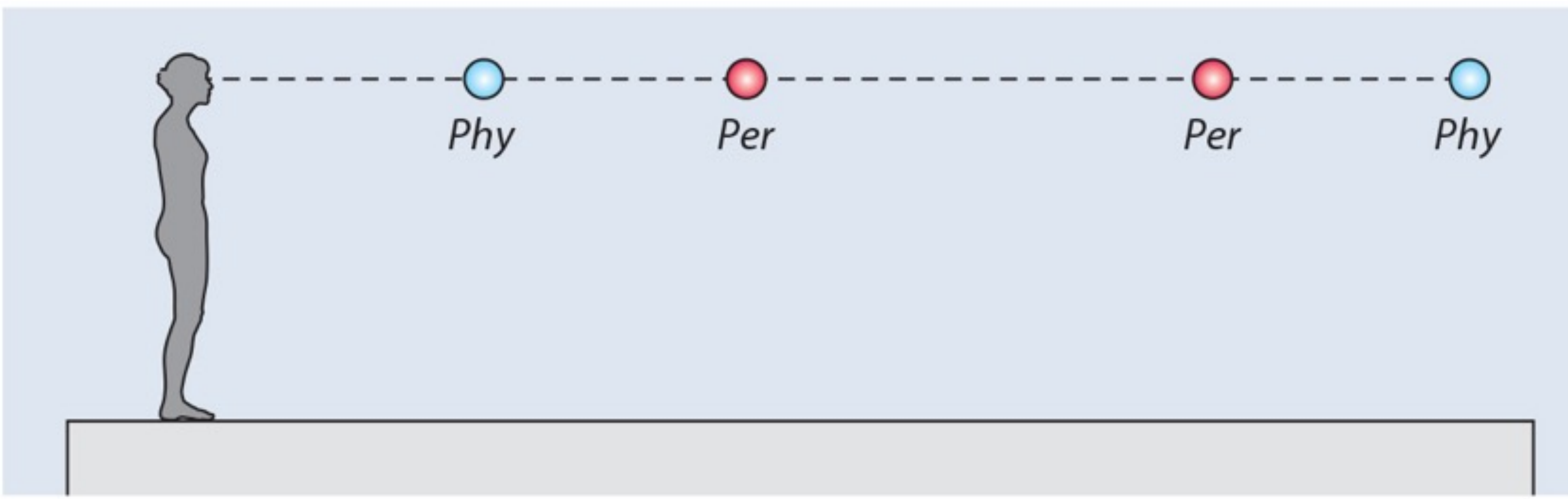
Motion parallax

Like all other aspects of visual perception, what we see does not correspond to physical measurements

