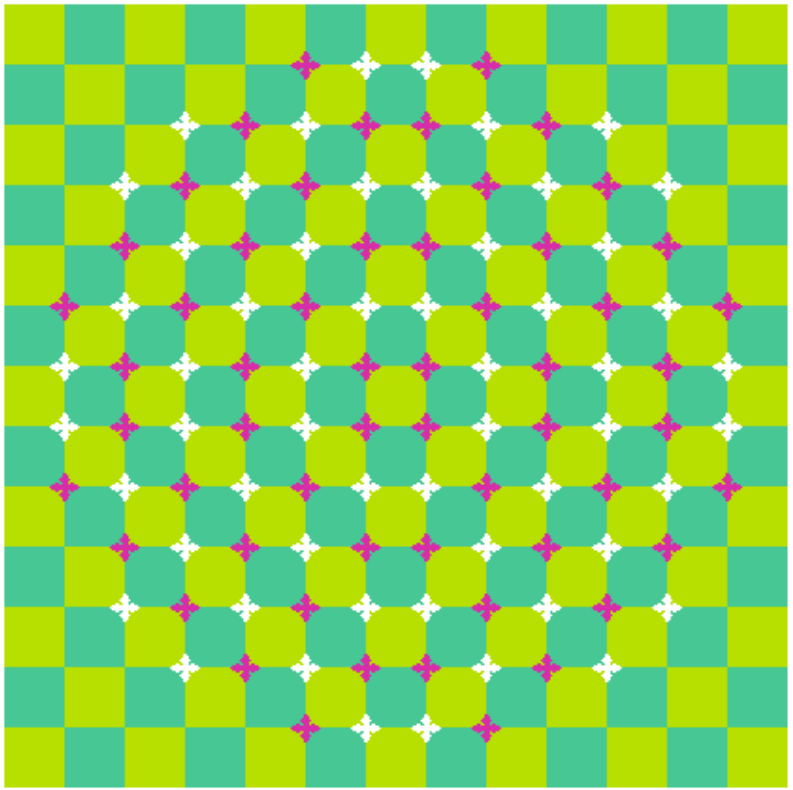
Percpetion

Georgia Tech College of Computing
Interactive & Intelligent Computing

- Human vision limitations
- Levels of perception
- Relative intensity
- Illusions of blinking
- Illusions of shapes
- Illusions of motion
- Illusions of depth
- Illusion of distortion
- Subliminal messages
- Pareidolia



Colors and their names

Do **not read** the words, say the **color** of each word.

YELLOW BLUE ORANGE

BLACK RED GREEN

PURPLE YELLOW RED

ORANGE GREEN BLACK

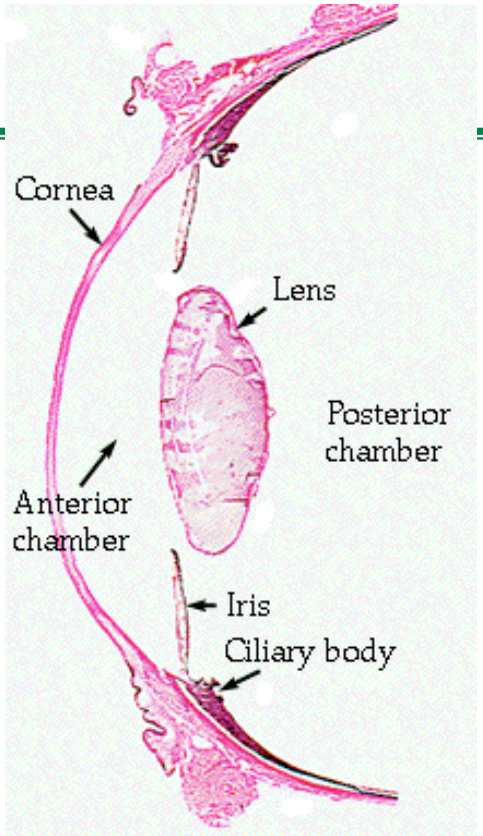
BLUE RED PURPLE

GREEN BLUE ORANGE

Motivation

- **Graphics is about communicating with the viewer's brain**
- **We need to understand how the pixels are perceived and interpreted**

The human eye



Light travels through **cornea**, **iris**, **lens** to the **retina**.

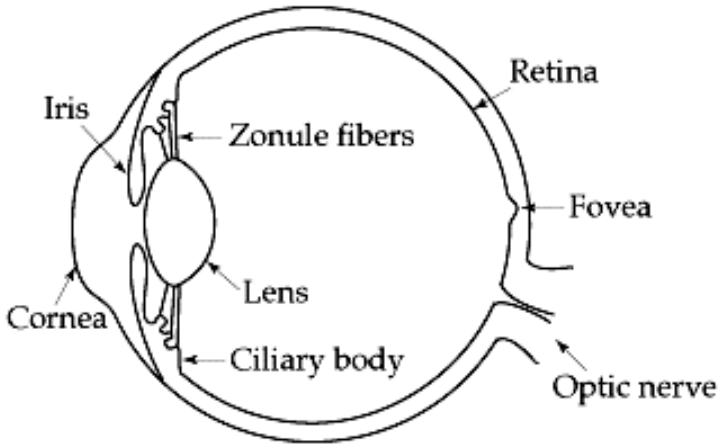
The **iris** contracts: 2 mm (day) -- 8 mm (night)

The **lens** changes shape to achieve focus.

The **retina** translates light into nerve signals. Made of 3 layers of photosensitive cells lining the interior of the eyeball :

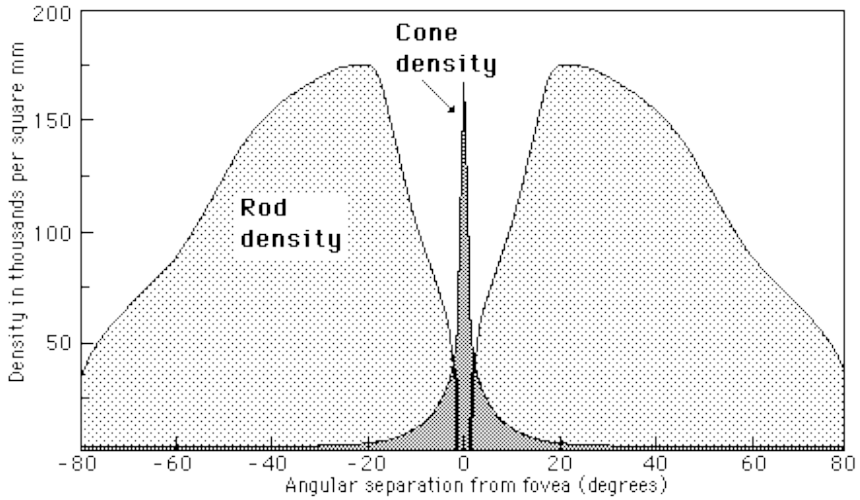
1. Ganglion cells (front layer).
2. Bipolar cells, horizontal cells, and amacrine cells.
3. **Rods** and **cones** (back layer) contain pigments that fire when hit by a photon: release energy and change molecular shape to become less sensitive to light (**bleached**).

The melanin (black pigment) behind the retina helps to chemically **restore the light-sensitive** visual pigment in the rods and cones after it has been bleached by light.



Rods and cones

- 120 million **rods** (1000x more **light sensitive** than cones, but not to color). More in the periphery. Can see dimmer objects. Better for detecting motion.
- 6 million **cones** (see **color**), concentrated in the macula which includes a 0.3 mm diameter fovea (only cones)



HLS model of chromatic light

Color perception may be discussed in terms of:

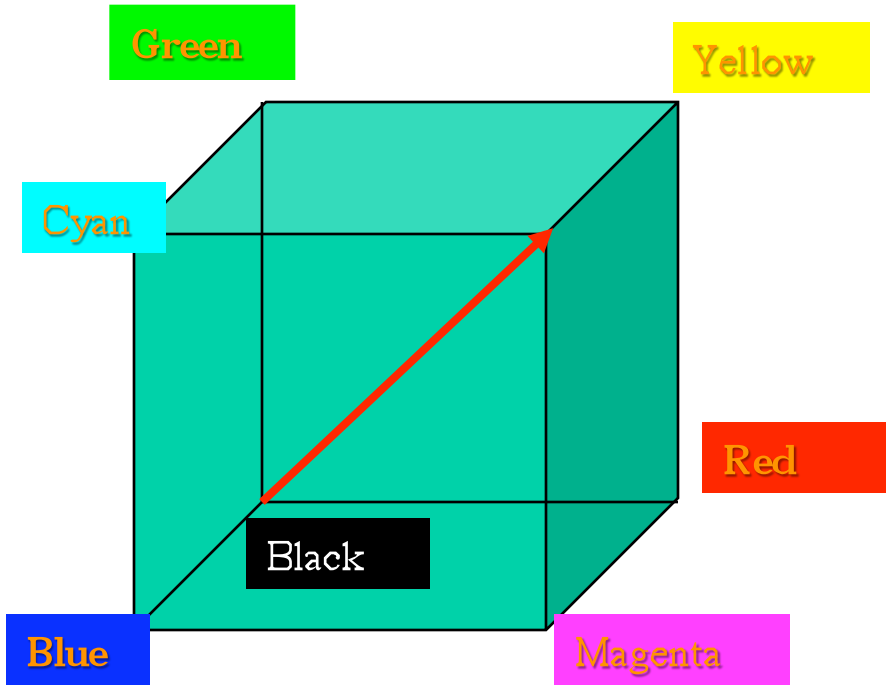
- **Hue**: red versus green versus blue
- **Saturation** (also **chroma**): vivid red versus pastel greyish pink
- **Lightness** (also **value**): perceived intensity reflected by object
  - The term **brightness** is used for emitters: light-bulbs

