
Visual Perception

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Content

- HVS
- Visual Illusions, **Form**, Brightness
- Adaptation - HDRI
- **Colour** Vision
- **Depth, Motion**
- Image Quality Assessment



Visual Perception

■ Perception

- psychological processes and underlying physiological mechanisms by which we gain *knowledge* of the world via our sense organs

■ Important Visual Tasks

- Identification of objects and materials
- Navigation through the environment
- Prediction of motion trajectories
- Estimation of physical dimensions
- Object manipulation
- Visual communication



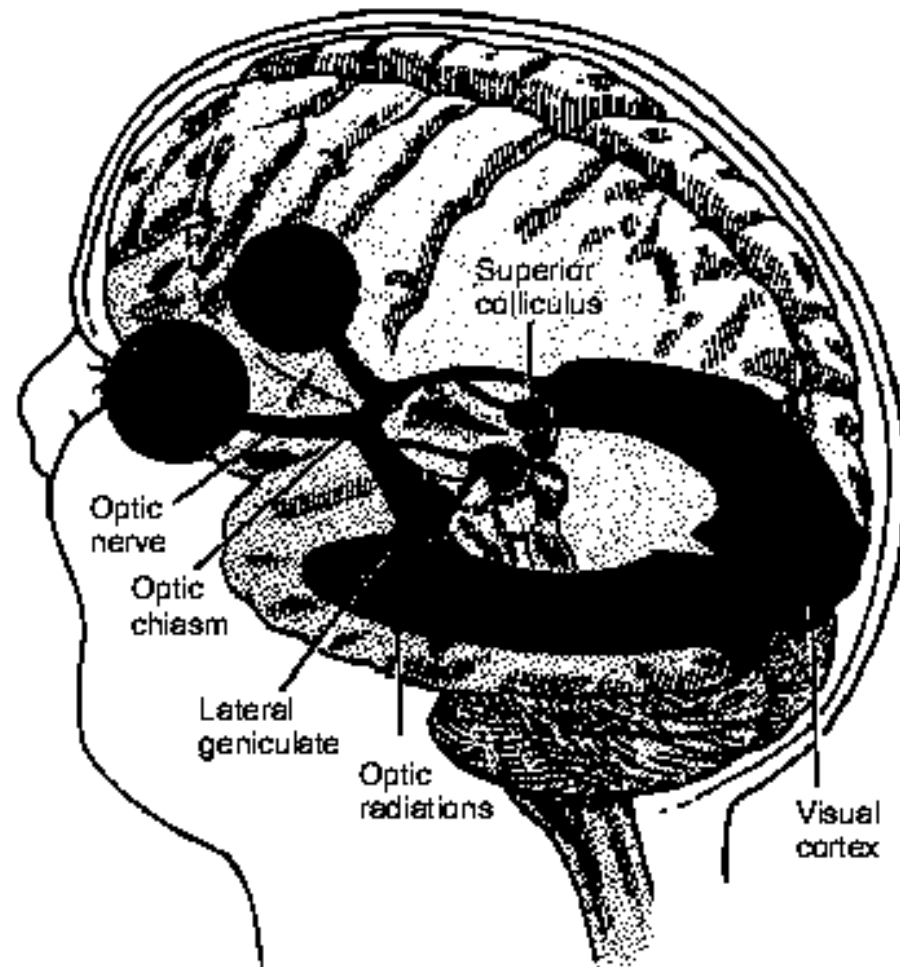
Visual Perception

- Study of visual perception
 - psychology, physiology, anatomy, computer vision, computer science...
 - psychophysical experiments [Weber 1834, Fechner 1860]
 - Measuring the thresholds (~75%)
 - detection threshold
 - discrimination (difference) threshold
 - neurophysiology (cell level)
 - receptive fields of single cells
 - [Hubel, Wiesel 1959] - Line and Edge Detection
 - study of brain
 - neuropsychology – study of patients (diseases, brain injuries)
 - various screening methods (PET, fMRI, EEG, MEG)



Human Visual System

- Eye
- Retina
- LGN
- Visual Pathways
- Visual Cortex



Neural Processing of Visual Information

■ Retina

- Measure the intensity and wavelength of the retinal image
- Encode small contrasts independent of the ambient light level
- Enhance local image contours
- Compress the image information to a manageable size

■ Striate Cortex

Represent the visual scene in terms of local image properties:

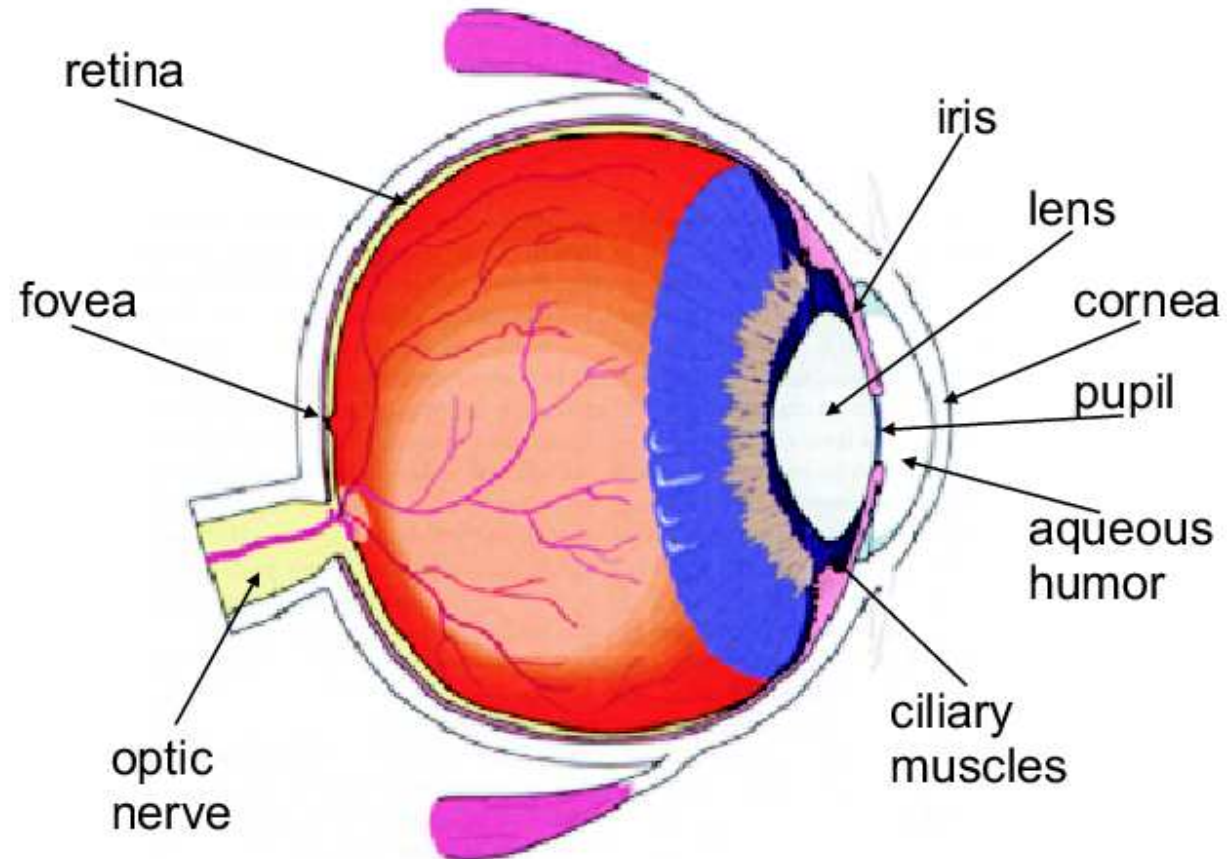
- Orientation
- Size
- Position
- Motion
- Brightness and color contrast
- Binocular disparity

■ Extrastriate Cortex

- Grouping and segregation
- Shape description
- 3D position description
- Object and material identification
- Image, object and self motion

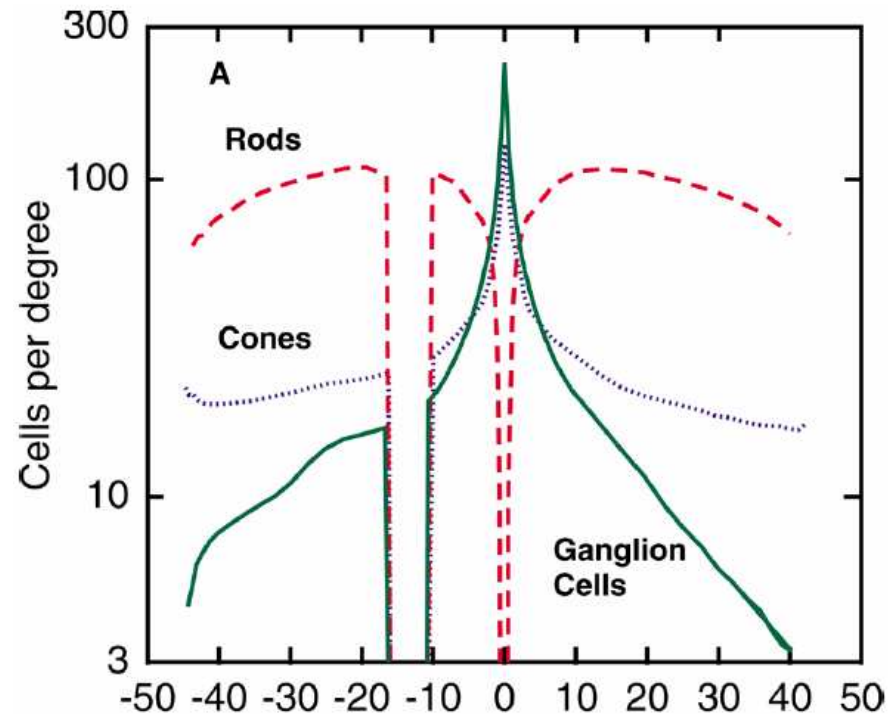


Eye



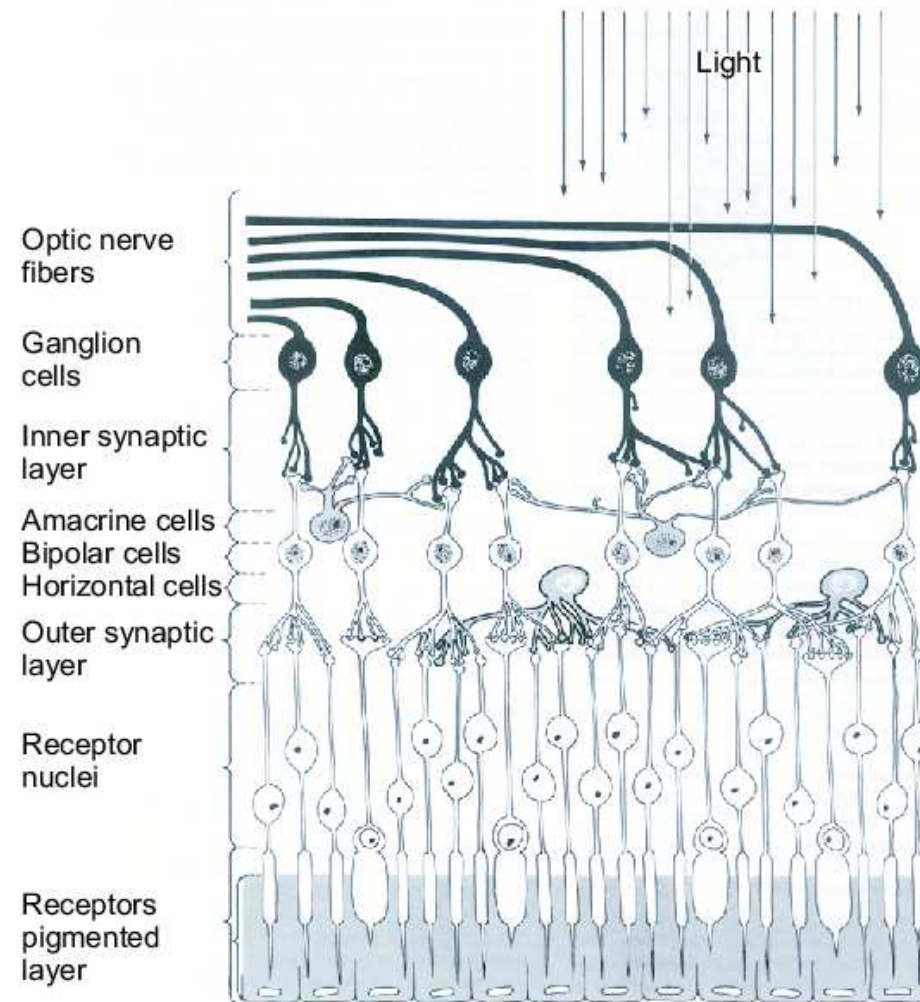
Retina

- Photoreceptors
 - **Rods** (~120 000 000), scotopic vision
 - **Cones** (~ 8 000 000), photopic vision, colour
- Fovea
 - just cones, no rods
- Blind spot
 - no receptors



Retina

- Horizontal cells
- Bipolar cells
- Amacrine cells
- Ganglion cells



Retina

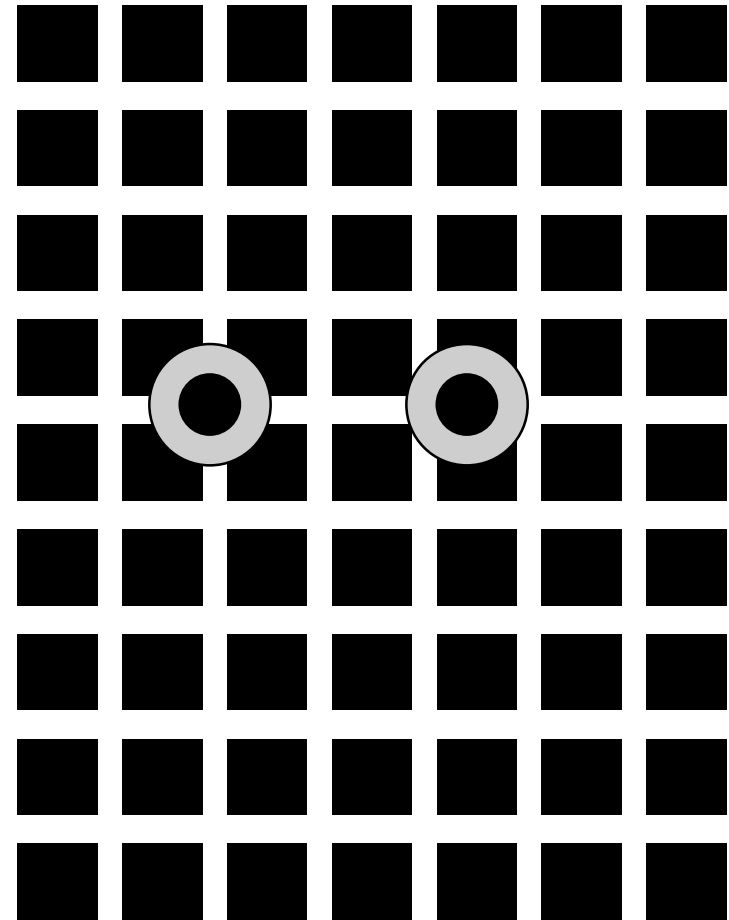
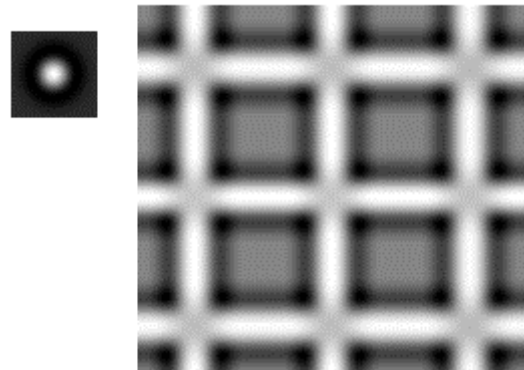
■ Ganglion cells

- receptive fields
- on-response/off-response
- RFs in centre of visual field tend to be smaller than those in the periphery
- → Errors in coding luminance
- → Emphasis on relative brightness at boundaries



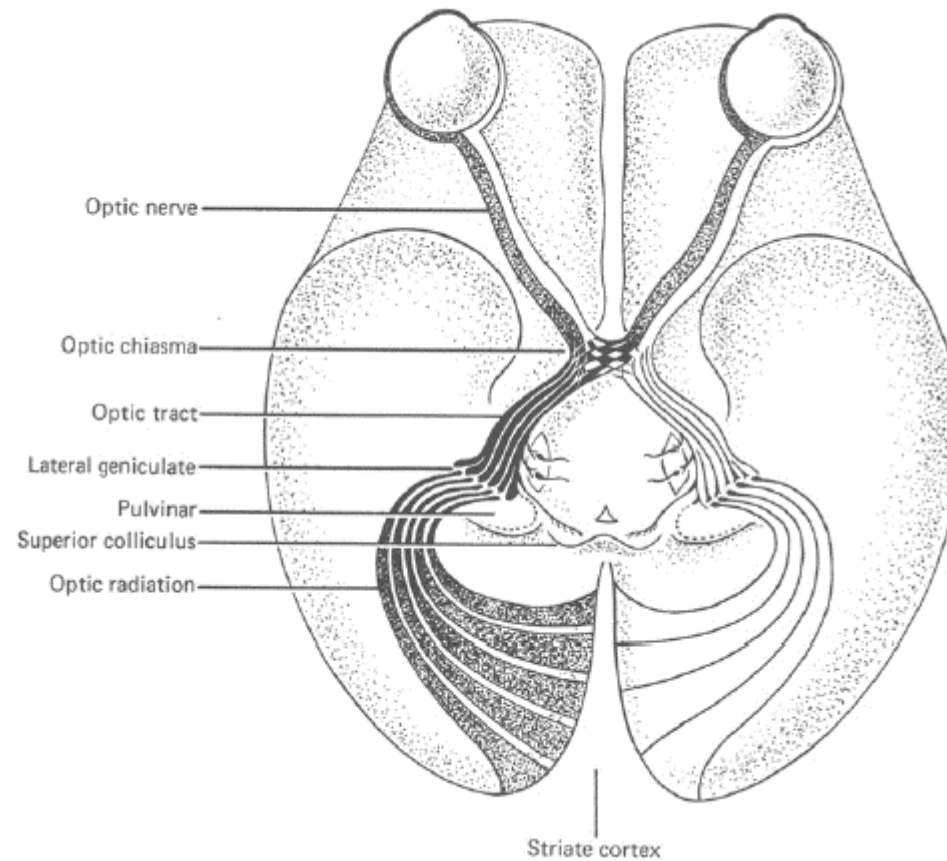
Ganglion Cells

- Hermann Grid
- Receptive fields at intersections have more light on surround
 - Makes centre look less bright



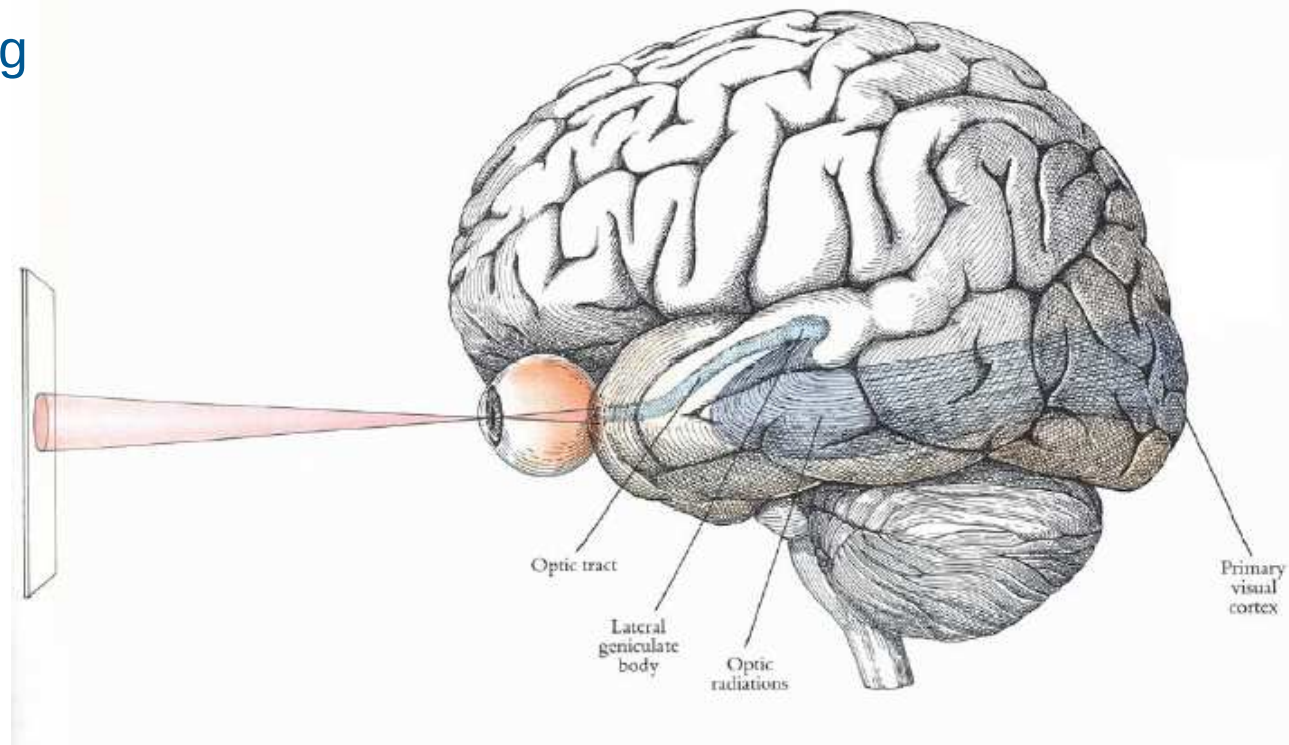
Visual Pathways

- Optic nerve
- Optic chiasma
- Superior colliculus (eye movements)
- LGN
- Visual Cortex



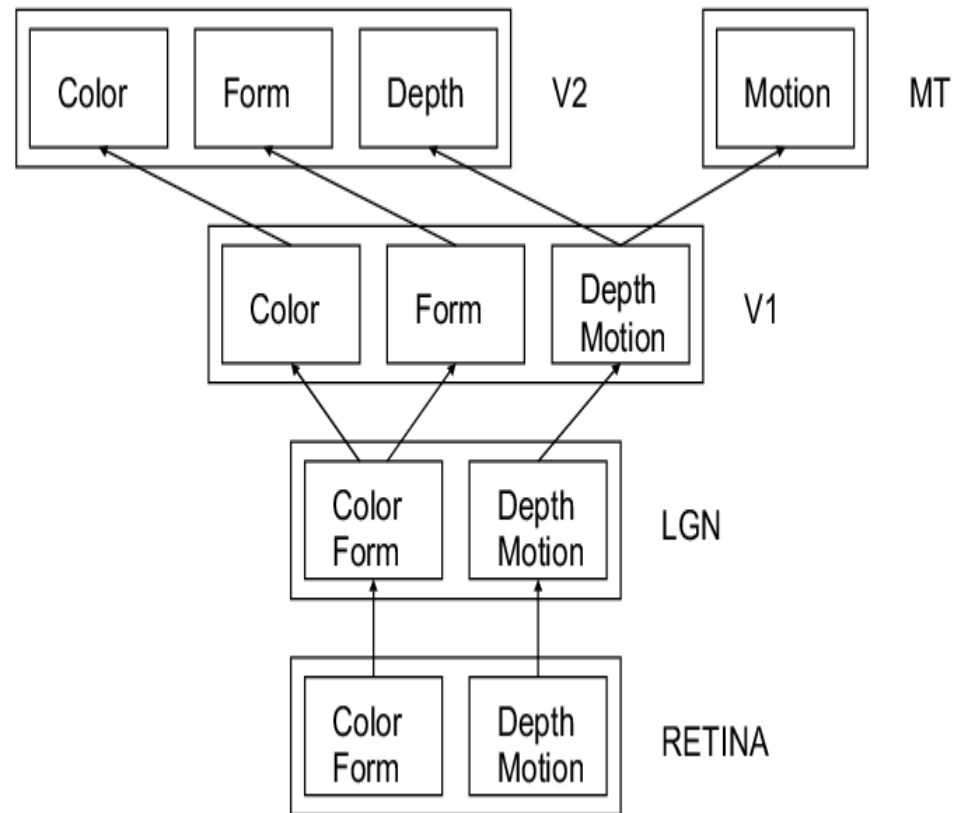
Visual Cortex

- visual parts ~50% of the brain
- 100 000 000 000 visual cells
- each cell is connected to 4000 others
- parallel processing