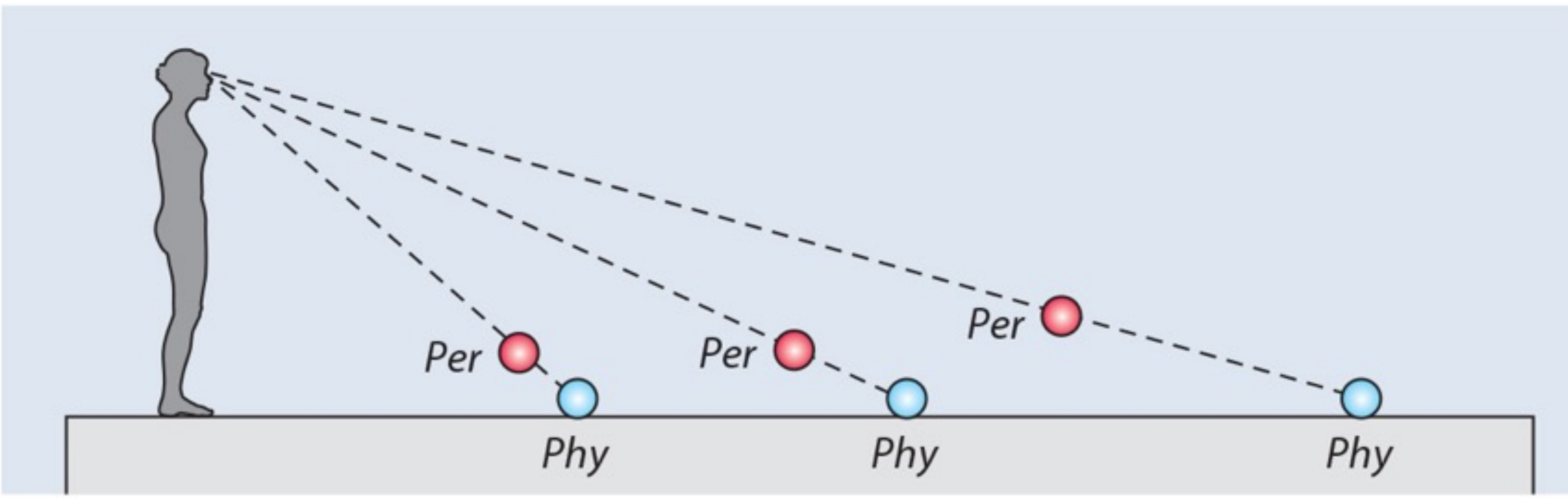



(A) Specific distance tendency
Phy
Per
(B) Equidistance tendency
Phy
Per
Per
Phy

(C) Distance perception at eye level

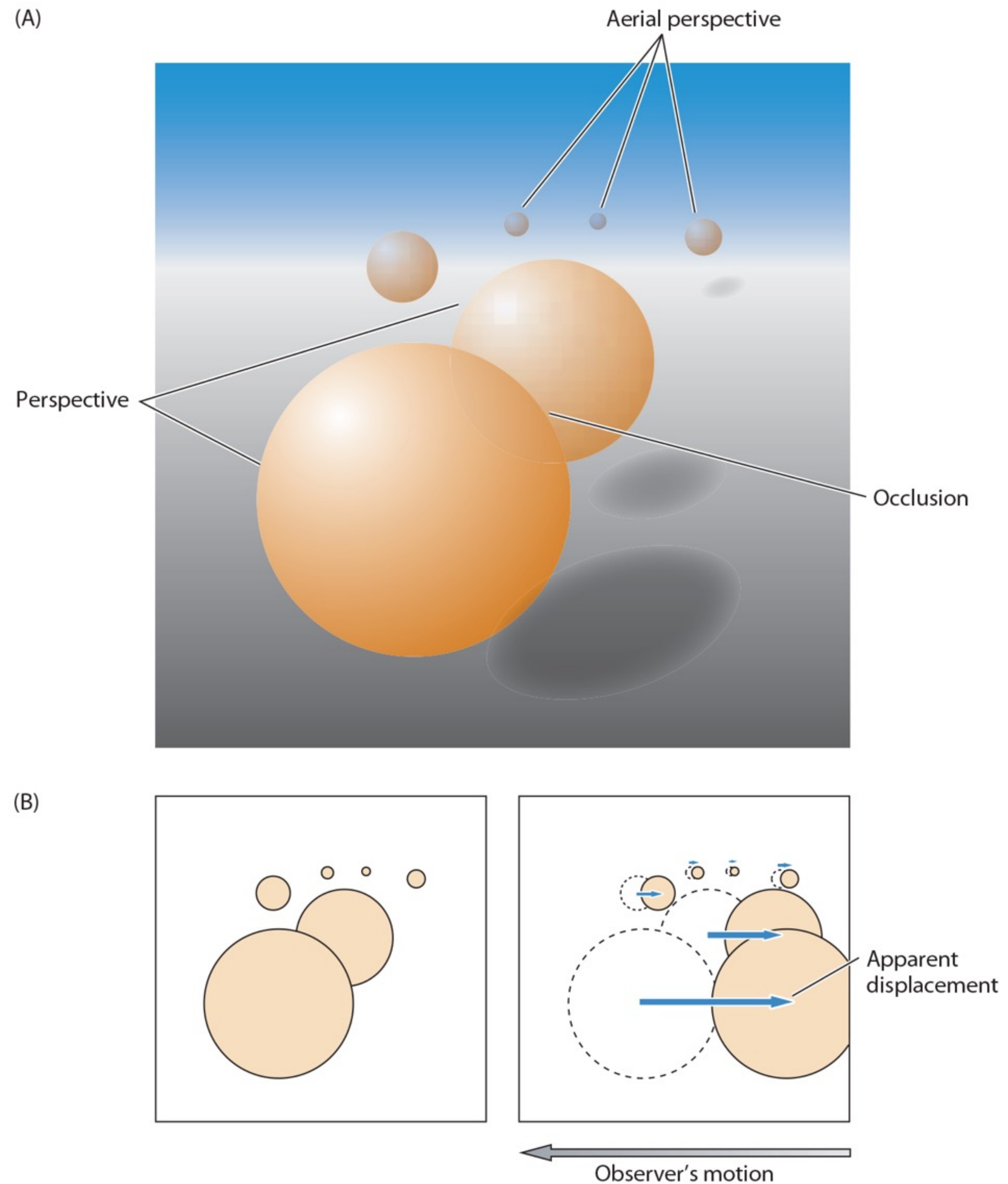


(D) Perceived distance to objects on the ground

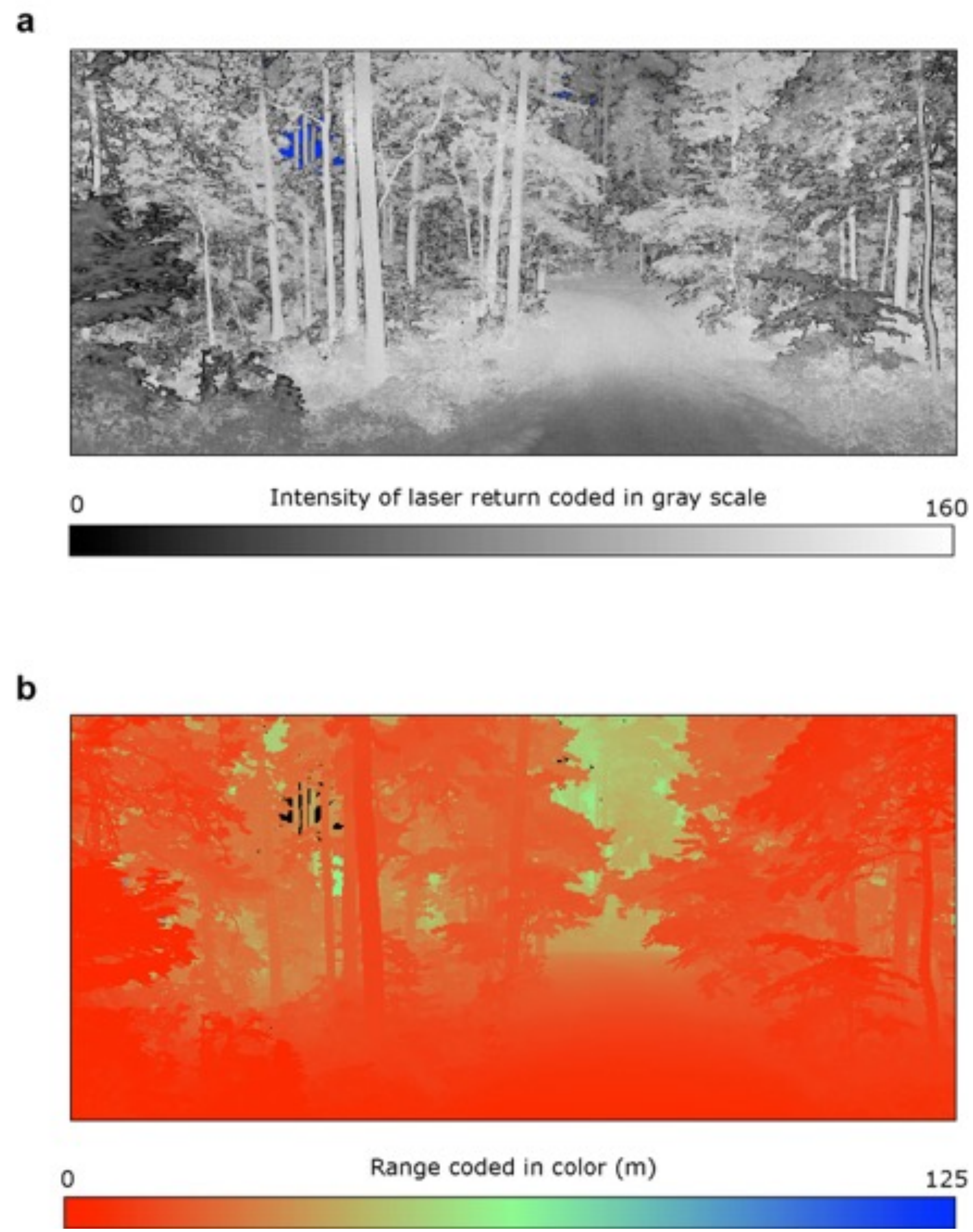


Lesson 3. An Empirical Explanation

Motion parallax



Gathering the Relevant Human Experience



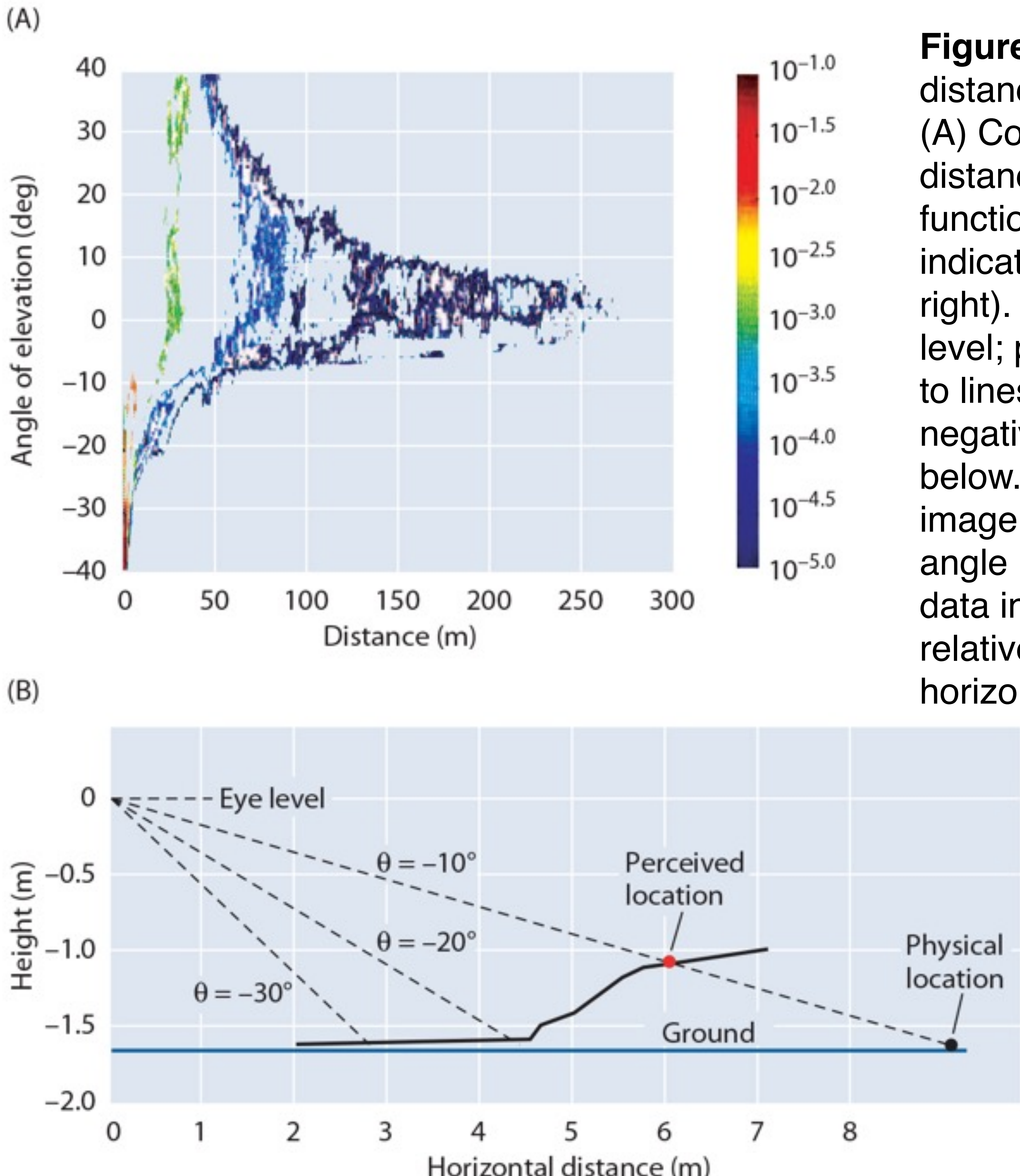


Figure 5.5 Distributions of physical distances at different elevation angles. (A) Contour plot of the distributions of distances from the image plane as a function of elevation; probabilities are indicated by color coding (bar on the right). An elevation angle of 0° is eye level; positive elevation angles correspond to lines of sight above eye level and negative values correspond to those below. (B) The typical distance from the image plane as a function of the elevation angle (θ) of the location derived from the data in (A). The vertical axis is the height relative to eye level; the horizontal axis is horizontal distance from the image plane. The blue line indicates the position of the ground plane at ~1.65 meters below eye level. These data predict that the apparent distance of an object on the ground more than a few meters away in a darkened environment should appear closer and higher than the actual location of the object. (From Yang and Purves, 2003.)

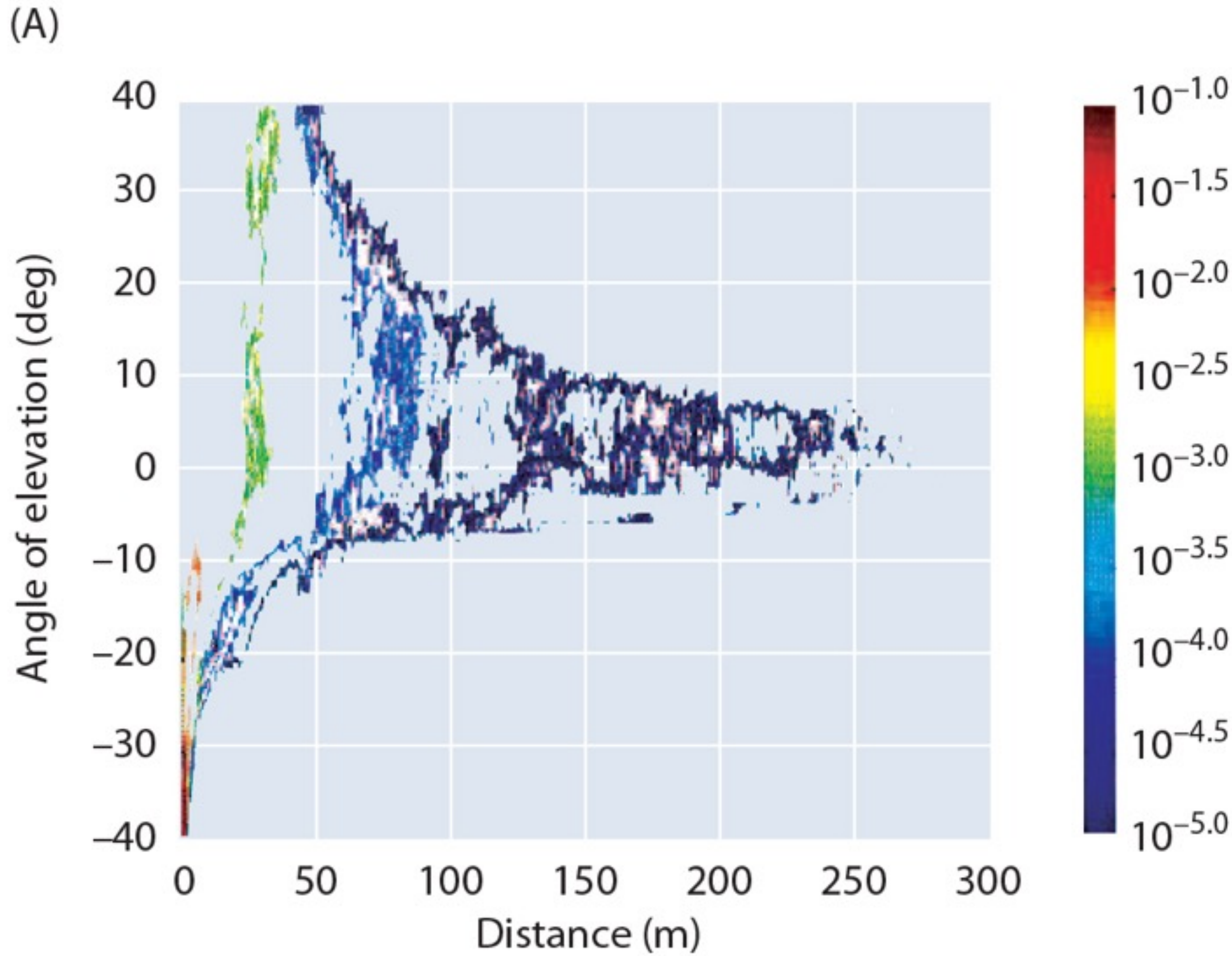


Figure 5.5 (A) Contour plot of the distributions of distances from the image plane as a function of elevation; probabilities are indicated by color coding (bar on the right).

