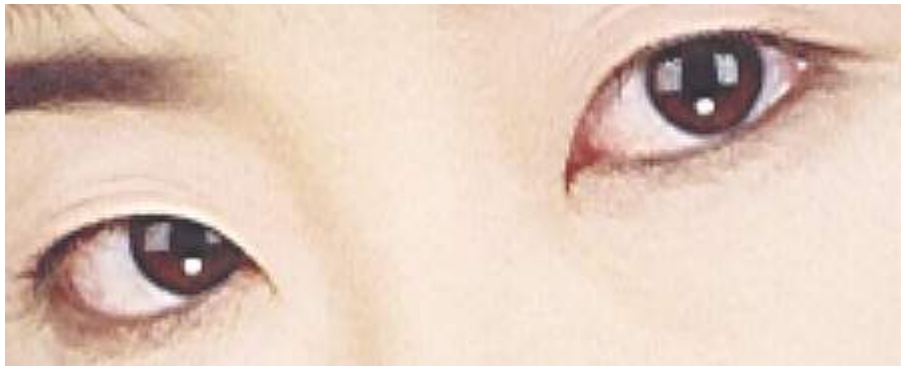
PHYS/ART 208
The Physics of Art and Visual Perception

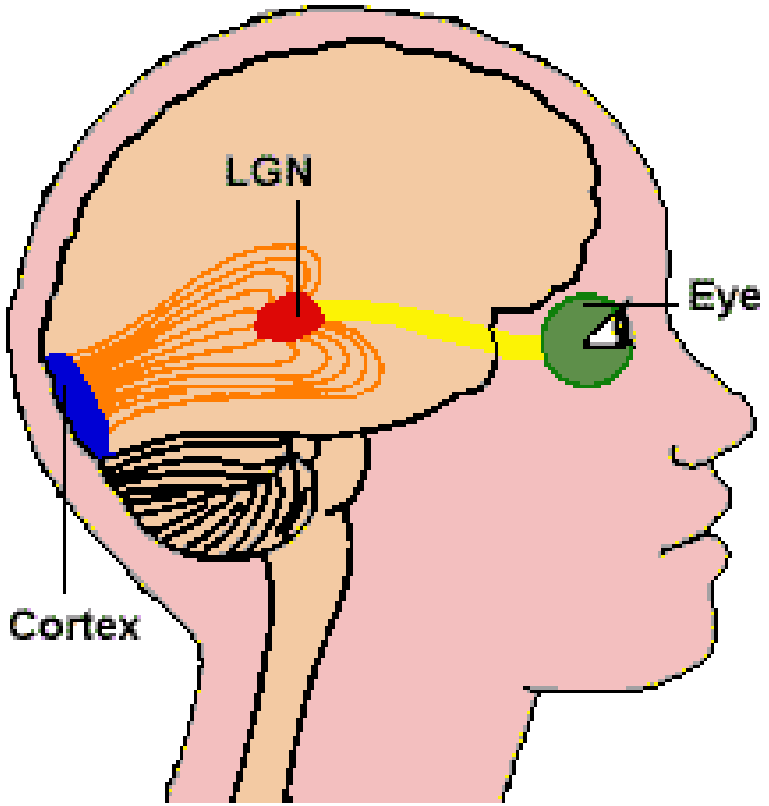
The Human Visual Pathway



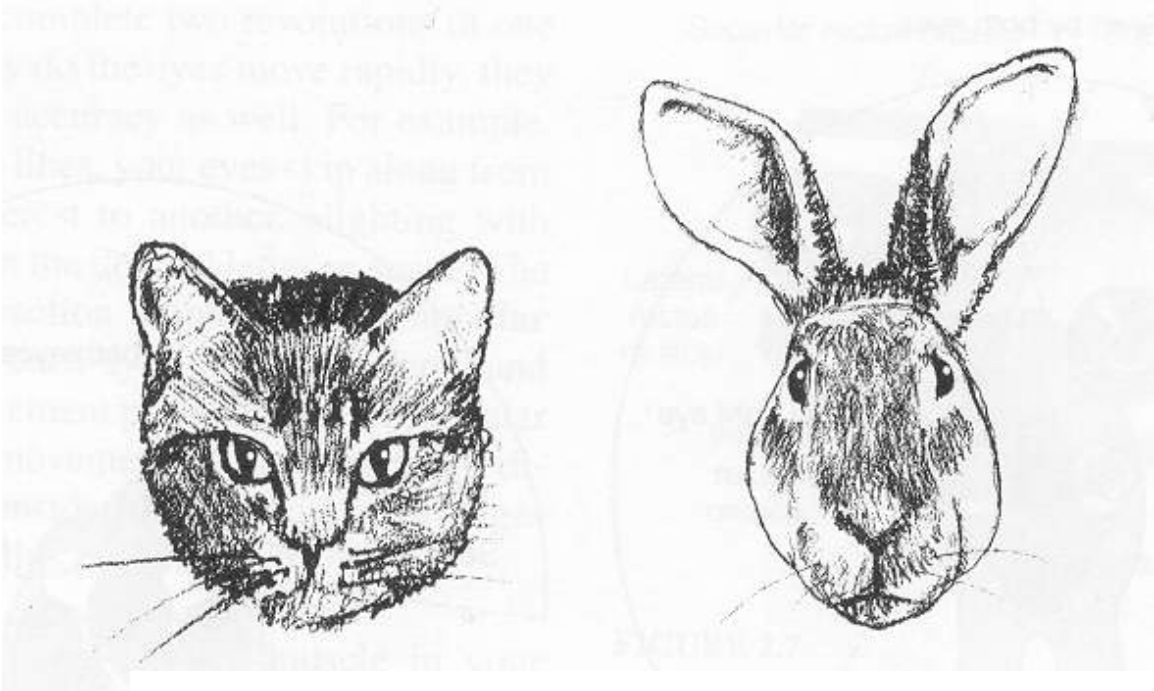
The Human Visual System

Follow the route of visual processing from the eyes, through the Lateral Geniculate Nucleus (LGN), and up to the cortex.

Much of the primate cortex is devoted to visual processing.



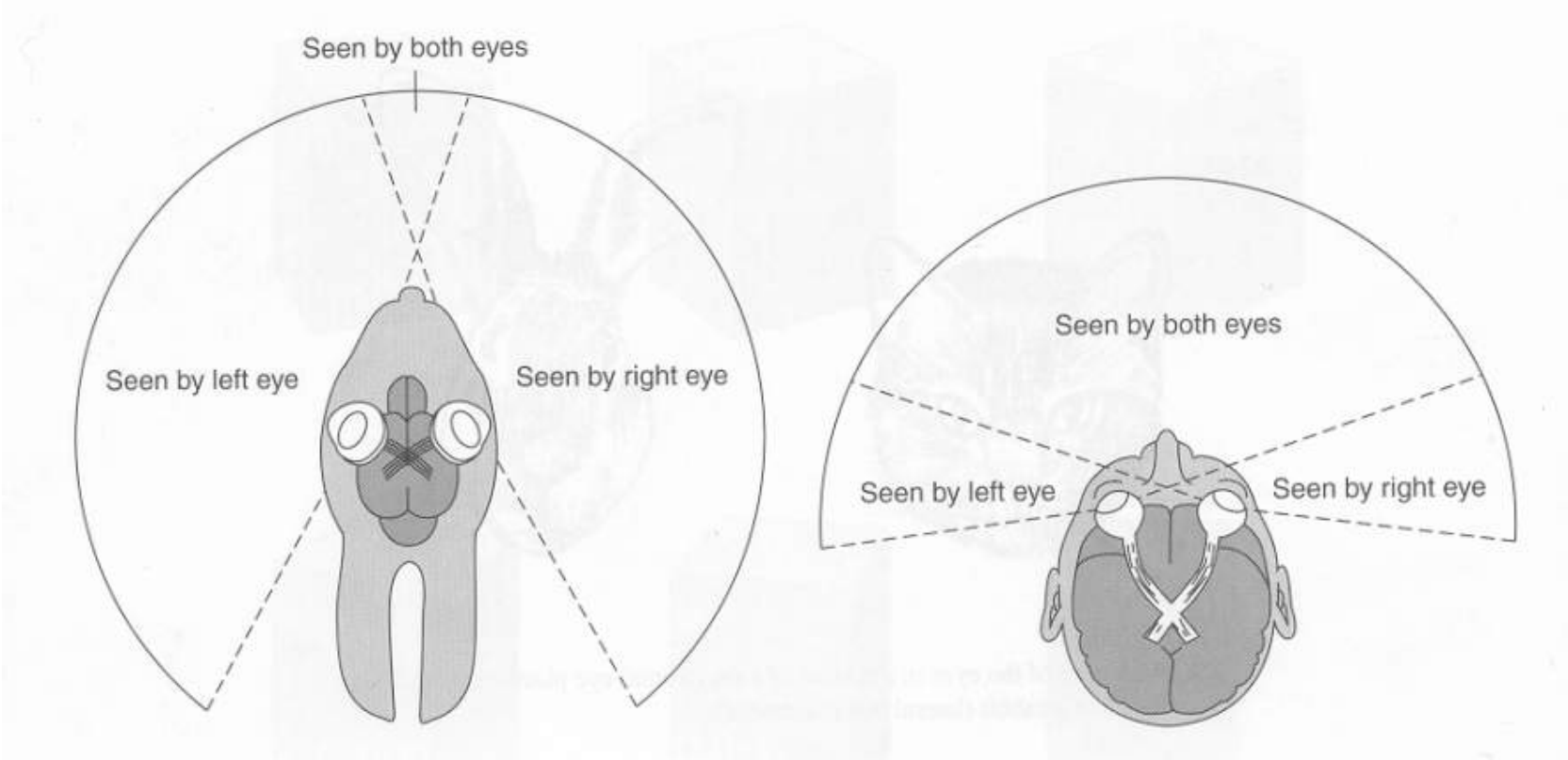
Where should the eyes be?



Frontal position

Lateral position

Predator or prey?



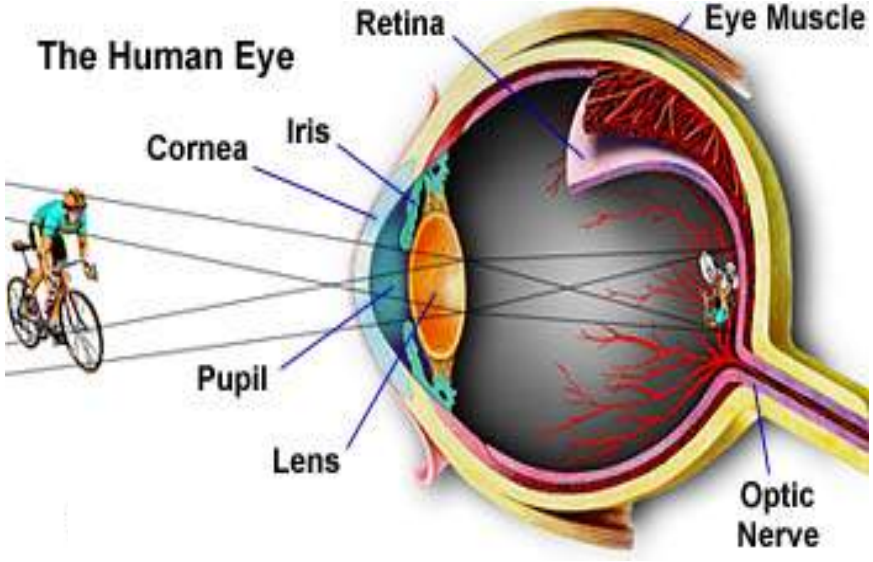
The eye

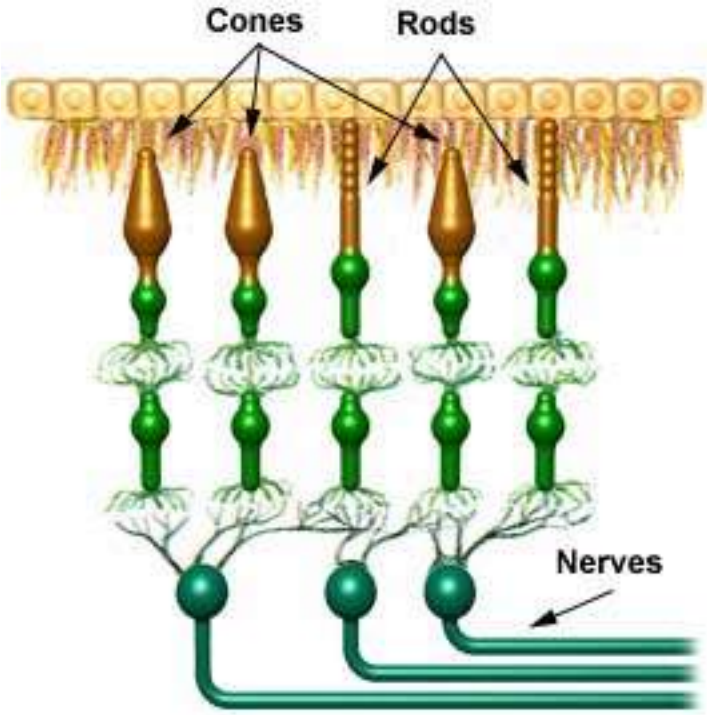
The outside of the eye is light-tight so that light can only enter through a small opening. This produces clearer vision, because a smaller opening, or aperture, creates a sharper image.

Prove it to yourself (best for the short-sighted):

Take an index card and puncture it using a pin. Be careful not to allow the hole to be too large! Look at something just far enough away that you cannot focus clearly on it. Hold your index card up to your eye and look through the tiny hole. While the aperture, the hole, blocks most of the light hitting your eye, it makes the far away object look clearer!

Light Detectors: the eye





The image

The image created by the eye is real and inverted. Many people are surprised to learn that the images we always see are inverted. The reason we do not notice this is that we know no other reality.

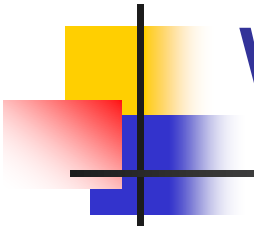
Try this: Go into a dark room with a friend, and have him or her look at a small light-emitting object, like a candle. If the room is dark enough, you will be able to see up to three images in his or her pupil. The first image (upright and brighter than the other images) is a reflection off the cornea. The second image (upright and very dim) is a reflection off the eye lens. The third image (dim and inverted) is a reflection off the retina. This third image is the image that is sent to the brain!

Light control

The human eye can respond to a wider range of light than any artificial device ever created. It is possible to see not only in very low light levels (such as a darkroom) but also in very high light levels (such as a sunny day). In fact, thebrightest conditions under which an eye can operate are around 10^{13} times as bright as the dimmest conditions.

How does the eye do this?

