ELL 788
Computational Perception & Cognition

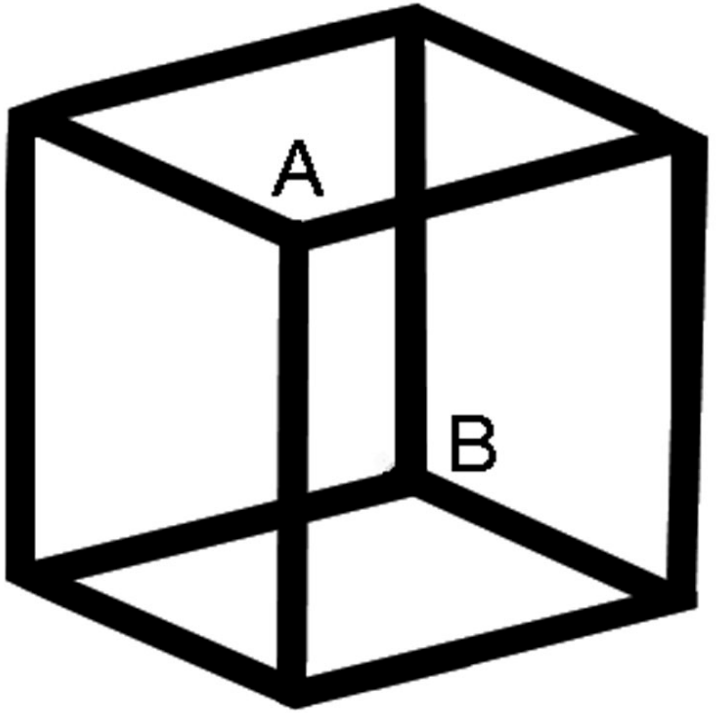
July – November 2015

Module 1-2

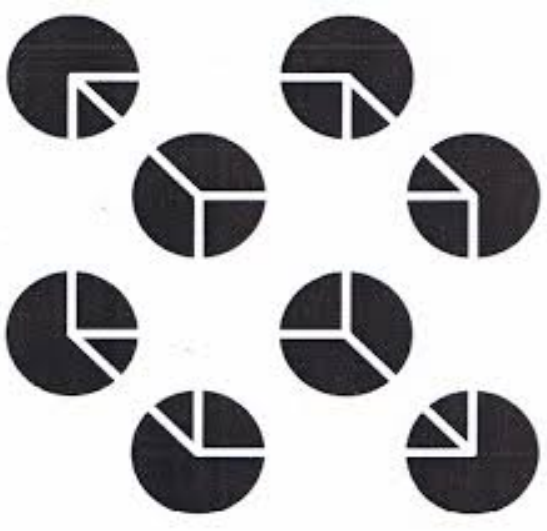
Visual perception
[Part 2]

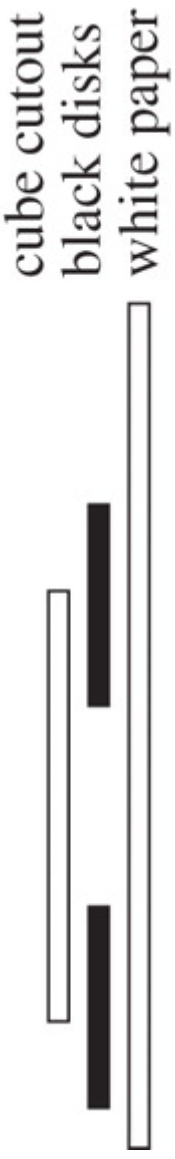
Object and ground

Multi-stability



What occludes what?



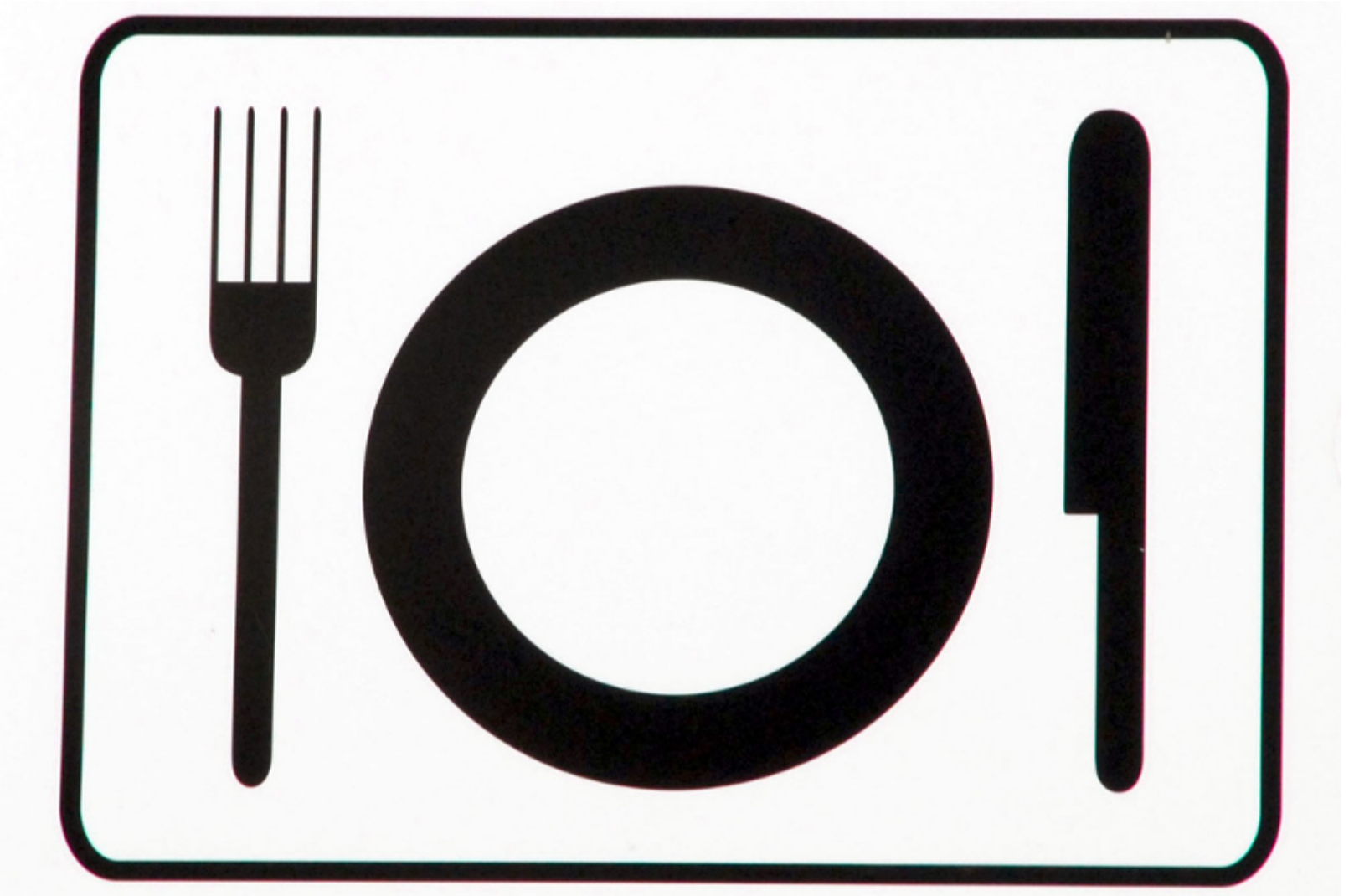


Old couple or musician by Salvador Dali (1930)

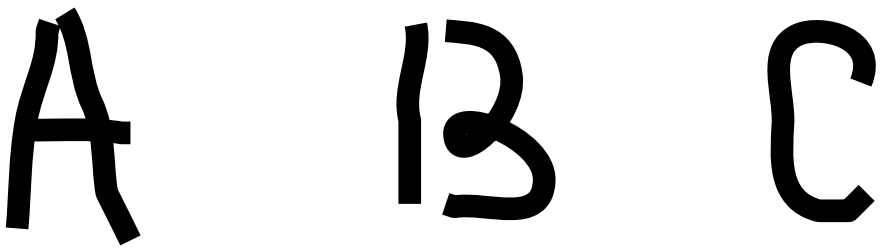
Spinning clockwise or anticlockwise ?

Context and perception

Context and perception

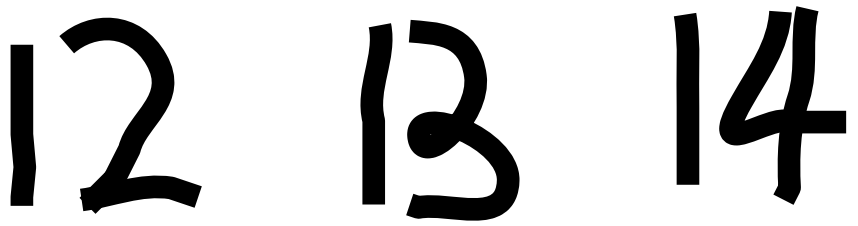


Context and perception



What is written above ?

Context and perception

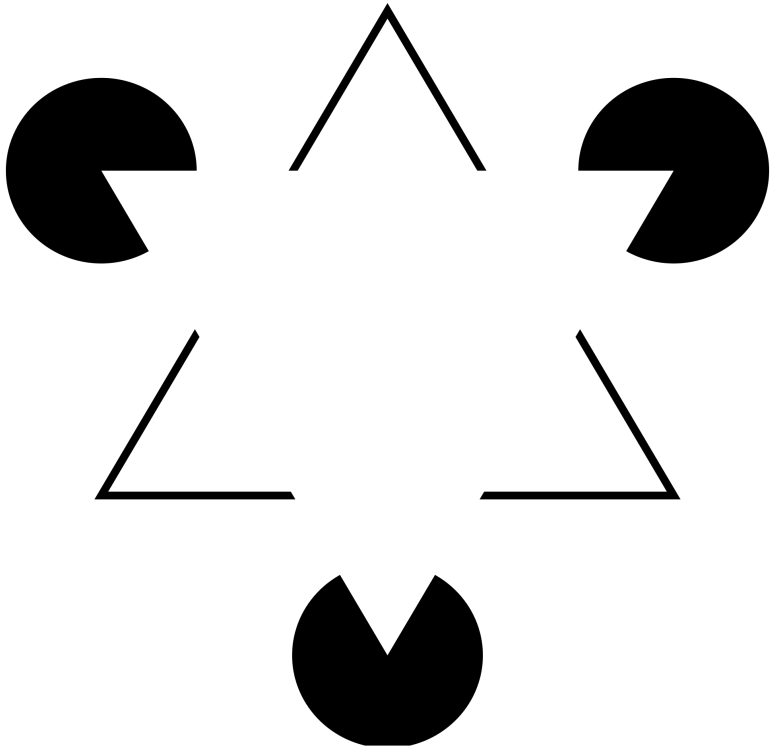


What is written above ?

Gestalt law of perceptual organization

The whole is greater than the sum of the parts

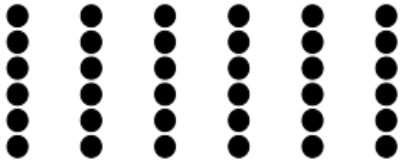
The fundamental principle of gestalt perception is the law of “prägnanz”, which says that we tend to order our experience in a manner that is regular, orderly, symmetrical, and simple.