Physiological Pathways Hypothesis

- [Livingstone, Hubel 1988]
- Color, shape, depth, motion
- V1 – primary visual cortex (striate cortex)
- V2, V4
- V5 – Medial Temporal cortex



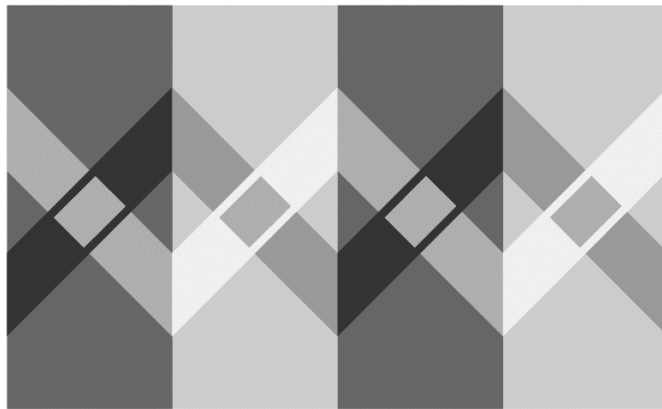
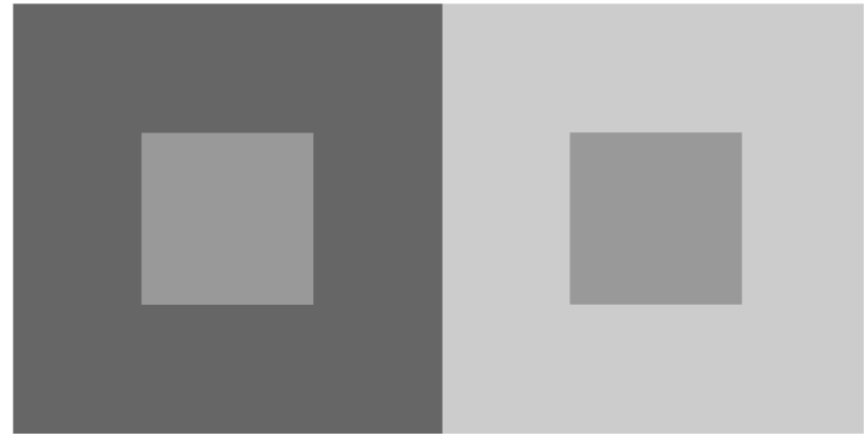
Visual Illusions

- Human sensations mostly reflect the reality
 - necessary to survive
- BUT not always
 - probabilistic rules of thumb (underlying assumptions) –
if are false → visual illusions



Illusions of Brightness

- Simultaneous Contrast effect
- Koffka ring
- Criss-Cross Illusion

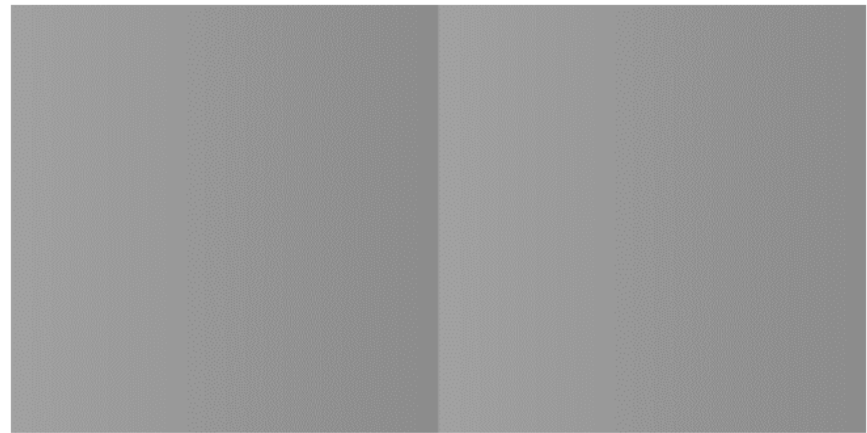
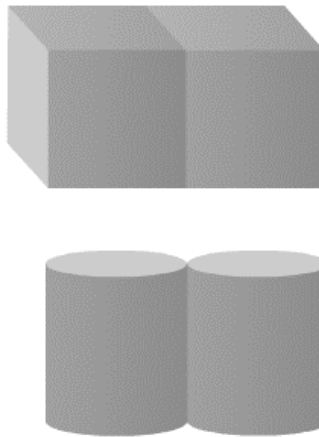
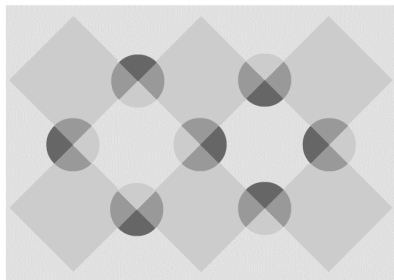
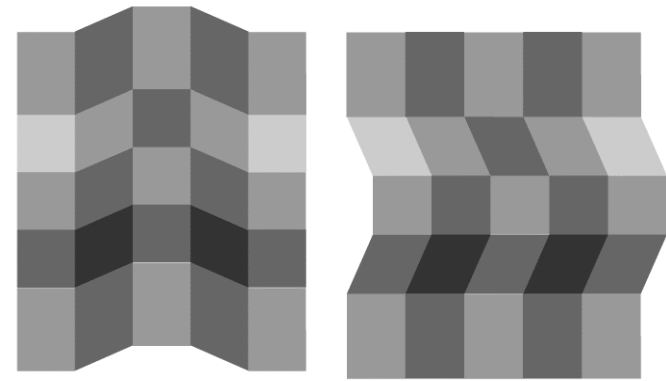


video



Illusions of Brightness

- Corrugated Plaid
- Cornsweet Effect
- Knill's Illusion
- Haze Illusion

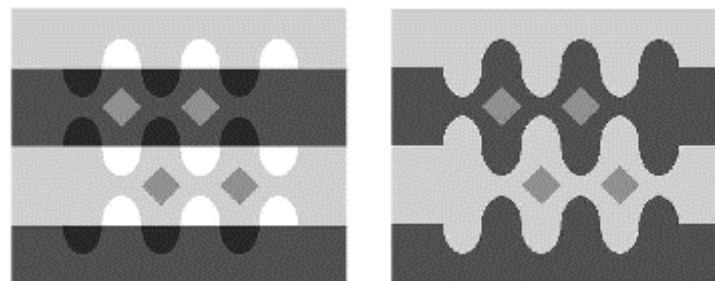
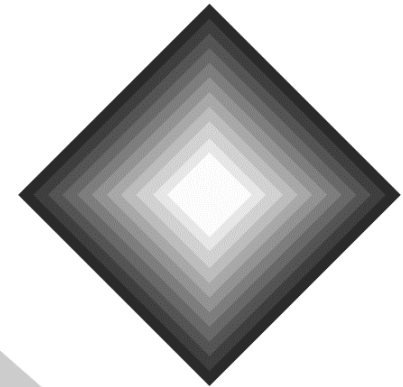
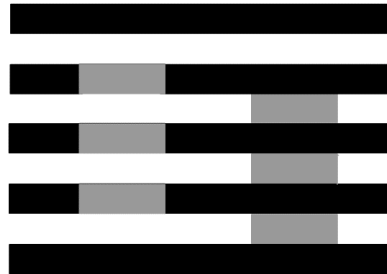


video



Illusions of Brightness

- White's Illusion
- Vasarely Illusion
- Impossible Steps
- Snake Illusion

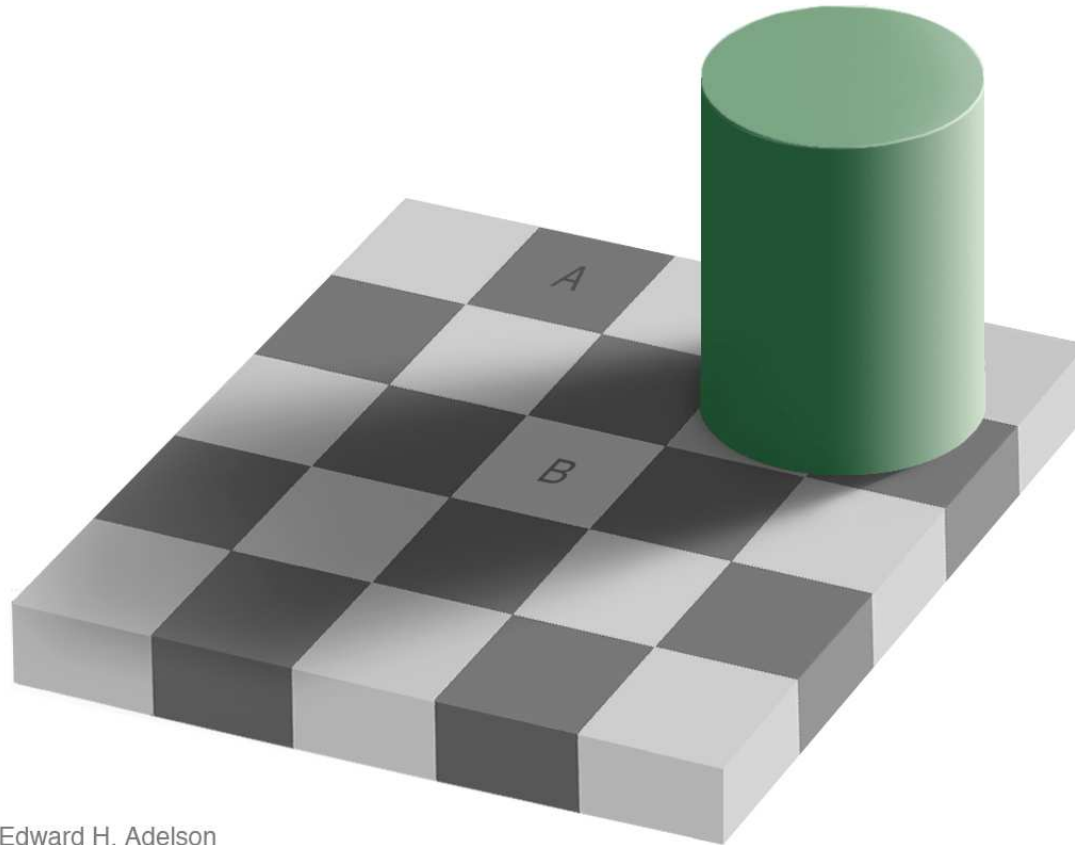


video



Illusions of Brightness

- Local Contrast

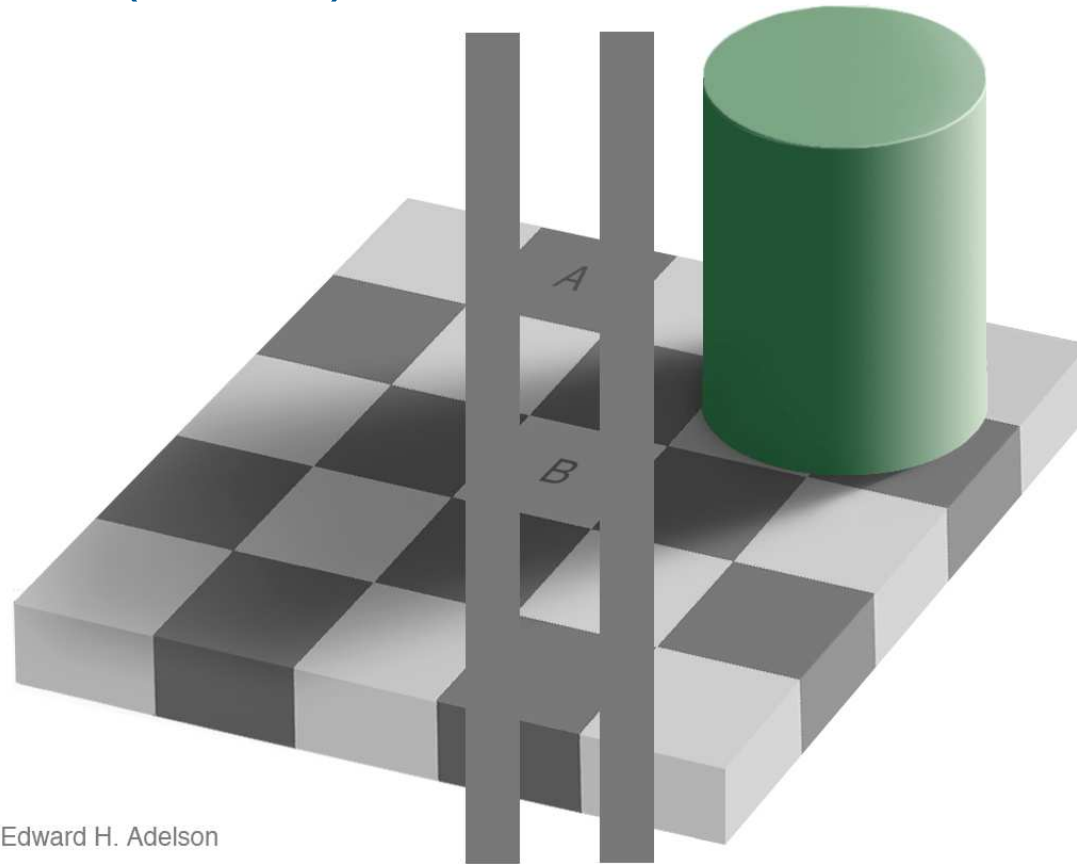


Edward H. Adelson



Illusions of Brightness

- Local Contrast (Adelson)



Edward H. Adelson



Adaptation

- Luminance values (cd/m^2)
 - Physical damage of retina
 - Sun surface: 10,000,000,000
 - Photopic area (just cones)
 - 100 W bulb: 1,000,000
 - directly sunlit paper: 10,000
 - comfortable reading: 10
 - Mesopic area (cones and rods)
 - 1
 - Scotopic area (just rods)
 - moonlit paper: 0.01
 - starlit paper: 0.0001
 - threshold of visibility: 0.000001
 - Visible dynamic range: **10,000,000,000:1**
 - Dynamic range of a neuron: **just 100:1**



Adaptation

- Let more light in
 - Pupil (Human 10:1)
- Use more sensitive photoreceptors
 - rods, cones
- Add up more light
 - Temporal integration
 - Spatial integration
- Weber's Law
 - Threshold proportional to background light level
- **Light** adaptation, **Dark** adaptation
 - pigment bleaching/regeneration



High Dynamic Range



f/8, 1/1000s



f/5.6, 1/250s



f/5.6, 1/30s



f/5.6, 1/4s



f/5.6, 2s

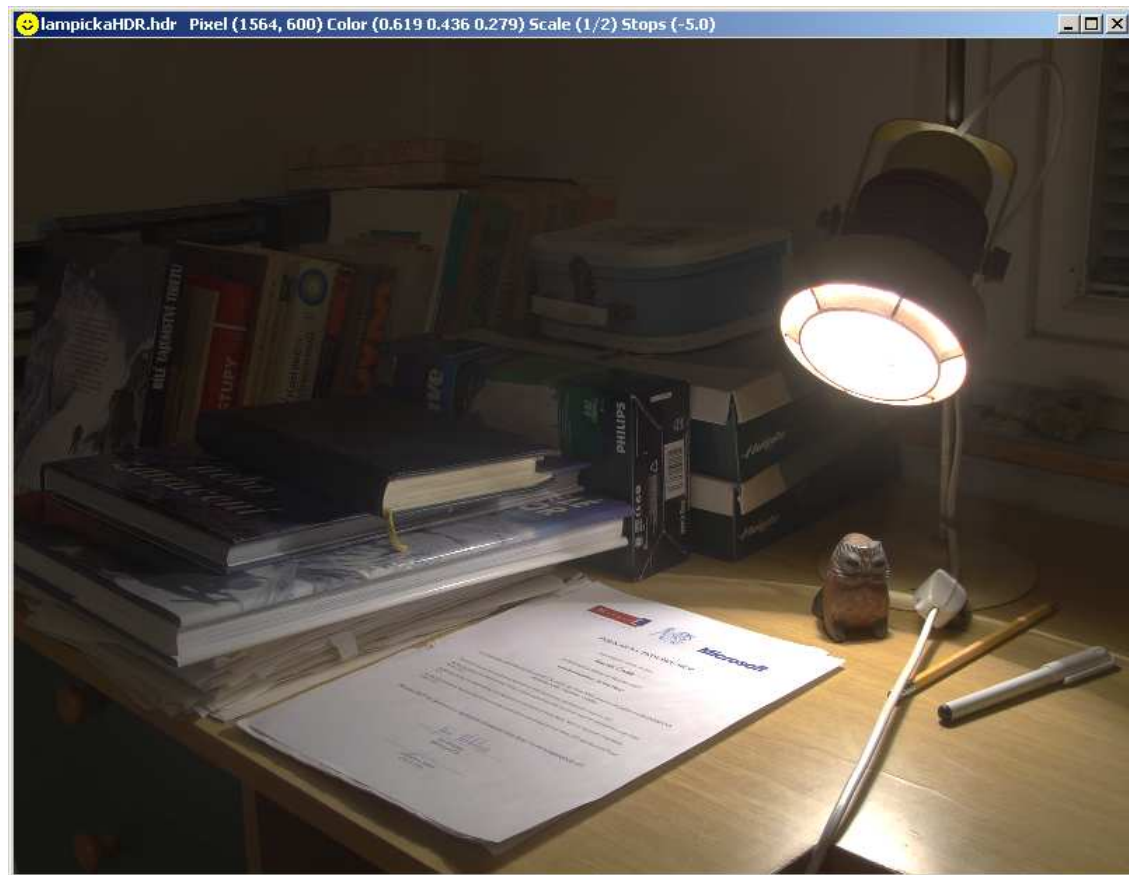


f/5.6, 8s

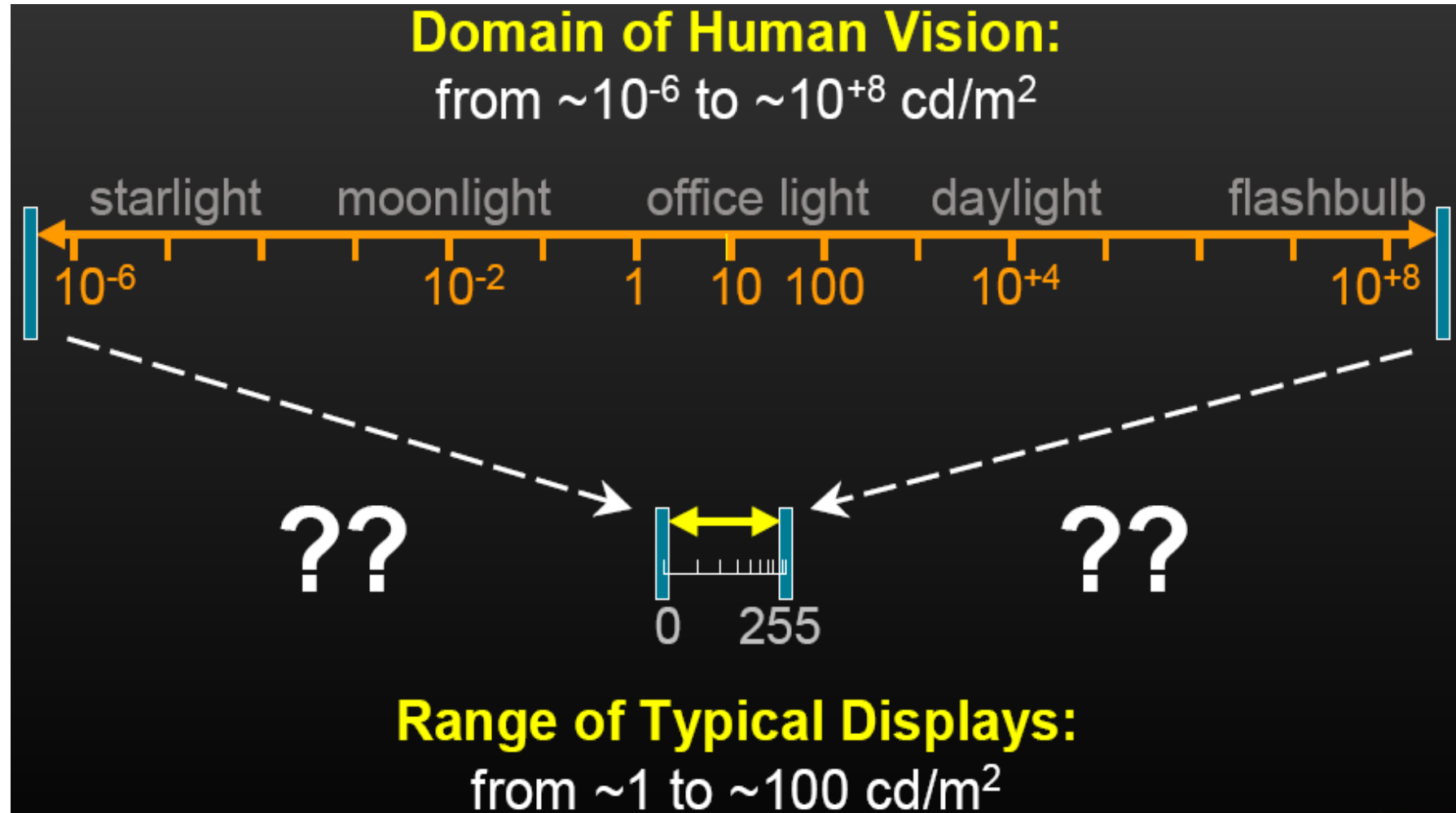


High Dynamic Range

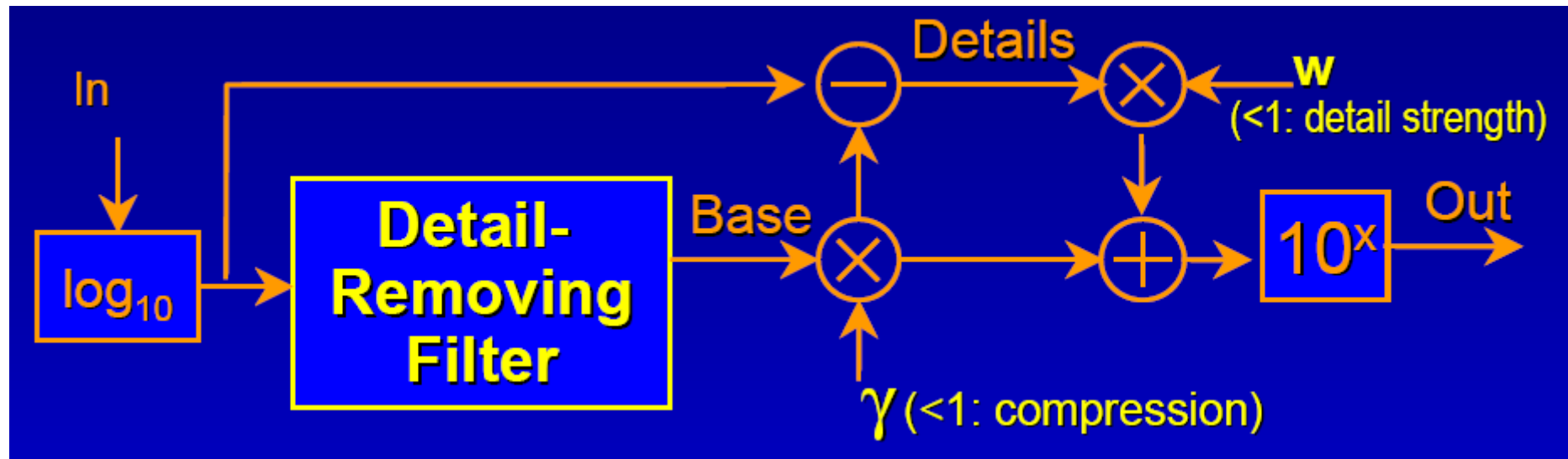
- [Debevec 1997]