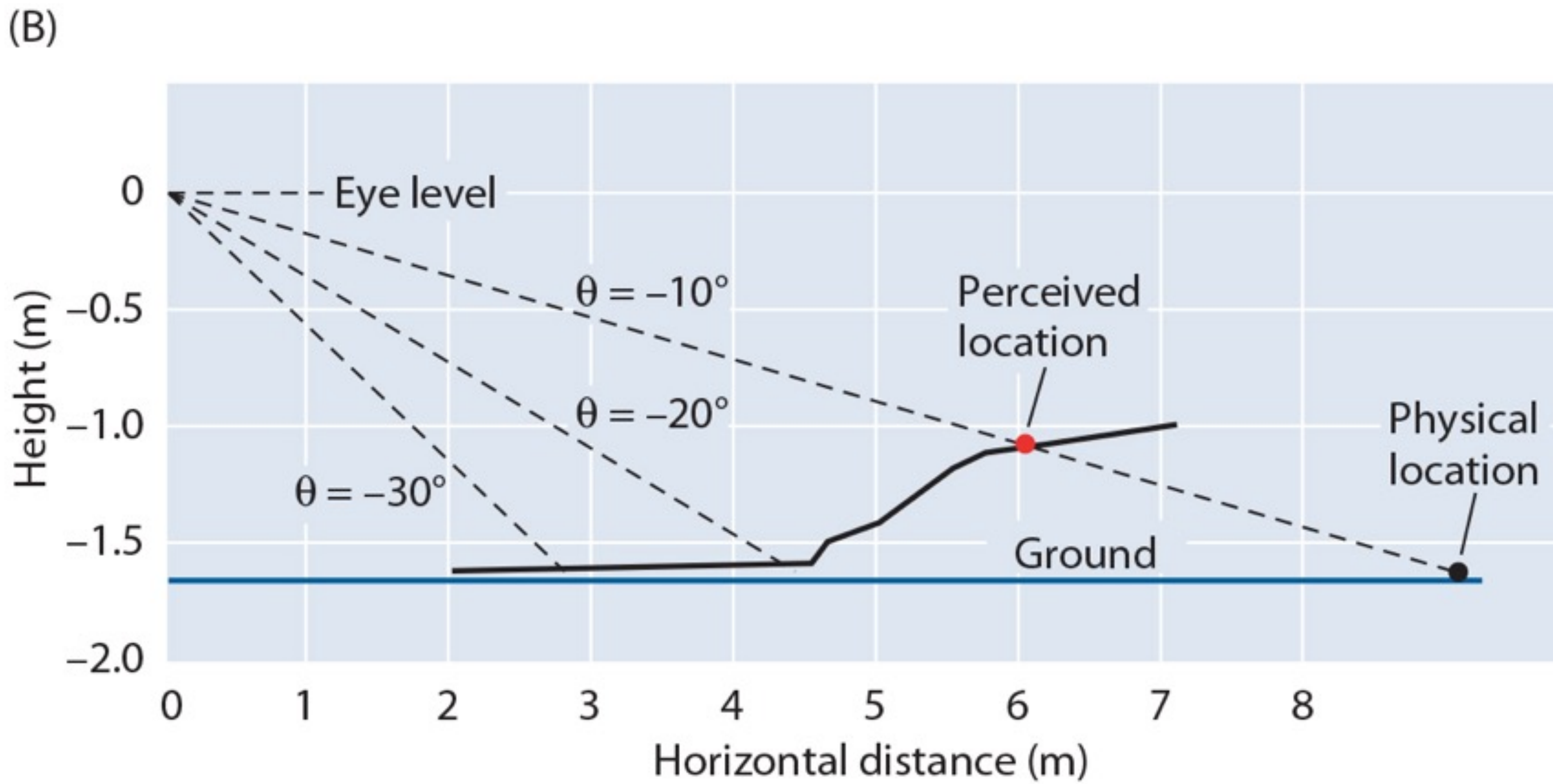
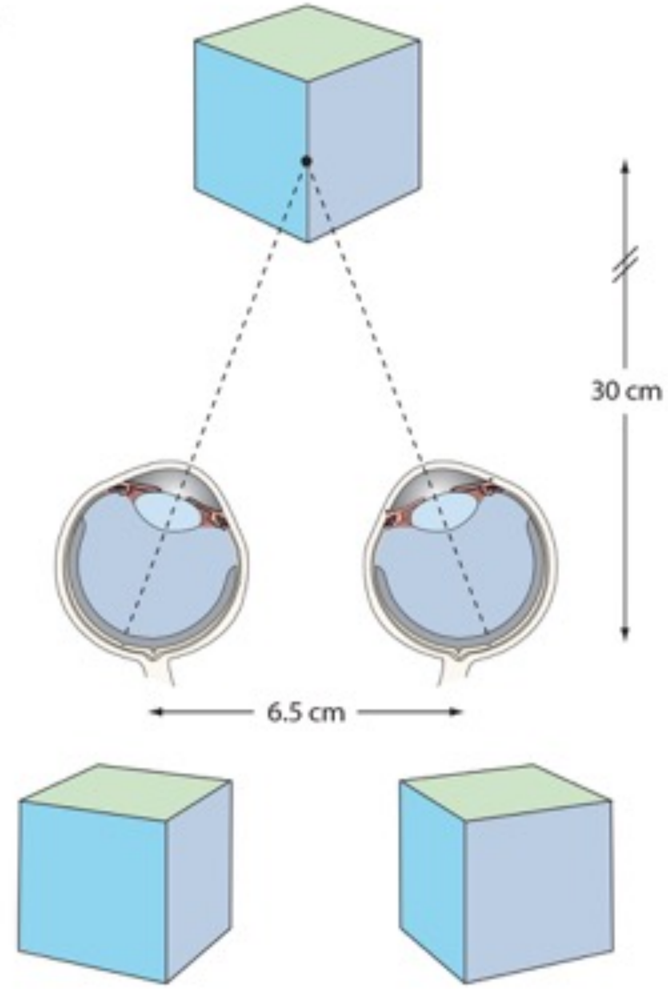


Figure 5.5 (B) The typical distance from the image plane as a function of the elevation angle (θ) of the location derived from the data in (A). The vertical axis is the height relative to eye level; the horizontal axis is horizontal distance from the image plane. The blue line indicates the position of the ground plane at ~1.65 meters below eye level. These data predict that the apparent distance of an object on the ground more than a few meters away in a darkened environment should appear closer and higher than the actual location of the object. (From Yang and Purves, 2003.)

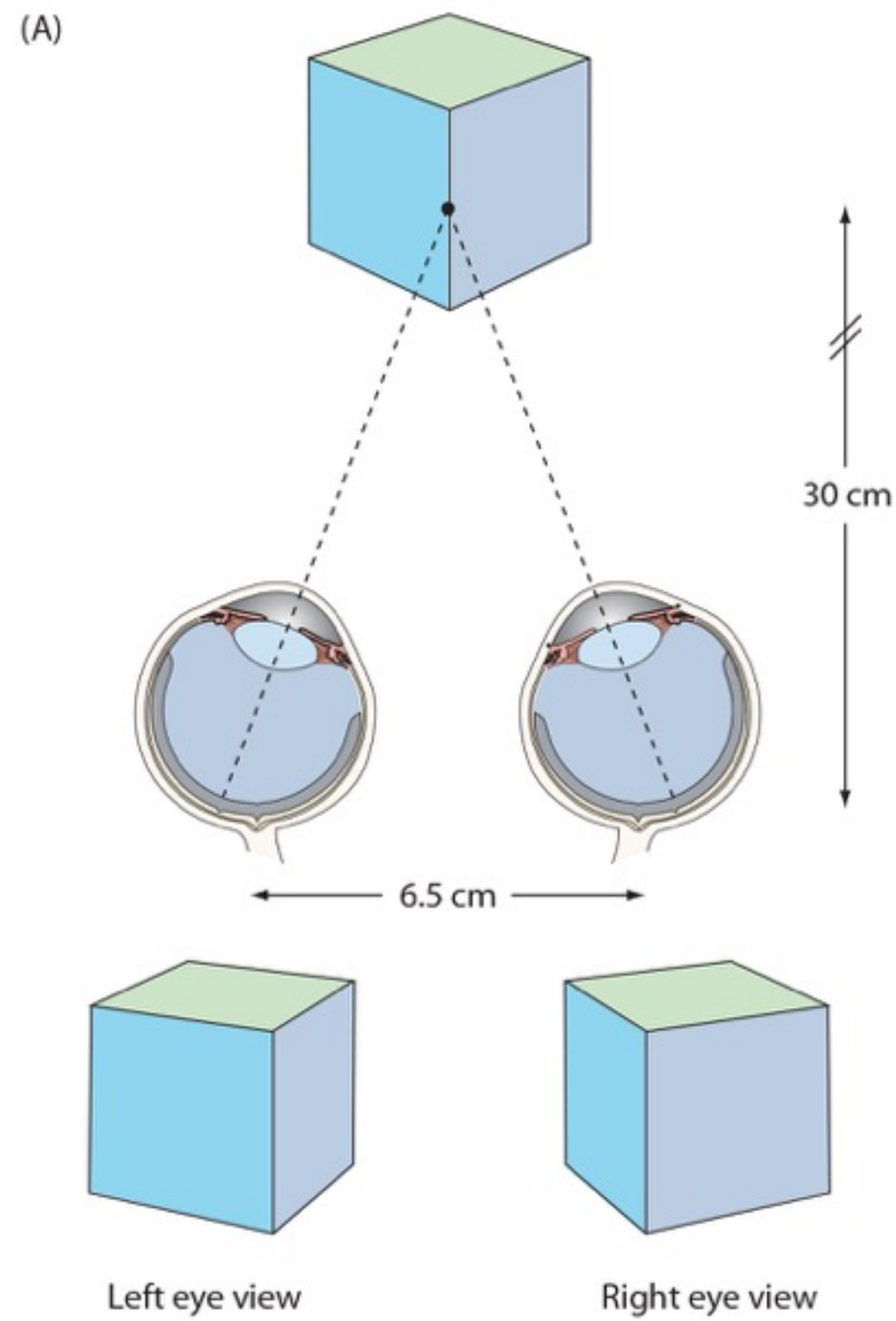
Lesson 4. Seeing Depth with Two Eyes (Stereopsis)

Charles Wheatstone
(1802–1875)