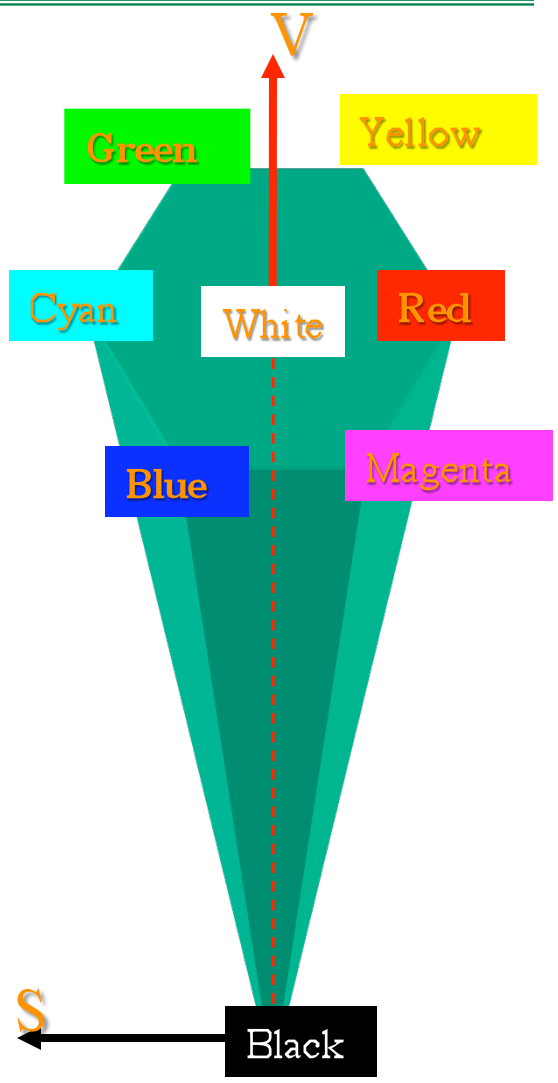
Artists discuss color in terms of

- **Tint**: the amount of white added to pure pigment to decrease saturation
  - Fully saturated (pure) color contains no white
- **Shade:** the amount of black added to decrease lightness
- **Tone:** the amount of black and white added to a pure pigment (a given hue)

HSV color coding

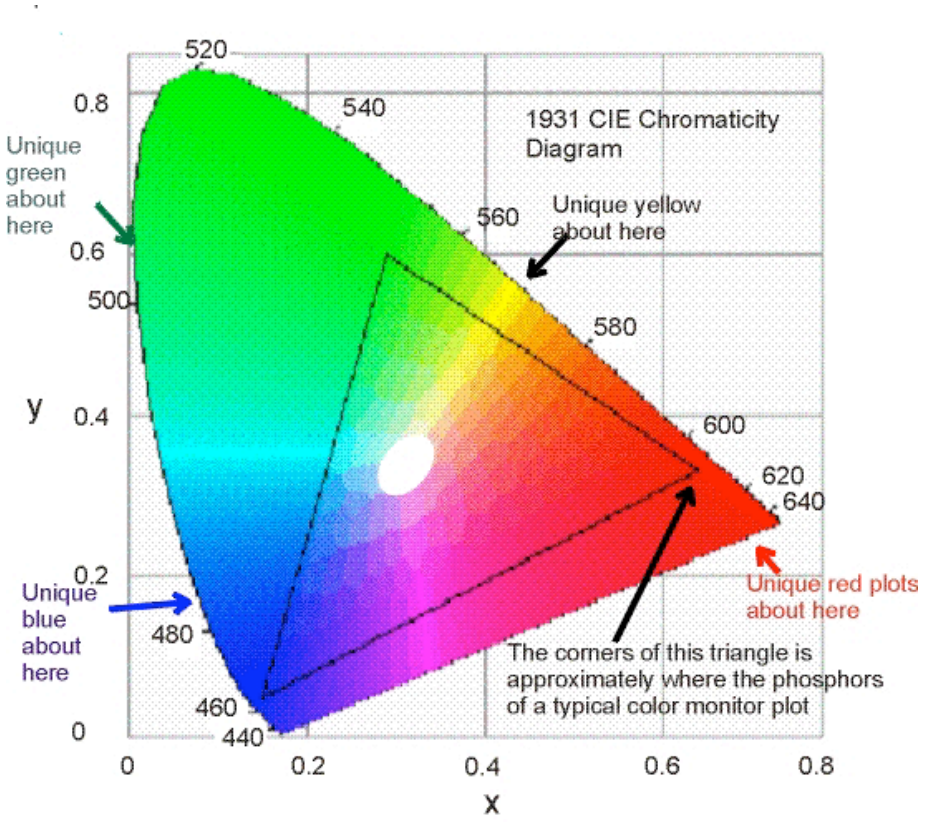
- **Hue**: cyclic [0,360] R-Y-G-C-B-M
- **Saturation**: pure color
- **Value**: Luminance or Brightness





Color Gamut

- Range of colors that may be produced by an output device/process
- CRT has a limited gamut that does not cover all visible colors
  - It uses phosphors to emit photons of given length
  - Would need to find new phosphors to expand it
- How to render colors that are not in the gamut?
  - Use mapping that distorts the desired color range into the gamut
  - For each desired color, find the closest one in the gamut

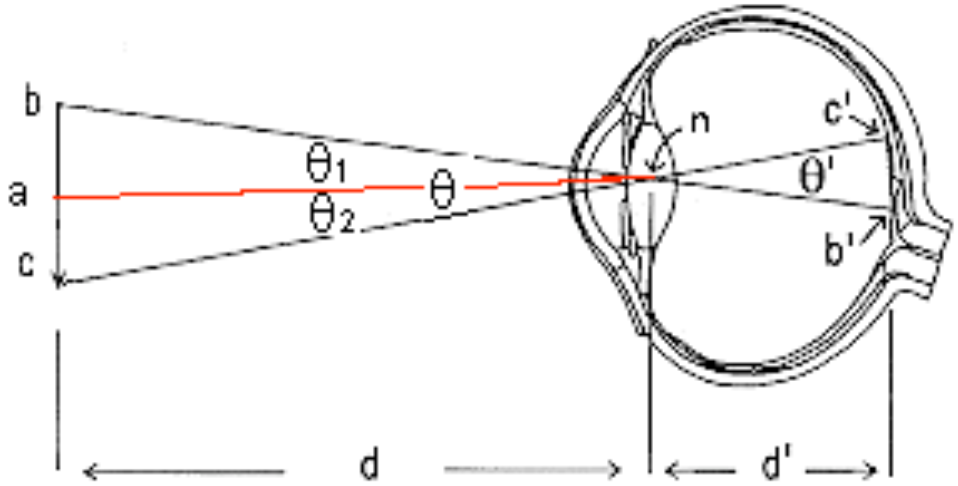


Perception of color

- Humans can distinguish hundreds of thousands of different colors
- **Tristimulus** theory (Young-Helmholtz): Humans have 3 receptors
  - 64% of cones measure red (peak response at wavelength = 580nm)
  - 32% of cones measure green (peak at = 545nm)
  - 2% of cones measure blue (peak at = 440nm)
- The eye's is **10x less sensitive to blue** than to the other two
  - It absorbs less energy in the blue range, light sensitive, out of fovea
- A human can **distinguish** about ***28 fully saturated hues***
  - At the center of the spectrum, we can distinguish hues separated by 2nm
  - At ends of spectrum, hues separated by less than 10nm cannot be distinguished
  - The eye is less sensitive to hue changes in less saturated colors
- Humans can distinguish ***23 different levels of saturation*** for a fixed hue and lightness at the extremes of the spectrum. This drops to **16 levels** at the center of the spectrum.

Visual acuity

- Normal visual acuity: Ability to resolve a spatial pattern separated by a visual angle of **one minute of arc** (1/60 degree)
  - We need 360*60=21600 columns of pixels on a panoramic display
  - 20/20 letter subtends 5 MOA
  - 300+ dpi at 12 inches



Blind spot

A small portion of the retina where the optic nerve connects to the brain has no receptors. Close your right eye. With your left eye, look at the L below. Slowly move your head closer or further away from the screen while looking at the L. The R will disappear when your head is approximately 50 cm (20 in) from the screen.

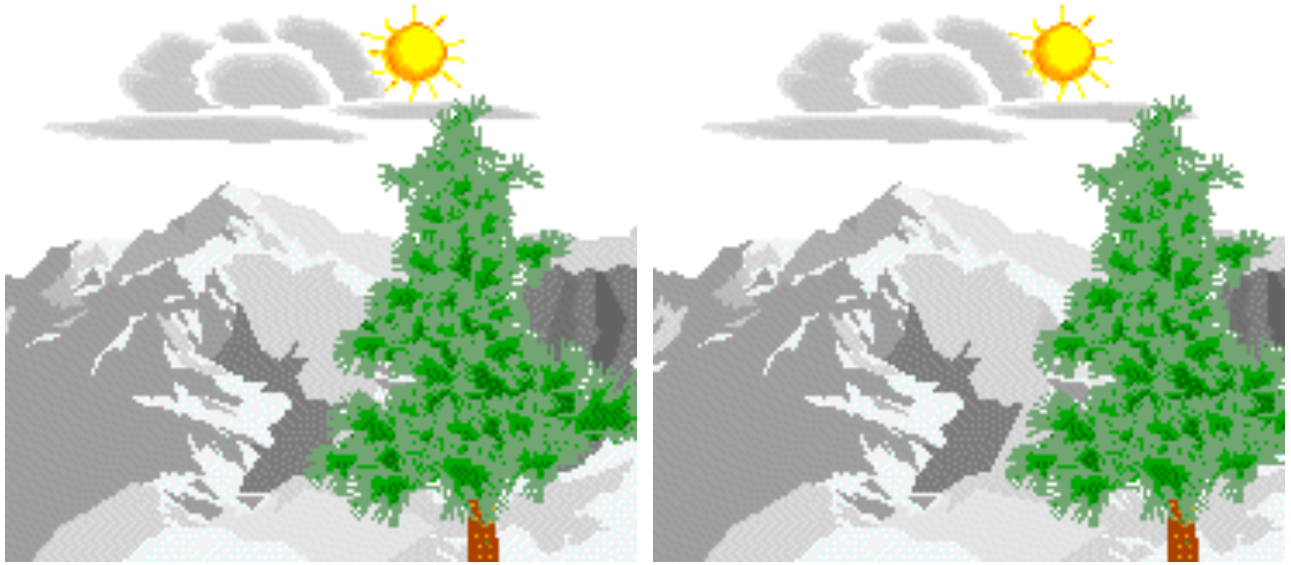
R L

Dominant eye

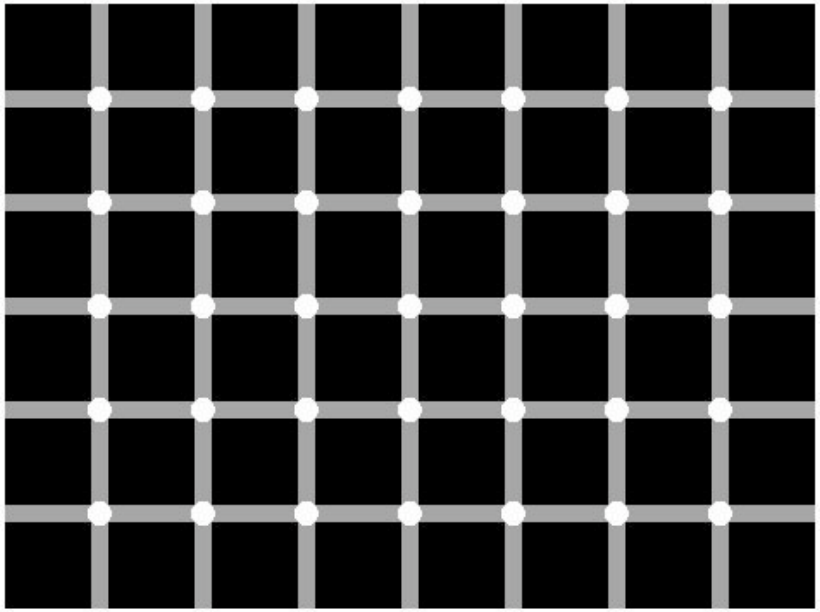
- Hold your thumb in front of you at arm length
- Look past it with both eyes
- **Close** the **right** eye.
- If the thumb **jumps** to the **right**, they your **left eye is dominant**.