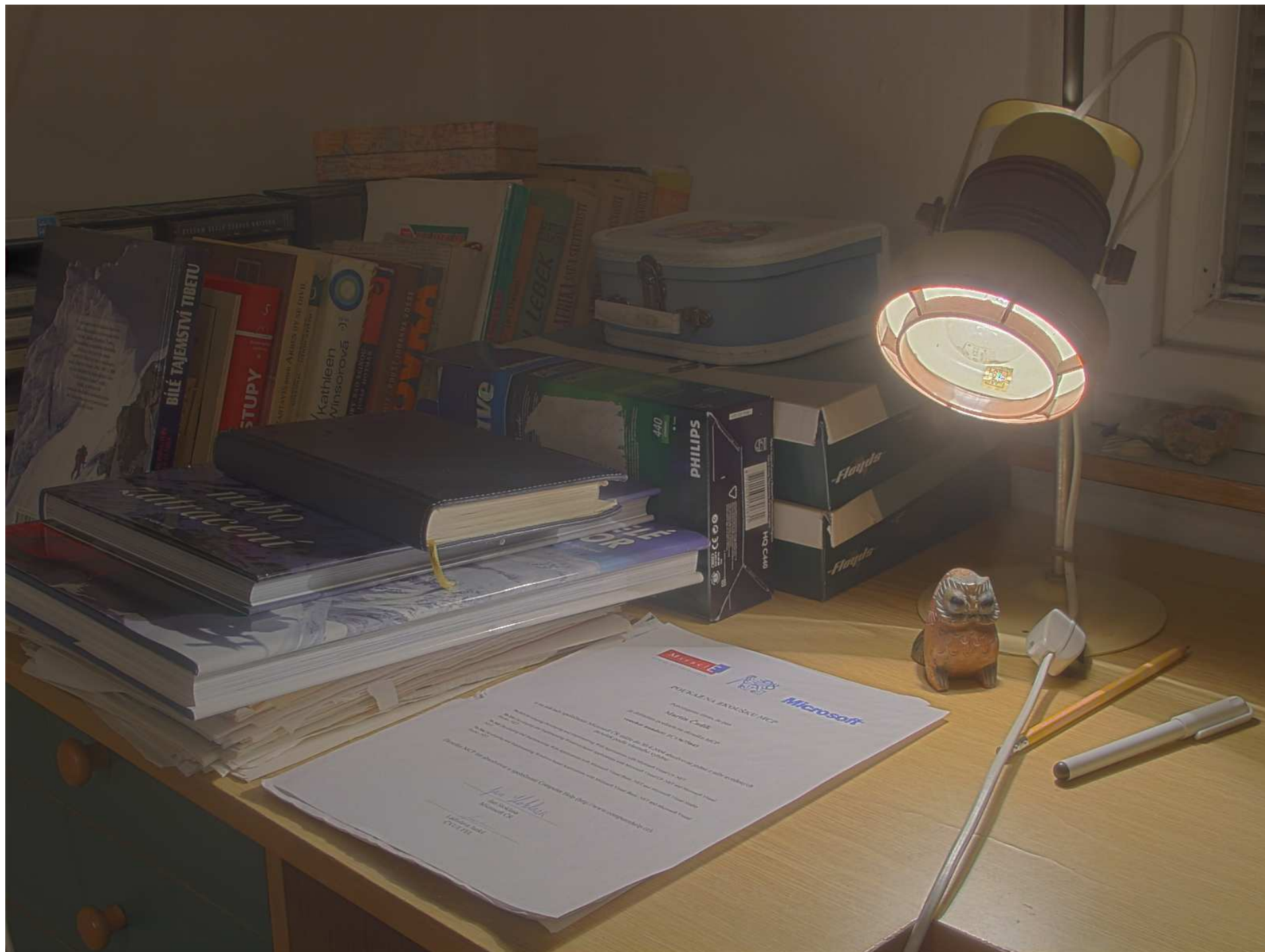


Tone Mapping Issue



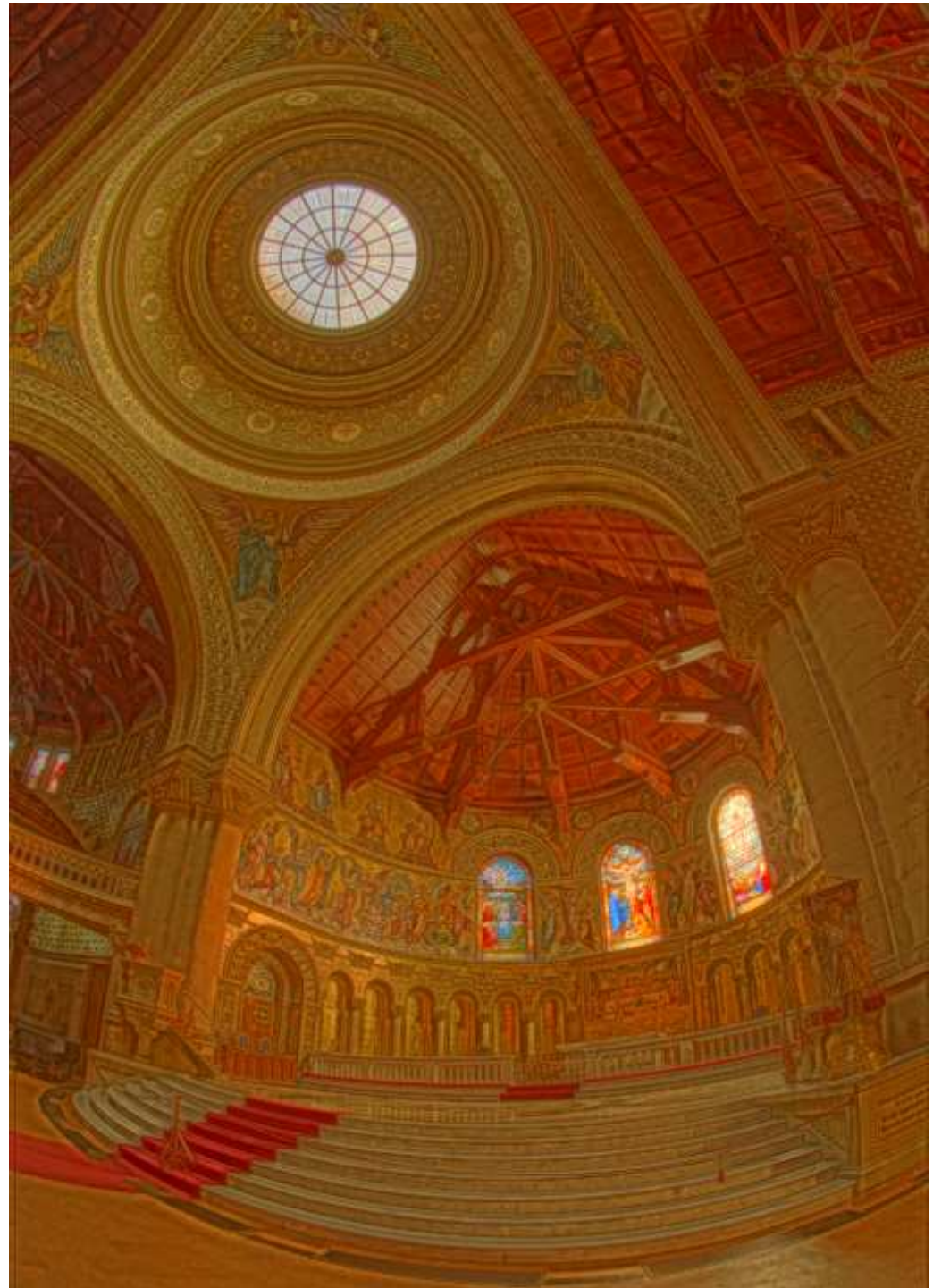
Tone Mapping – Example





Tone Mapping Goals

- Cognitive
 - [LCIS 99]



Tone Mapping Goals

- Aesthetical
 - [Lischinski et al. 06]



Tone Mapping Goals

- Perceptual
 - human observing a HDR scene



HDR Image Acquisition & Reproduction

- Software simulation
- Specialized input devices: Spheron VR, HDR video, etc.
- Specialized output devices: LCD/projector



Tone Mapping – Time Dependent

- [Pattanaik et al. 2000]











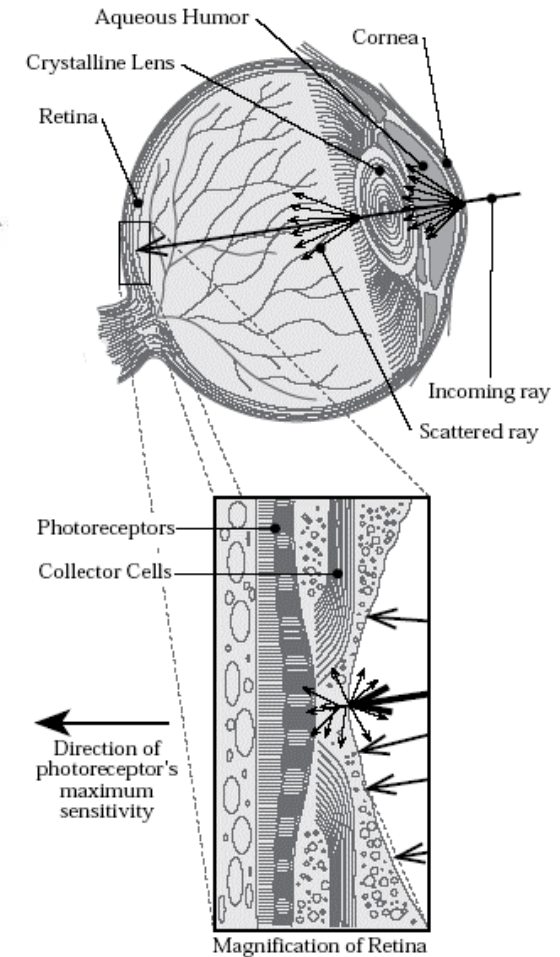
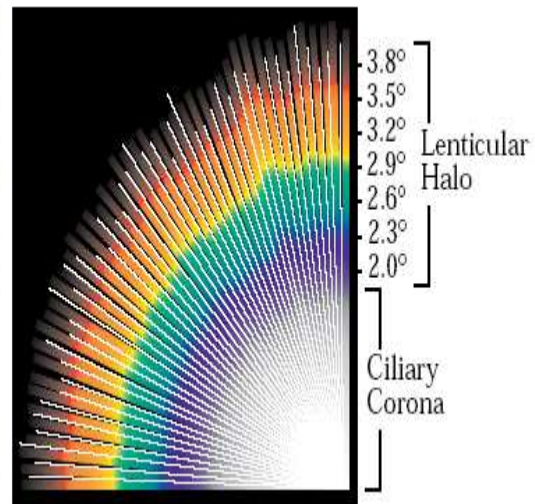




Tone Mapping – Glare

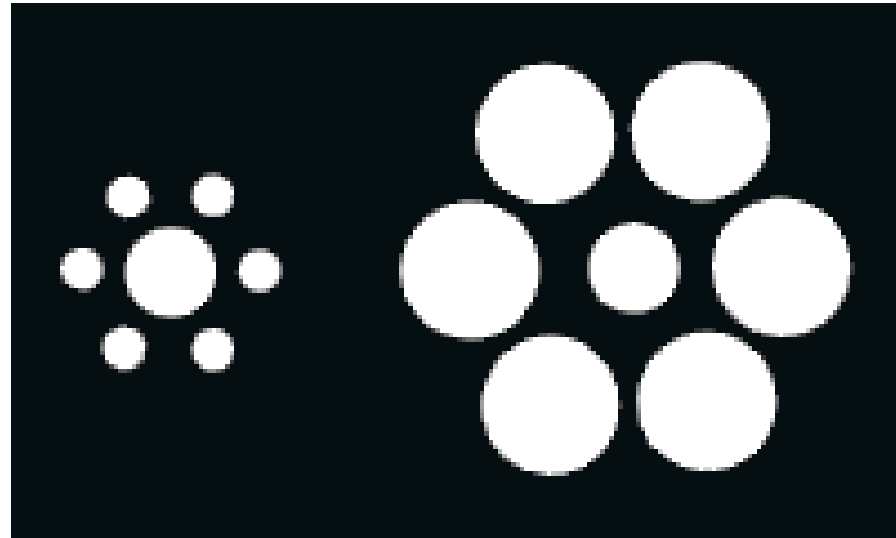
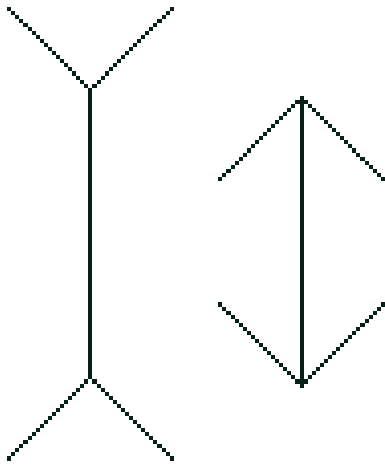