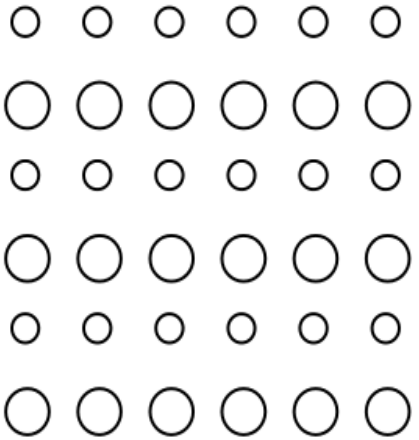
Artworks based on Gestalt principle

Gestalt principles

Proximity



Similarity

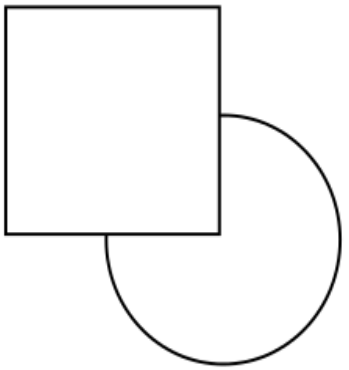


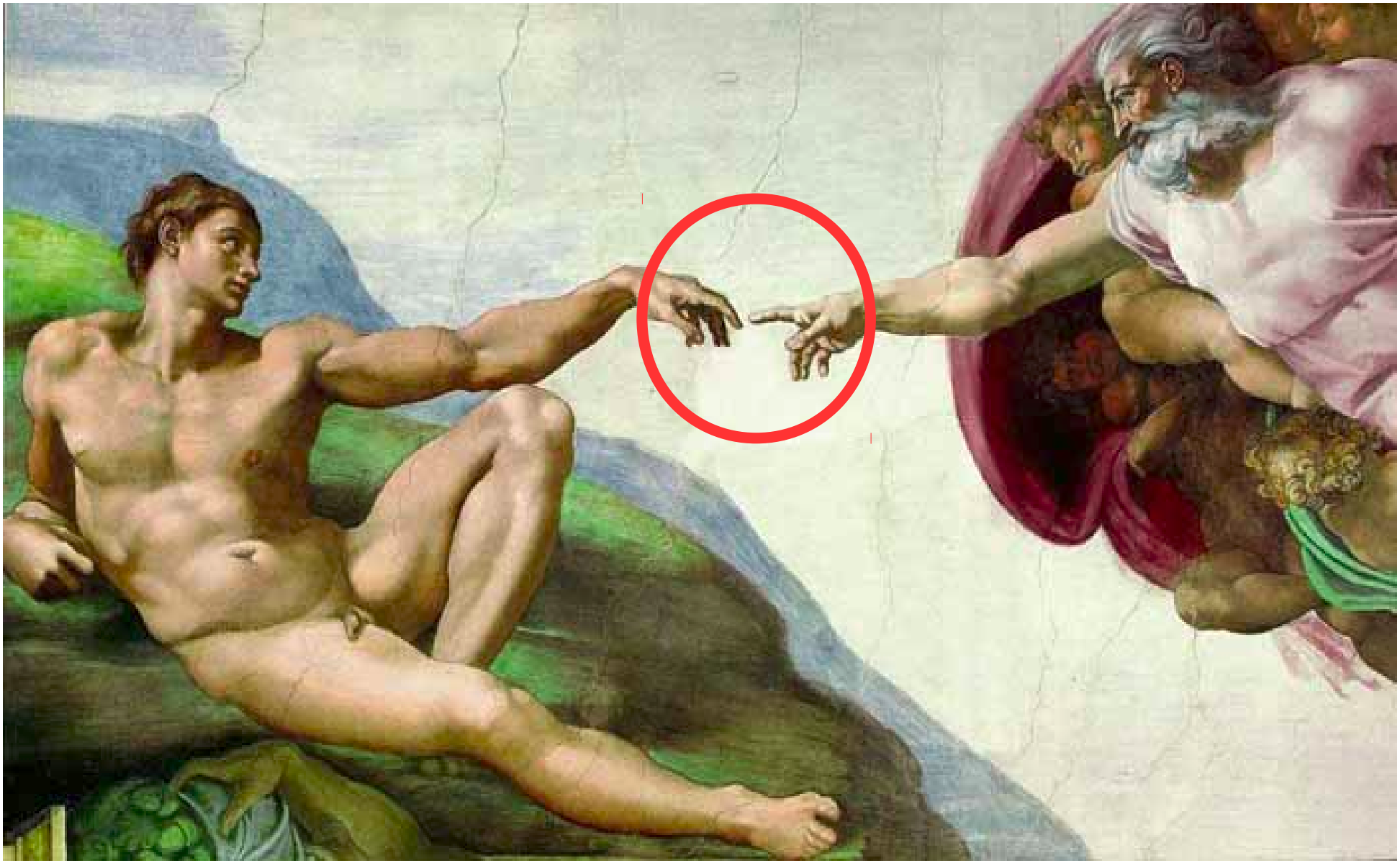
Symmetry

( ) ( )

[ ] [ ]

Closure

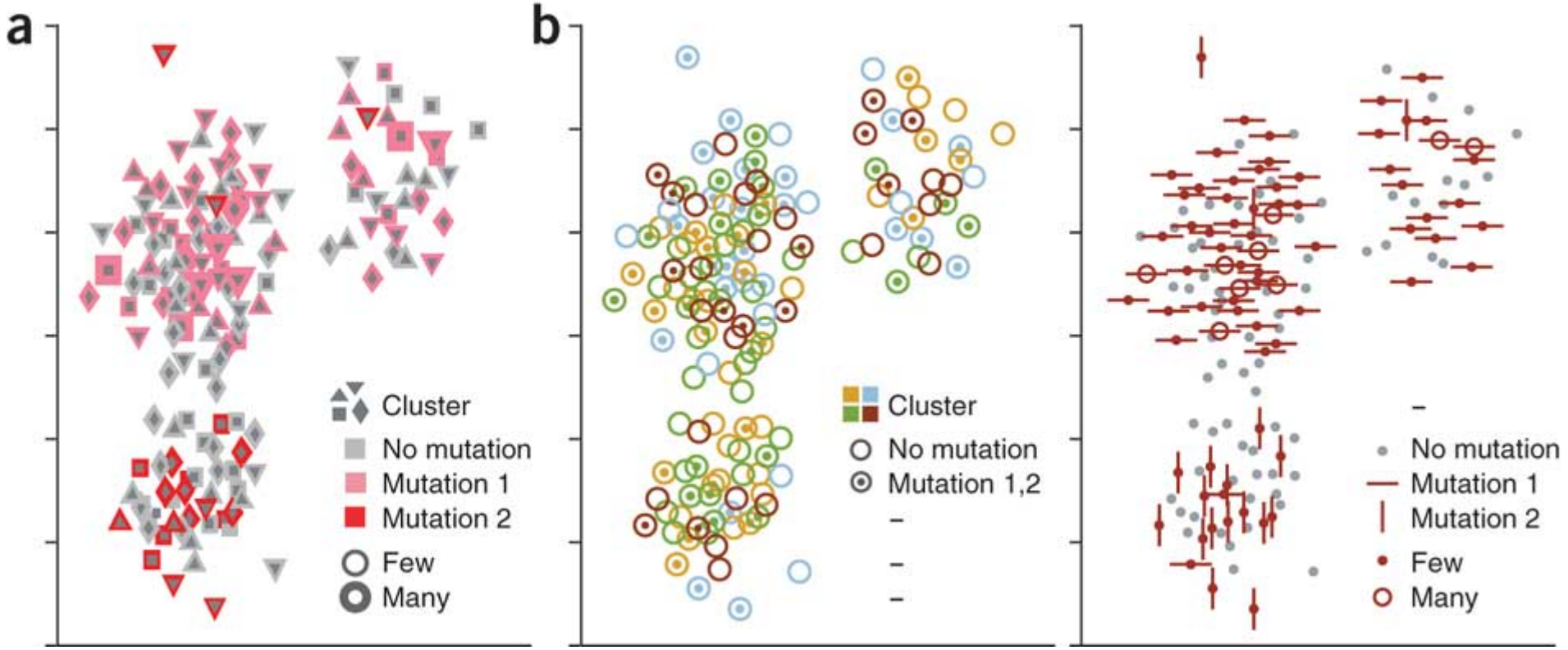




Principle of proximity

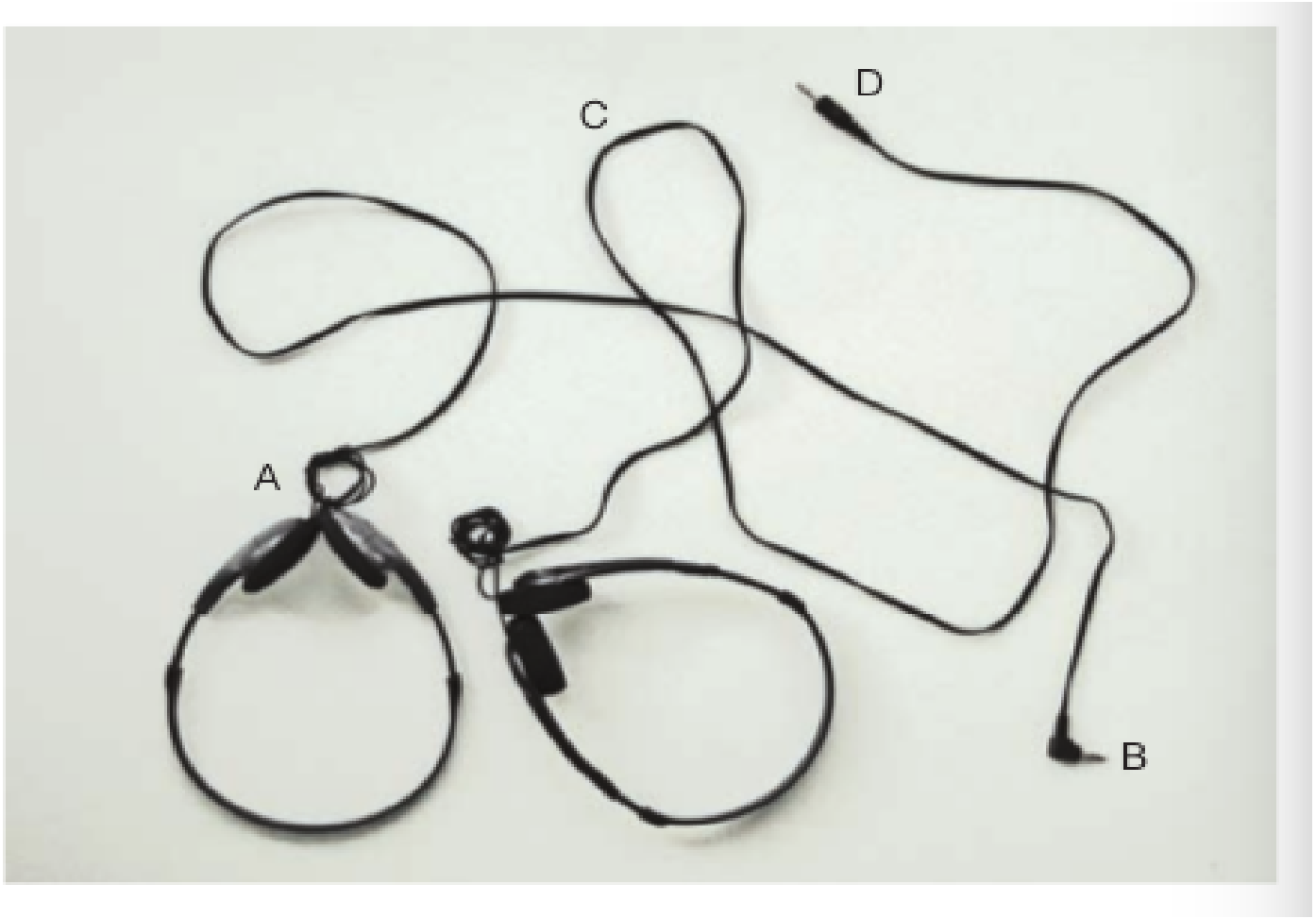
Michelangelo, Creation of Adam, c. 1510.

