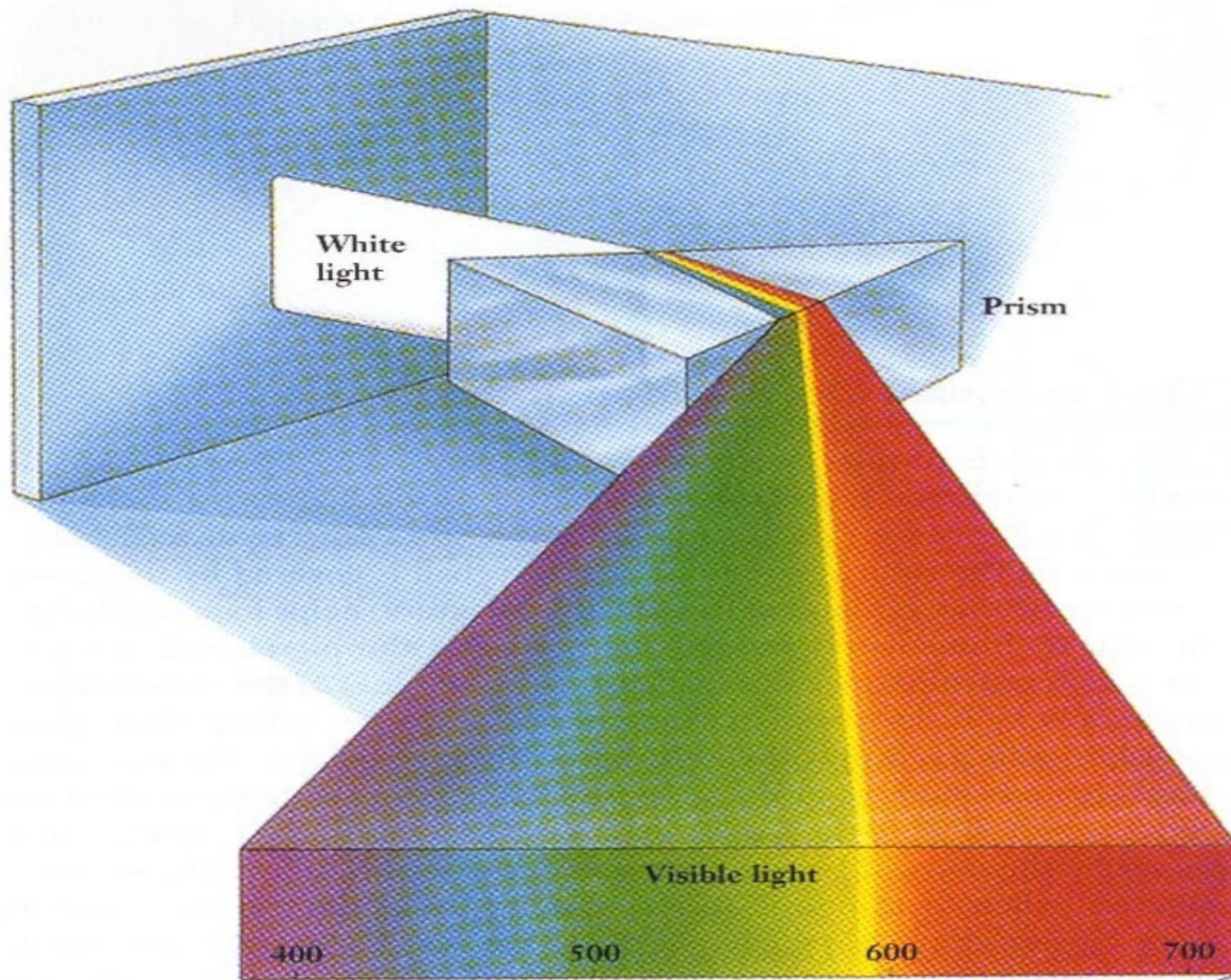# Perception

Fiser

What will be covered and why?

- Why to study perception when I am interested in joint action, social cognition or cultural diversity?

- What shall we cover to be useful?

  - Cover basic logic, dominant and/or promising framework, general rules

  - Do not cover specifics, the full scope of proposed ideas
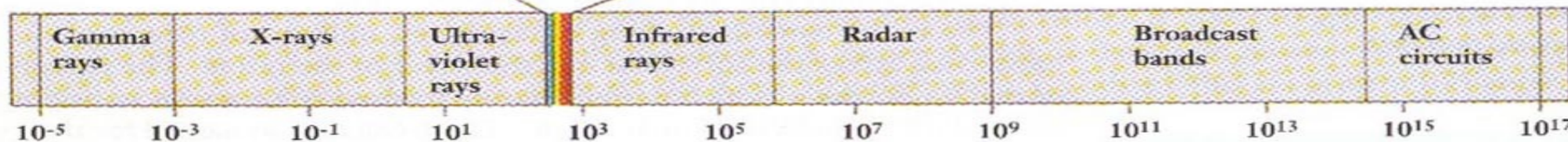
  ### So those are not important?

- How does the Marr chapter fit into this argument?

What is perception?

- Case study: Is visual perception for capturing the outside world?

White light

Prism

Visible light

400   500   600   700

Gamma rays	X-rays	Ultra-violet rays	Infrared rays	Radar	Broadcast bands	AC circuits

10^{-5} 10^{-3} 10^{-1} 10^{1} 10^{3} 10^{5} 10^{7} 10^{9} 10^{11} 10^{13} 10^{15} 10^{17}

Wavelength in nanometers (billionths of a meter)

- Visible light is just a fraction of light information

- Visible light does not reflect all the information that radar, x-rays, etc. carry

- Therefore, visual perception CANNOT be used for capturing the outside world in its entirety.

Then what is perception?

- Definition:

Sensation and perception involves the study of how information is extracted and interpreted from the environment

Sensation and perception involves the study of how (some) information is extracted and interpreted from the environment (for our specific purposes)

Consequences

- Old view:

    Capture AS MUCH INFORMATION as you can, work from there to restore what is out there

- New view:

    Capture AS LITTLE INFORMATION as you can, which is still sufficient to reach your goals

Further consequences

- Perception is a biological process:

    - Sensory nerve fibers provide our only link to the outside world

    - Our perceptual worlds are different from our physical worlds because certain environmental events cannot be detected by our sensory channels

- Perception is a psychological process:

    - Perception relies on symbolic representations of latent quantities
        - ~ Environmental stimuli trigger neural activity
        - ~ Neural patterns are symbols for environmental events that occur in the physical world
        - ~ Perception is the interpretation of neural symbols

Biological, psychological and computational approaches to perception

- **Biological Approaches** (anatomy, physiology, biochemistry, molecular biology and imaging)

- **Psychological Approaches** (behavior)

- **Computational Approaches** (modeling underlying causes, and possible mechanisms)

Which one is the best?