Carl Saltzmann, 1884



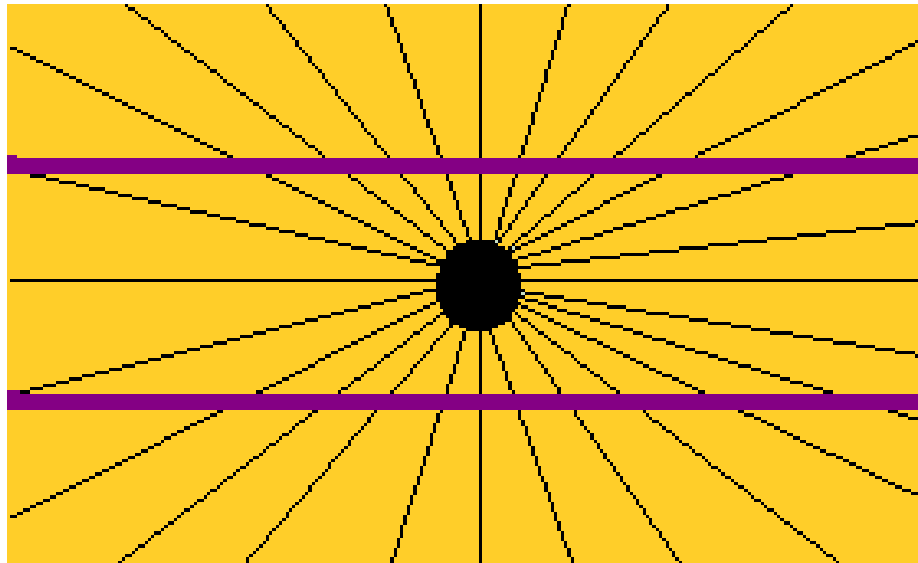
Geometrical illusions

- Müller-Lyer illusion



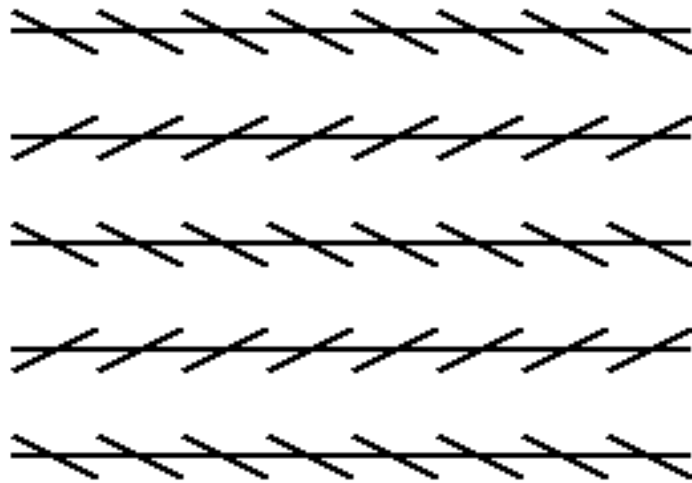
Geometrical illusions

- Orbison illusion

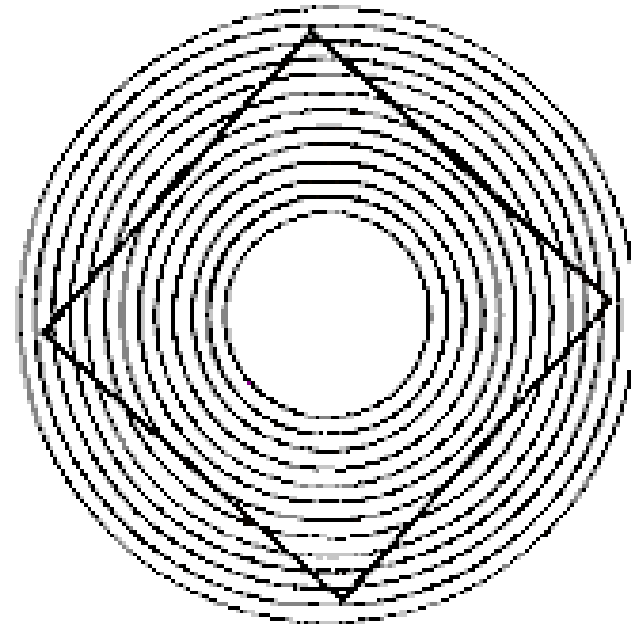


Geometrical illusions

- Zöllner illusion

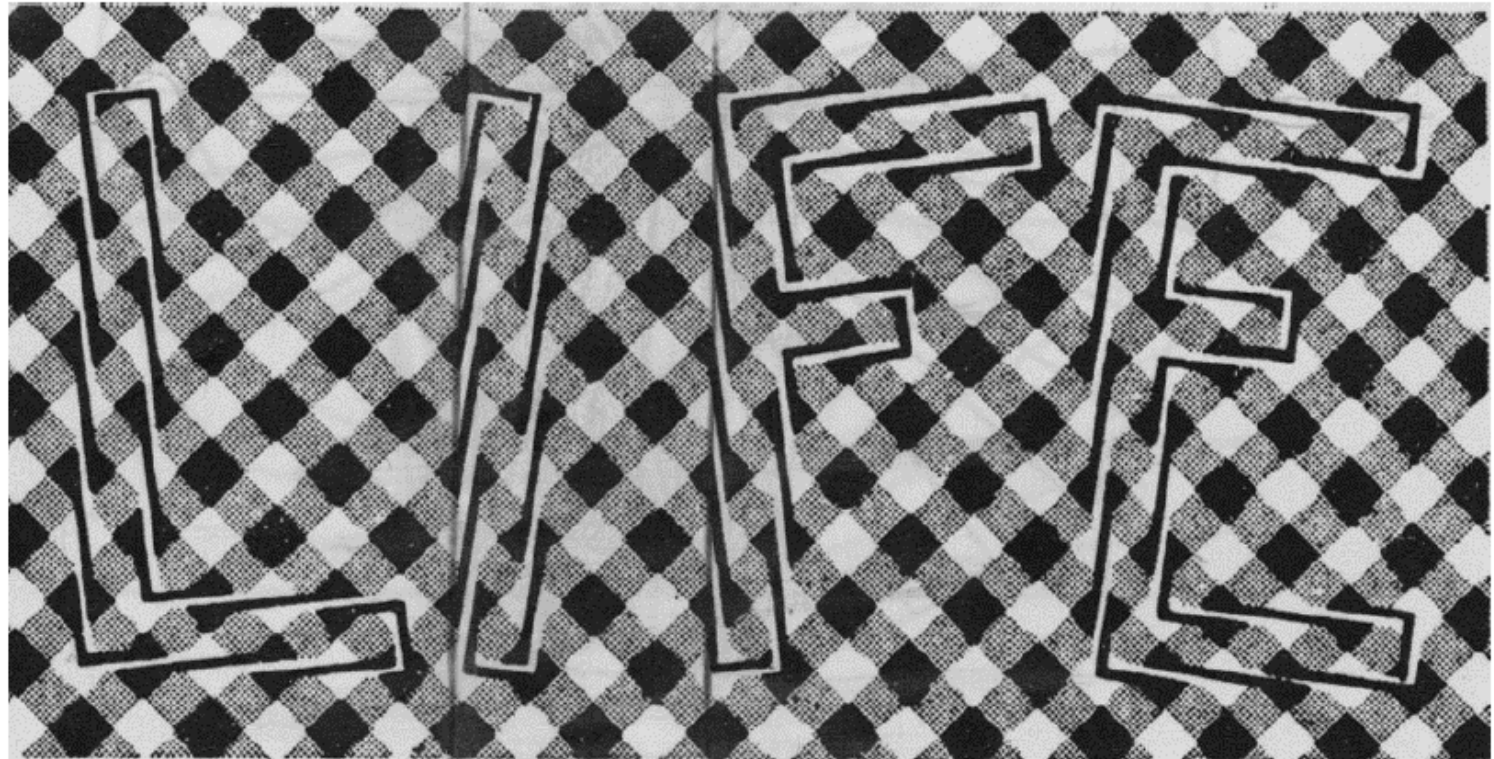


- Hering illusion



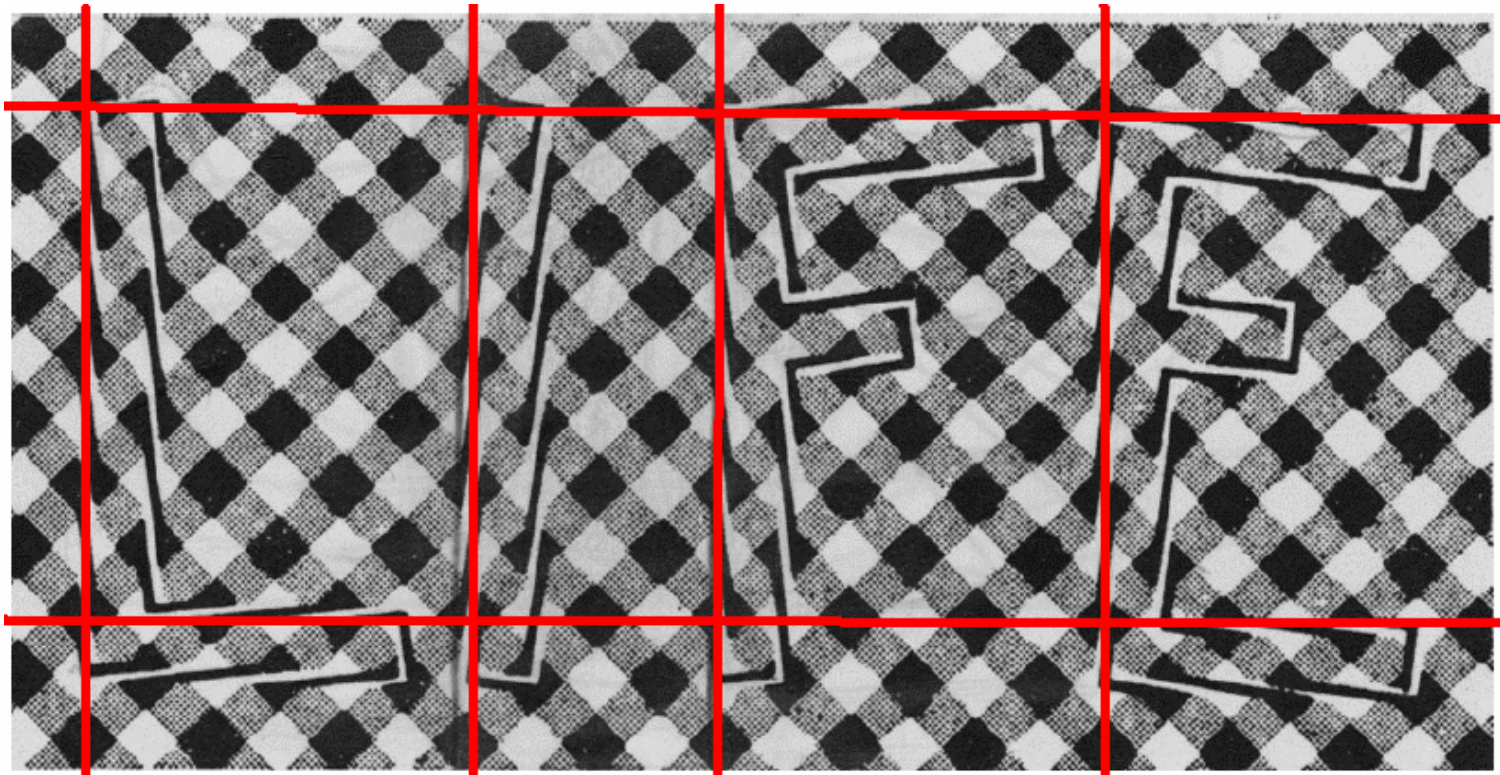
Geometrical illusions

- Fraser illusion - Twisted Cord Illusion



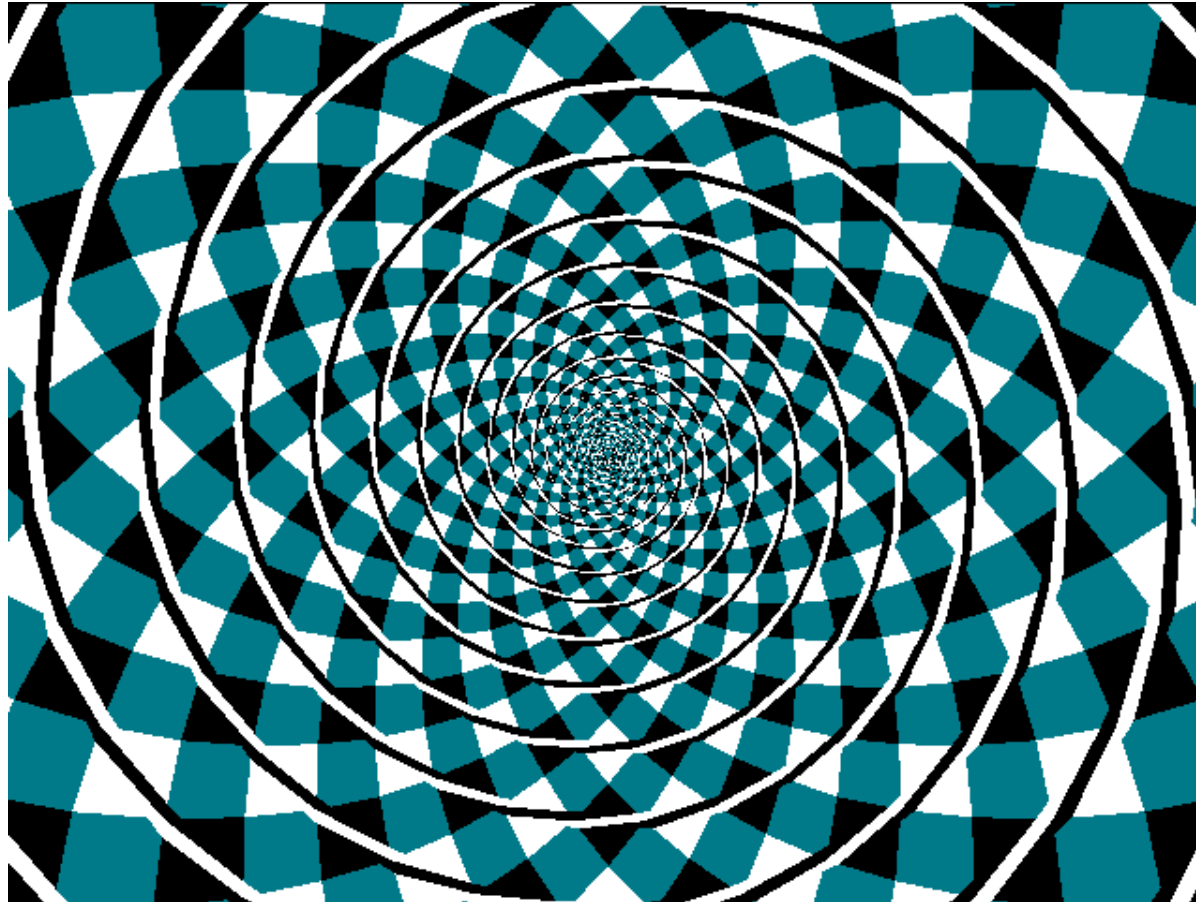
Geometrical illusions

- Fraser illusion - Twisted Cord Illusion



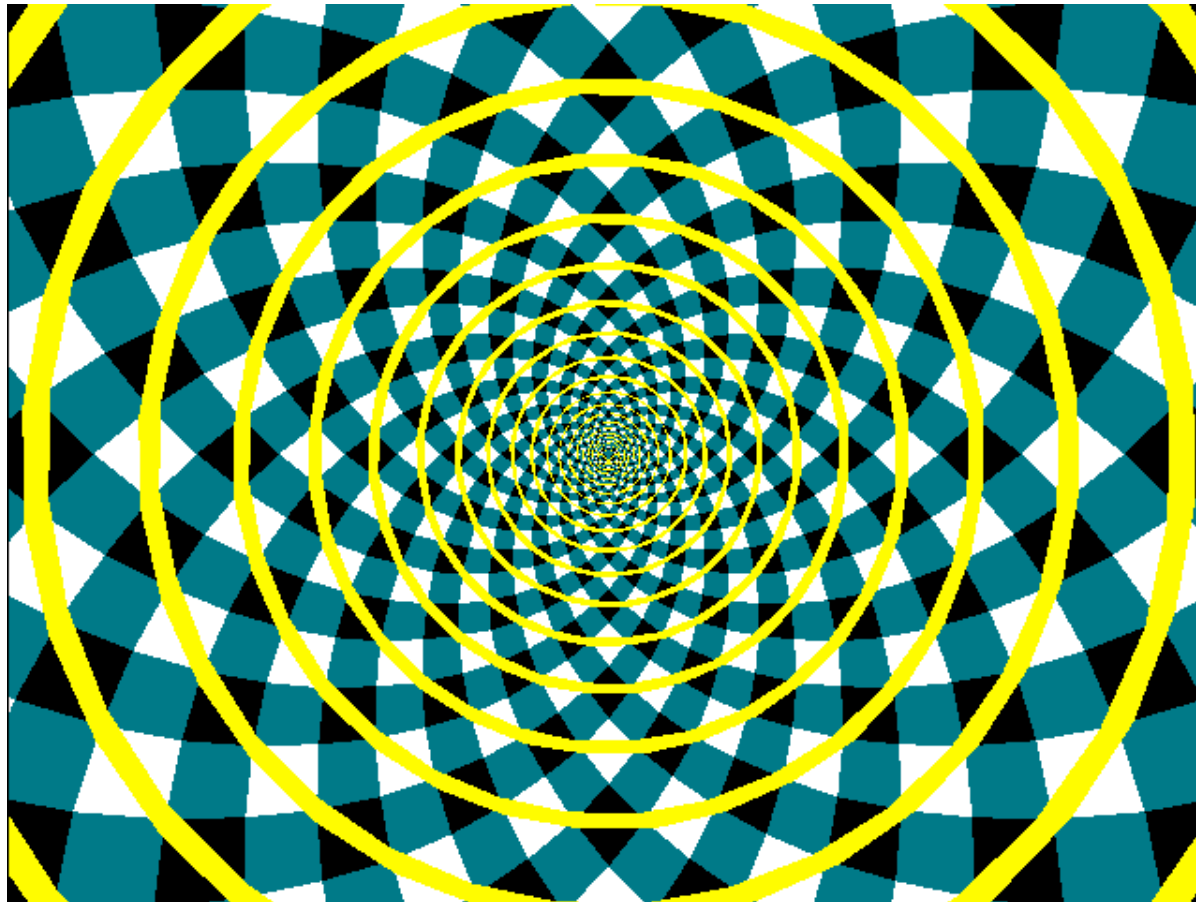
Geometrical illusions

- Fraser illusion – whorl (1908)



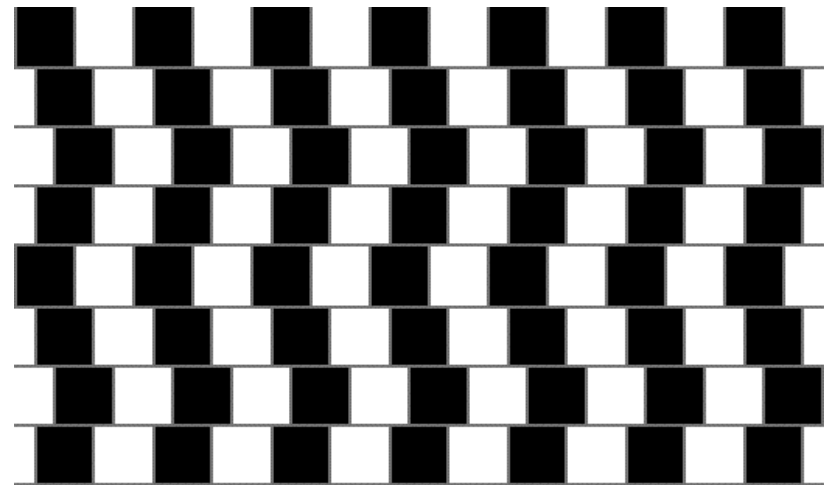
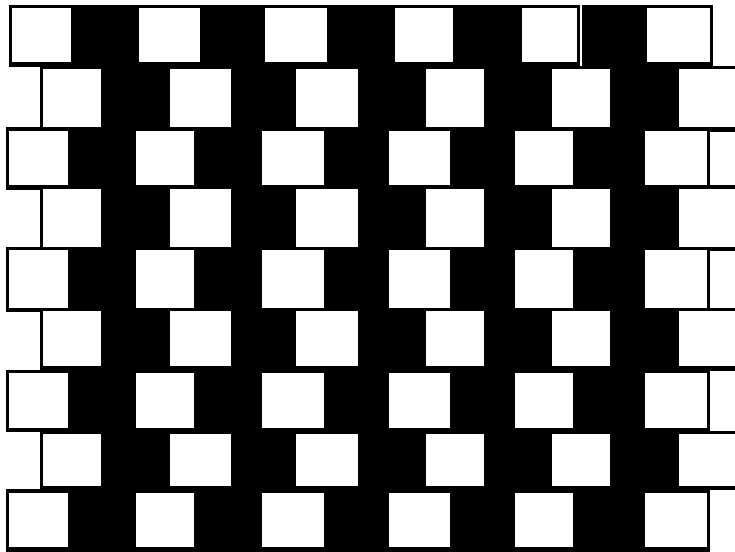
Geometrical illusions

- Fraser illusion – whorl (1908)



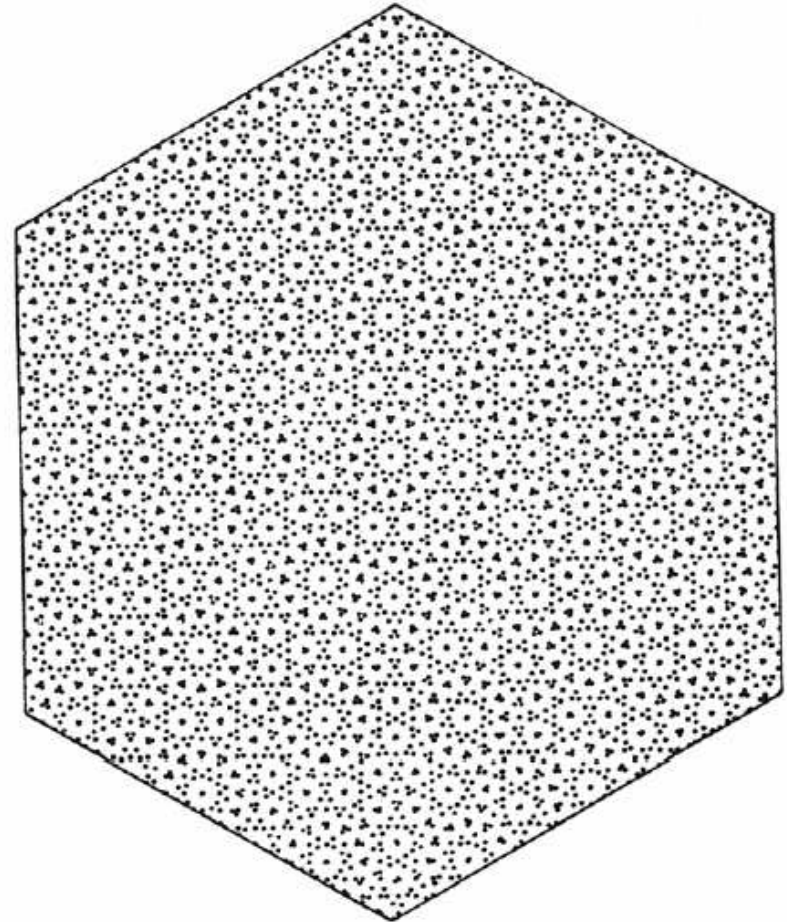
Geometrical illusions

- Münsterberg (Cafe-Wall illusion)

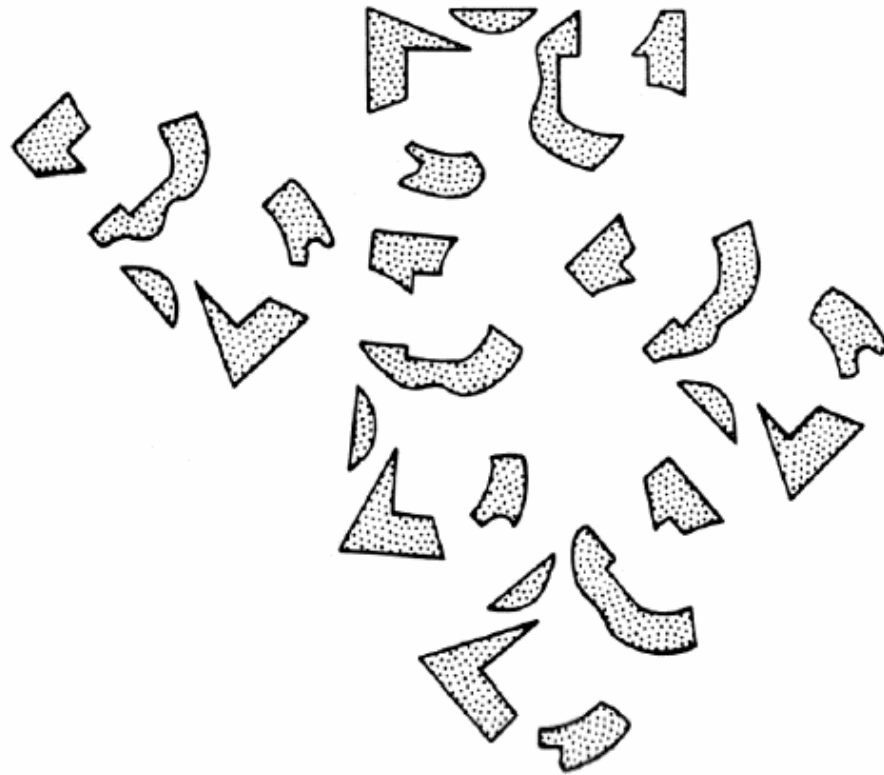


Perceptual Grouping

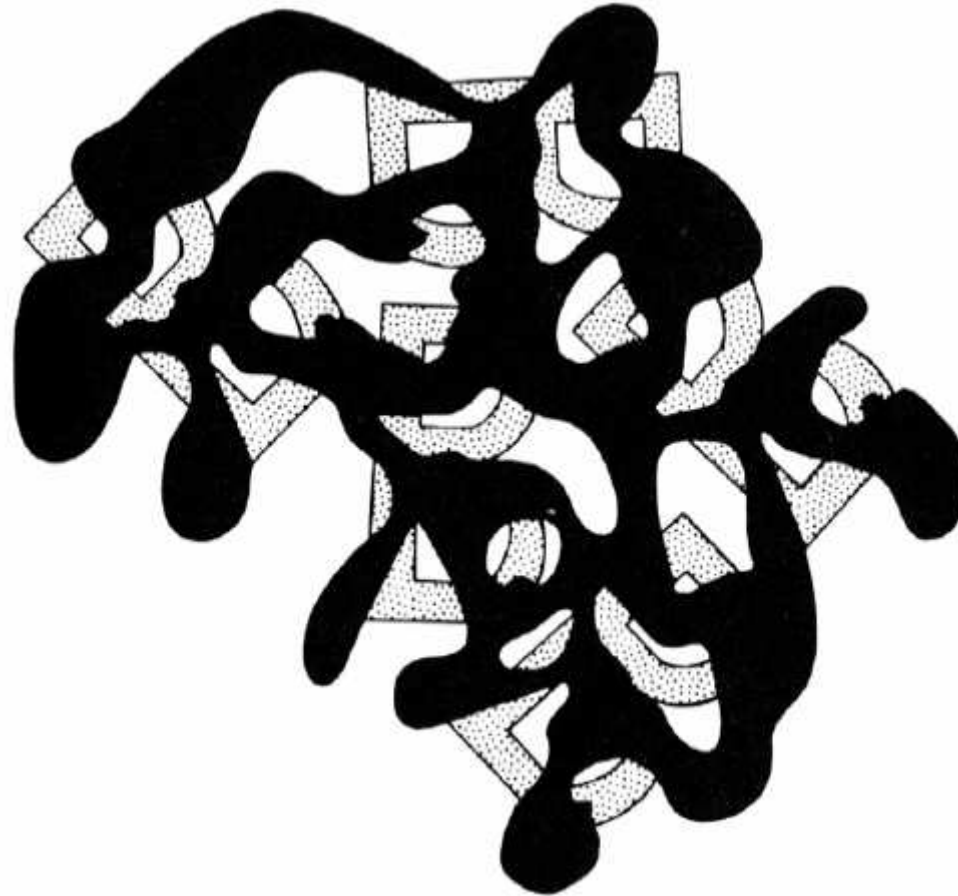
- Gestalt psychologists
- Principles of grouping
 - Proximity
 - Similarity (size, color, orientation)
 - Symmetry
 - Parallelism
 - Continuity
 - Closure
- [J.L.Marroquin]
 - we see group of circles with various radii



Perceptual Grouping

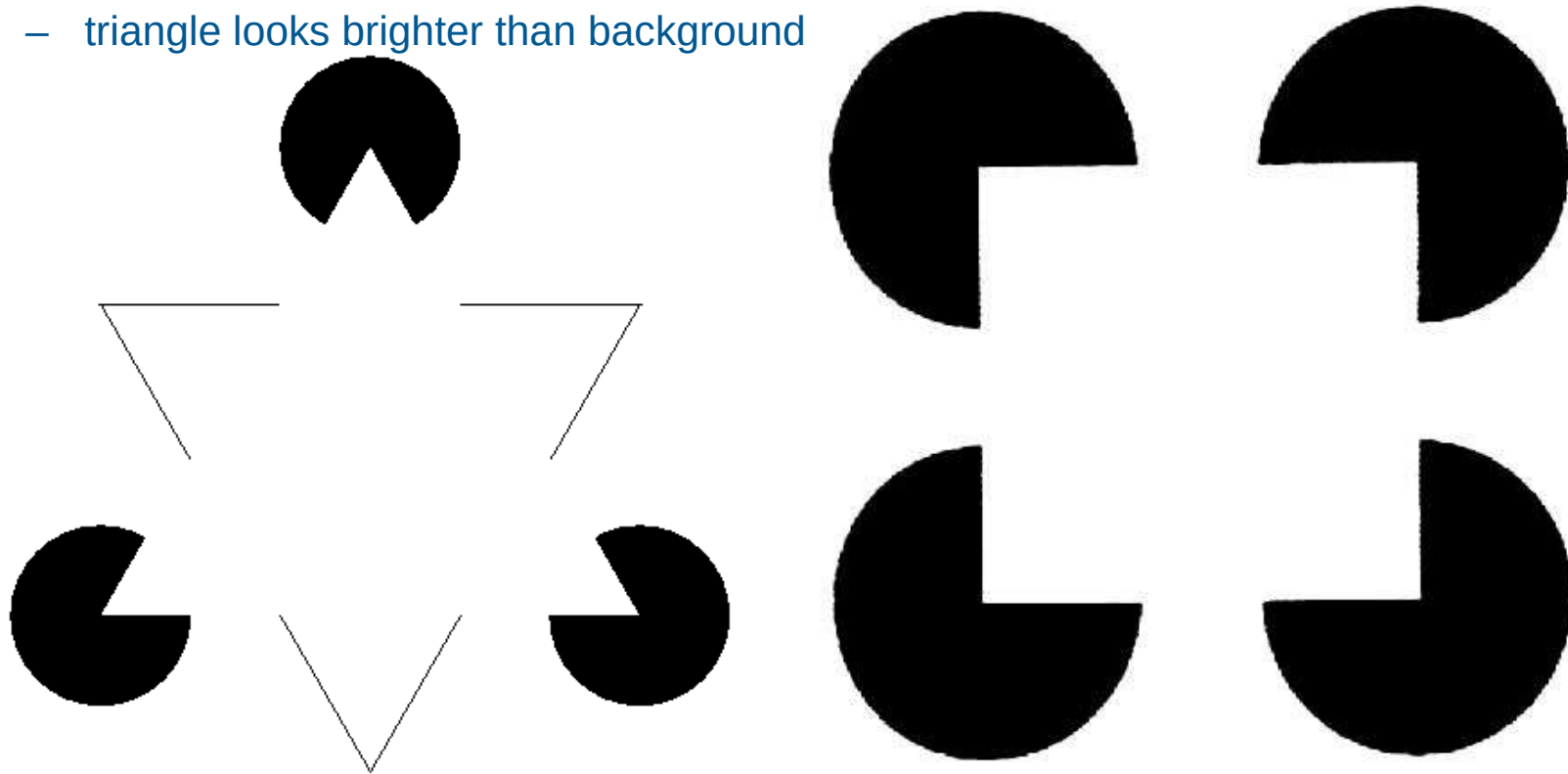


Perceptual Grouping



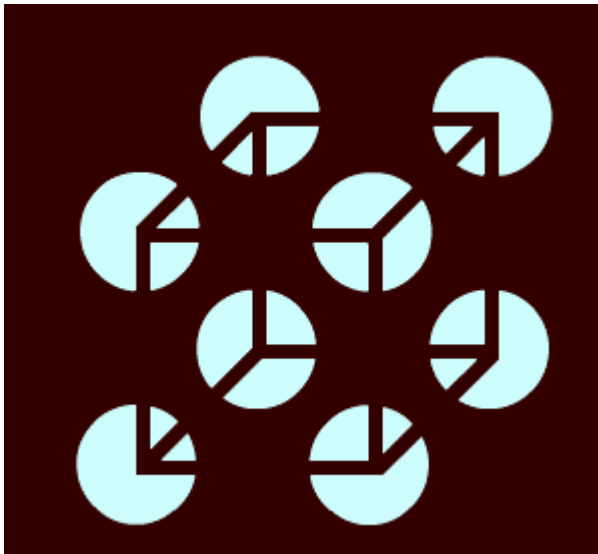
Subjective Contours

- Kanisza triangle
 - illusory contours
 - triangle looks brighter than background