Application:
Graphical Data Visualization



Principle of similarity

Example



Source: Goldstein's e-book

Continuation

Another example

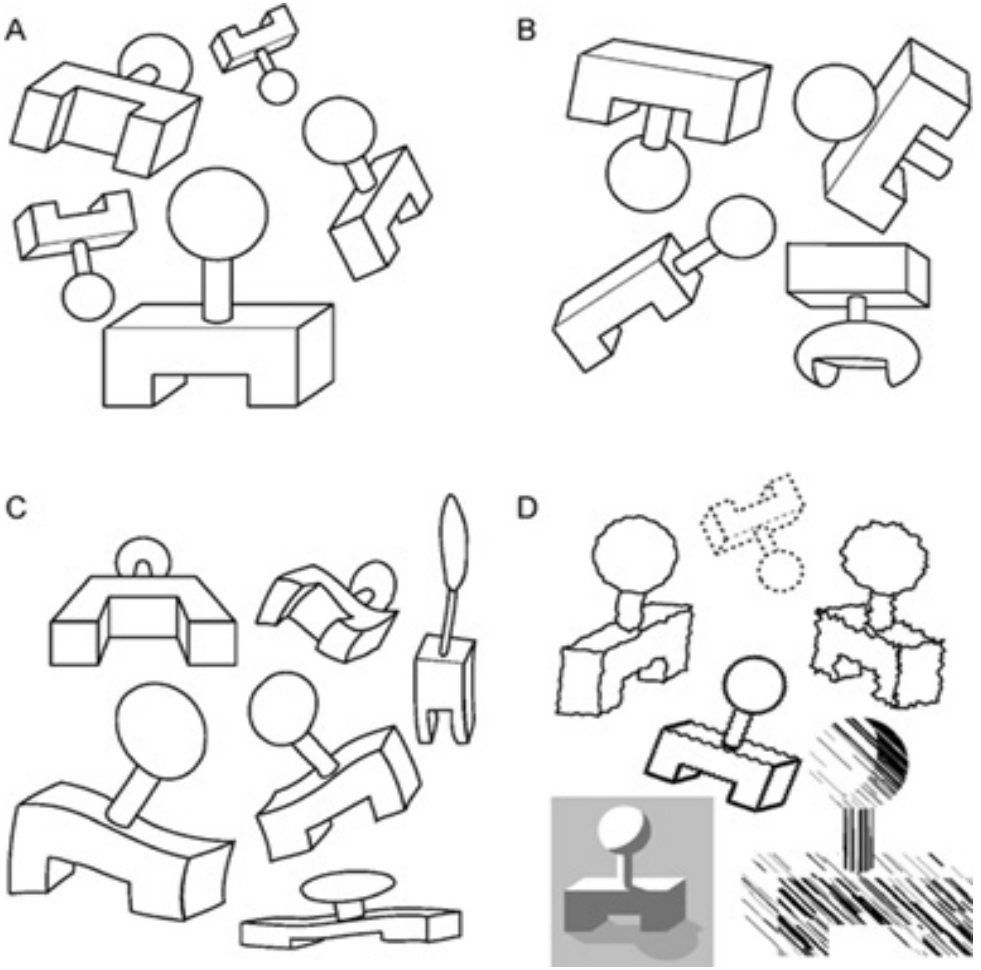
What do you see in this image?

Source: Perception and Imaging: Photography a Way of Seeing
By Richard D. Zakia

Perceptual invariance

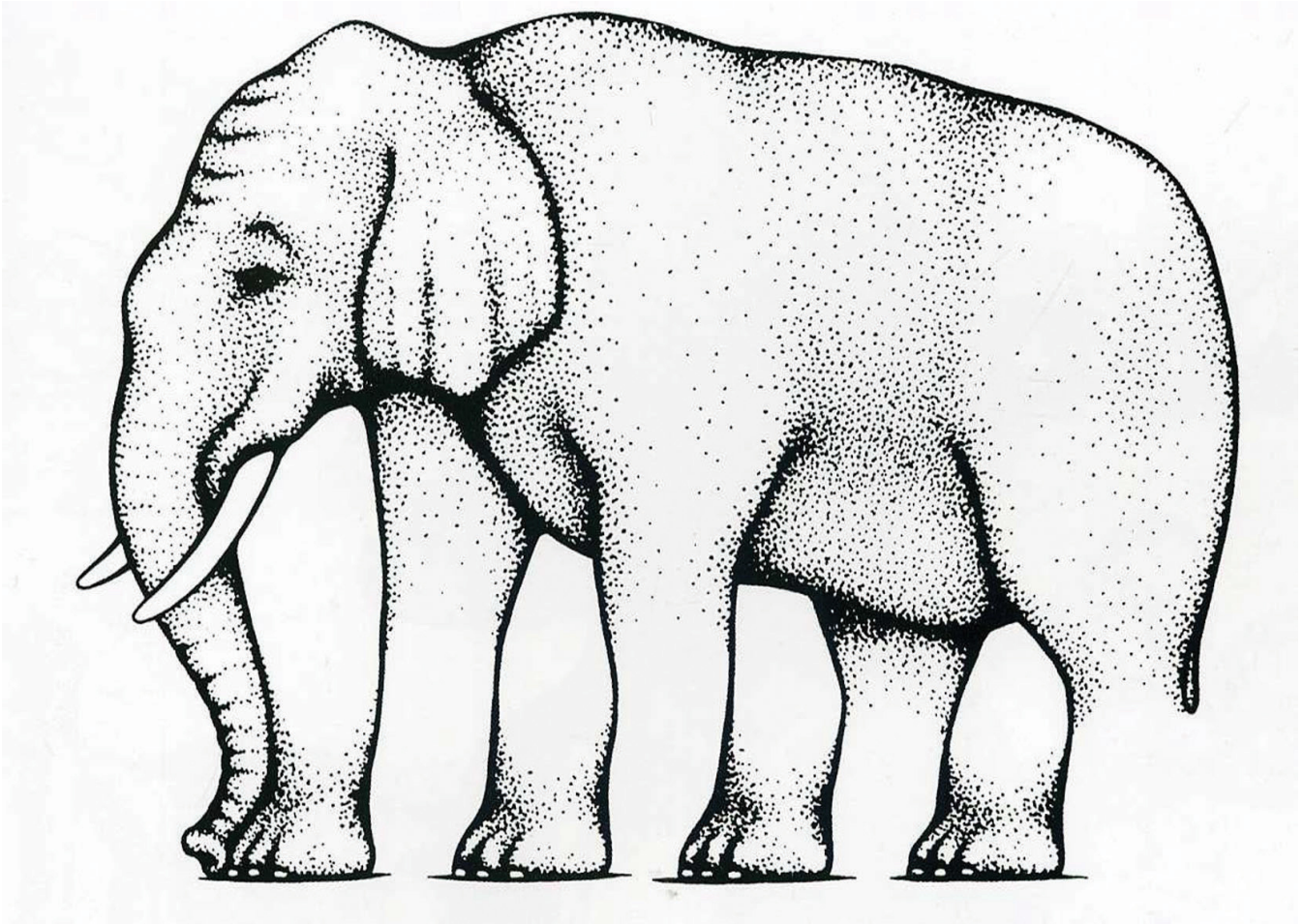
Invariance is the property of perception

- simple geometrical objects are recognized independent of rotation, translation, and scale;
- as well as several other variations such as elastic deformations, different lighting, and different component features.



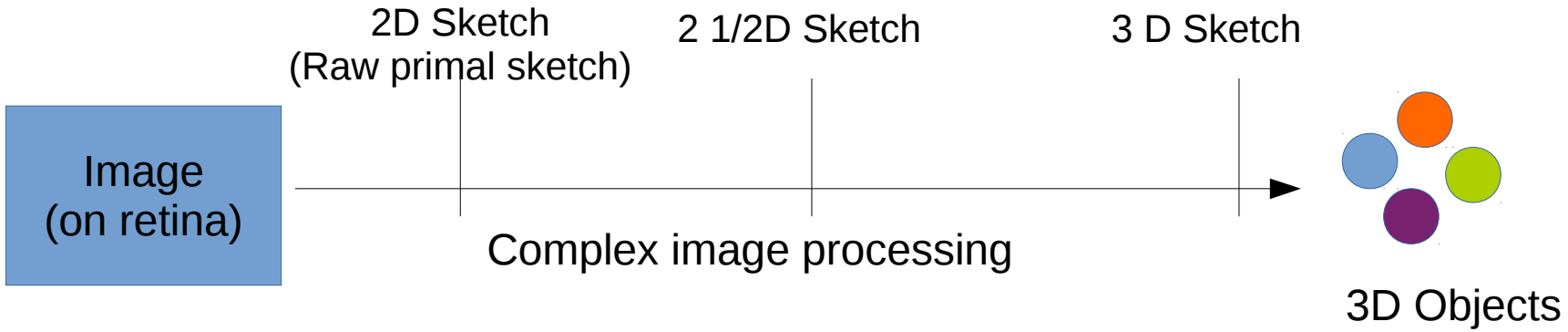
"Law of Symmetry" by Hsokolow via Wikipedia

How many legs do the elephant has ?



