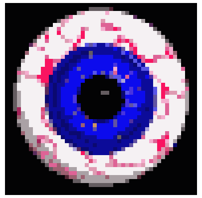
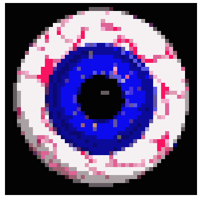
Crown 85: Visual Perception:

A Window to Brain and Behavior





Lecture 8: Processing of Color and Art & Illusion

lecture 8 outline

Visual Perception: A Window to Brain and Behavior

Lecture 8 Perception of Color and Art & Illusion

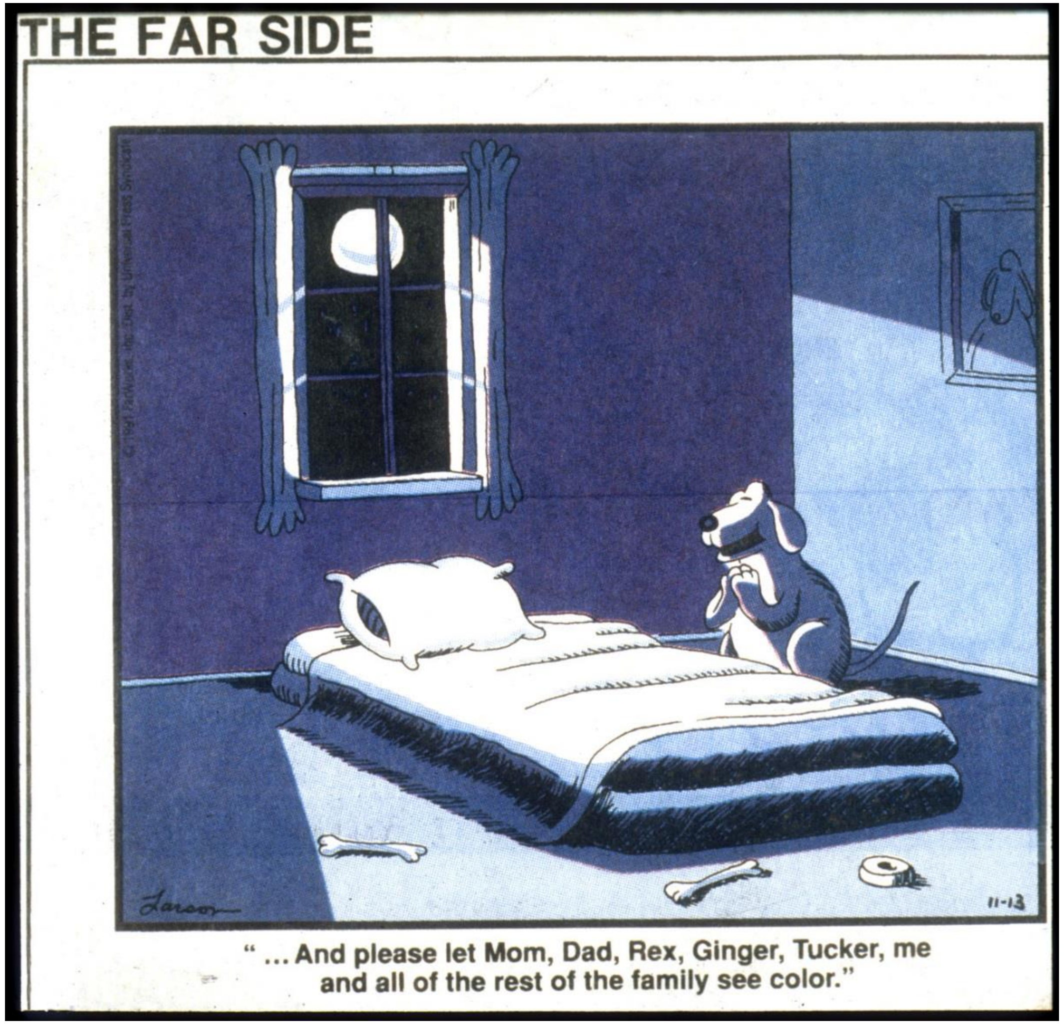
OVERVIEW: In the final two lectures we will discuss how the visual system enriches perception by adding the dimensions of depth, motion, and color to the canvas of visual information. These lecture will bring more *psycho* in our treatment. Although we will not be able to be as definitive in assigning specific neural networks, we will connect perceptions to the kinds of information processing which neurons can accomplish. Artists are perhaps the most astute “viewers” of the visual world. In the second part of lecture 8 we will look a visual illusion and how artists recognize and take account of visual information processing in their works.

READING: Joy of Vision and Joy of Vision
Eye, Brain, and Vision

LOOKING: Additive Colors (needs JAVA)
Subtractive Colors (needs JAVA)
Illusions (Illusion Art Museum, U. Mass Lowell, Illusion of the Year Galleries)
Interactive Illusions (see CROWN85 WWW Project Page)
Vision and Art (see CROWN85 WWW Project Page)

color

another bad joke

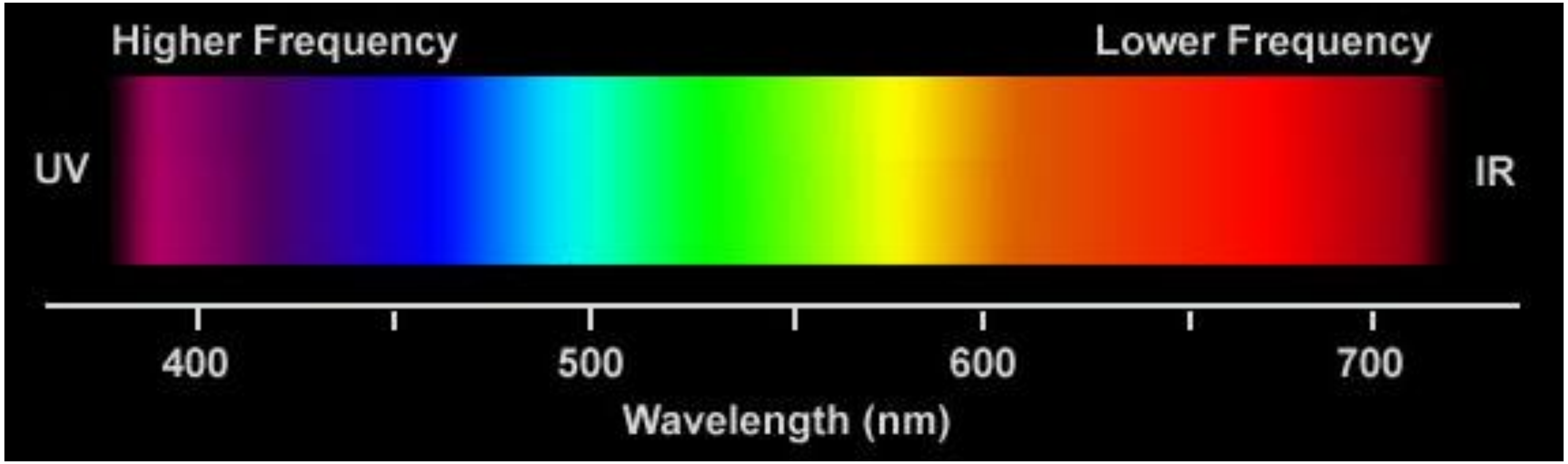


from lecture outline: COLOR

1. What property of light is responsible for color information?
   Under white light why does an opaque or translucent blue object appear blue? What would be the appearance of the blue object when illuminated with red light?

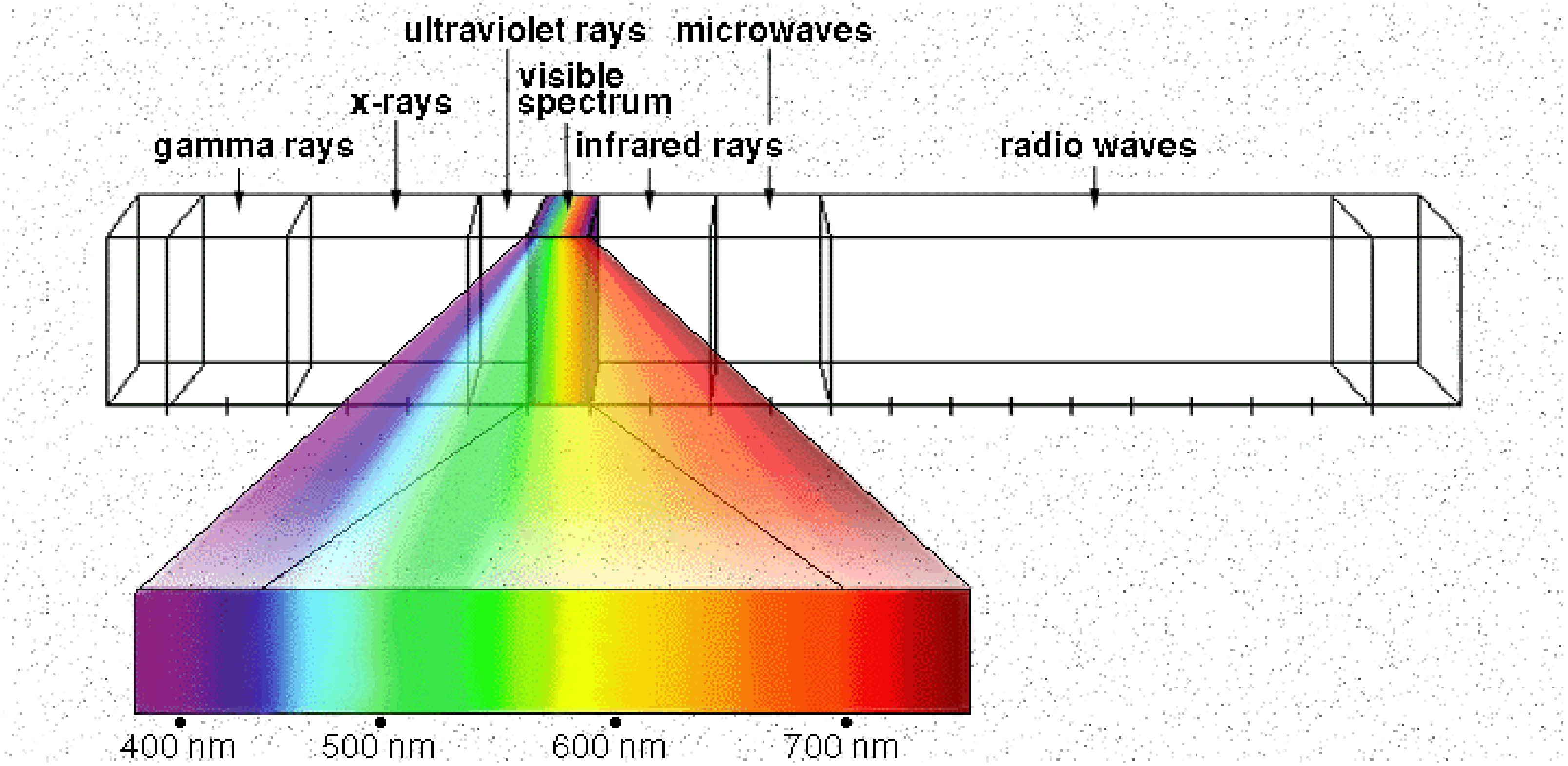
What's wrong here ??????

spectrum of visible light

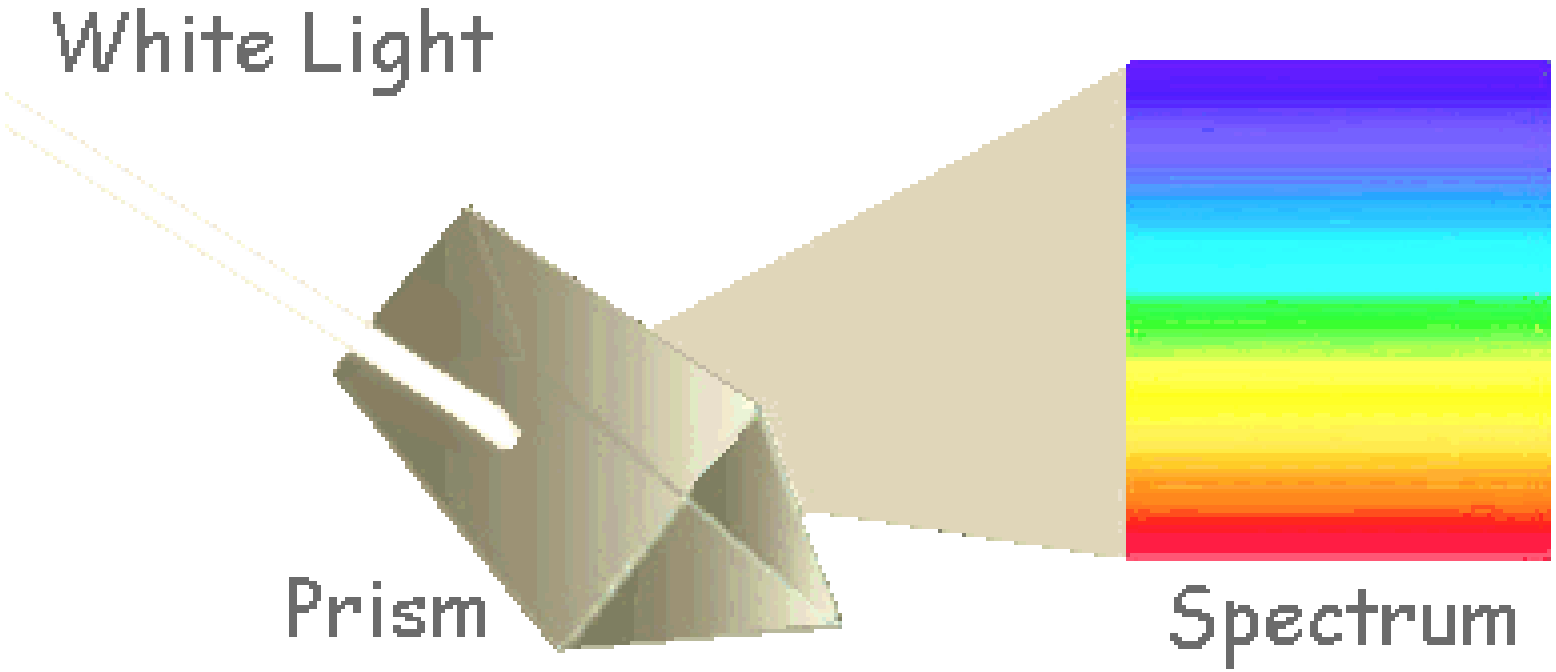


V I B G Y O R

visible light is only region of electromagnetic spectrum



white light is combination of all wavelengths

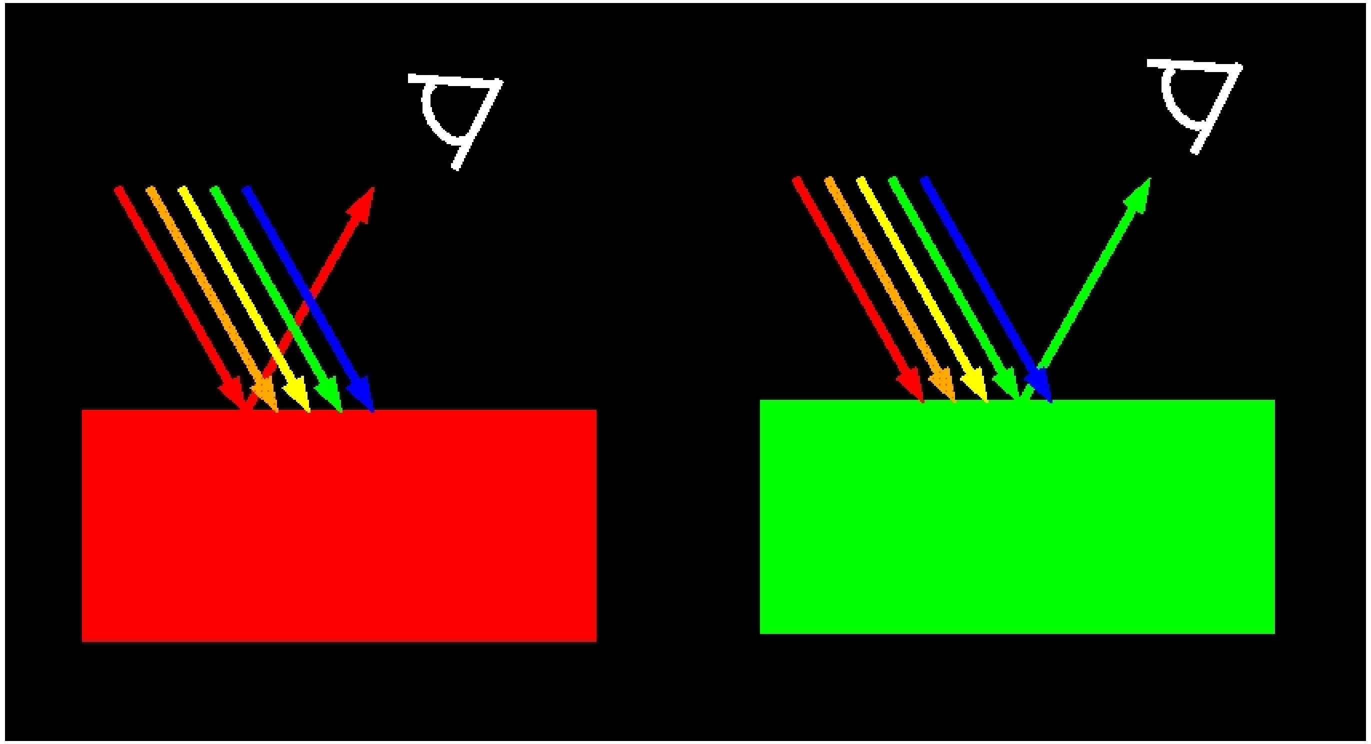


white and black

white: the presence of all wavelengths

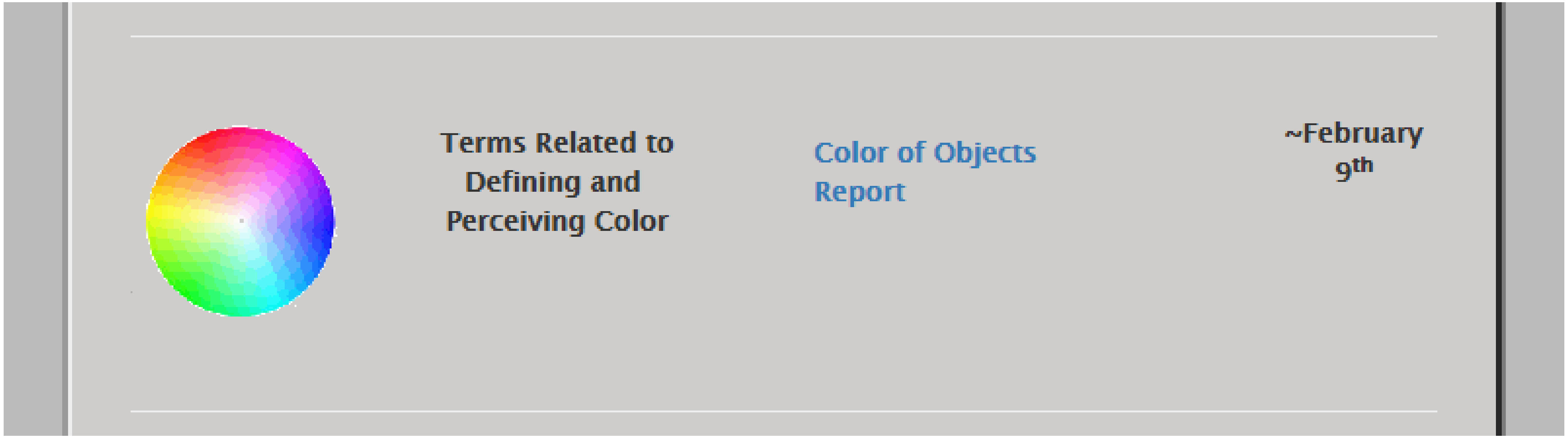
black: the absence of all wavelengths

color getting to your eye:



what wavelengths are contained in the light (illumination)?
what wavelengths are reflected (reflectance) ?

2. Know the following terms related to the color of objects:
    a. hue
    b. brightness
    c. saturation
    d. value
    e. trichomacy



Color Terminology

Malia Mendiola

hue

value (lightness)

saturation

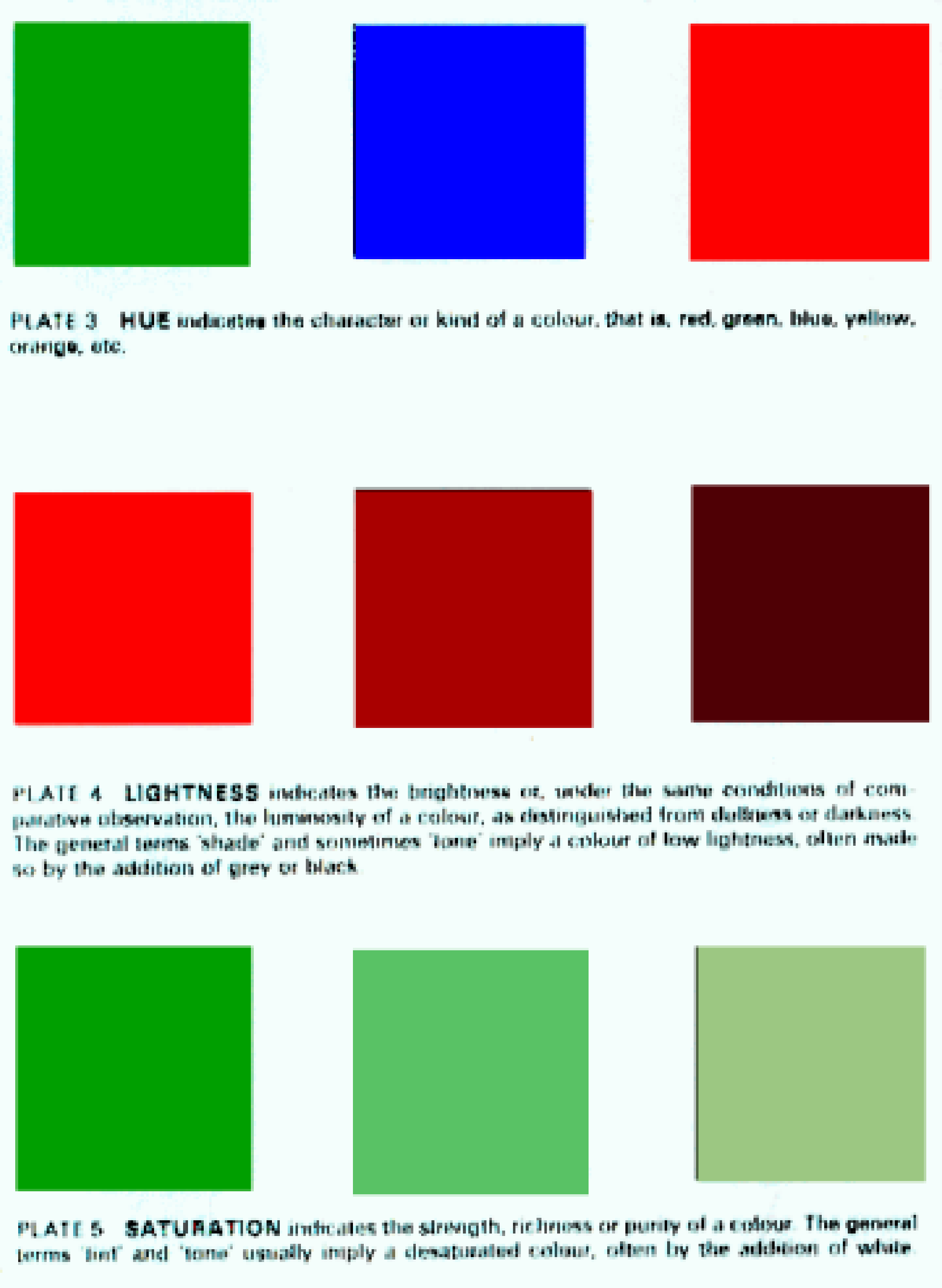


PLATE 3 **HUE** indicates the character or kind of a colour, that is, red, green, blue, yellow, orange, etc.

PLATE 4 **LIGHTNESS** indicates the brightness or, under the same conditions of comparative observation, the luminosity of a colour, as distinguished from dullness or darkness. The general terms 'shade' and sometimes 'tone' imply a colour of low lightness, often made so by the addition of grey or black.

PLATE 5 **SATURATION** indicates the strength, richness or purity of a colour. The general terms 'tint' and 'tone' usually imply a desaturated colour, often by the addition of white.

Hue

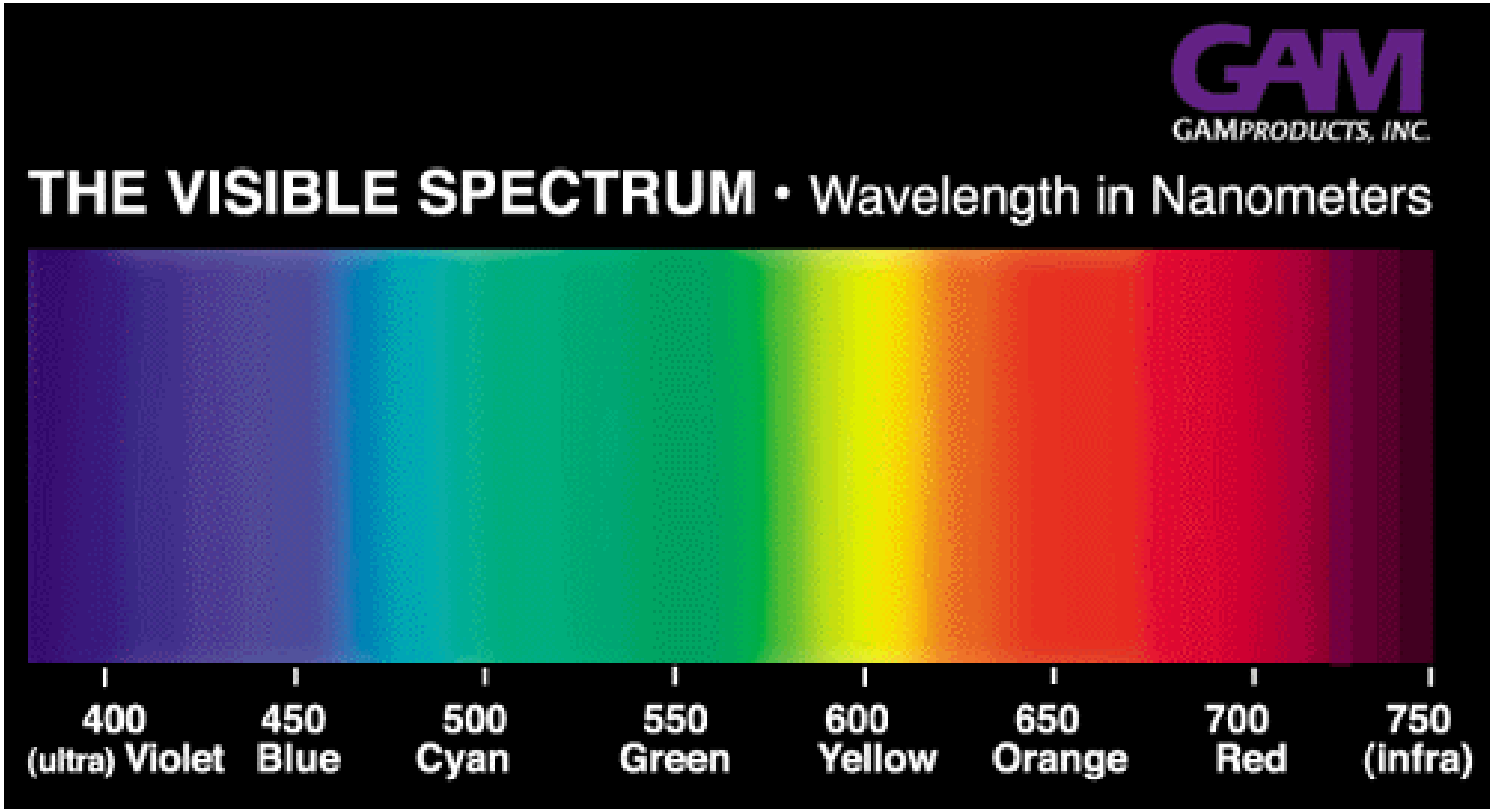
Hue (color) is determined by the dominant wavelength (the wavelength within the visible-light spectrum at which the energy output from a source is greatest)

"What is the hue?"

means

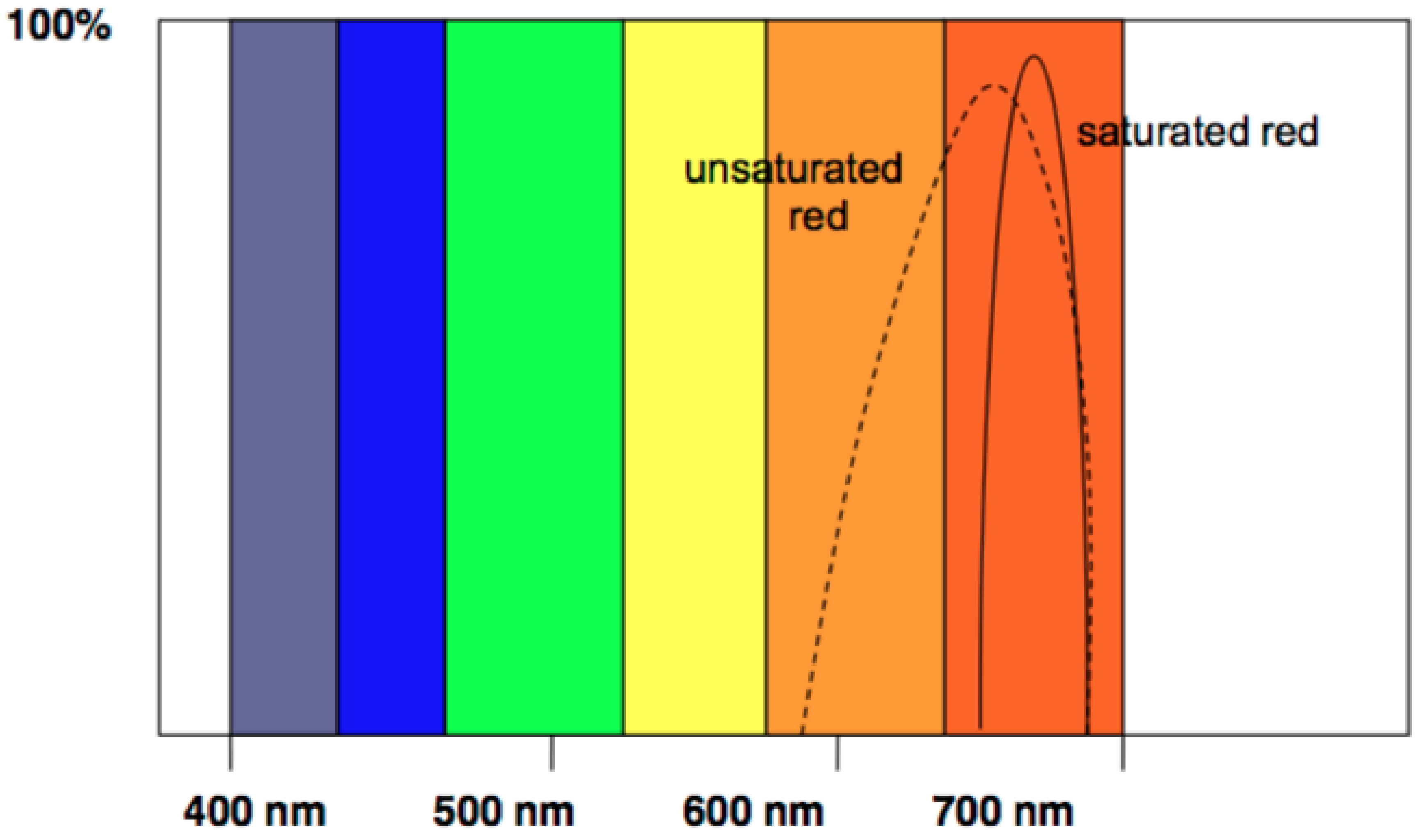
"What is the color?"