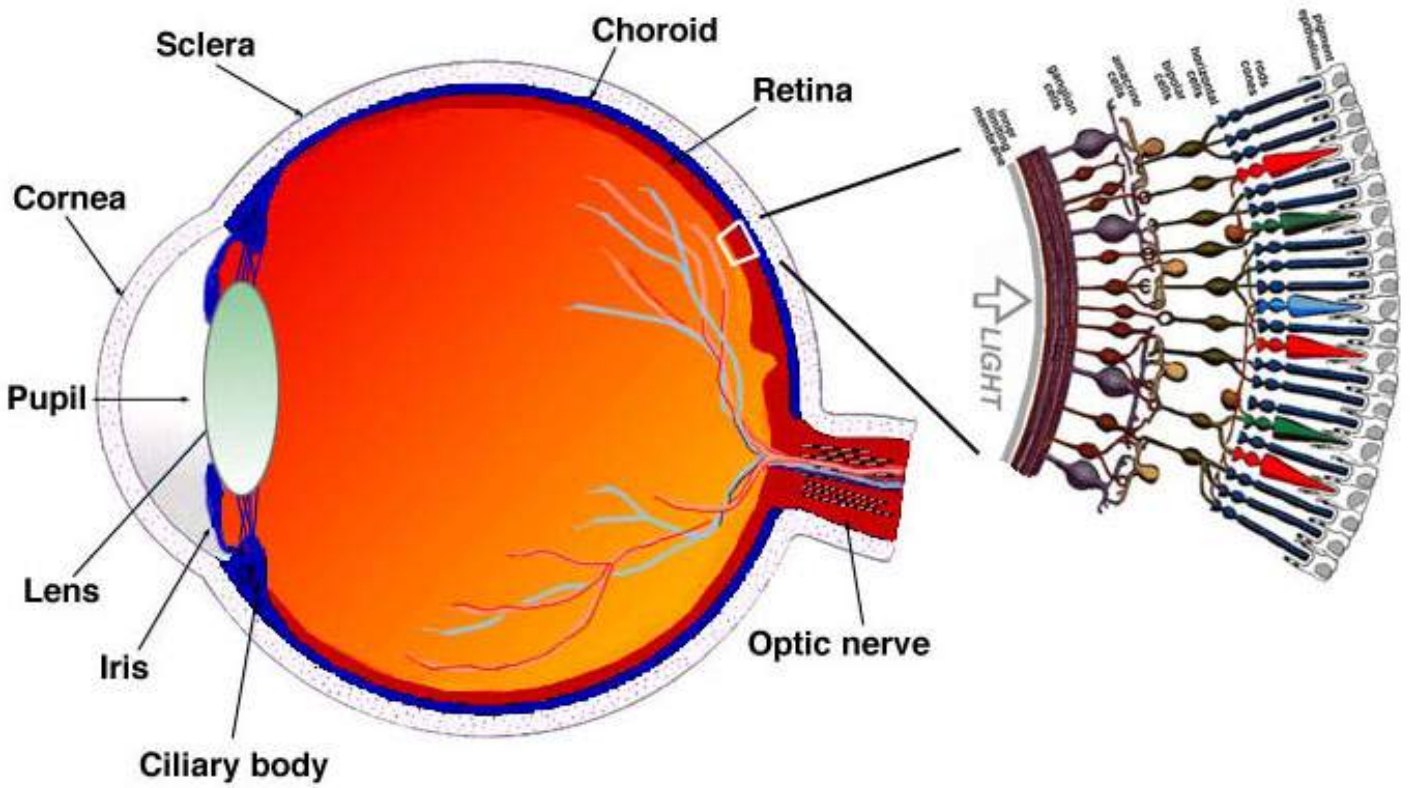
Prove it to yourself: There is a very simple way to see the iris at work. Stand in a dark room and look at a mirror. Suddenly turn on a light. You will see the iris, the black circle in your eye, quickly shrink as it adjusts to a greater level of light.



Why?

- Why does the pupil appear black?
- What causes “red eye” in flash photographs?

The human eye



. A drawing of a section through the human eye with a schematic enlargement of the retina.

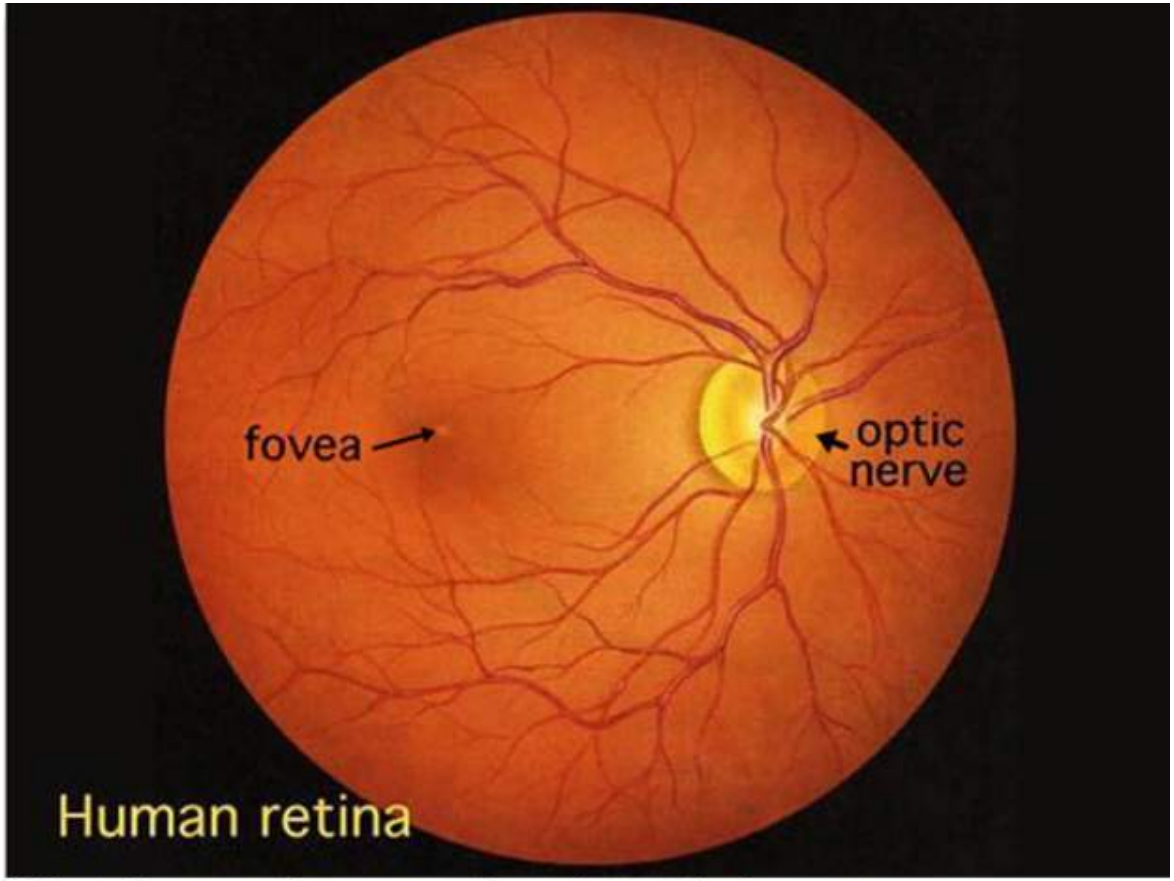
The retina

The retina is a direct extension of the central nervous system.

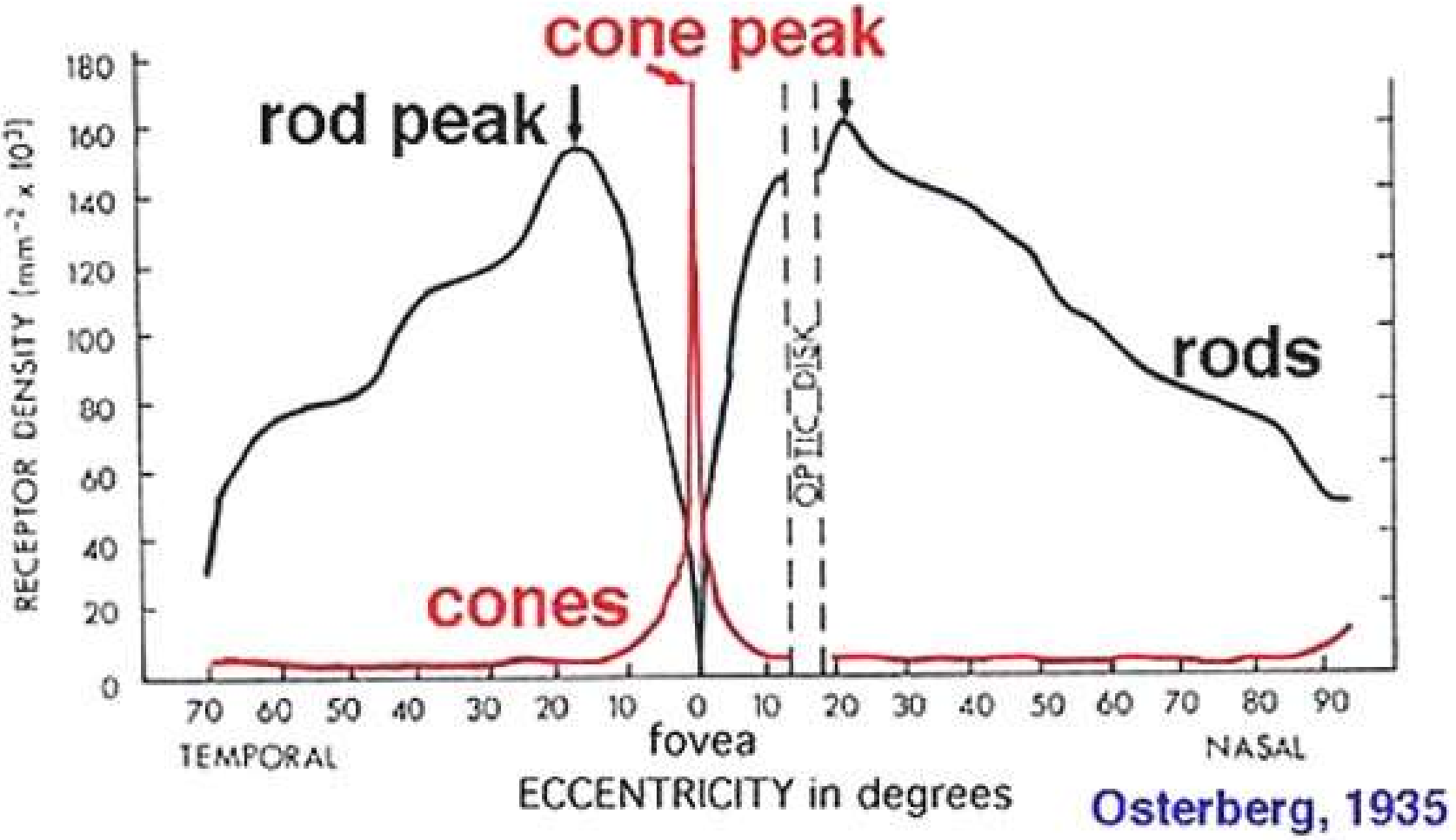
An ophthalmologist can use an ophthalmoscope to look into your eye and see the nervous system and blood supply directly without surgery.

(Why can't you see these by looking directly into someone's eye?)

Quick-time movie



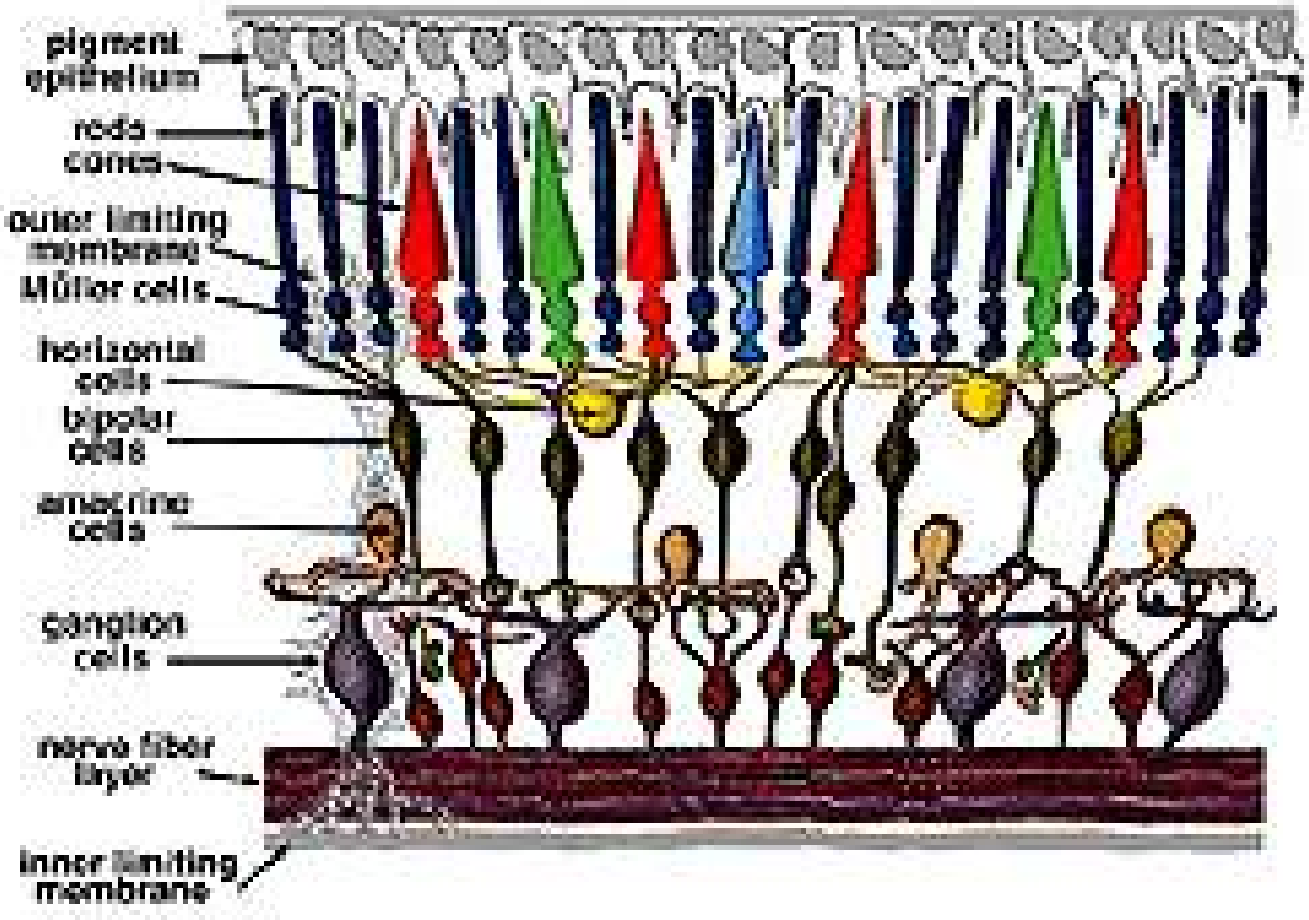
Human retina as seen through an opthalmoscope.