Further consequences

- **Definition of sensation:**

  - Input of sensory information

  - Process of receiving, converting, and transmitting information from the outside world

- **Definition of perception:**

  - Process of selection, organization and interpretation of the incoming information

- **Definition of cognition:**

  - Process of utilisation of presently and formally perceived information for achieving goals
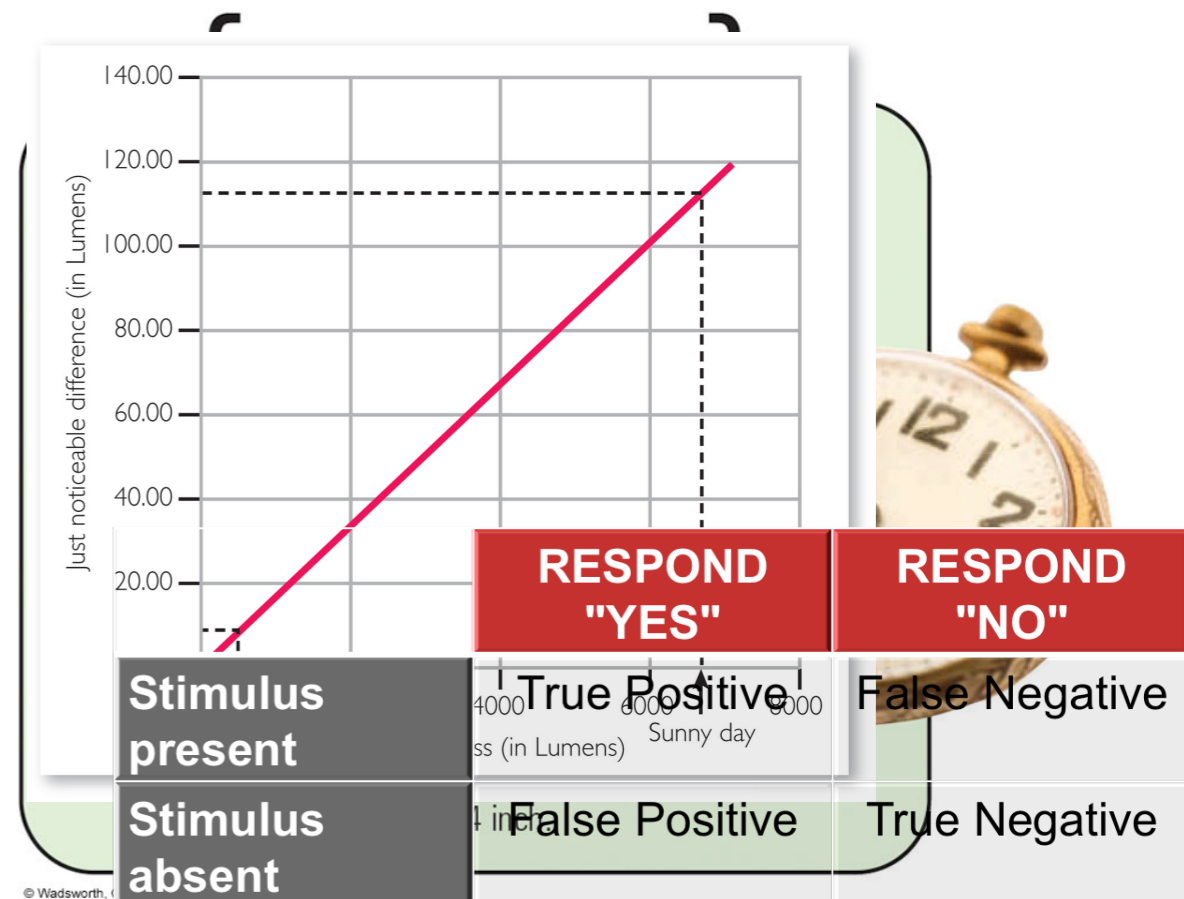
How separable are these?

Sensation

- **Despite their differences, all our senses rely on a handful of principles.**

  - The external stimulus is converted by a sense receptor into neural activity via transduction.
  - Activation is highest when stimulus is first detected, then sensory adaptation occurs.
  - Sensation is explored by psychophysics, the study of we perceive sensory stimuli based on their physical characteristics
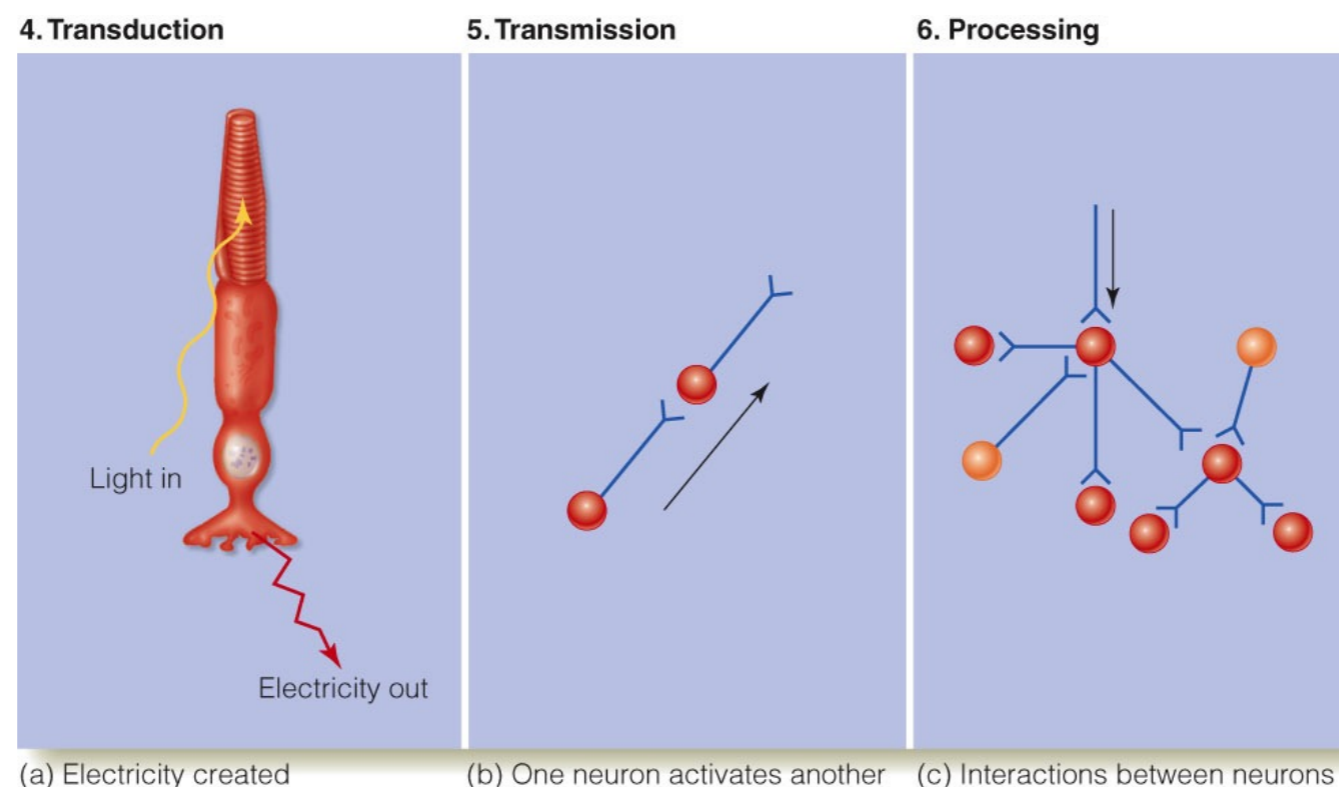
Psychophysics

- Most typical tool: finding absolute thresholds, the lowest level of a stimulus we can detect 50% of the time

- Another typical tool: finding the just noticeable difference, i.e the smallest amount of stimulus change we can detect.