Exercise: Explain the phenomenon with Gestalt principles

Computational theory of vision [David Marr]



- Stage 1: (Raw Primal Sketch)
  - Perceptual grouping of pixels (brightness, color, contrast)
  - Contours and edges
- Stage 2: (2 1/2D Sketch)
  - Feature grouping (Gestalt principles)
  - Surfaces and layouts

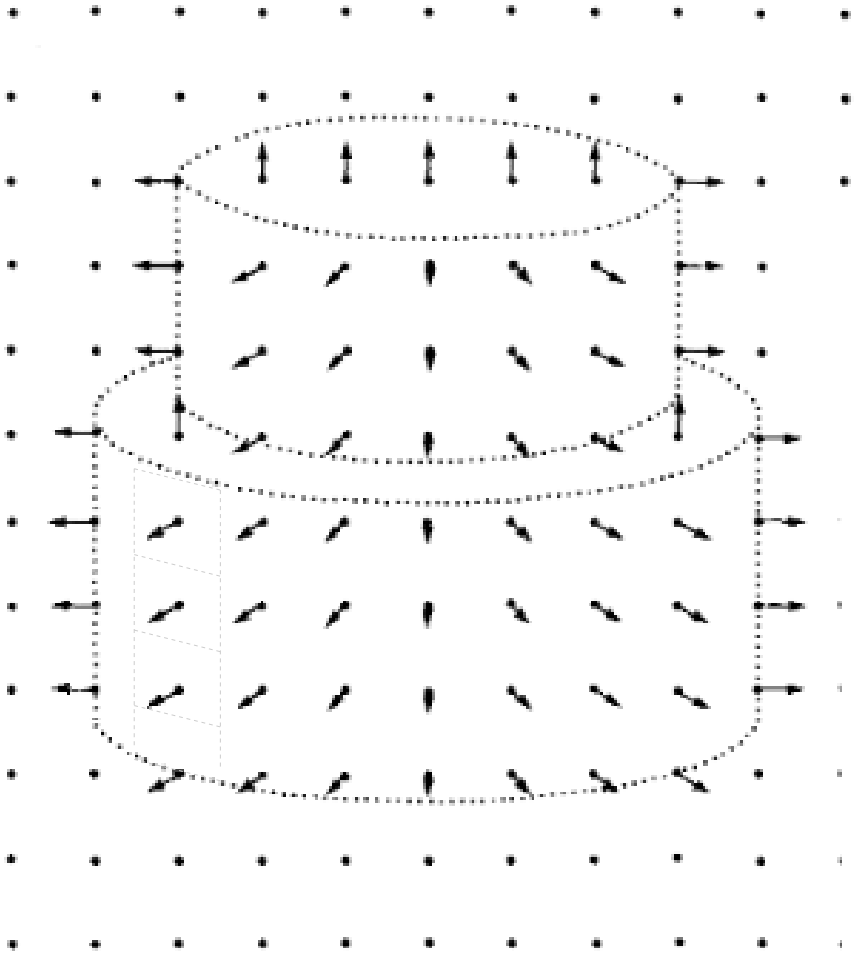
Viewer centric description

- Stage 3: (3D Sketch)
  - Parts linked, axis of symmetry determined
  - 3D image completed (*incl*. occluded areas)

Object centric description

Objects recognized despite disperate points of view

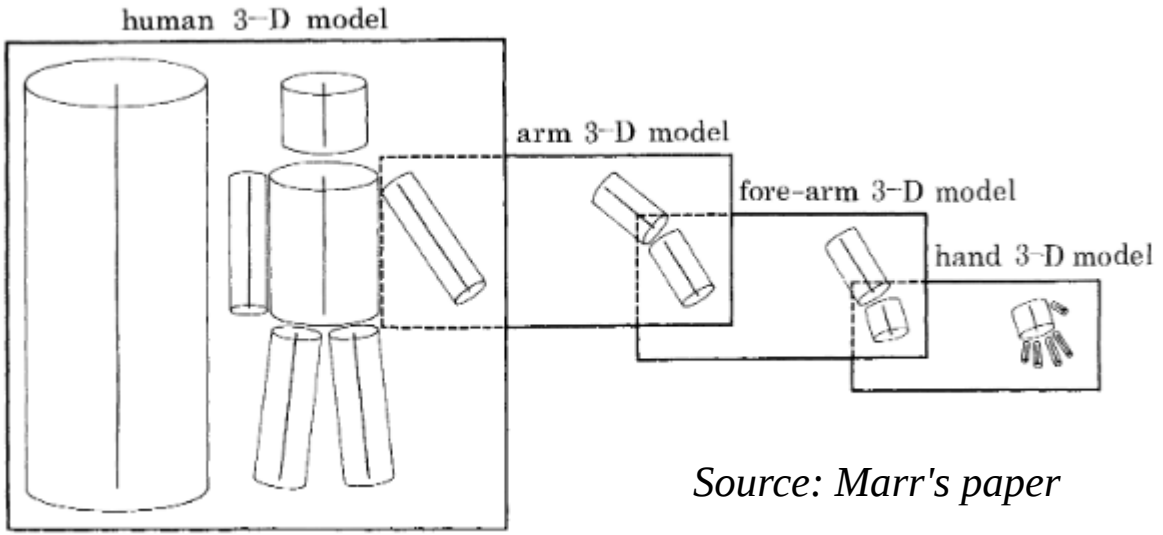
Shape representation (2 1/2D)



- Models the surfaces
- Viewer centric

Source: Marr's paper

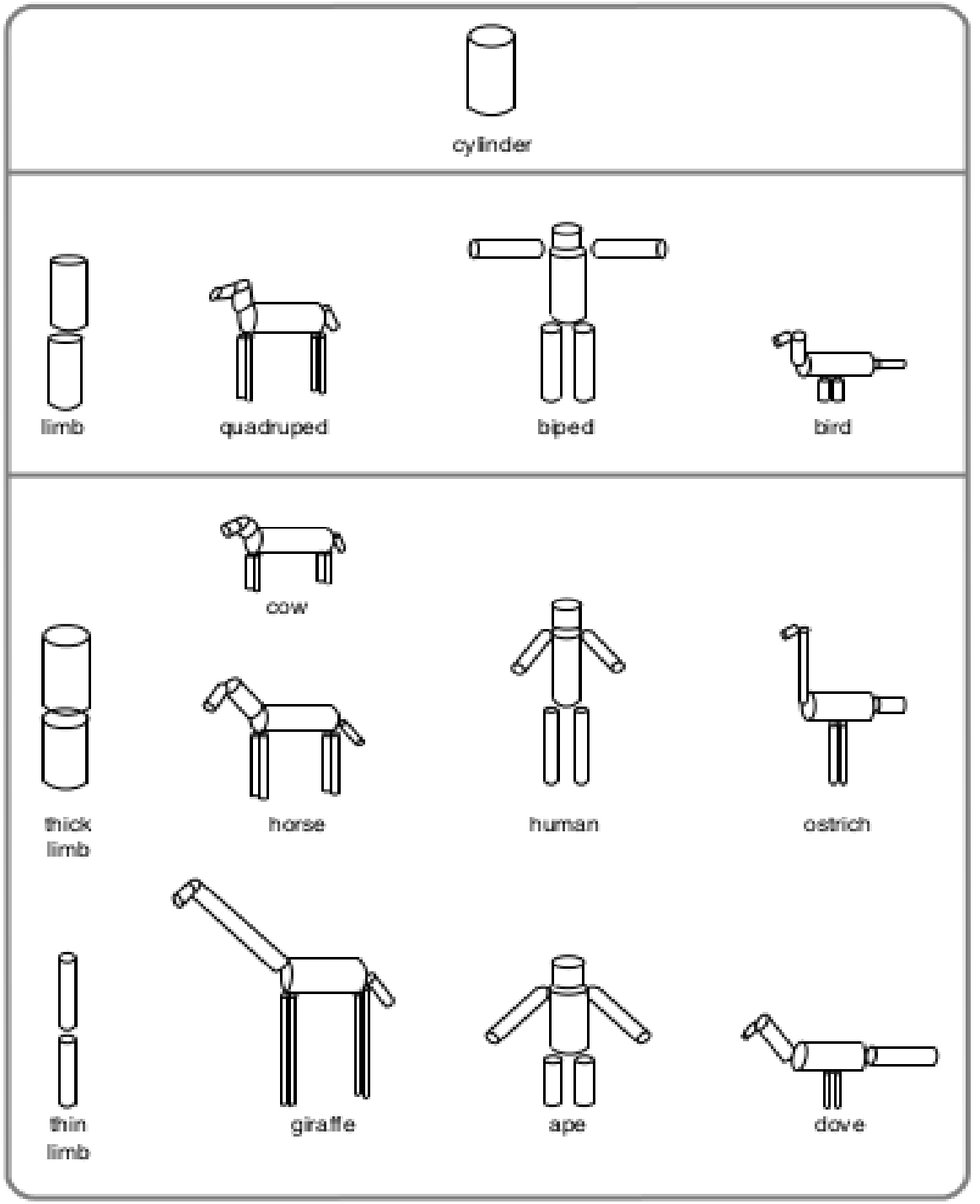
Shape representation (3D)



Source: Marr's paper

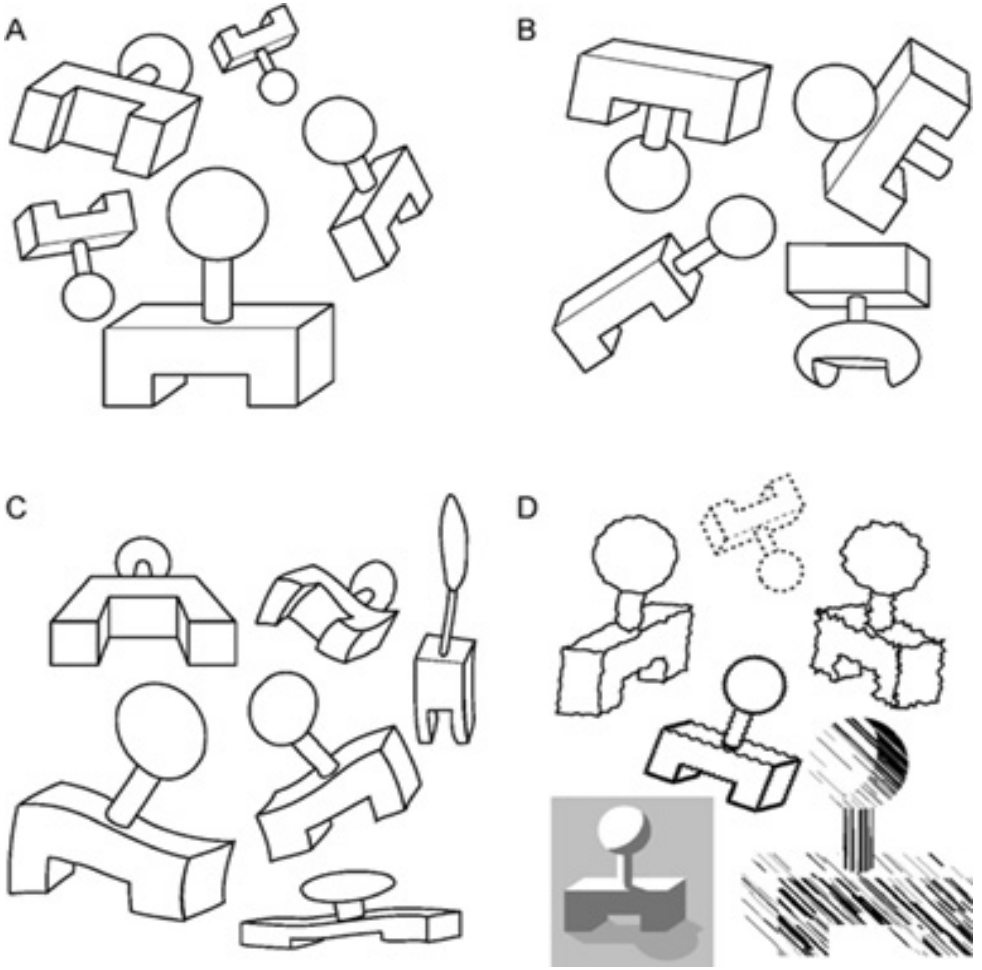
- Hierarchical model (Modular decomposition) -- different levels of details
- Model axis: Natural axis -- represents orientation
- Coordinate system: canonical coordinate system at each level of decomposition
- Object centric – neutral to viewer perspective