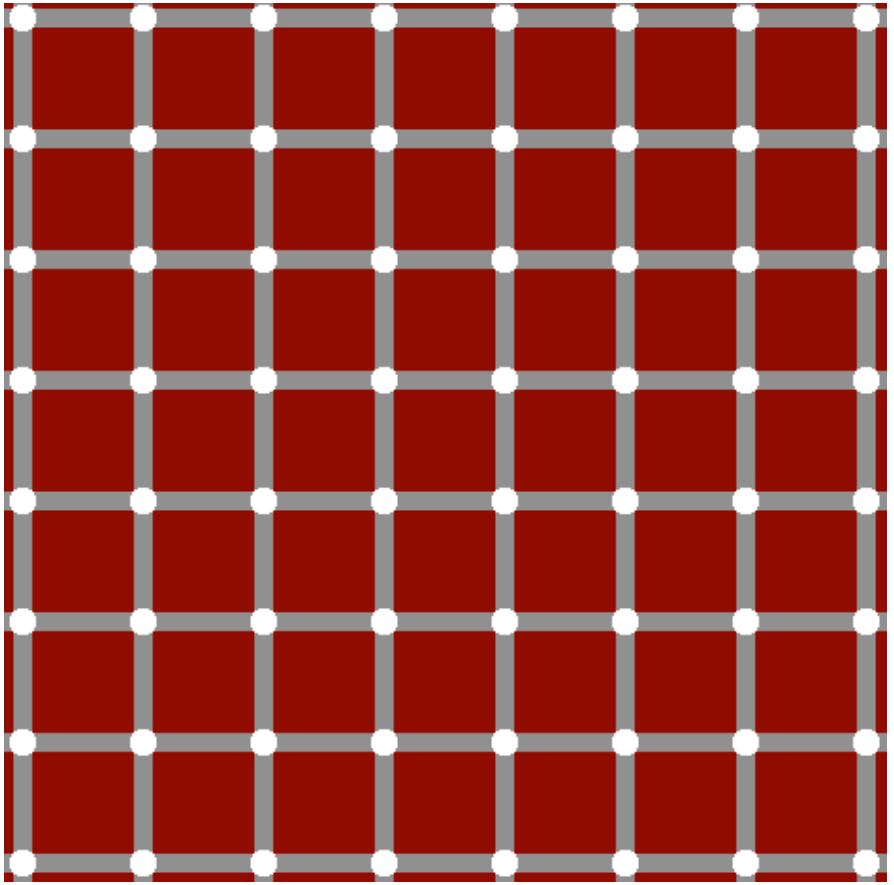
Stereo

- Use inverted binoculars to look at these

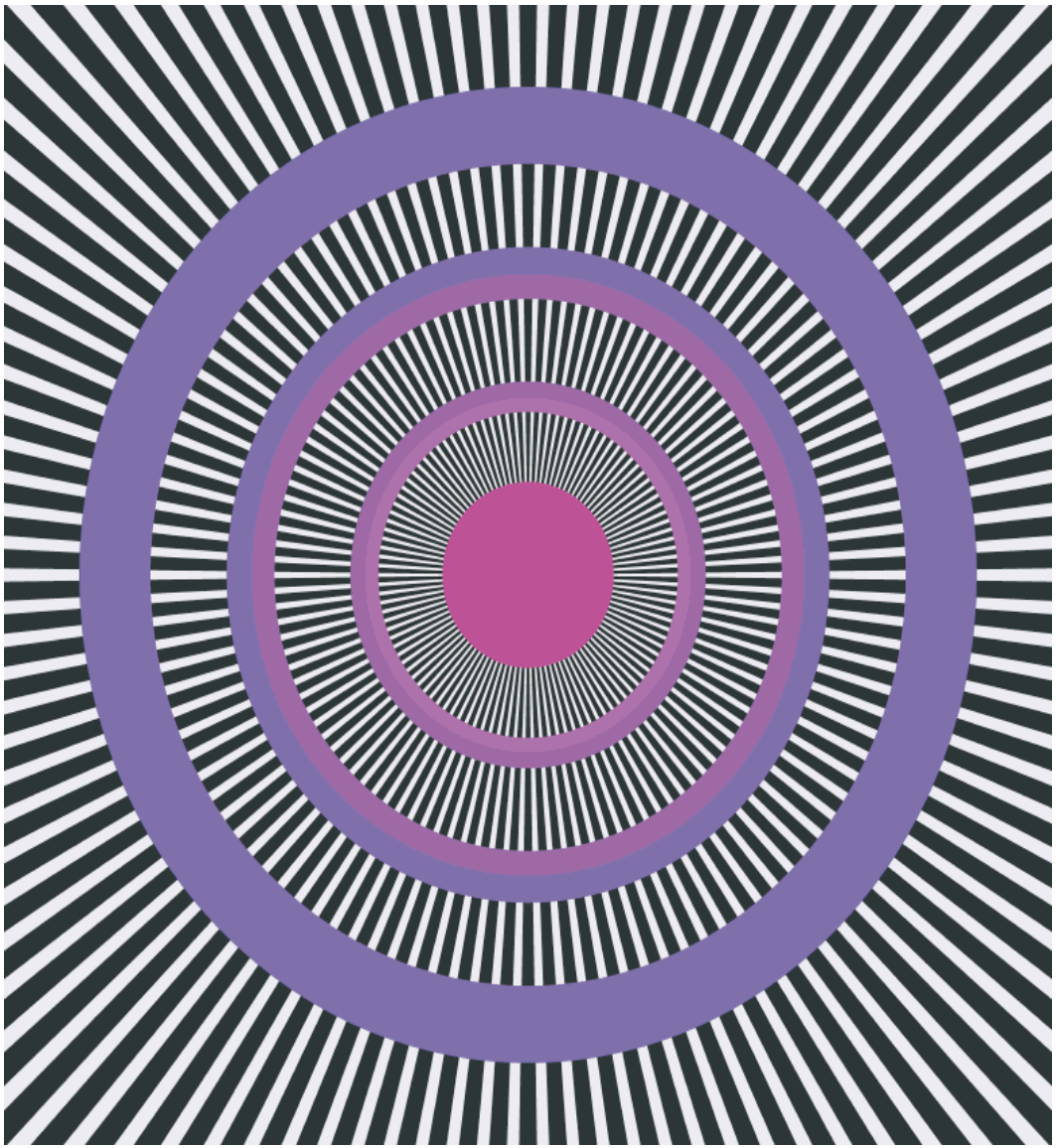


Illusion of blinking

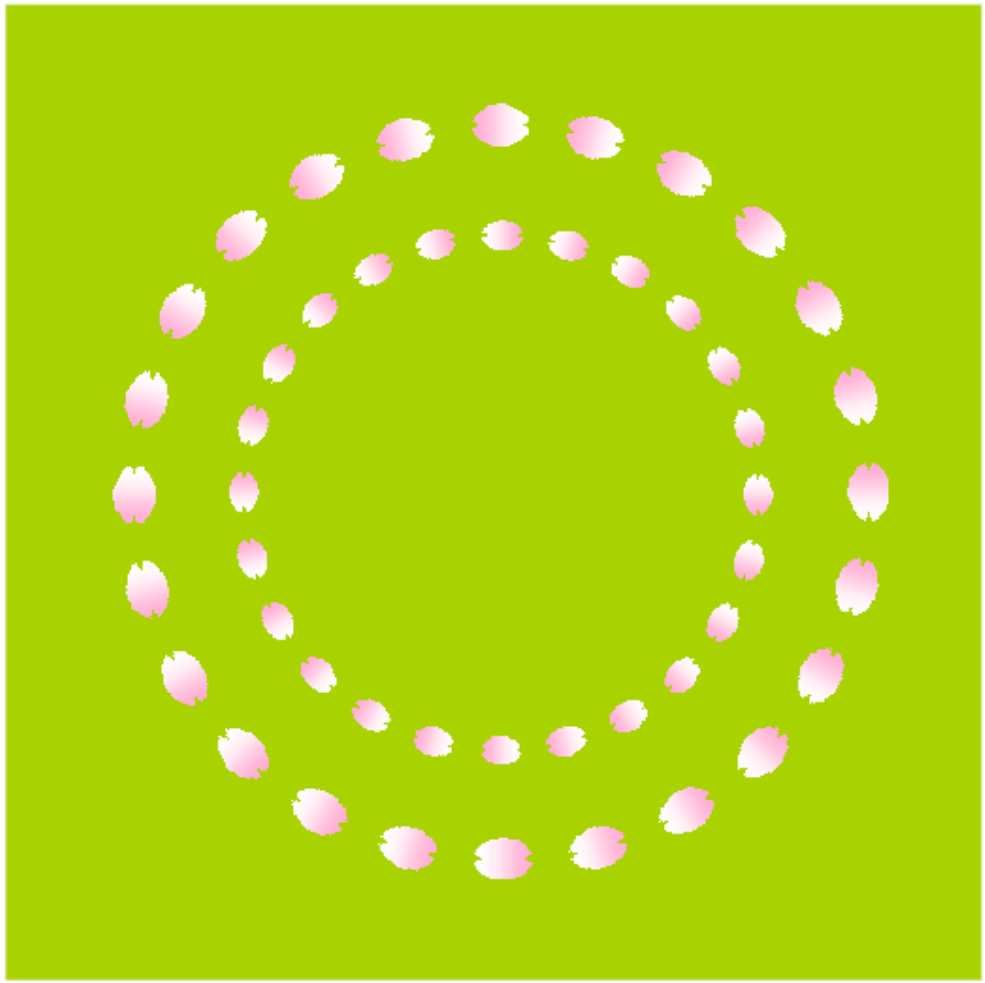




Illusion of scintillating

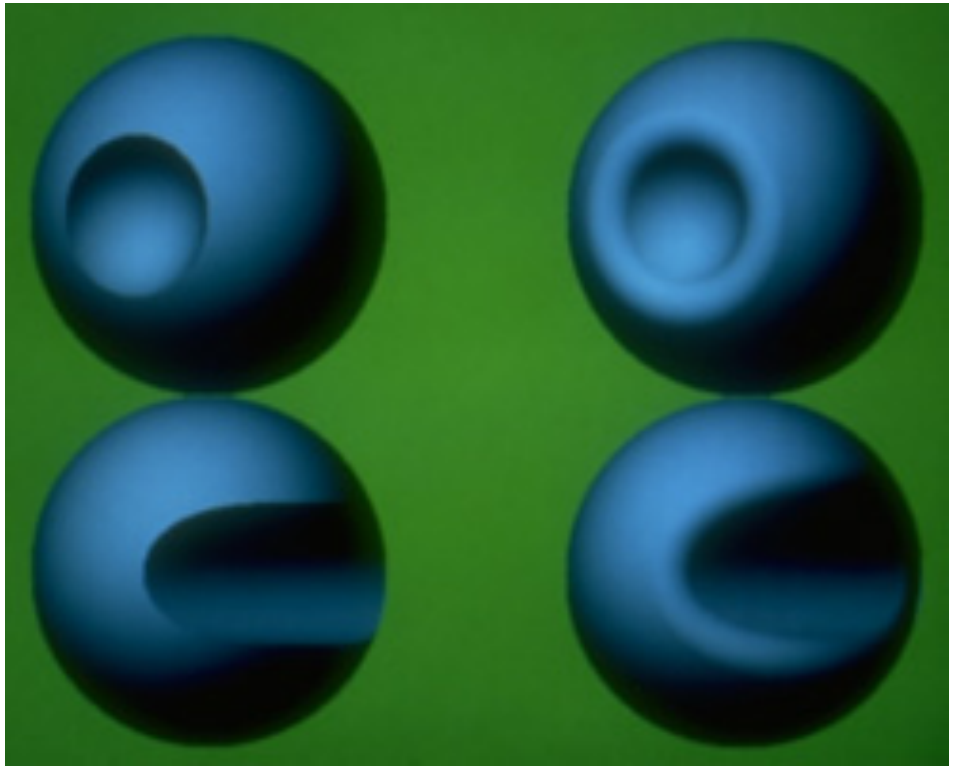


Illusions of motion



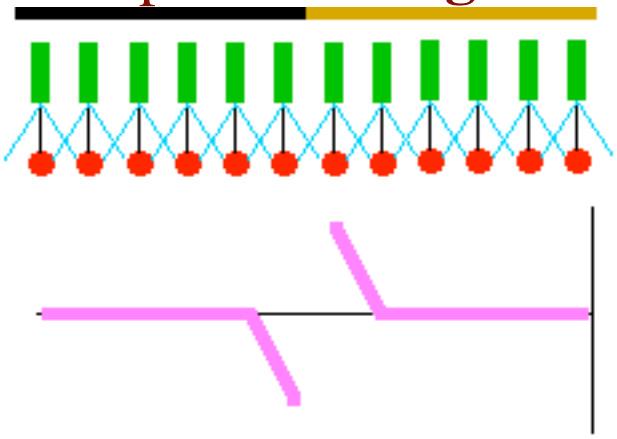
Mach band

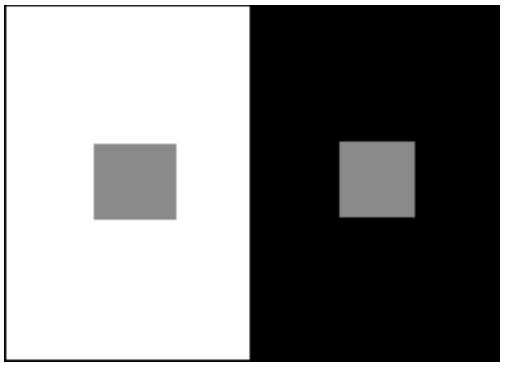
- In 1865, Mach discovered that we **perceive** an edge (**change of intensity**) at lines that separate surface regions with identical intensity on both sides, but different intensity **derivatives**.