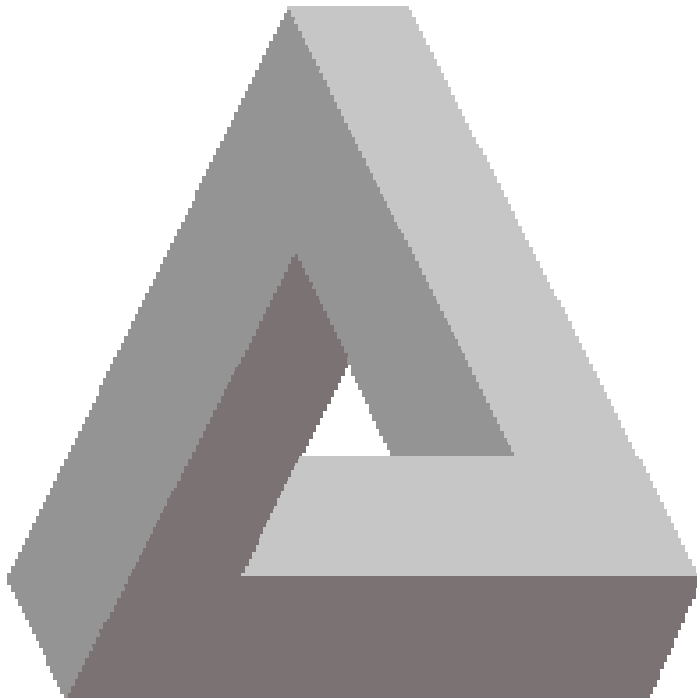
Subjective Contours

- Nonexistent cube

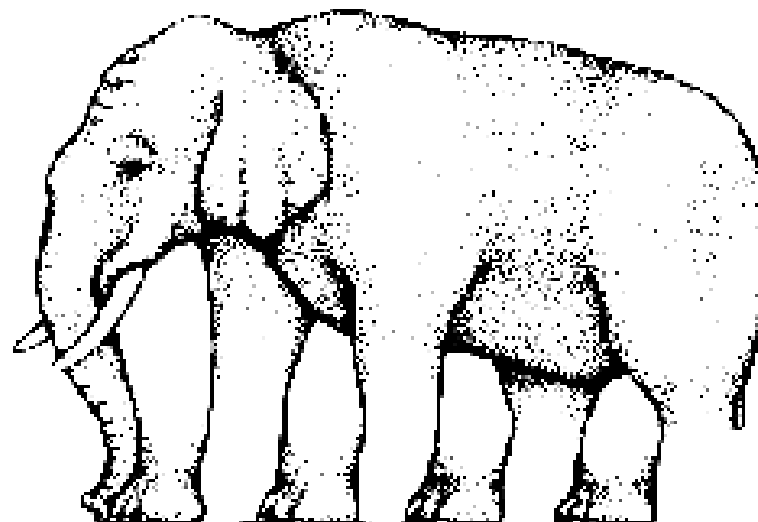
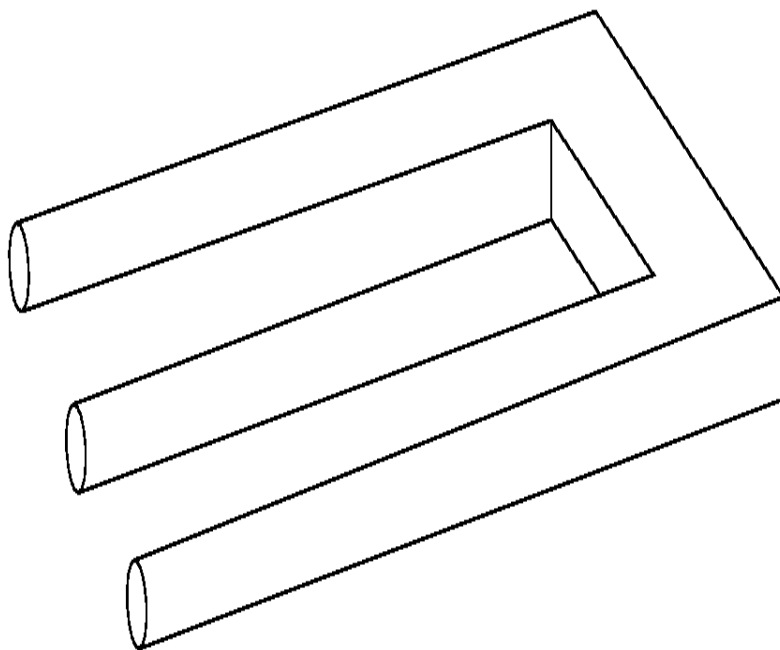


Impossible Objects

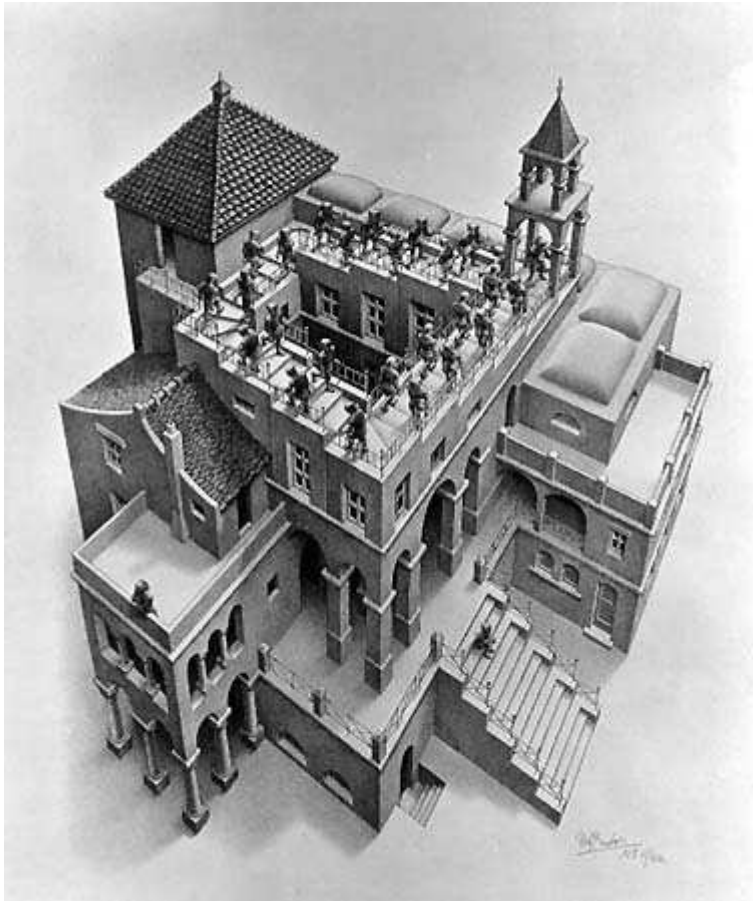
- Vision actively constructs environmental models



Impossible Objects



M. C. Escher

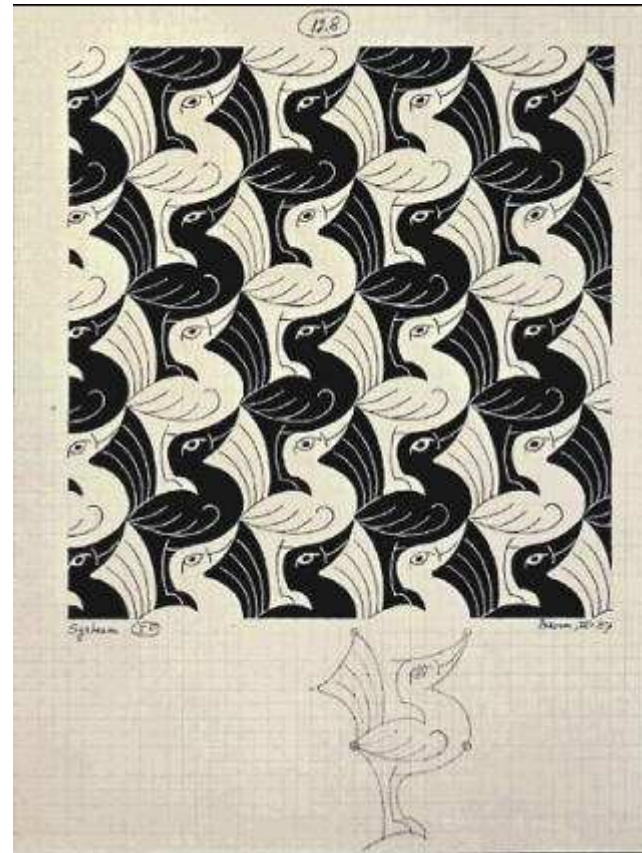


M. C. Escher

■ video

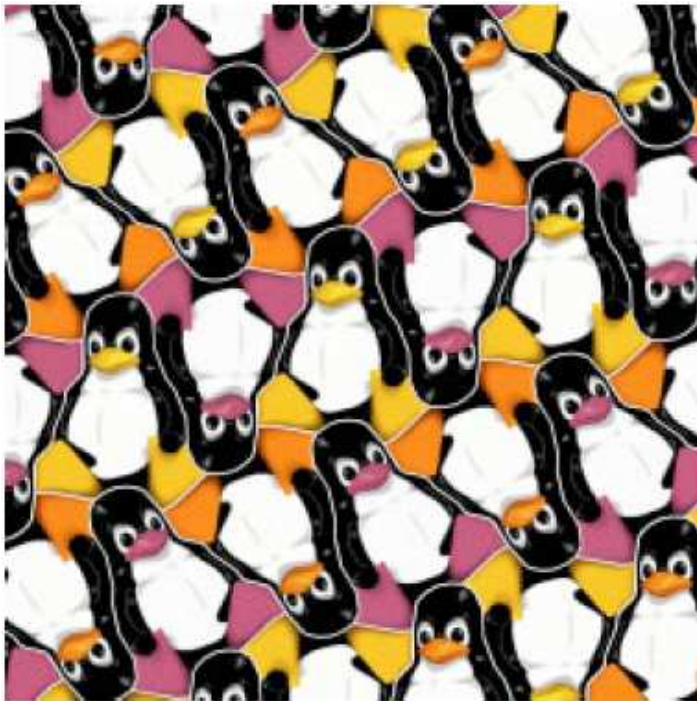


-symmetry



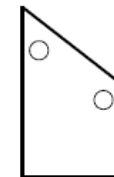
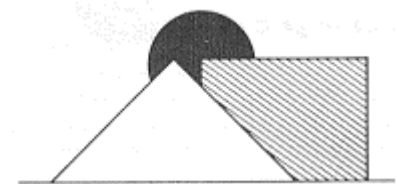
“Escherization”

- (Kaplan, Salesin 2000):
given a closed figure in the plane, find a new closed figure
that is similar to the original and tiles the plane



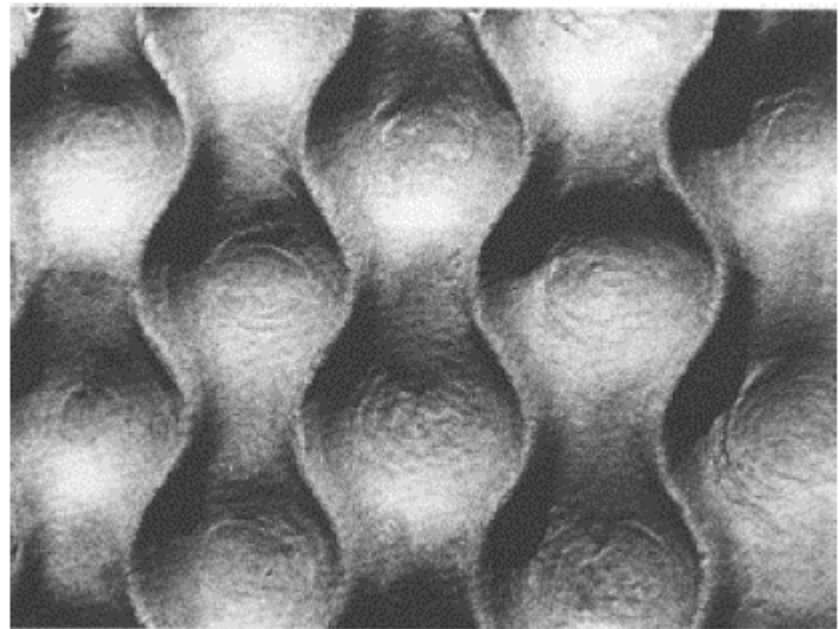
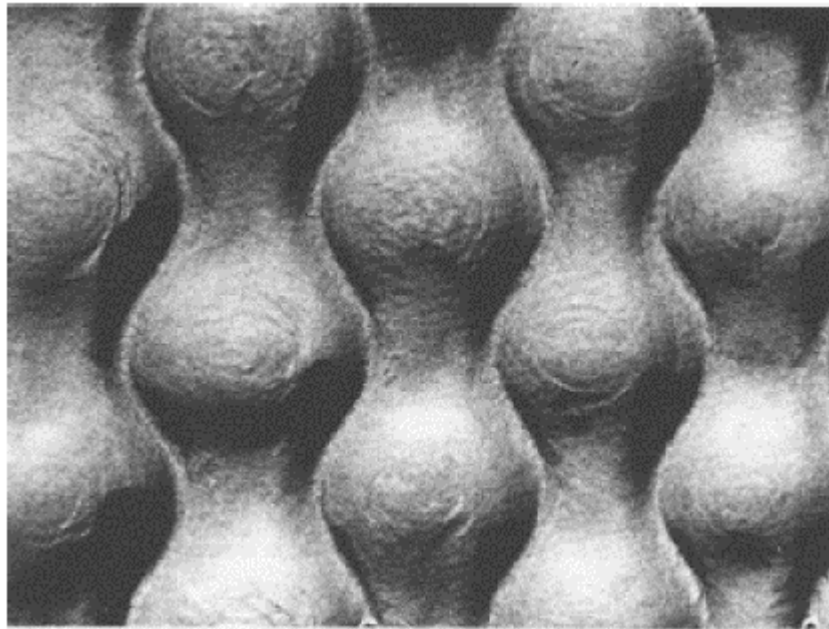
Depth Perception

- physiological cues:
 - accommodation
 - convergence
 - → not accurate
- monocular depth cues (require just one eye):
 - pictorial depth cues
 - occlusion (relative)
 - aerial perspective
 - linear perspective
 - texture gradients

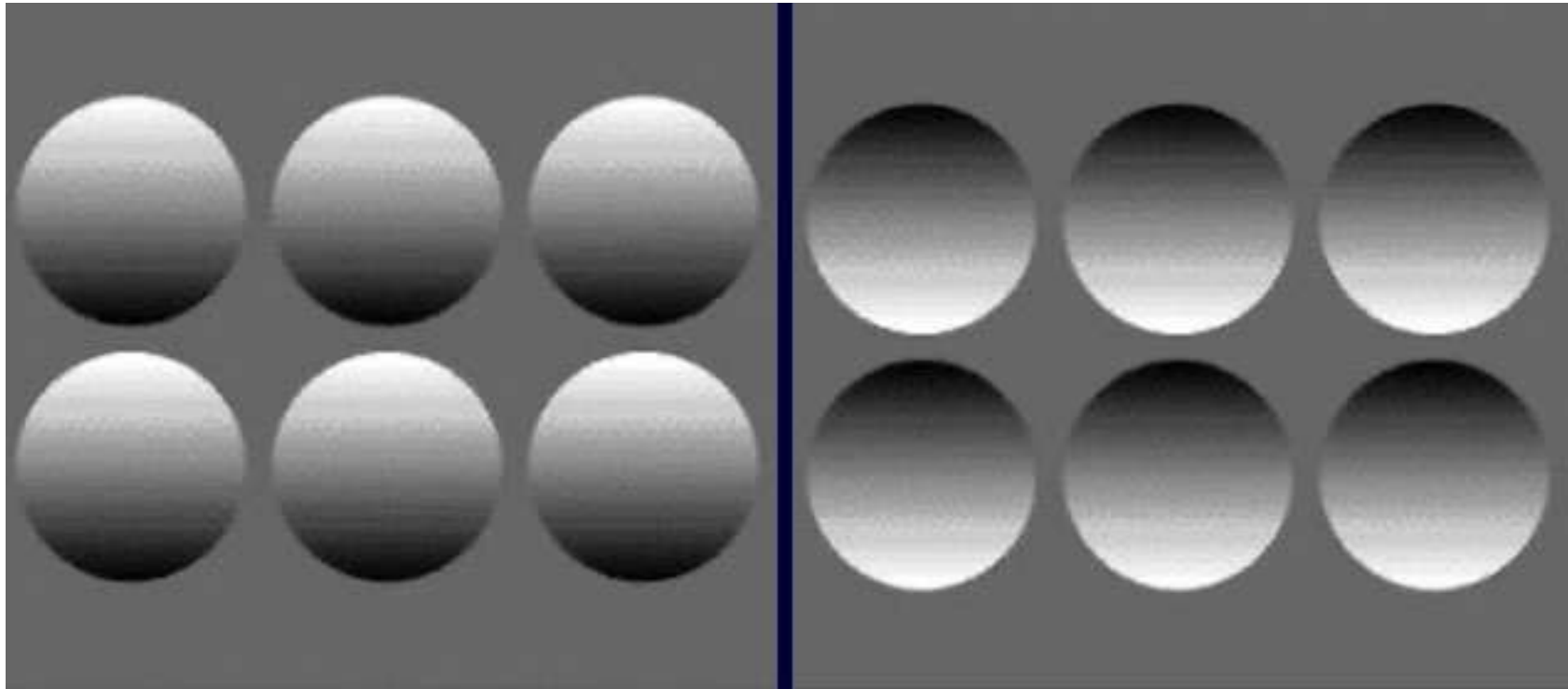


Depth Perception

- pictorial depth cues
 - shading (brain supposes light from above)

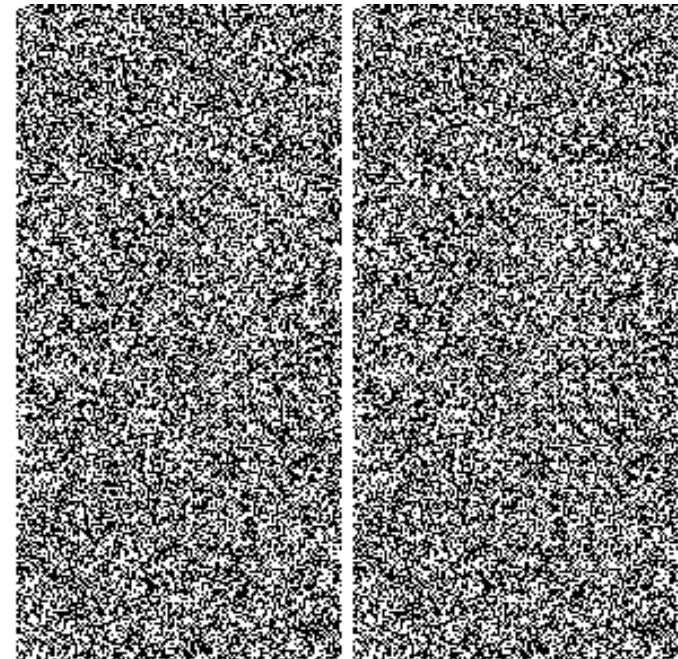


Depth Perception



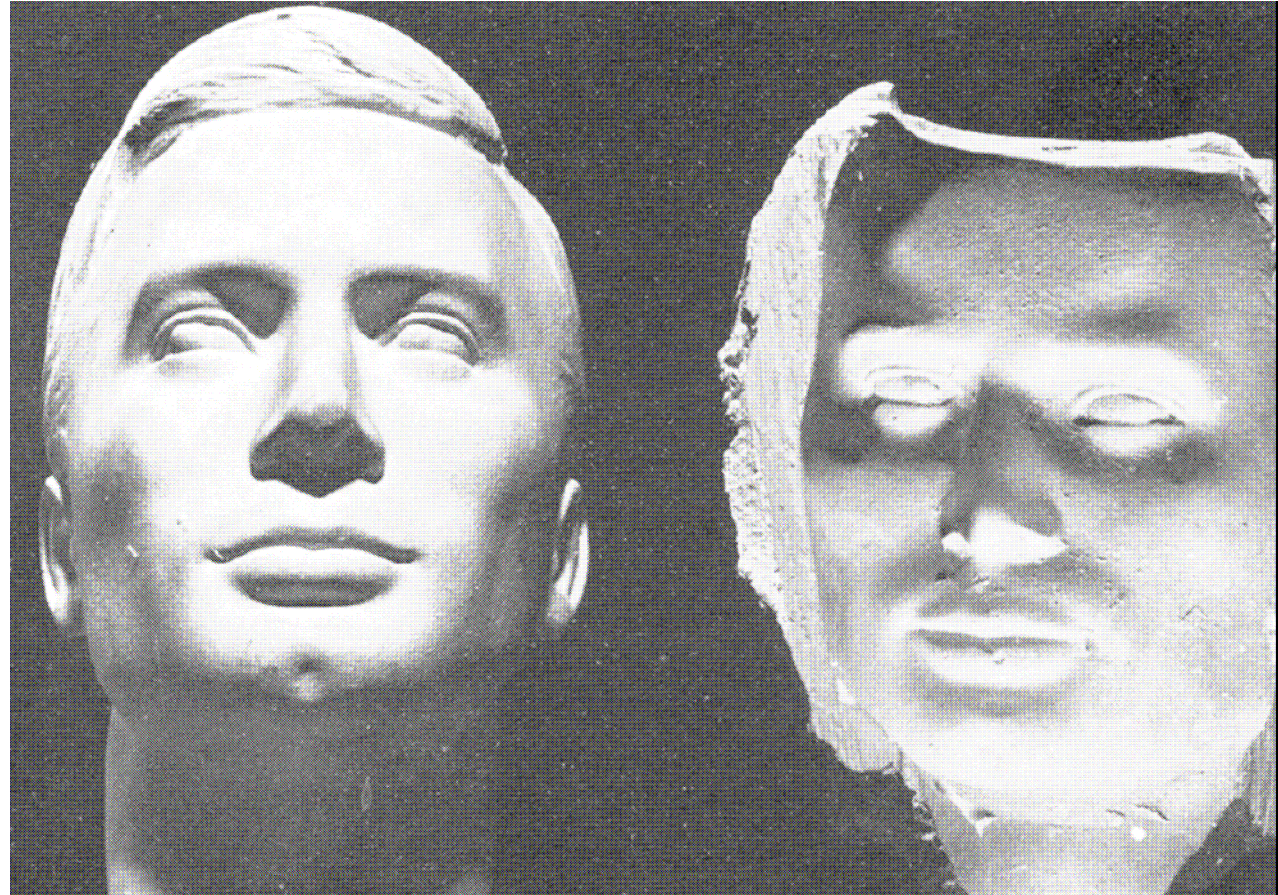
Depth Perception

- pictorial depth cues
 - elevation
 - relative size
- dynamic monocular cues to depth
 - motion parallax
- binocular vision – disparate images
 - correspondence problem
 - but: random-dot-stereograms [Julesz 1965]