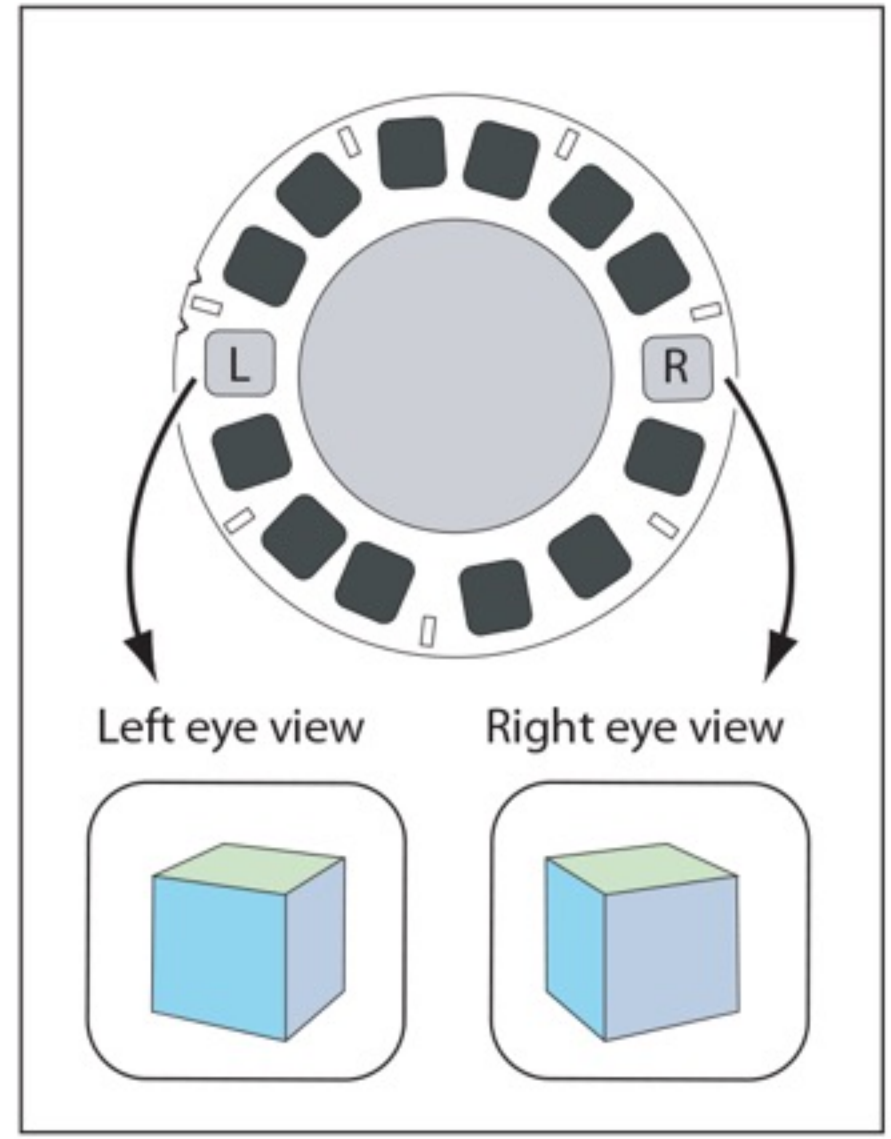
(A)



(B)

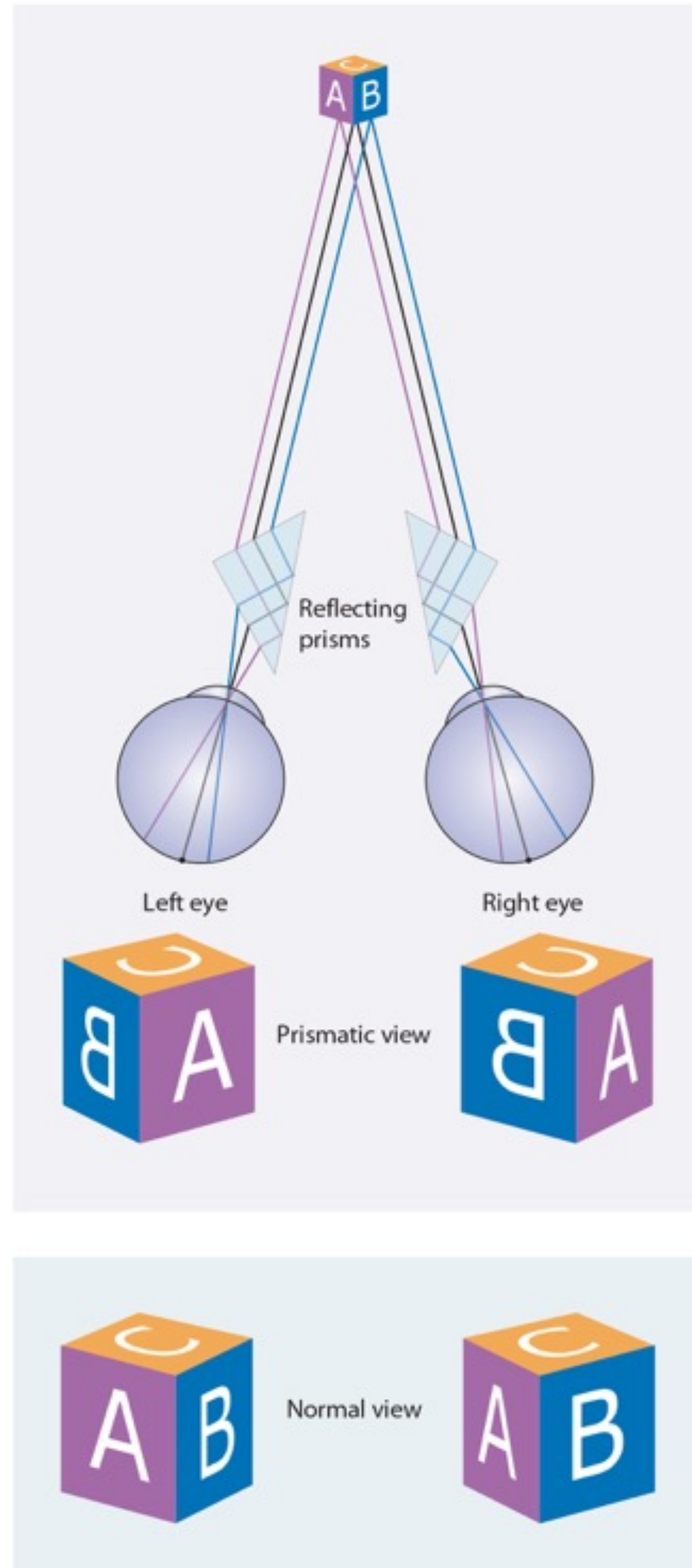

(A)
30 cm
6.5 cm
Left eye view
Right eye view

(B)



But there were disconcerting observations from the beginning

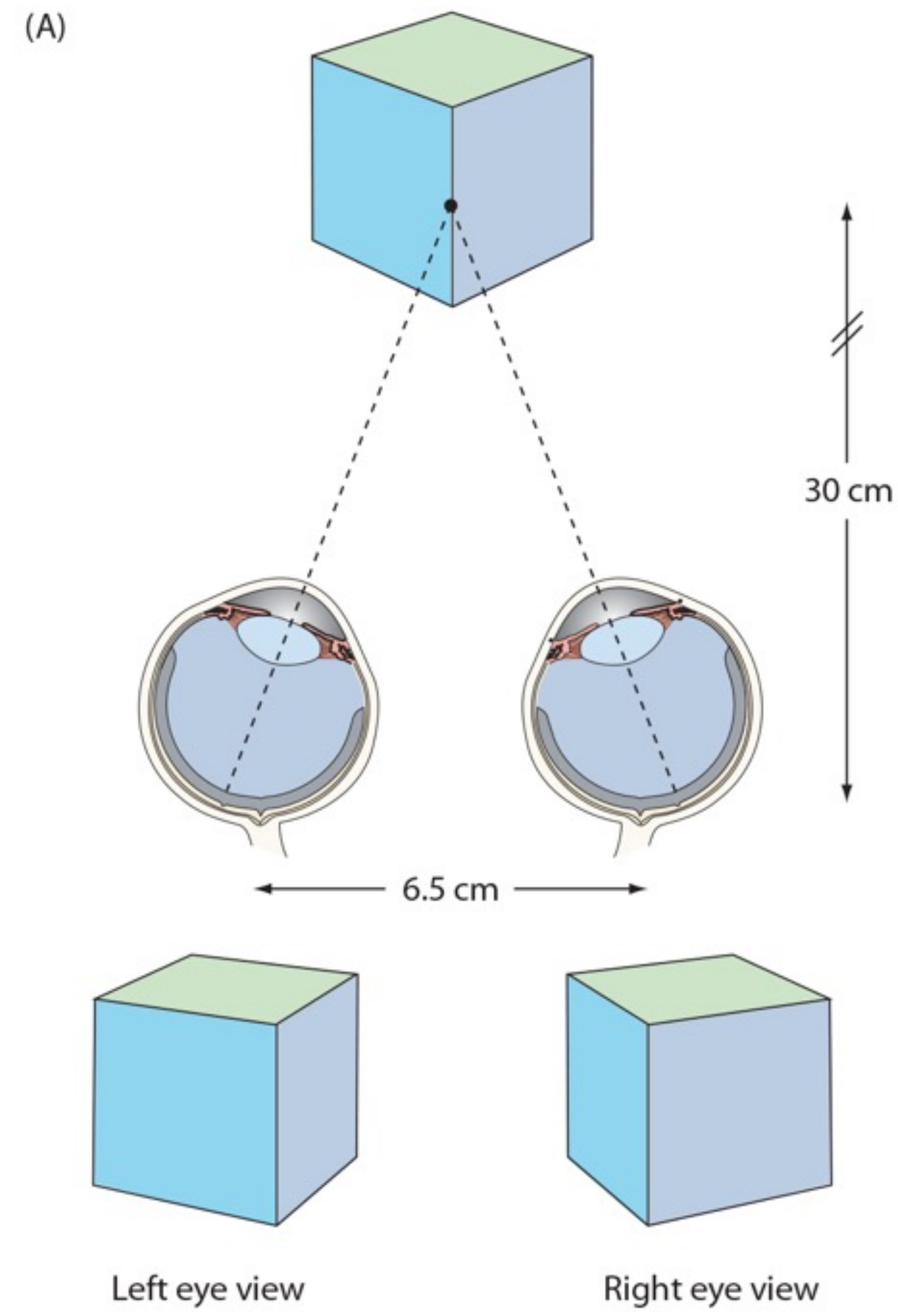
Wheatstone's "pseudoscope"