"What is the wavelength?"



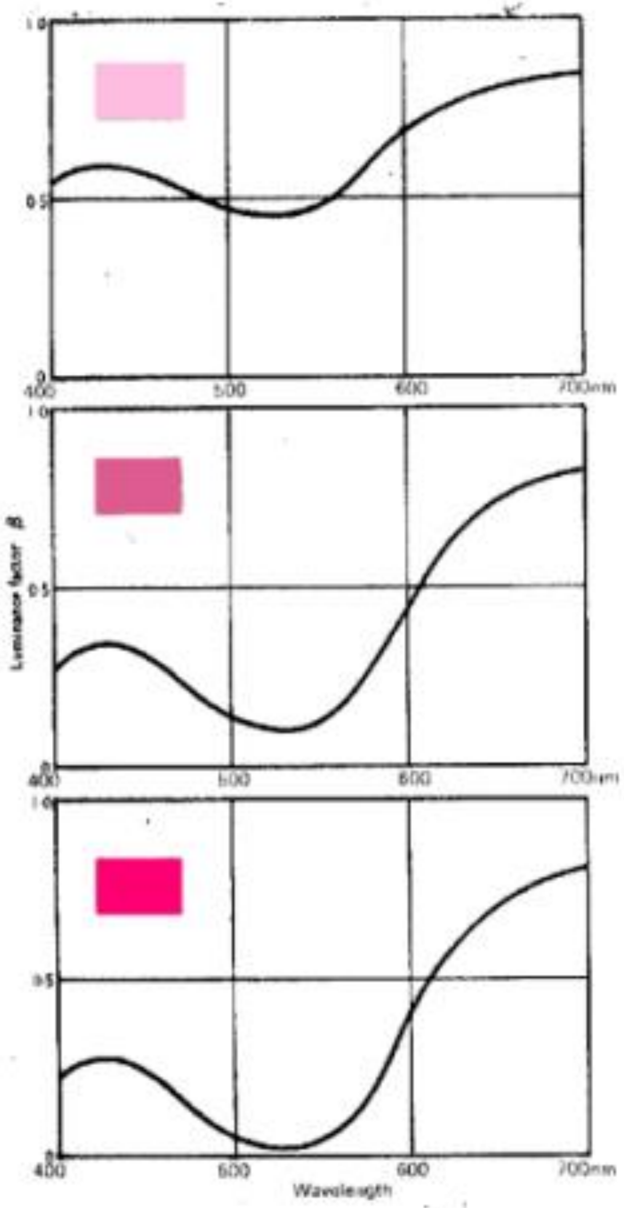
Saturation

Saturation or colorfulness depends on light complexity and **purity**, the **range of wavelengths** in light. The color of a single wavelength is pure spectral color.



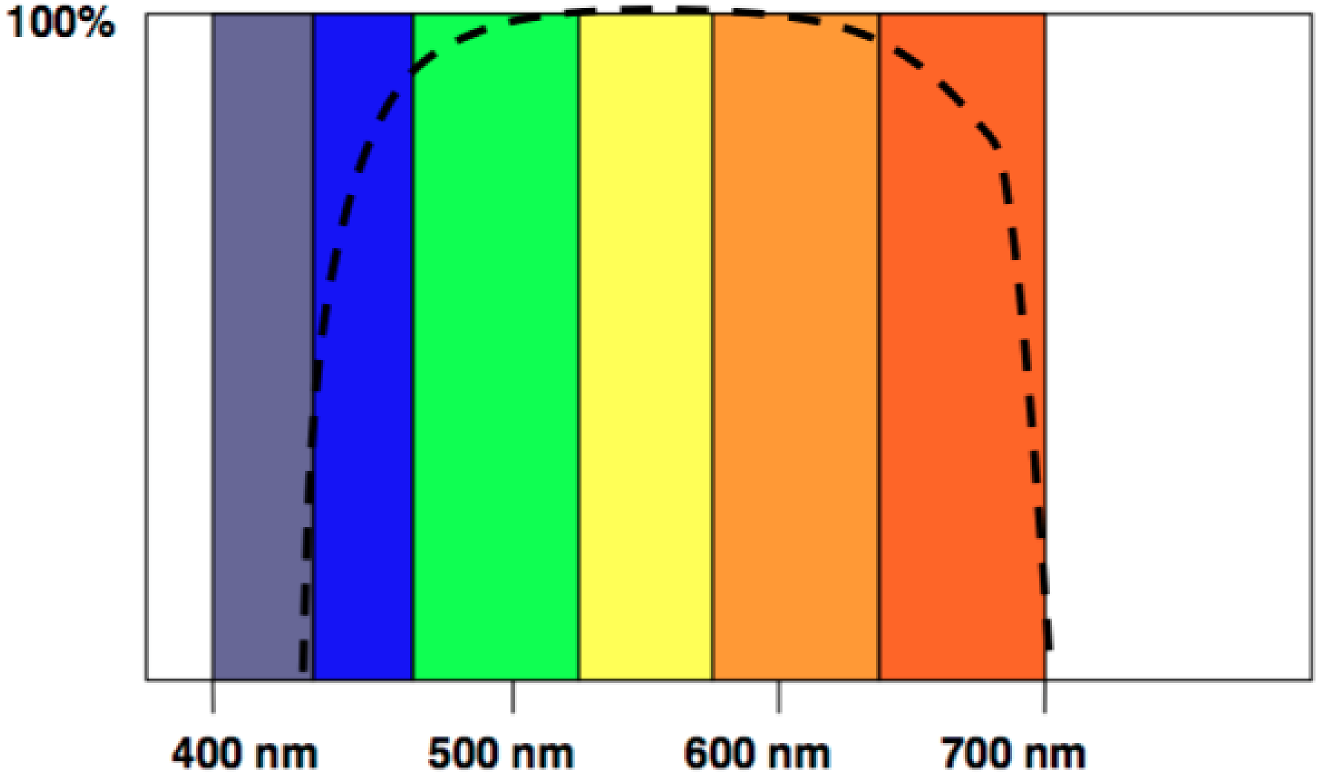
less saturated

more saturated



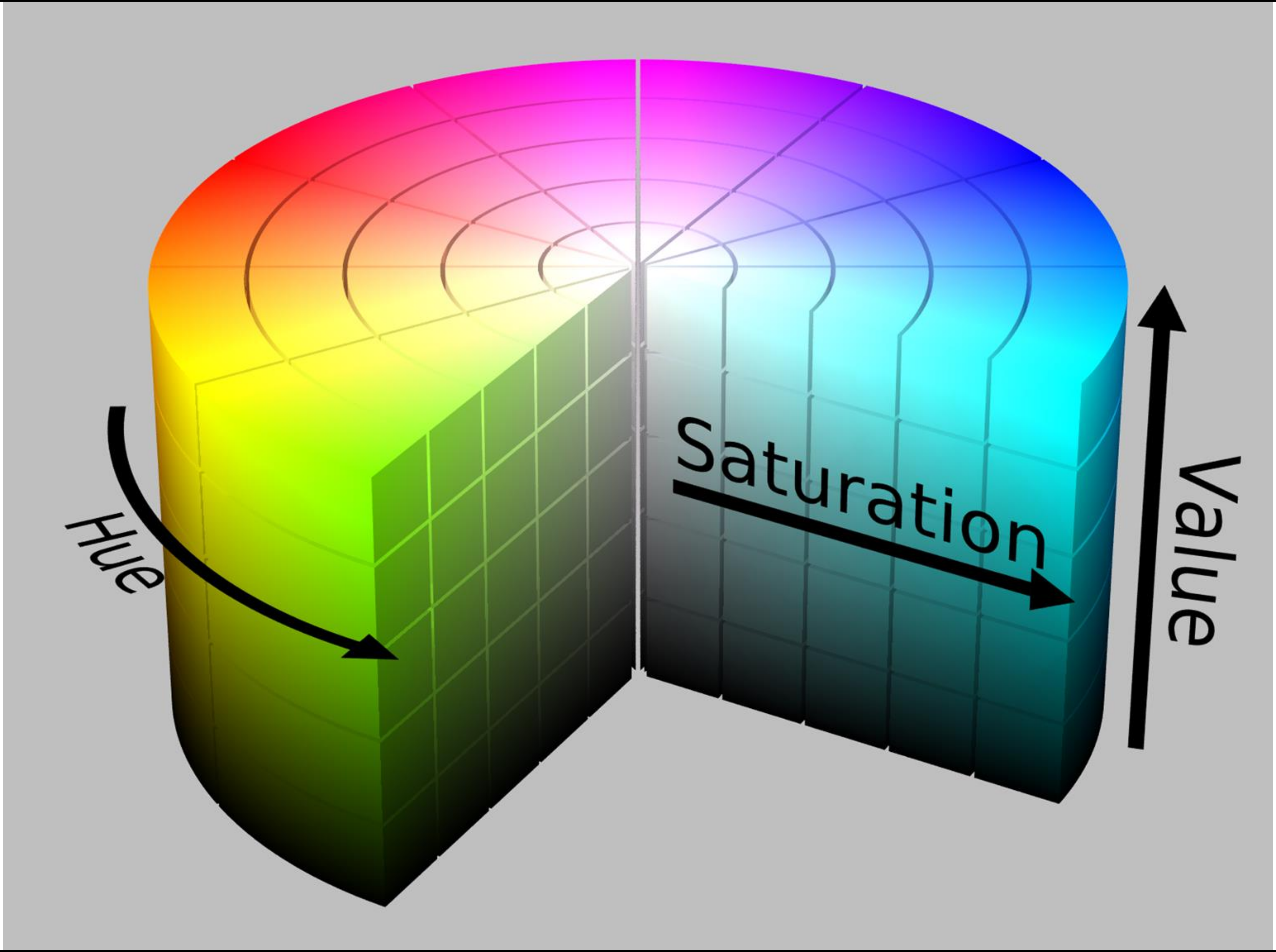
What color does this spectral curve look like?

Answer: White



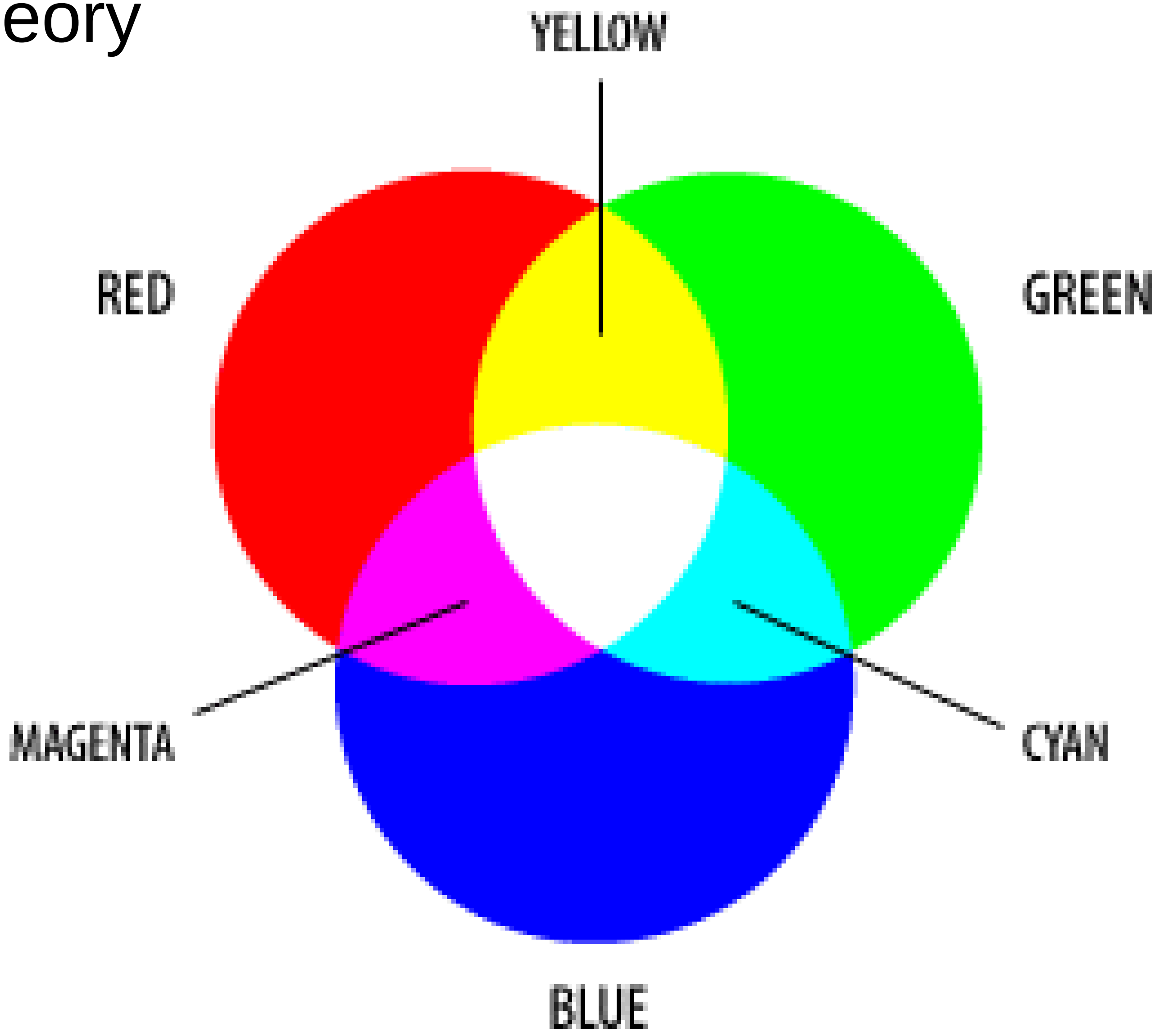
Value - “Brightness” of a color

The brightness of light is related to intensity or the amount of light an object emits or reflects. Brightness depends on light **wave amplitude**, the height of light waves. Brightness is also somewhat influenced by wavelength. Yellow light tends to look brighter than reds or blues. Change in value can be achieved with the addition of blacks or greys.


Hue
Saturation
Value

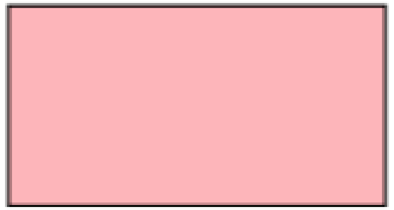
Trichromacy Color Theory

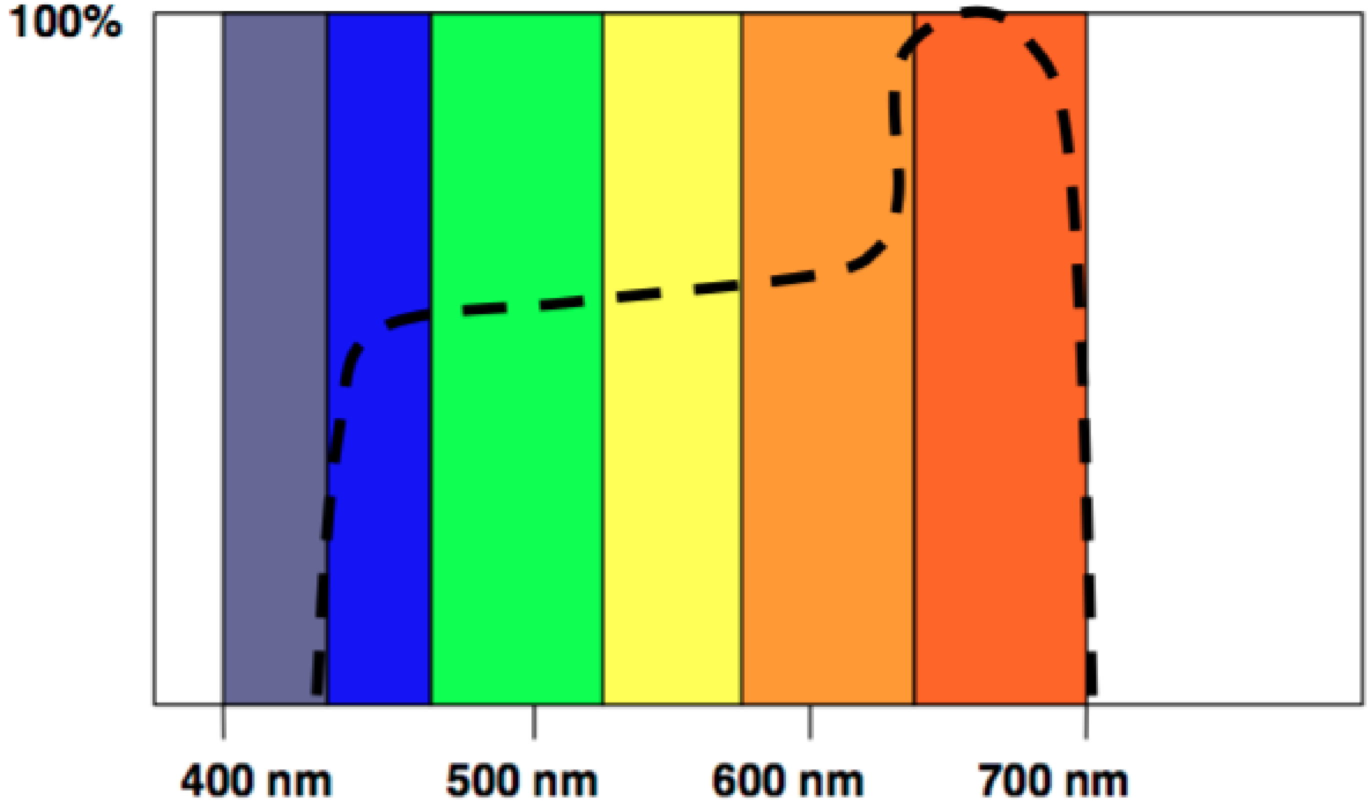
All colors can produced from three different light waves: Red,
, and Blue



What color does this spectral curve look like?

gray + red = pink





2. Know the following terms related to the color of objects:

- ✓ a. hue
- ✓ b. brightness
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- ✓ d. value
- ✓ e. trichomacy

from outline

3. Describe the differences between additive and subtractive color mixing. Which types of color mixing applies to (1) paint pigments, (2) stage lighting (multi spotlight), and (3) Pointillist art?

Additive and Subtractive Color Mixing

By Claire Campbell

Crown 85

Additive Colors Intro

- Colored lights are mixed using additive color properties
- With additive colors, combining two or more colors together creates a color that is closer to white (a ‘lighter’ color)
- Examples of additive color sources include TVs and computer screens

Additive Color Mixing

- The additive primary colors are **red, green, and blue**
- Combining one of these additive primary colors w/ equal amounts of another one results in the additive secondary colors of **cyan, magenta, and yellow**
- Combining all three primary colors (in equal parts) will result in in the color **white**
- Absence of all light= black
- Adding all colors= white

Additive Colors

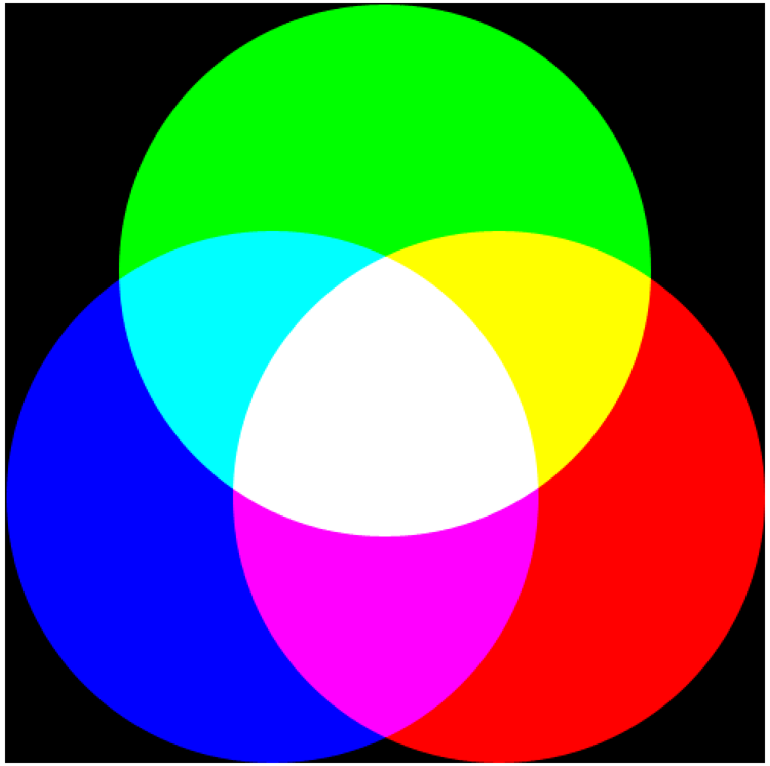
Combined in Equal Parts

Blue + Green=Cyan

Red + Blue=Magenta

Green + Red=Yellow

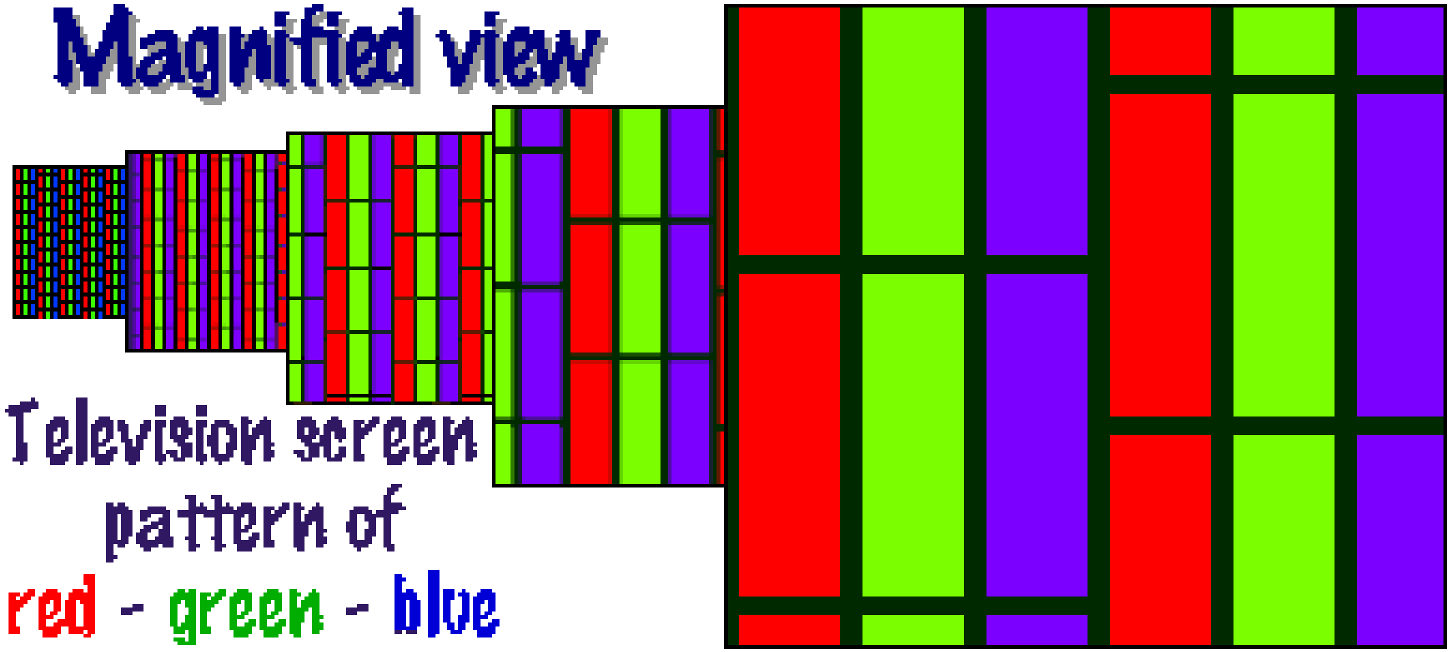
Red + Green + Blue=White

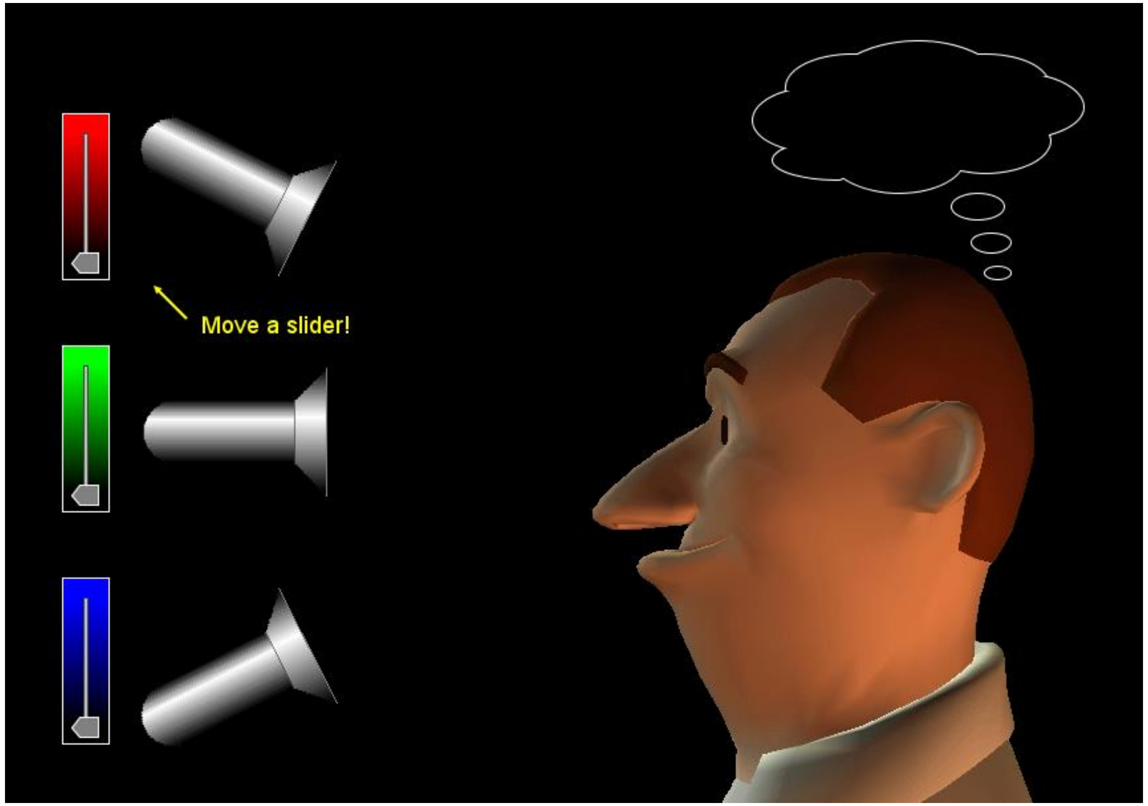


Additive Color Mixing Contin.

Computers and Televisions

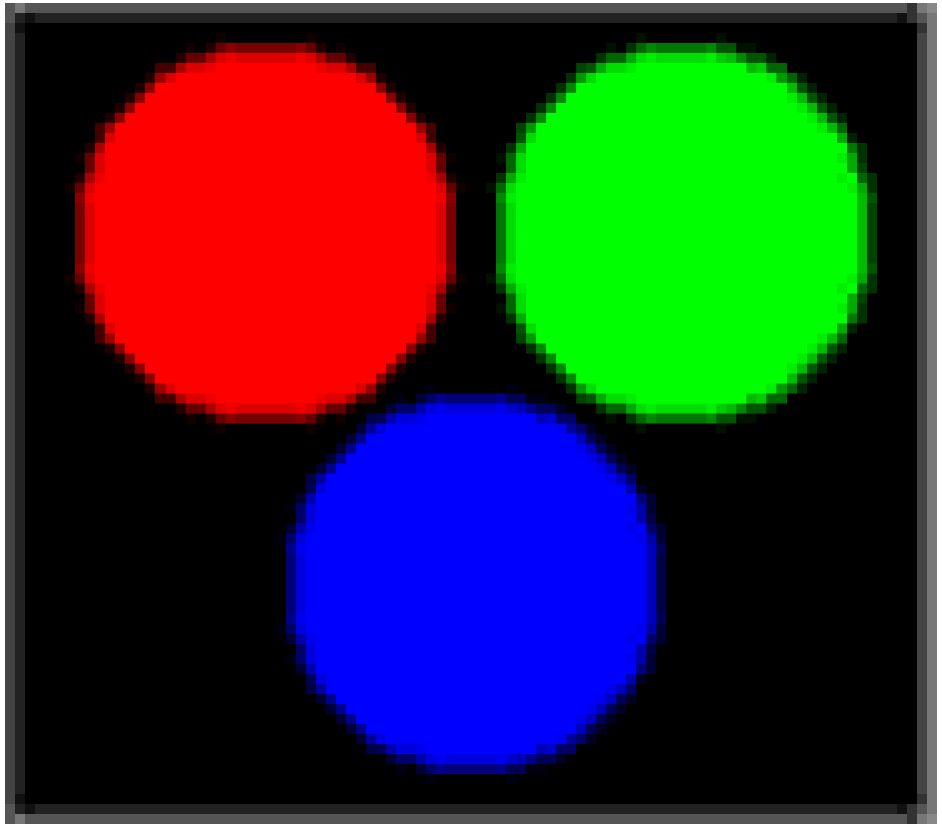
- Use additive color
- Lighted screens use a mosaic of red, green, and blue dots –glowing phosphorus
- Our eyes do not distinguish the individual dots, instead the dots stimulate the rods in our retina by adding/blending the light together to create a composite color





http://phet.colorado.edu/sims/color-vision/color-vision_en.jnlp

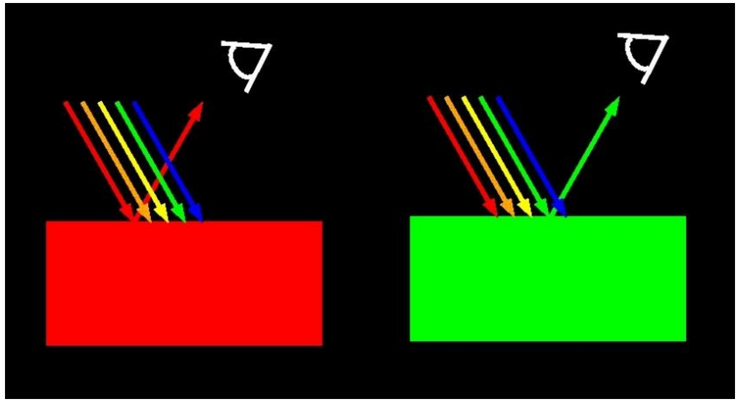
additive color mixing (red, green, blue)



demo: https://micro.magnet.fsu.edu/primer/java/scienceopticsu/light/additive.html

Subtractive Color Intro

- Subtractive or pigment colors are used when the image is derived from reflected natural/white light, like an image from a book, photo, etc.
- This is opposed to additive color, where the image is emitted from a light source (TVs, phone screens, computers)
- Subtractive/pigment colors are seen by the reflection of light
- The colors that are not reflected are absorbed (subtracted)
- Subtractive color mixing is used in printer ink cartridges and paint, for example
- If the object is viewed in white light (as is usual) the color seen is the **complement of the wavelengths absorbed**