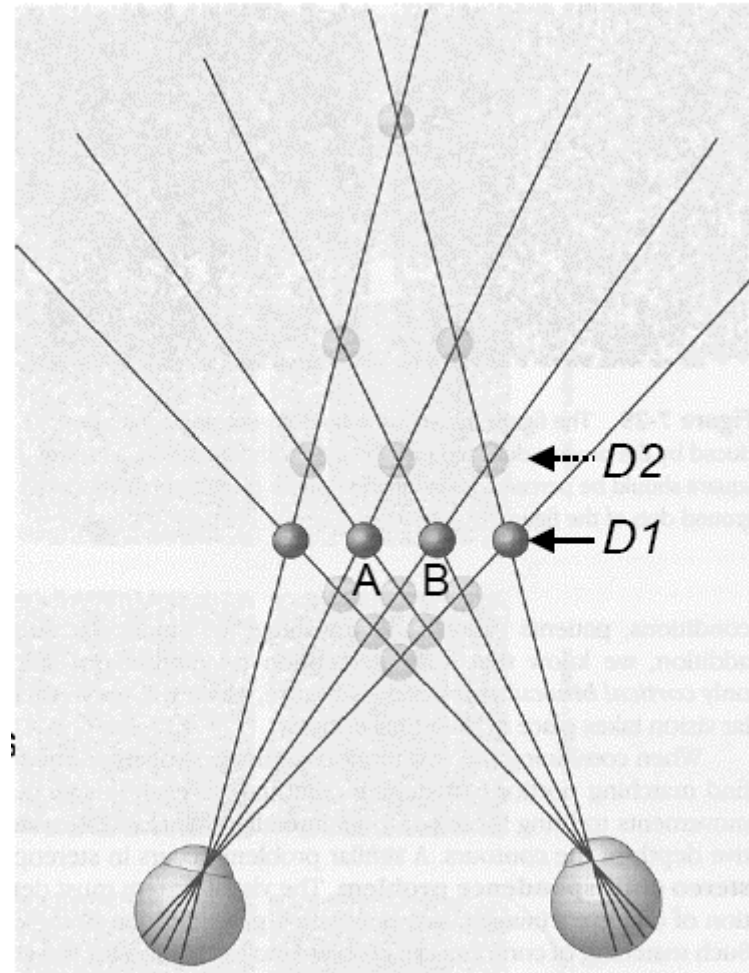
Perception of Face

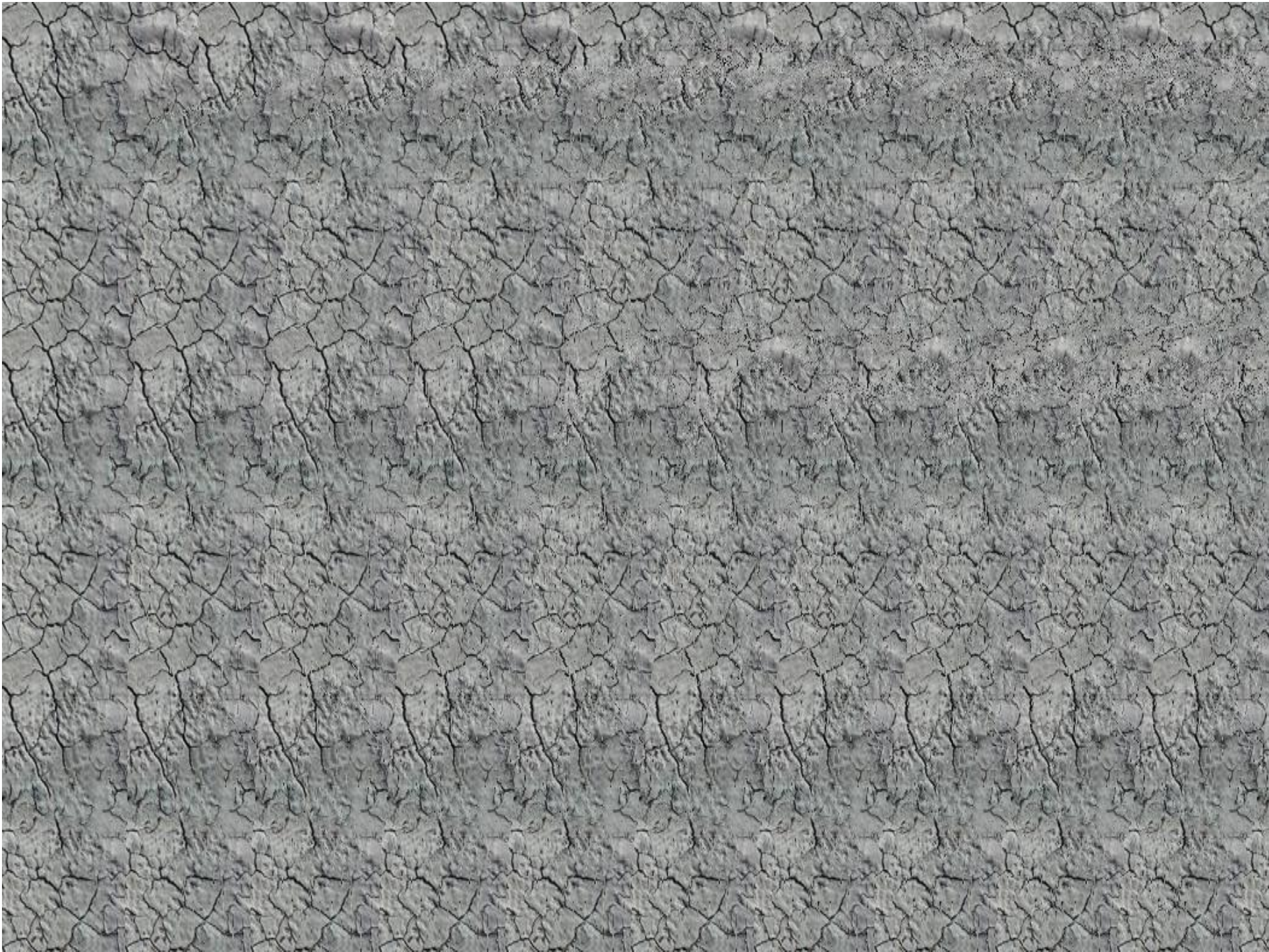
- Hollow faces are rare
- Both positive and hollow face seen convex!
- show



Autostereograms

- [Christopher Tyler, Maureen Clark 1979]
- if the left eye fixates on a different object (e.g. A) than the right eye (e.g. B), the visual system assumes that they are looking at the SAME
- object and all the objects will appear to be farther away ($D2$)! — false matches



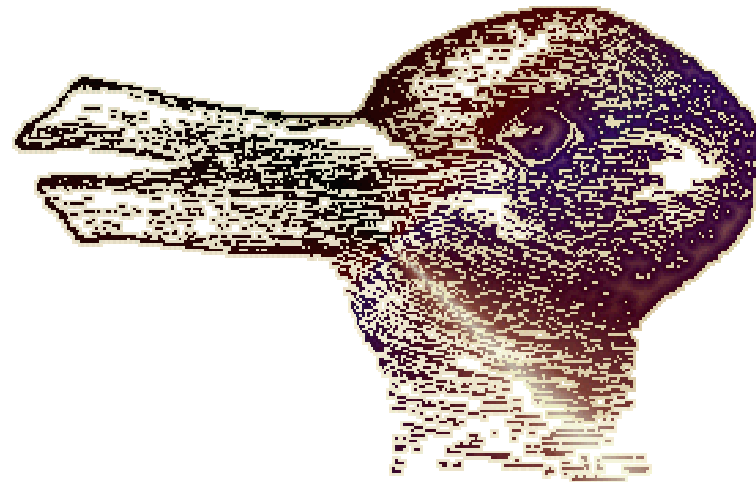


Autostereograms



Ambiguous Figures

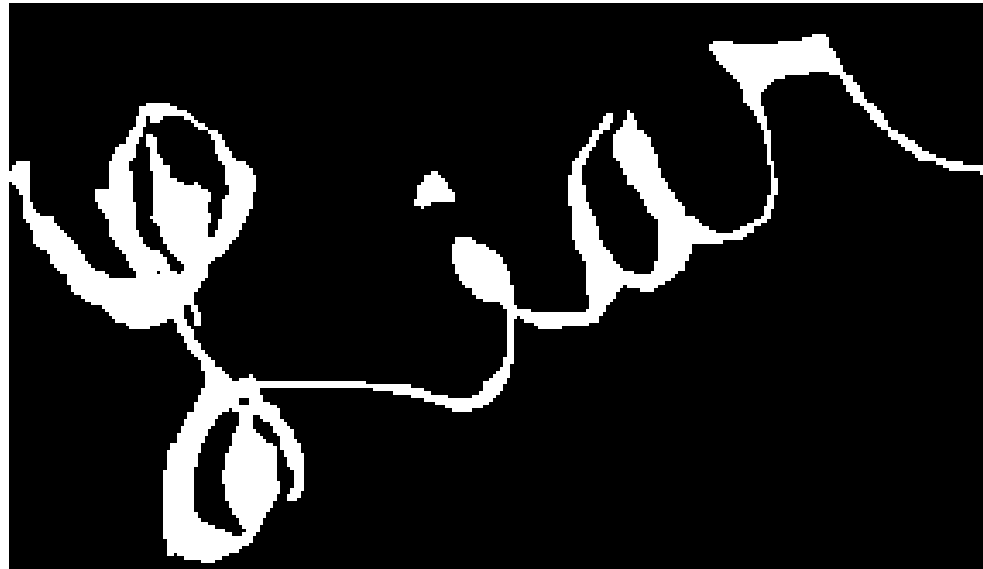
- Vision is *interpretive process*
- Mutually exclusive interpretations of one figure
- Construction of interpretive model



Ambiguous Figures



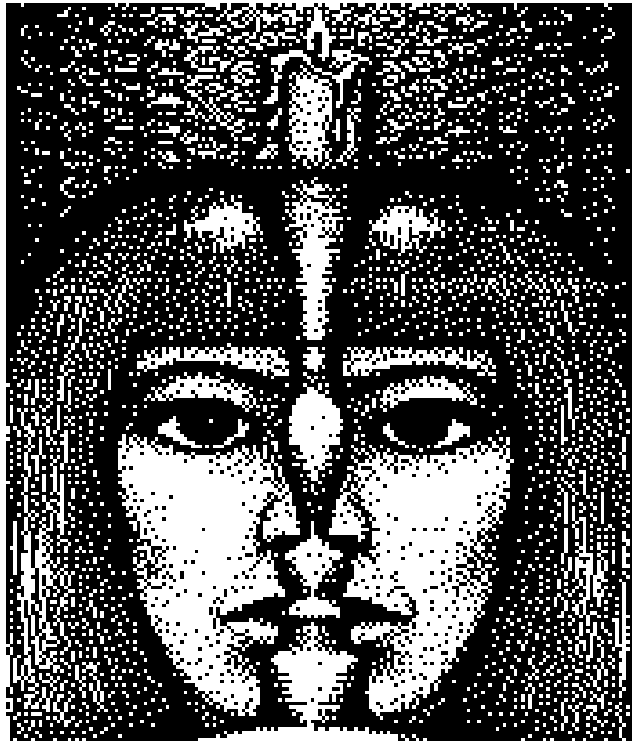
Ambiguous Figures



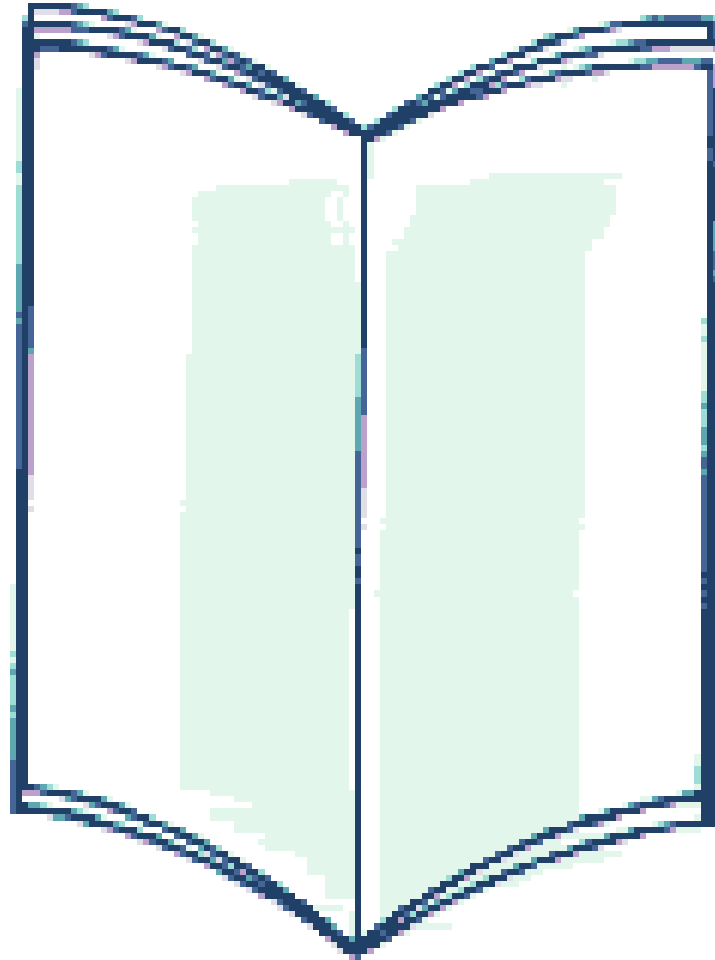
Ambiguous Figures



Ambiguous Figures



Ambiguous Figures



Ambiguous Figures



Ambiguous Figures

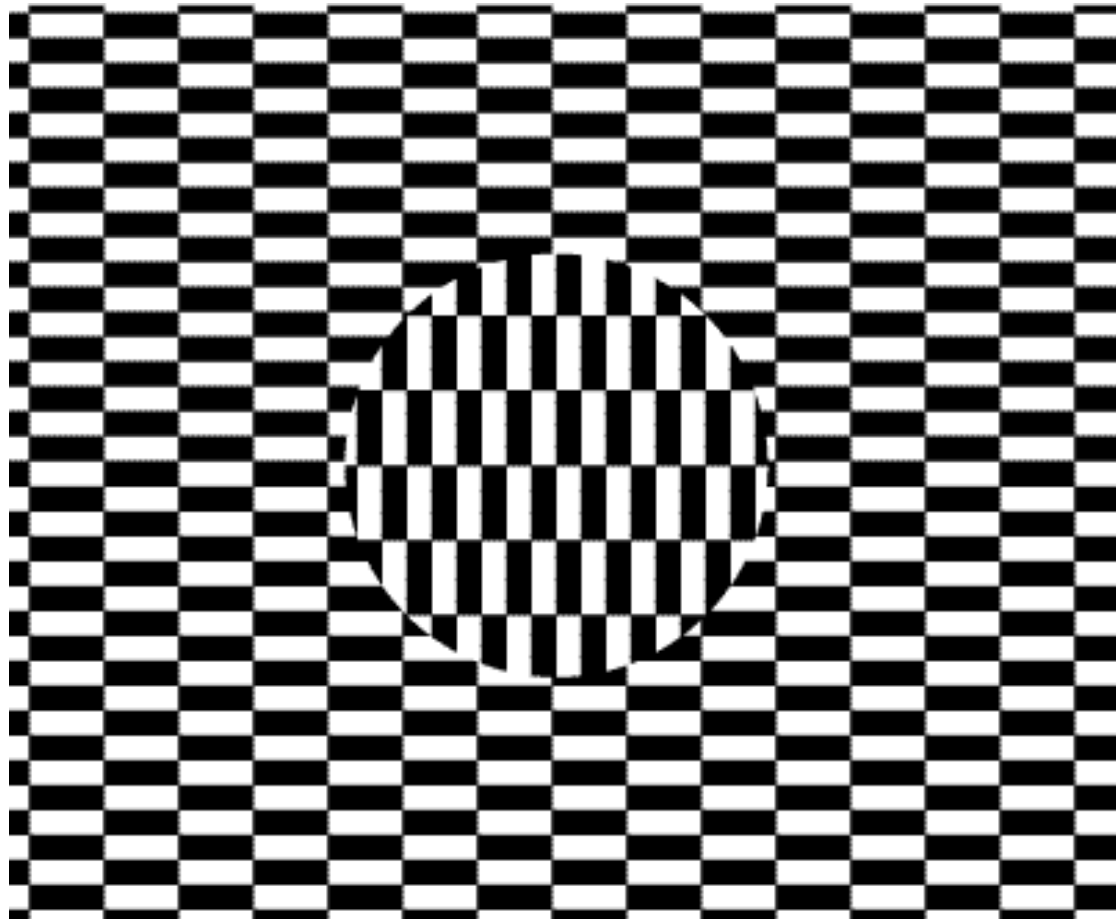


Ambiguous Figures

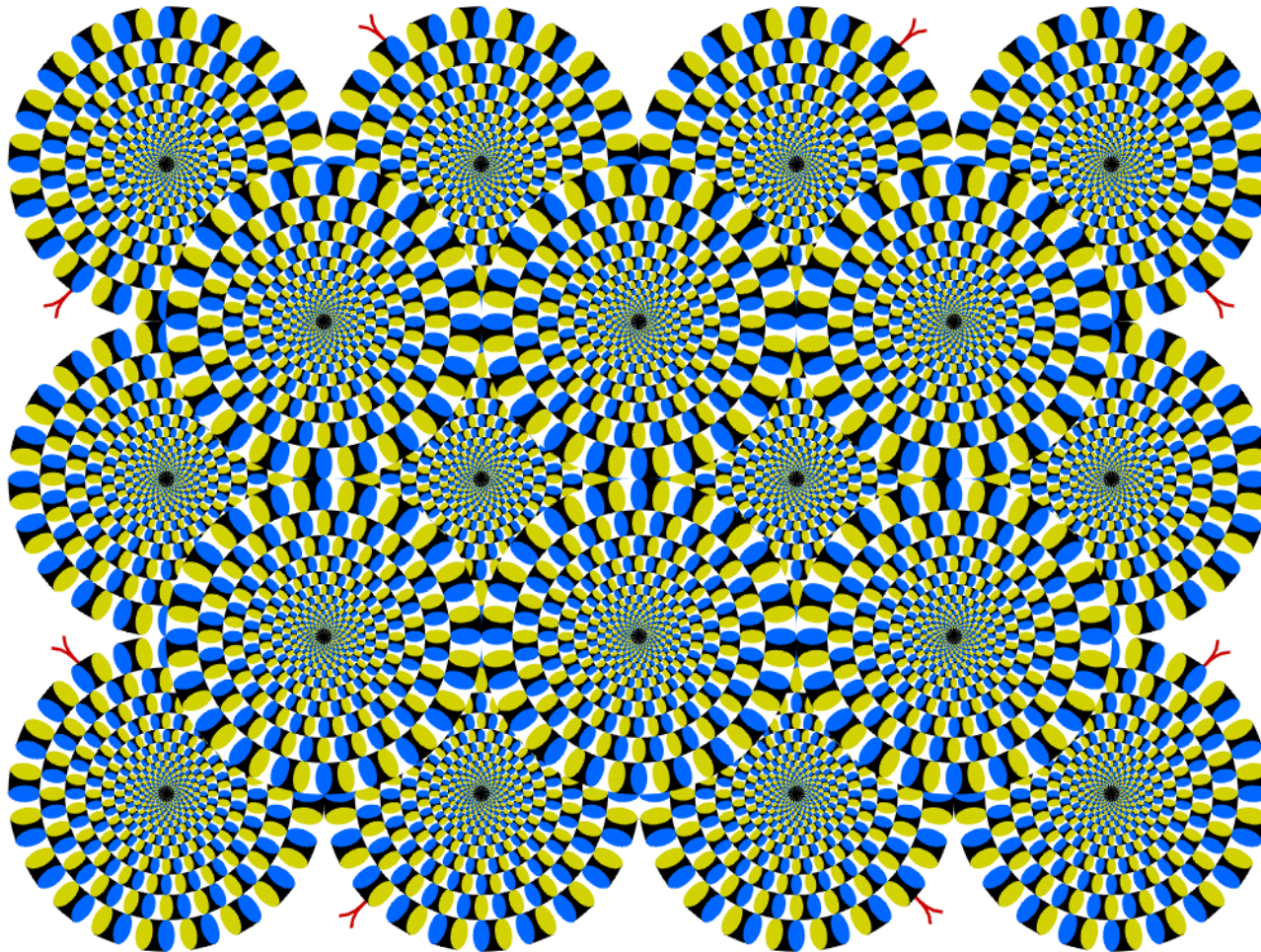


Motion Illusions

- Ouchi illusion



Peripheral Drift - Rotating Snakes



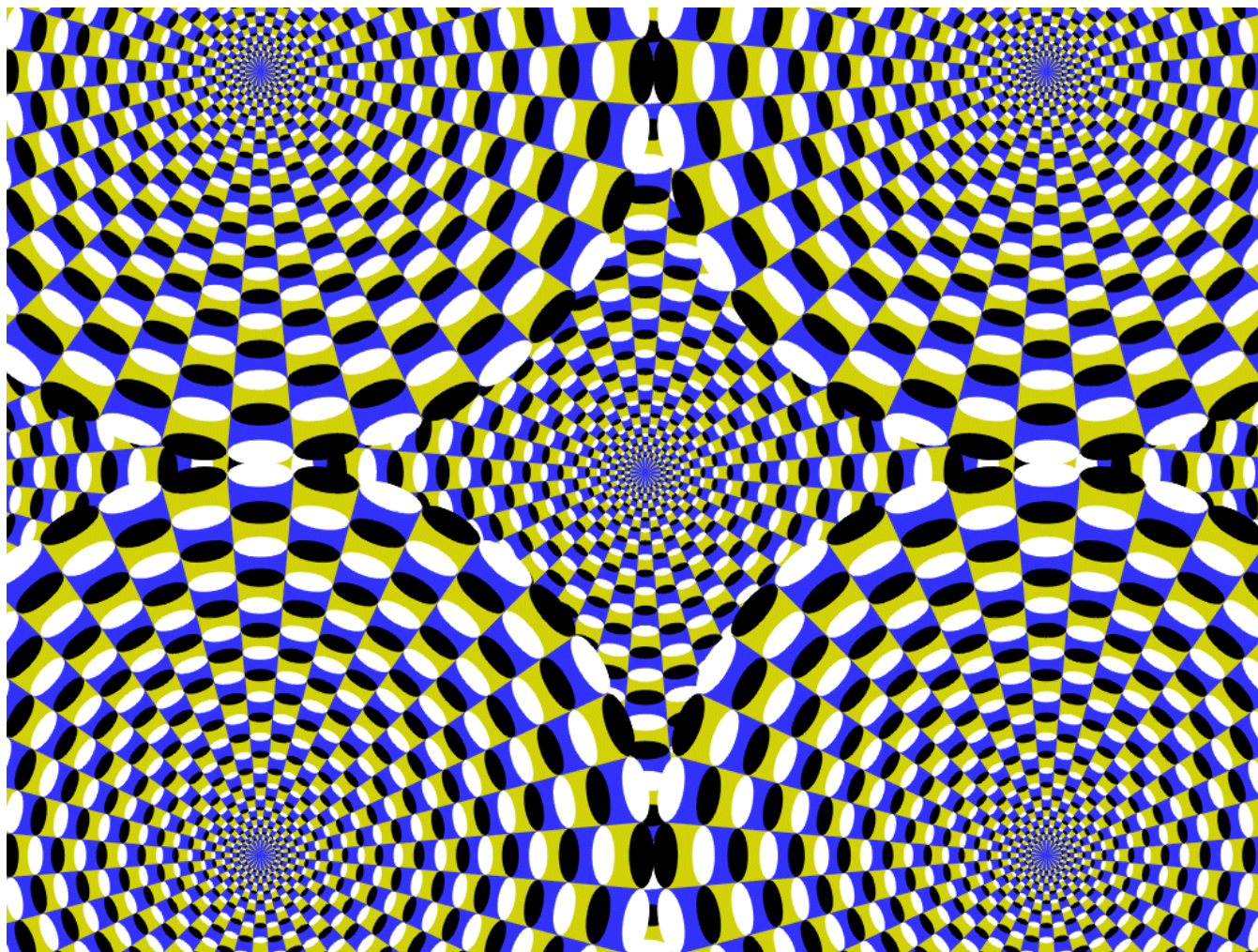
(A.Kitaoka 2003)