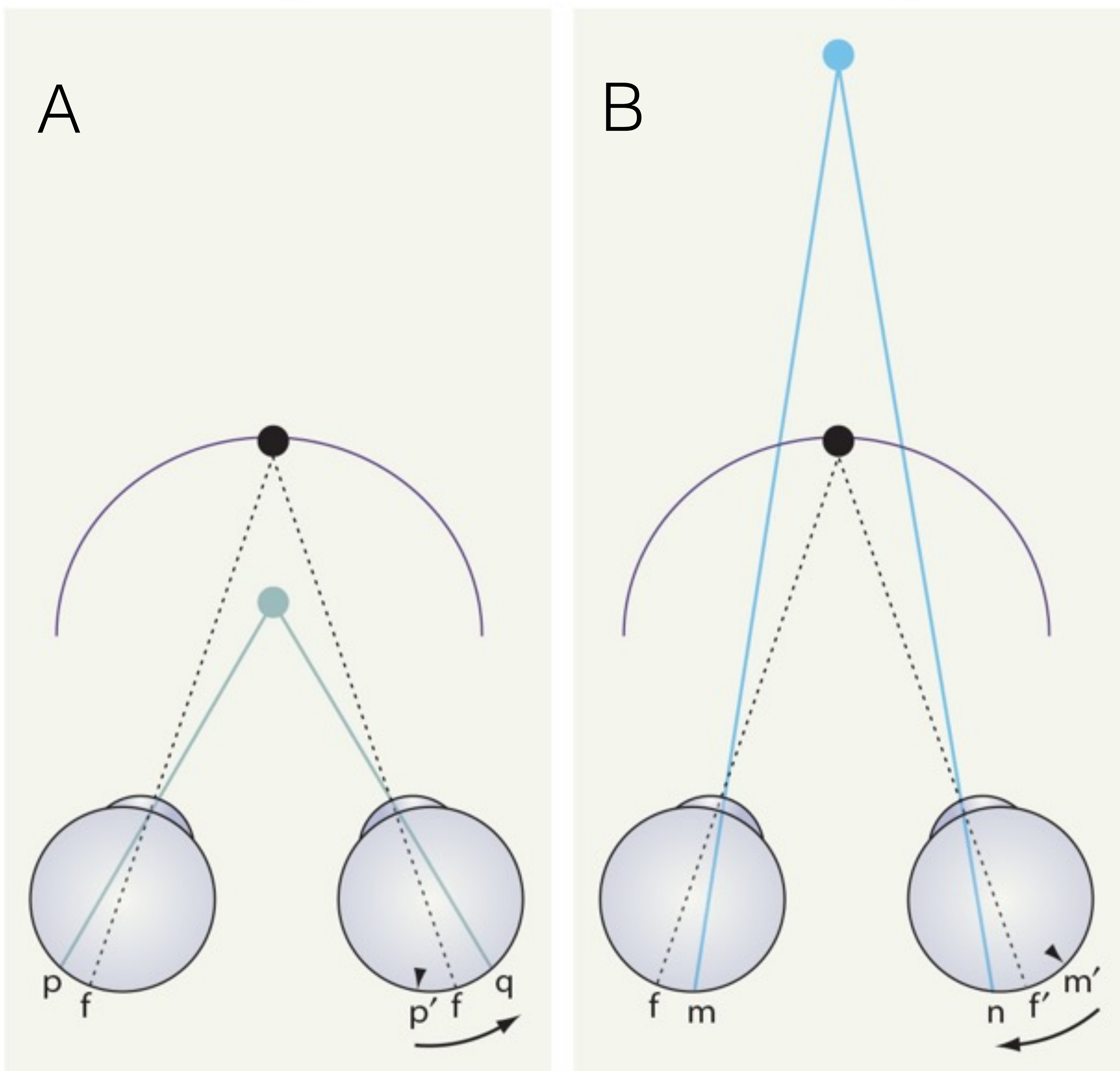
Lesson 5. Explaining Stereopsis

Remember the different views of the two eyes

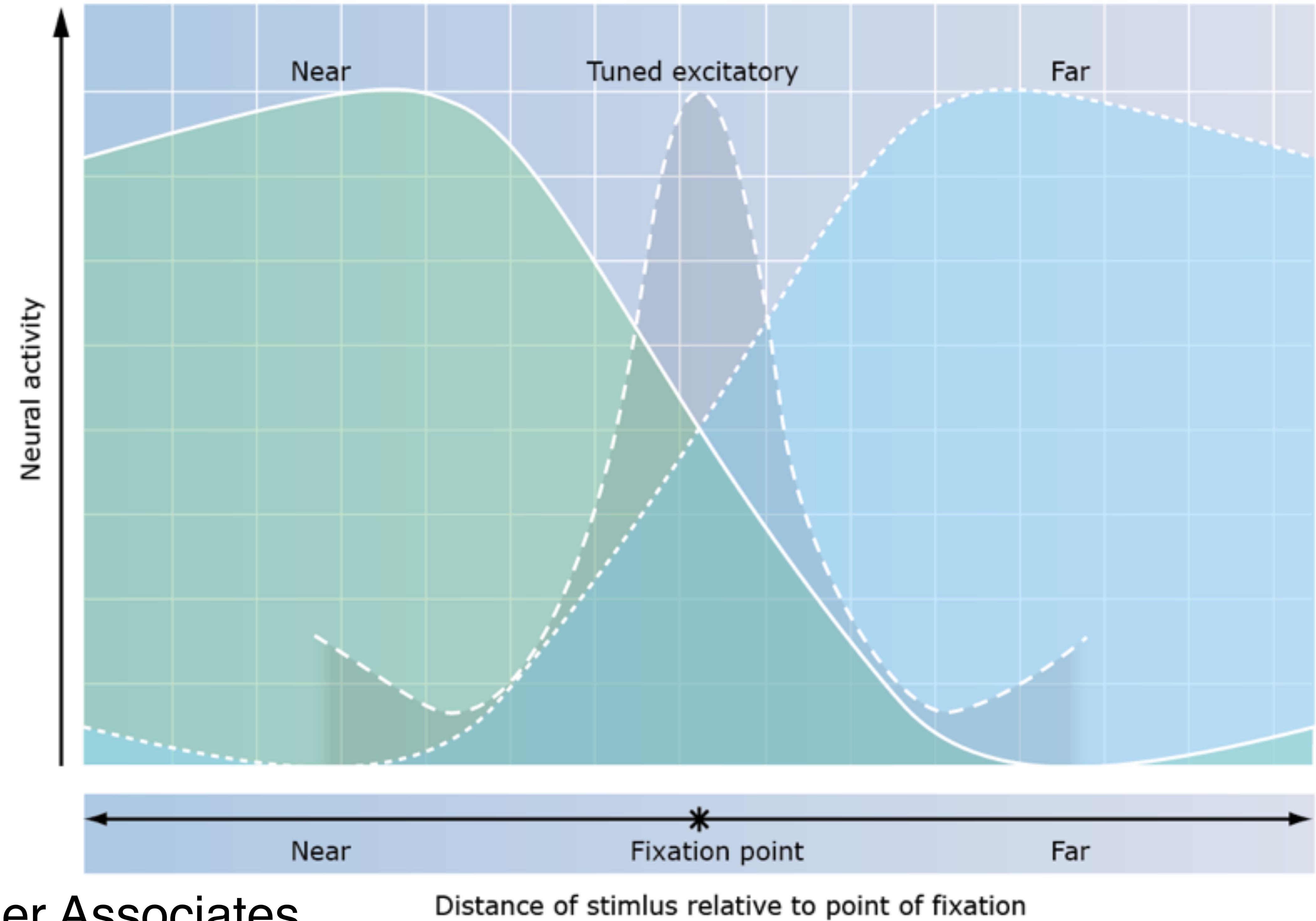
This basic fact leads to the idea of matching corresponding image points