Hierarchical organization and indexing



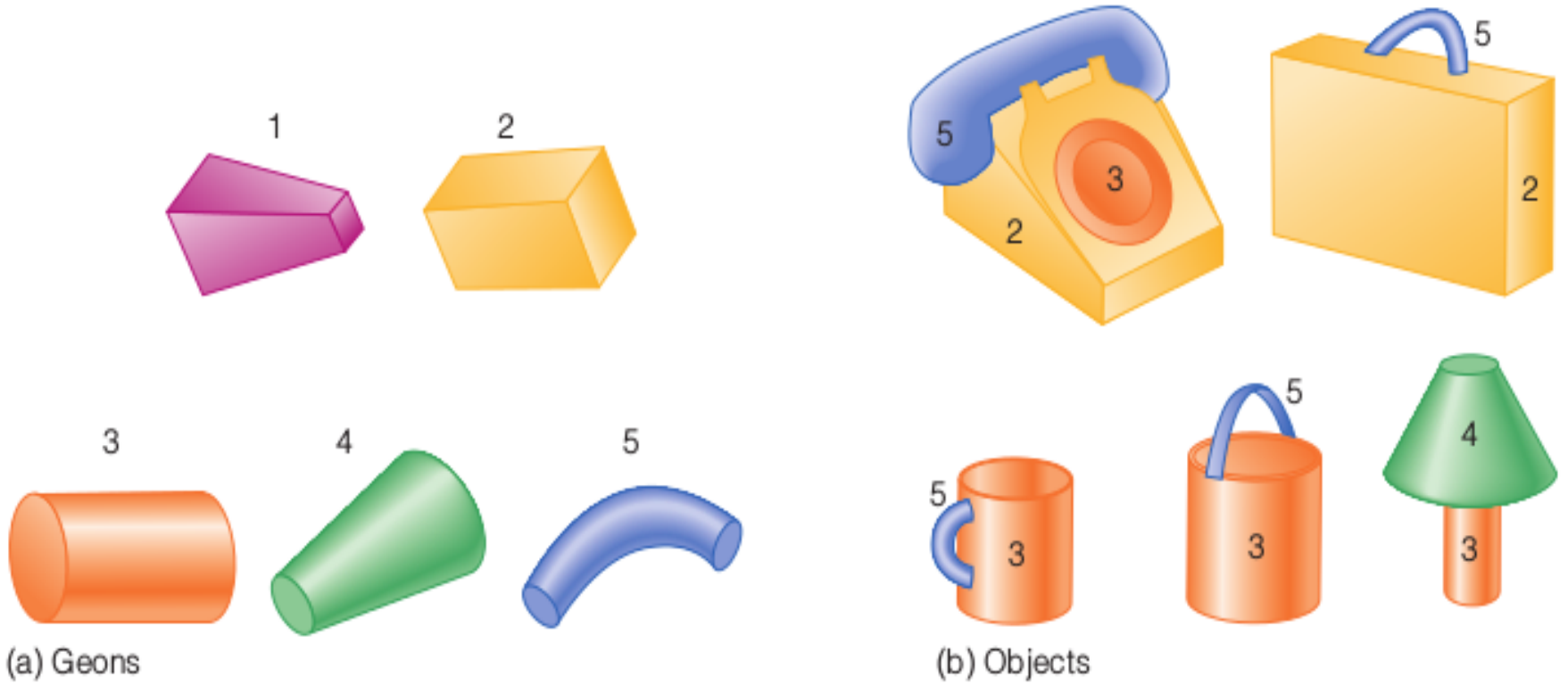
Source: Marr's paper

Another way to interpret “law of symmetry”



Figures in A, B and D share the same 3D model

Parts-based model (Biedman)