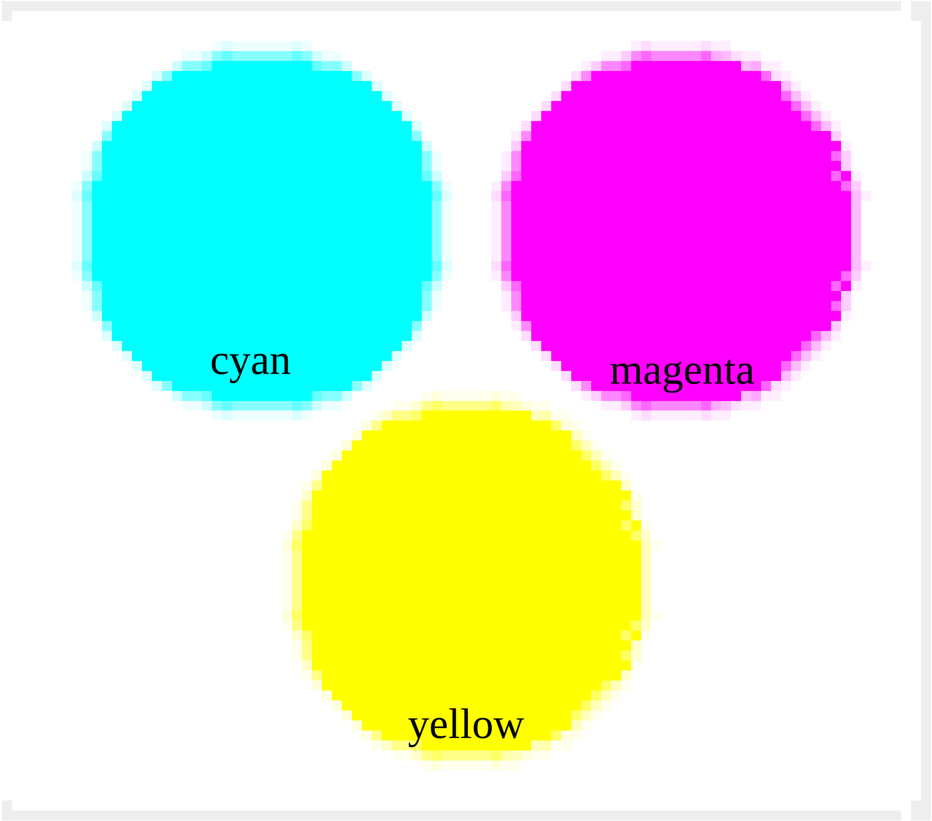
Subtractive Color Mixing

- Pigments or dyes yield different results when combining colors than additive color
- The subtractive primary colors are **cyan, magenta, and yellow**

Subtractive Colors Mixing

Combine	**Absorbs**	**Leaves**
Cyan + Magenta	Red + Green	Blue
Cyan + Yellow	Red + Blue	Green
Magenta + Yellow	Green + Blue	Red
Cyan + Magenta + Yellow	Red + Green + Blue	Black

subtractive color mixing (magenta ('red'), yellow, cyan ('blue')



demo: https://micro.magnet.fsu.edu/primer/java/scienceopticsu/light/subtractive.html

Examples of Additive & Subtractive Color Mixing

Filters

- The same process of subtractive color mixing applies to mixing color filters, as various colors are absorbed into the filter

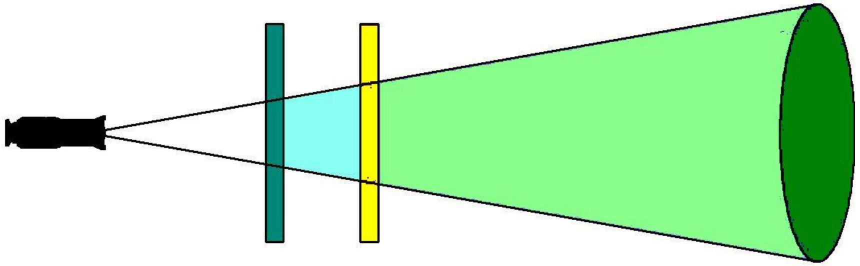
Stage Lighting

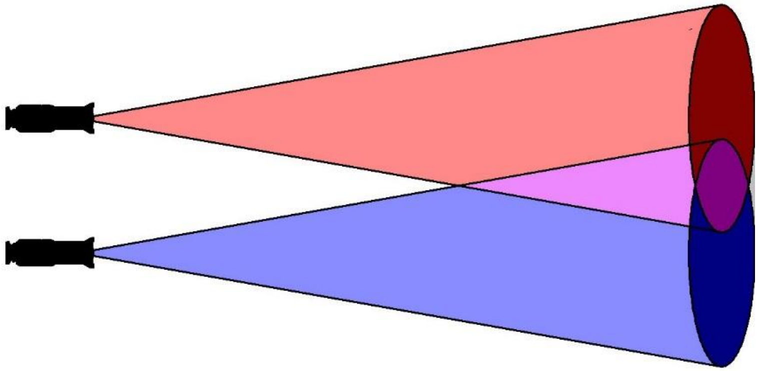
- In stage lighting, there are two ways to mix colors:
- Additive: when 2 or more differently colored lights are aimed at the same surface
- Subtractive: when a single light source shines through different colored filters, and each filter allows certain colors to pass while blocking and absorbing the other colors

Pointillism

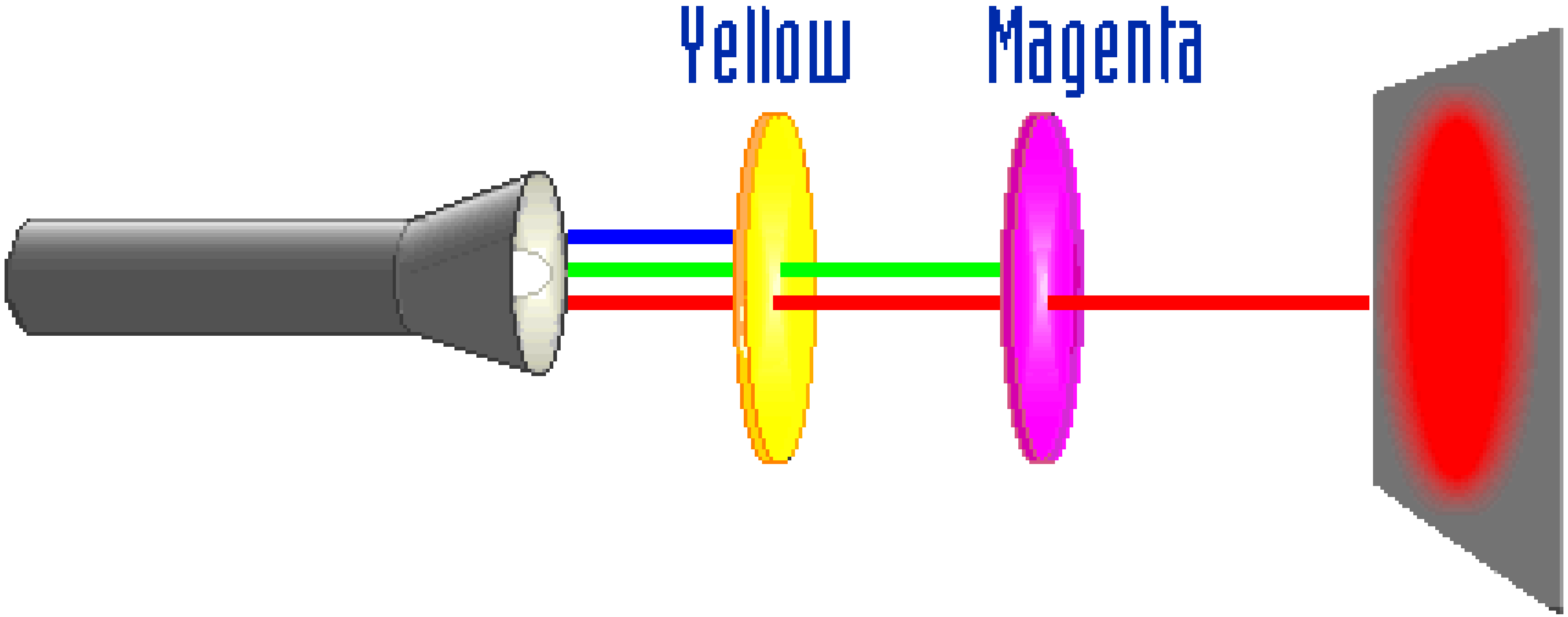
- Paints can be made to behave as additive colors
- Rather than mixing the colors, artists use individual dots of the additive primary colors
- At a distance, your eye creates the additive result

Filters and stage lighting

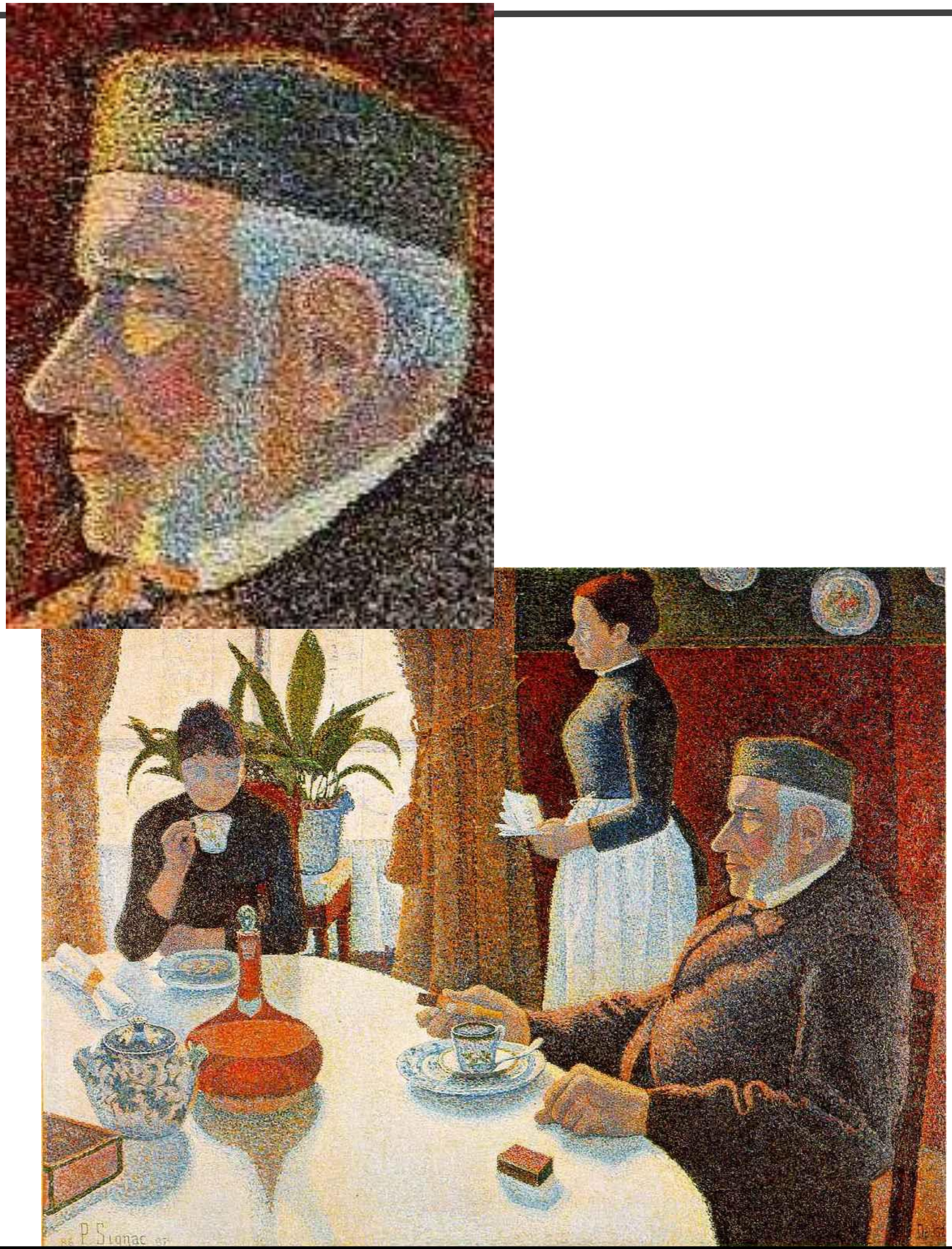


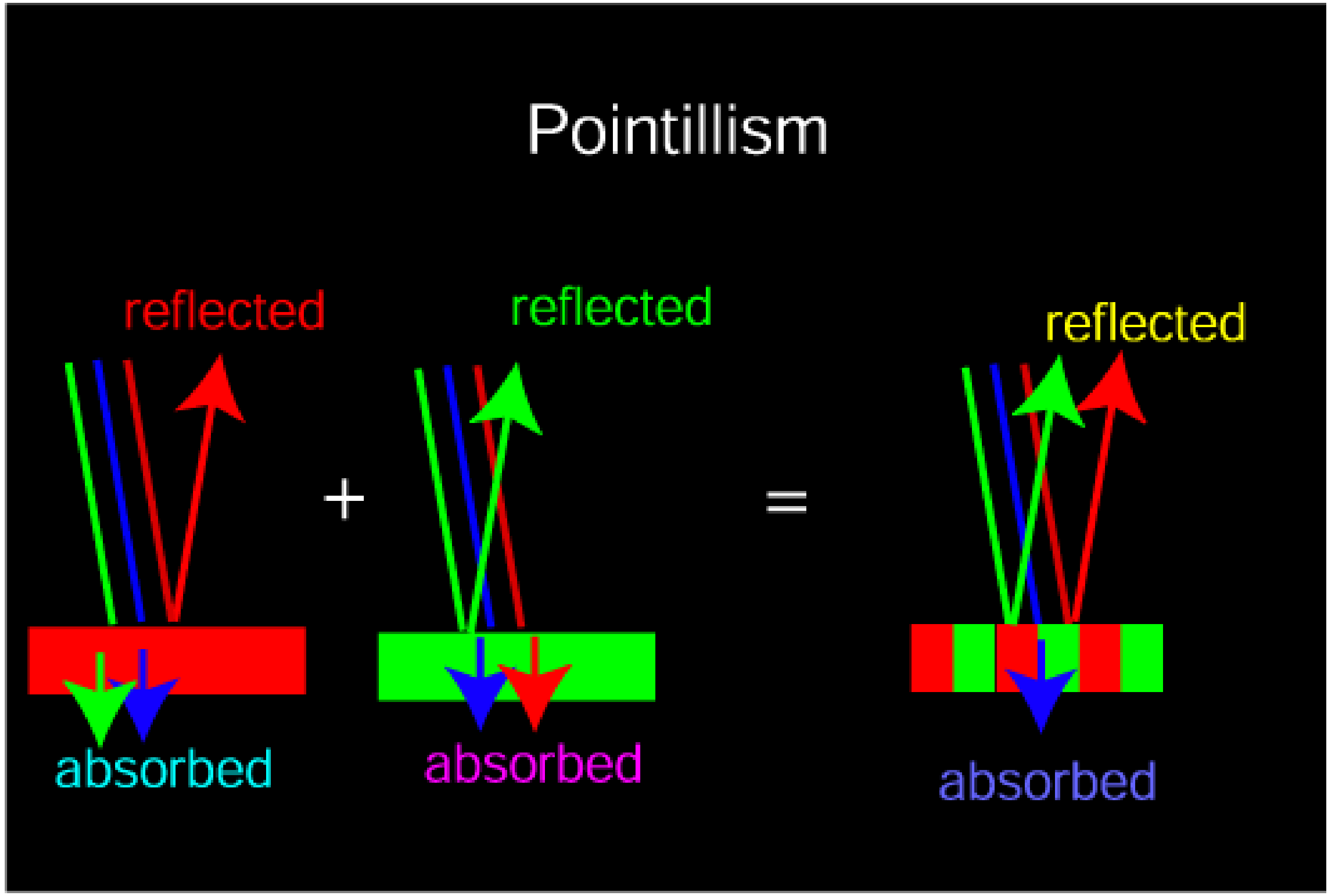


subtractive: Yellow (-B) + Magenta (-G) == RED



additive color mixing: Pointalist art (la salle a manger (Paul Signac)





Online Sources

http://www.willamette.edu/~gorr/classes/GeneralGraphics/Color/add_sub.htm

http://www.stagelightingprimer.com/index.html?slfs-color.html&2

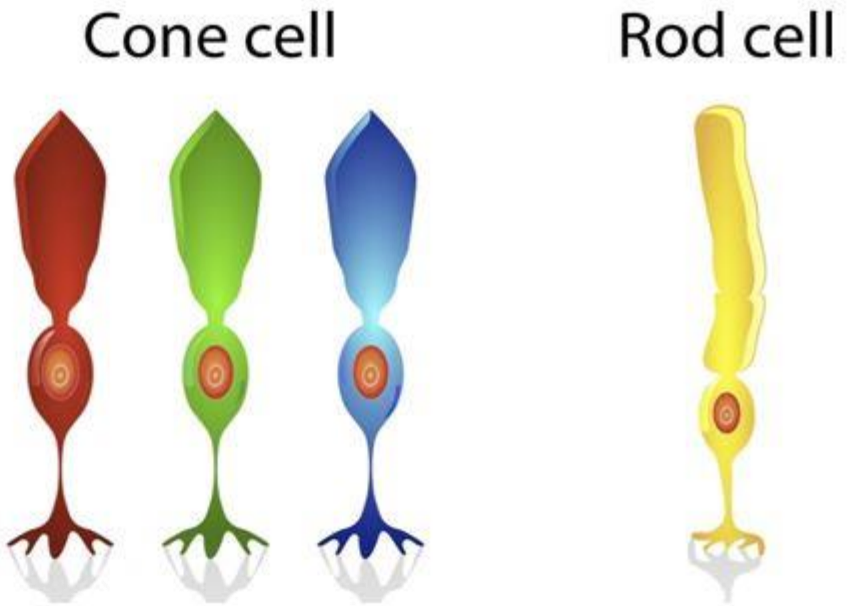
http://www.colorado.edu/physics/phys1230/phys1230_sm10/Lecture_Notes/class15_Colors_AddorSubtractiveColors_ColorVision_posted.pdf

http://www.colorbasics.com/AdditiveSubtractiveColors/

✓ 3. Describe the differences between additive and subtractive color mixing. Which types of color mixing applies to (1) paint pigments, (2) stage lighting (multi spotlight), and (3) Pointillist art?

4. Which receptors cells of the retina allow us to see color? To what general regions of the color spectrum do each of them respond? What is the origin of the different spectral sensitivities of the three cone pigments?

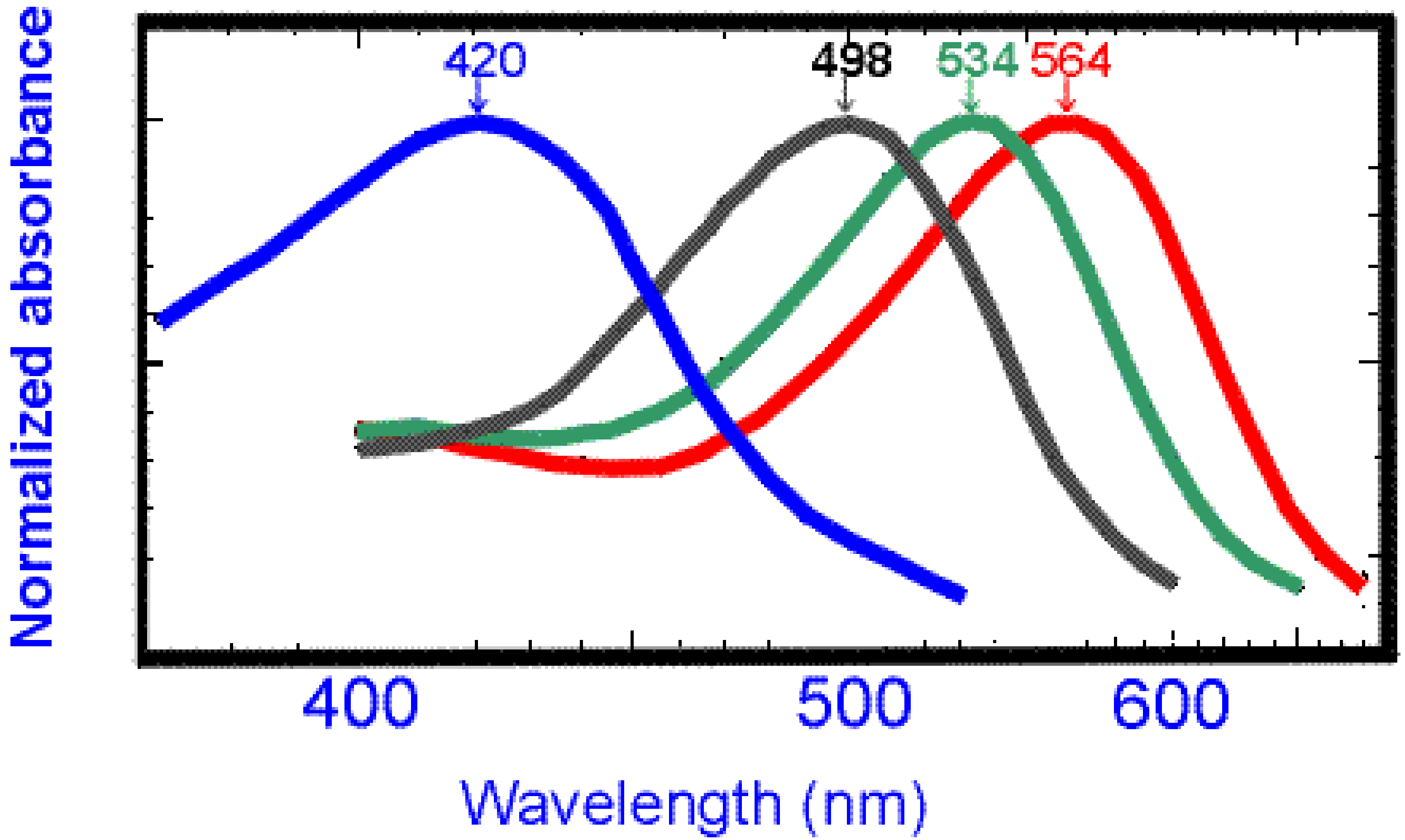
there are 3 varieties of cones with differing spectral absorptions



https://www.kotafoundation.org/elephant-science/elephant-vision/

L-cones (long wavelength sensitive, “Red”)
M-cones (middle wavelength sensitive “Green”)
S-cones (short wavelength sensitive “Blue”)

spectra of L, M, S cones



After Bowmaker & Dartnall, 1980

3 pigments: same 11-cis retinal, differing amino acids in the opsins

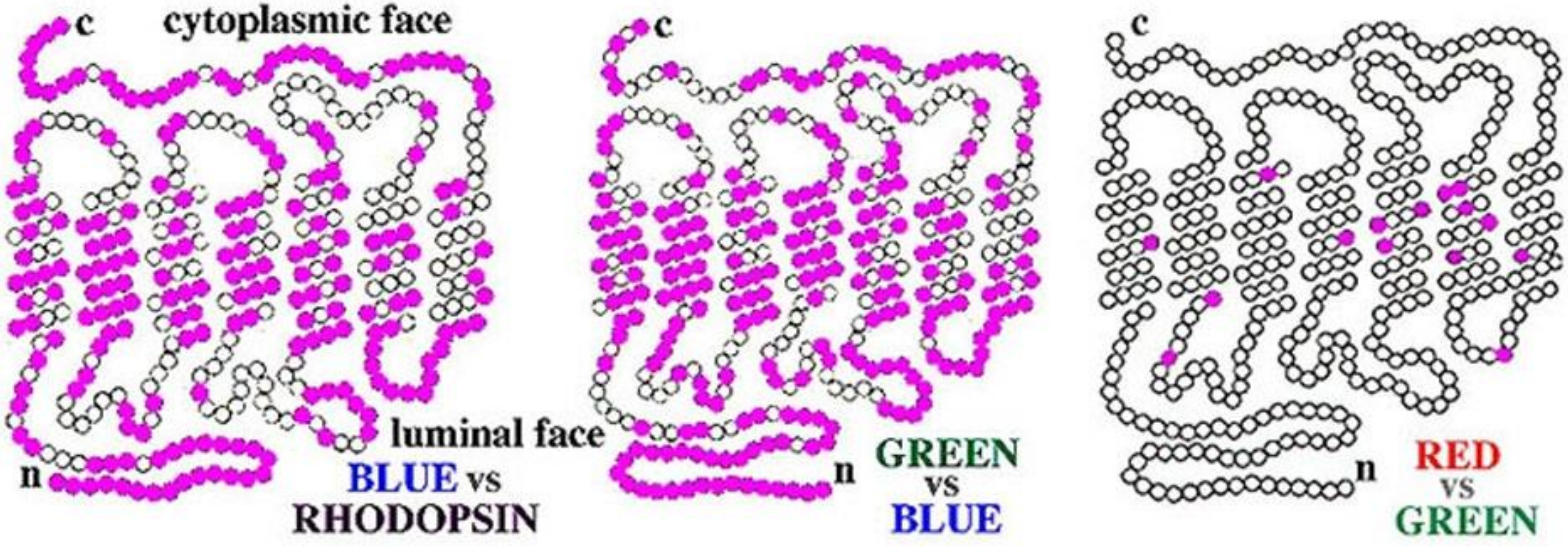


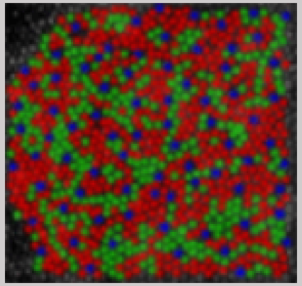
Figure 12. The closely related molecular structure of the cone opsins. The blue-cone opsin compared with rhodopsin. The blue-cone opsin compared with the green opsin and the minimal difference between the red- and green-cone opsins. The pink-filled circles represent amino acid substitutions between these molecules. The open circles indicate identical amino acids. Adapted from Nathans et al. (1986)

http://vignette3.wikia.nocookie.net/science/images/8/81/Molecular_structure_of_the_cone_opsins_.jpg/revision/latest?cb=20120410150452&path-prefix=ru

✓ 4. Which receptors cells of the retina allow us to see color? To what general regions of the color spectrum do each of them respond? What is the origin of the different spectral sensitivities of the three cone pigments?

adaptive optics and cones

5. The UC Center for Adaptive Optics (CfAO) is located on the hillside adjacent to Natural Sciences II and Thimann Lecture Halls. What is adaptive optics, how was it used to obtain maps of the color sensitive receptors in the 'alive' human eye? What did it reveal about the relative numerosity of L-, M-, and S-cones among individuals?



Adaptice Optics Cone Identification

Adaptive Optics Report

~February 9th

Adaptive Optics

By: Alexandra Caselman
Crown 85

I Don’t Speak Science Translation Guide

- **Theoretical Diffraction**- theoretical maximum resolving power of the lens
- **Arcmin**- is a unit of angular measurement equal to 1/16 of 1 degree (or 1/21600 of a circle because 1/360 is 1 degree of a circle)
- **Photoreceptor cell**- is a specialized type of neuron found in the retina. Photoreceptors convert light into signals that can stimulate biological processes. The two classic photoreceptor cells are rods and cones, each contributing information used by the visual system.

What is Adaptive Optics?

- Refers to optical systems which adapt to compensate for optical effects introduced by the medium between the object and its image.
- Relating to Astronomy: A method of bending light to diffuse visual distractions in the atmosphere.
- The resolution of an optical system is limited by the diffraction of light waves (AKA theoretical diffraction limit)
- AO helps compensate for the imperfections. For example, the eye should theoretically be able to see up to .3 arcmin, but because of imperfections of the cornea and lens it is only able to see around 1 arcmin

How AO Works in Telescopes

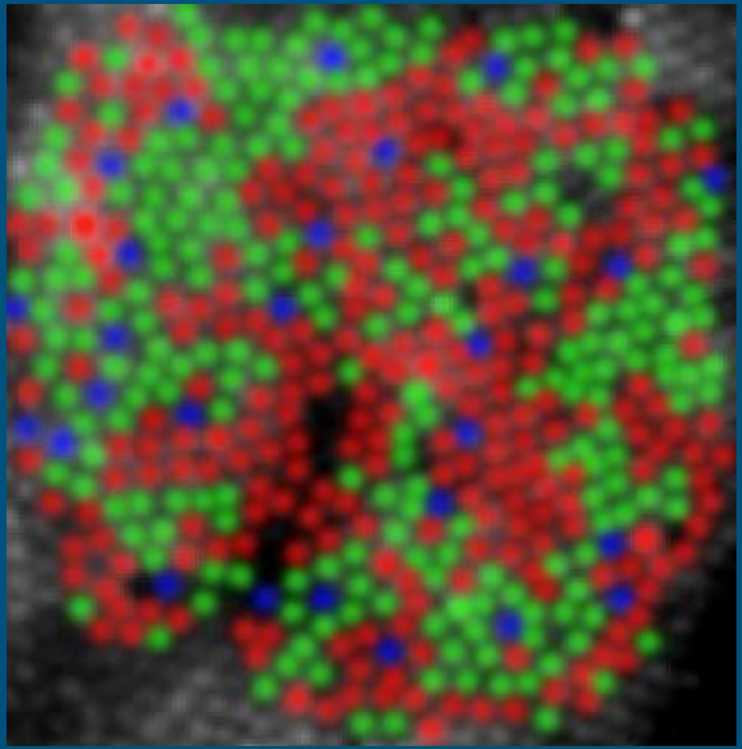
- Atmosphere causes turbulence (effect is “twinkling” of stars)
- Shoots a laser into the sky
- Reaches the edge of atmosphere and stimulates particles causing them to glow (used as a fake star)
- The glow is used as a reference to calculate the distortion
- Sent to a computer to calculate the atmospheric distortion
- The computer creates an opposite wavelength to mirror the one sent down
- Applied to a formable mirror that is transformed into the opposite wavelength
- Lightwave becomes evened out which creates a clear image
- https://www.youtube.com/watch?v=gDGvNyVApgg

The Three Cone Types

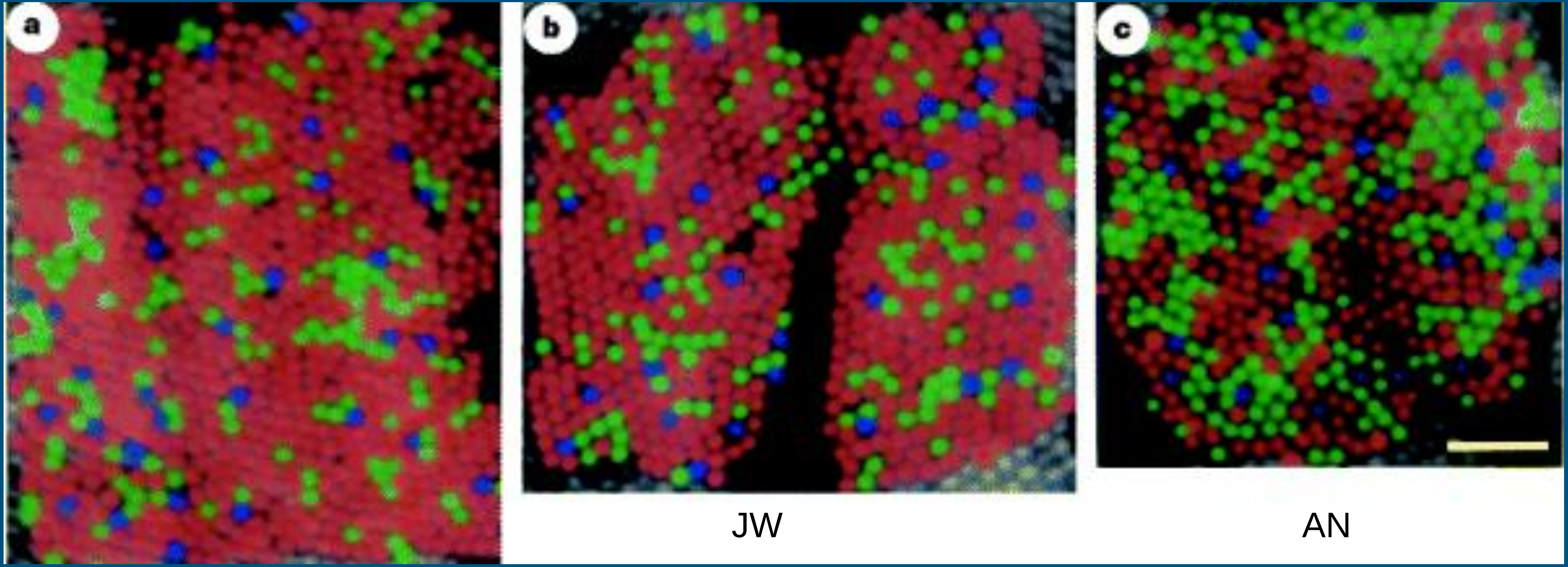
Human colour vision depends on three classes of receptor, the short- (S), medium- (M), and long- (L) wavelength-sensitive cones. These cone classes are interleaved in a single mosaic so that, at each point in the retina, only a single class of cone samples the retinal image.

How are the Three Cone Types Measured?