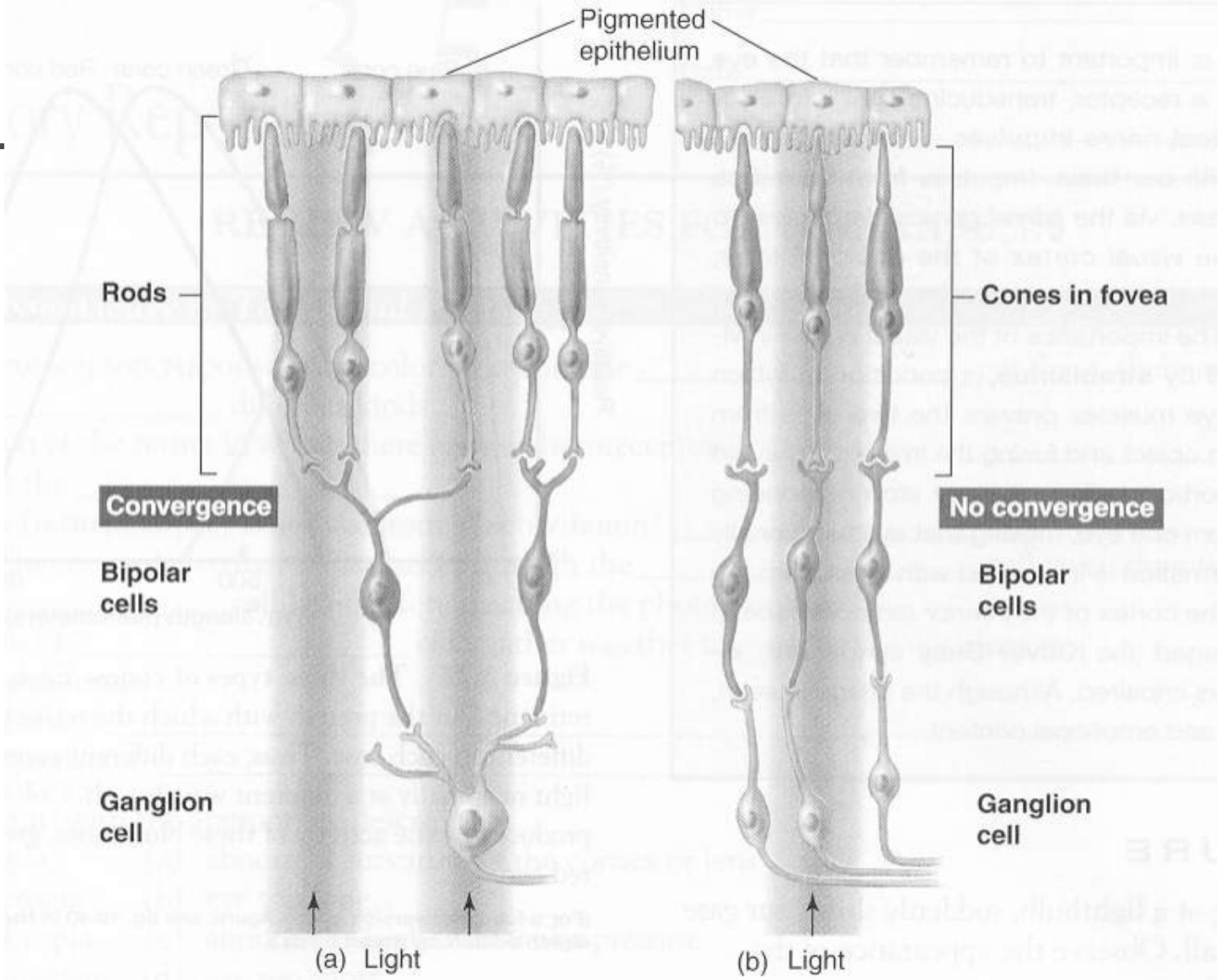


Graph to show rod and cone densities along the horizontal meridian.

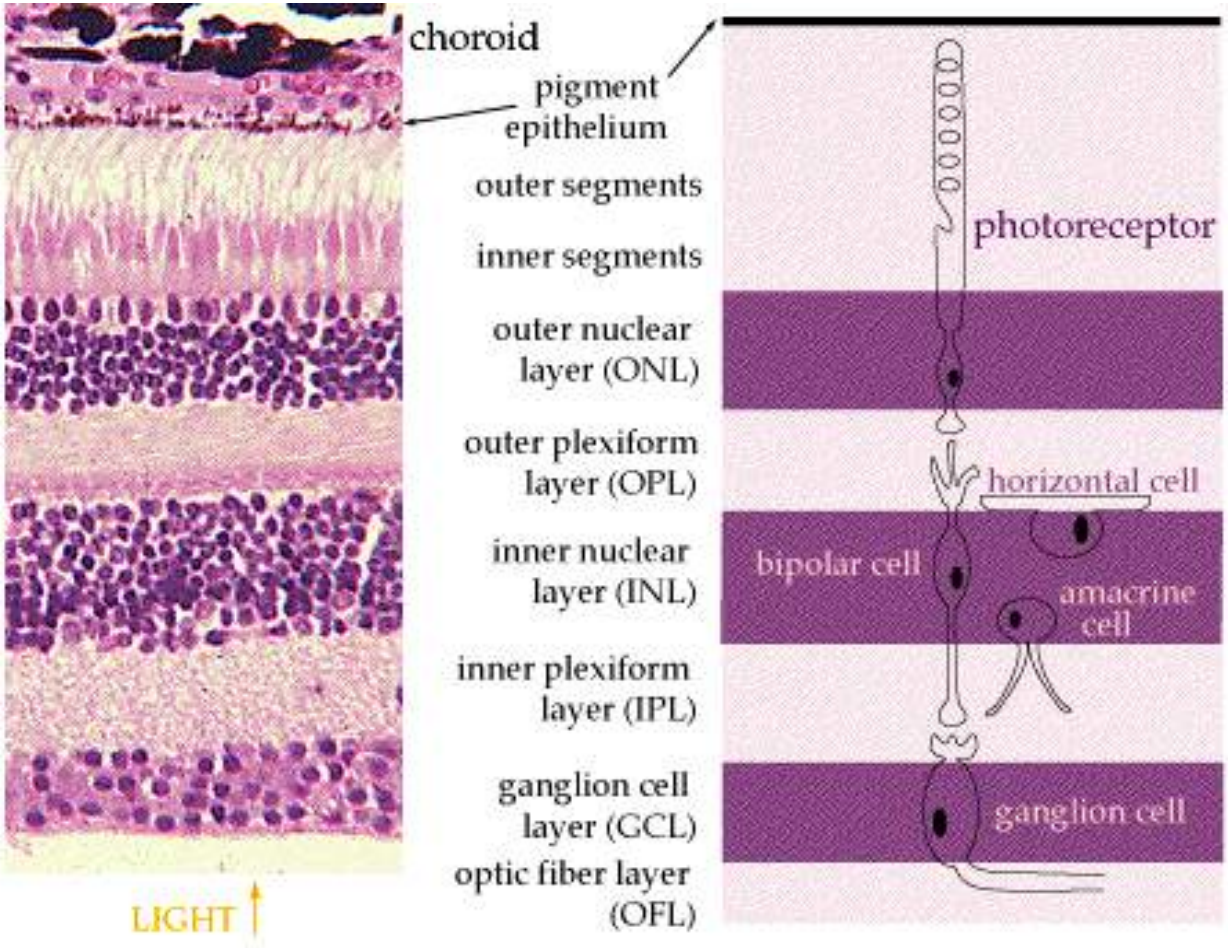
The Blind Spot

Cross-section through the retina

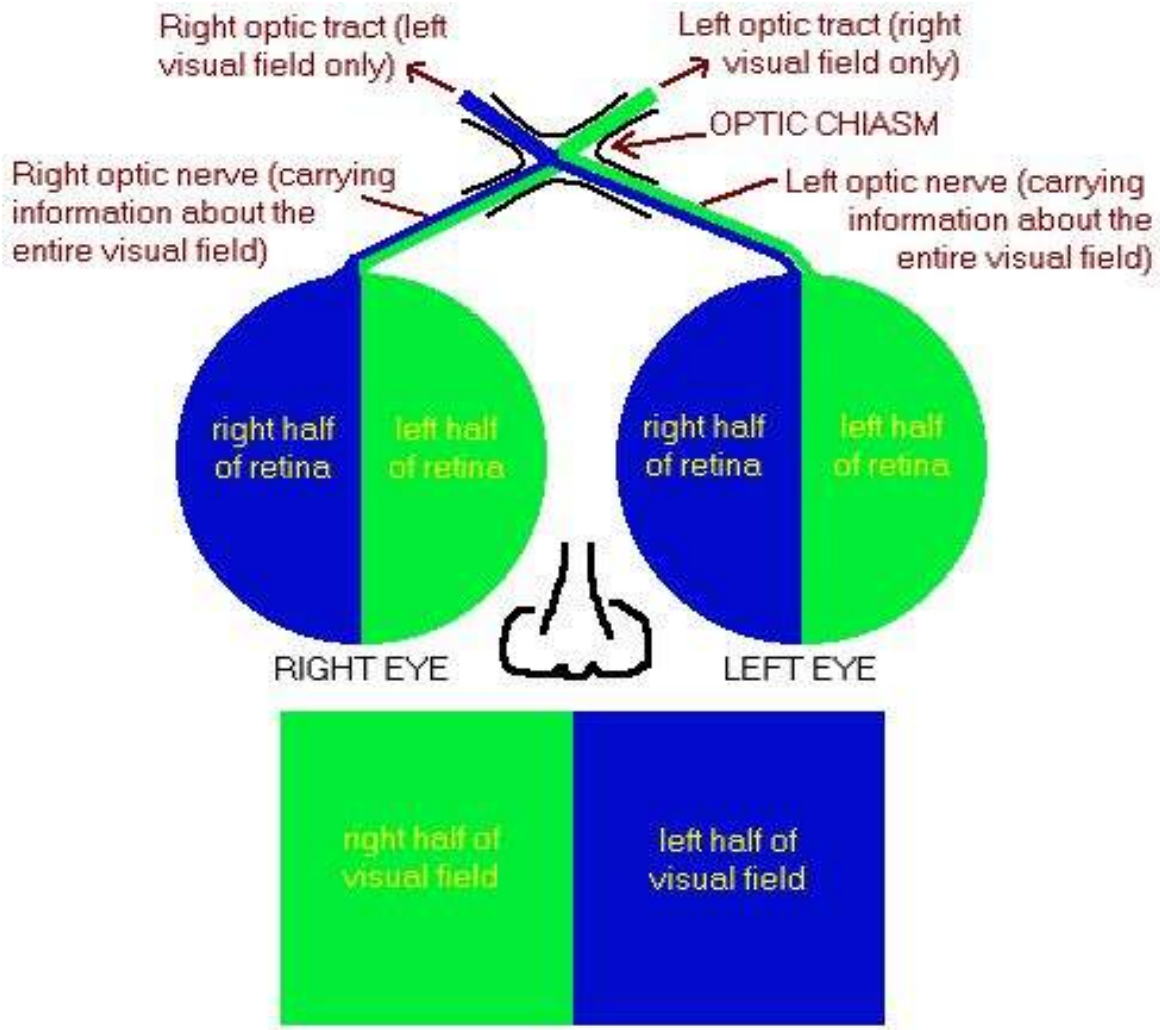



Pigmented epithelium
Rods
Cones in fovea
Convergence
No convergence
Bipolar cells
Bipolar cells
Ganglion cell
Ganglion cell
(a) Light
(b) Light

Cross-section through the retina

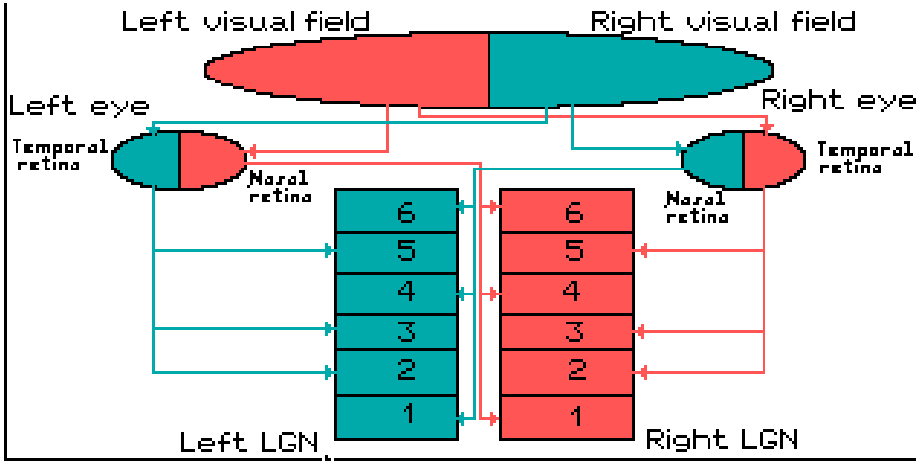


The Human Visual Pathway



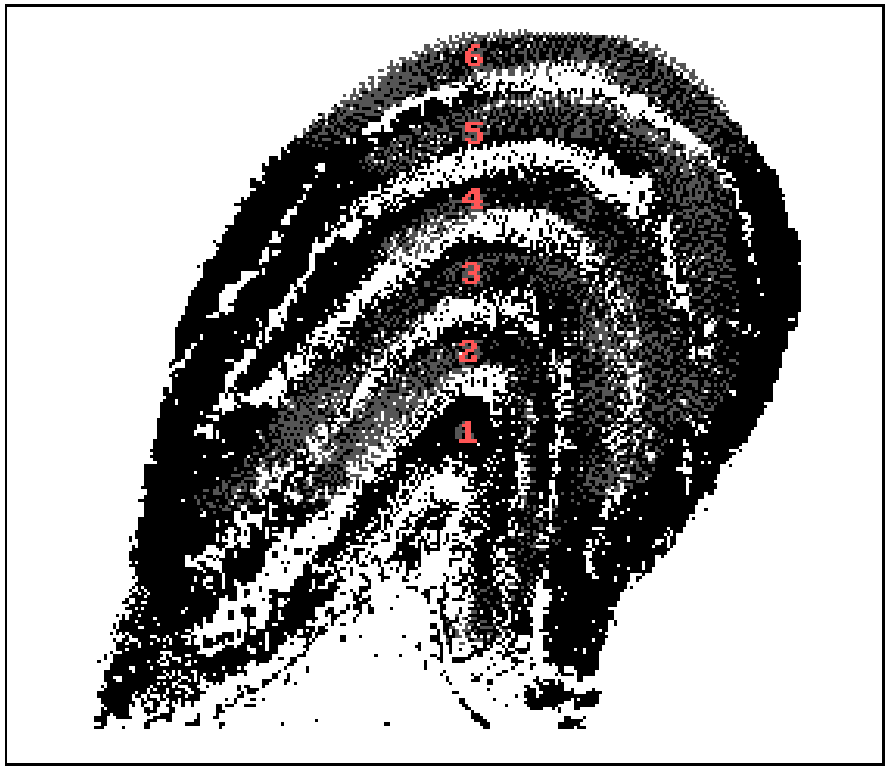
The Human Visual Pathway

- **Optic nerve fibres from the eyes terminate at two bodies (LGNs) in the thalamus (a structure in the middle of the brain).**
- **This apparently complicated arrangement is engineered so that the right LGN receives information about the left visual field, and the left LGN receives information about the right visual field.**