- JNDs obey Weber's Law:

- Psychophysics typically handled by Signal Detection Theory, which is built on how stimuli are detected under different conditions
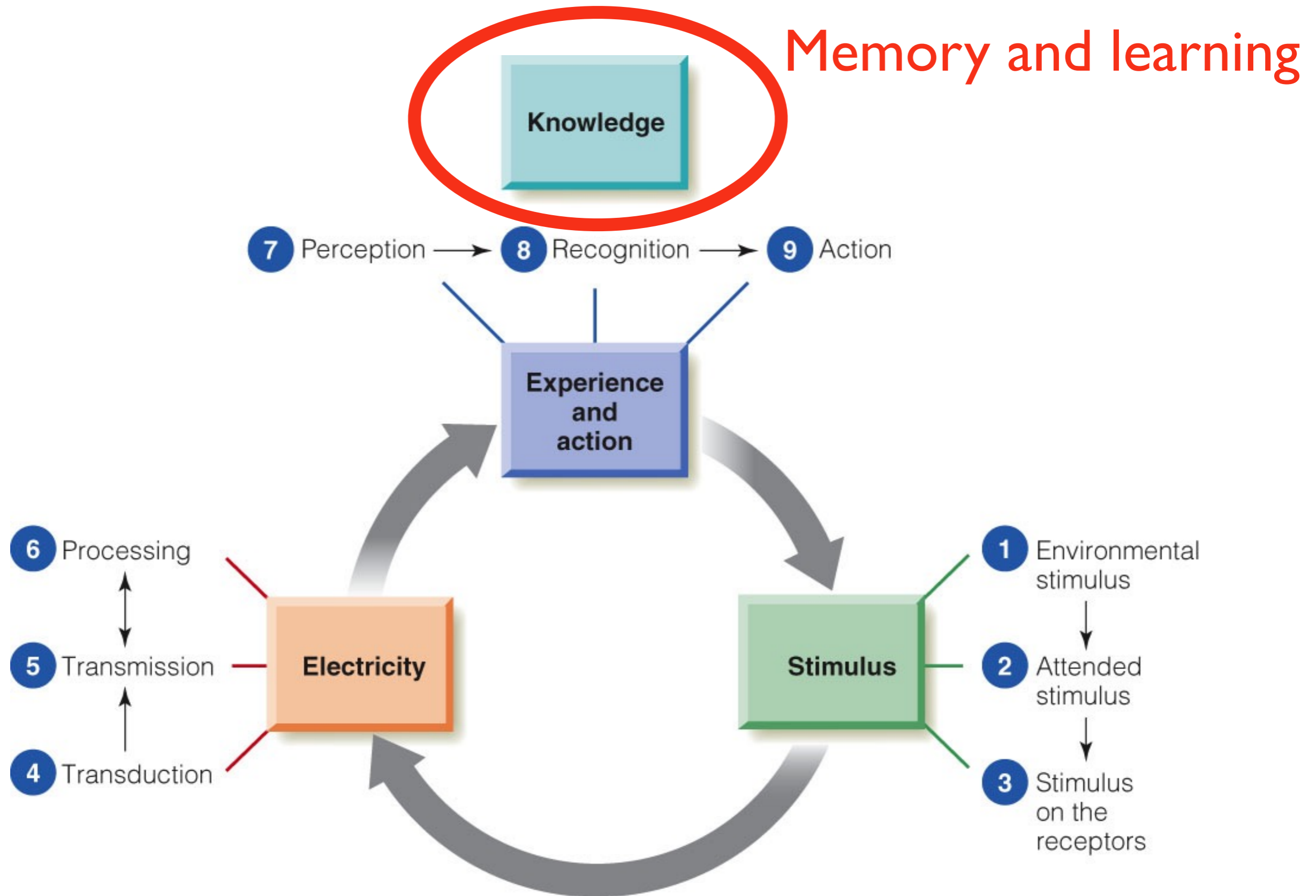

	RESPOND "YES"	RESPOND "NO"
Stimulus present	True Positive	False Negative
Stimulus absent	False Positive	True Negative

From sensation to perception

- **Three types of processes are the building blocks**
  - Transduction: it changes environmental energy to nerve impulses
  - Transmission occurs when signals from the receptors travel to the brain.
  - Processing: occurs during interactions among neurons in the brain

4. Transduction   5. Transmission   6. Processing

Light in

Electricity out

(a) Electricity created   (b) One neuron activates another   (c) Interactions between neurons

The entire loop from sensation to perception

Memory and learning

Knowledge

7 Perception → 8 Recognition → 9 Action

Experience and action

6 Processing

5 Transmission

4 Transduction

Electricity

Stimulus

1 Environmental stimulus

2 Attended stimulus

3 Stimulus on the receptors

Visual perception

Perception (visual)

- Process that organizes sensory impressions caused by the light that strikes our eyes

- While sensation is described as a mechanical process, perception is an active process that involves experience, expectations and motivations

- Has rudimentary theoretical frameworks, it is mostly a set of observations

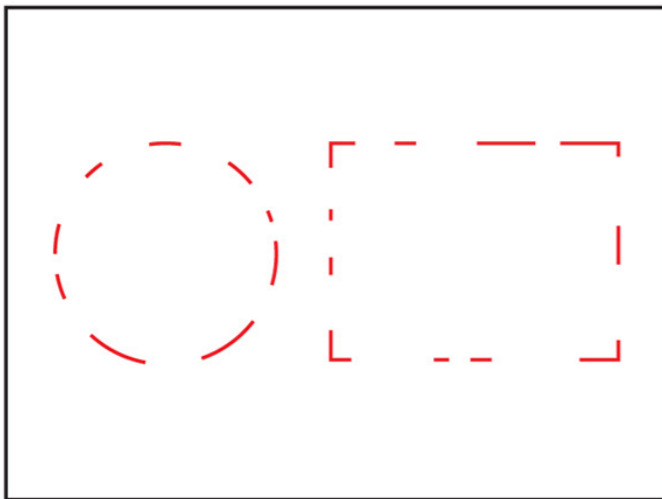# Where in the brain do we perceive things visually?

The rest: perception

Secondary visual cortex (V2) (association cortex)

Thalamus

Primary visual cortex (V1) (striate cortex)

Eye

Extrastriate cortex

Optic nerve

Secondary visual cortex (V2) (association cortex)