Binocular Disparity

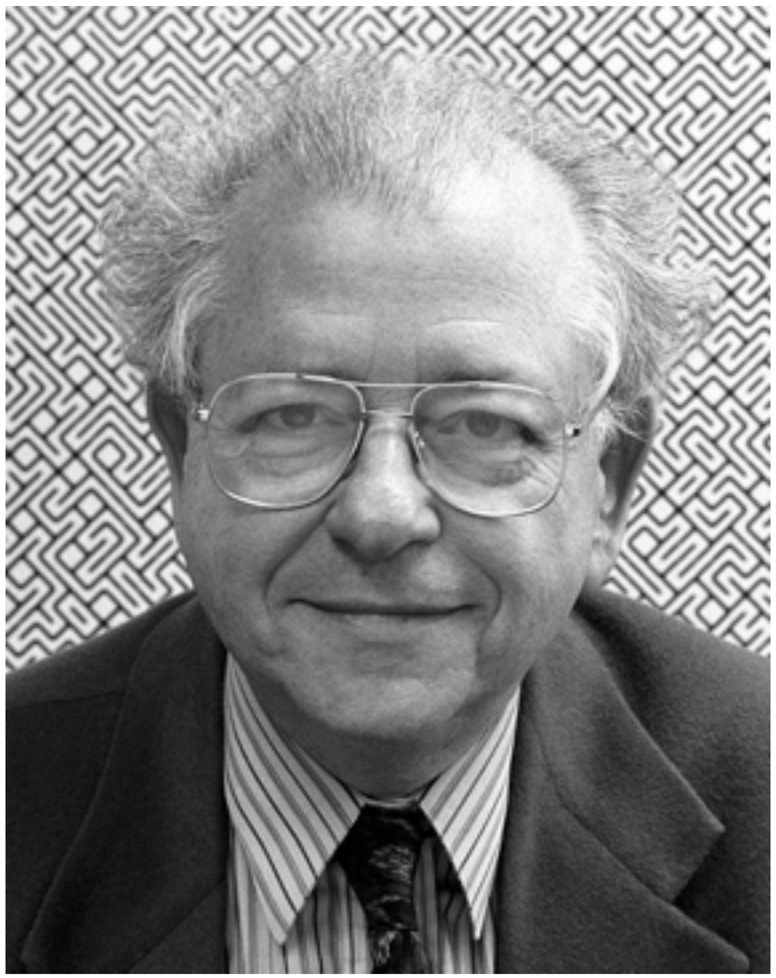


The Discovery of “Near” and “Far” Neurons in the Visual Cortex

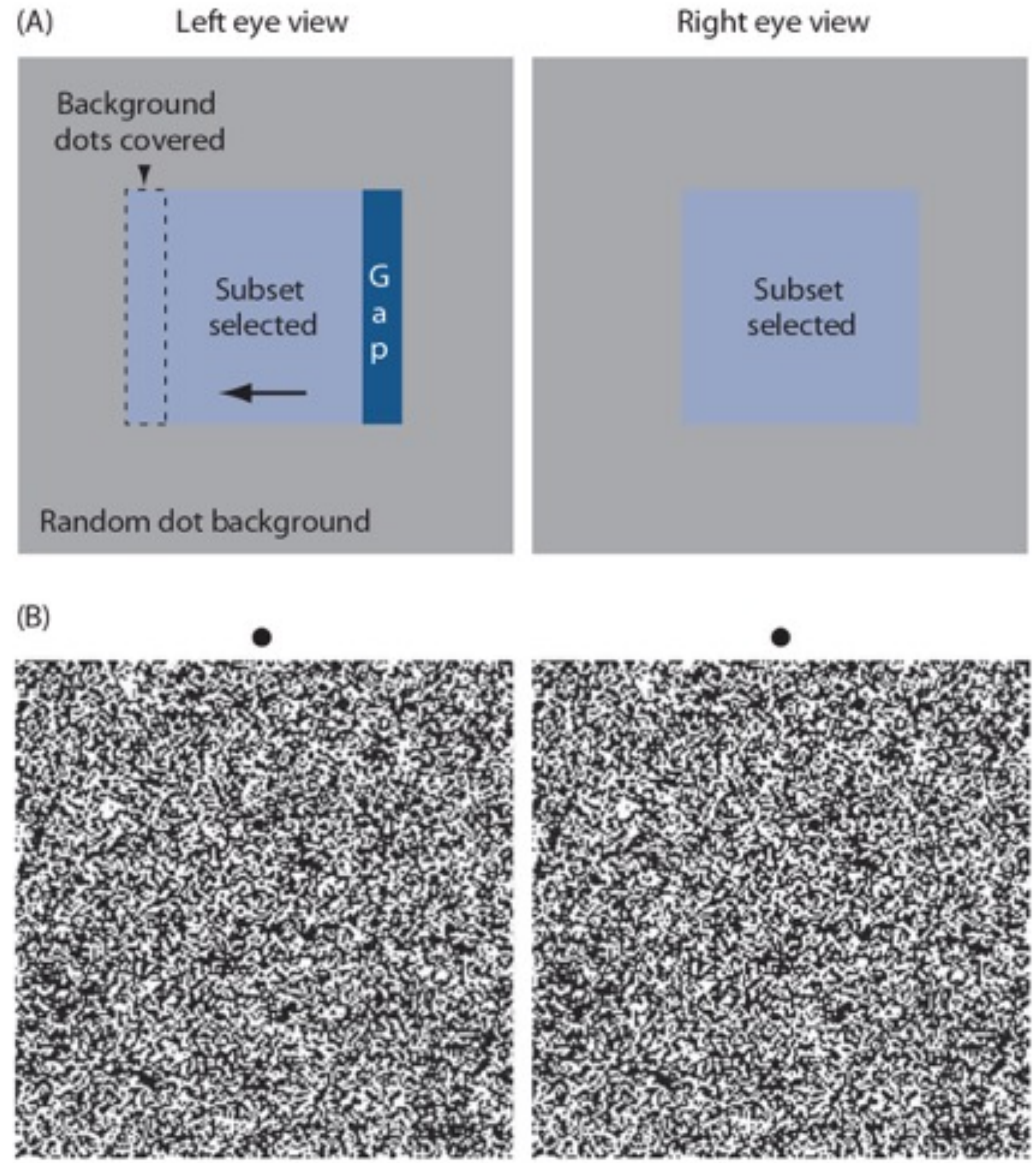


Lesson 6. Random Dot Stereograms

The Correspondence Problem



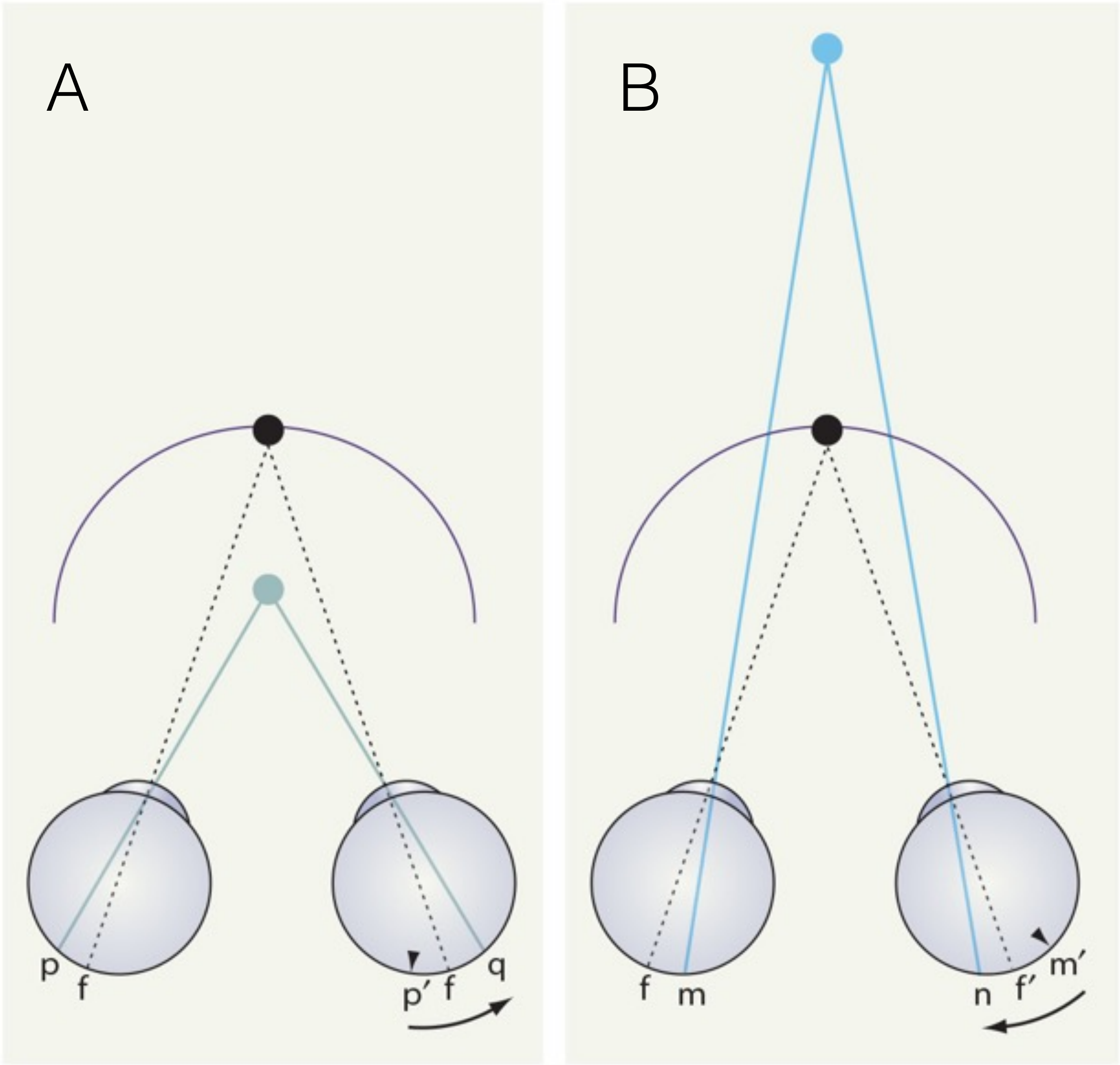
Béla Julesz
(1928–2003)



Breaking
camouflage

Remember the Inverse Problem

- The significance of image features for behavior in the real world, including geometrical features, is inherently uncertain
- Implication: real world geometry is unknowable by any direct, logical operation on retinal images
- So how is it that we behave appropriately in responding to the geometry of the world?



The correspondence problem is manifestation of inherent ambiguity in stereopsis

Remember the Inverse Problem

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Remember the Inverse Problem

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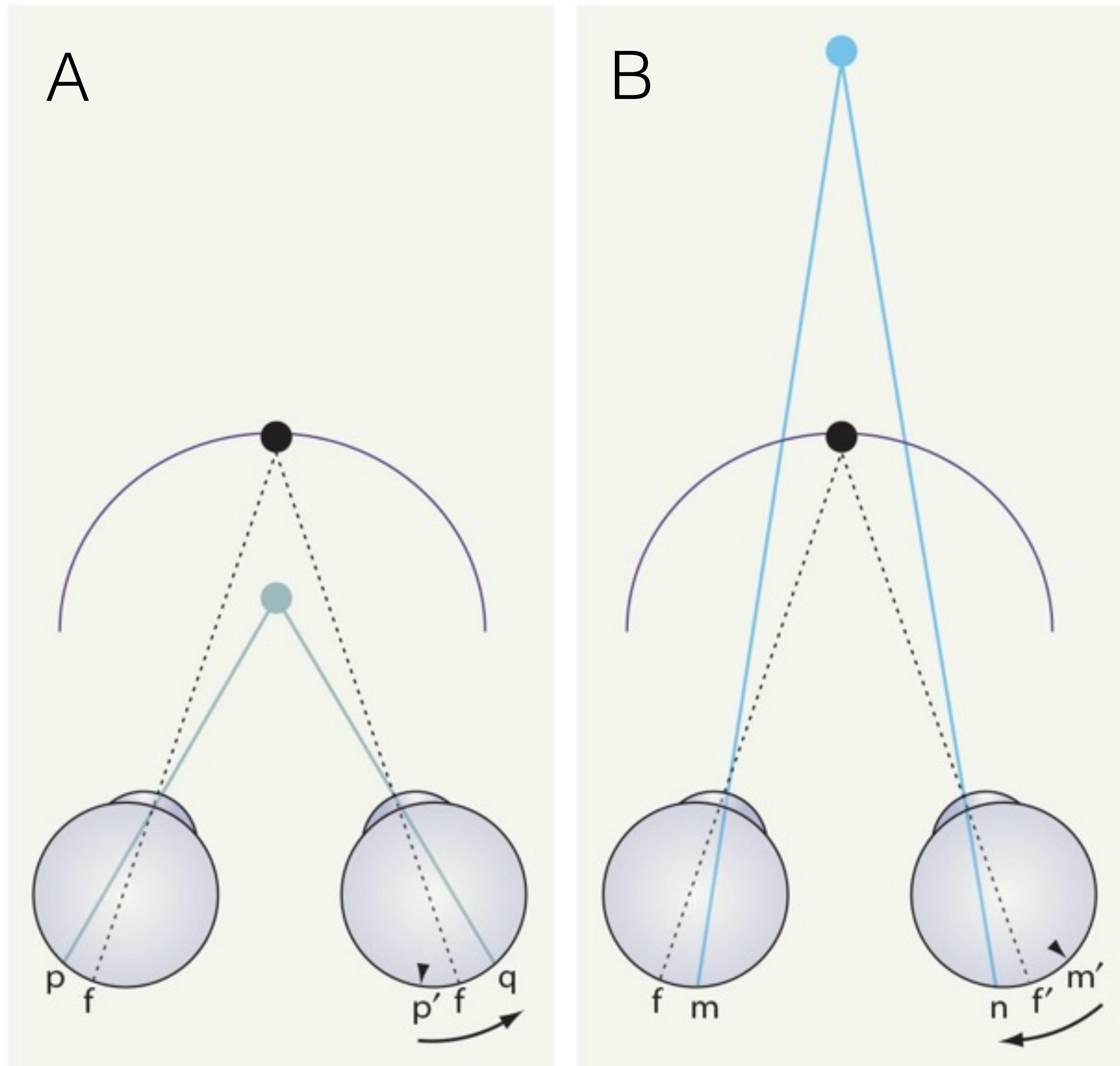
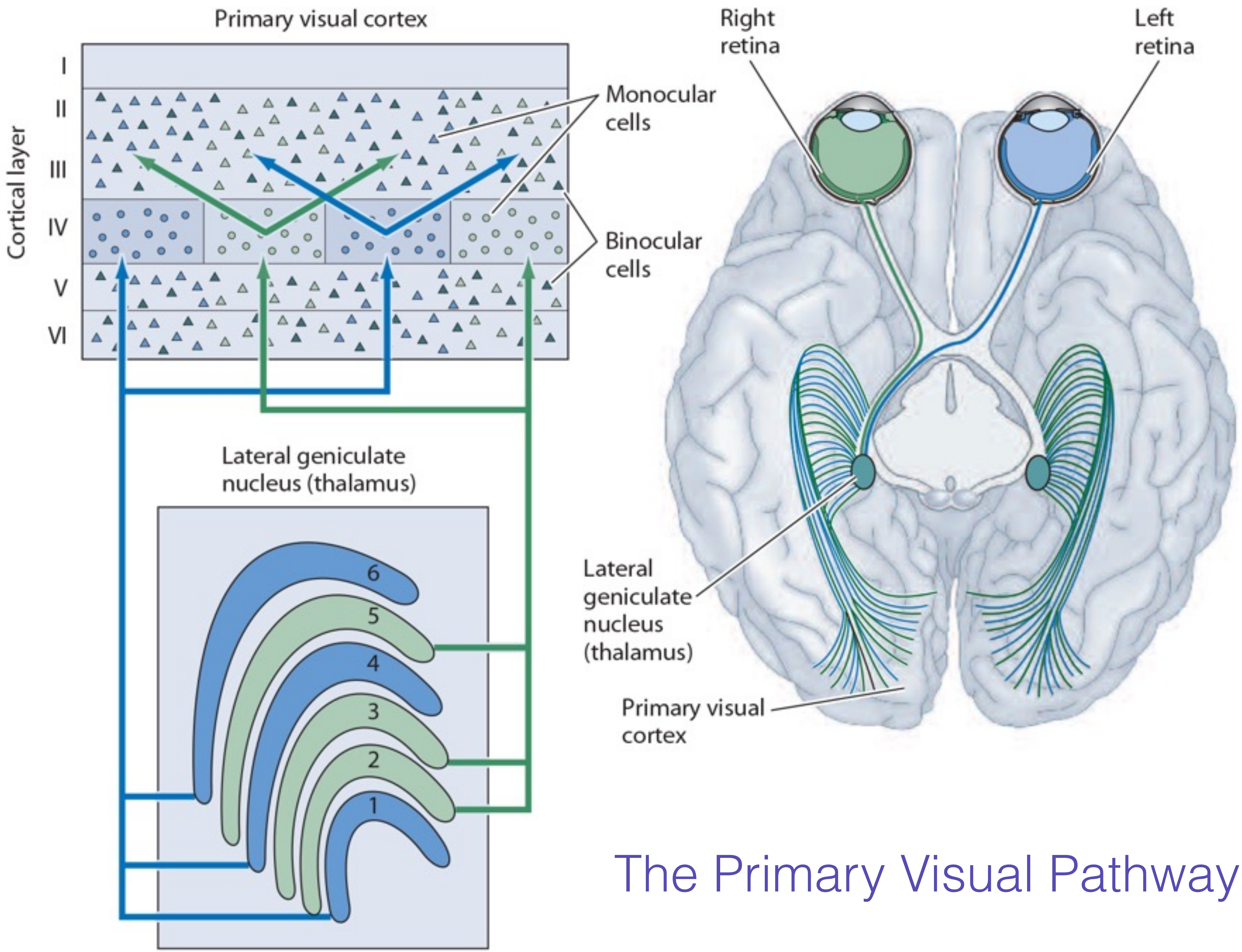
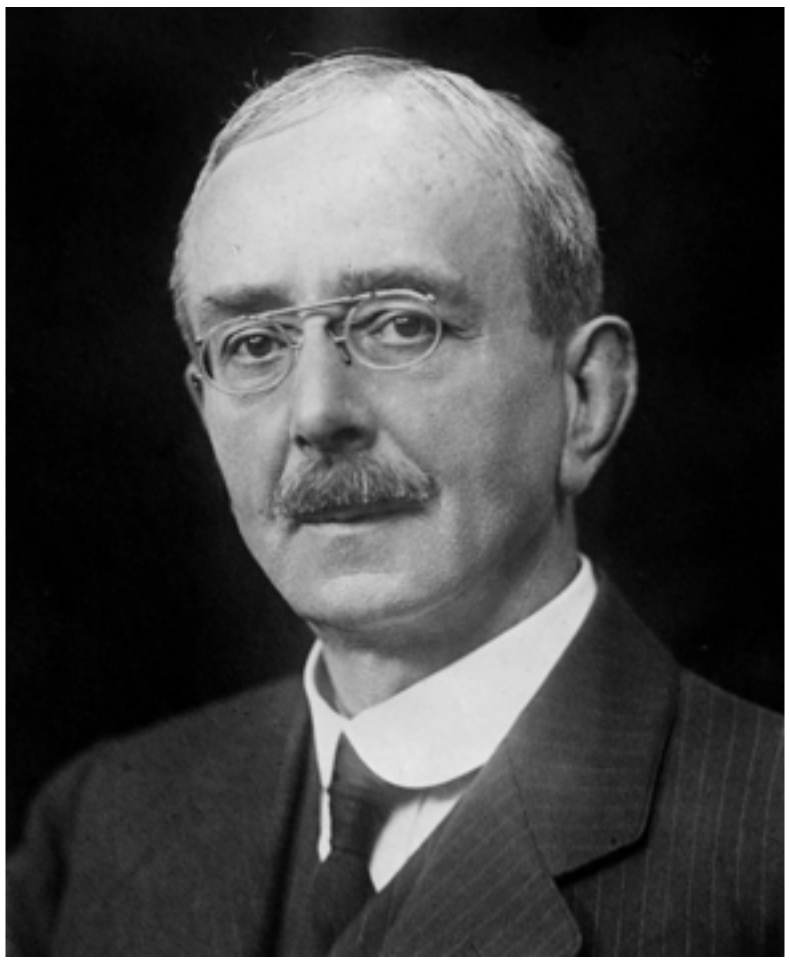