- It is caused by the lateral inhibition of the receptors in the eyes.

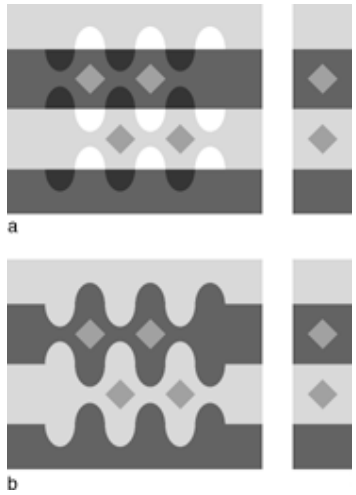


Lateral Inhibition

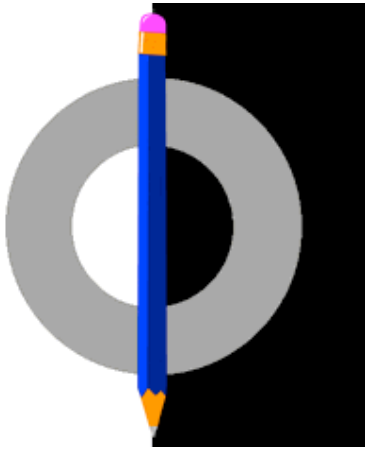
- Consider a light pattern on the retina that changes abruptly from dark to bright
- The photoreceptors (green) communicate to the retina output neurons (red dots):
  - An excitatory input to the corresponding neuron (black lines)
  - Inhibitory input to the adjacent neurons (blue lines) so that we detect variations with respect to the surrounding intensity (contrast)
- The signal in the output neurons (purple line) shows how this helps detect **edges** and **steep gradients**.