Sensation
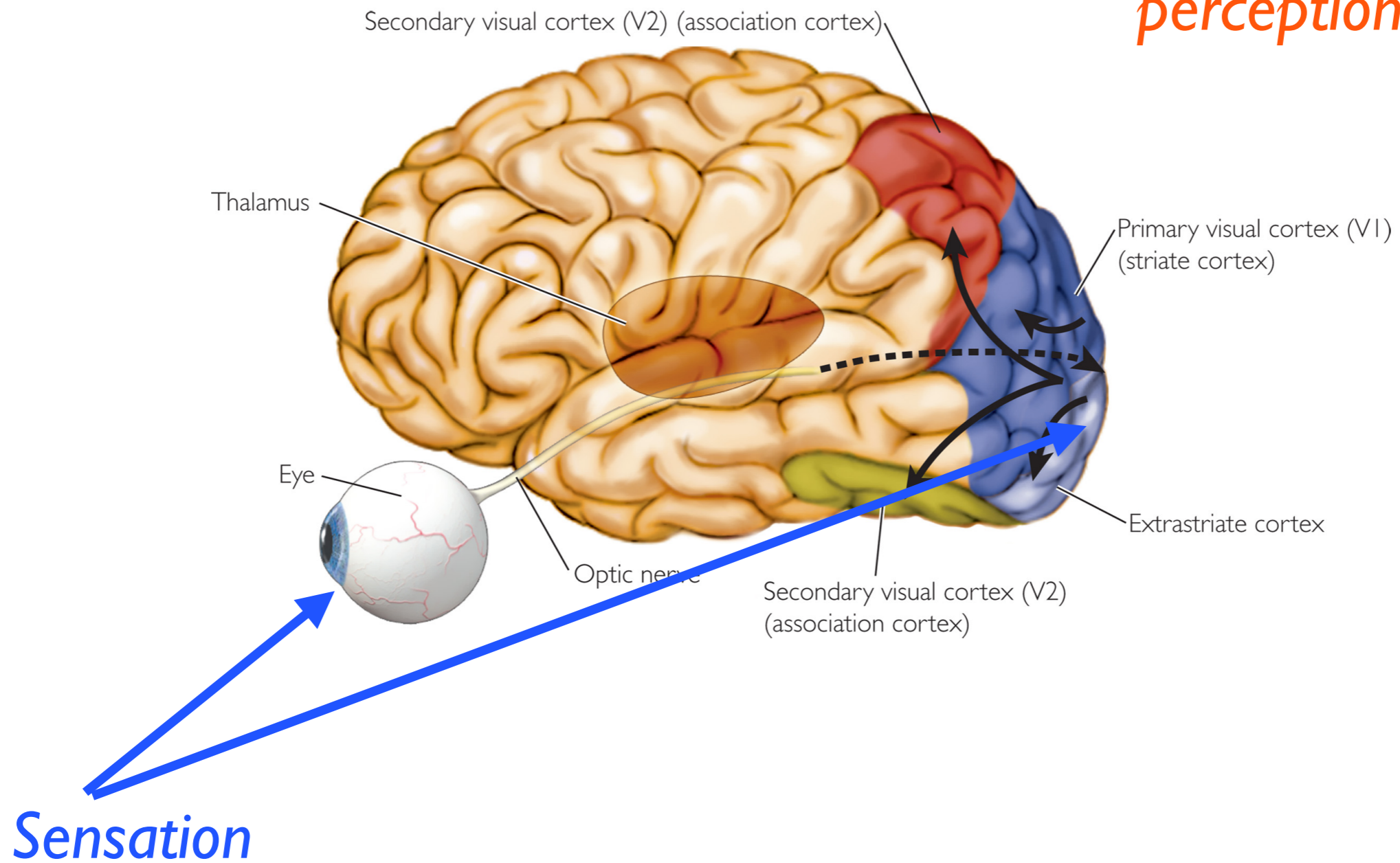
Gestalt Rules for Perceptual Organization
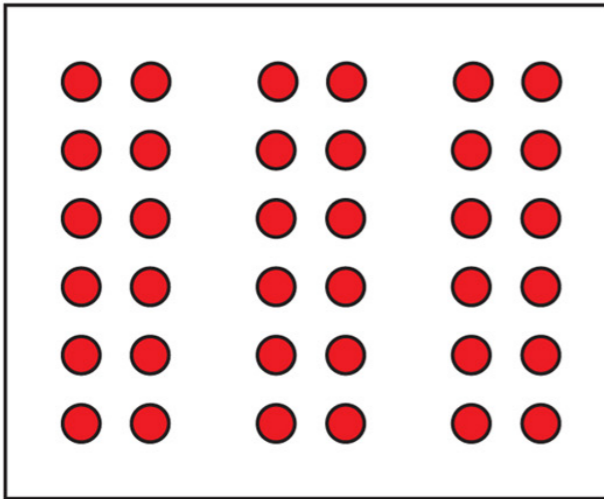
(a) Proximity
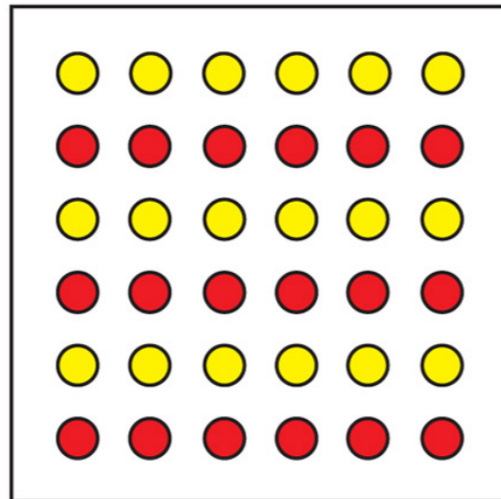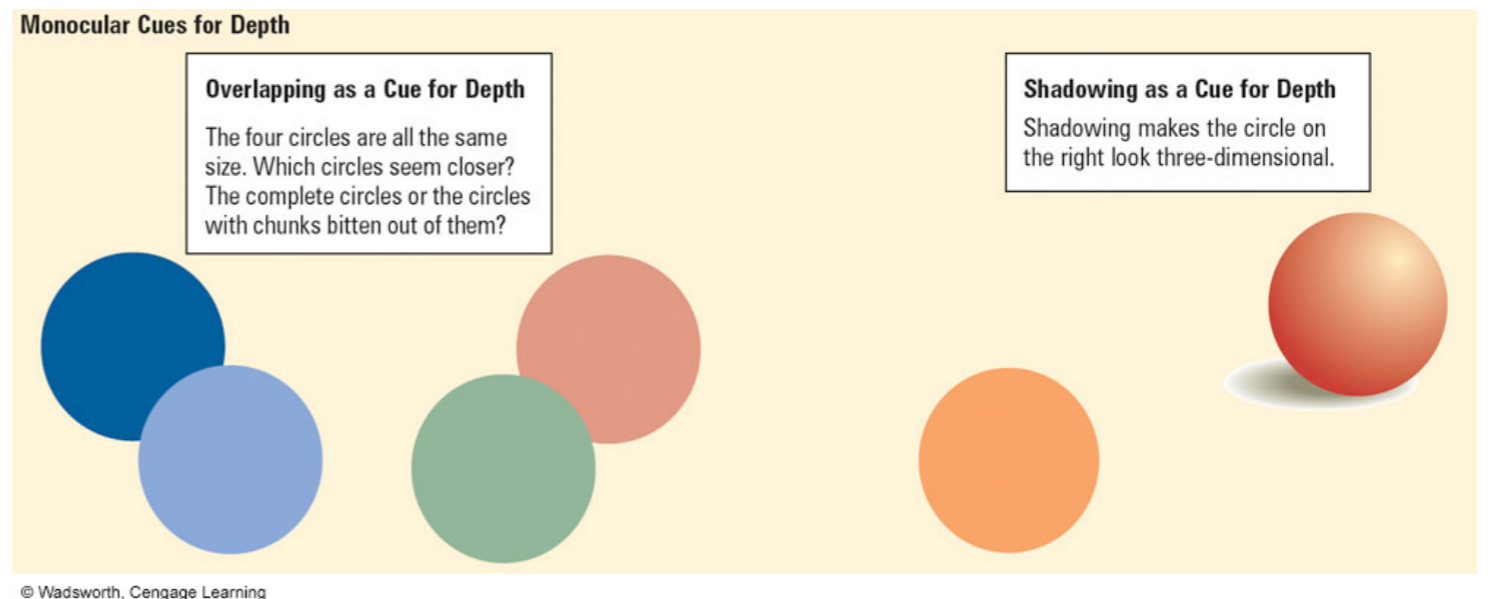
(b) Similarity
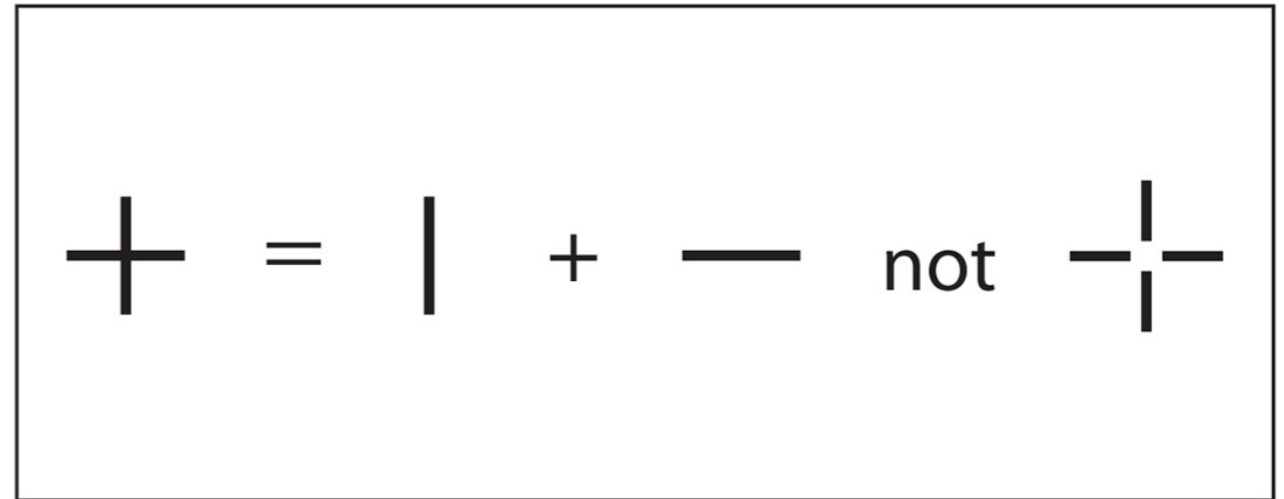
(c) Continuity