Lesson 7. Binocular Fusion

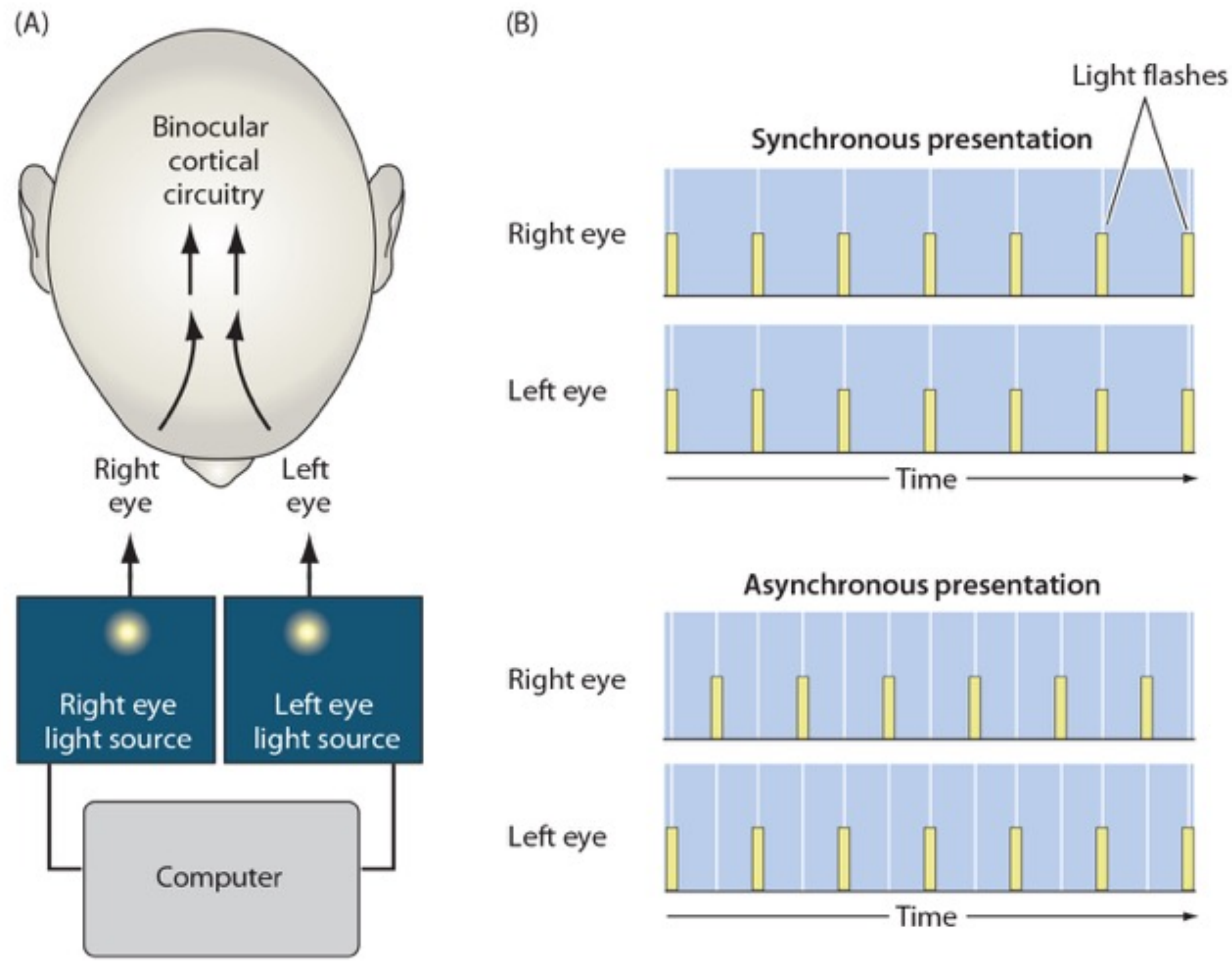


The Primary Visual Pathway

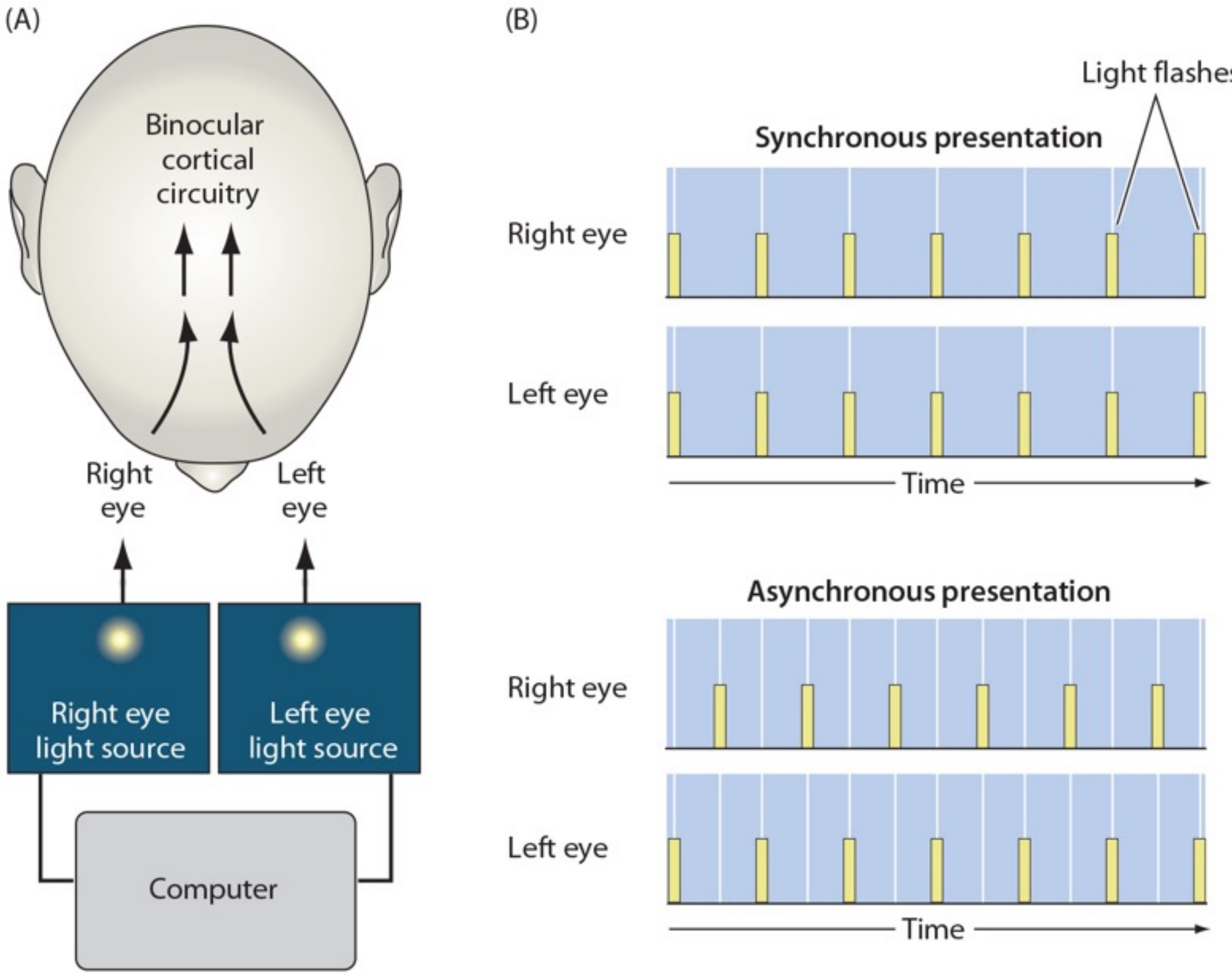
Another Strange Observation: The Perception of Light Flashes