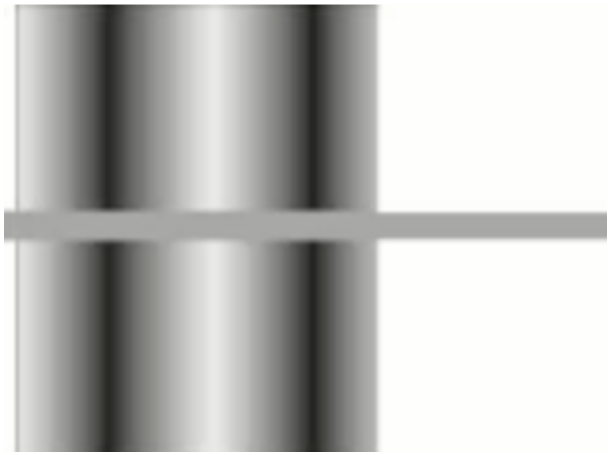


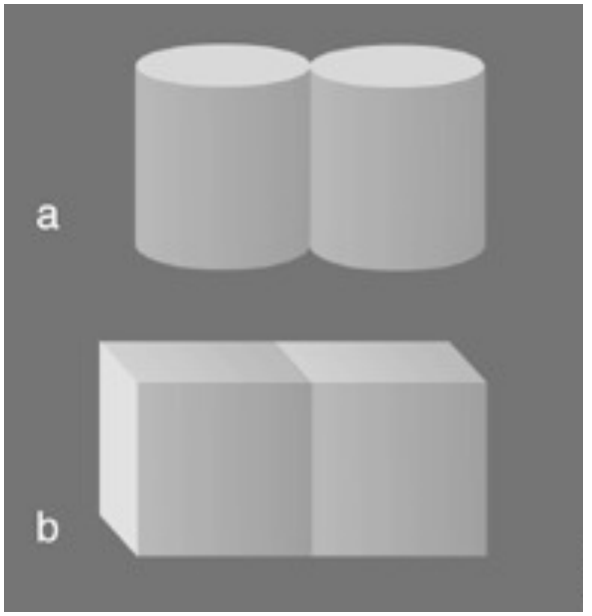




More contrast illusions

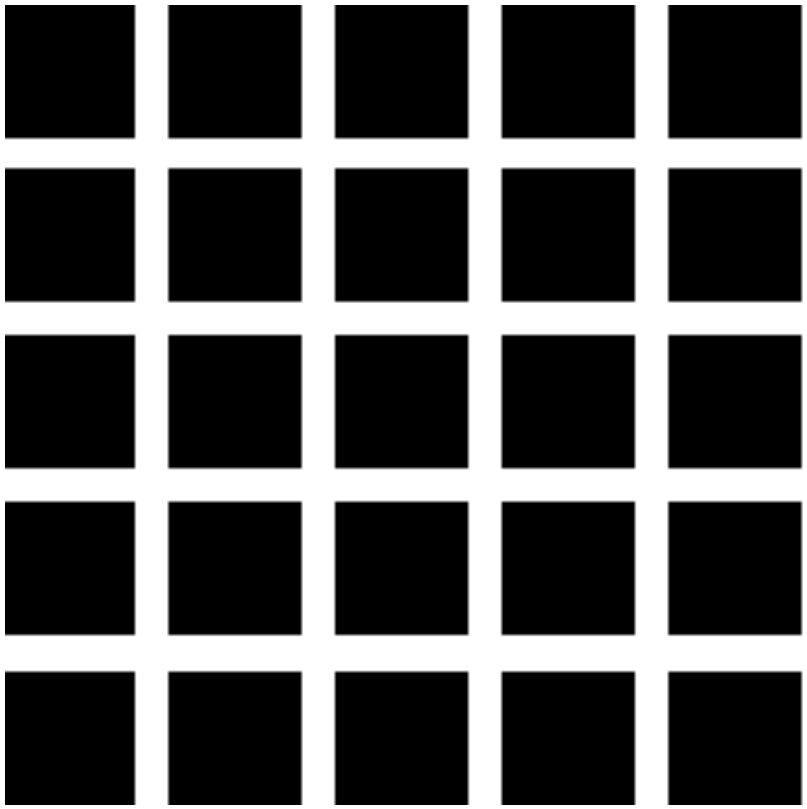


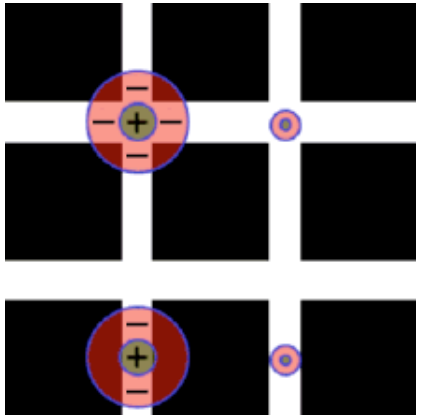




Herman Grid

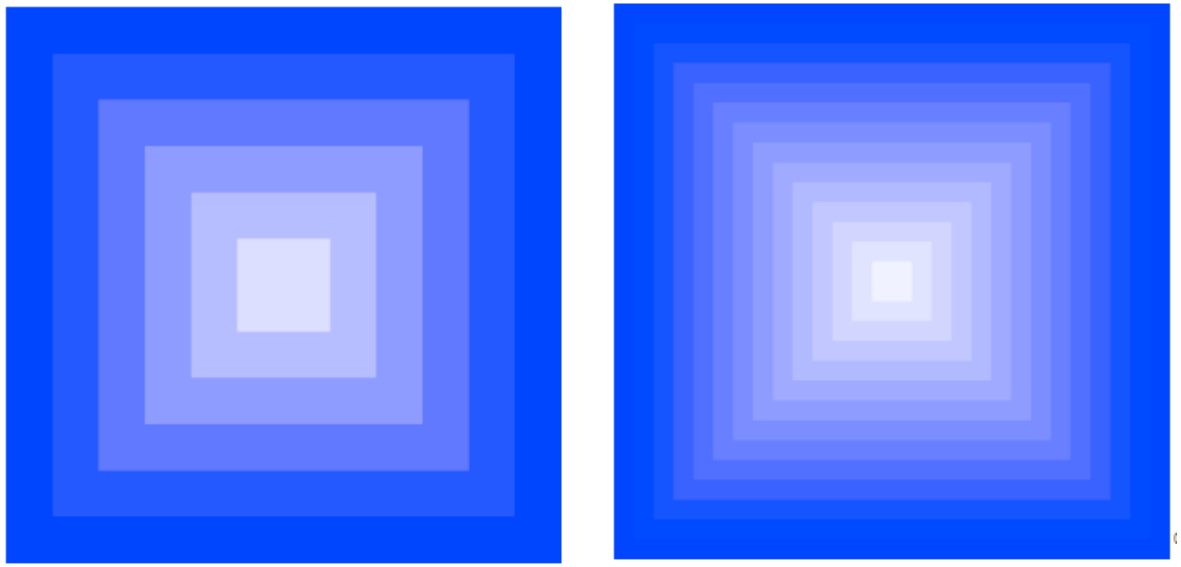
- A ganglion cell looking at a crossing sees 4 bright patches in the inhibitory neighborhood. When looking at a street, only 2.
- The effect vanishes when we look at a crossing, because the fovea has higher resolution (smaller neighborhood)





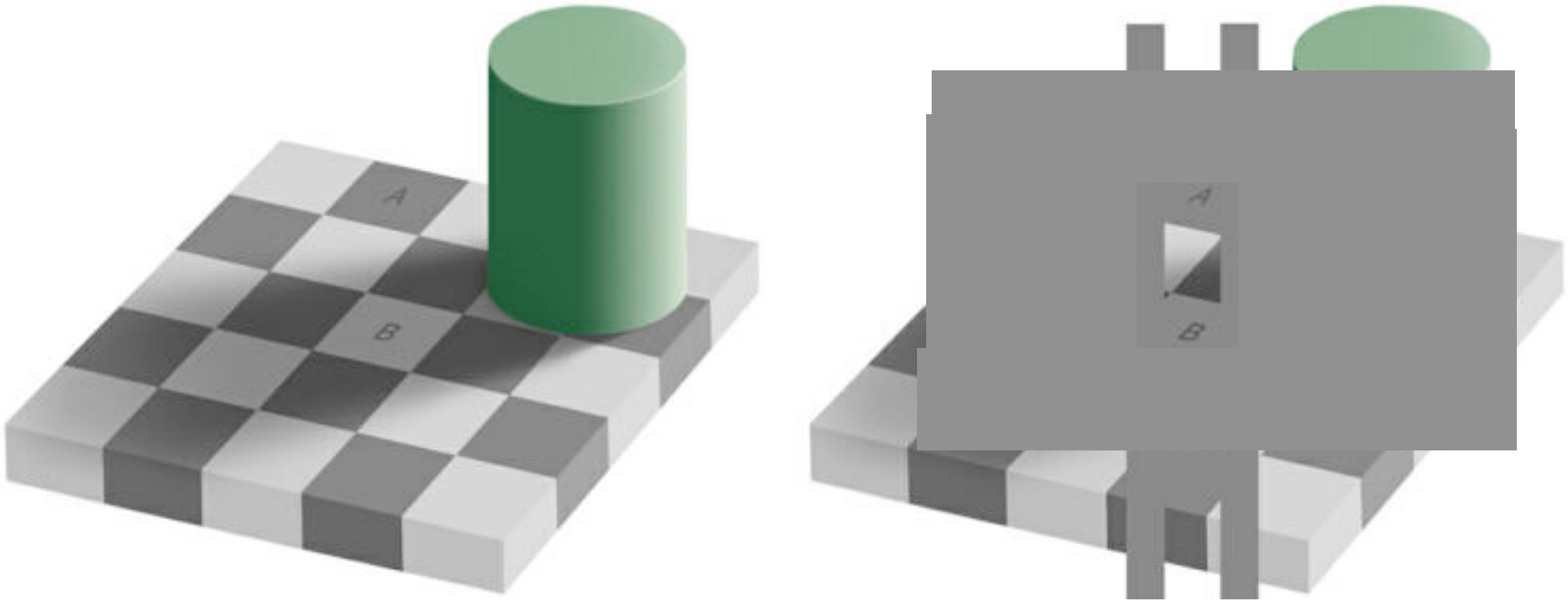
Variation on contrast illusion

- Why do we perceive an X?

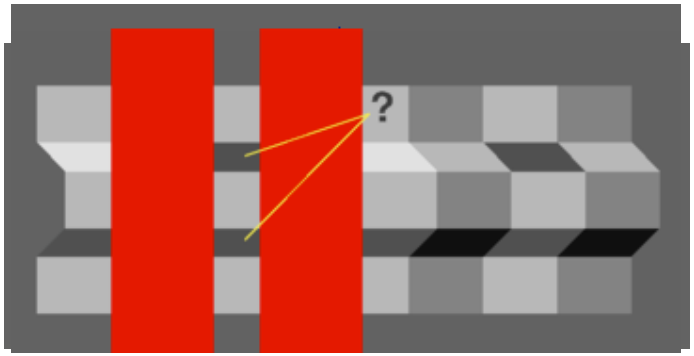


Intensity is relative

Squares A and B have the same intensity. Illusion is due to colors of neighbors and to the fact that we compensate for the shadow



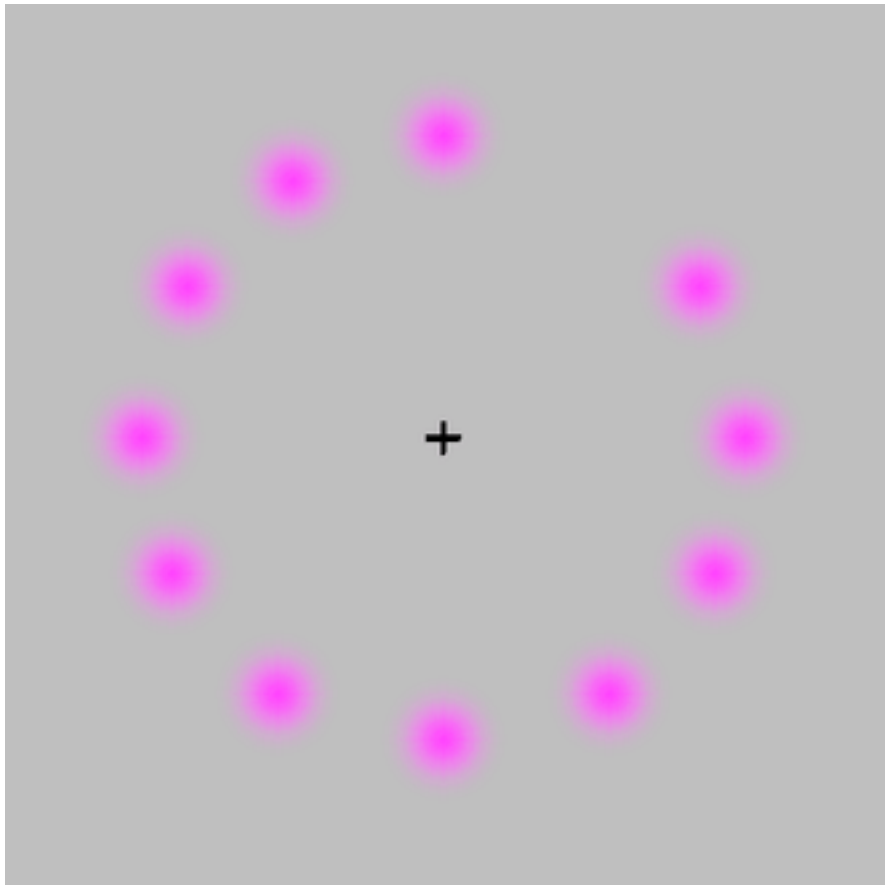
Contrast illusions enhanced by 3D interpretation