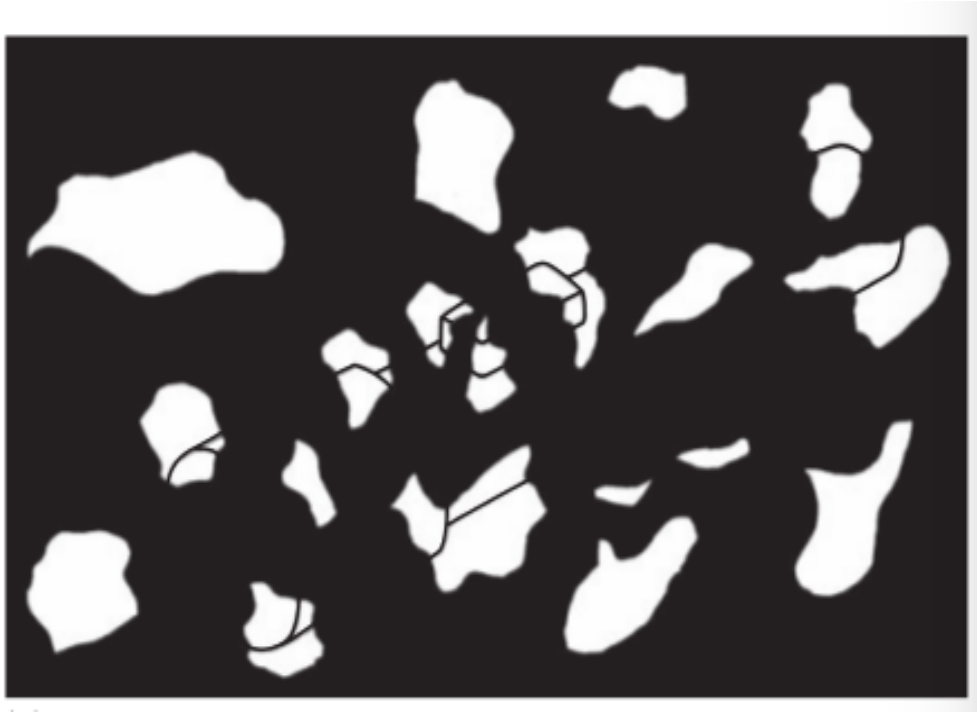


Source: Goldstein's e-book

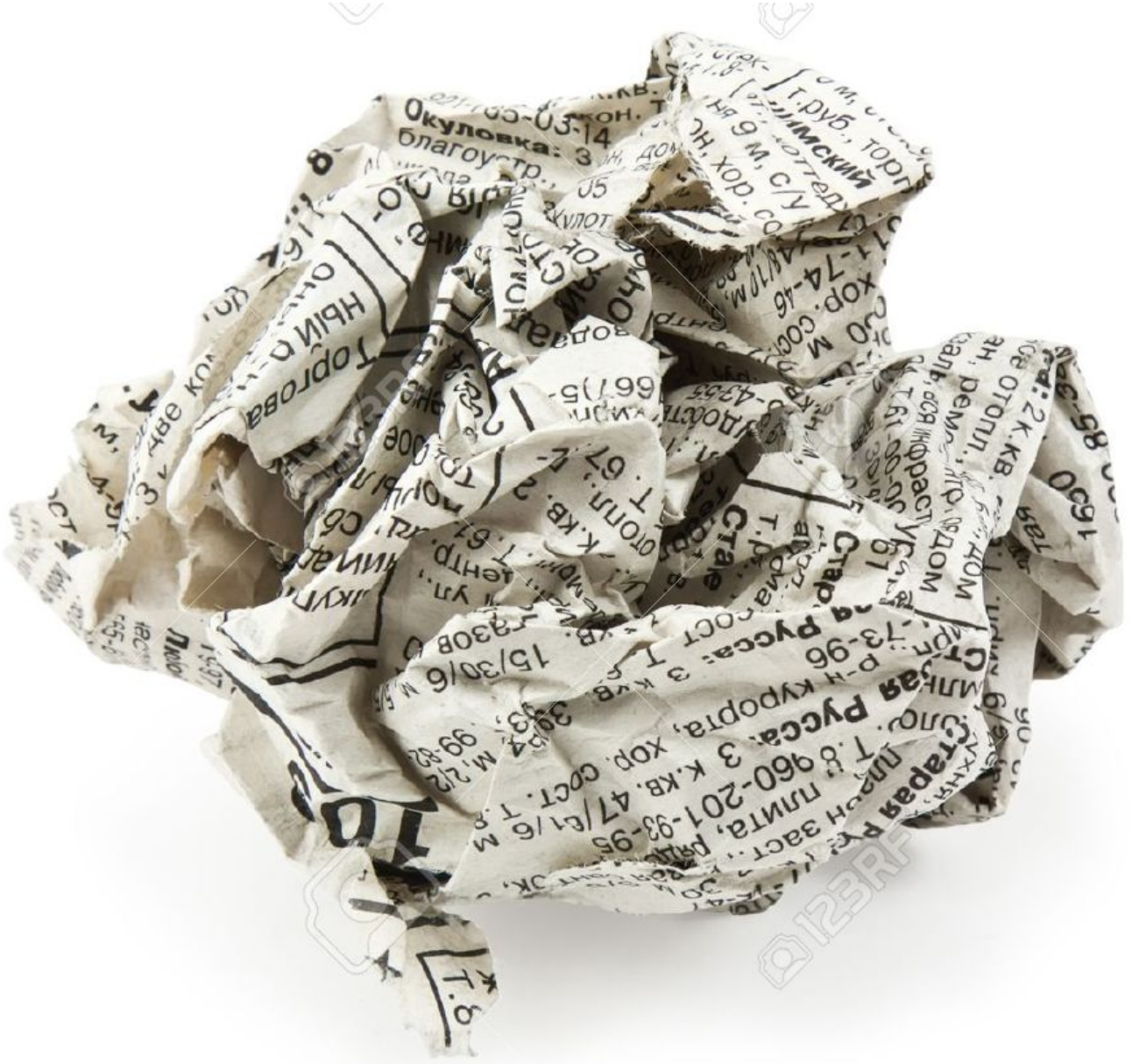
A real example

Source: Goldstein's e-book

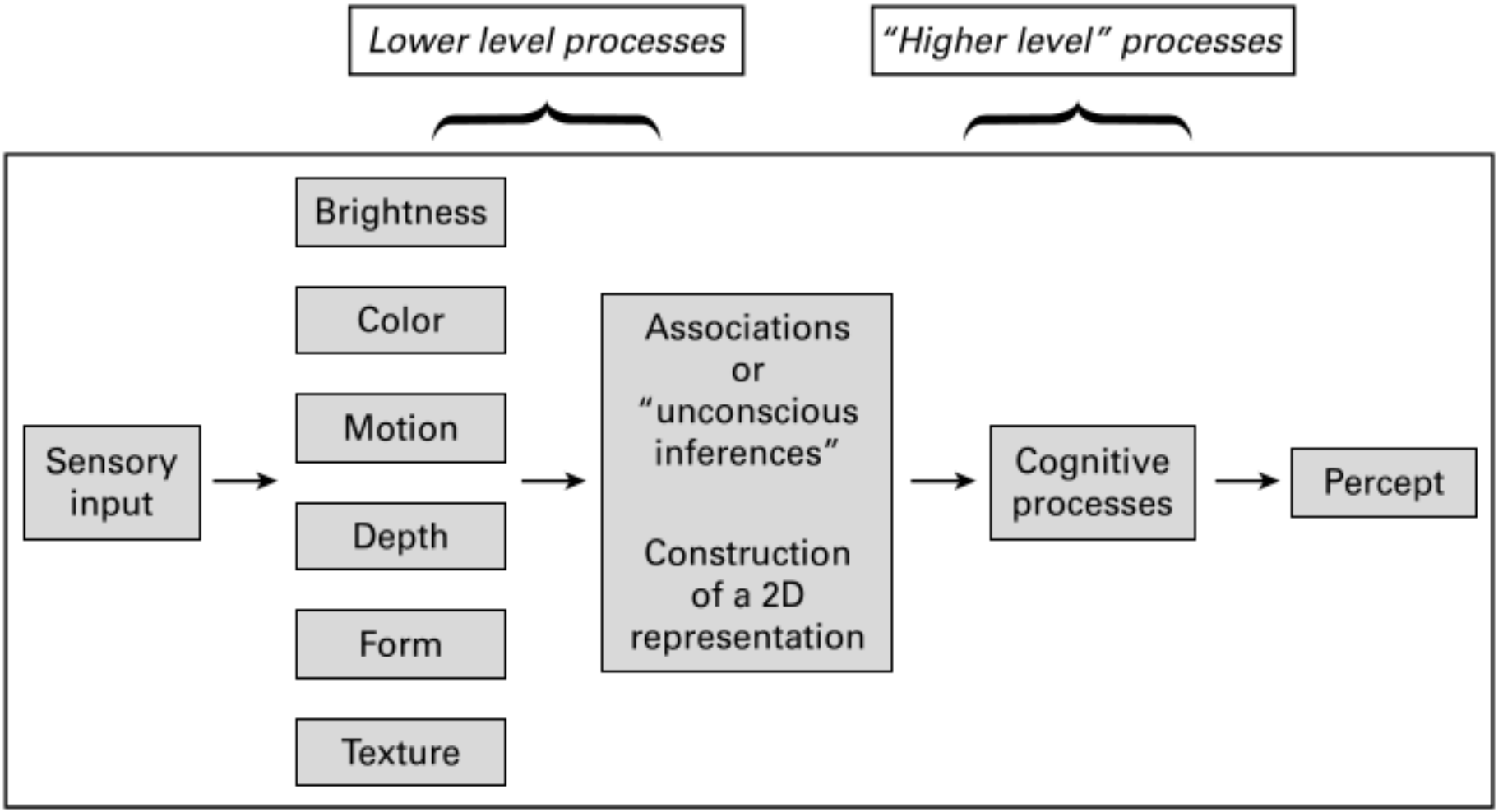
A final example



Counter-example

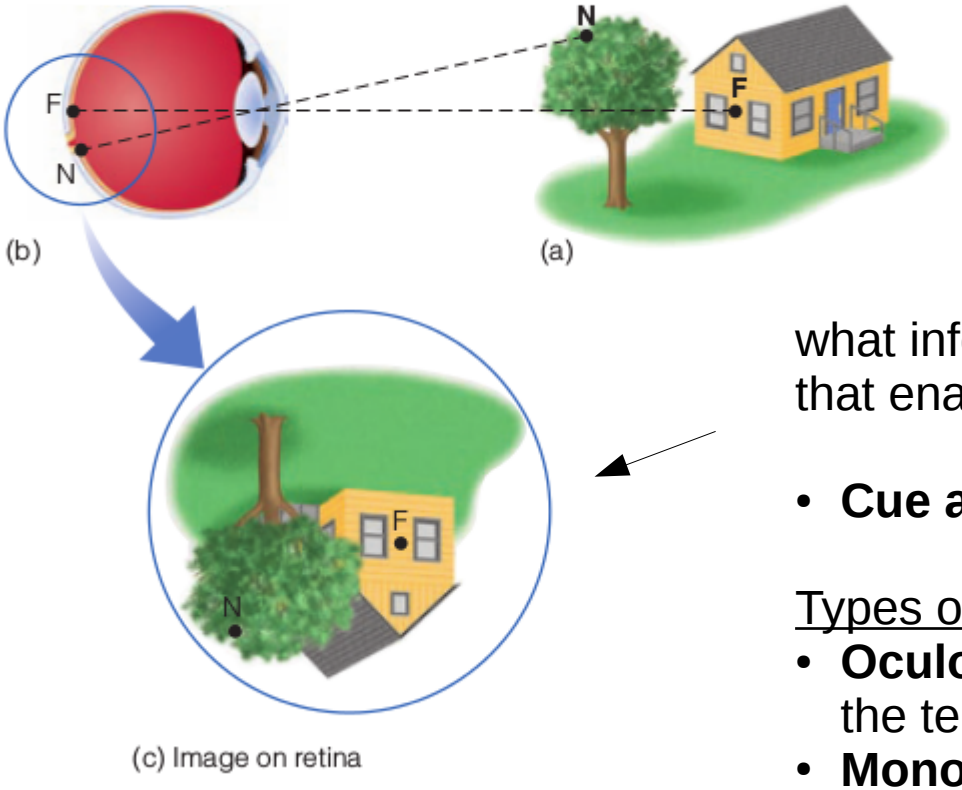


Standard model of (visual) preception



Source: Albertazzi, Tonder & Viswanath (Ed). Perception beyond inference

Perception of depth



what information is contained in this 2D image that enables us to perceive depth ?

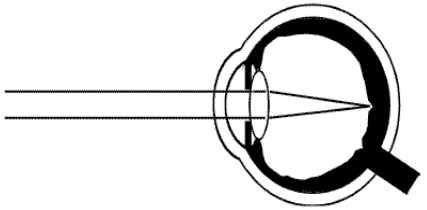
- **Cue approach**

<u>Types of cues</u>:

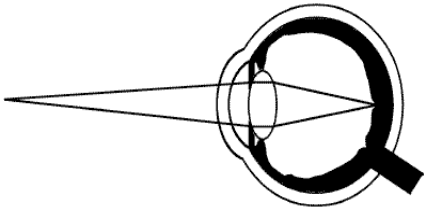
- **Oculomotor**. The position of our eyes and the tension in our eye muscles.
- **Monocular**. Cues that work with one eye
- **Binocular**. Cues that depend on two eyes

Oculomotor cues

Accomodation

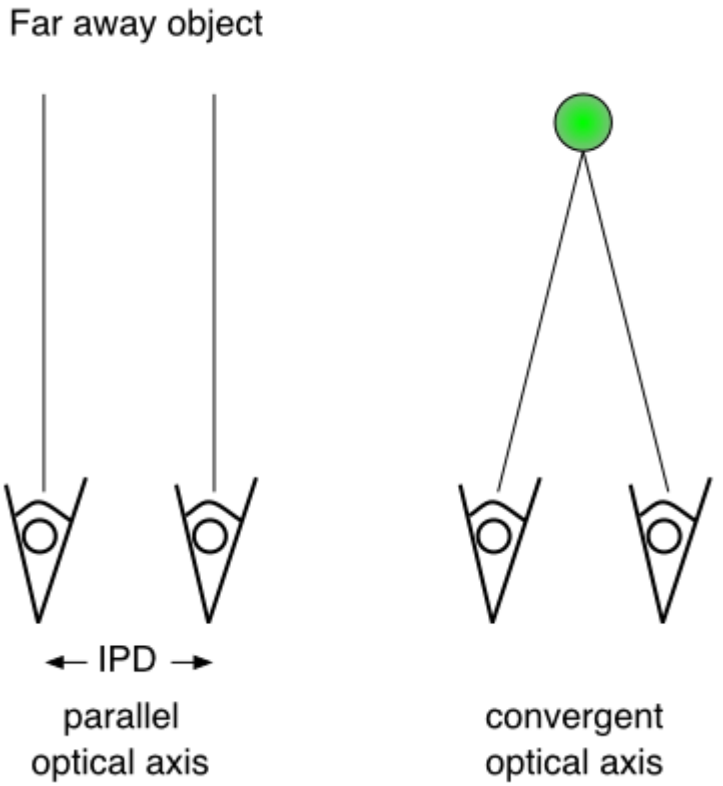


Accommodation to the infinity



Accomodation to a short distance

Convergence



Monocular cues

Pictorial cues

- Occlusion
- Relative height
- Relative size
- Familiar size
- Perspective convergence

Bruce Goldstein

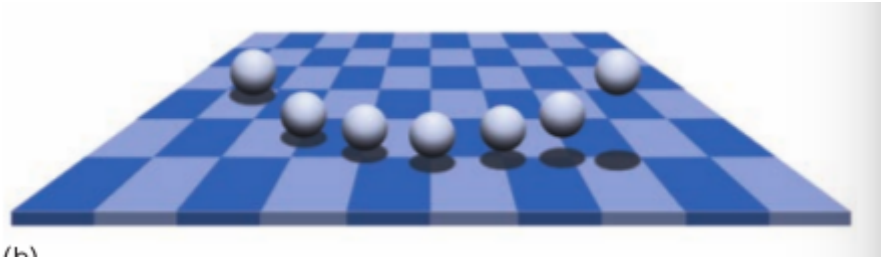
Monocular cues ... more

Pictorial cues

- Texture gradient
- Atmospheric perspective (sharpness)