LGNs

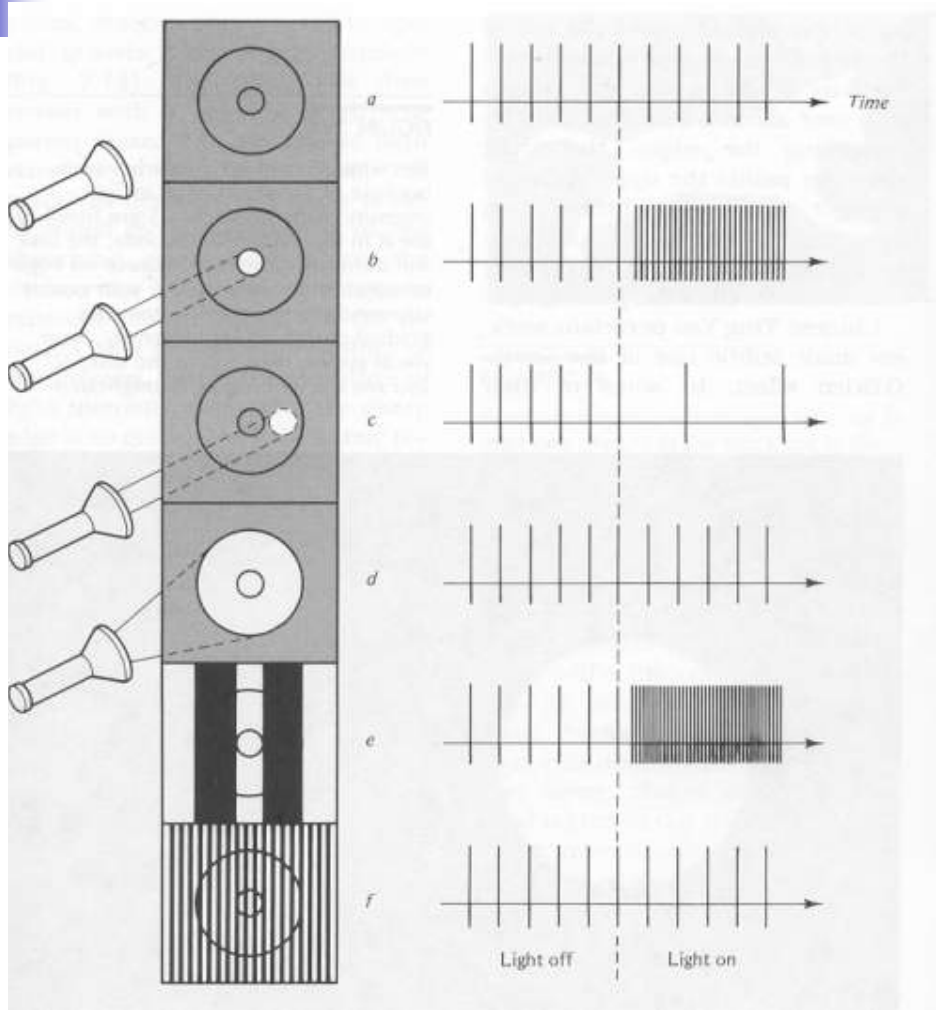
- LGN cells are arranged in layers, with cell neighbors in one layer corresponding to ganglion neighbors in the retina. Corresponding image locations are stacked "above" each other in adjacent layers.
- Color information goes through layers 3-6, while bright-dark information goes through layers 1 and 2.
- Comparison of the layers (one from one eye and another from the other eye) is the first step toward binocular depth perception.

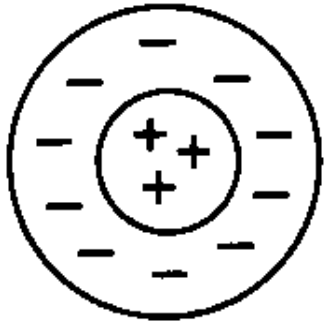


Processing in the visual cortex

- Our entire visual system exists to see borders and contours. We see the world as a pattern of lines. A system known as *lateral inhibition* in the retina is the first step towards sharpening contours and picking up on borders between light and dark.
- We judge colors and brightness by comparison (i.e. contrast), not by any absolute scale.

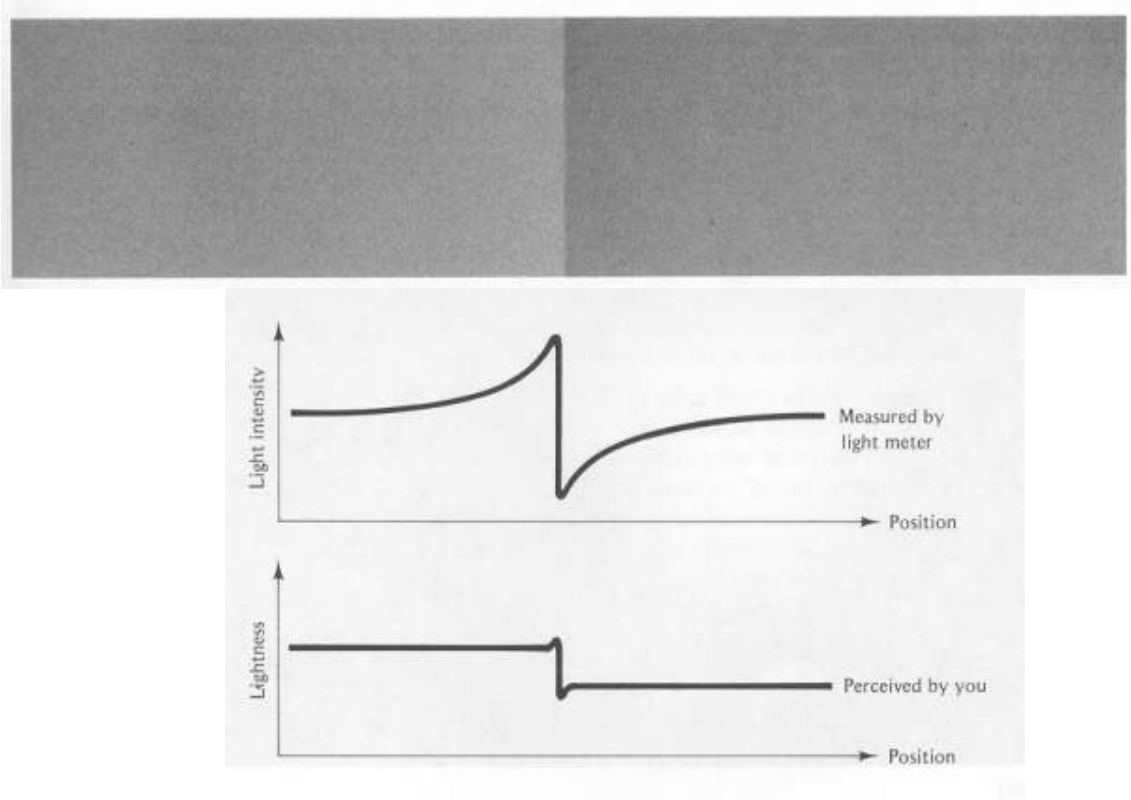
Neural activity





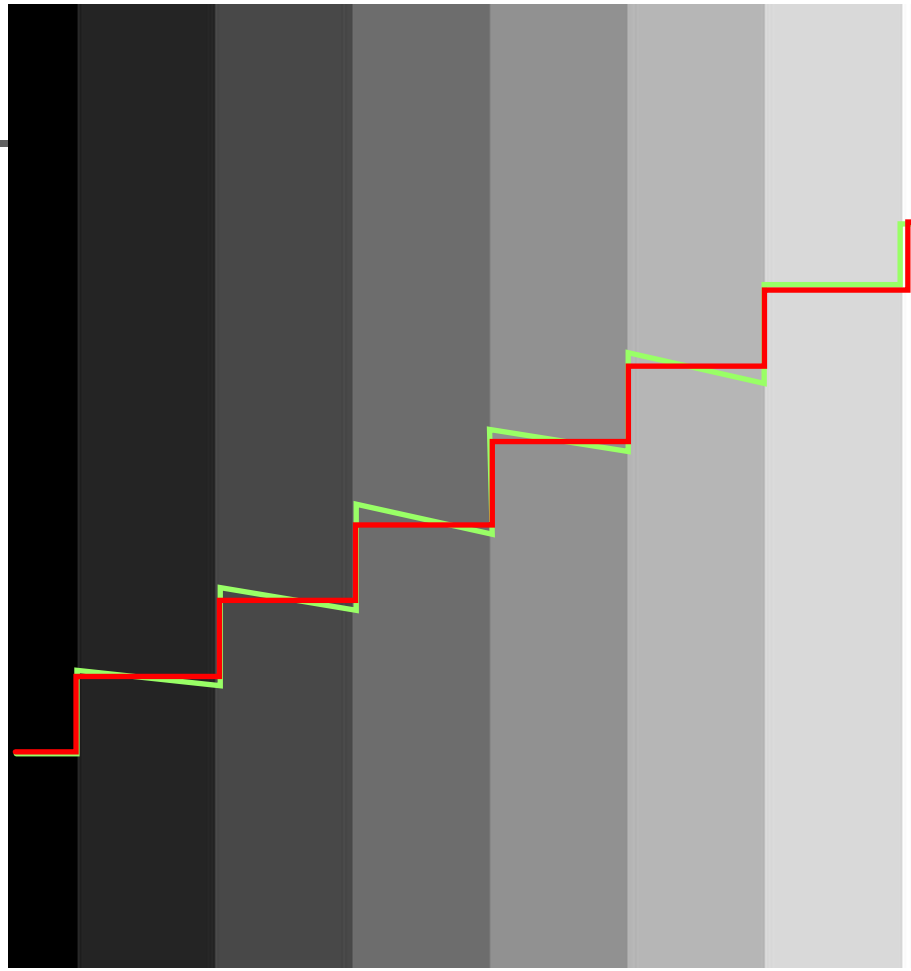
+ = On
– = Off

The Craik-O'Brien illusion shows how much we rely on edges…..



Go to **http://infohost.nmt.edu/~armiller/illusion/checkerboard.htm**

Mach Bands

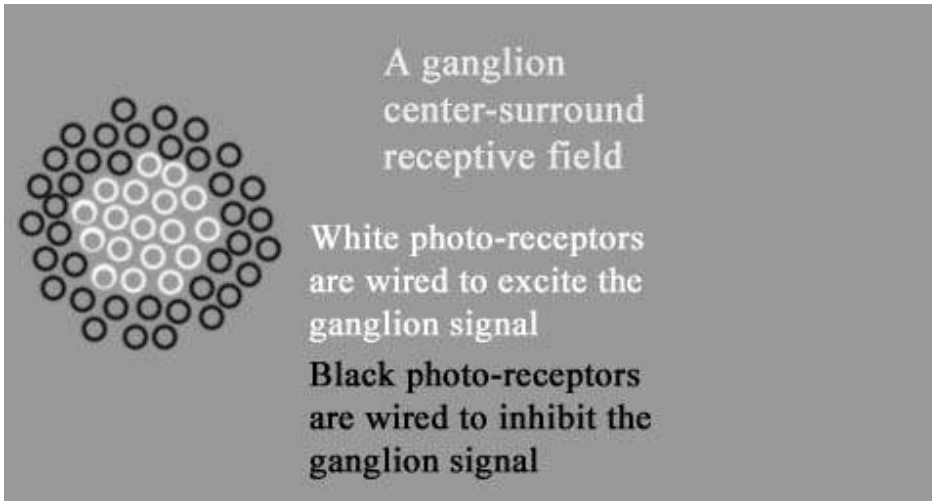


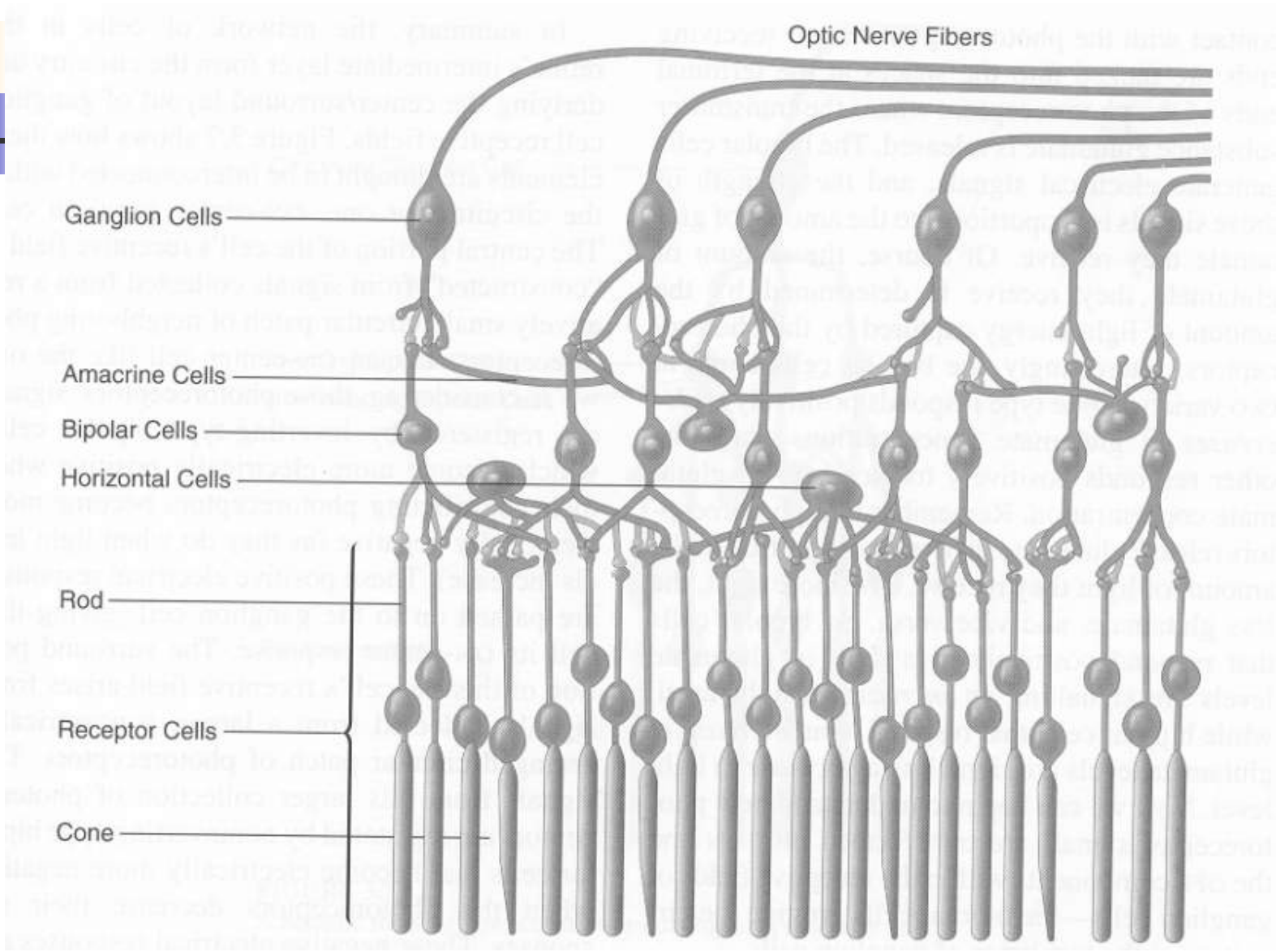
Subjective (perceived) value

Objective value (intensity)