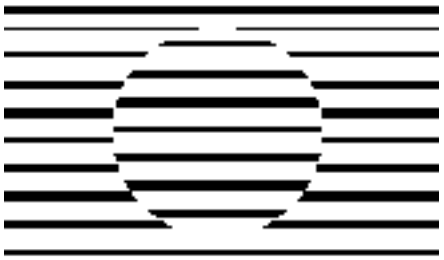
Contrast adaptation

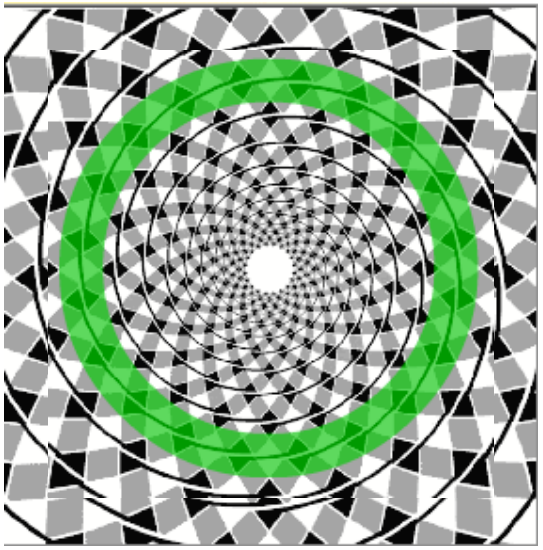
Afterimage

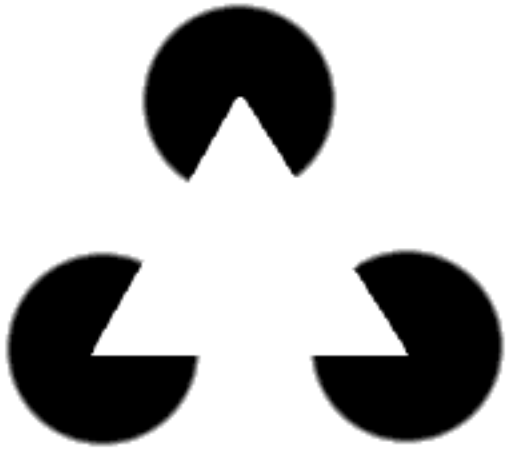
Impression on the retina remaining after the initial stimulus is removed. It has colors that are complementary to those of the original image. Look steadily at the cross in the center of the picture to see a green afterimage rotating.

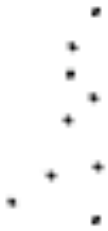


Perceived shapes and motions



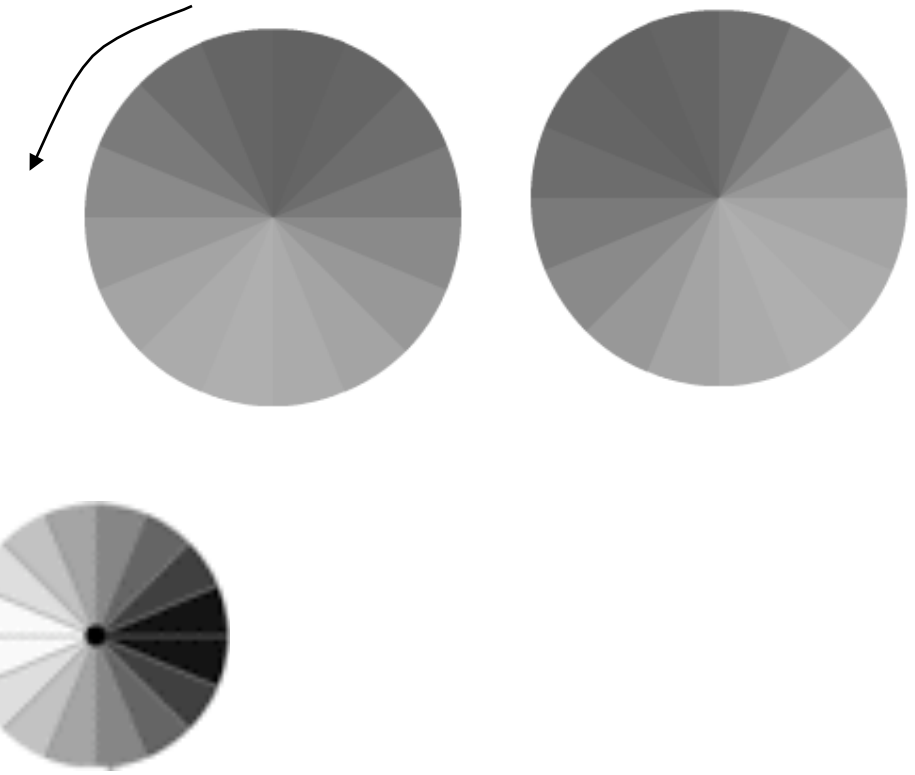




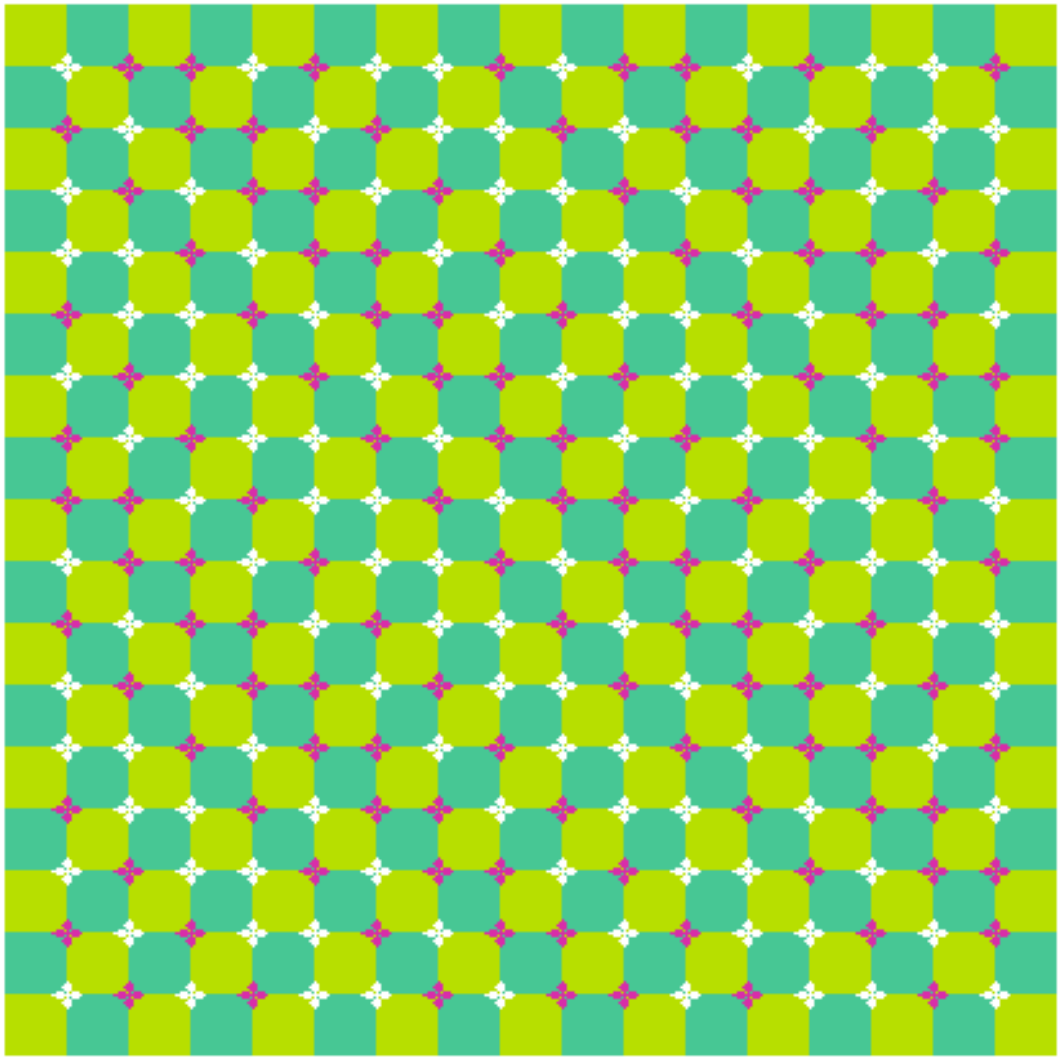


Illusion of relative motion

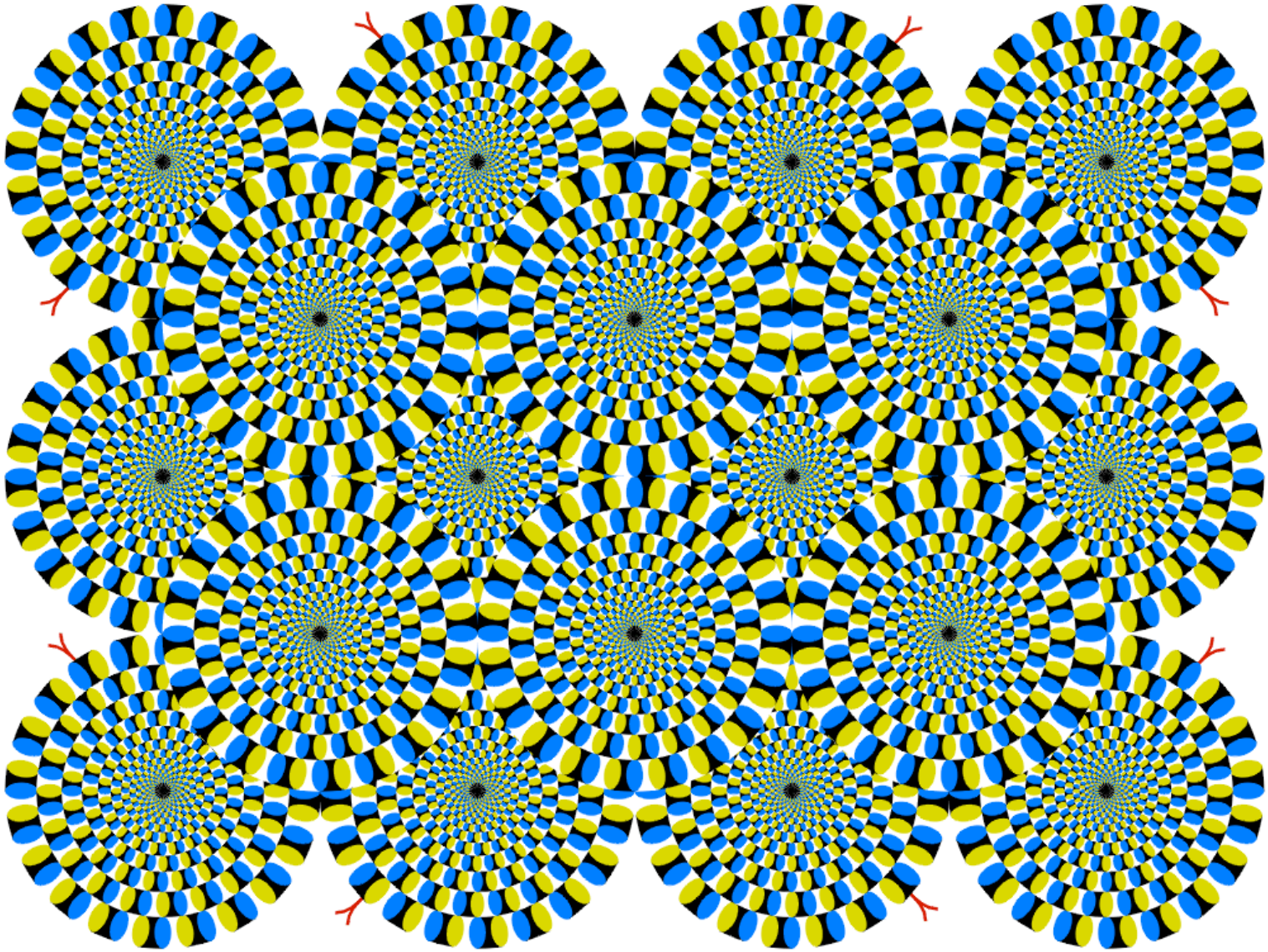
- Background rotates
- Spokes are fixed
- Yet they appear to rotate