Bruce Goldstein

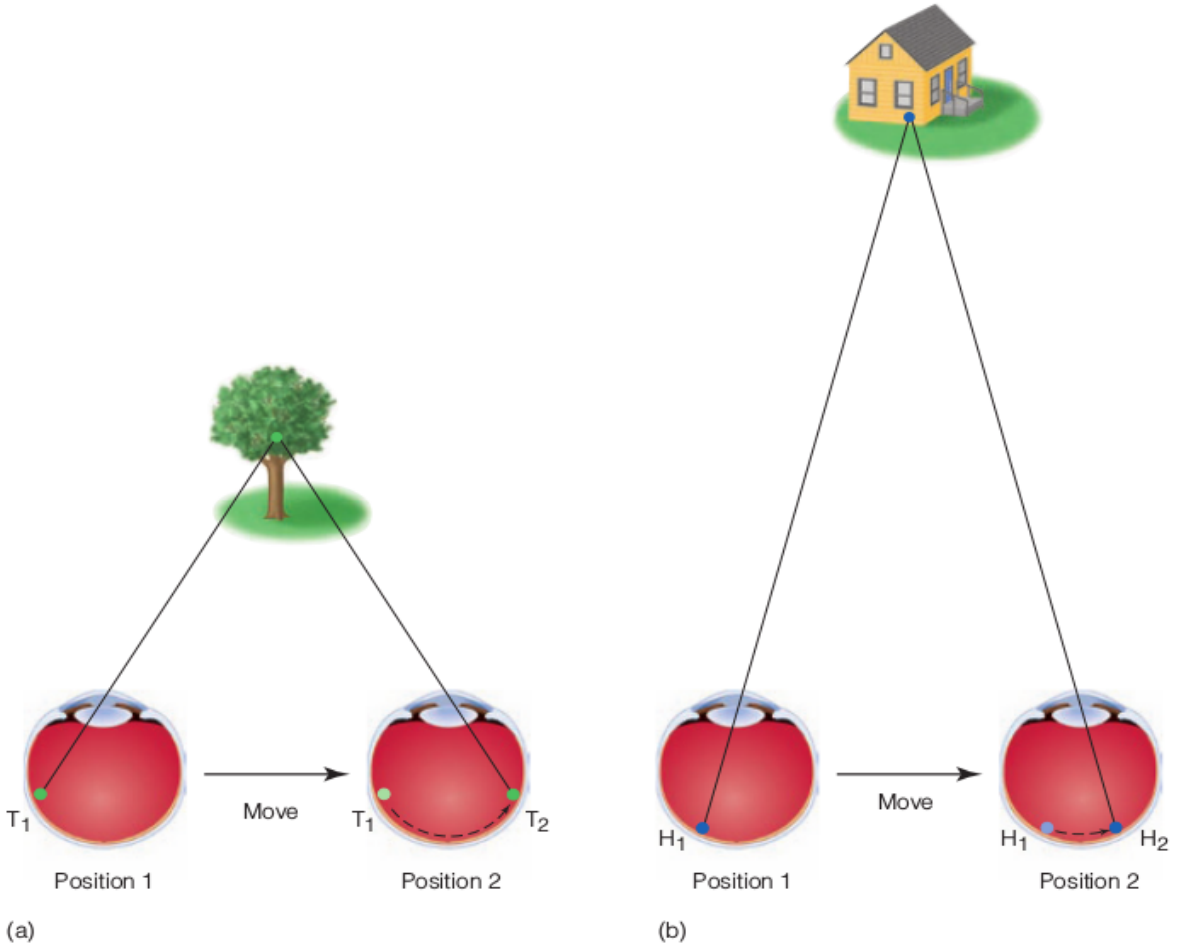
- Shadows



Monocular cues ... more

Motion cues

- Parallax



Monocular cues ... more

Motion cues

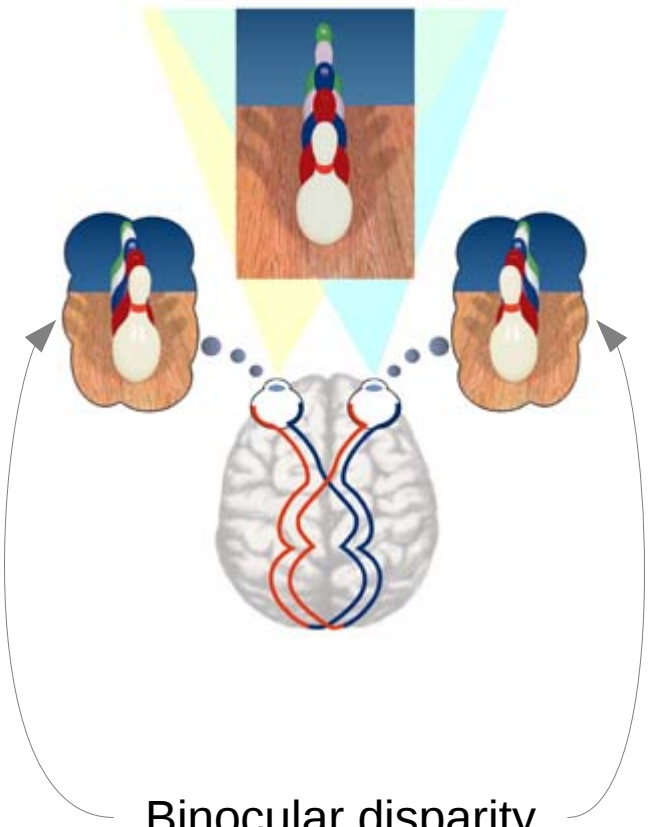
- Deletion and accretion

Range effectiveness of different cues

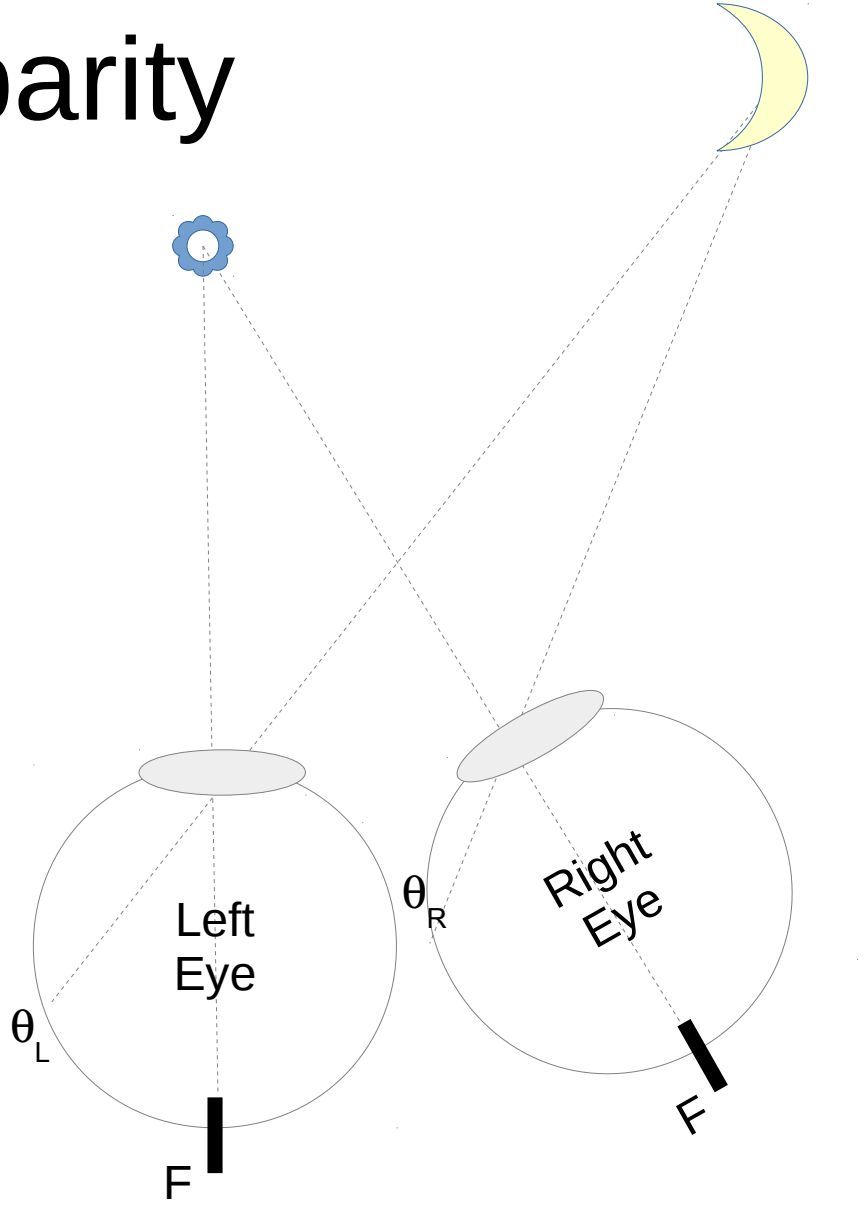
DEPTH INFORMATION	0–2 METERS	2–20 METERS	ABOVE 30 METERS
Occlusion	✓	✓	✓
Relative size	✓	✓	✓
Accommodation and convergence	✓		
Motion parallax	✓	✓	
Relative height		✓	✓
Atmospheric perspective			✓

Source: Based on Cutting & Vishton, 1995.