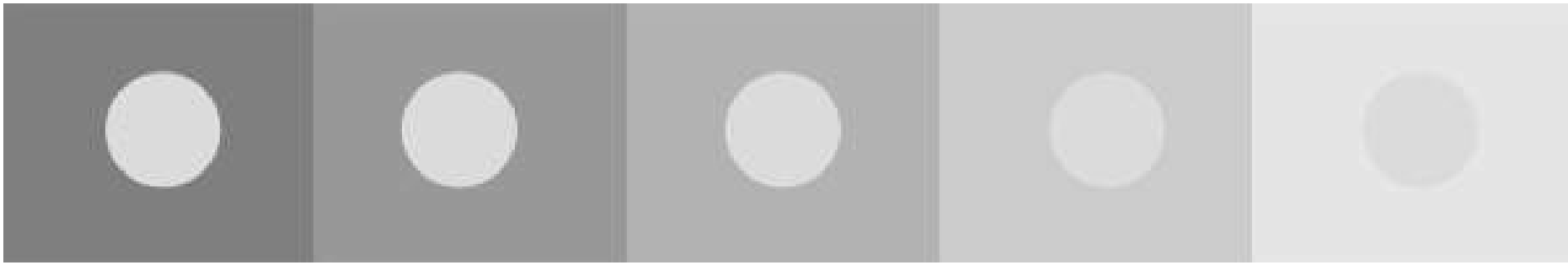
Receptive fields

- **The overall effect is that the photo-receptor - ganglion system is a *contrast* detector, not an absolute brightness detector.**
- **Cones are wired to transmit an opponency too (r-g or b-y)**

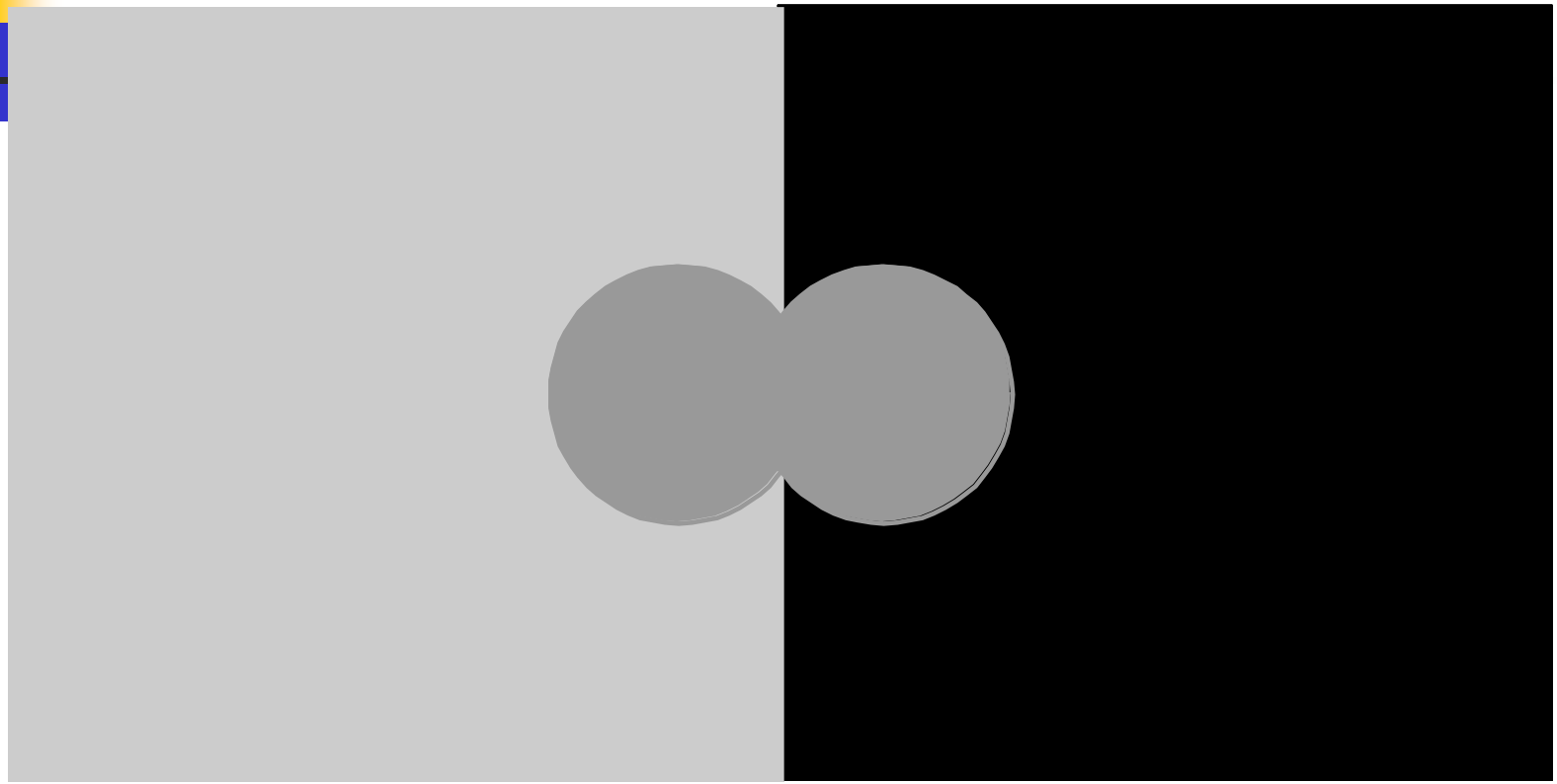



Optic Nerve Fibers
Ganglion Cells
Amacrine Cells
Bipolar Cells
Horizontal Cells
Rod
Receptor Cells
Cone

Simultaneous Contrast

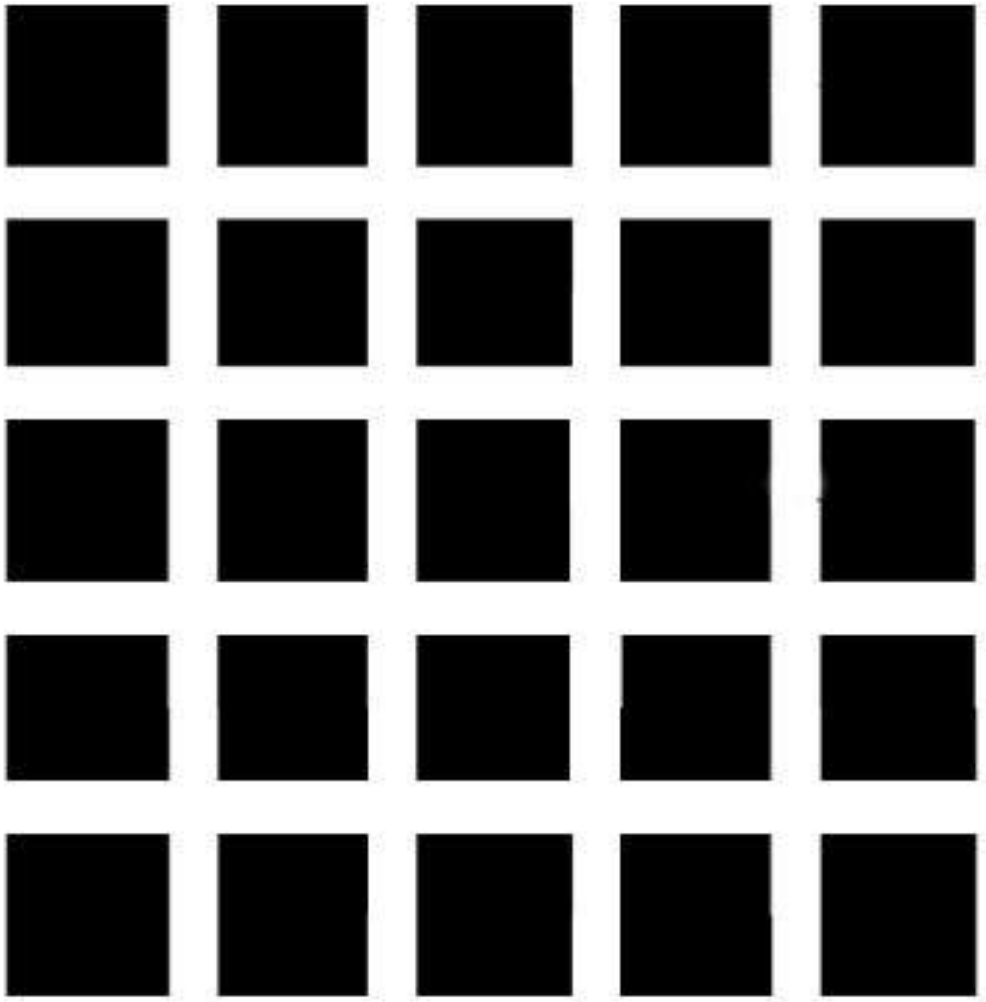


Because of lateral interactions, we perceive contrast rather than absolute bightness, i.e. the backgound affects the foreground.

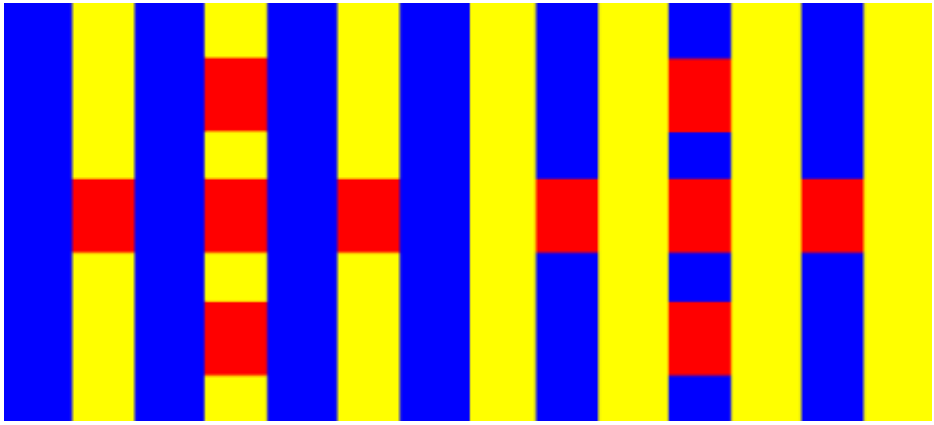


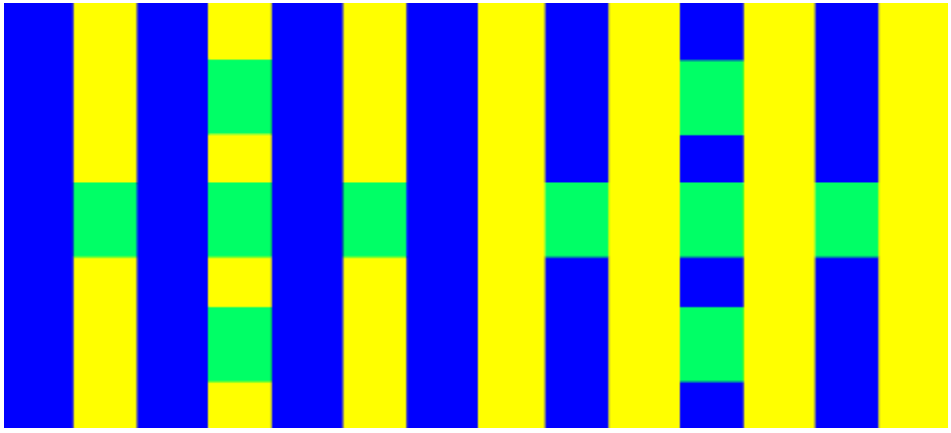
Hermann Grid Illusion

The gray blobs can be explained by reference to *receptive fields* and *lateral inhibition*.