(d) Closure
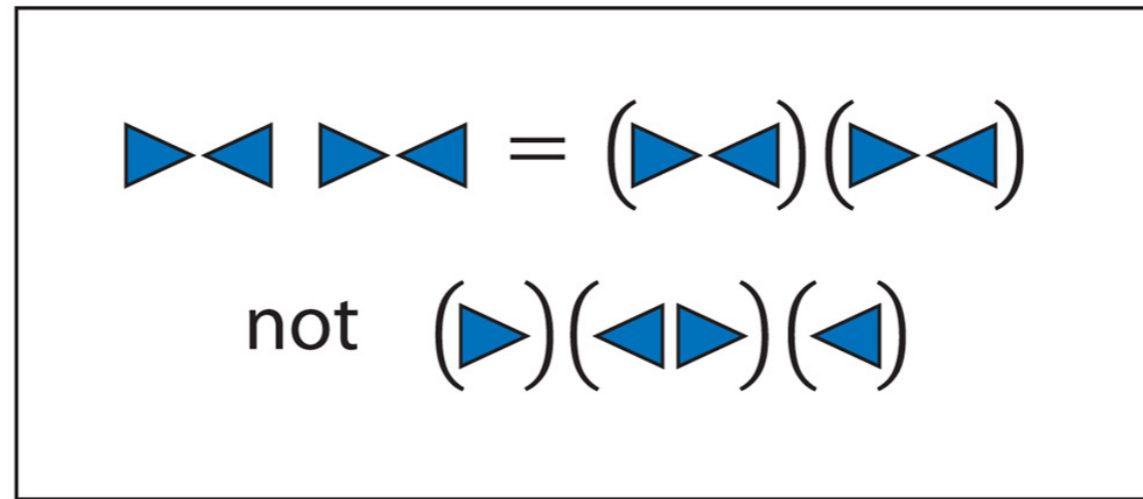
(e) Symmetry

(f) Figure–ground

Gestalt Rules for Perceptual Organization

- Common Fate
  - Elements moving together are grouped together (runners)
- Closure
  - Fit bits of information into familiar patterns;
  - Perception of a complete figure, even when there are gaps in sensory information
- Proximity
  - Nearness of objects
- Similarity
  - Similarity of objects
- Continuity
  - Series of points having unity

Special cases of complex perception: depth perception

- Monocular Cues
  - Perspective
  - Clearness
  - Overlapping
  - Shadows
  - Texture gradient
  - Motion parallax

- Binocular Cues
  - Retinal disparity
  - Convergence

Monocular Cues for Depth

Overlapping as a Cue for Depth

The four circles are all the same size. Which circles seem closer? The complete circles or the circles with chunks bitten out of them?

Shadowing as a Cue for Depth

Shadowing makes the circle on the right look three-dimensional.

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Special cases of complex perception: perceptual constancies

- Perceptual constancies allow us to perceive stimuli consistency across conditions by not seeing the size, shape, or color of an object changing despite the objective fact that they do.