Individual cones were classified by comparing images taken when the photopigments were fully bleached with those taken when the photopigments were either dark-adapted or exposed to a light that selectively bleached one photopigment. From these images, we created absorptance images that remove static features to reveal only the distribution of the photolabile pigments that distinguish the cone classes. S= Blue M= Green L= Red

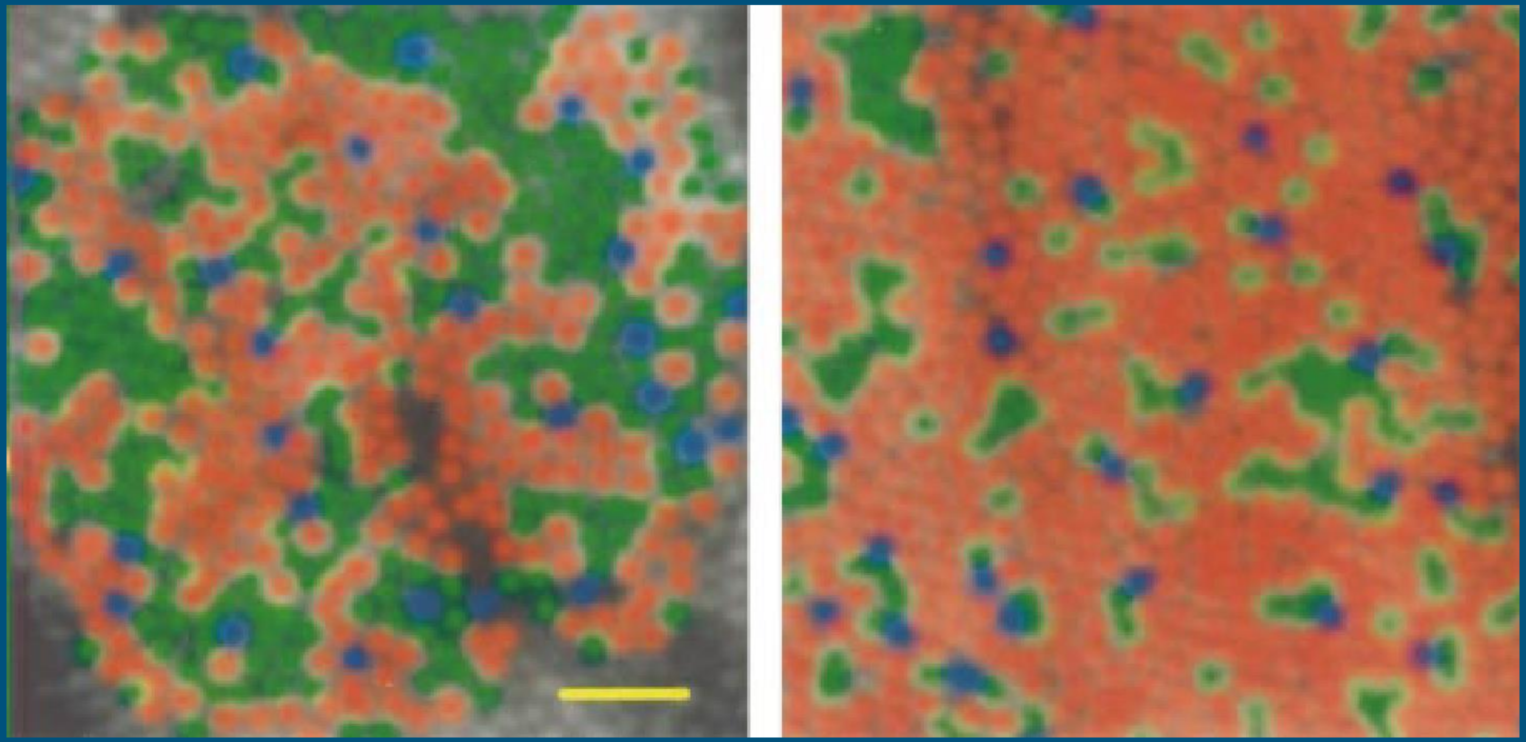


Variation in Ratios of Cone Types



Do individuals with differing L/M cone ratios ‘see’ differently ?

Physical measures (electroretinogram) were different and consistent with the differing relative numbers of L- and M-cones

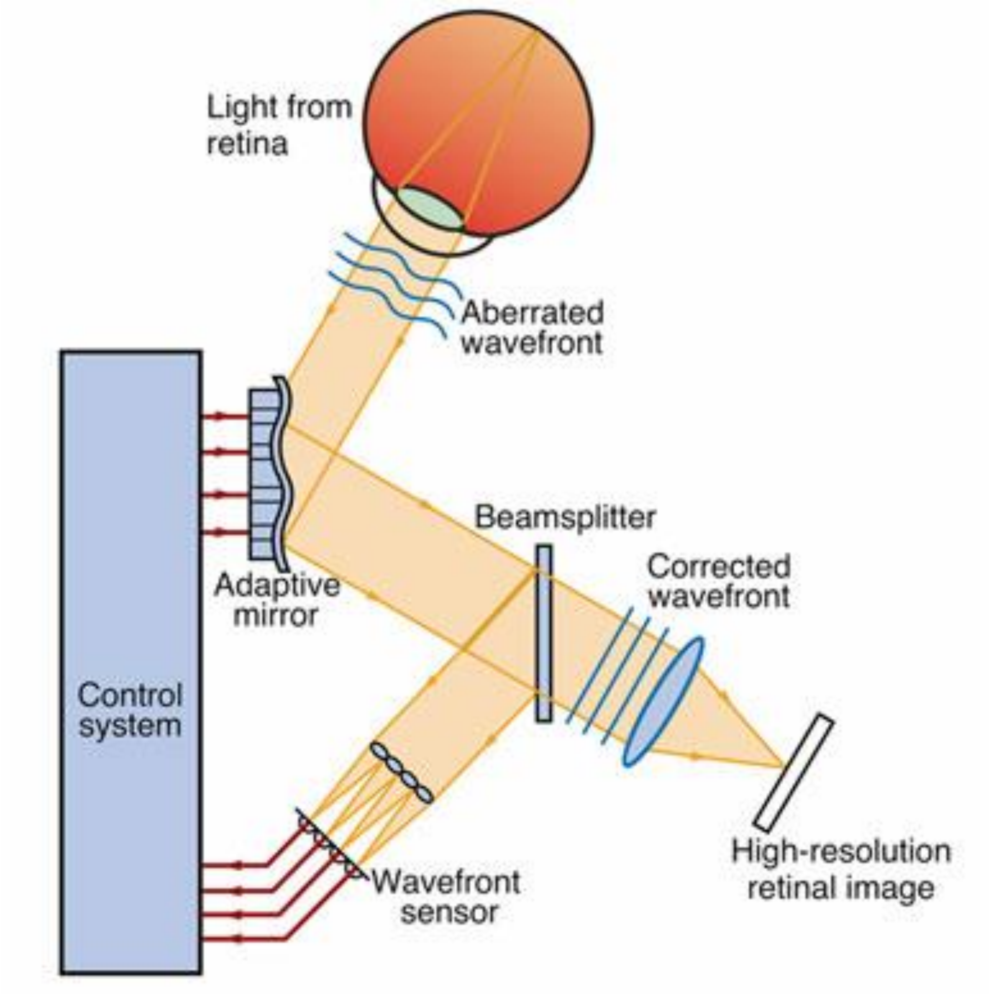


***AN* L/M=1.15**   ***JW* L/M=3.79**

Perceptual measures (unique yellow) were almost identical despite the differing relative numbers of L- and M-cones

Experience with the environment, either during development or continuing throughout life, could be used to adjust the relative strength of L and M inputs

how adaptive optics creates 'perfected' image



adaptive optics and cones

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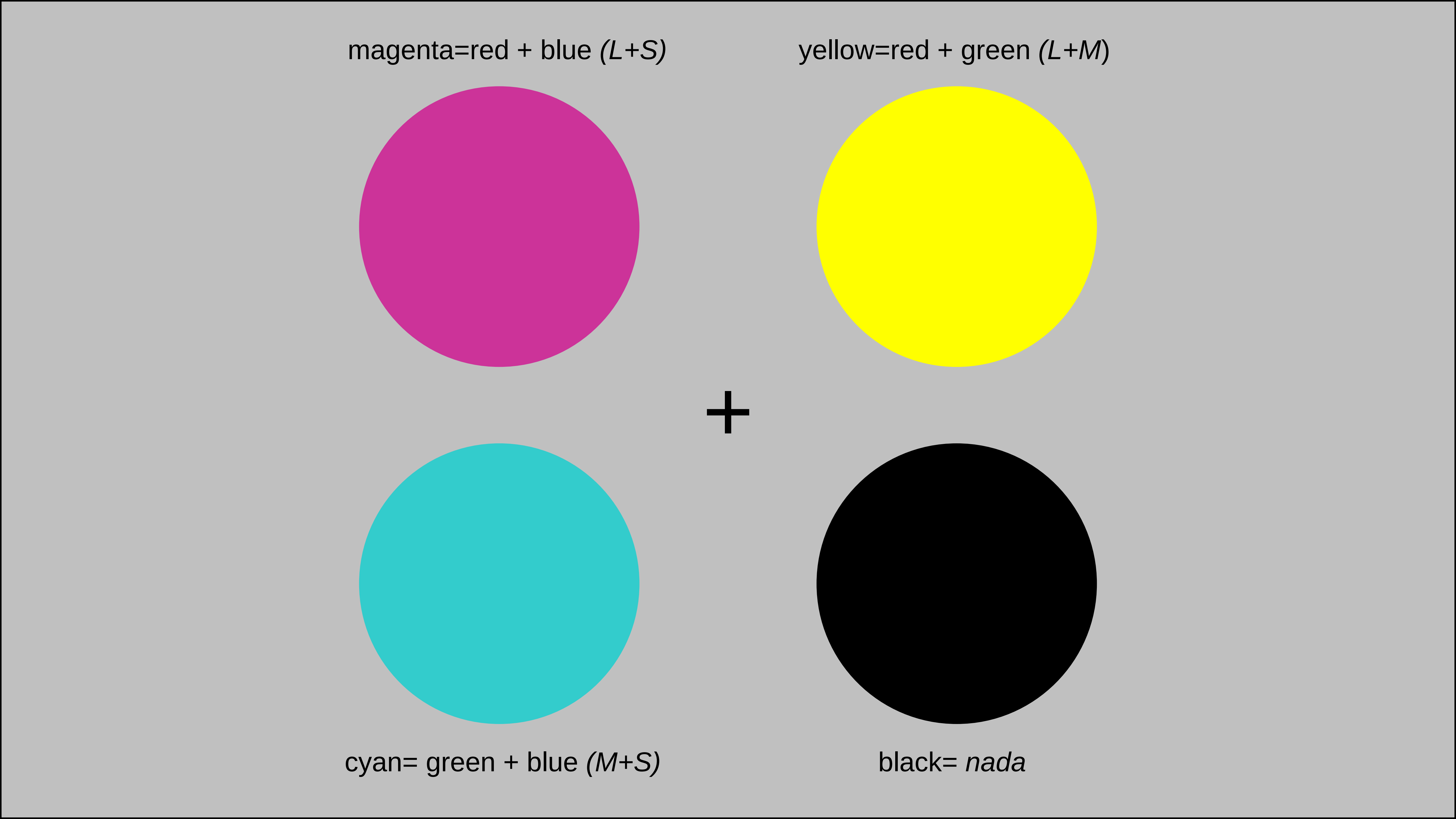
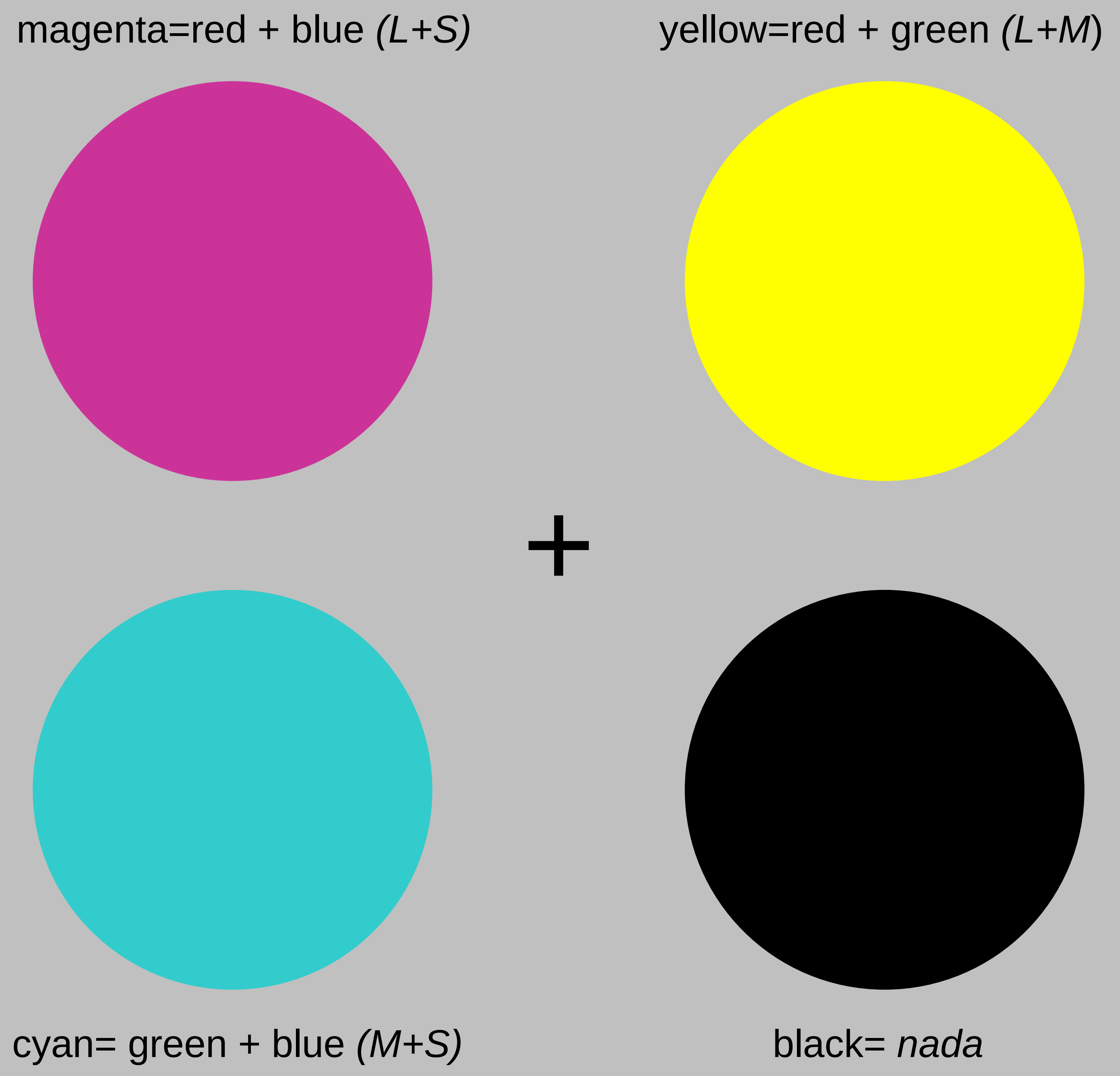
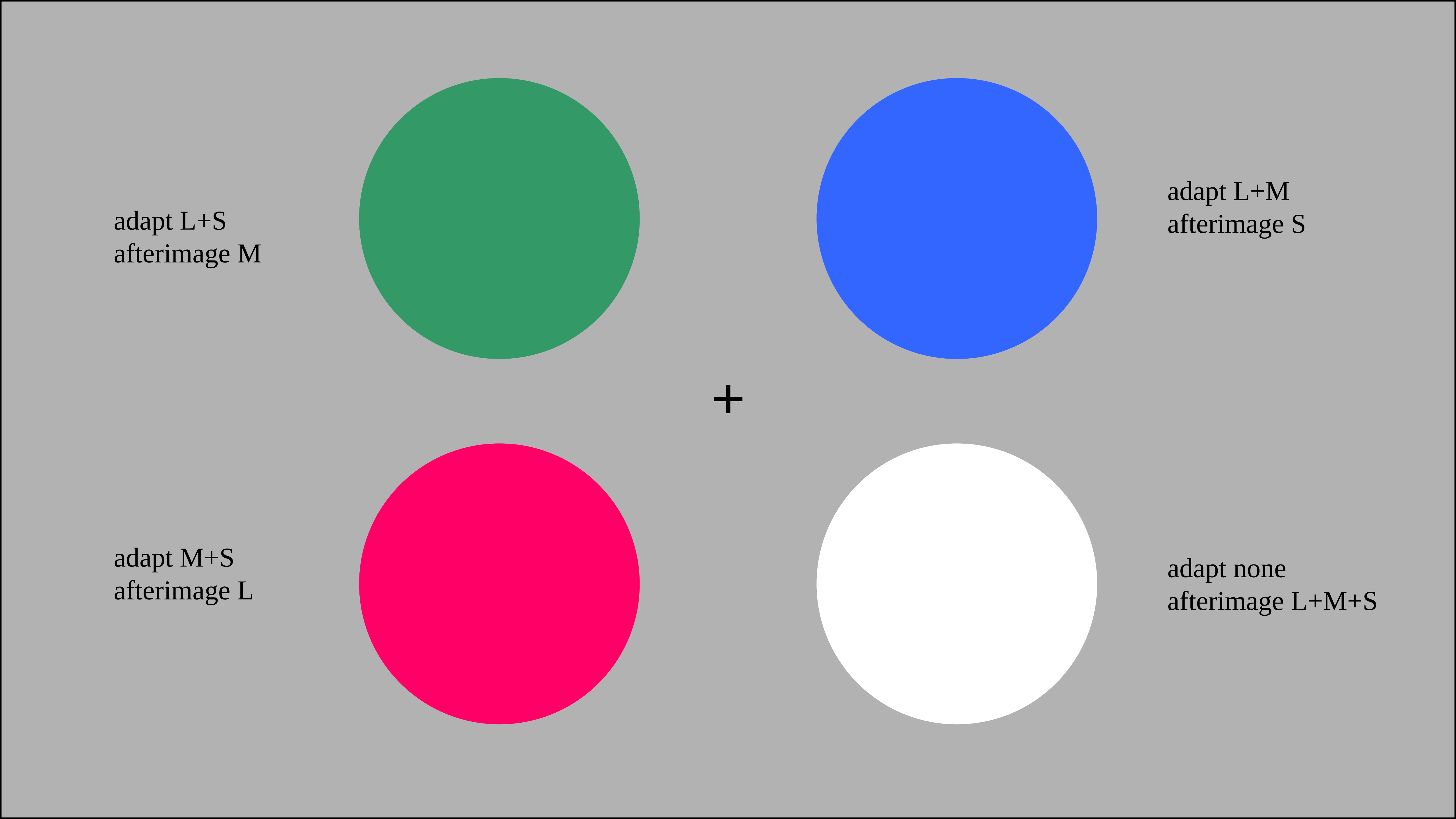
chromatic adaptation

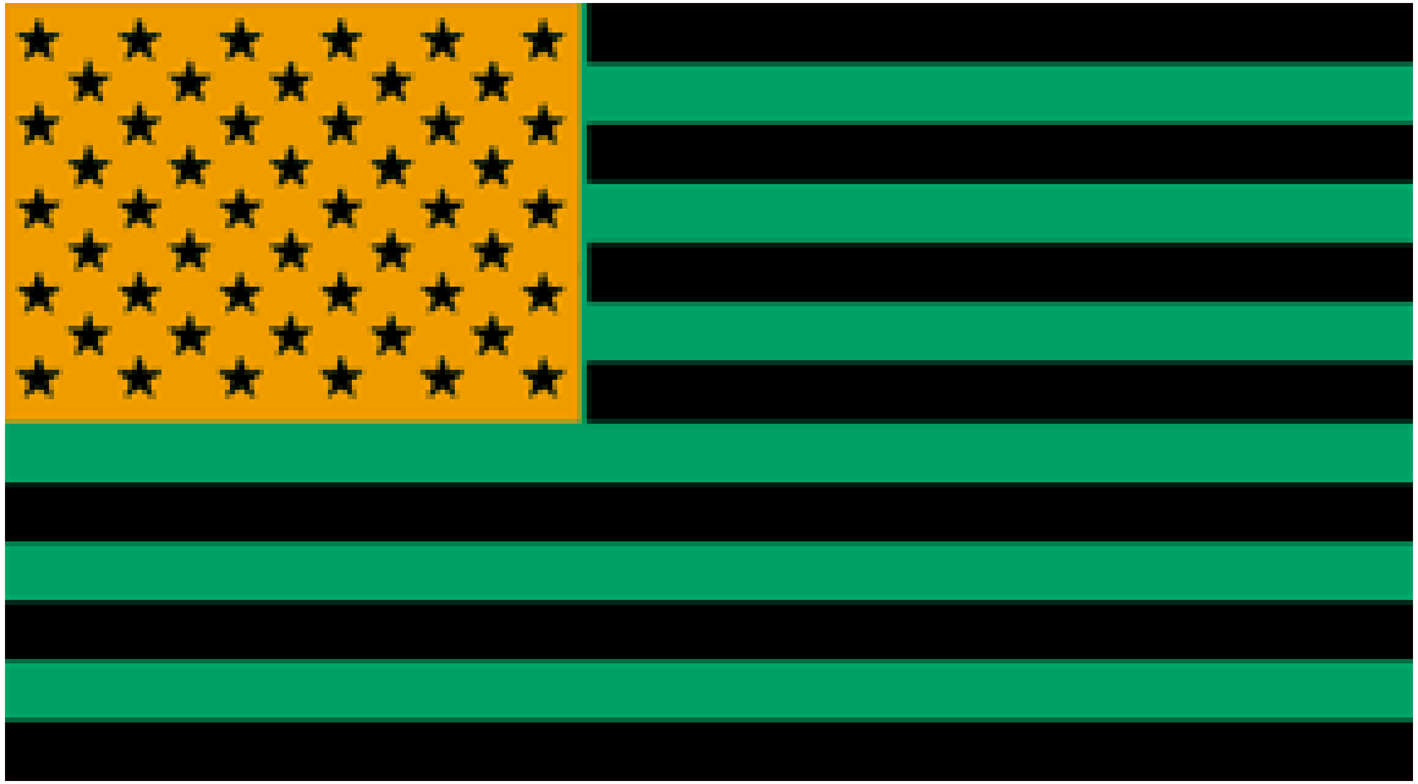
Look at a color that adapts ("fatigues") one set of cones (*or color mechanisms-later*);

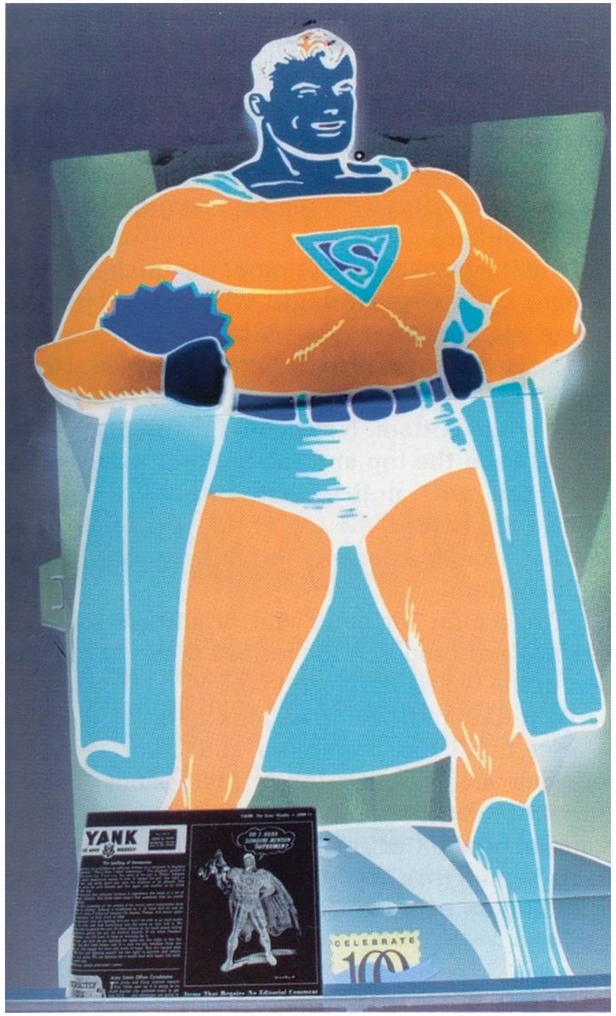
After adaptation cones that are not fatigues "take over" and give complementary perception


magenta=red + blue (L+S)
yellow=red + green (L+M)
+
cyan= green + blue (M+S)
black= nada

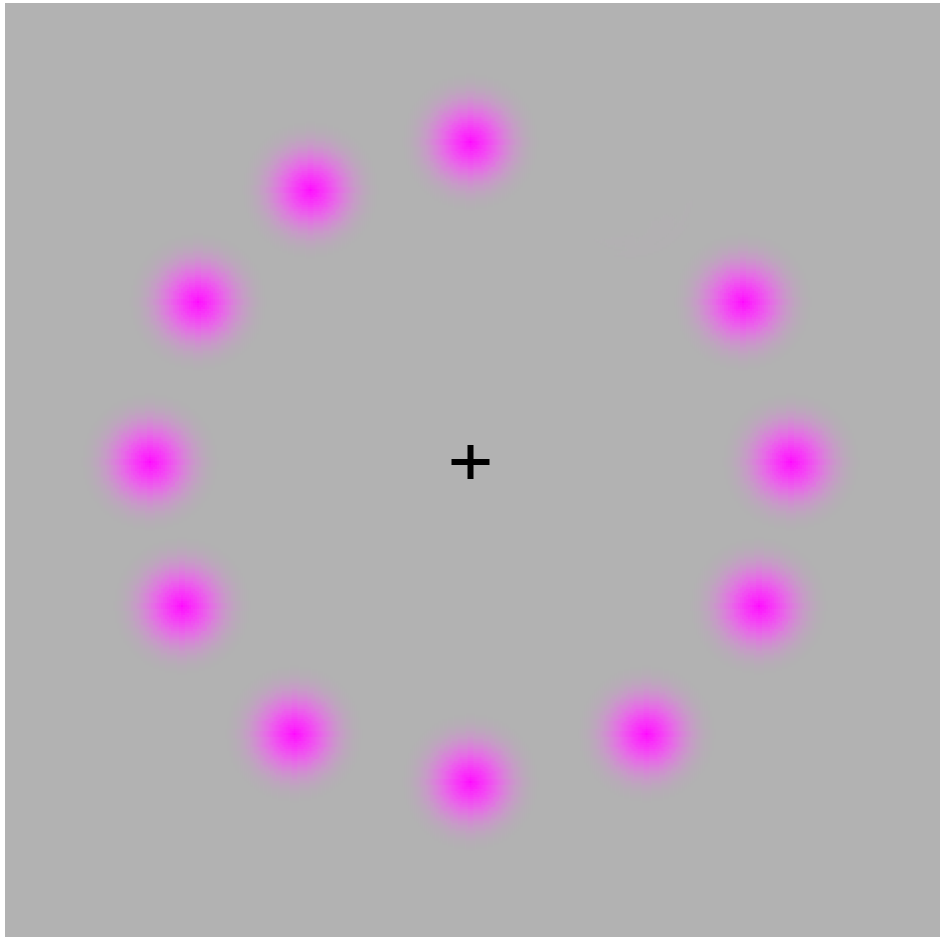

magenta=red + blue *(L+S)*
yellow=red + green (*L+M*)
cyan= green + blue *(M+S)*
black= *nada*


adapt L+S
afterimage M
adapt L+M
afterimage S
+
adapt M+S
afterimage L
adapt none
afterimage L+M+S



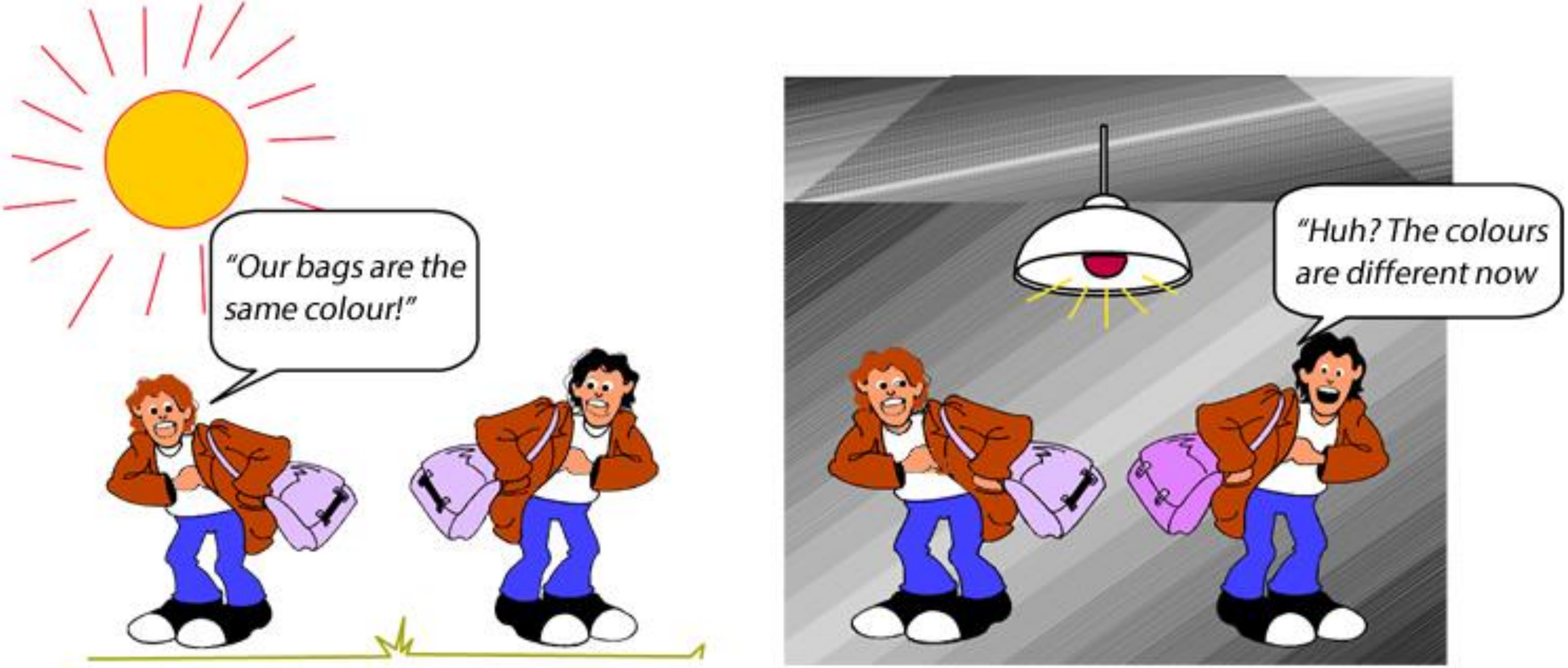

YANK
CELEBRATE
100

cool image



6. Know the following terms related color vision:
    a. metameric match
    b. simultaneous contrast

Metamers


"Our bags are the same colour!"
"Huh? The colours are different now

- For observers with normal color vision only three elements of information are captured from a [large] patch of light and reported to the nervous system: **the activity of the L-cones**, **the activity of the M-cones**, **and the activity of the S-cones**