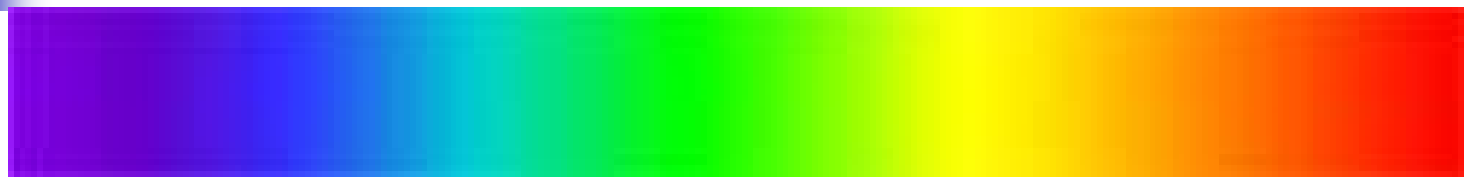


Simultaneous Contrast – in color





Color Opponency

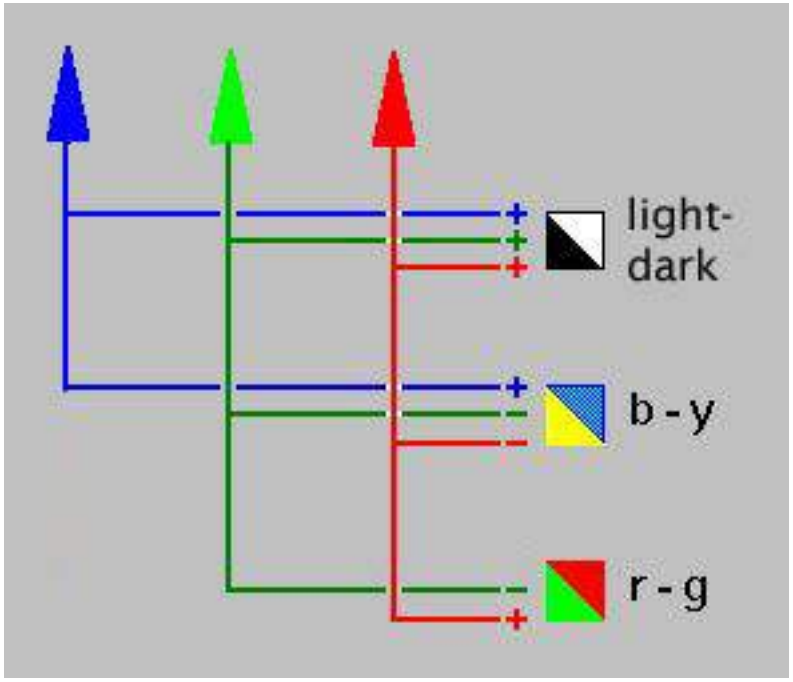


- Look carefully at the spectrum of light. Which colors seem "pure"? Although there will be some disagreement, most color phychologists claim there are ***four*** such **"psychological primaries"** - red, yellow, green, and blue.
- In addition, one never sees a reddish-green or a yellowish-blue. Red and green are ***opponents***, as are yellow and blue. It *is* possible to mix one opponent with either of the colors of the other pair: reddish-blue (the magentas and purples) and reddish-yellow (the oranges), or greenish-blue and greenish-yellow.
- By adding an opponent light to a sample it is possible to negate the original hue. For example adding blue light to yellowish-green cancels the yellowness and does not affect the greenness. By this technique of hue cancellation, one can measure how yellow a sample is.

Opponency:

Cellular connections for opponent processing

- Recent analysis suggests that the R-cone(L) came first in the evolution of life.
- Next came an G,B (*I,S)* precursor cone, wired in B-*Y* opponency with the R-cone.
- Later this precursor cone split into two slightly different varieties for the R-*G* opponency, giving animals another dimension of color.



Simultaneous contrast

Go to

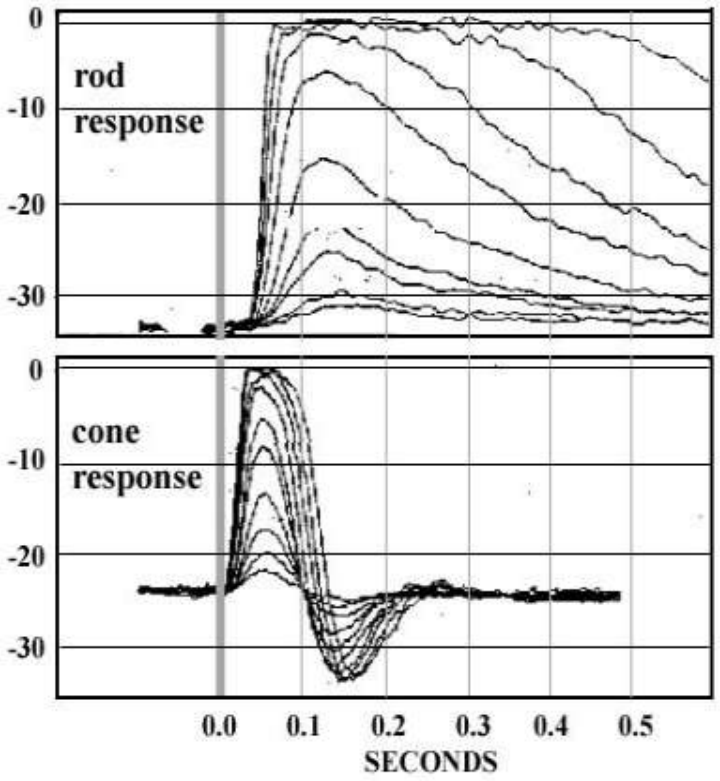
http://library.thinkquest.org/27066/theeye/nlsimcontrast.html

And look at the different examples.

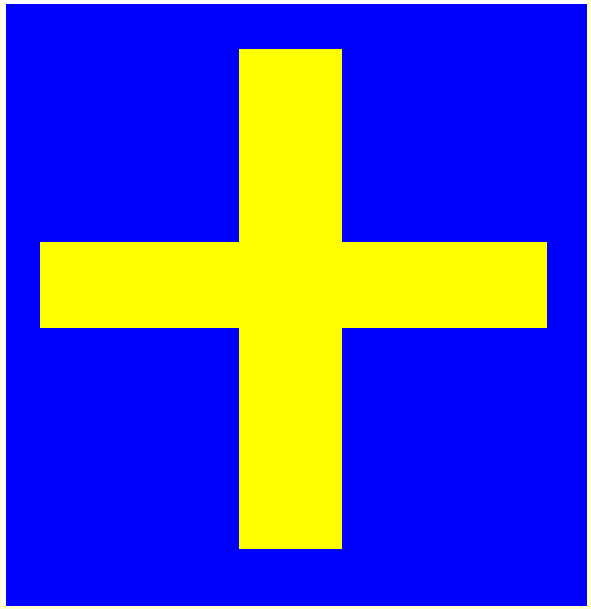
Afterimages

The photo-receptors do not respond immediately to light. The electro-chemistry takes about 0.05 seconds to respond (the *latency* period) and *persists* for some time after the stimulus (~0.15 s for cones, anywhere from 0.2 - > 1 s for rods).

These delays and the persistence in later cell communications produce a *positive afterimage* that remains after a flash of light.

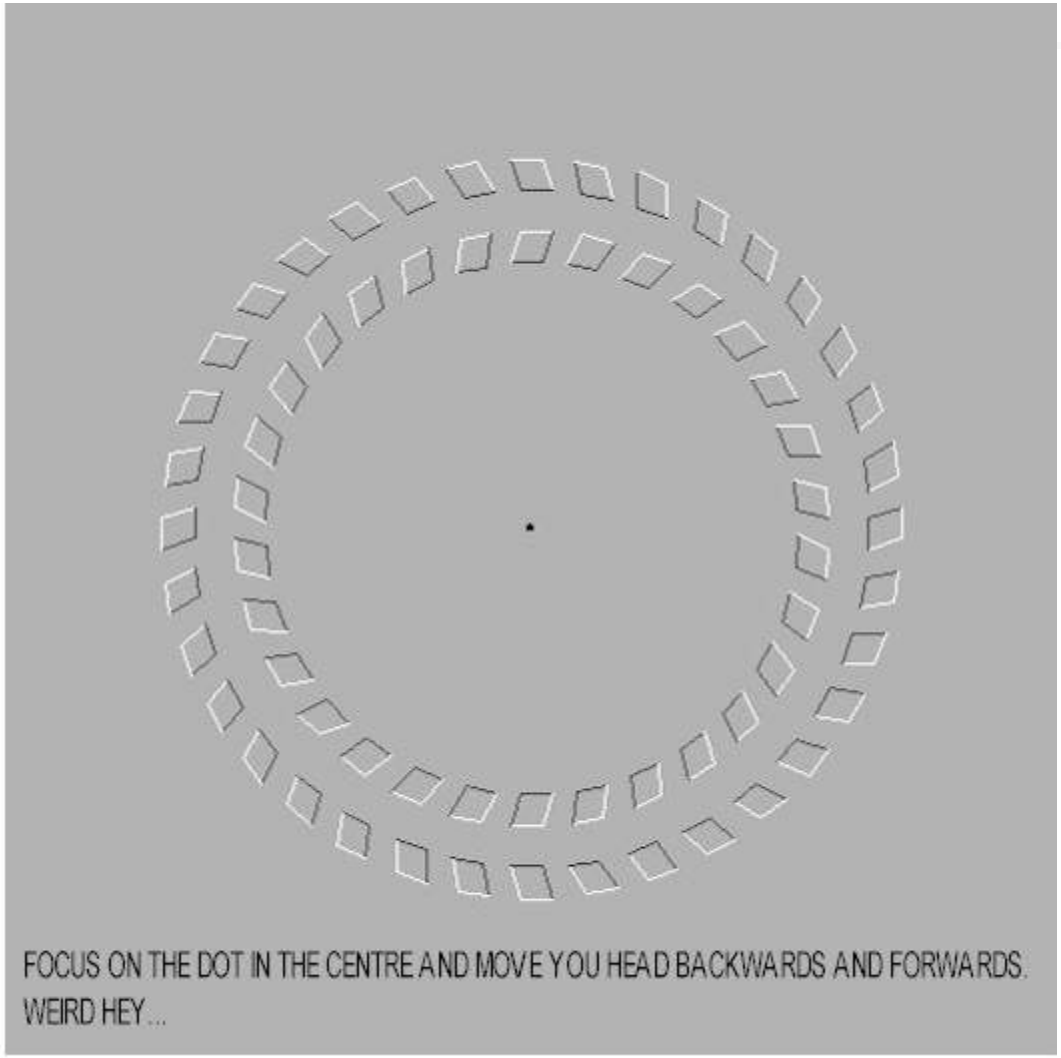


Afterimages



Also: http://faculty.washington.edu/chudler/after.html

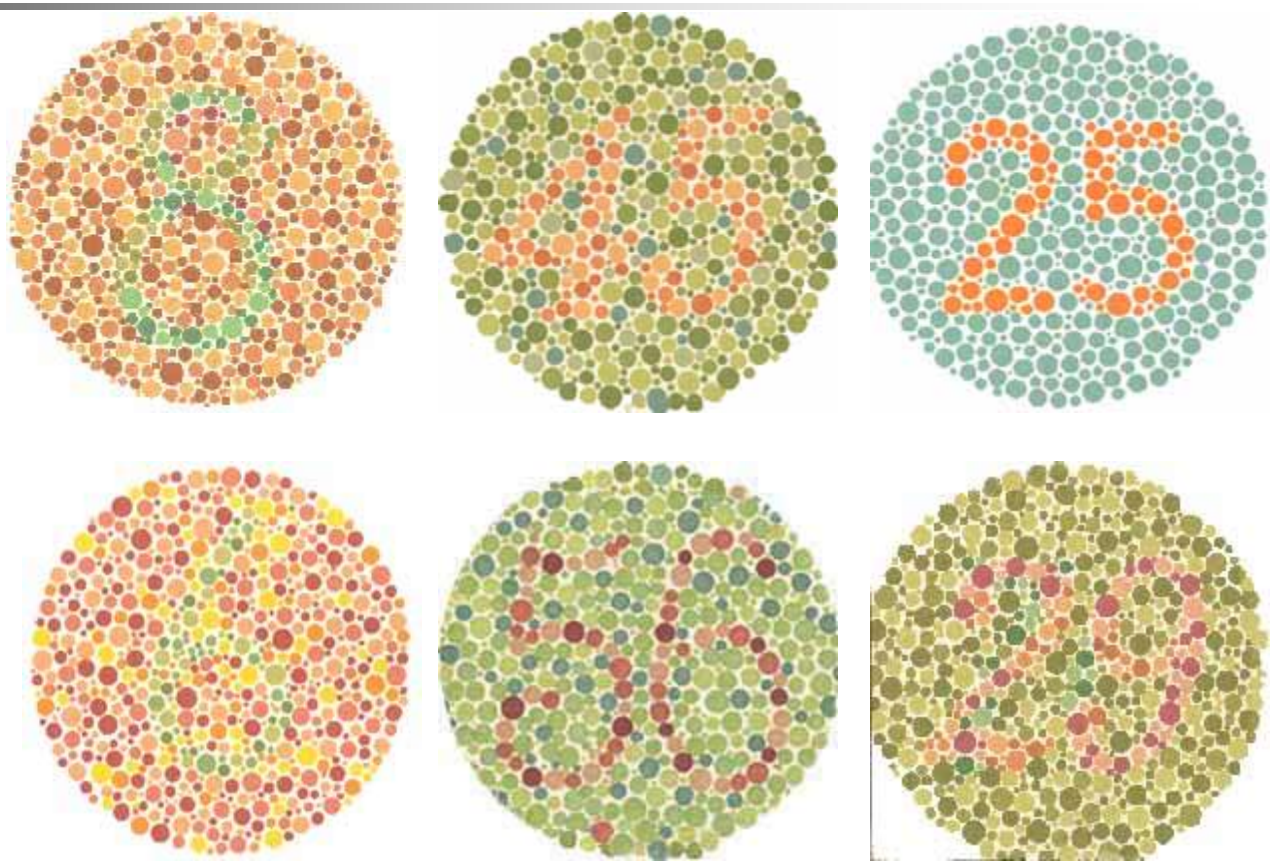
Optical Illusions



Color vision deficiency

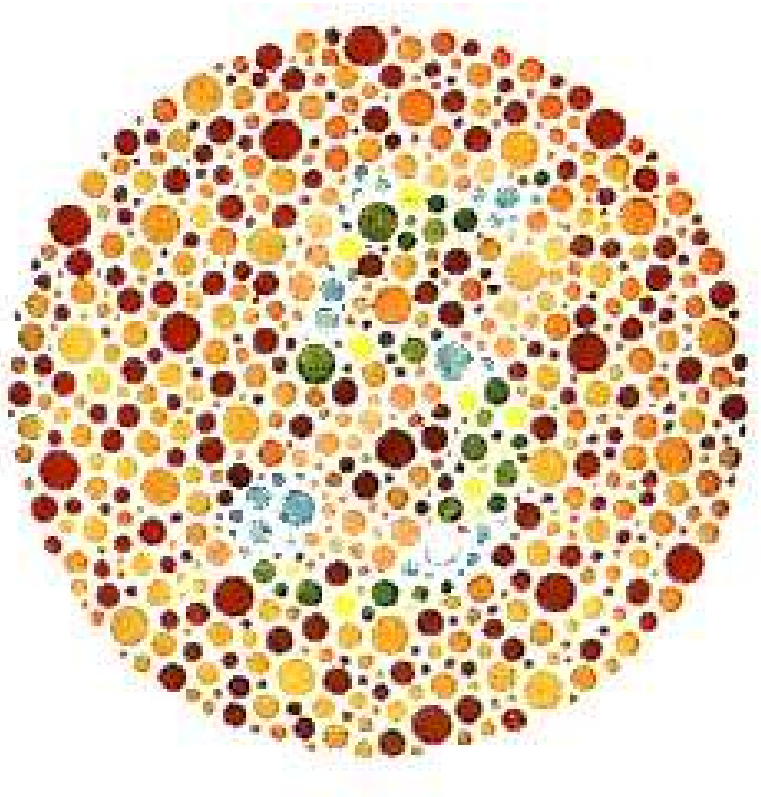
A mild color deficiency is present when one or more of the three cones functions "poorly", due to deficient or missing cone pigments.