Waves

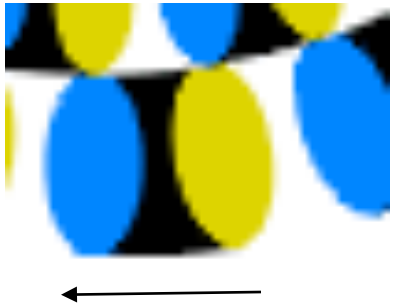


Rotating Snakes

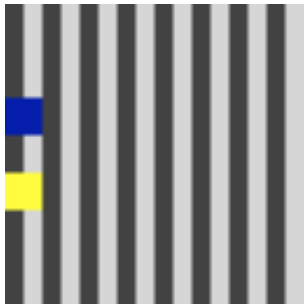


Explanation of motion illusion

- "Rotating Snake" by Akiyoshi Kitaoka,
- http://www.ritsumei.ac.jp/~akitaoka/rotsnake.gif
- Rotation perceived during eye movements.
- On steady fixation the effect vanishes.
- Asymmetric luminance steps cause illusory movement
- Direction of perceived motion from light to medium



Perceived motion irregularities



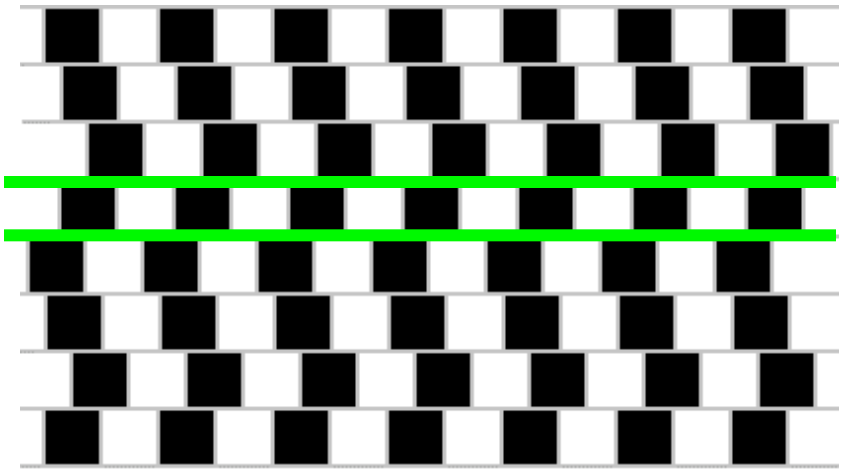
The two squares move at constant speed.

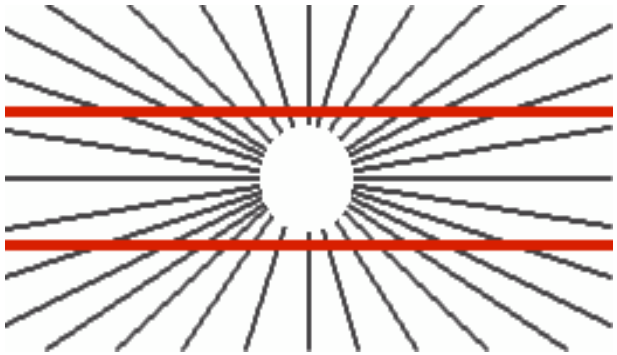
http://www.michaelbach.de/ot/mot_feet_lin/index.html

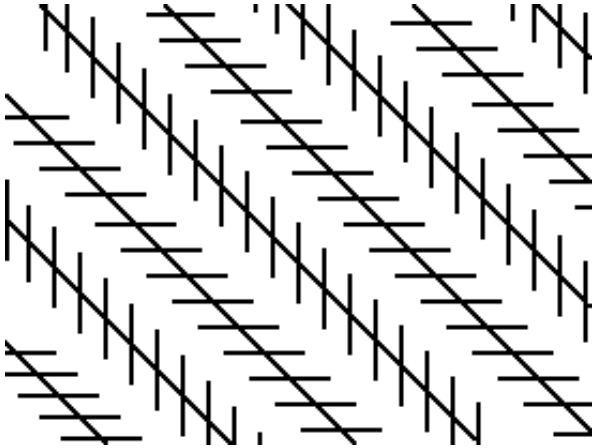
Half the time, no motion cue.

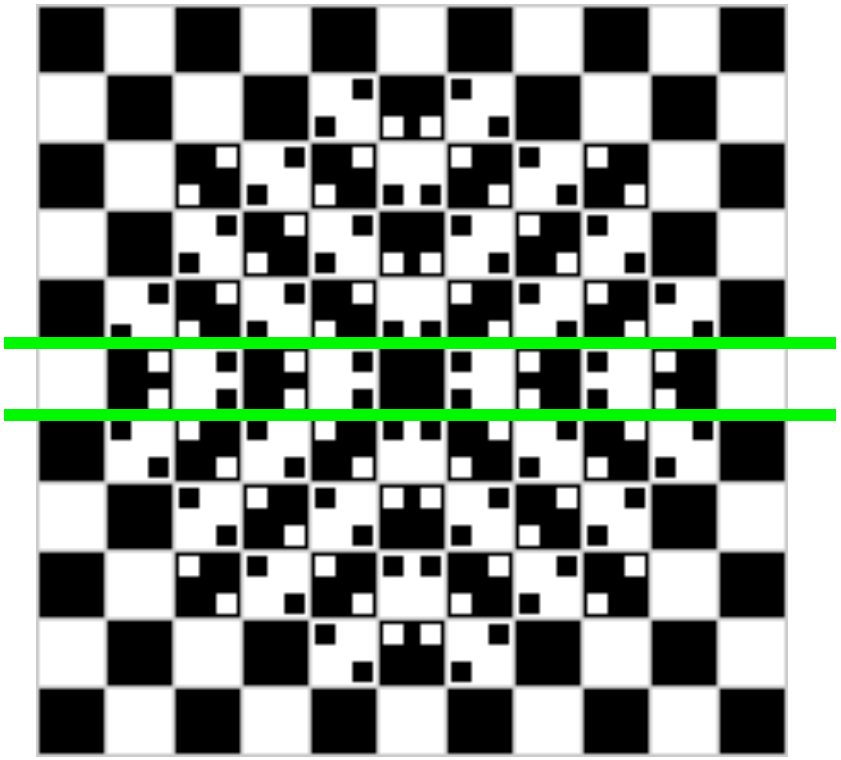
Moving objects appear to slow down at low contrast.