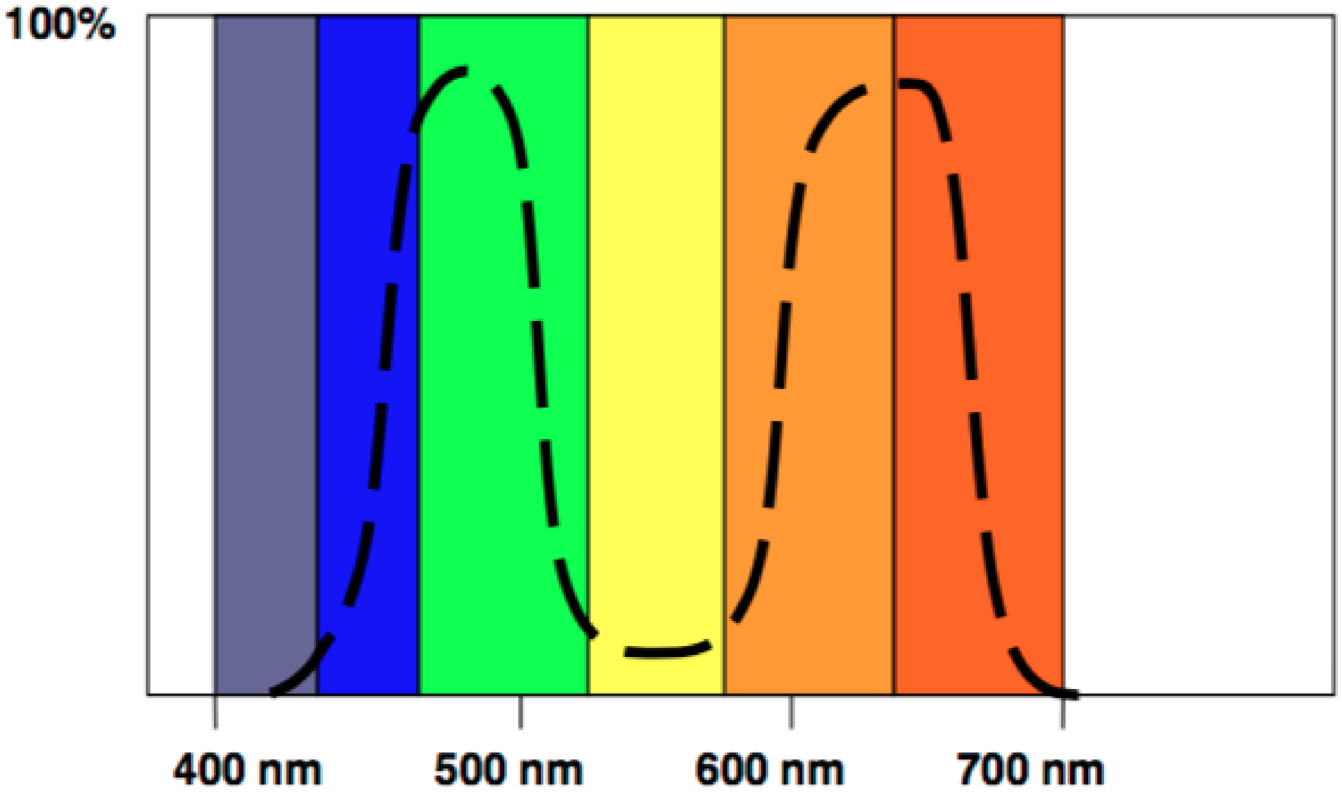
- Two light of differing spectral composition (intensities at various wavelengths) can **produce the same activity in each of the L-, M-, and S-cones and thus will appear to be the same color ! ! ! !!!!!!!!!**

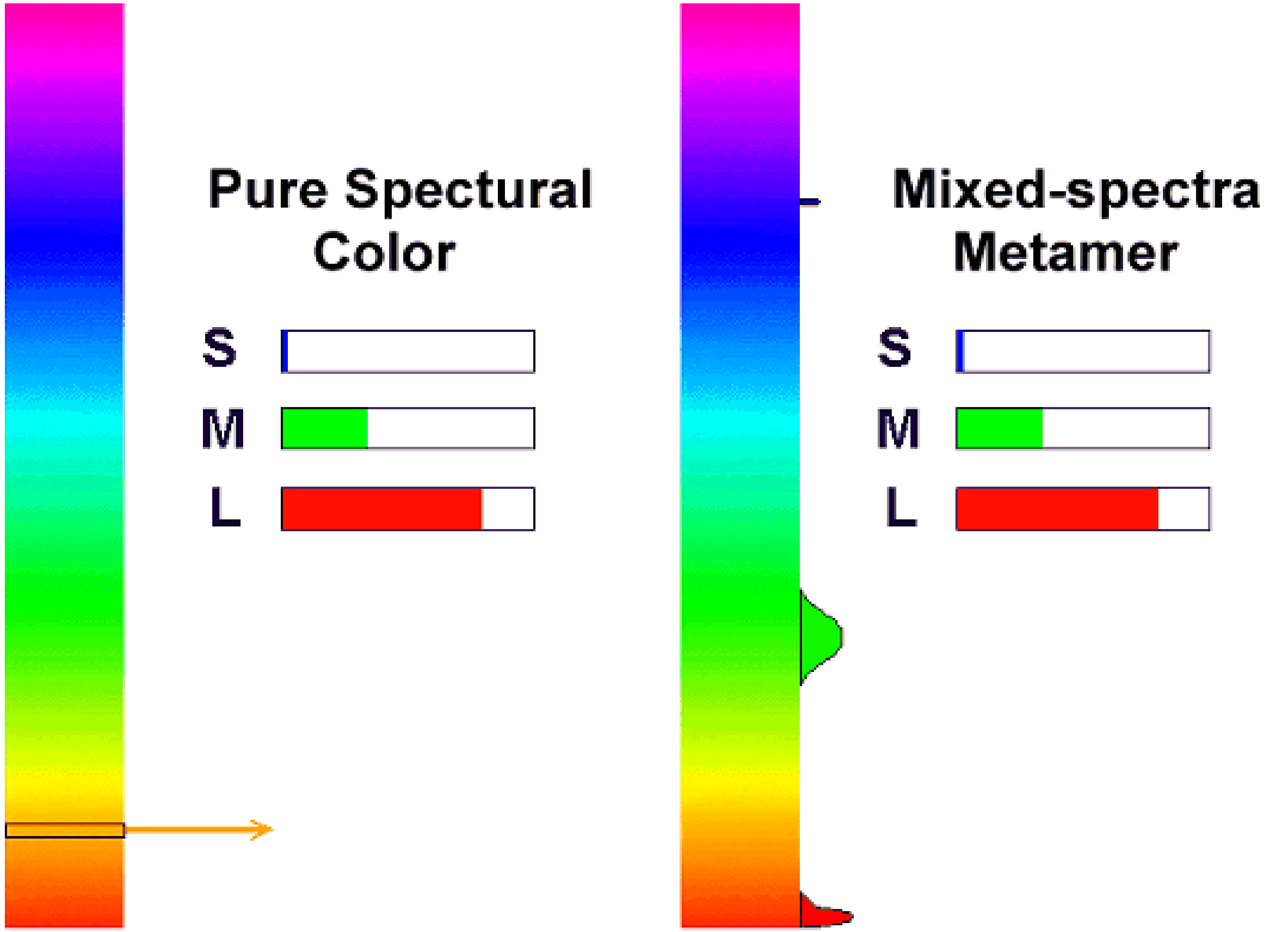
- Two lights of differing spectral composition but which appear identical are **METAMERS (a METAMERIC MATCH)**.

For example: an appropriately chosen mixture of red + green is a metameric match with a pure yellow

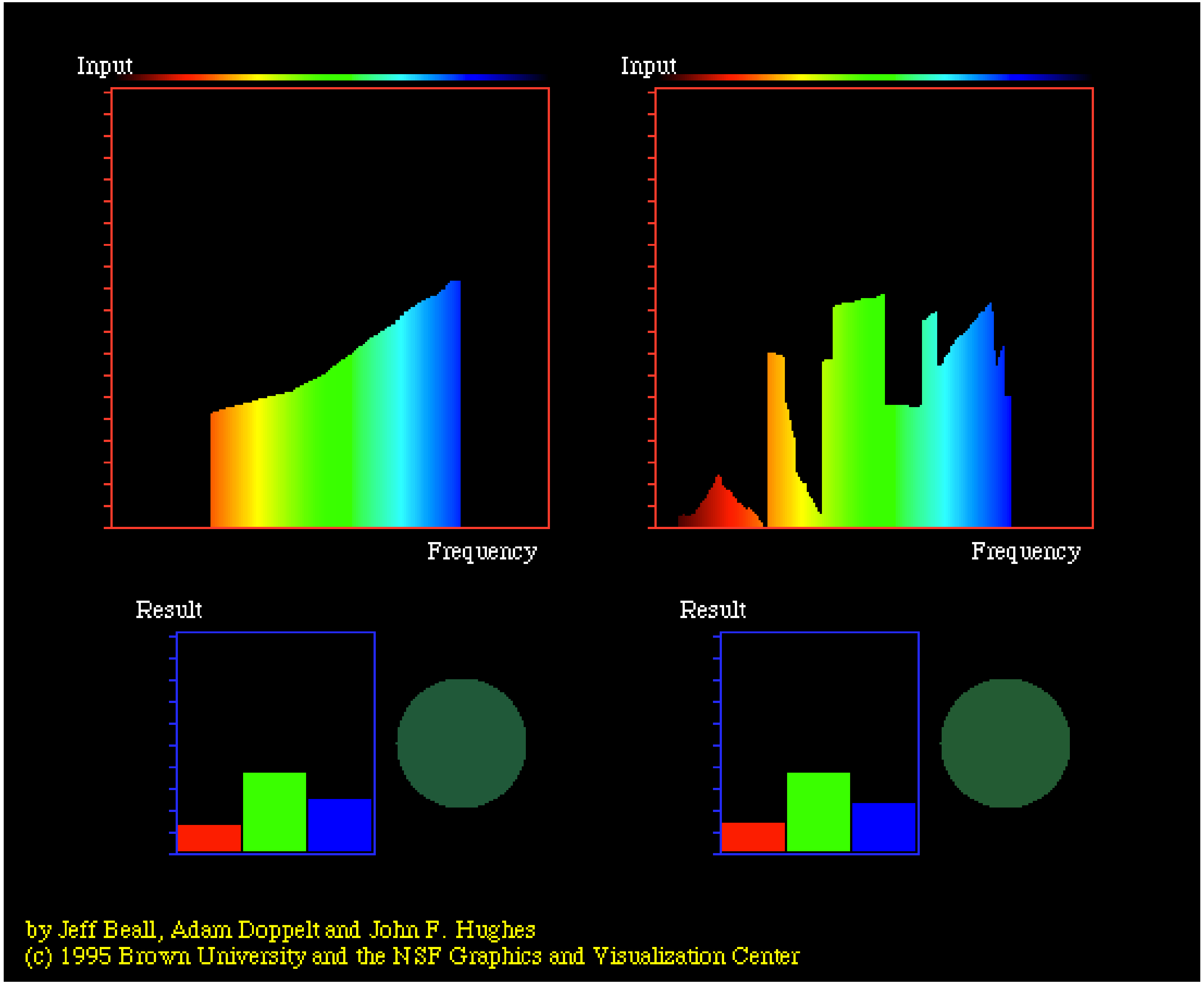
What color does this spectral curve <u>look like</u>?

Answer: Yellow, although there is no yellow light

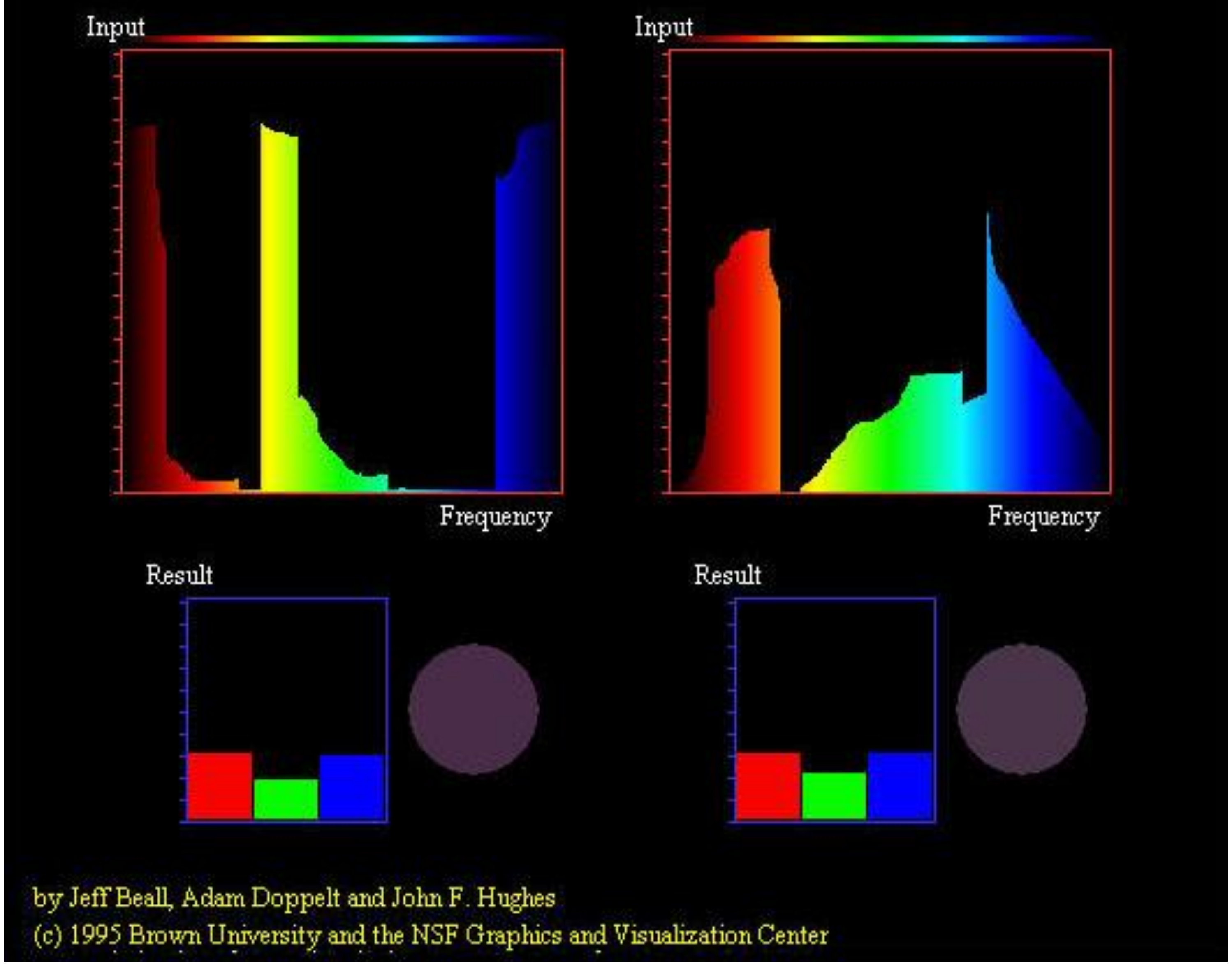




Pure Spectural Color
S
M
L
Mixed-spectra Metamer
S
M
L


Input
Frequency
Result
Input
Frequency
Result
by Jeff Beall, Adam Doppelt and John F. Hughes
(c) 1995 Brown University and the NSF Graphics and Visualization Center

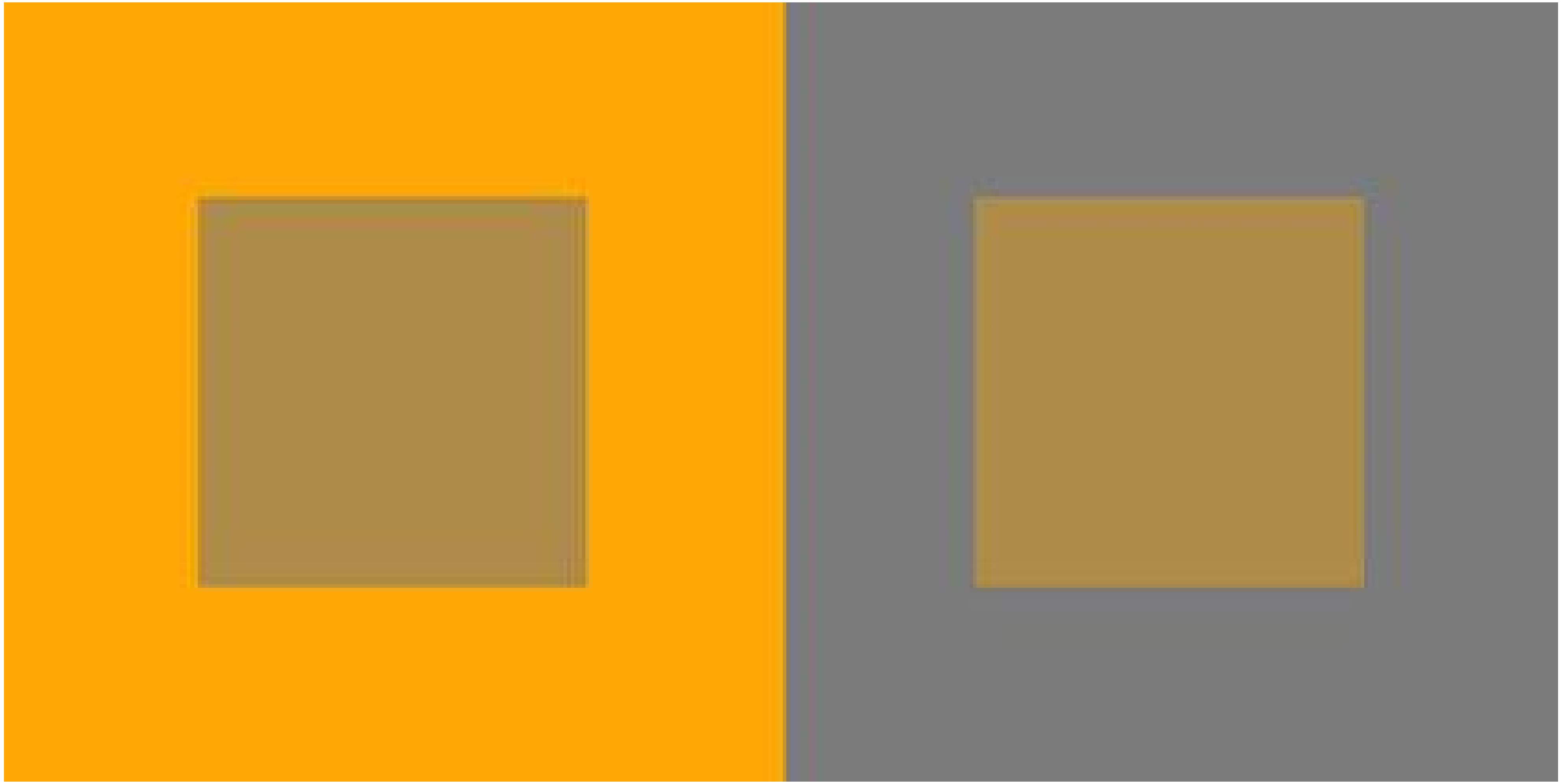
Metamers


Input
Frequency
Result
Input
Frequency
Result
by Jeff Beall, Adam Doppelt and John F. Hughes
(c) 1995 Brown University and the NSF Graphics and Visualization Center

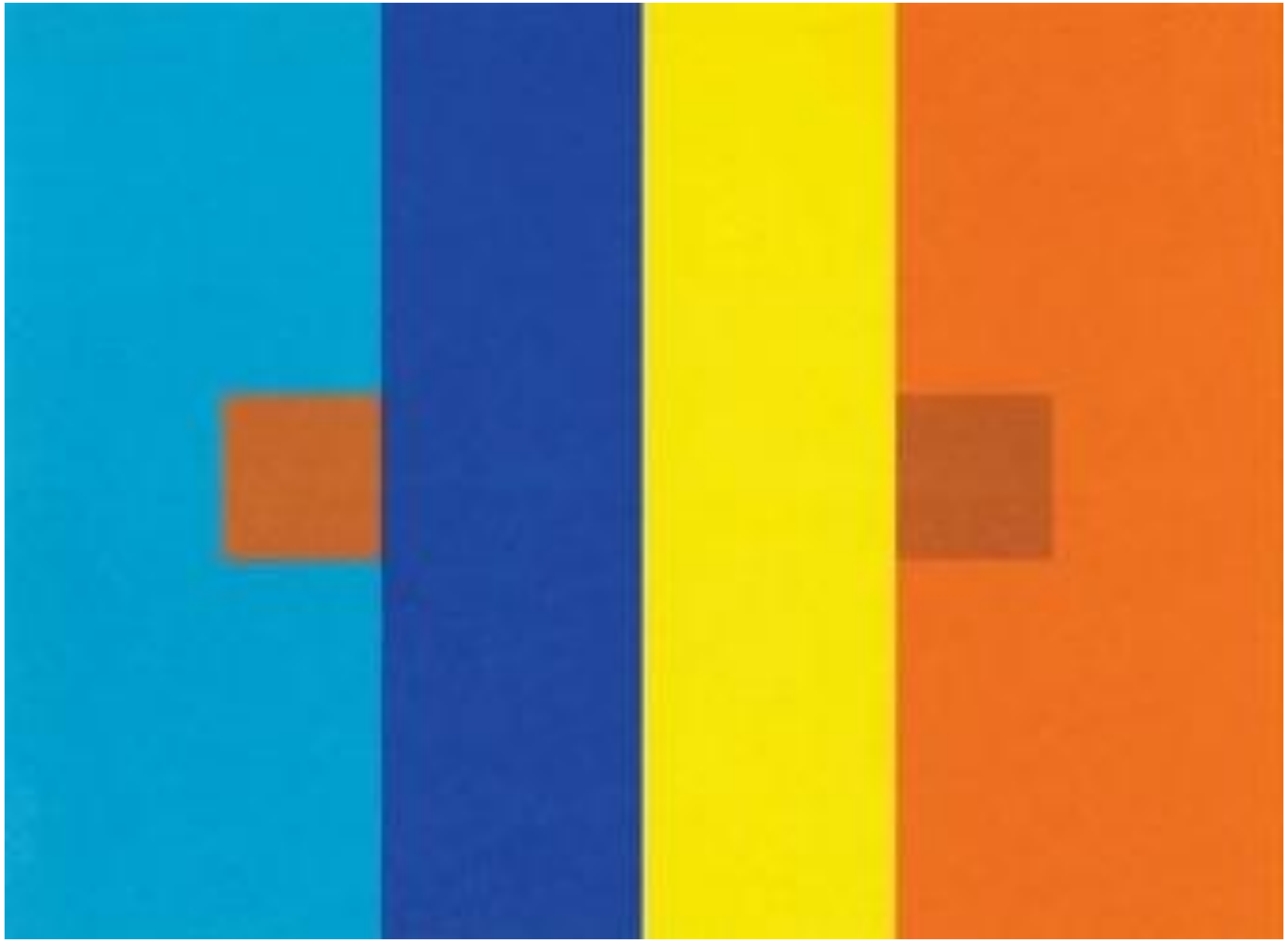
Simultaneous Contrast

Perception of a color “repelled” by surround color

Surround a color with a less saturated color and it will appear more saturated



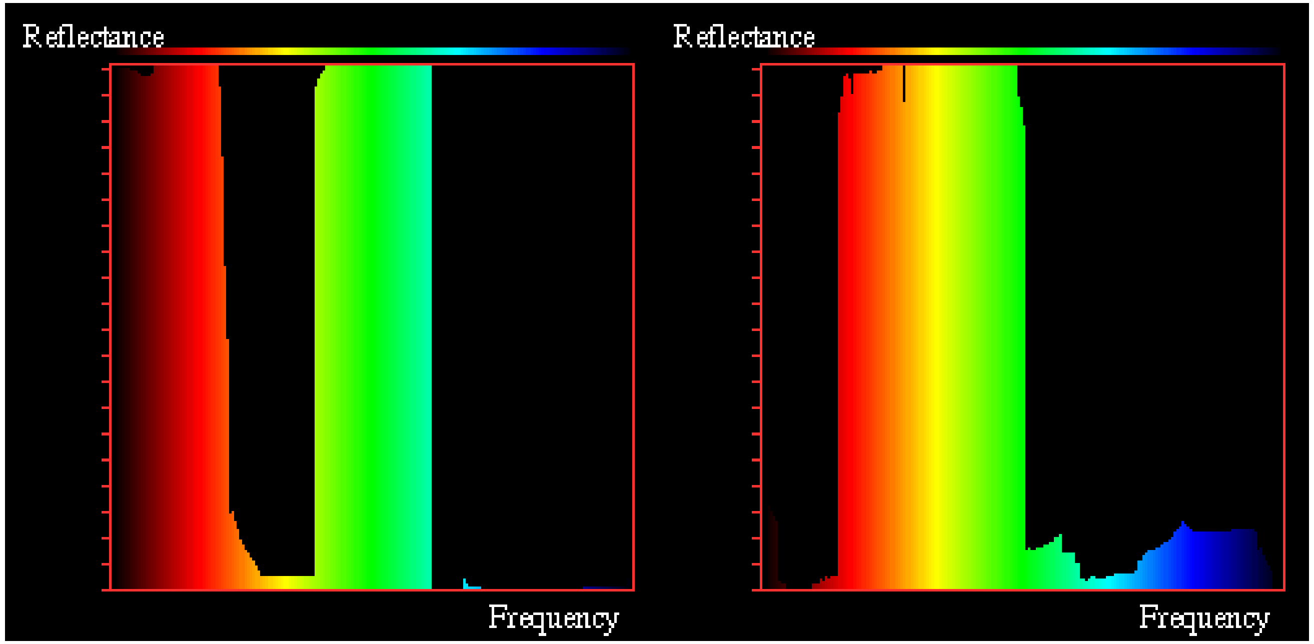
Surround a color with different hues and its will shift in appearance towards the complementary hue of the surrounding color.



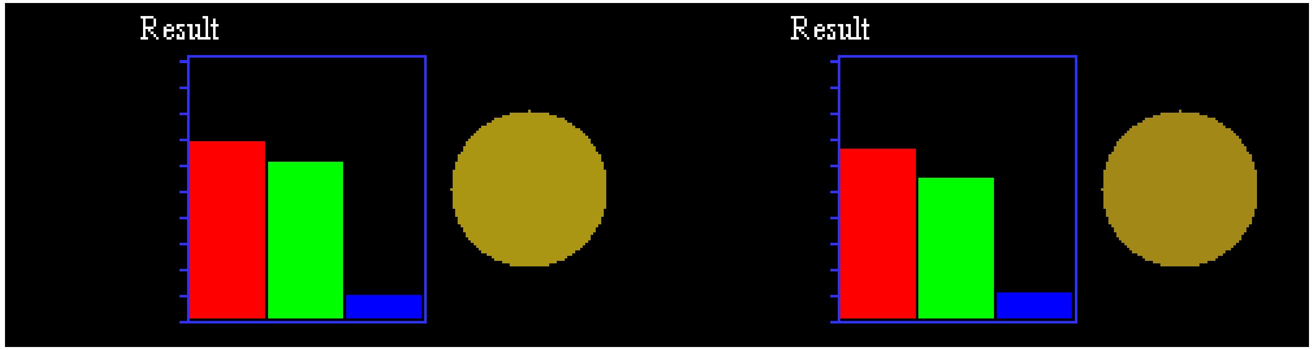
6. Know the following terms related color vision:
   - ✓ a. metameric match
   - ✓ b. simultaneous contrast