A more severe color deficiency is present when one of the cones does not function at "all" or is missing (dichromat vision).



"Color blindness"

An individual with normal color vision will see a 5.
An individual with Red/Green (the most common) color blindness will see a 2.



Perception

The brain interprets the optical information it receives.

Most "optical illusions" are visual constructions designed to "confuse" the brain's inherent ability to recognize and interpret patterns. As such, they are invaluable tools for understanding what cues the brain uses for pattern interpretation.

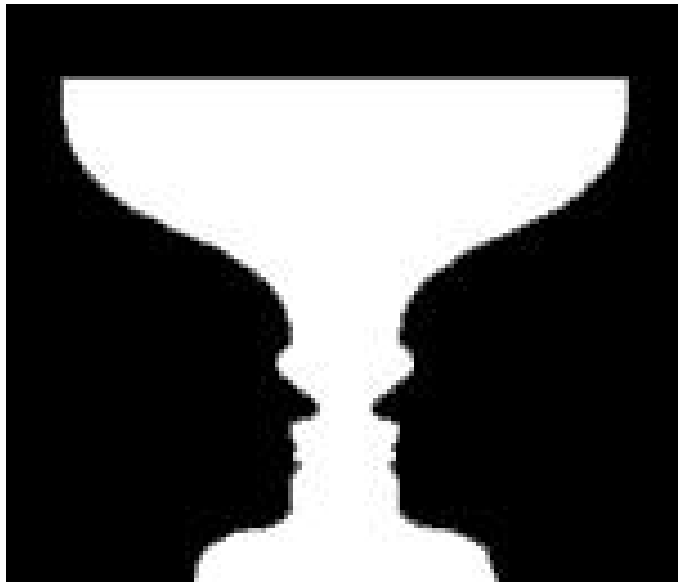
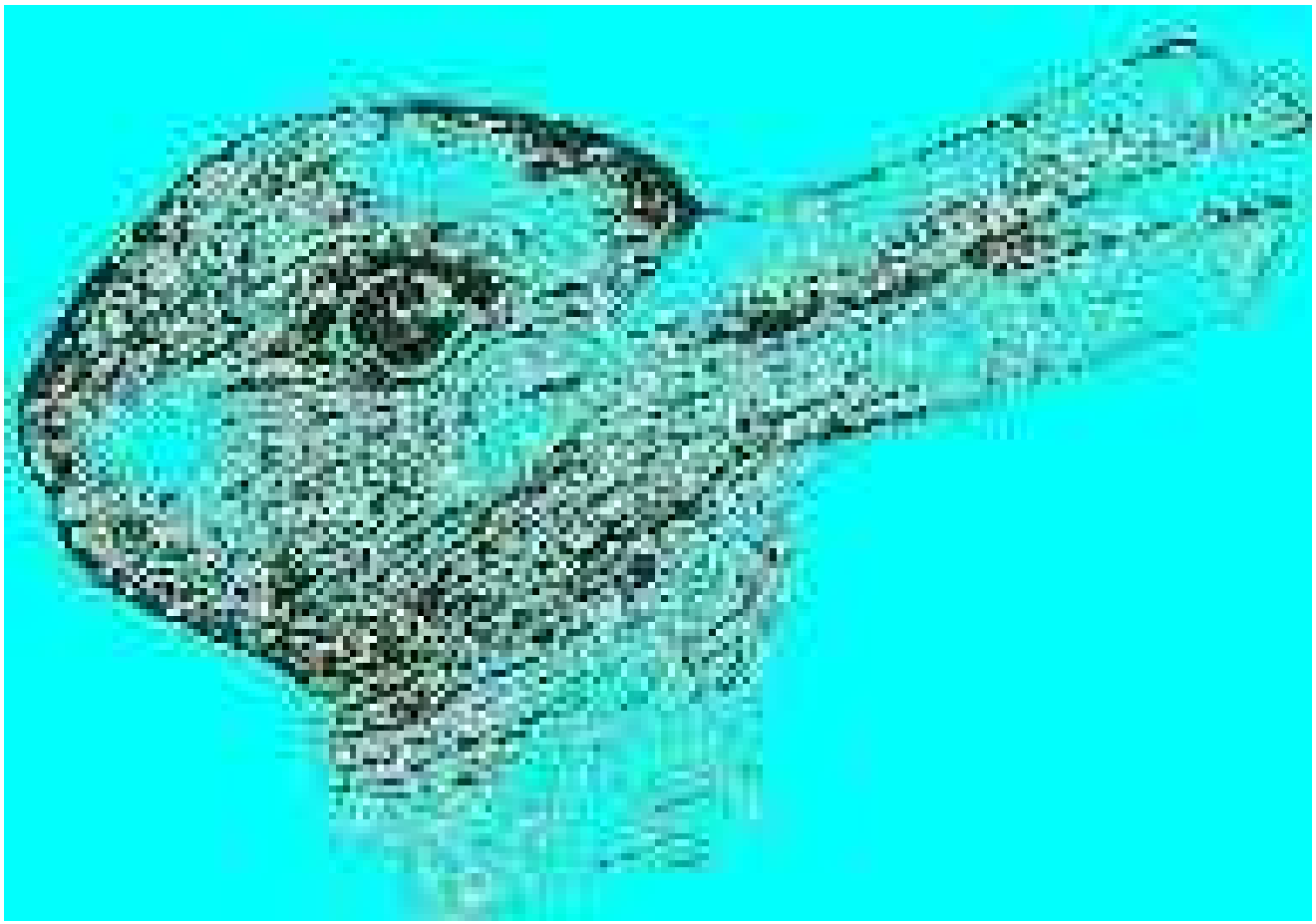


Figure-background ambiguity.

Optical Illusions

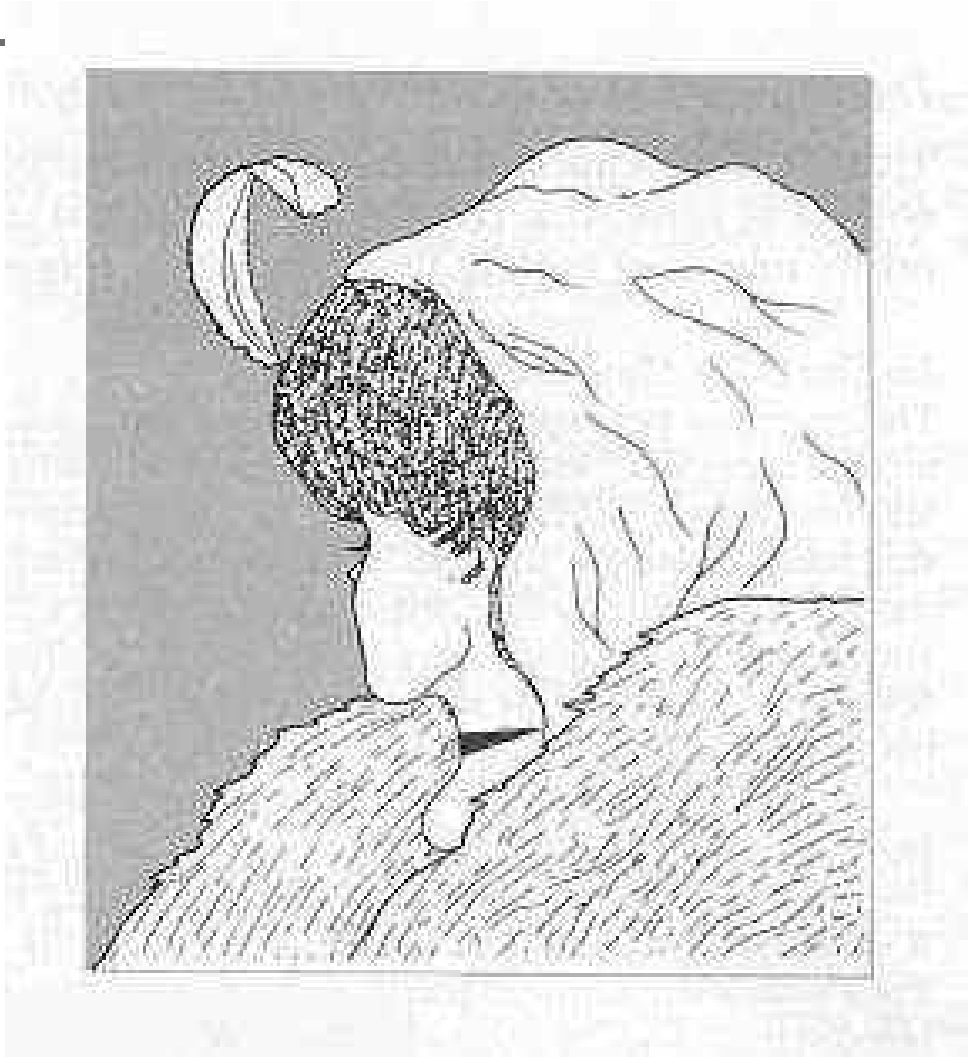
This illusion also holds even in animated form.

Optical Illusions



Optical Illusions

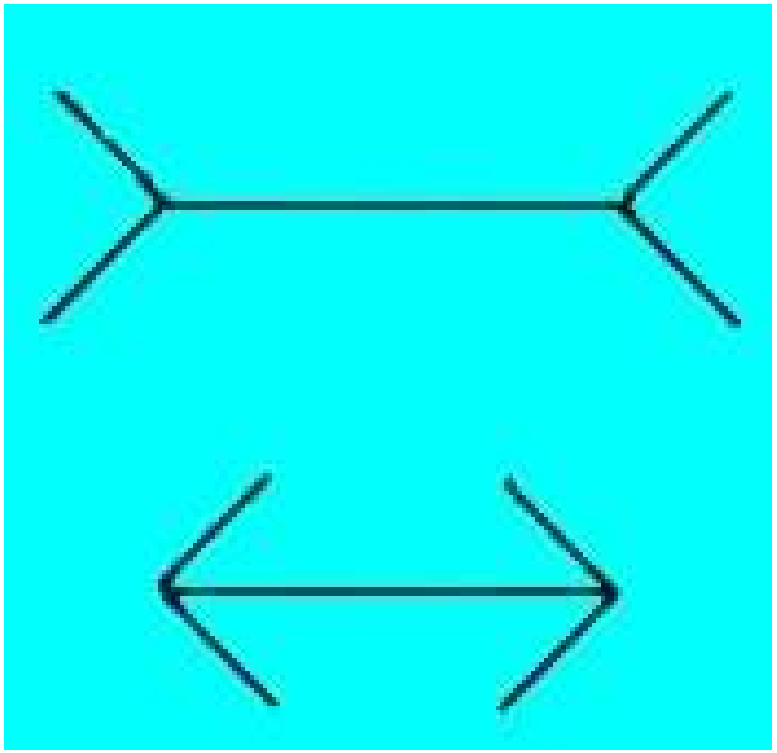
What do you see?



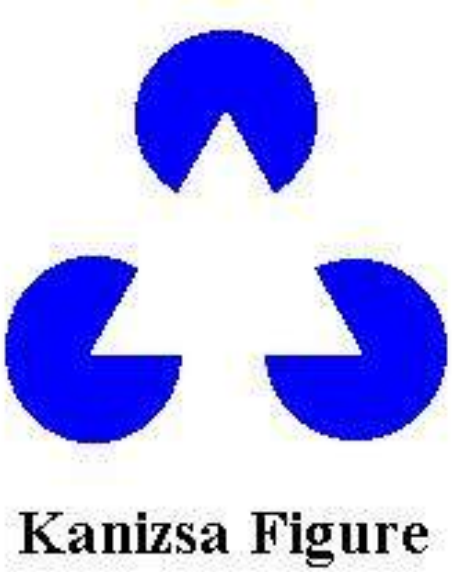
Optical Illusions

A simple example is the Muller-Lyer illusion.

Which is the longer line?

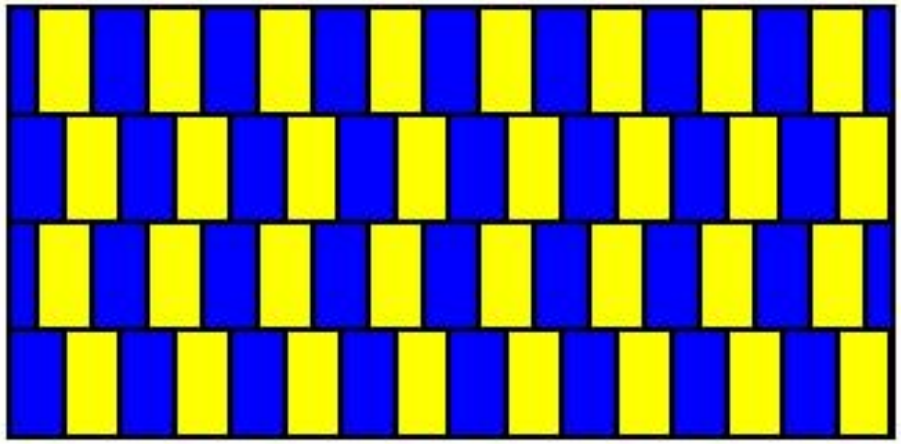


Optical Illusions



Kanizsa Figure

Figure completion.