Binocular cues: disparity



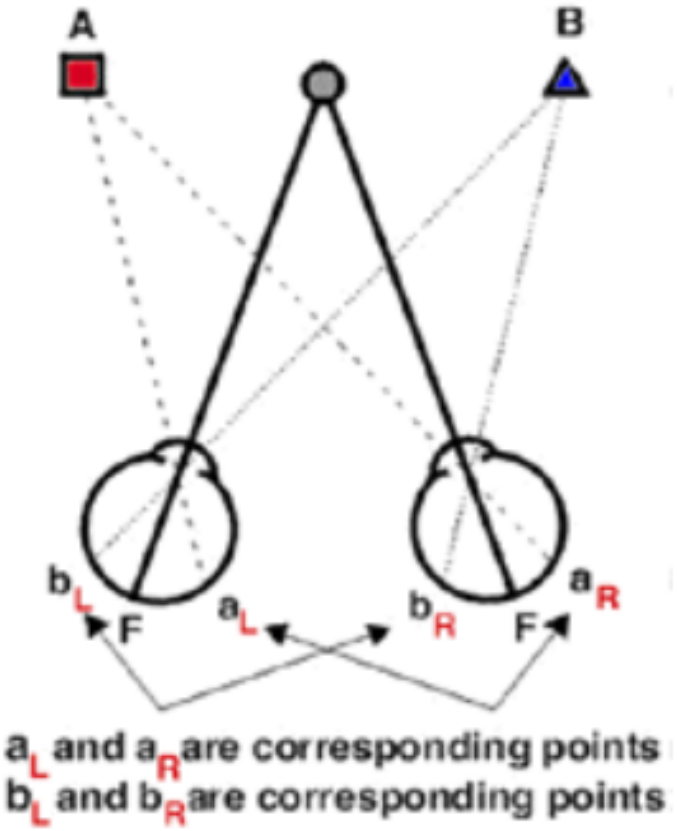
Binocular disparity



Absolute (angular) disparity = $\theta_L - \theta_R$

Closer distance → Greater disparity

Absolute and relative disparities



Absolute disparity of A = $\theta_A = a_L - a_R$

Absolute disparity of B = $\theta_B = b_L - b_R$

Relative disparity between A and B = $\theta_A - \theta_B$

does not depend on where the eyes are looking at

Invariant so long the objects do not move

Stereopsis and perception of depth

View Master

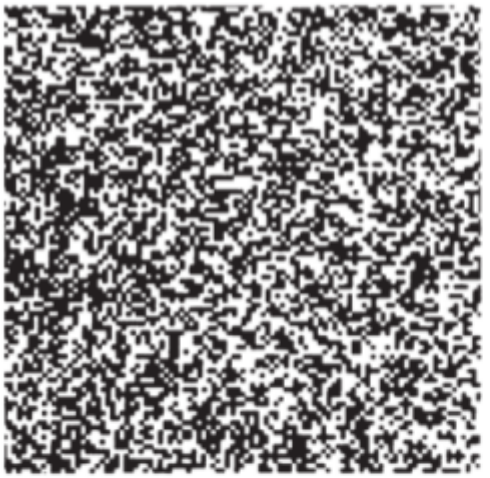
Bruce Goldstein

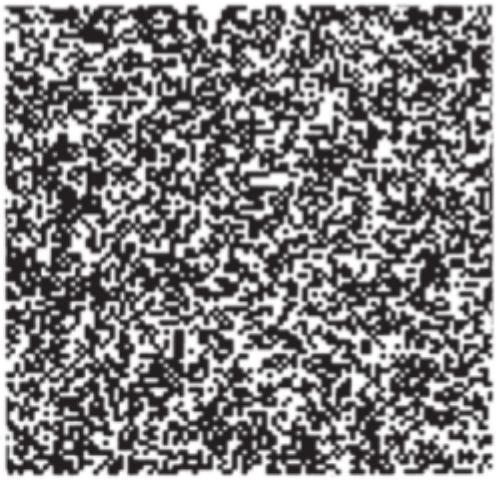
(a) Left eye image

(b) Right eye image

3D Movies

Random dot stereograms





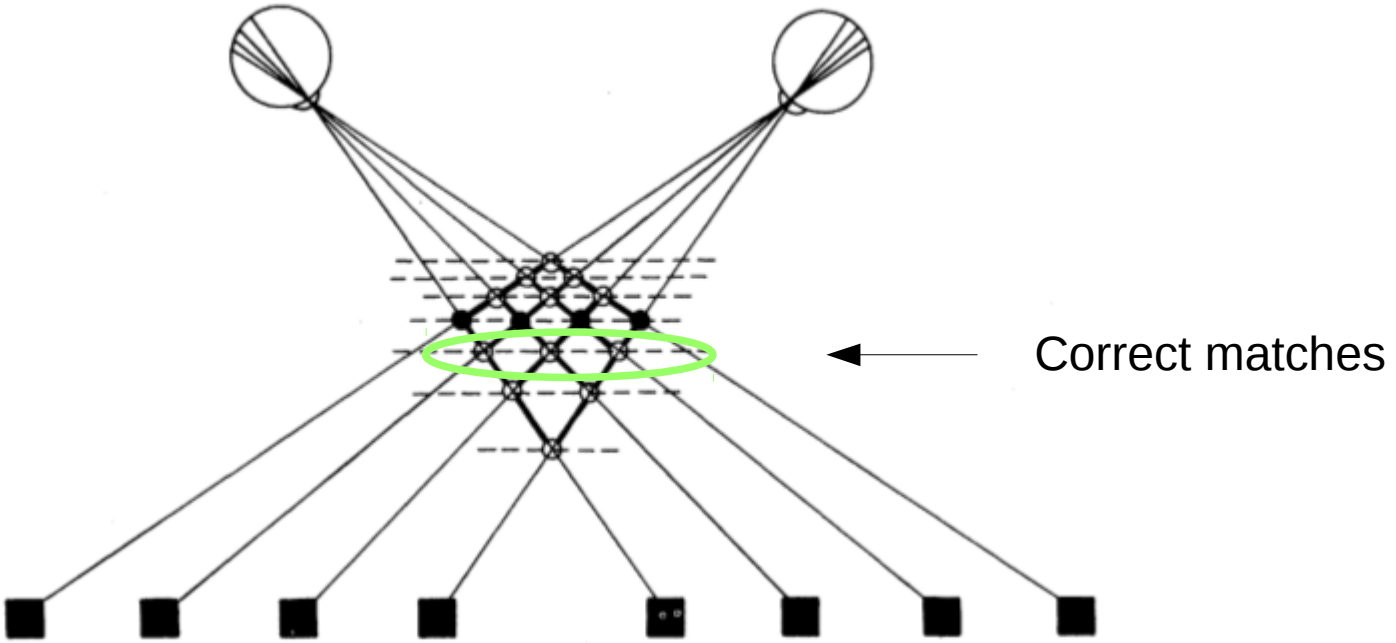
(a)

1	0	1	0	1	0	0	1	0	1
1	0	0	1	0	1	0	1	0	0
0	0	1	1	0	1	1	0	1	0
0	1	0	A	A	B	B	1	0	1
1	1	1	B	A	B	A	0	0	1
0	0	1	A	A	B	A	0	1	0
1	1	1	B	B	A	B	1	0	1
1	0	0	1	1	0	1	1	0	1
1	1	0	0	1	1	0	1	1	1
0	1	0	0	0	1	1	1	1	0

1	0	1	0	1	0	0	1	0	1
1	0	0	1	0	1	0	1	0	0
0	0	1	1	0	1	1	0	1	0
0	1	0	Y	A	A	B	B	0	1
1	1	1	X	B	A	B	A	0	1
0	0	1	X	A	A	B	A	1	0
1	1	1	Y	B	B	A	B	0	1
1	0	0	1	1	0	1	1	0	1
1	1	0	0	1	1	0	1	1	1
0	1	0	0	0	1	1	1	1	0

(b)

The correspondence problem



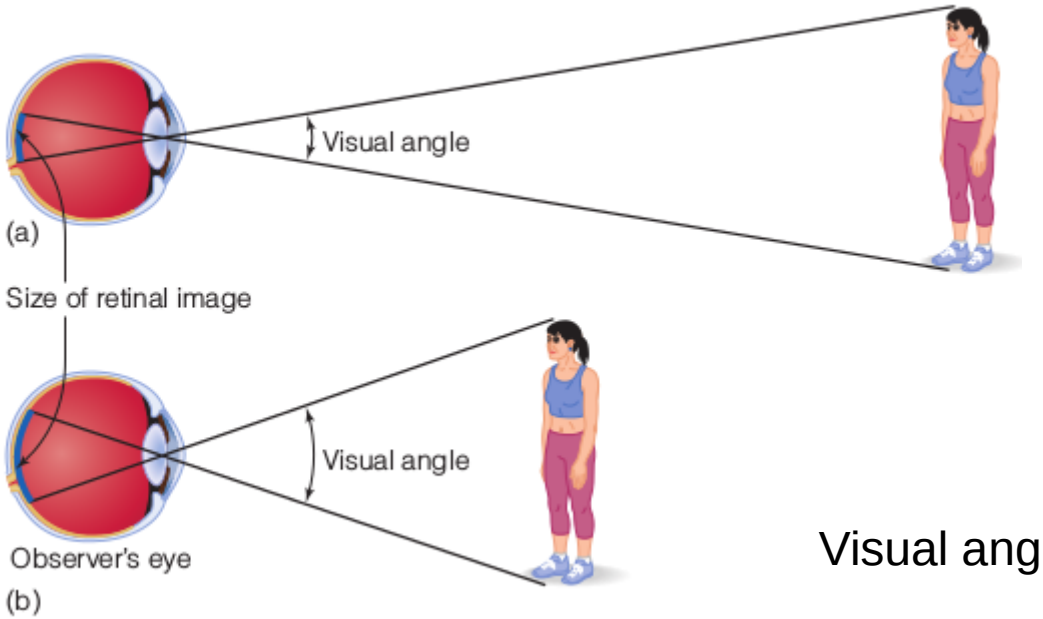
How to resolve ?

- **Uniqueness:** Each image point represents a unique point in the real world
- **Continuity**: Cohesiveness of matter. Depth has discontinuity only at few places in an image

More on uniqueness

- Cannot be established with gray levels alone
  - Intensity gradients
  - At multiple spatial resolution
  - Peaks of the first derivatives ≡ Zero crossings of the second derivatives

Perception of size



Visual angle (Retinal size)

Perceived size S μ R * D

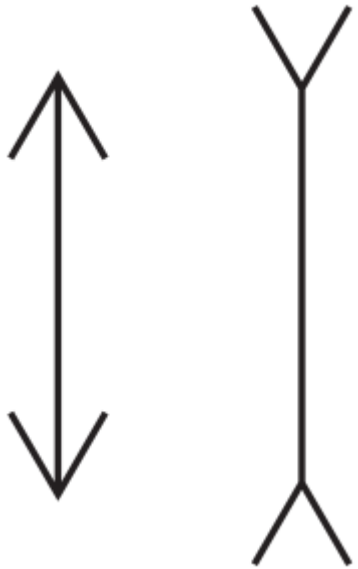
R = Retinal size,
D = Perceived distance

Reference
(close by objects)

Bruce Goldstein

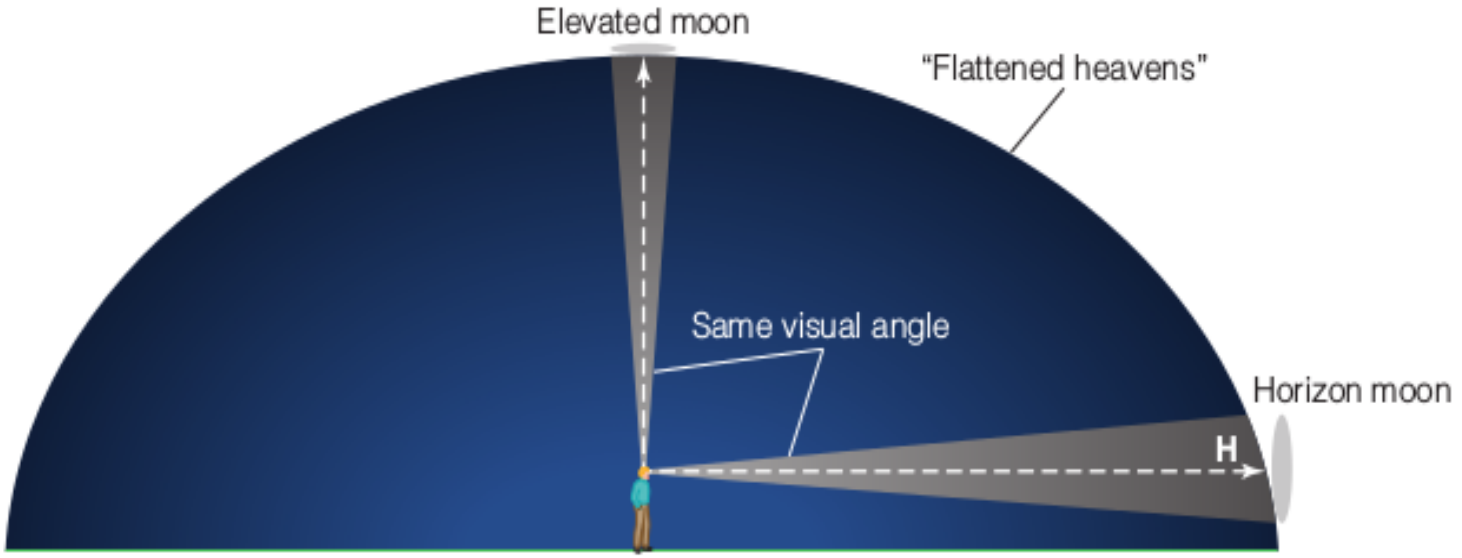
Bruce Goldstein

Muller-Lyer illusion



Misapplied size constancy scaling

Why the moon looks bigger near the horizon than when it is up in the sky?



Flattened heaven theory

Angular size contrast theory

An object appears smaller when surrounded by larger objects

References

1. Goldstein. Sensation and perception (e-book)
   http://cartesians.biz/ctfile/sensation-and-perception-goldstein-9th-edition.pdf

Perception of color, contrast, motion ...