metamers

spectra of light from objects



activation of L-, M-, and S-cones and resultant color

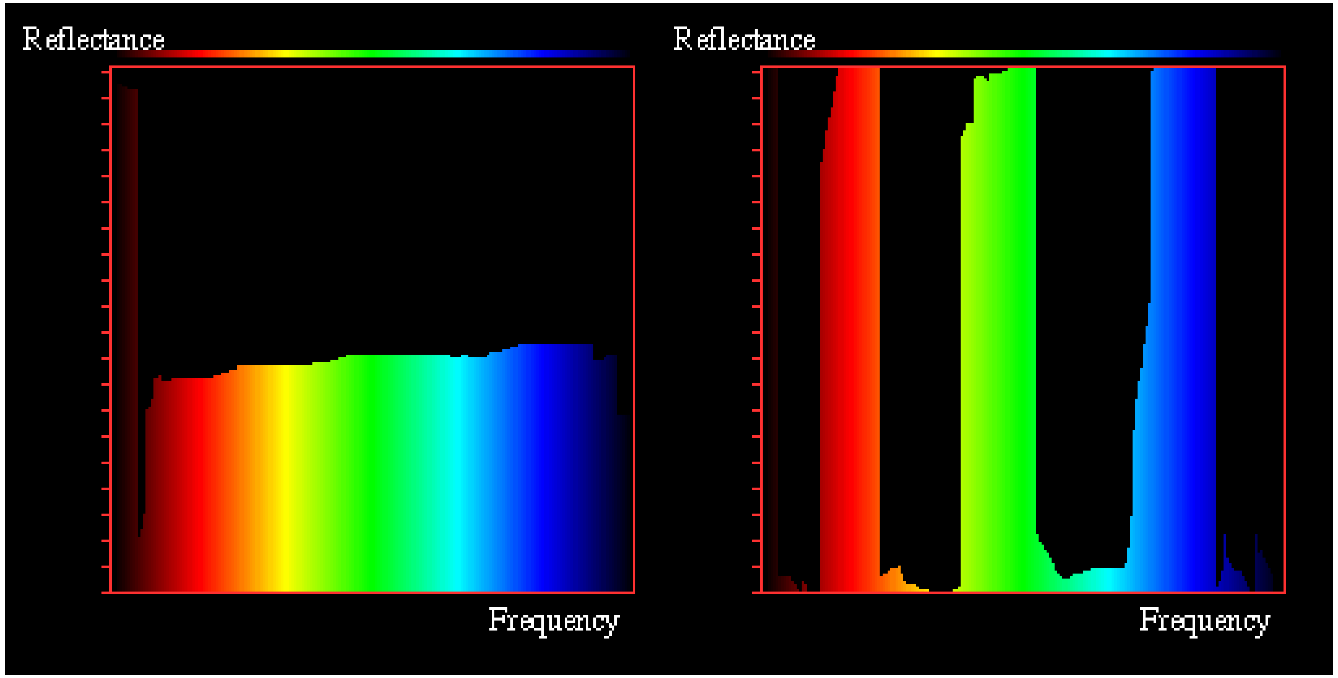


http://tux.cs.brown.edu/exploratory/ColorWeb/color_TOC.html

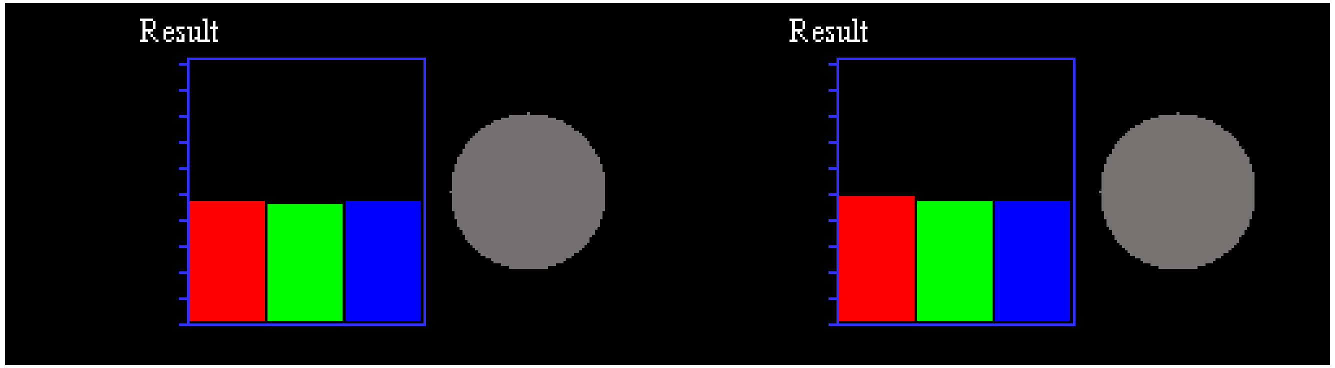
more metamers

more metamers

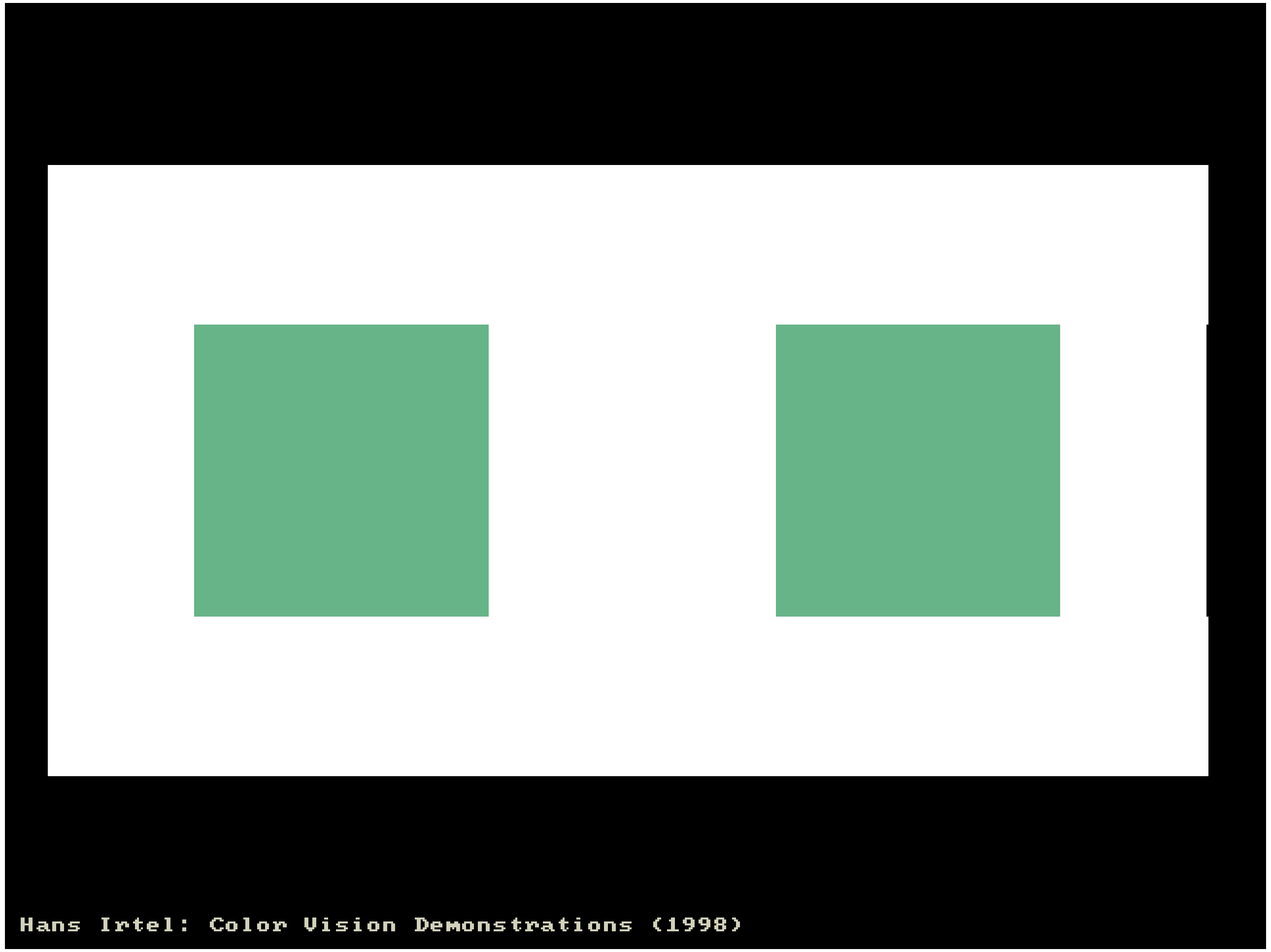
spectra of
light from
objects



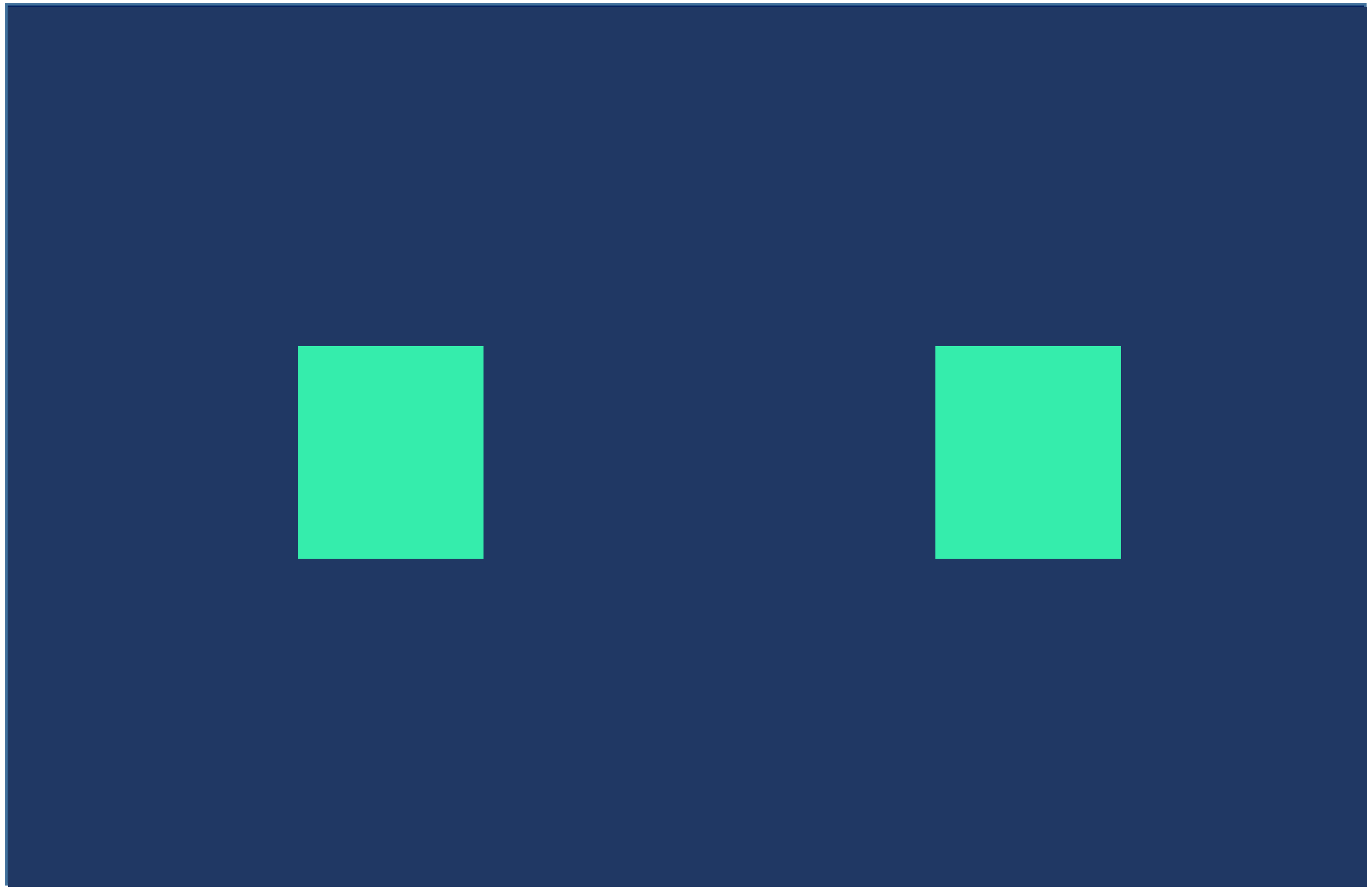
activation of
L-, M-, and S-
cones and
resultant color



http://tux.cs.brown.edu/exploratory/ColorWeb/color_TOC.html *simultaneous color contrast (perception of a color "repelled" by surround color)*

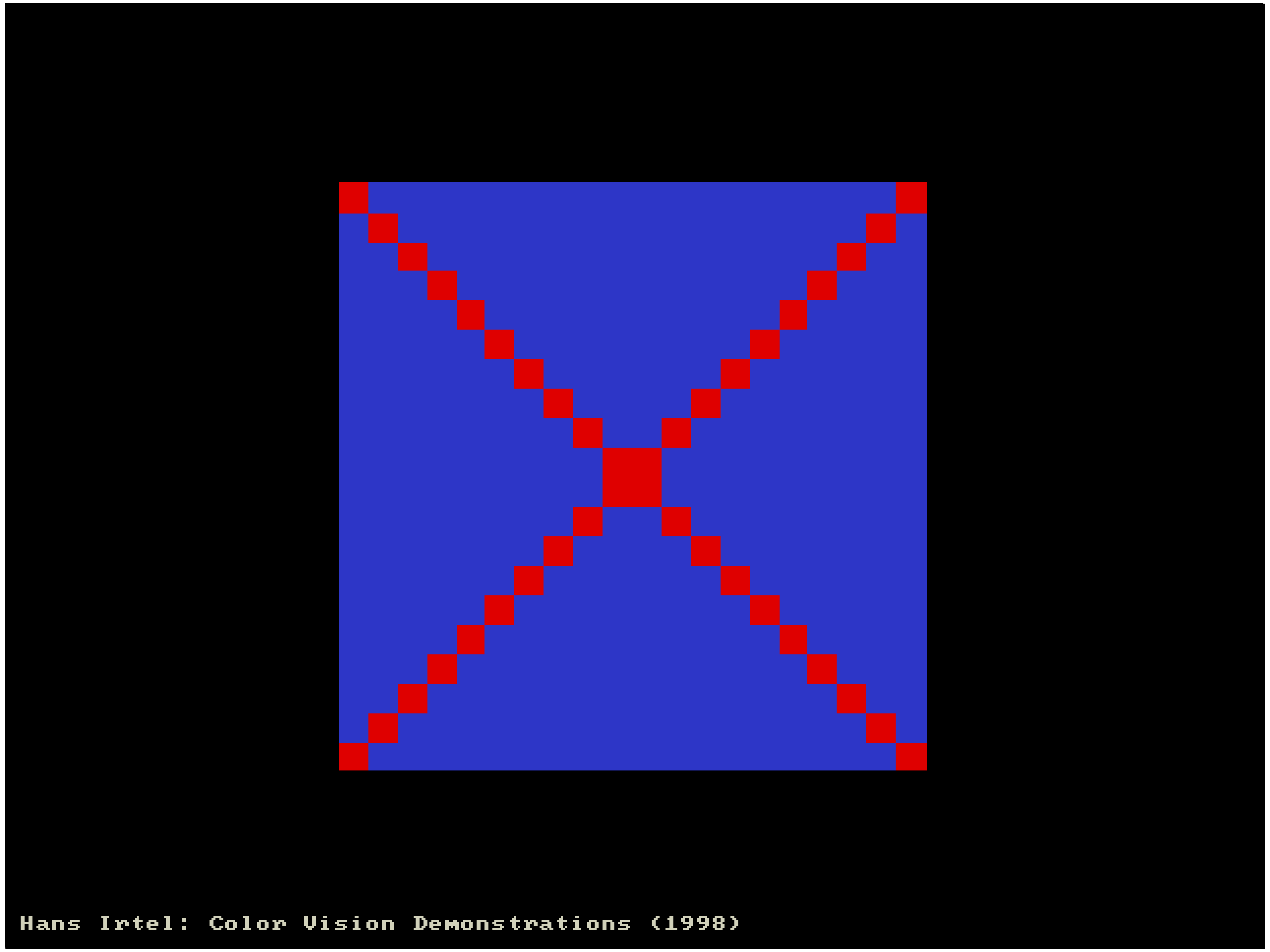


more simultaneous contrast



color assimilation (perception of a color "attracted" by surround color)

color assimilation (perception of a color “attracted” by surround color)



from outline

6. Know the following terms related color vision:
   - ✓ a. metameric match
   - ✓ b. simultaneous contrast

7. What are color opponent cells?

8. How do the Young-Helmholz and Herring theories of vision differ? Are they incompatible?

Young-Helmholtz vs Herring

Young

- Three basic colors: red, green, blue
- Trichromacy
- physiologically: 3 cone types

Helmholtz

Herring

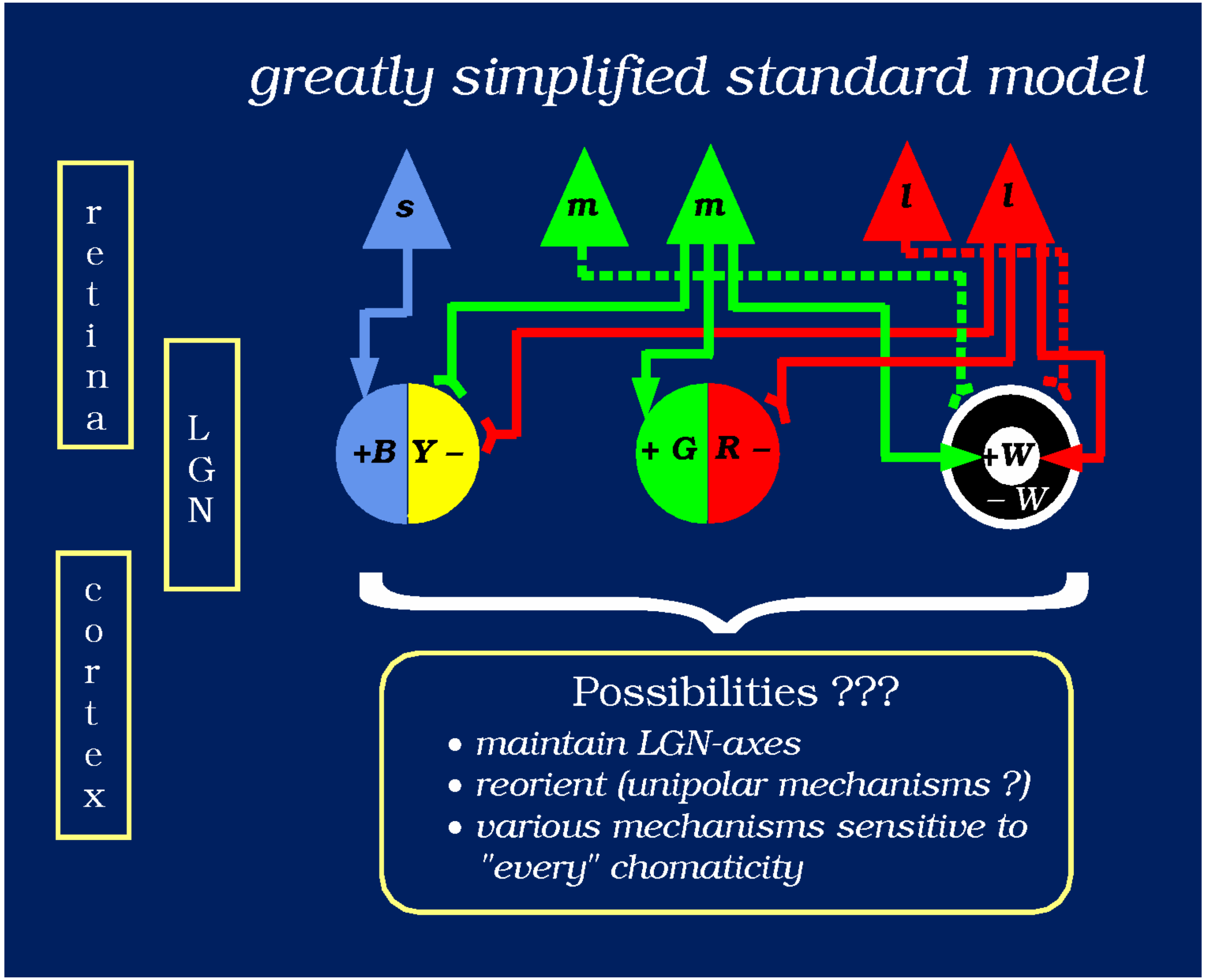
- Two sets of perceptually opposing collors: red vs green and blue vs yellow
- Perceptual independence: **NO** “reddish-green” and **NO** “bluish-yellow”
- physiologically ???

second stage of processing: color-opponent ganglion cells in retina and LGN

- the 3 cone types cones provide the "first-stage" of the processing of color information

- in the retina cone signals are combined (via excitation and inhibition) to yield ganglion cells that have chromatic OPPONENT receptive fields

- R-G ($R^+ G^-$ and $G^+ R^-$)
  B-Y ($B^+ Y^-$ and $Y^+ B^-$)
  Wh-Blk ($Wh^+ Blk^-$ and $Blk^+ Wh^-$)



opponent receptive fields

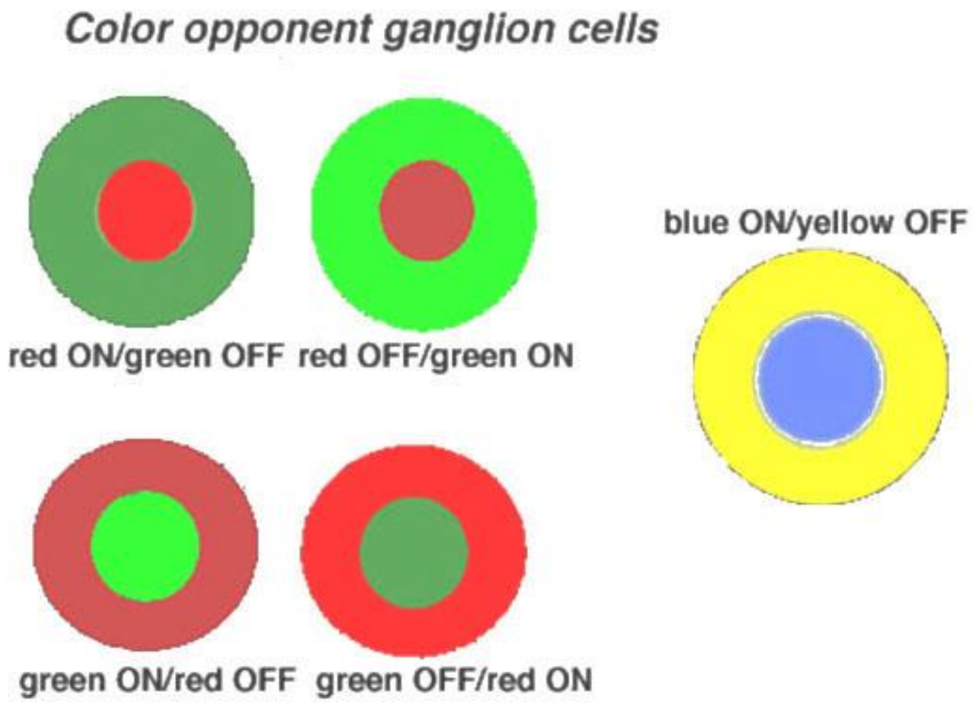


Fig. 18. Color-opponent units as recorded in monkey retina by Gouras (1968).

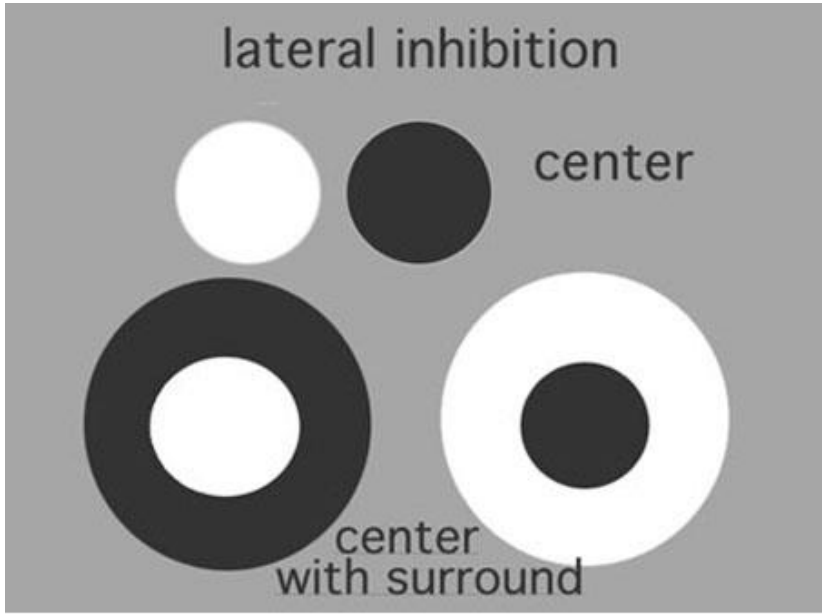
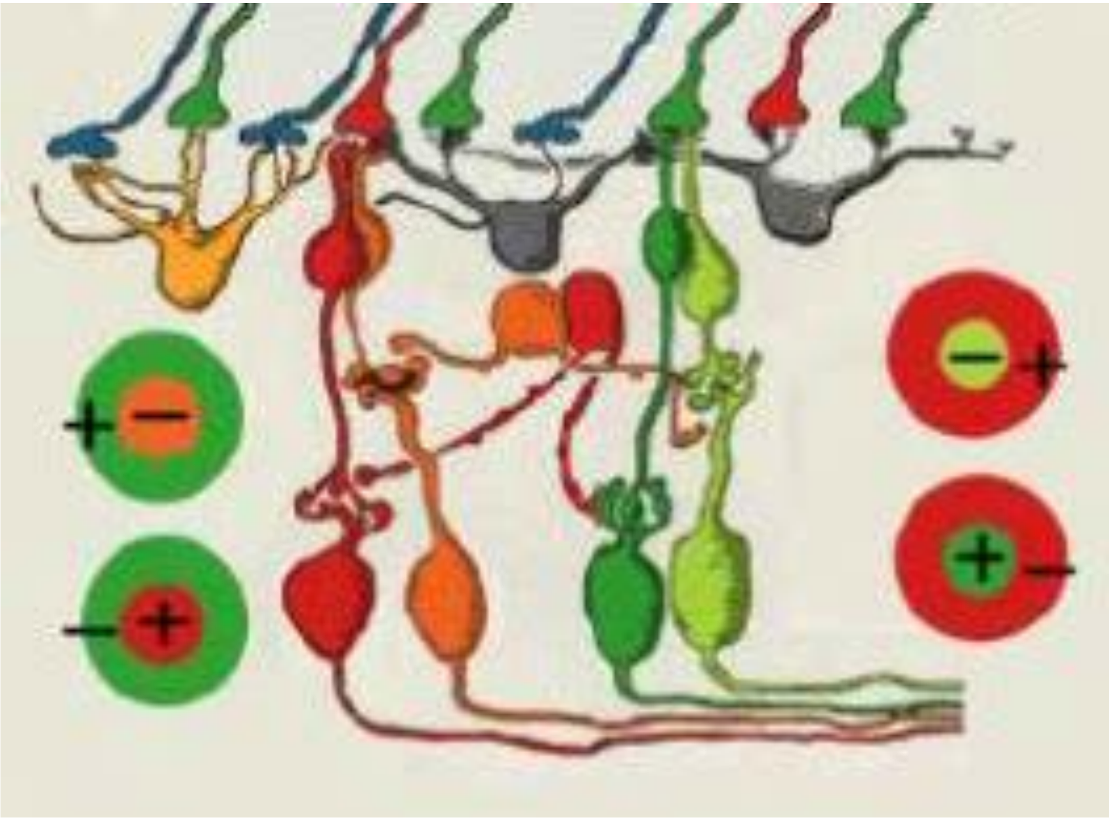


Fig. 10. Center-surround receptive fields can be ON center or OFF center with the oposite sign annular surround.

http://webvision.med.utah.edu/imageswv/simcontr.jpeg

http://webvision.med.utah.edu/wp-content/uploads/2011/03/colorop.jpeg

webvision R-G opponent animation



http://webvision.med.utah.edu/movies/Midget.mov

Young-Helmholtz vs Herring

Young

Helmholtz

VS

Herring

who was correct ????

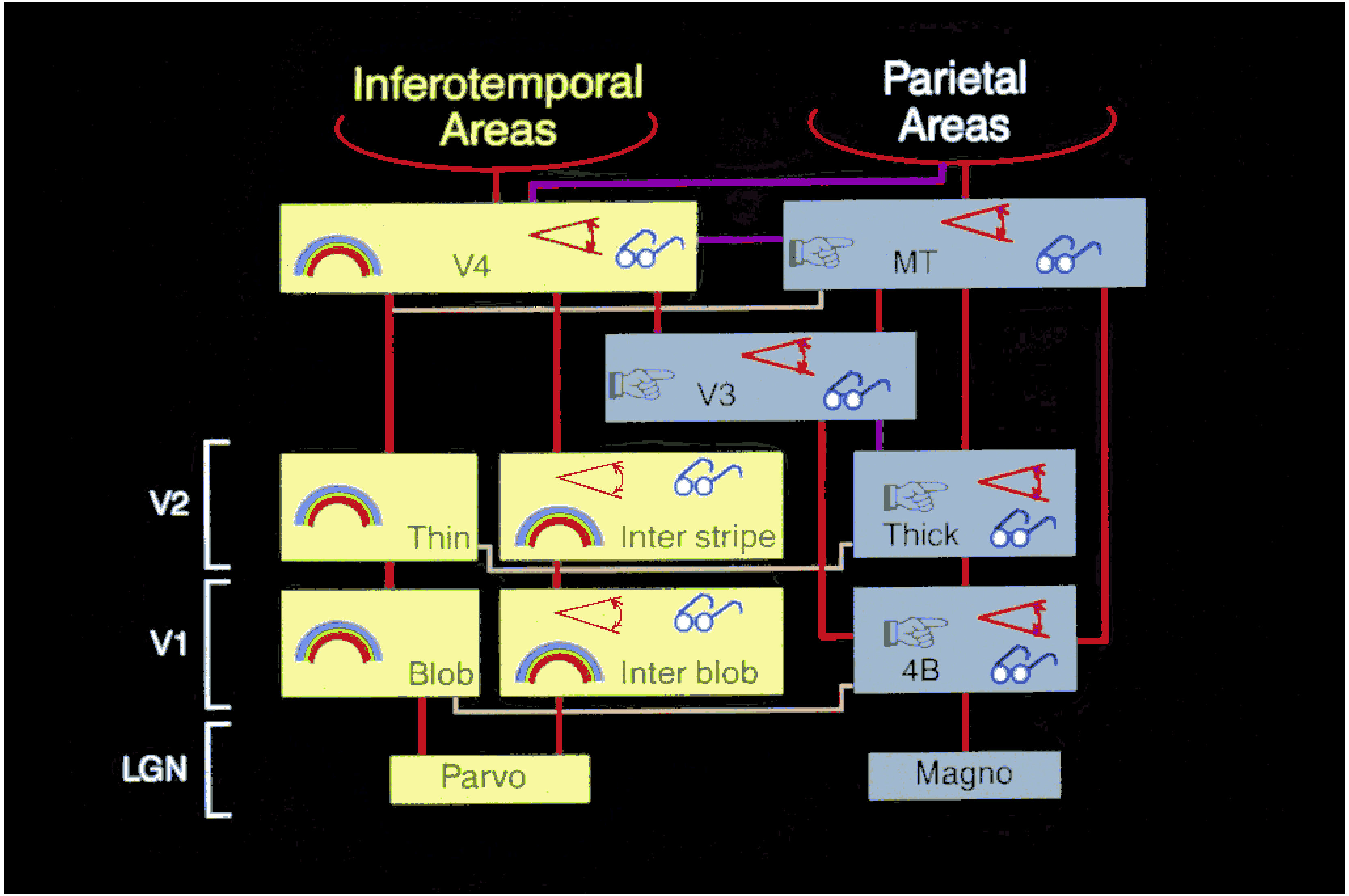
BOTH WERE !!!!!

✓ 7. What are color opponent cells?

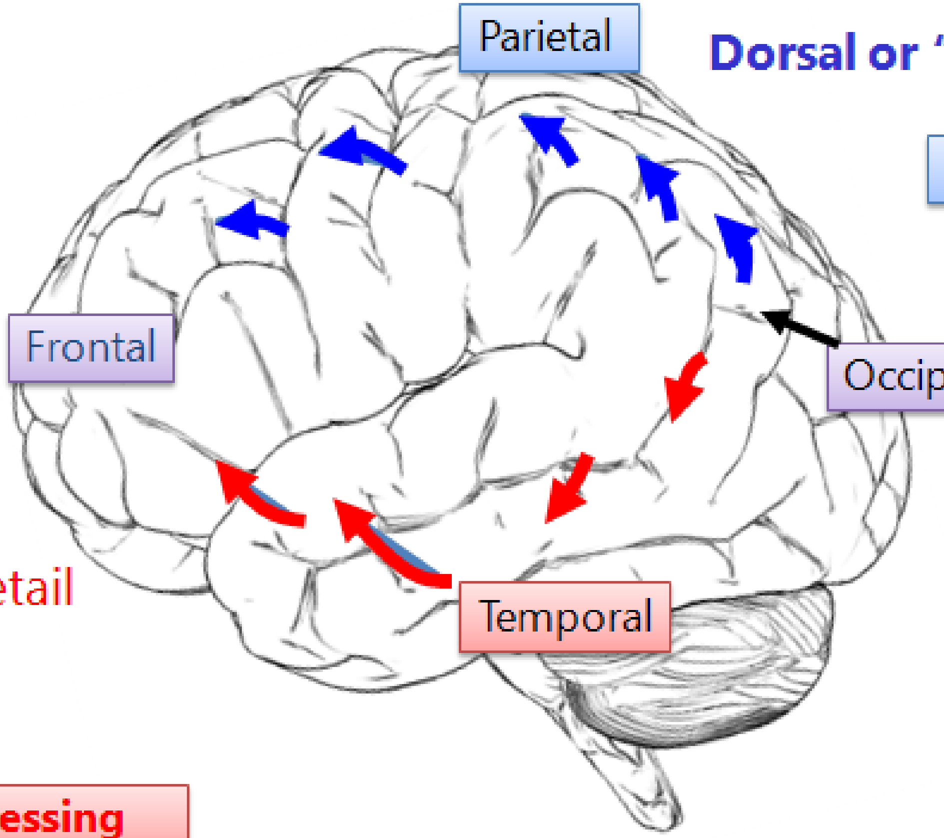
✓ 8. How do the Young-Helmholz and Herring theories of vision differ? Are they incompatible?