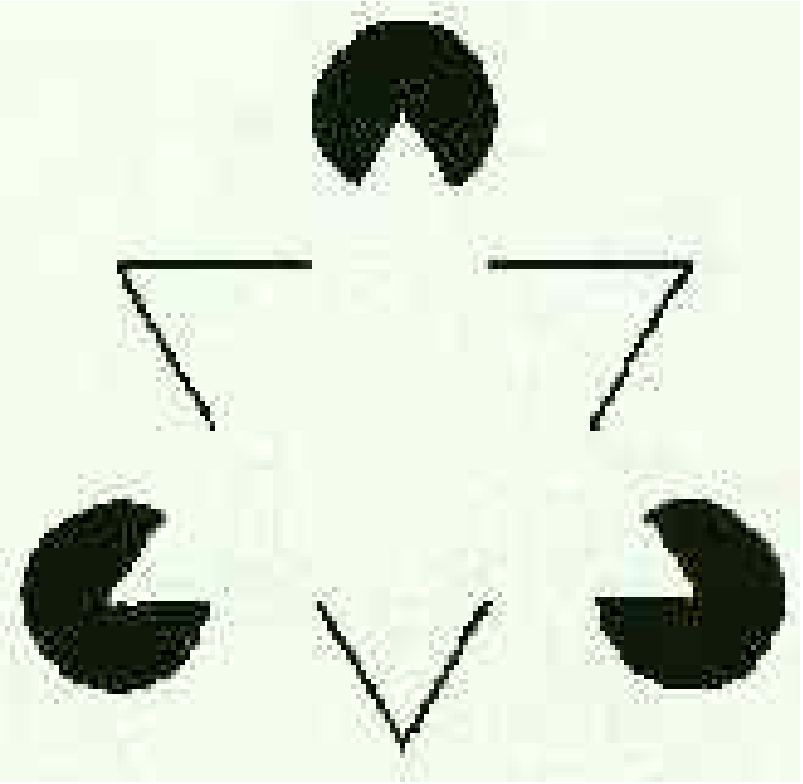


Cafe Wall

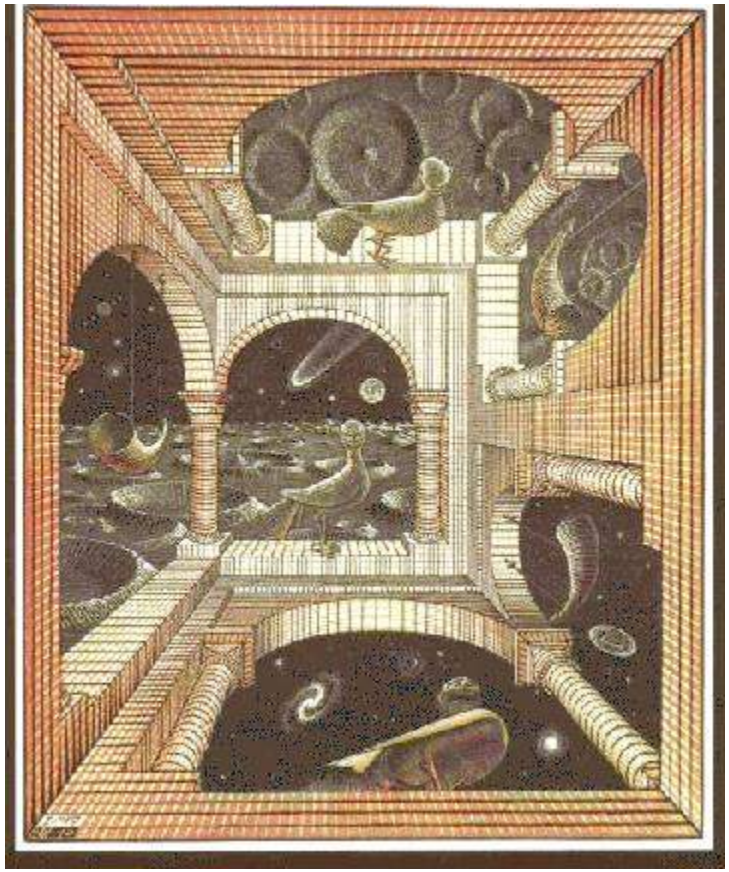
Lines and patterns.

Optical Illusions

- Try drawing this illusion yourself.
- Black figures on a white background
- produce the strongest effect.
- Producing this image on your own piece of paper reinforces the notion that it is an unconscious process that leads to perception of the bright area in the centre.
- Even though you know what you are doing and you know that the paper you are using is all the same colour you cannot prevent your perceptions changing.



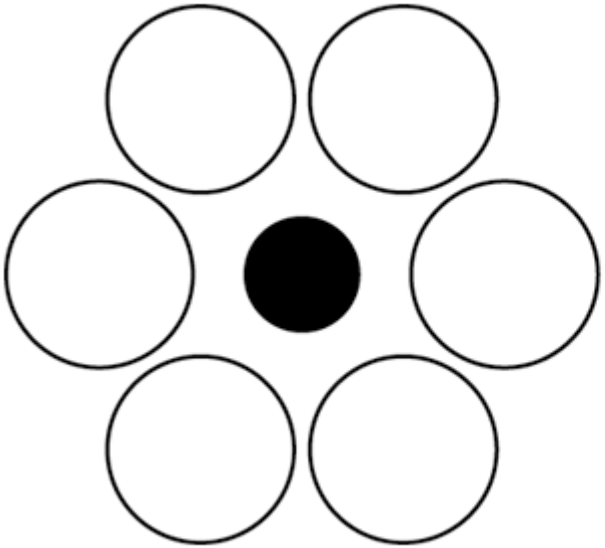
Optical Illusions

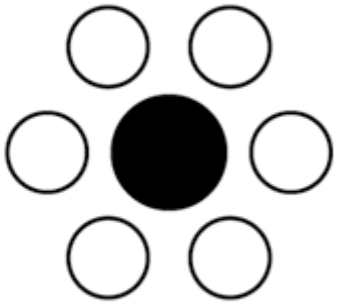


Another World, 1947. M. C. Escher.

Escher, Ascending and Descending, 1960

Context affects perception



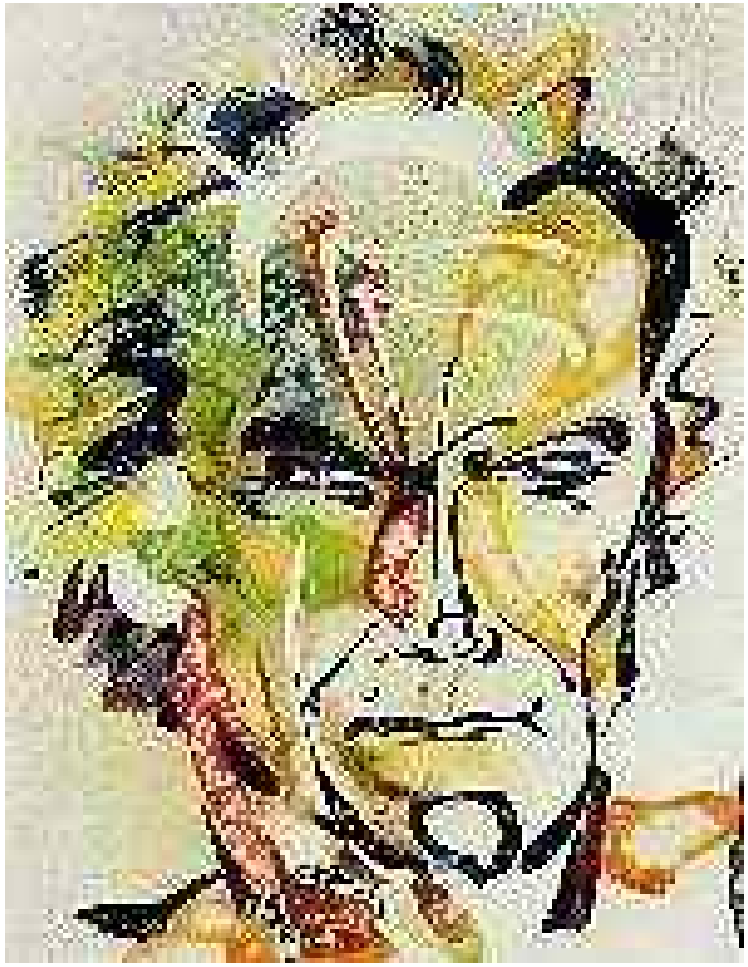


Context affects perception

Ambiguous information

Perception

The combination of lines and colours lead you to perceive a likeness of a certain movie star.



Subliminal images

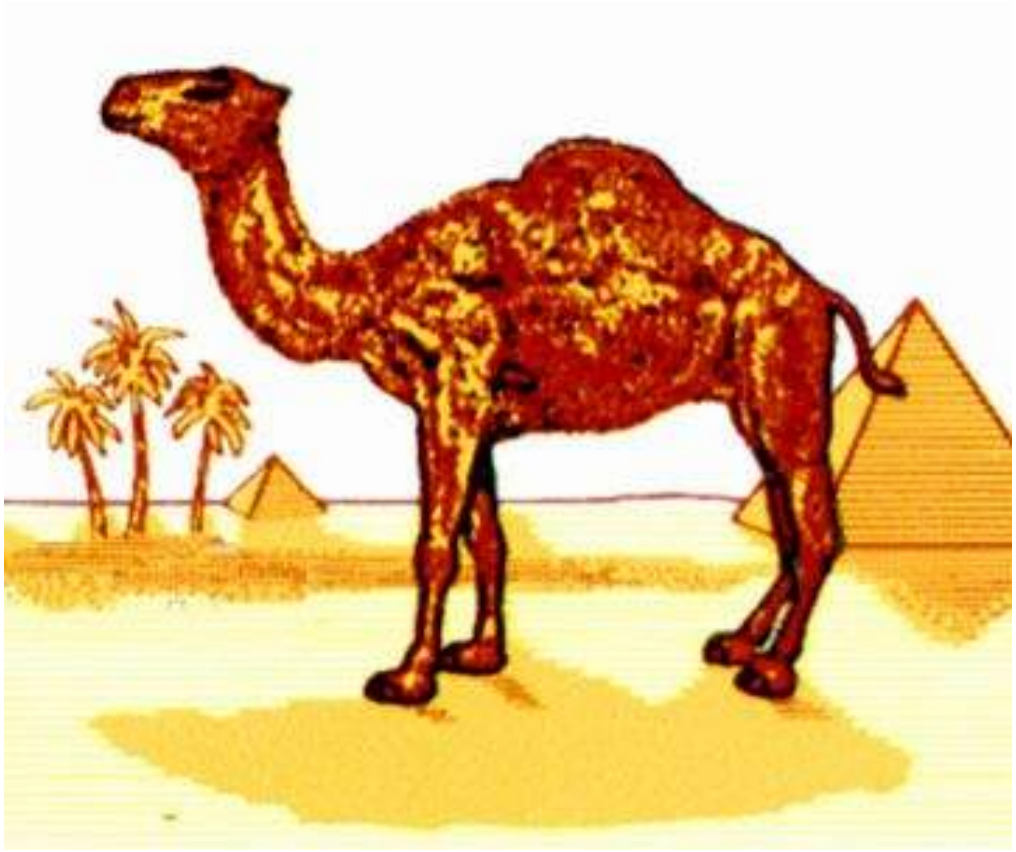
In 1990, Pepsi withdrew one of its "Cool Can" designs after someone protested that Pepsi was subliminally manipulating people by designing the cans such that when six-packs were stacked at grocery stores, the word SEX would emerge from the seemingly random design.

Subliminal images

Subliminal images

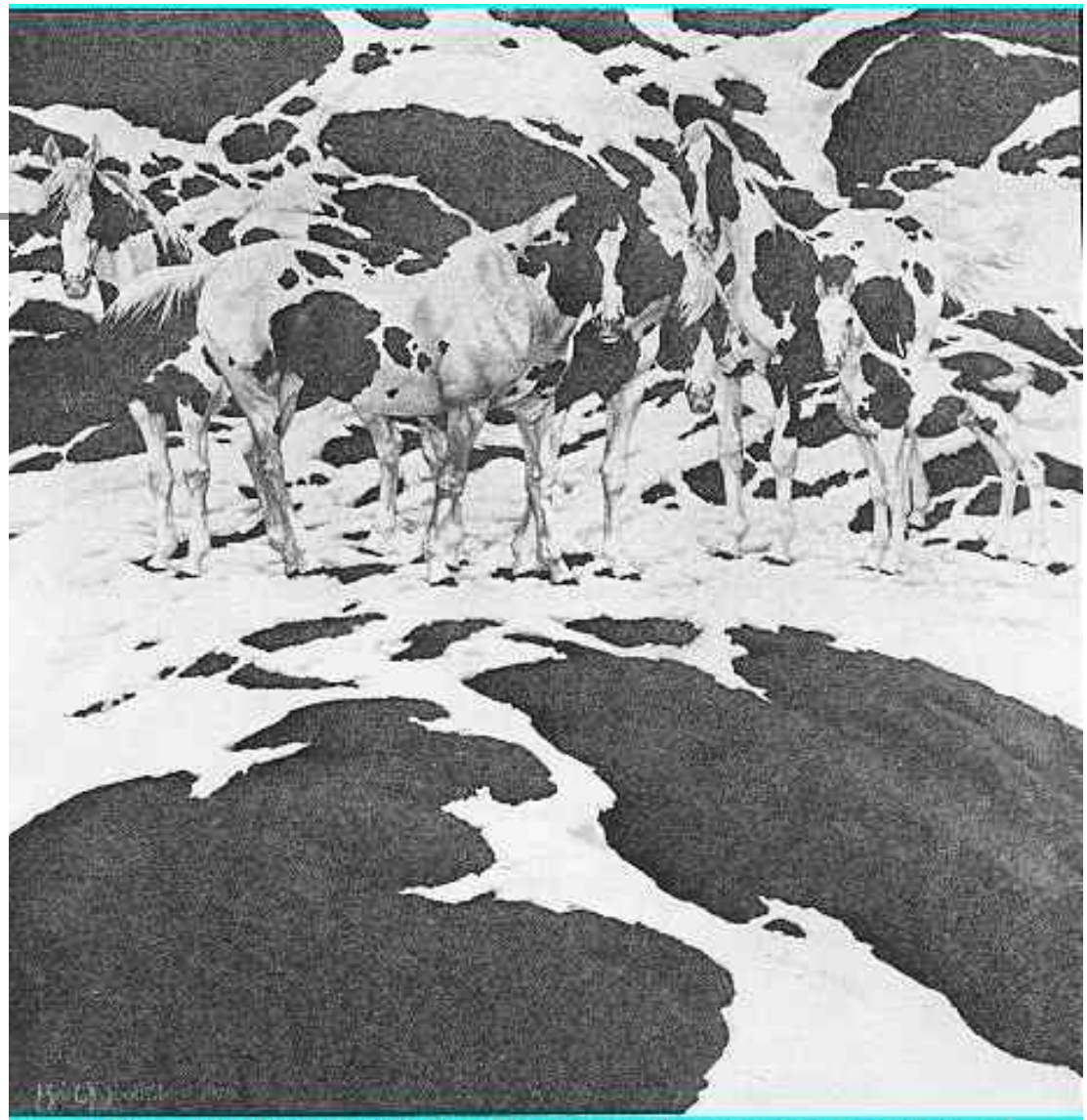
Tobacco companies have also been the target of accusations of visual embeds.

One common alleged embed of sexually suggestive imagery is on the standard pack of Camel cigarettes.



Embedded images

Artists also often embed images within their paintings for a variety of reasons.



Pintos by Bev Doolittle. How many horses can you detect? Unlike most embedded figures in Ads one is expected to look for such figures in Doolittle's paintings.

Embedded images

The forest has eyes by Bev Doolittle. There are 13 faces embedded in this painting.
Unlike most embedded faces in Ads one is expected to look for these faces in Doolittle's paintings.

Perception

- Involves interpretation
- Is context-dependent
- Is constructive
- Groups bits and pieces together

Feedback

Send 5 lines (by e-mail) explaining

(i) the most important thing you've learnt in this class,

or (ii) the subject you would like to see developed in more detail:

or (iii) send as jpeg an image illustrating one of the issues covered.