Charles Sherrington
(1857–1952)



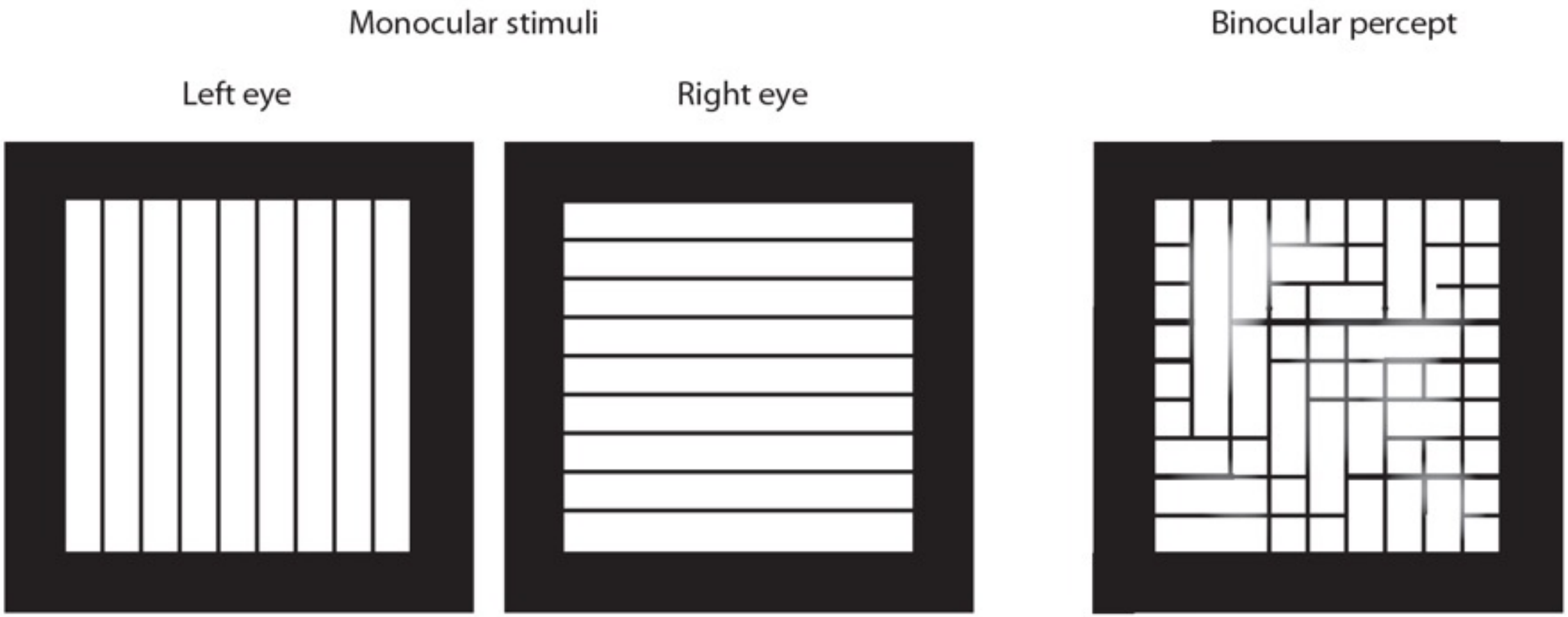
Flicker-fusion rate



Flicker-fusion rate

Lesson 8. Binocular Rivalry

Things are not so simple

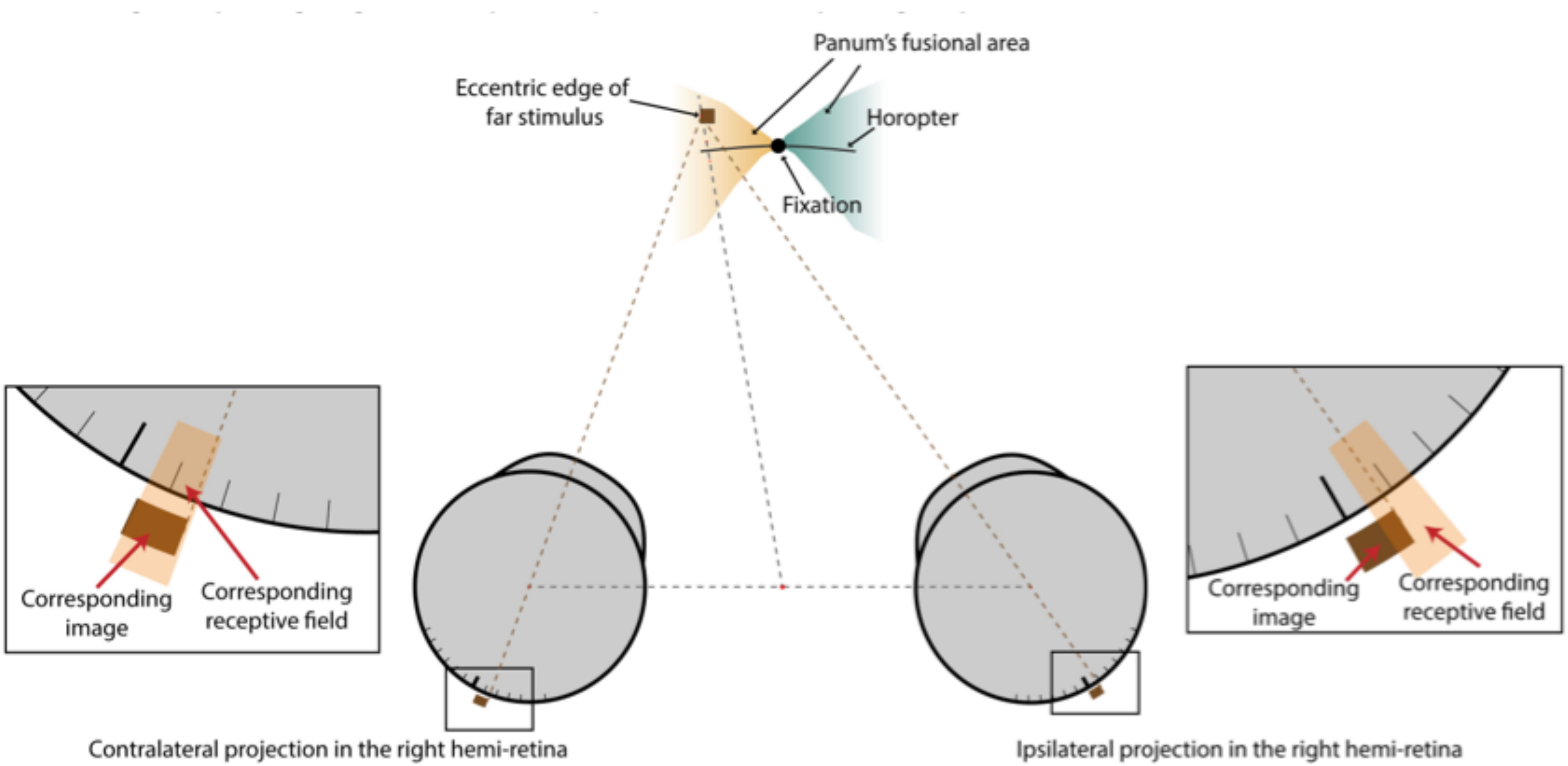


Upshot: Not clear how the views of the two eyes come together for perception

Lesson 9. Is there an Empirical Explanation of these Related Binocular Phenomena?

Could there be a way around the correspondence problem, and a simpler explanation of stereopsis?

Maybe retinotopy is the answer



Summary of the Main Points

- The real-world sources of images can't be known directly; nonetheless, we must behave in terms of the real world and it properties
- The apparent solution we are going to consider is that percepts are not generated on the basis of feature detection and representation, but on the basis of accumulated trial and error experience

Summary of the Main Points

- Distance is made apparent by a number of monocular cues
- Depth (stereopsis) is determined by the different views of the two eyes
- The perceptual phenomenology of stereopsis presents many puzzles

Summary of the Main Points

- The idea that stereo depth is based on matching right and left eye image points is undermined by the correspondence problem, but what should take its place is not clear
- How the views of the two eyes come together in the visual brain is also mysterious

Credits

Dale Purves, R. Beau Lotto. *Why We See What We Do Redux*, Sinauer Associates Inc. 2011

- Motion parallax, pg. 127
- Perception vs. physical measurements, pg. 129
- Motion parallax, pg. 127

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Dale Purves, R. Beau Lotto. *Why We See What We Do Redux*, Sinauer Associates Inc. 2011

- Distributions of physical distances at different elevation angles, pg. 133
- Stereopsis and stereoscope viewer, pg. 135
- Wheatstone’s “pseudoscope”, pg. 147
- Stereopsis and stereoscope viewer, pg. 135
- Binocular disparity, pg. 145

Credits, Cont.

The Discovery of “Near” and “Far” Neurons in the Visual Cortex, Dale Purves, R. Beau Lotto. *Why We See What We Do*, Sinauer Associates Inc. 2003, pg. 174

- Bela Julesz, CC BY 2.5 Rutgers University

Dale Purves, R. Beau Lotto. *Why We See What We Do Redux*, Sinauer Associates Inc. 2011

- Breaking camouflage, pg. 149
- Binocular disparity, pg. 145
- The Primary Visual Pathway, pg. 137
- Flicker-fusion rate, pg. 141
- Monocular stimuli and binocular percept, pg. 138
- Retinotopy, ©2014 Dale Purves