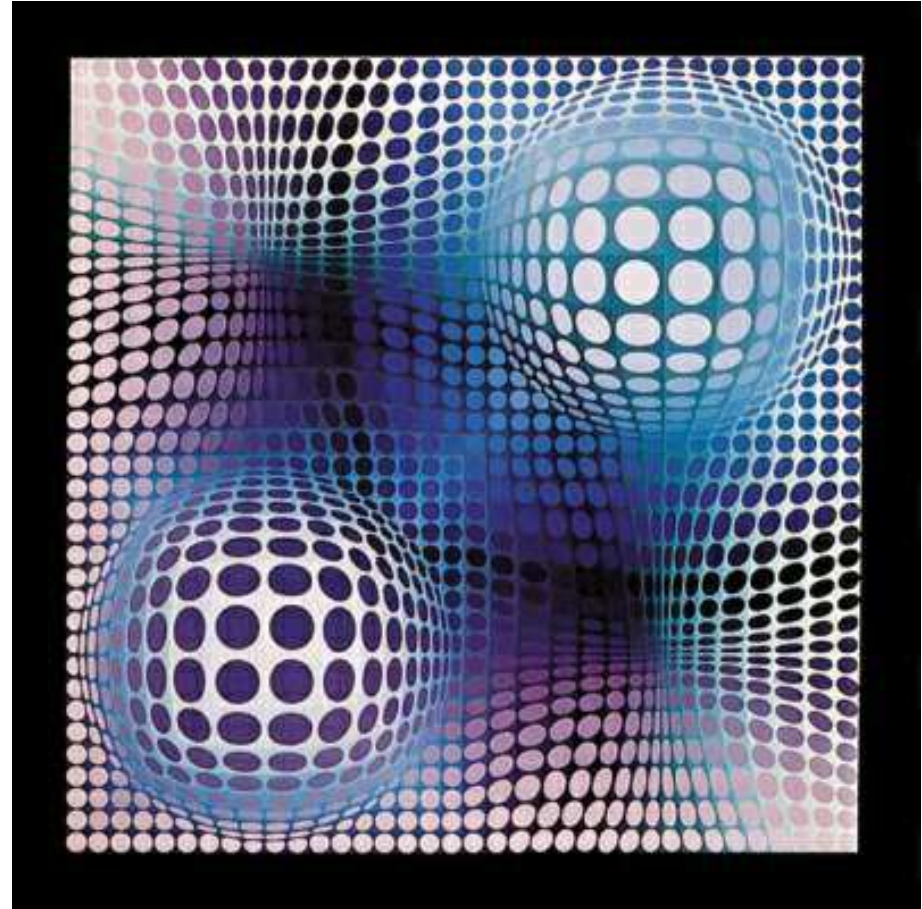
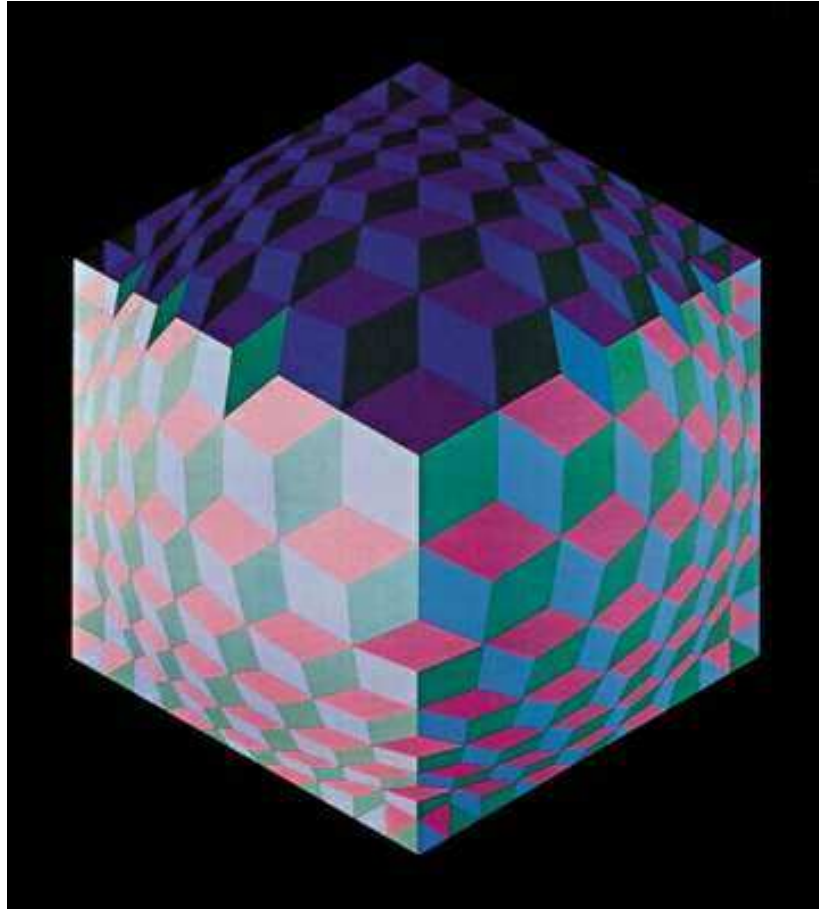
Peripheral Drift - Rotating Snakes



Peripheral Drift



Op Art

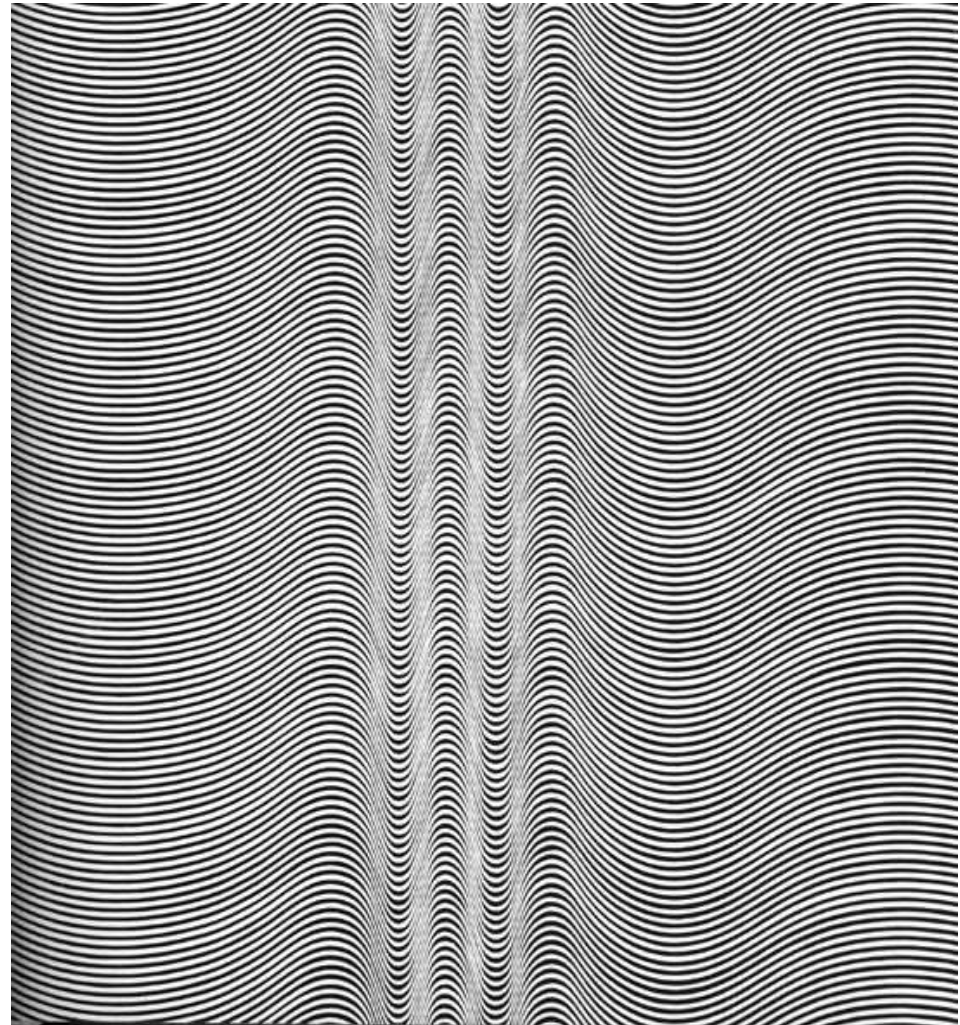
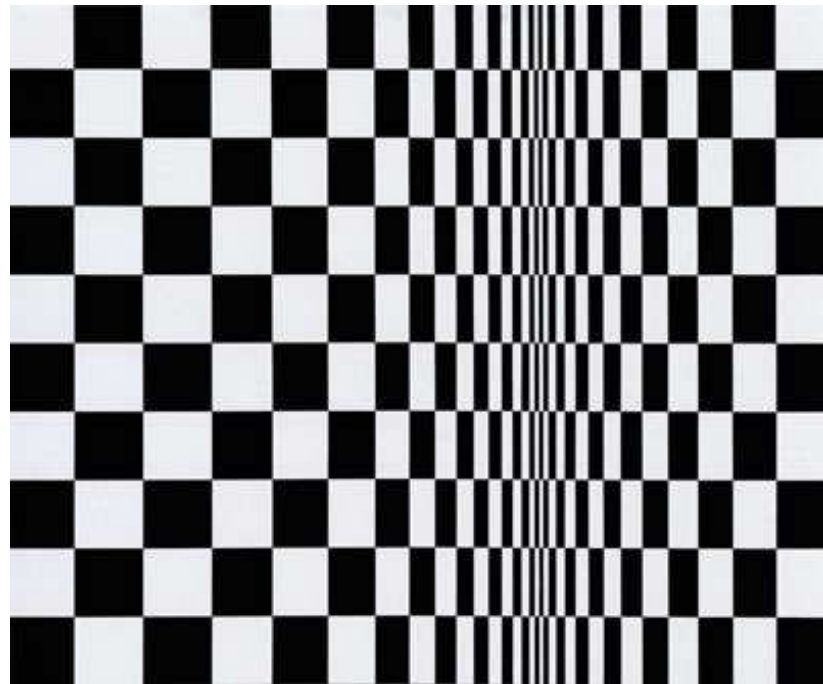


[Victor Vasarely]



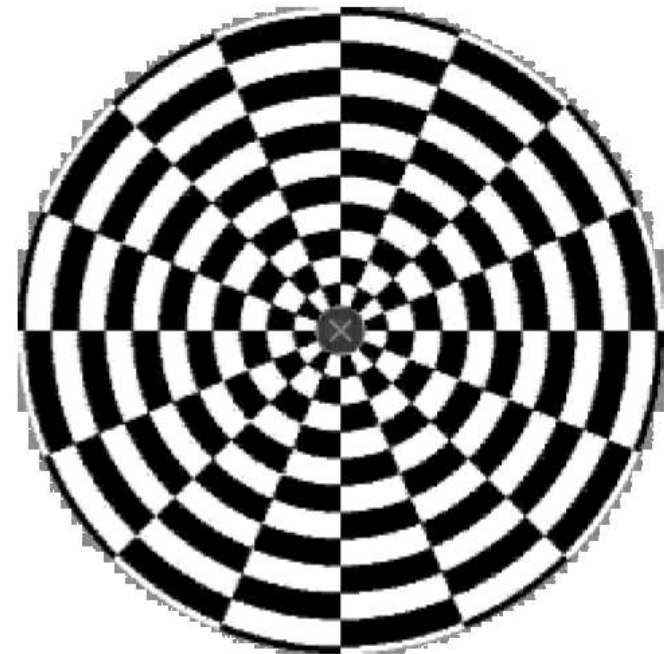
Op Art

[Bridget Riley]



Perception of Motion

- TV, films – apparent motion
- specialized motion detectors
 - respond maximally to motion in particular direction
- Motion aftereffect (waterfall illusion)
 - Prolonged viewing of movement (adaptation) in one particular direction (e.g. contraction) selectively fatigues cells sensitive to that direction so that they respond less. First shown by Barlow & Hill (1963) in rabbit retina
 - When a stationary object is subsequently seen, cells tuned to the opposite direction (e.g. expanding motion) respond most causing a MAE



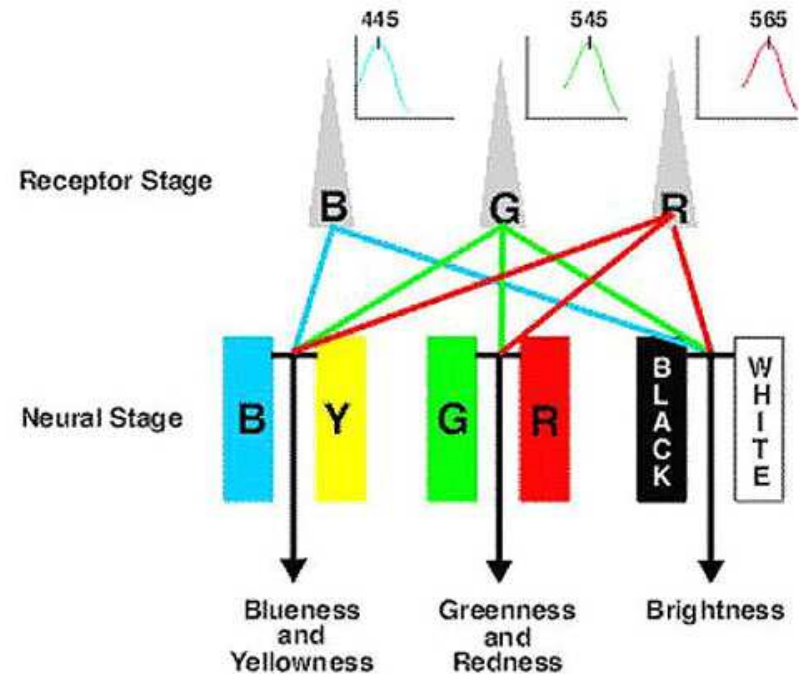
Perception of Motion

- kinetic depth effect
 - When this image is stationary it looks like a flat collection of rings
 - When the rings move you should see 3-d structure!

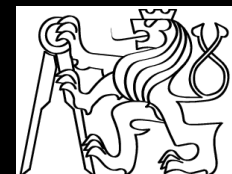
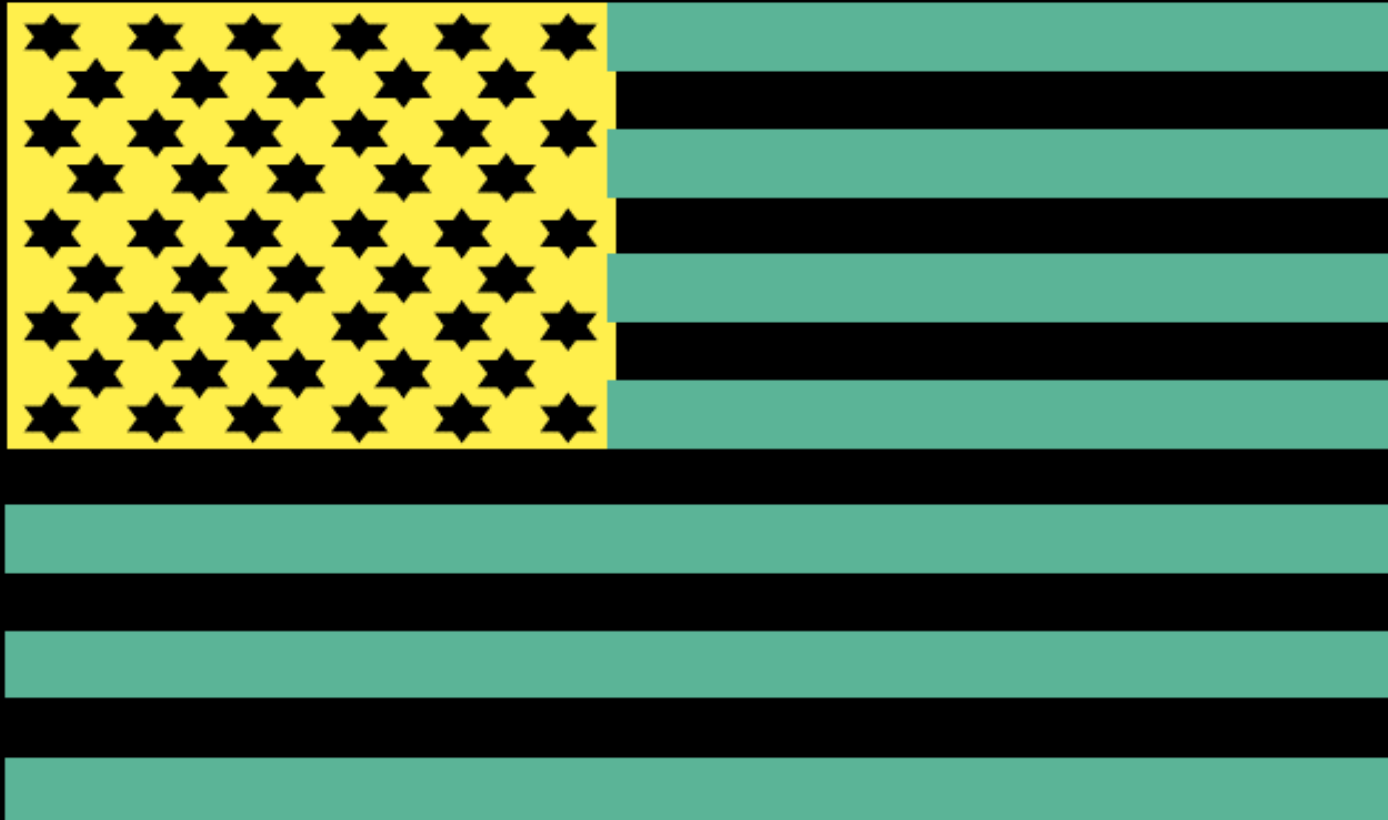


Colour Vision

- Component (Trichromatic) theory [Young 1802, Helmholtz 1866]
 - red, green, blue
- Opponent colour theory [Hering 1872]
 - red-green, blue-yellow, black-white
- Stage theory
 - incorporates both the trichromatic theory and the opponent colour theory into two stages
- Chromatic adaptation



Color - Aftereffects



Color - Aftereffects

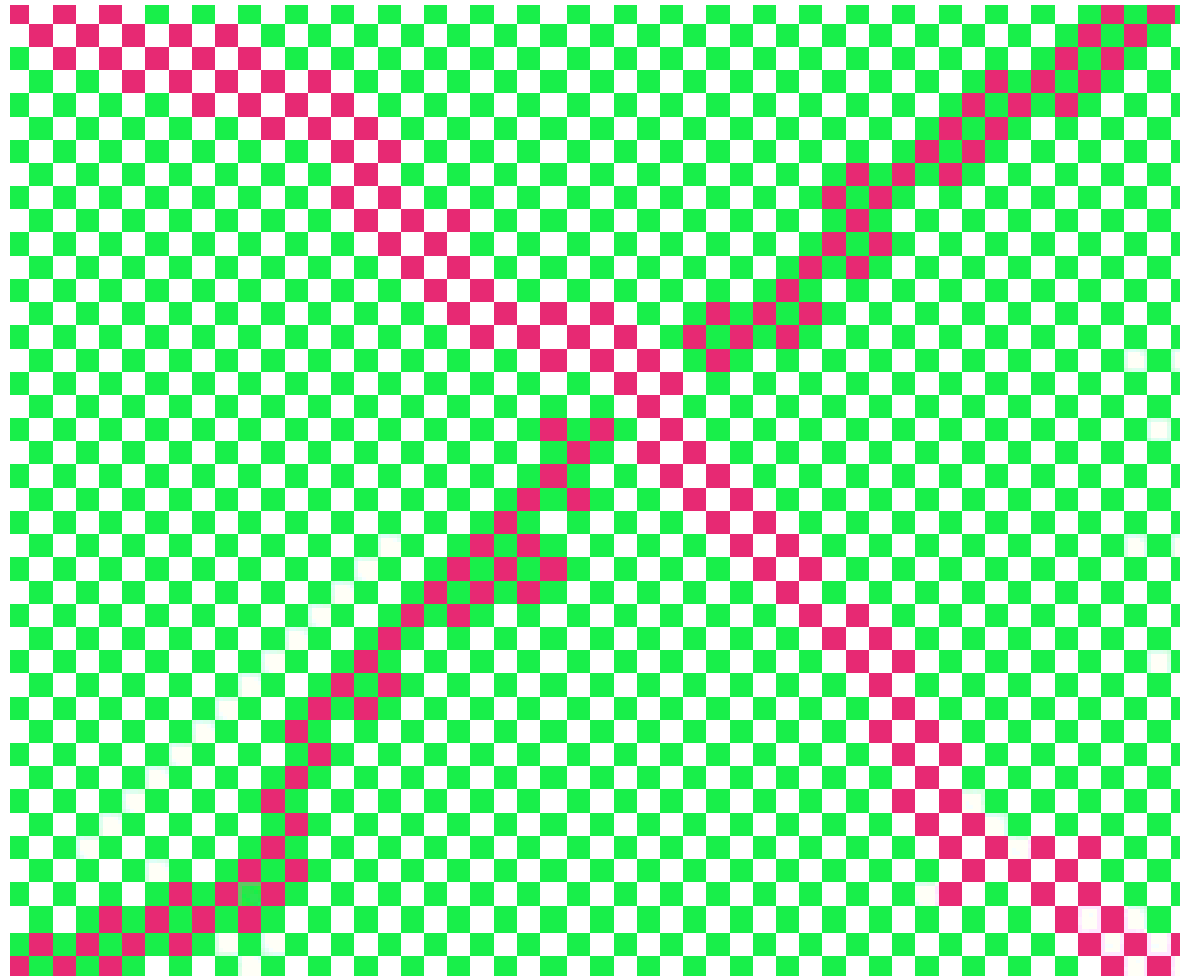


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ITT 27.10.2006 (85)