- Classical constancies thought to be acquired through experience for creating stabile interpretations
  - Size Constancy
  - Color Constancy
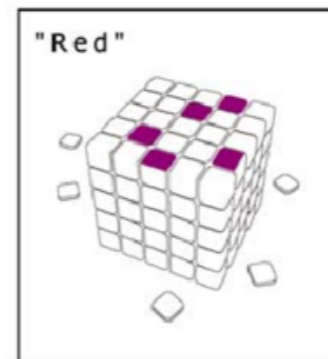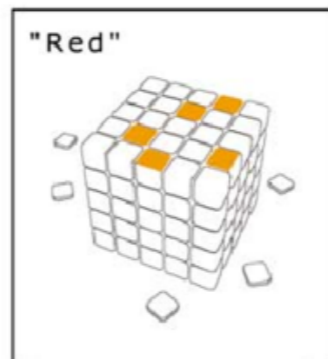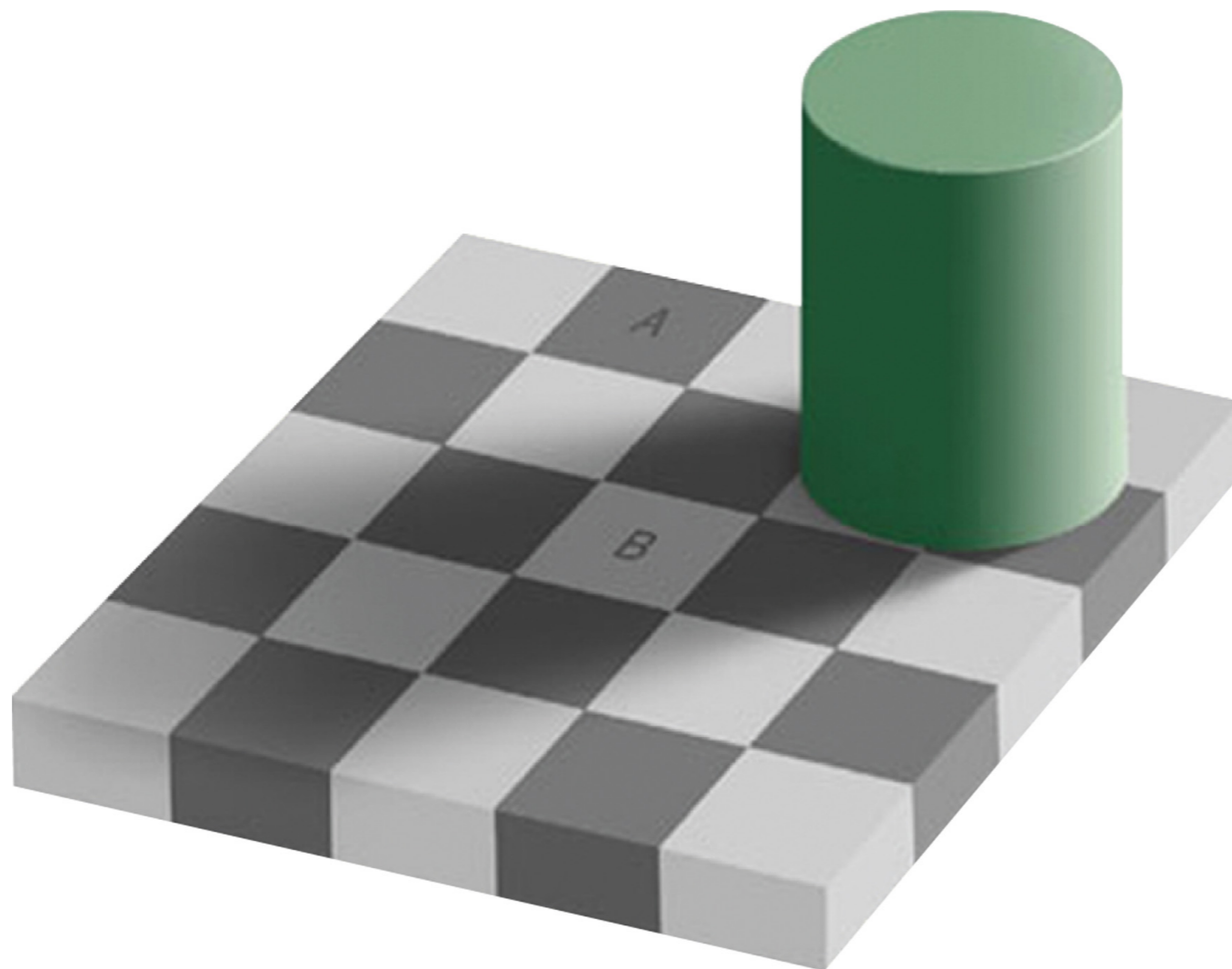 - Brightness Constancy
  - Shape Constancy

Size Constancy
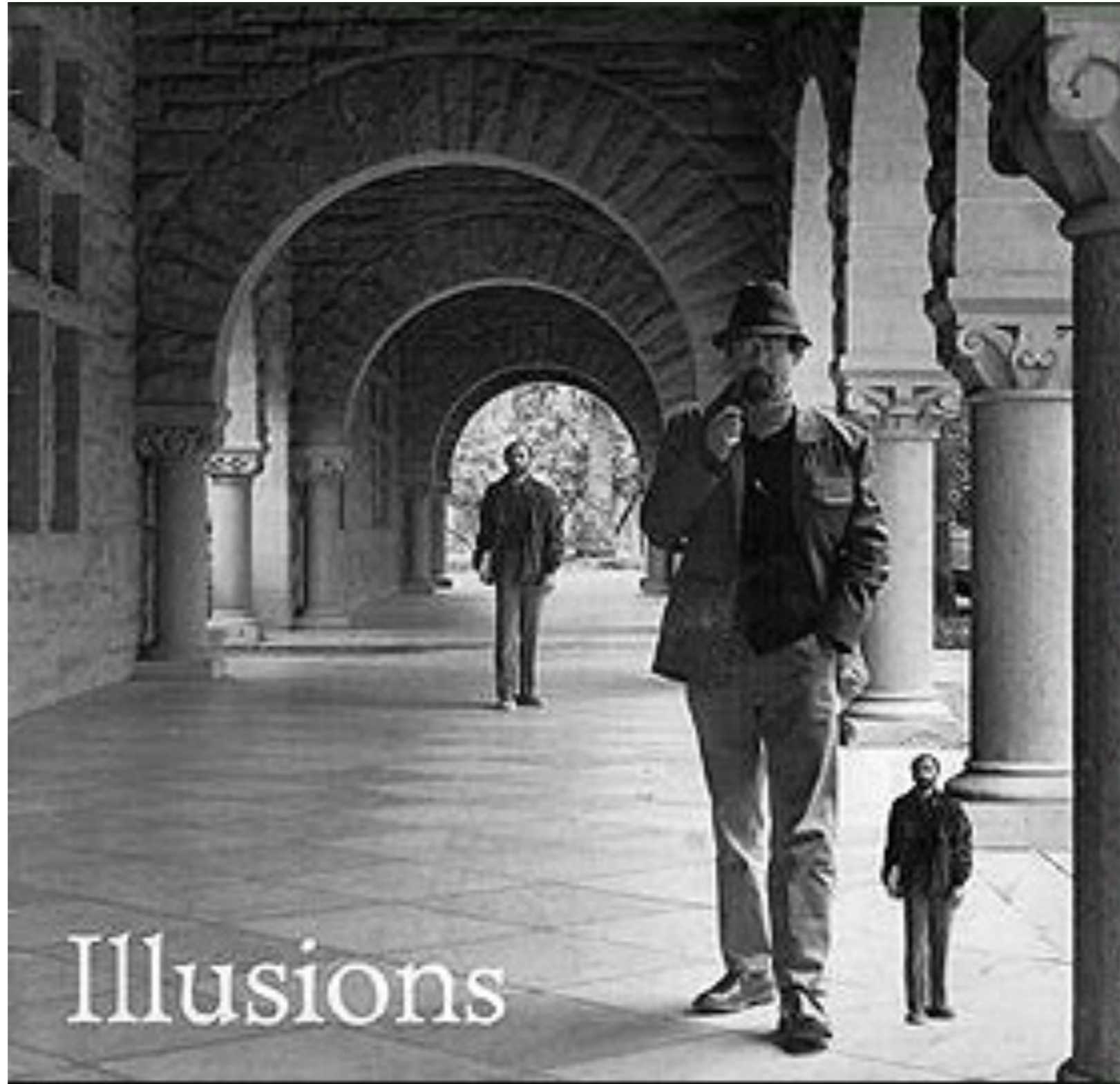
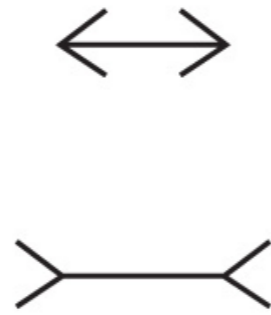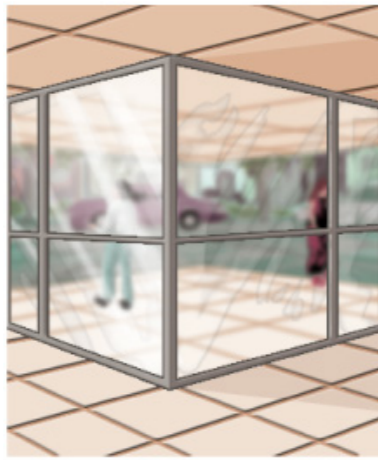Illusions