9. Which of the major “parallel pathways” transmits color information?

parvo – temporal/ventral pathway processes color



what *(temporal, ventral) pathway processes color*



http://www.nmr.mgh.harvard.edu/mkozhevnlab/?page_id=663

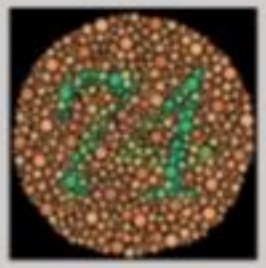
from lecture outline—color Blindness – Benham's disk

10. Know the following terms related to congenital color blindness:
    a. protanopia
    b. deuteranopia
    c. tritanopia
    d. protanomaly, deuteranomaly, tritanomaly

11. How is congenital color blindness inherited? Are men or women more likely to have inherited color blindness?

12. What is a possible explanation for Benham's color wheel?

class reports: color blindness

	Types of Color Blindness	Types of Color Blindness Report	~February 9th
	Heredity of Color Blindness	Heredity of Color Blindness Report	~February 9th

color blindness-- terms

10. Know the following terms related to congenital color blindness:

   a. protanopia
   b. deuteranopia
   c. tritanopia
   d. protanomaly, deuteranomaly, tritanomaly

Types of Color Blindness

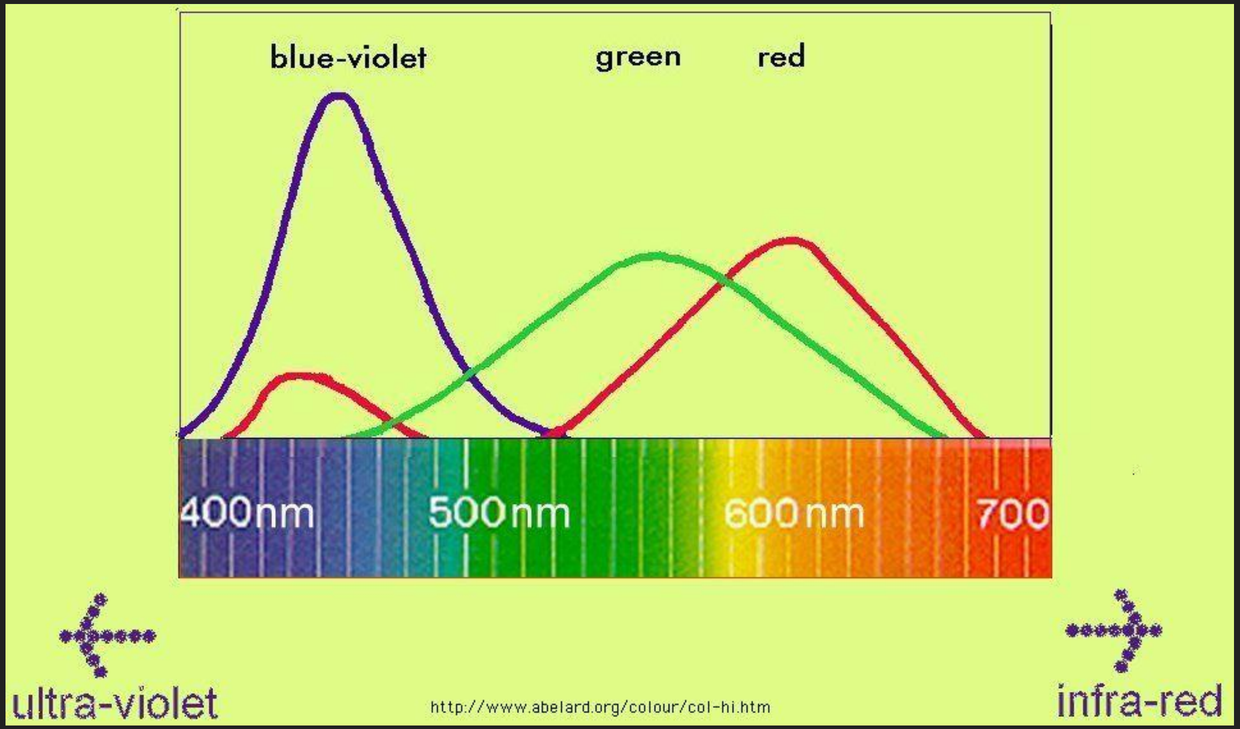
Maia Baltzley

There are three different wavelengths to sense different parts of the color spectrum

short wavelength (S): blue

medium wavelength (M): green

long wavelength (L): red



Basic Types

1. Trichromancy: Regular color vision
2. Anamolous Trichromancy: Mild color blindness
    a. One type of cone perceives light slightly out of alignment
    b. All colors are slightly off
3. Dichromancy: Only two of three cones are working
    a. One type of cone completely absent, other cone must compensate
    b. Colors are greatly distorted
4. Monochromacy: Cannot see color
    a. Everything is in different shades of grey
    b. No working color receptors

Anomolous Trichromancy

Mild color blindness

Types:

1. **Protanomaly:** defective L pigment (red)
   a. more likely to confuse red and green
2. **Deuteranomaly:** defective M pigment (green)
   a. shift toward L pigments
   b. confusion of red and green
3. **Tritanomaly:** defective S pigment (blue)
   a. extremely rare
   b. confusion of blue and yellow

Dichromancy

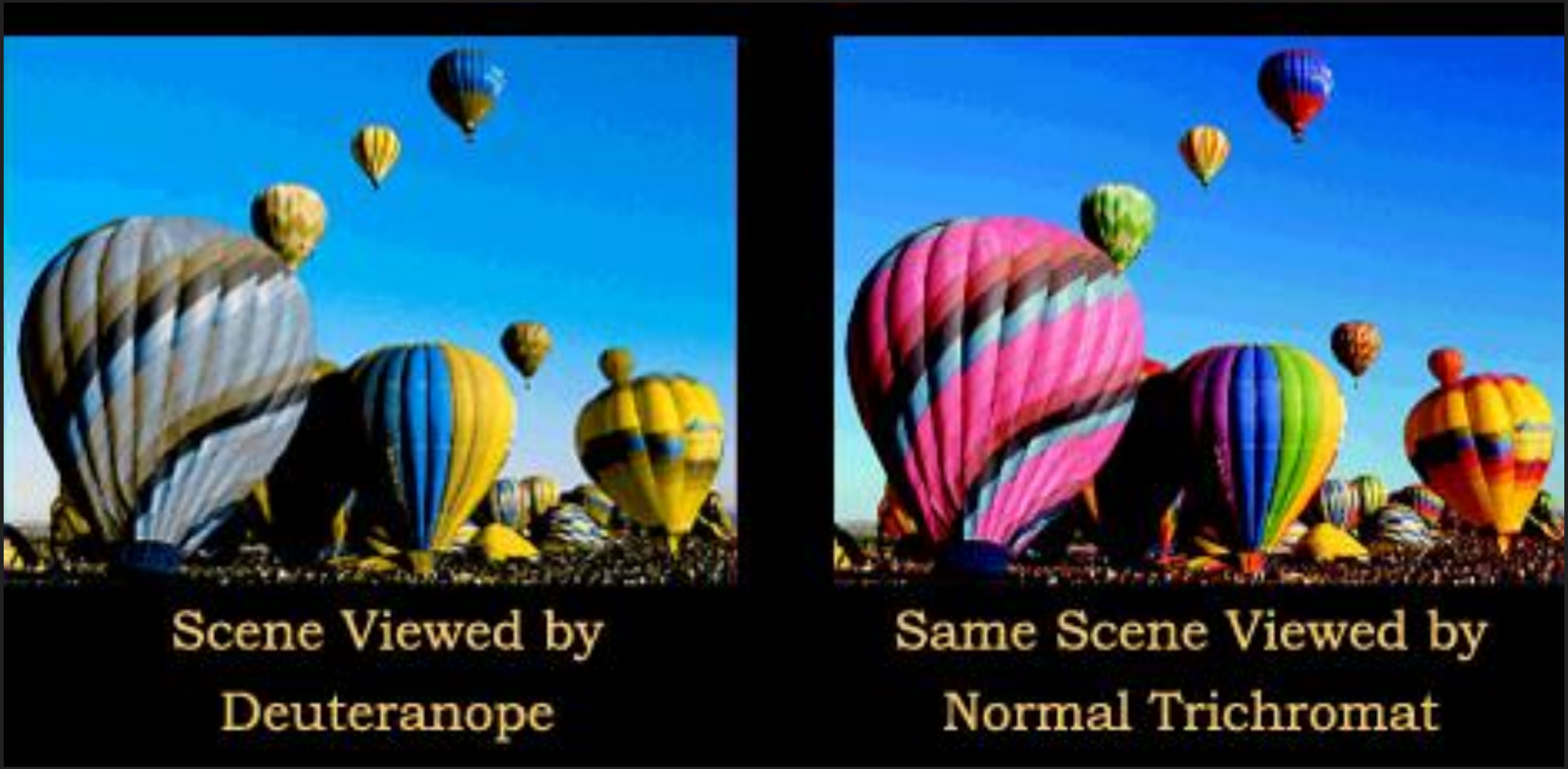
Those with a dichromatic deficiency can only mix and match colors with two primary colors instead of three

1. **Protanopia:** absence of long (L) wavelength photopigment (red), which is replaced by medium wavelength (green)
2. **Deuteranopia:** absence of M pigment (green), replaced by L pigment (red)
3. **Tritanopia:** absence of S pigment (blue)
   a. very rare
   b. cannot see blue or yellow

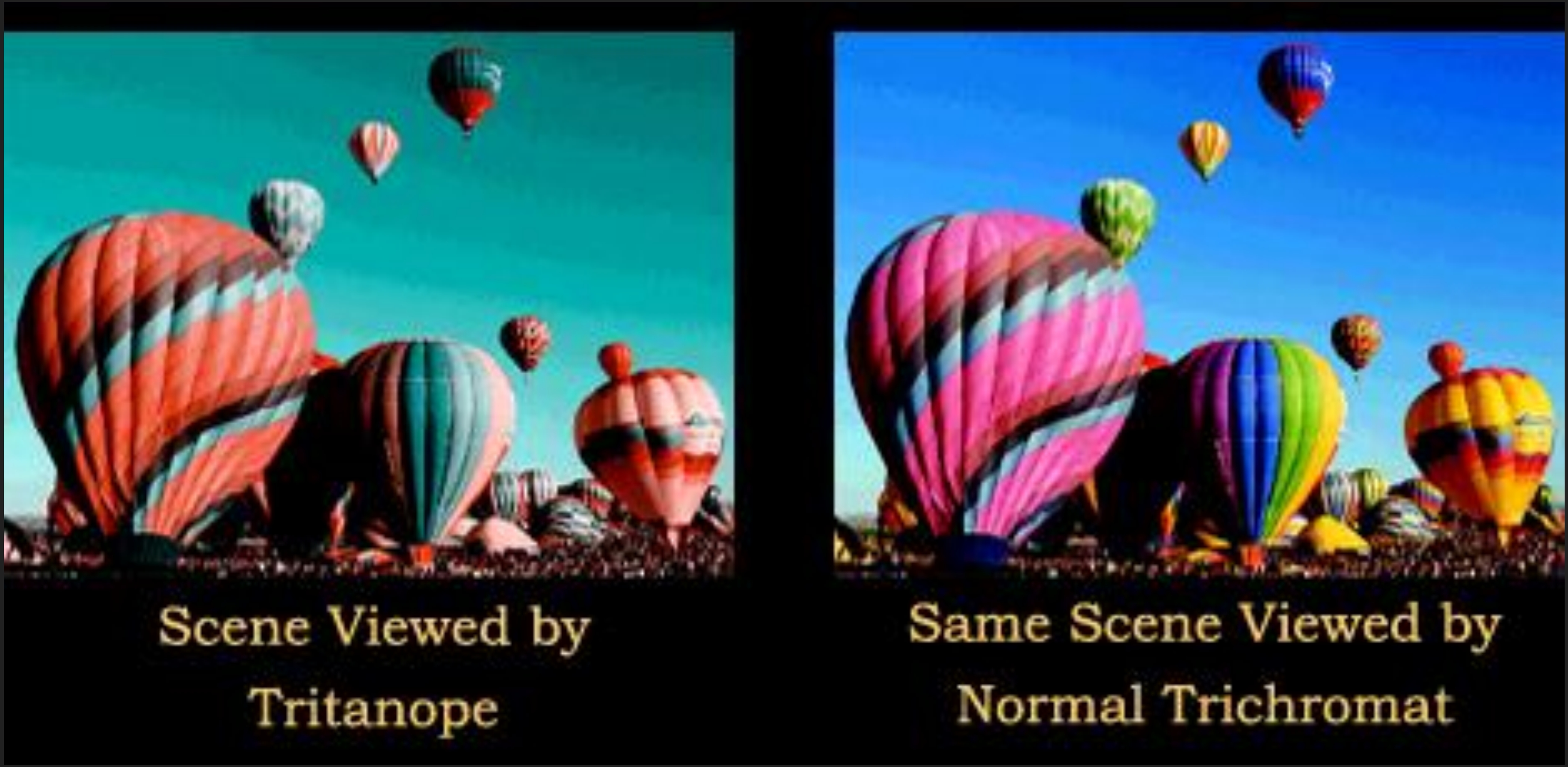
Protanopia


Scene Viewed by
Protanope
Same Scene Viewed by
Normal Trichromat

Deuteranopia



Tritanopia


Scene Viewed by
Tritanope
Same Scene Viewed by
Normal Trichromat

Color Blindness Tests

Ishara Plates Test

http://www.color-blindness.com/ishihara_cvd_test/ishihara_cvd_test.html?iframe=true&width=500&height=428

D-15 Test

http://www.color-blindness.com/color-arrangement-test/

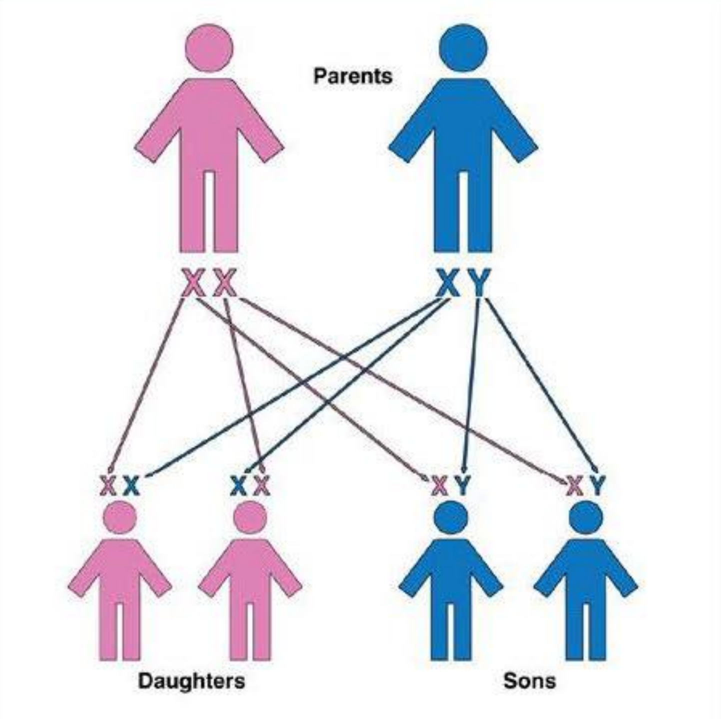
11. How is congenital color blindness inherited? Are men or women more likely to have inherited color blindness?

Color Blindness Heredity

By Winggo Tse

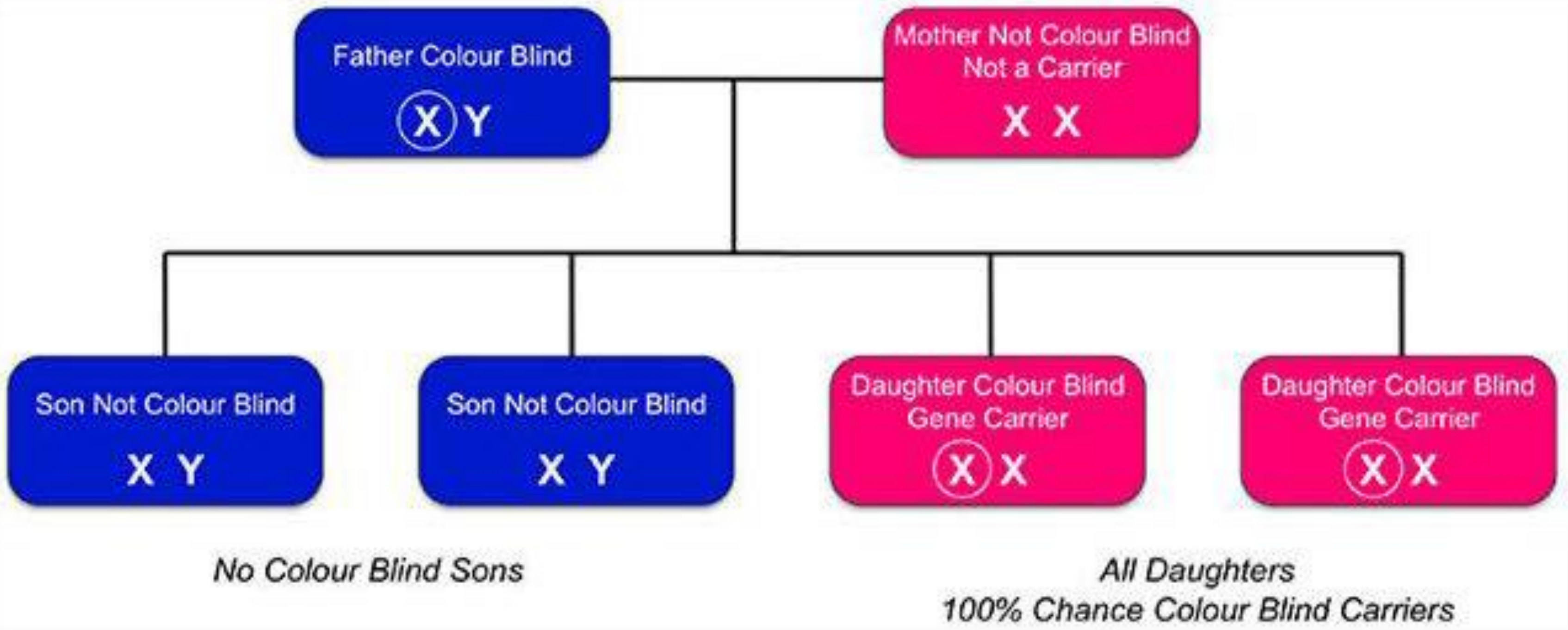
Parent-Child Heredity Pattern

- Red-green colorblindness is a common hereditary condition that is passed down through the 23rd chromosome, also known as the sex chromosome
- Each parent provides one of two parts of the chromosome
- The 23rd chromosome consists of 2 x-chromosomes if you are female or 1 x-chromosome and 1 y-chromosome if you are male

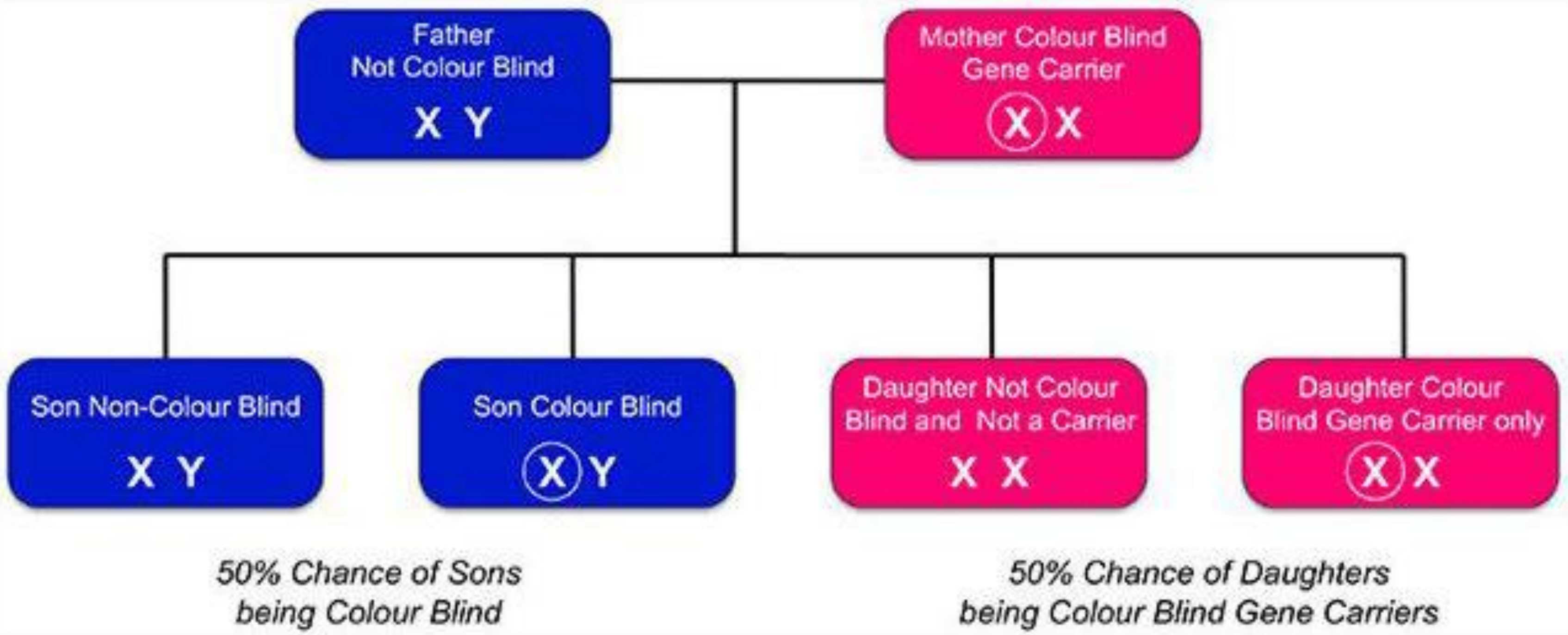


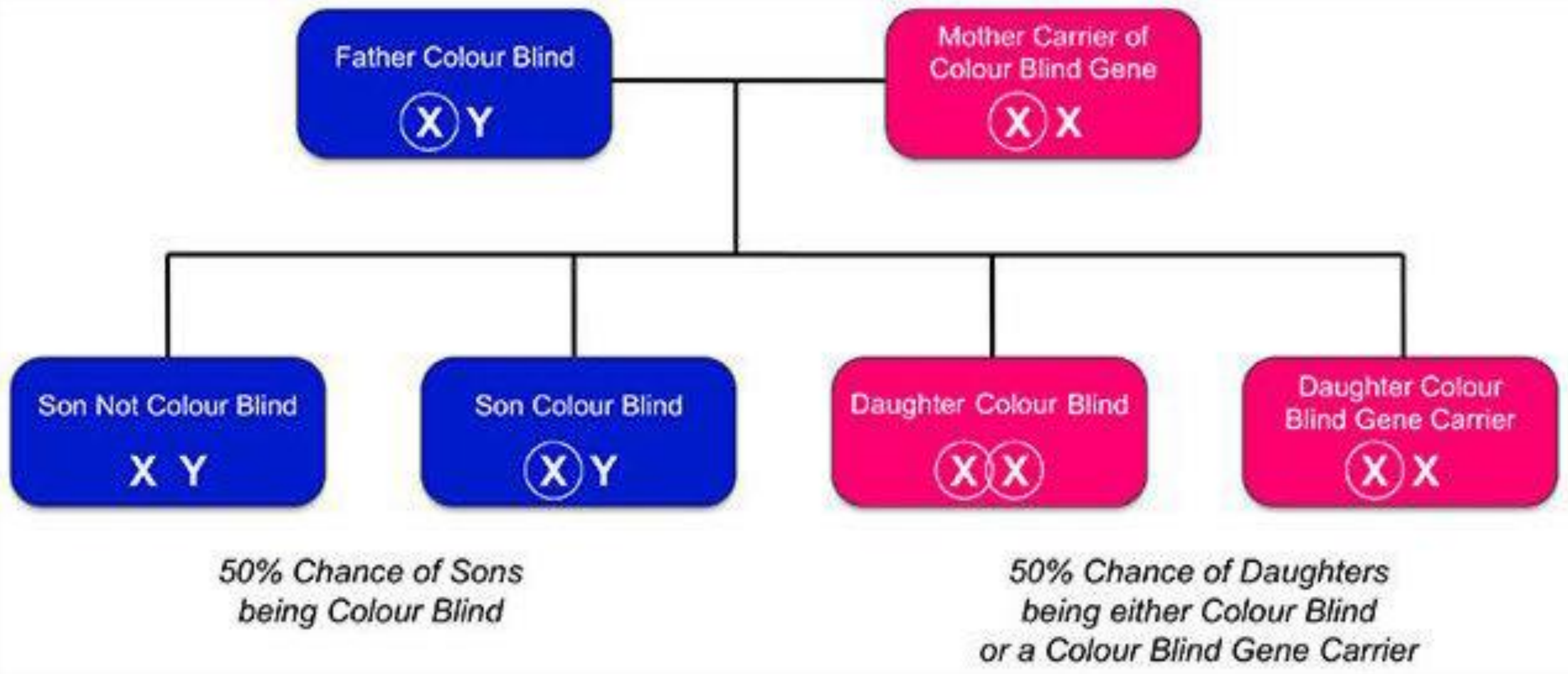
Parent-Child Heredity Pattern

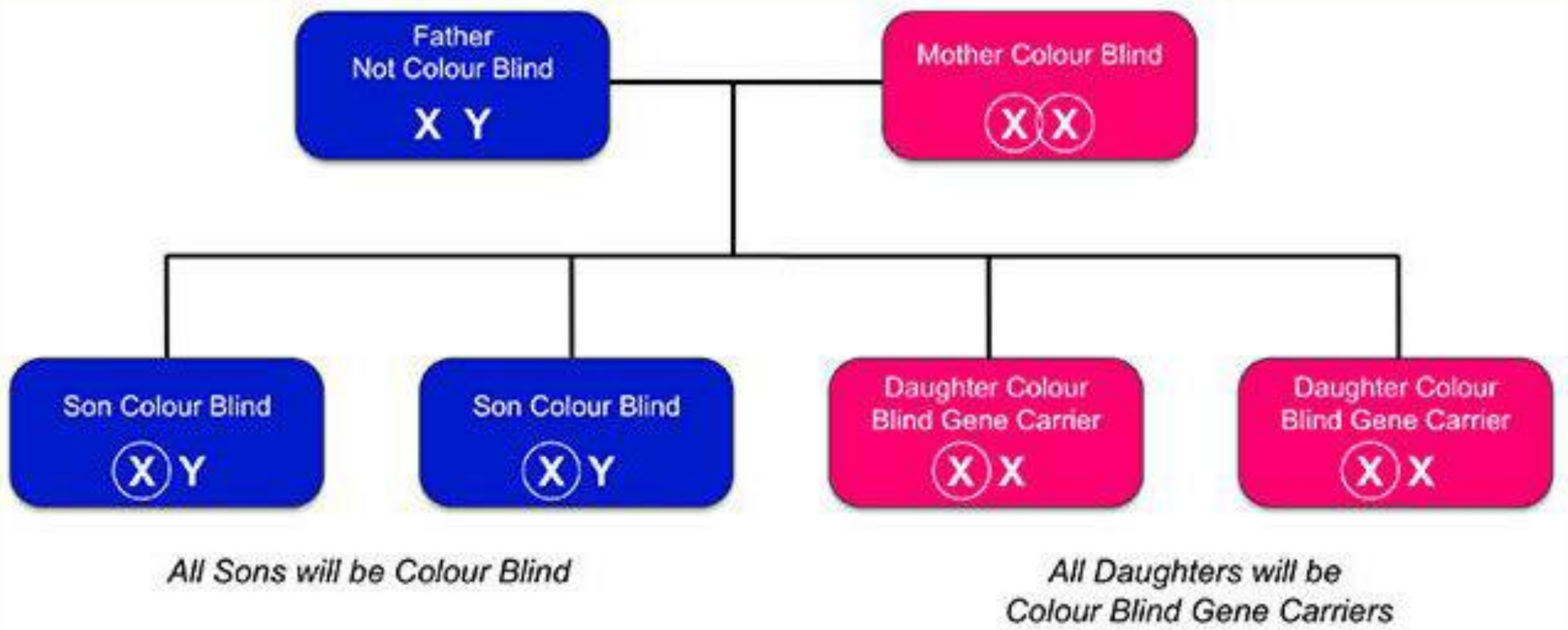
- The colorblind ‘gene’ is only found in the x-chromosome
  - Since males only have 1 x-chromosome, inheriting just one affected colorblind x-chromosome would make the male colorblind
  - Females have 2 x-chromosomes
    - both x-chromosomes need to be affected in order for the female to be colorblind
    - if only 1 x-chromosome is affected, the female is NOT colorblind but is a carrier for the colorblind gene



Father Colour Blind
X Y
Mother Not Colour Blind
Not a Carrier
X X
Son Not Colour Blind
X Y
Son Not Colour Blind
X Y
Daughter Colour Blind
Gene Carrier
X X
Daughter Colour Blind
Gene Carrier
X X
No Colour Blind Sons
All Daughters
100% Chance Colour Blind Carriers

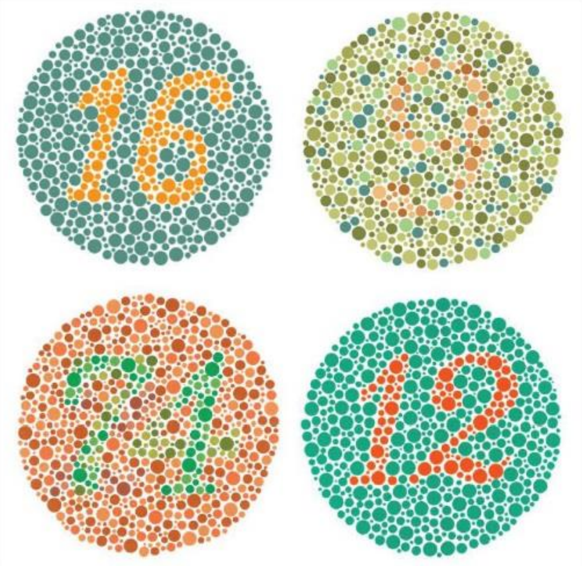

Father
Not Colour Blind
X Y
Mother Colour Blind
Gene Carrier
X X
Son Non-Colour Blind
X Y
Son Colour Blind
X Y
Daughter Not Colour
Blind and Not a Carrier
X X
Daughter Colour
Blind Gene Carrier only
X X
50% Chance of Sons
being Colour Blind
50% Chance of Daughters
being Colour Blind Gene Carriers


Father Colour Blind
X Y
Mother Carrier of Colour Blind Gene
X X
Son Not Colour Blind
X Y
Son Colour Blind
X Y
Daughter Colour Blind
X X
Daughter Colour Blind Gene Carrier
X X
50% Chance of Sons being Colour Blind
50% Chance of Daughters being either Colour Blind or a Colour Blind Gene Carrier


Father
Not Colour Blind
X Y
Mother Colour Blind
X X
Son Colour Blind
X Y
Son Colour Blind
X Y
Daughter Colour Blind Gene Carrier
X X
Daughter Colour Blind Gene Carrier
X X
All Sons will be Colour Blind
All Daughters will be Colour Blind Gene Carriers

Numbers of men vs. women who are colorblind

- Much higher chance of colorblindness in males because males only have 1 x-chromosome in the 23rd chromosome
- Color Vision Deficiency(CVD) affects 1 in 8 males(12%) and 1 in 200 females(0.5%)



Rod Monochromacy(Achromatopsia)

Characterized by:

- complete color blindness
- involuntary eye movements
- the rods and cones your vision relies on don't work properly
- irregular distribution of rods and cones
- affects ~1 in 40,000 people

Blue-cone Monochromacy

- Caused by faulty genes responsible for L and M cones
- Only rods and S cones (blue) are able to function and transmit color information
- Results in Complete blindness except in situations when rods and S cones are able to function
- found ~1 in 100,000 men and unknown for women
- intolerance to light
- very similar to rod monochromacy

color vision in birds

	Tetrachromatic Vision in Brids	What Birds See Report	~February 9th

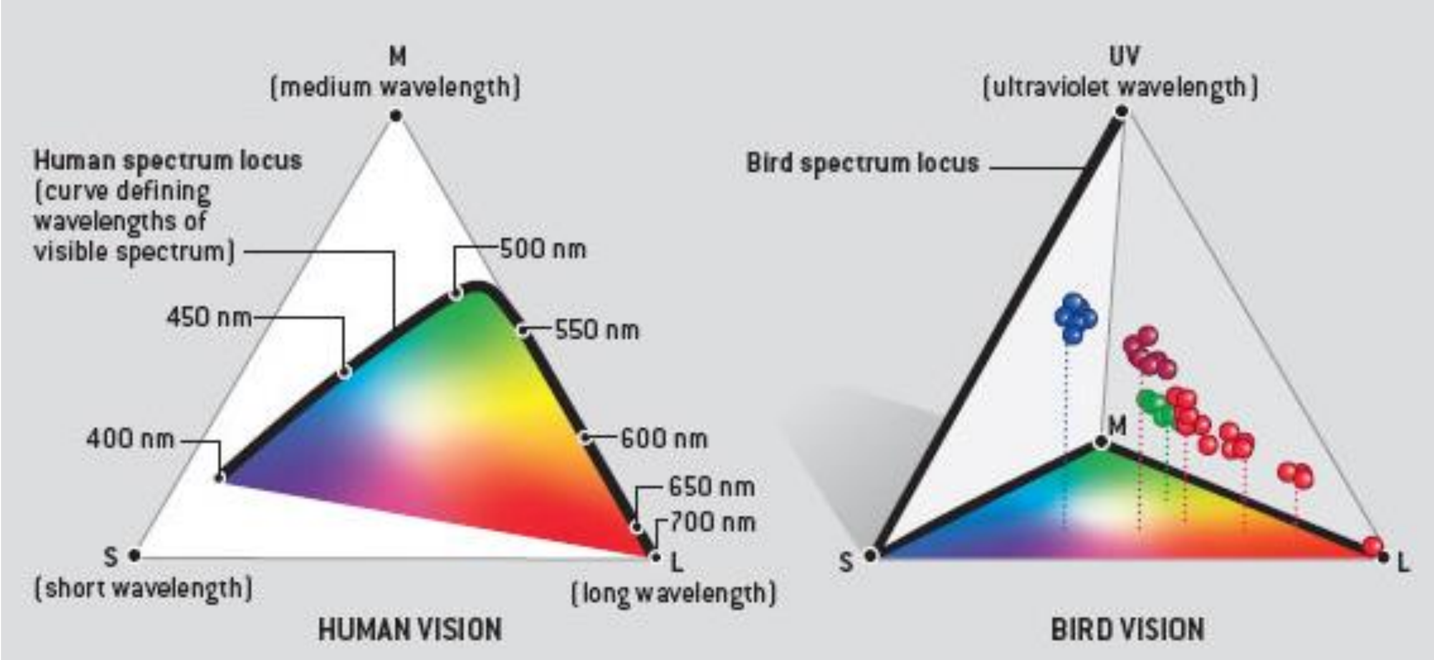
What Birds See

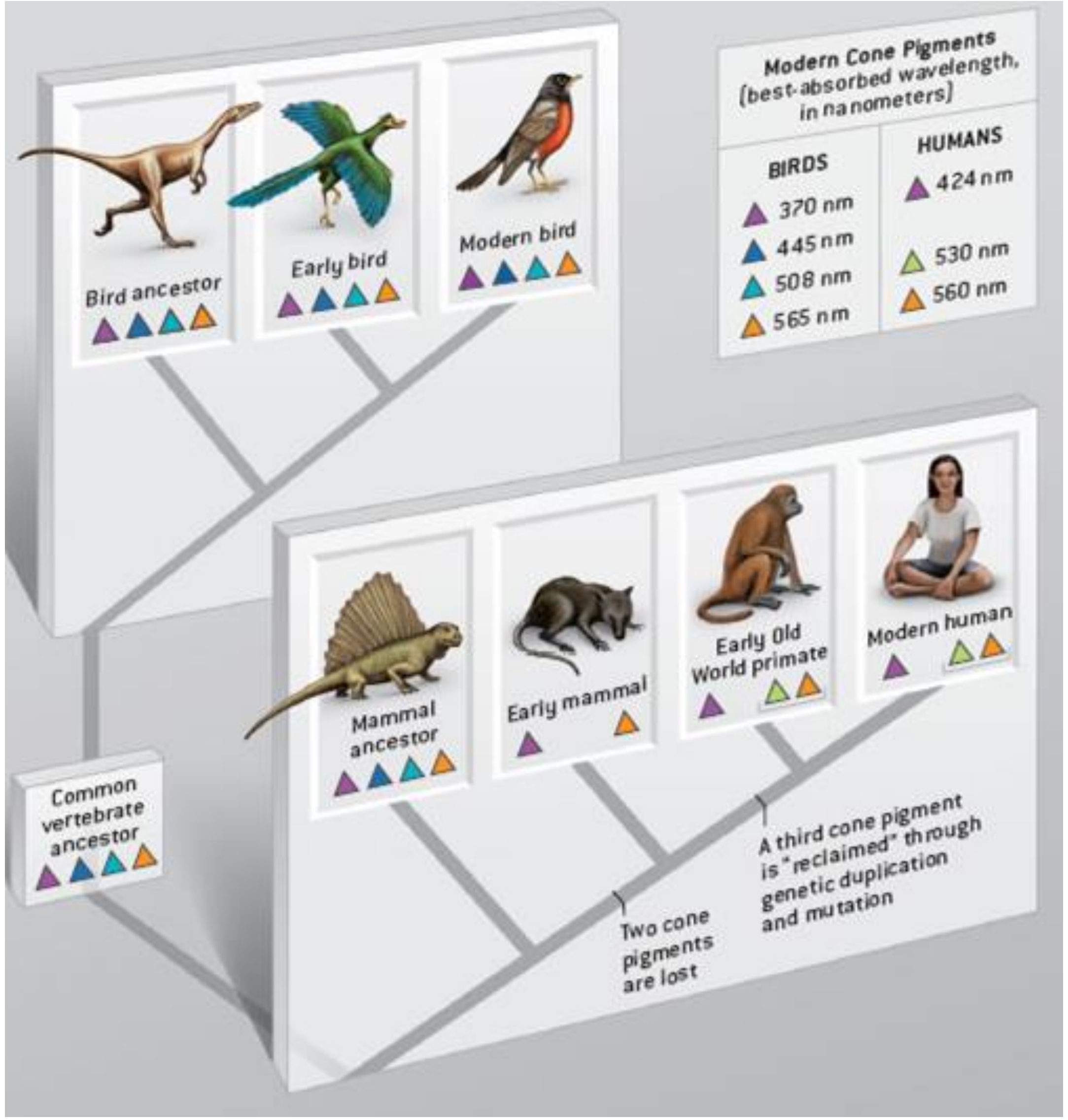
Matthew Kuzara

Spectra Pigments in Birds

Birds have four spectrally different cone pigments, including ultraviolet

- 3 cones detect long-wavelengths
- 1 cone detects ultraviolet
  - 300-400nm
- Vastly enhances vision of birds