Perceived distortions

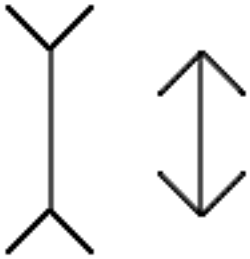


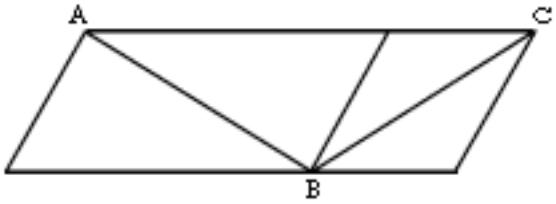


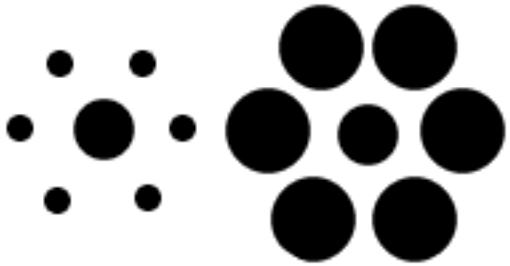




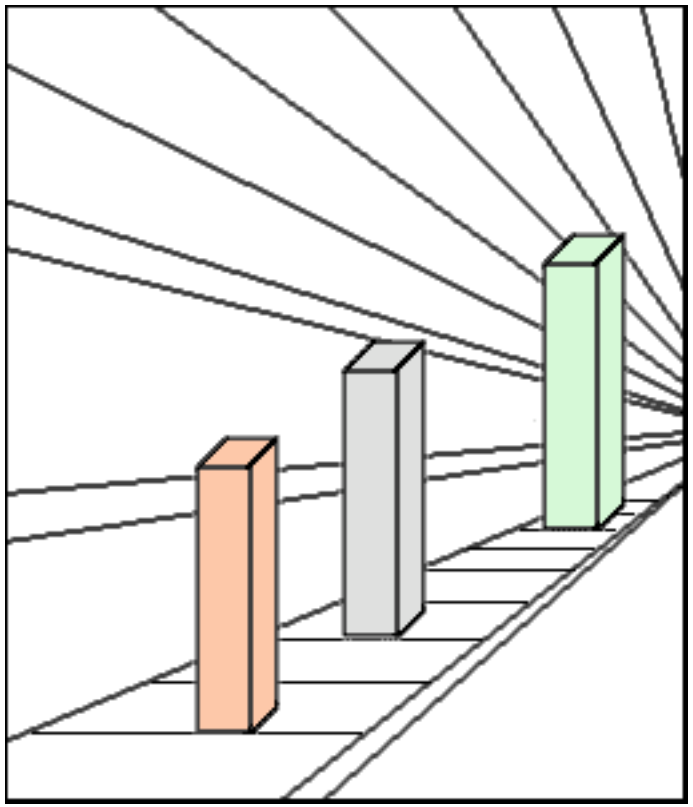
Scale illusions due to context

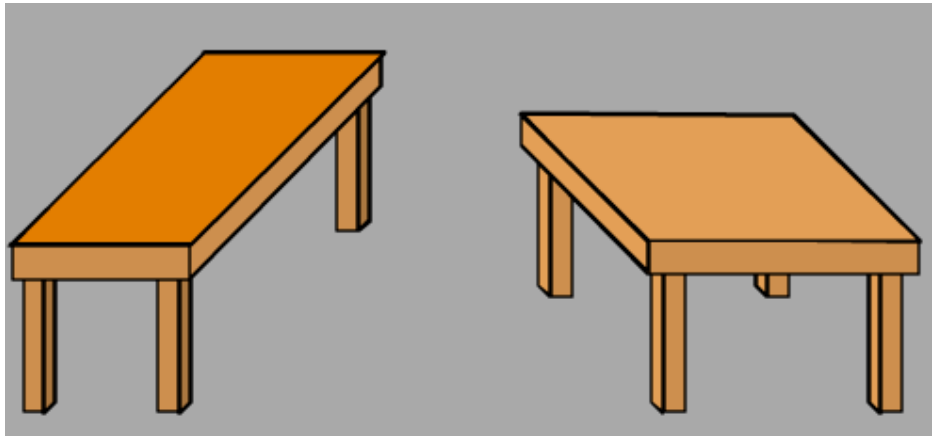


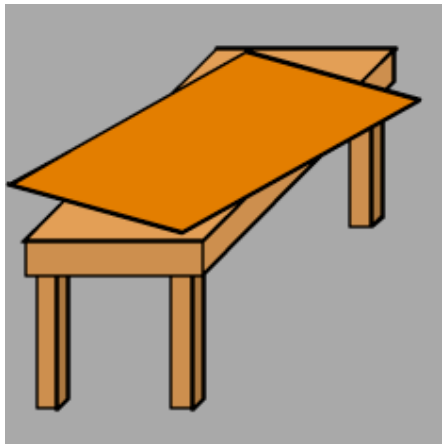


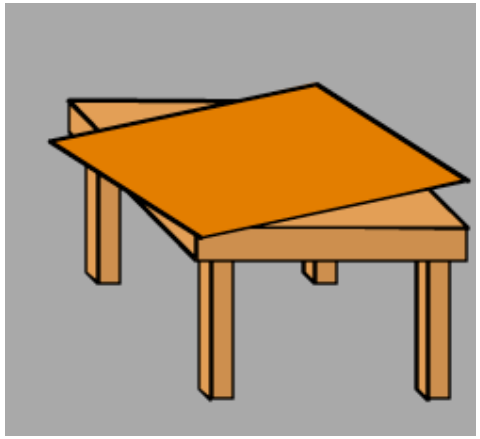


Size illusions due to perspective

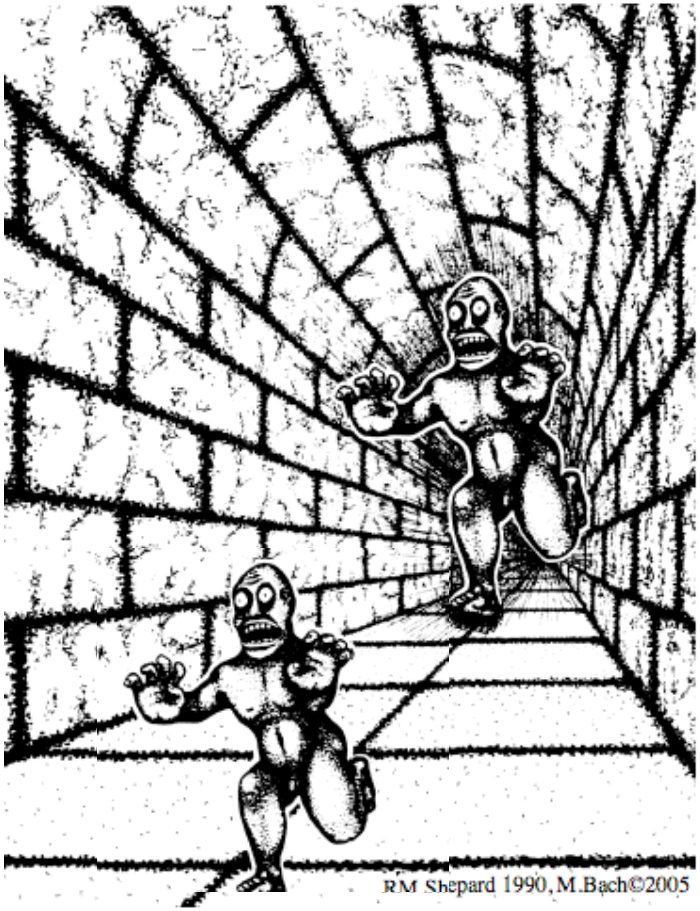




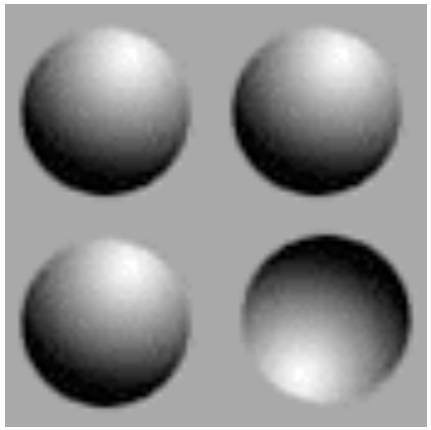




More size illusions due to perspective

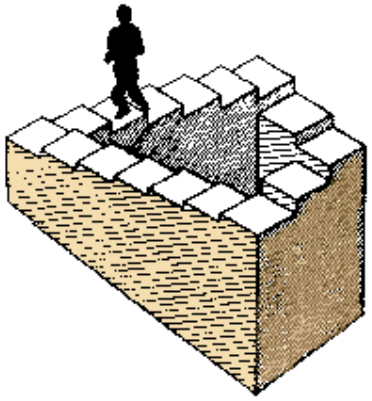


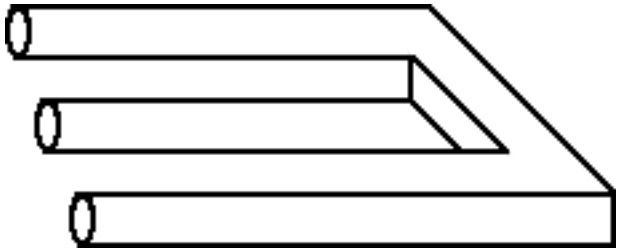
Illusions due to shading

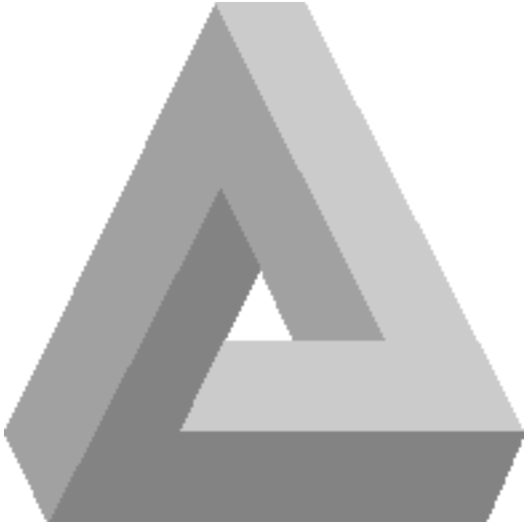


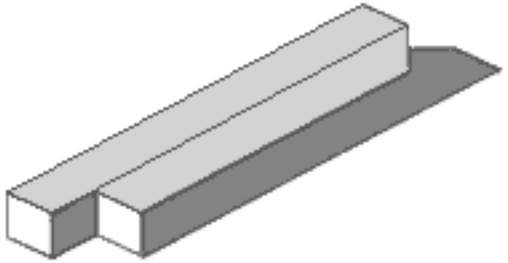
Perceived depth

Impossible figures

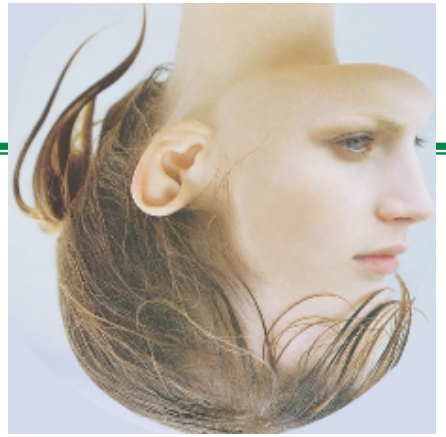




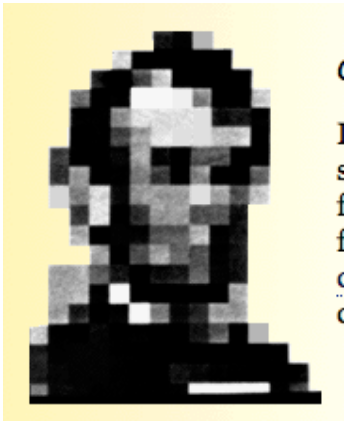




Faces - Pareidolia



See a face?



Resources

- http://www.colourware.co.uk
- http://serendip.brynmawr.edu/bb/latinhib.html
- http://www.scientificpsychic.com/graphics/
- http://www.michaelbach.de/ot/
- http://isg.cs.tcd.ie/gap/resources.html
- http://www.yorku.ca/eye/thejoy.htm

Additional Reading

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Examples of questions

- If we wanted to build a panoramic theater where viewers would not see the pixels, how many colums of pixels would we need? How many pixels total (assuming 90 degrees vertical field of view)?
- Explain why one portion of the image may appear darker than another of exactly the same color.
- Explain why we may perceive an edge on a smooth surface.
- Explain why spots appear at the crossings of the Herman grid.
- Why do Kitaoka's snakes rotate?
- Why do we see faces in strange places? What is the name of this tendency?