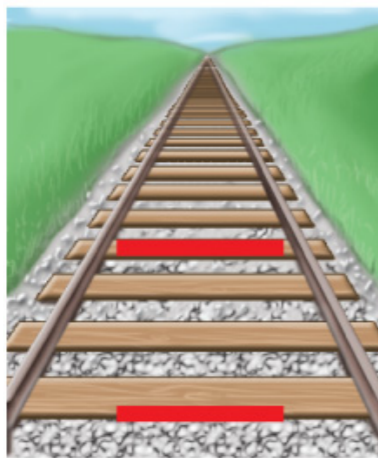# Color Constancy
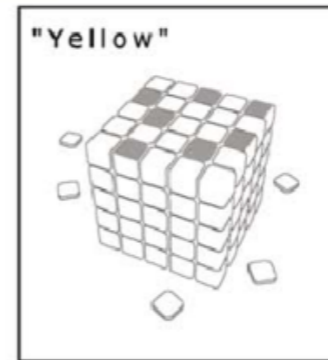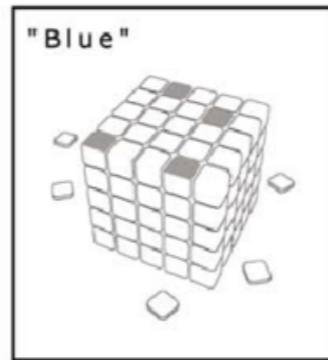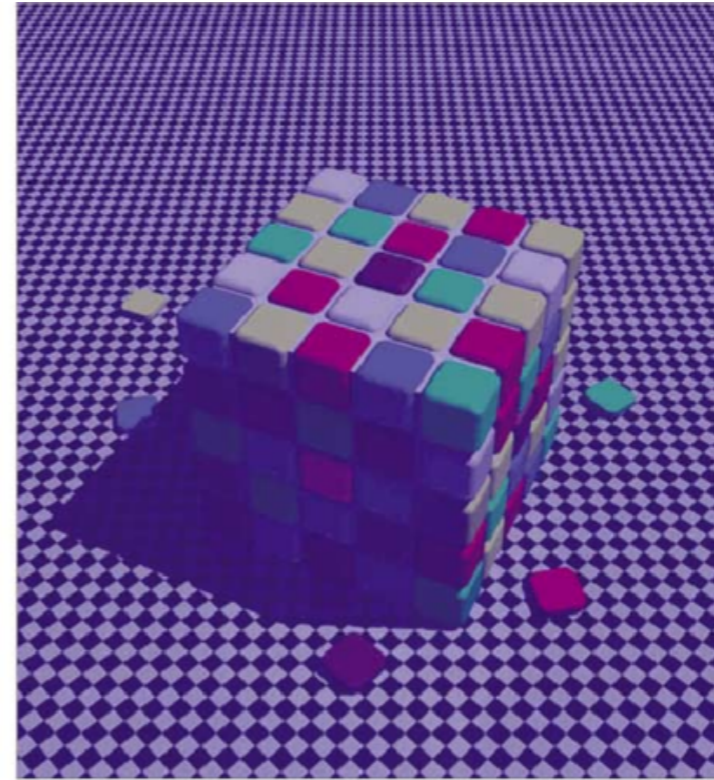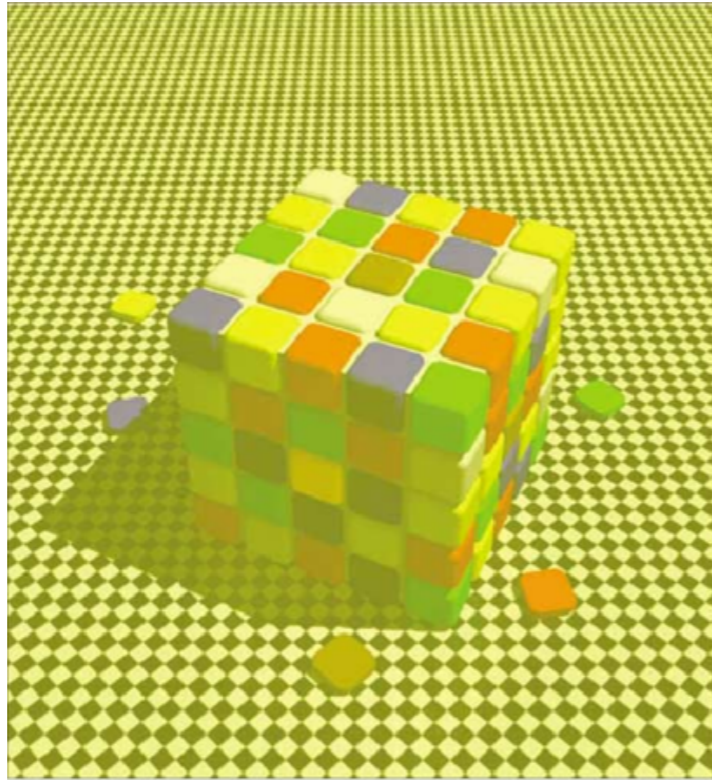
Brightness Constancy

Shape Constancy

Opposite special cases of complex perception: perceptual illusions

(a) Which horizontal line is longer?