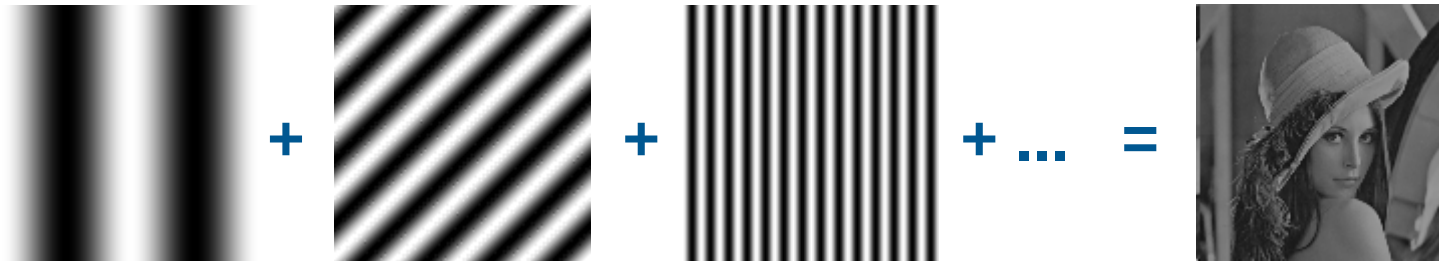


Color Contrast



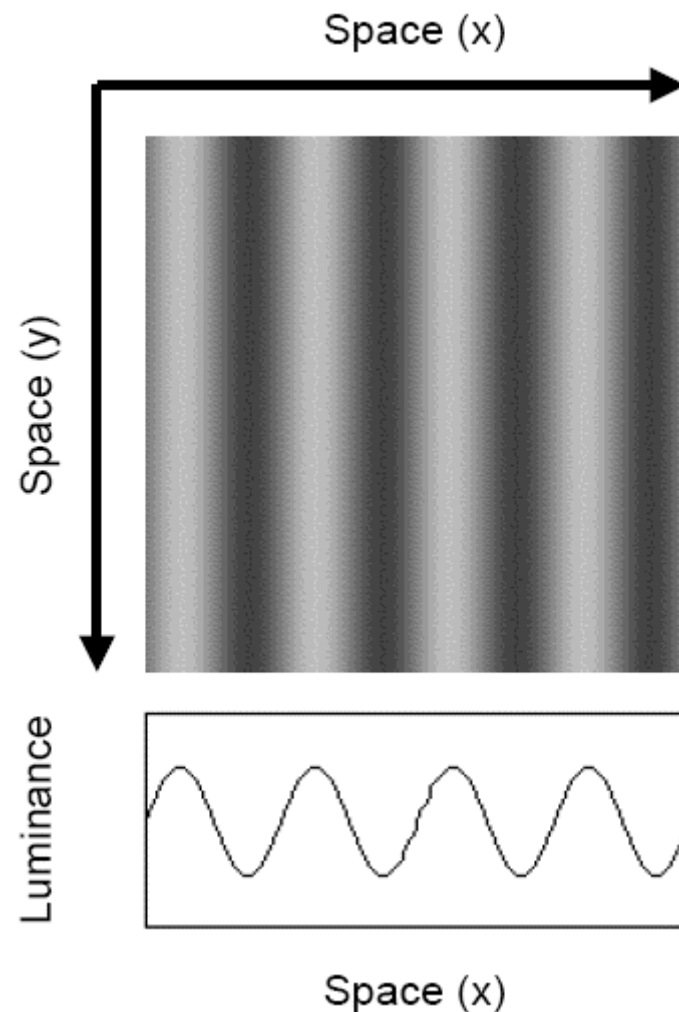
Spatial Frequency Theory

- assumption: representation of an image is an assemblage of **sinusoidal gratings**
- spatial frequency channels

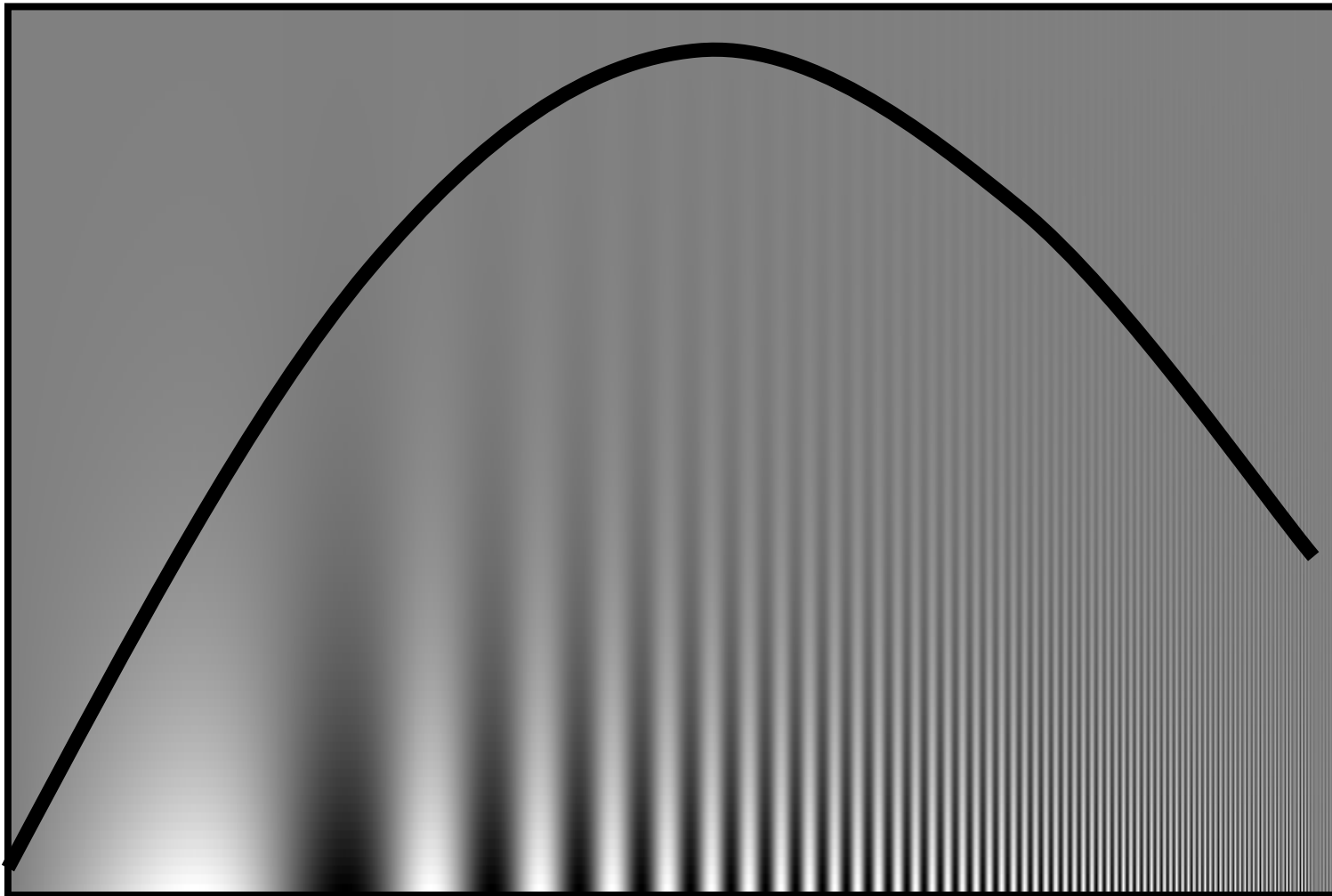


Sinusoidal Gratings

- spatial frequency
 - number of cycles in 1 degree of visual angle
- contrast
 - intensity difference between the light and dark bars
- orientation
 - axis of the grating's bars
- spatial phase
 - relative position of the bars
- FOURIER ANALYSIS/SYNTHESIS



Contrast Sensitivity Function



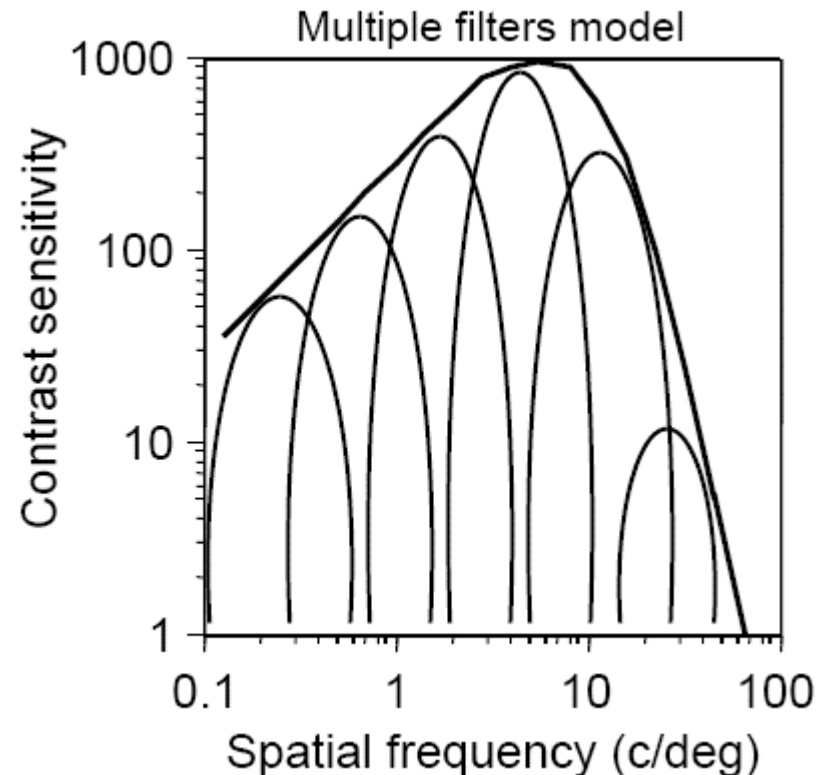
Contrast Sensitivity Function

- MTF (modulation transfer func.) of the whole visual system
- specifies the detection threshold as a function of the spatial frequency
- several measurers [Campbell & Green, 1965; Campbell & Robson, 1968, Patel, 1966; De Valois et al., 1974], moving gratings: [Van Nes et al., 1967; Robson, 1966; Kelly, 1979]
- high frequency sensitivity loss
 - optical imperfections of the eye
- low frequency sensitivity loss
 - receptive fields (On-Off) not enough large → both On & Off receive similar luminance



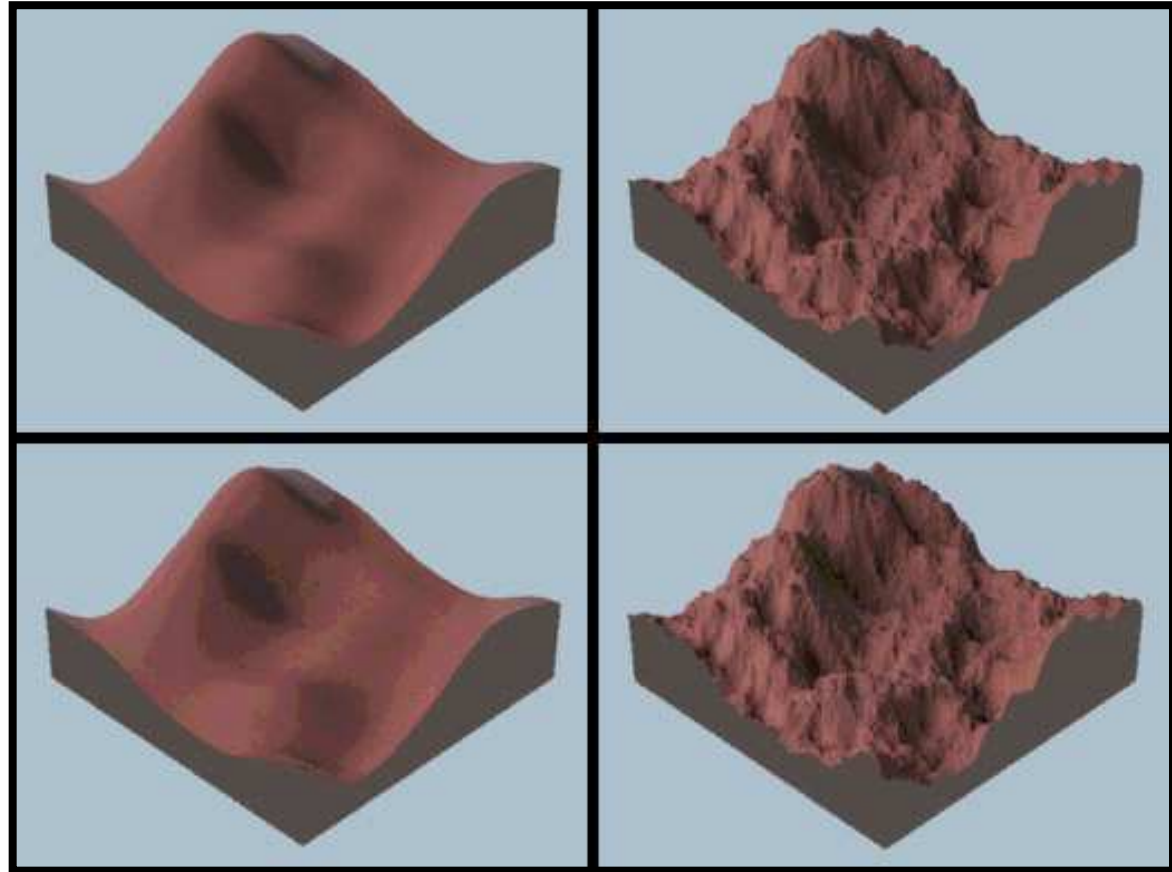
Psychophysical Channels

- large number of overlapping psychophysical channels
 - different spatial frequencies
 - orientations
- [Campbell, Robson 1968]
 - CSF does not reflect the sensitivity of a single mechanism, but the combined activity of many independent mechanisms (called 'filters', 'detectors', or 'channels')
- subthreshold summation



Visual Masking

- visual pattern of one type changes the detectability of a pattern of another type



Hybrid Images

- pictures with two interpretations



[Oliva et al. 06]



Hybrid Images

- Dr. Angry and Mr. Smile
 - fine spatial scale
 - coarse spatial scale
- HVS is able to separate information coming from different spatial frequency channels

Video

[Oliva & Torralba 99]



Image Quality Assessment

- assessing the quality of images
 - image compression
 - transmission of images
- subjective testing
 - the proper solution
 - expensive
 - time demanding
 - impossible embedding into algorithms



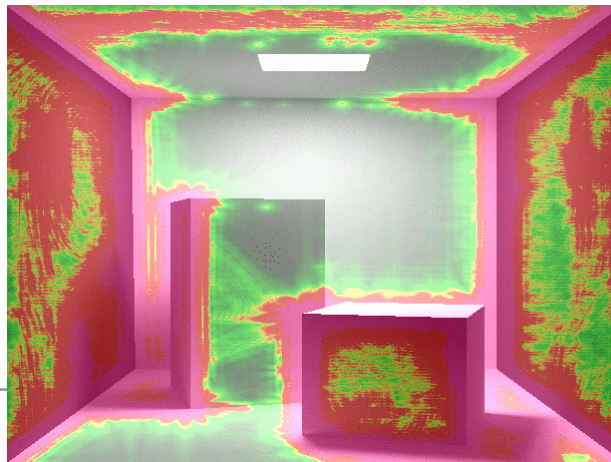
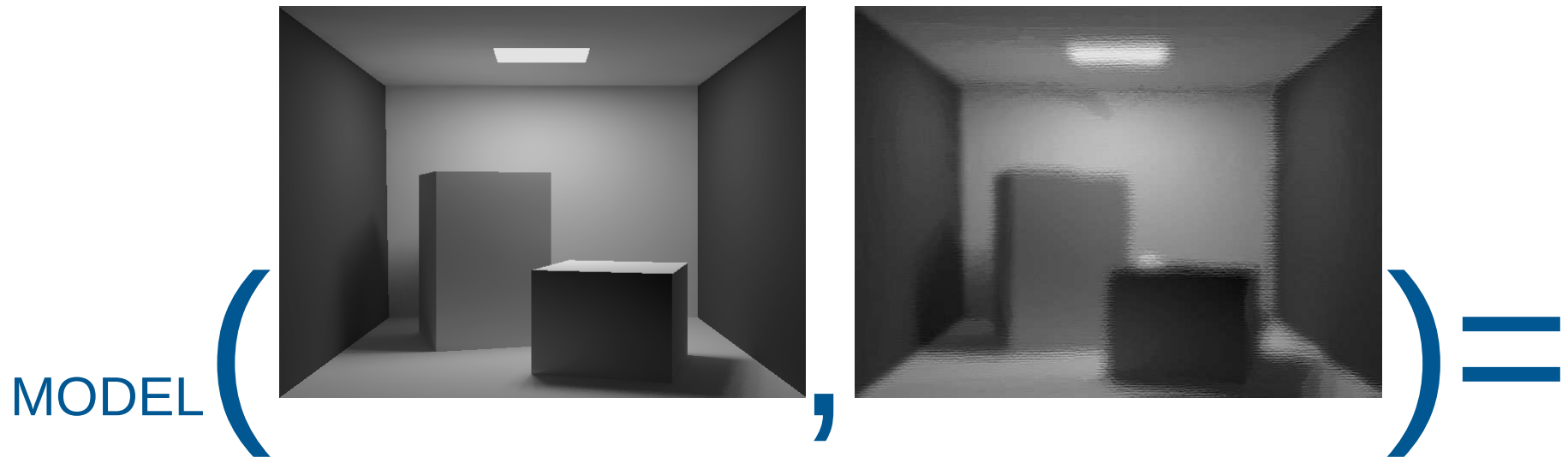
Image Quality Assessment & Computer Graphics

- quality improvement
- saving of resources
- effective visualization of information
- etc.



Image Quality Assessment Models

- RMSE is NOT sufficient

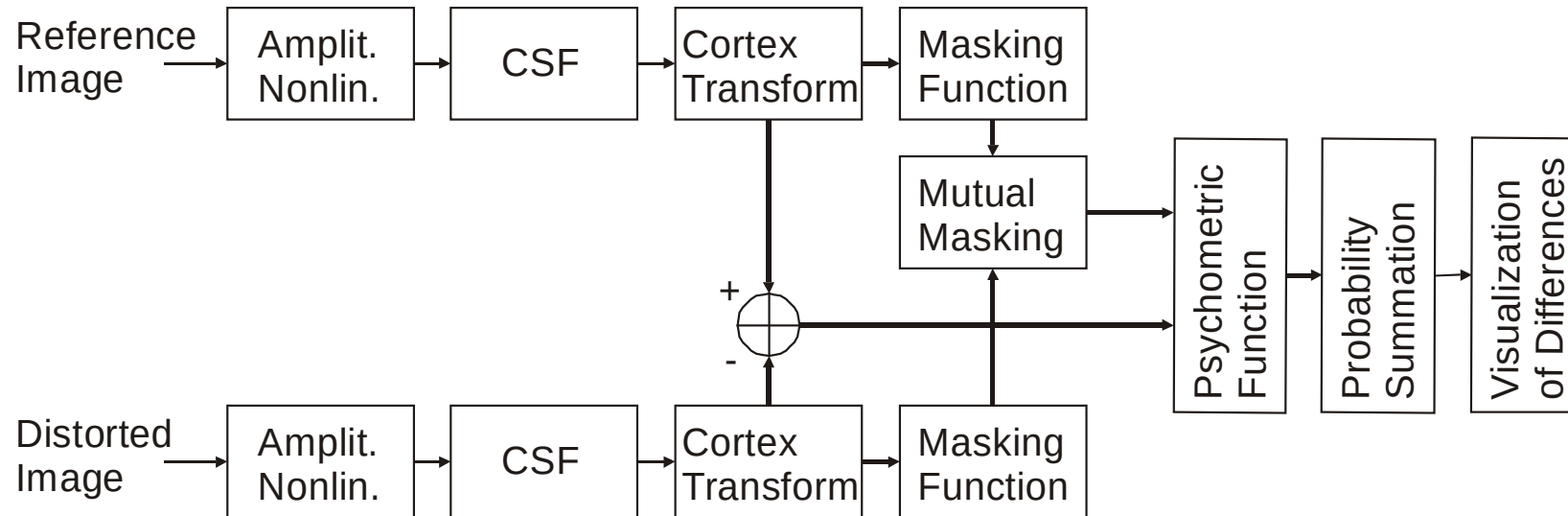


Detection
probability map



Visible Differences Predictor

- [Daly 93]



- threshold sensitivity
- visual Masking



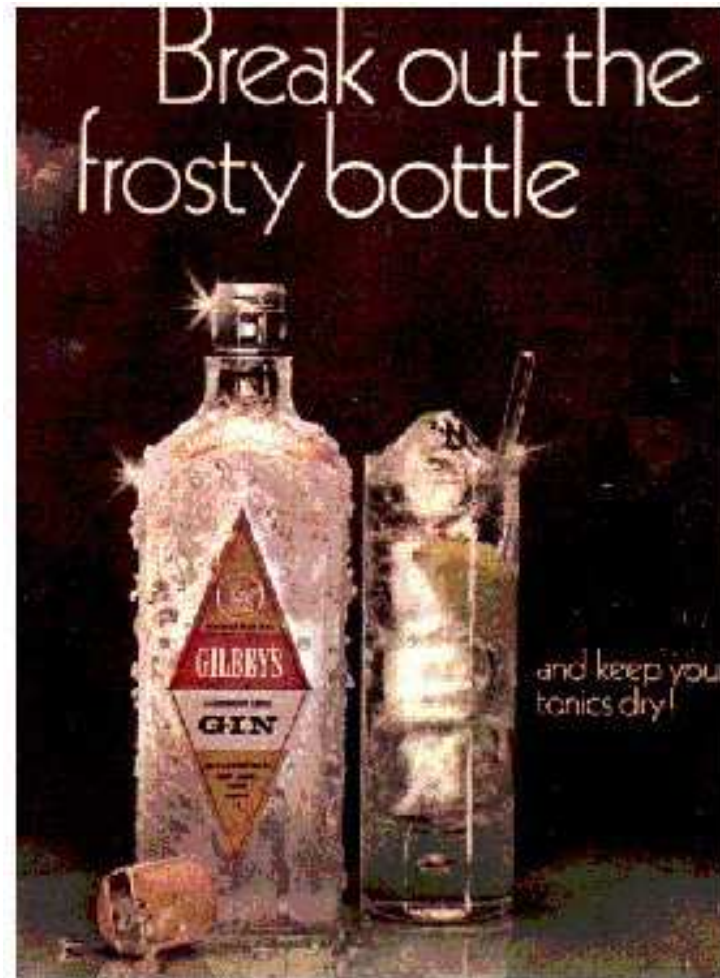
Line and Edge Detection Theory

- [Hubel, Wiesel 1959]
- Cortical cells:
 - simple (line/edge at specific orientation)
 - complex (moving lines/edges)
 - hypercomplex (end-stopped cells)



Visual Subliminal Perception

- advertising
 - afterimages
 - masking
 - etc.
-
- video



Visual Subliminal Perception



Visual Perception Even Complicated

- visual perception affected by non-visual sensations
- f.e. „What you see is what you hear“
 - sound background (beeps) affects recognition of number of flashes



Thank You for Your Attention

- ANY QUESTIONS?
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