(b) Which line above is longer, and which circle is bigger?
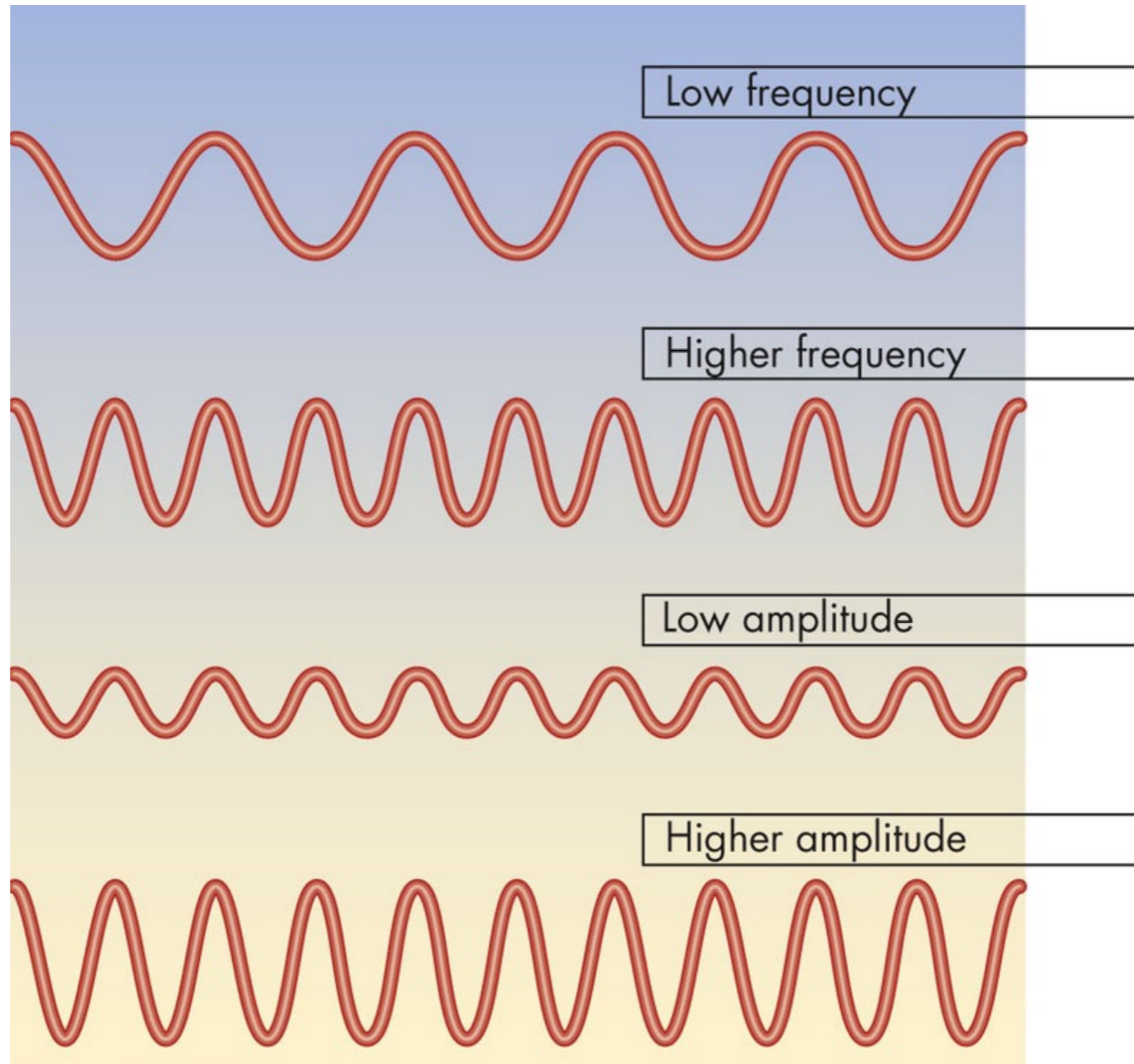
(c) Which line is longer?
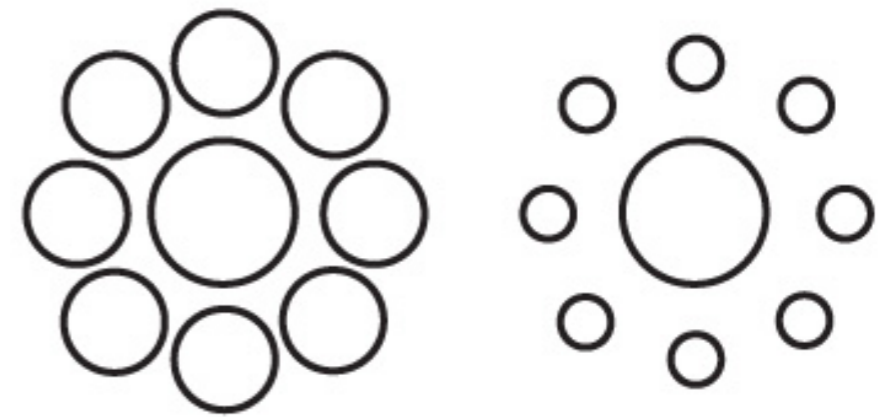
(d) Which center circle is bigger?

Auditory perception

- Sound waves require a medium; air or water
- Sound waves compress and expand molecules of the medium, creating vibrations
  - A single cycle of compression and expansion is one wave of sound
- Human ear is sensitive to sound waves with frequencies of 20 to 20,000 cycles per second
- Pitch
  - Frequency (# of cycles per second)
  - Expressed in hertz (Hz)
- Loudness
  - Height (amplitude) of sound waves
  - Expressed in decibels (dB)

Sound waves of various frequencies and amplitudes

Low frequency

Higher frequency

Low amplitude

Higher amplitude

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The human ear

Organ of Corti

Section through cochlea

Basilar membrane

Tectorial membrane

Hair cells

Hammer (malleus)

Anvil (incus)

Stirrup (stapes)

Semicircular canals

Auditory nerve

Oval window

Cochlea

Auditory nerve

Round window

Eardrum

Middle ear

Outer ear (auditory canal)

Eustachian tube

To the cortex

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Auditory perception

- Different periphery processing, same central processing

- Has the same kind of illusions, constancies as vision does

- Has the same problem: no viable model of how it works

What is missing?

- A flexible framework that can handle complex perceptual phenomena

What is a complex perceptual phenomenon?

- E.g. a method that can reconstruct the approximate shape and texture of a novel object from a single view, at a level indistinguishable to humans while it accounts quantitatively for human behavior in "hard" recognition tasks that foil conventional machine systems

Proposed solution

- Analysis-by-synthesis probabilistic approach (Yuille & Kersten 2006):
  - Bayesian inference on structured representations
  - Goal: estimate the factors that generated the image
  - Define a formalism describing how the input is generated
  - Bottom-up processing and top-dow generative component
  - Use low-level cues to access high-level MODELS

- System of bottom-up proposals validated by high-level models

Proposed solution

- Analysis-by-synthesis probabilistic approach (Yuille & Kersten 2006)

- Generative model
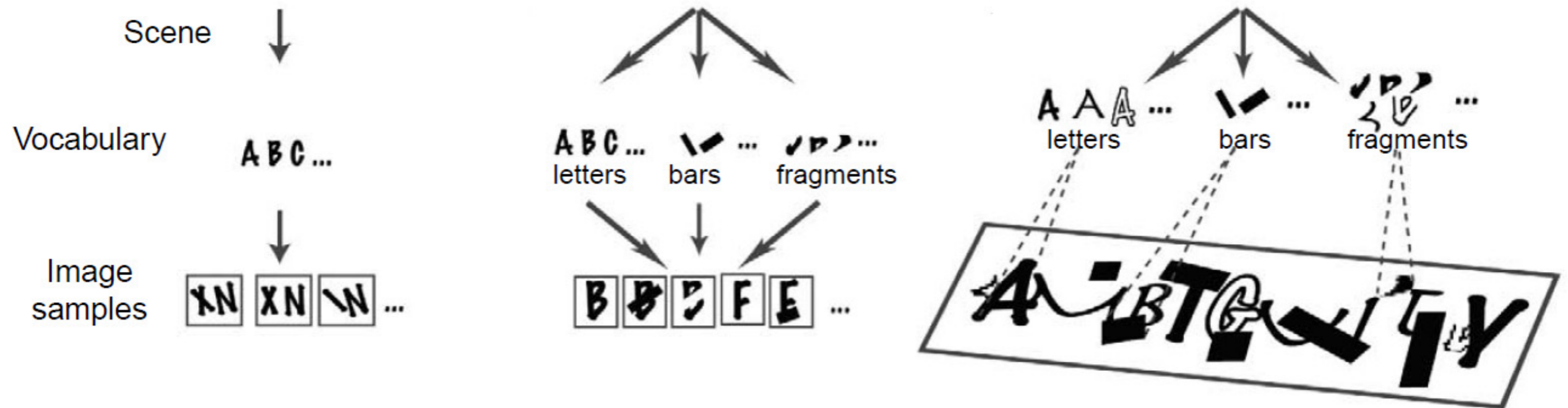
Further questions raised

- How to implement in the brain?
- Is it viable computationally?
- How does it emerge?
- …….

Answer

- See the Vision Course……

The end