Evolutionary Changes

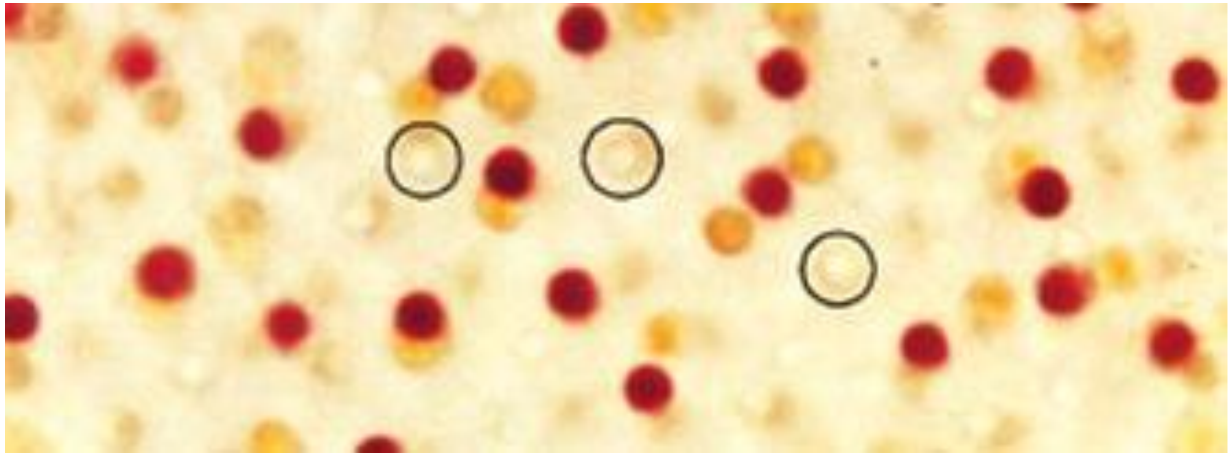
- Early vertebrates had four cones
  - Mammals lost two
    - Humans recovered one
  - Birds retained all

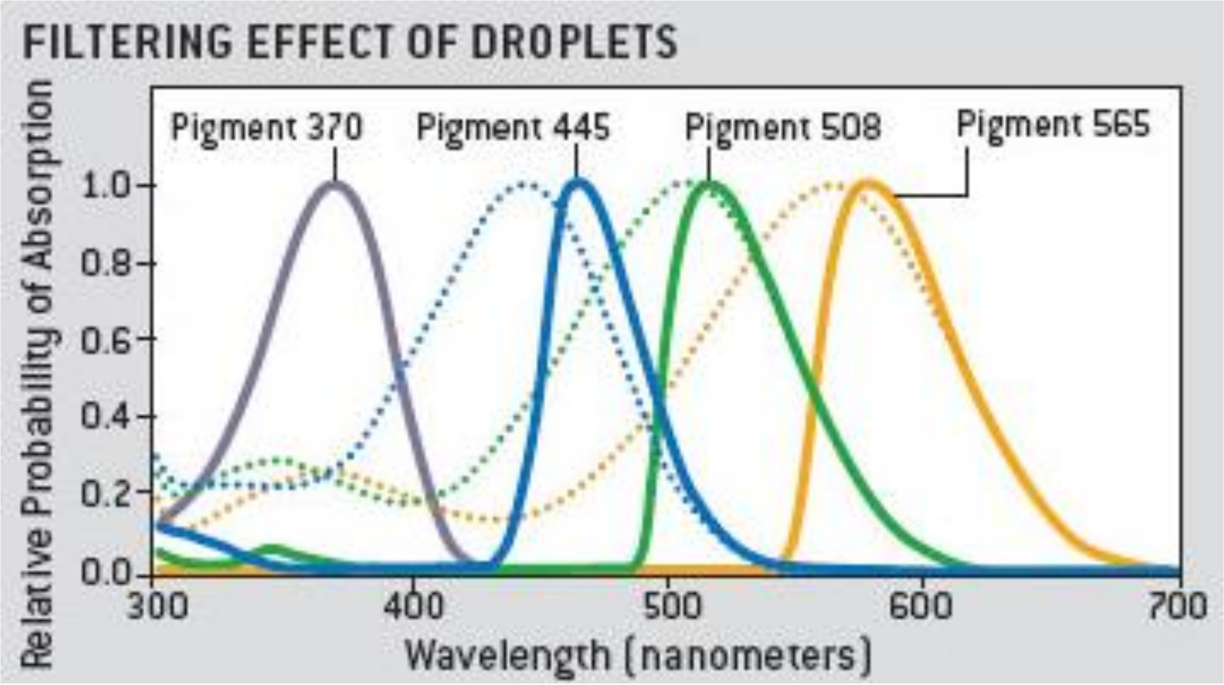
- Most sensitive to the following:
  1. 370nm (UV)
  2. 445nm
  3. 508nm
  4. 565nm

Avian Oil Droplets

- Each cone contains an **oil droplet**
  - contains high concentrations of **carotenoids**

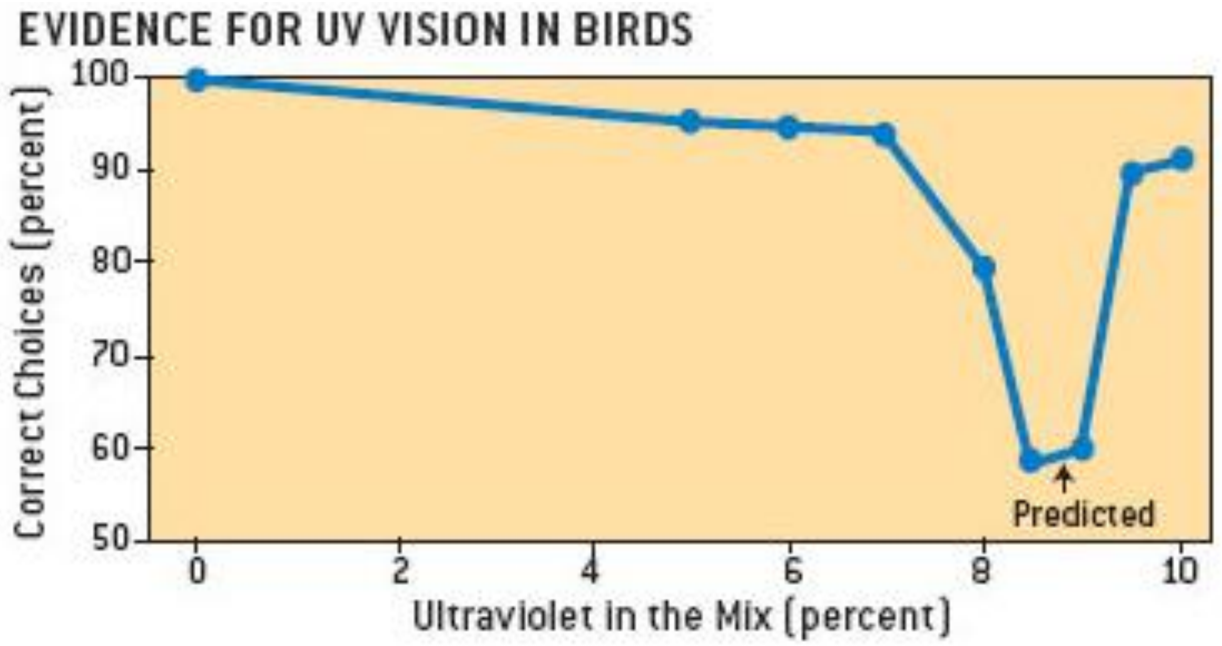
- Droplets filter out short wavelengths
  - Reduces overlap
  - More distinguishable colors

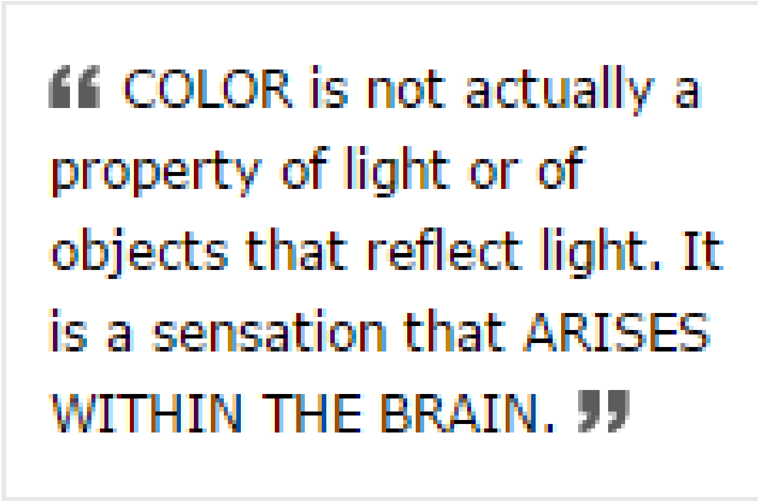




Testing for Tetrachromatic Vision

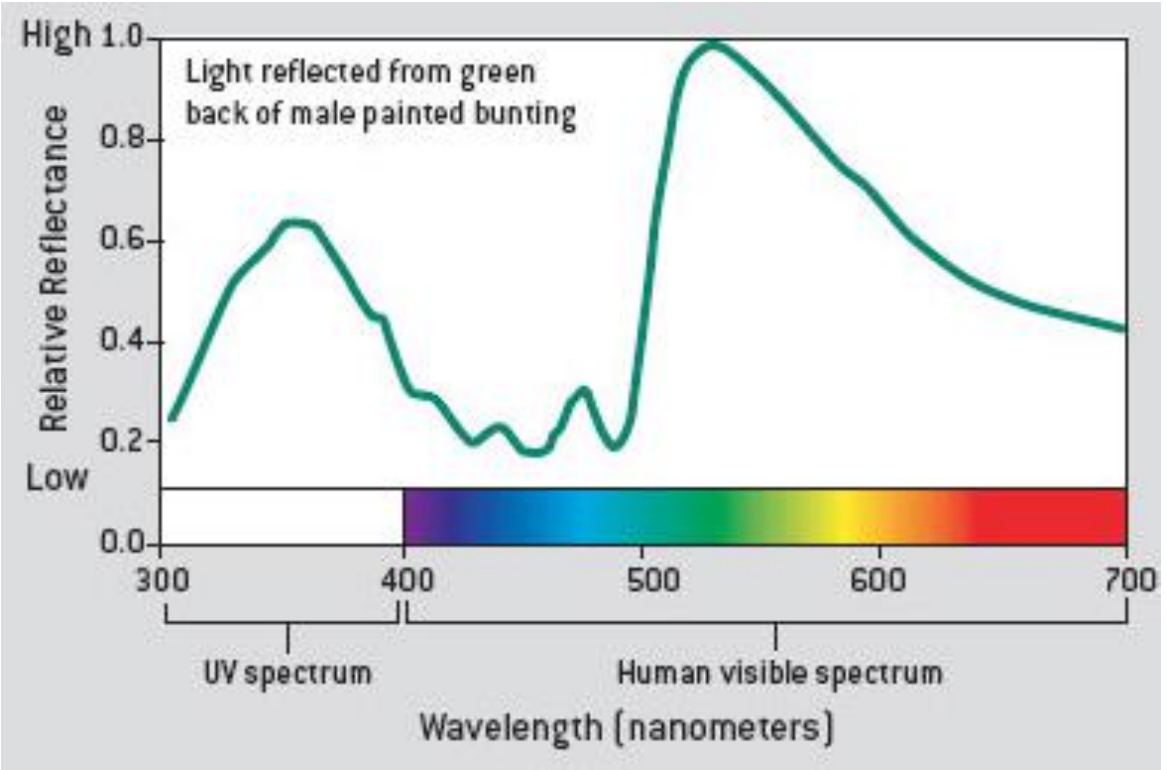
- Color is perceived by comparing response from two or more cones w/differing pigments
  - Allows for **color matching**
- Yellow light creates a response replicable with a mixture of red and green light
  - Violet light is replicable through a mixture of blue and ultraviolet





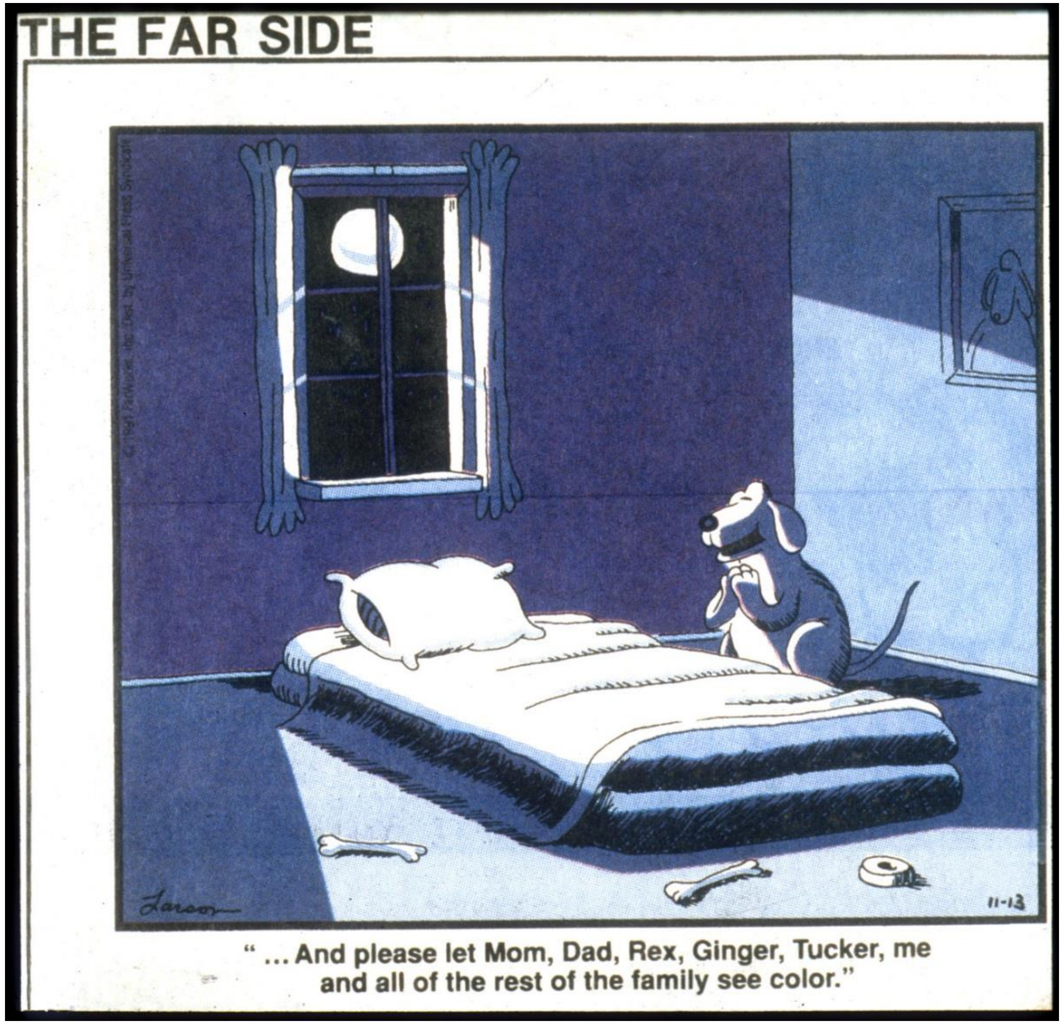
Behavioral Aspects of Tetrachromatic Vision

- Wider spectrum of colors
- Plays a role in mate selection
  - Females attracted to males with brightest UV reflectance
- Foraging and tracking food
  - Fruits and berries reflect UV light
  - Some prey leave behind UV trails



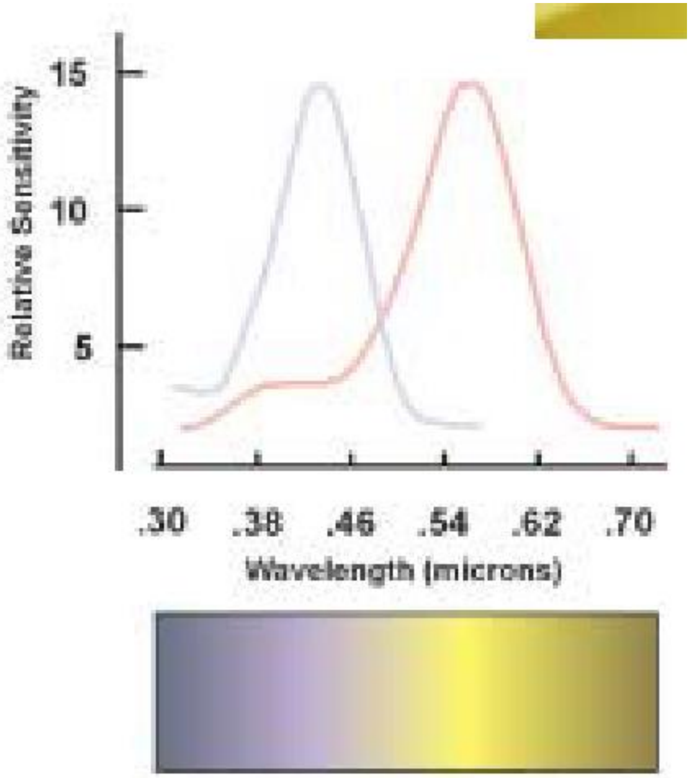
Any questions?

another bad joke



"... And please let Mom, Dad, Rex, Ginger, Tucker, me and all of the rest of the family see color."

animal psychophysics of wavelength discrimination



Neitz, J., Carroll, J., & Neitz, M. (2001).Color Vision: Almost Reason Enough for Having Eyes, Optics and Photonics News 12:26-33.

YES, FiFi la chienne can discriminate colors !!

Visual Neuroscience (1989), **3**, 119–125. Printed in the USA.

Color vision in the dog

JAY NEITZ, TIMOTHY GEIST, AND GERALD H. JACOBS
Department of Psychology, University of California, Santa Barbara

(RECEIVED February 28, 1989; ACCEPTED April 19, 1989)

Abstract

The color vision of three domestic dogs was examined in a series of behavioral discrimination experiments. Measurements of increment-threshold spectral sensitivity functions and direct tests of color matching indicate that the dog retina contains two classes of cone photopigment. These two pigments are computed to have spectral peaks of about 429 nm and 555 nm The results of the color vision tests are all consistent with the conclusion that dogs have dichromatic color vision.

gene therapy for colorblindness

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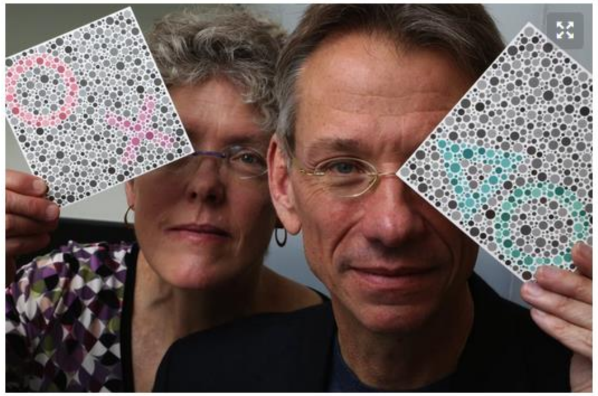
Health | Local News

UW scientists, biotech firm may have cure for colorblindness

Originally published April 11, 2015 at 3:45 pm

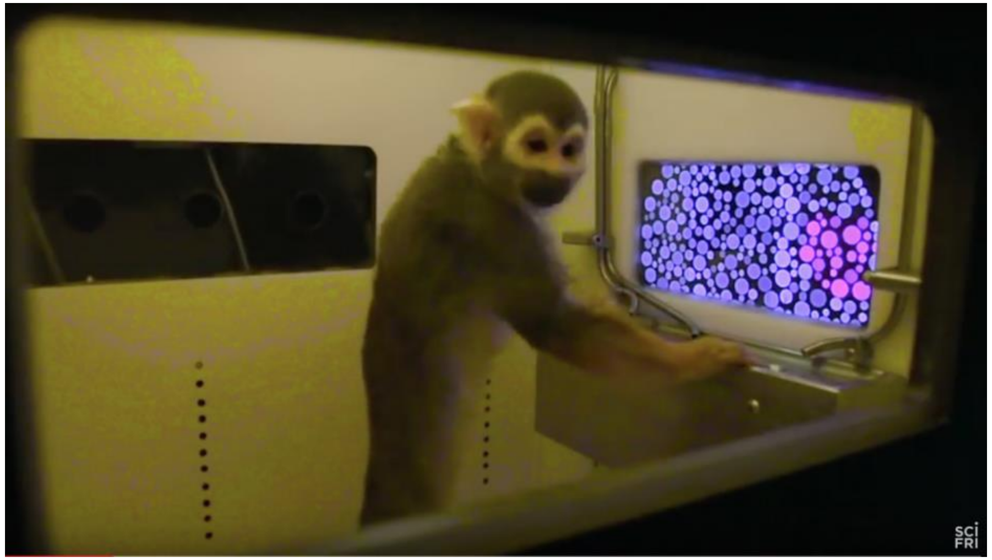


University of Washington researchers Jay and Maureen Neitz, seen holding testing cards for color perception, have teamed with a California biotech company for a prospective gene-therapy cure for colorblindness. (Ken Lambert/The Seattle Times)

A pair of researchers at the Univeristy of Washington have successfully cured colorblindness in two squirrel monkeys.

00:00 04:39

This story is based on a radio interview. Listen to the full interview. PRI

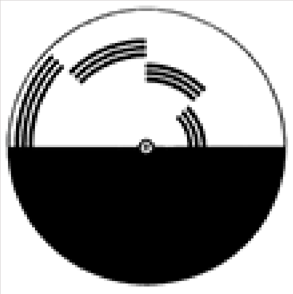


https://youtu.be/EgPMc90uXlU

http://www.pri.org/stories/2015-09-20/cure-colorblindness-may-be-sight

Benham’s disk

12. What is a possible explanation for Benham’s color wheel?

	Benham's Disk	Benham's Disk Report	~February 9th

Benham’s Disk

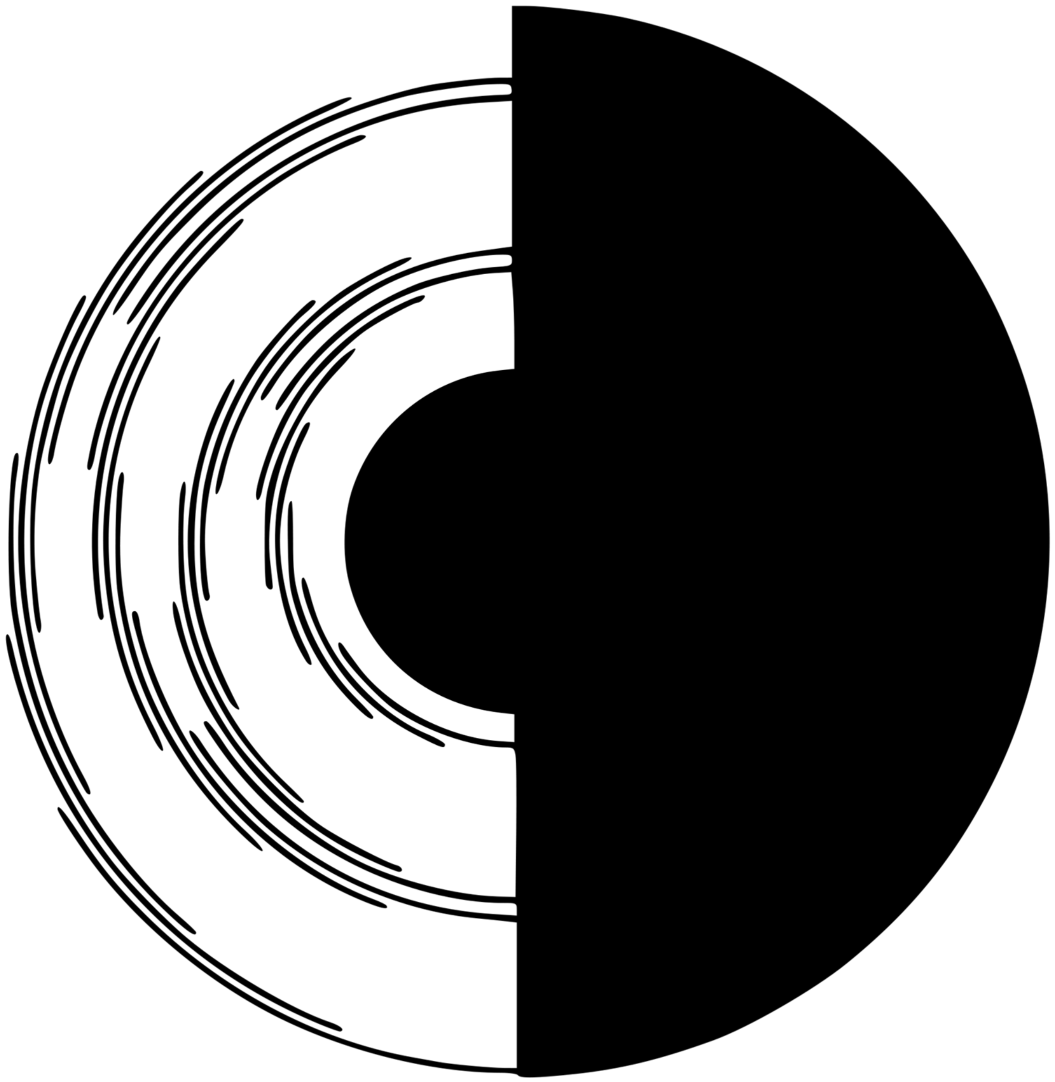
Bryant Mohan
Crown 85

What is it?

English toymaker Charles Benham sold a top with this pattern on it.

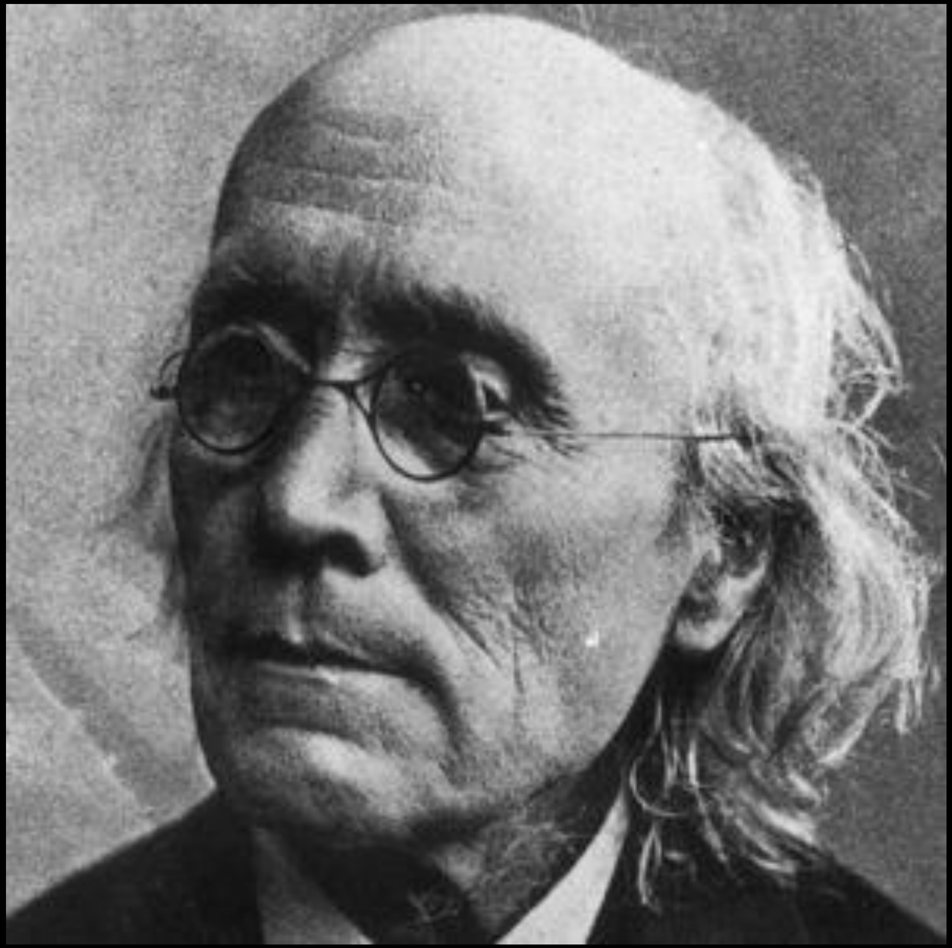
When it spins, arcs of pale color become visible on different parts of the disk.

Not everyone sees the exact same colors.



The Fechner Color Effect

- Also called pattern-induced flicker colors (PIFCs), it is an illusion of color created with rapidly moving or changing black and white patterns.
- Dr. Gustav Theodor Fechner discovered this effect. Benham later created a more intricate, detailed example.



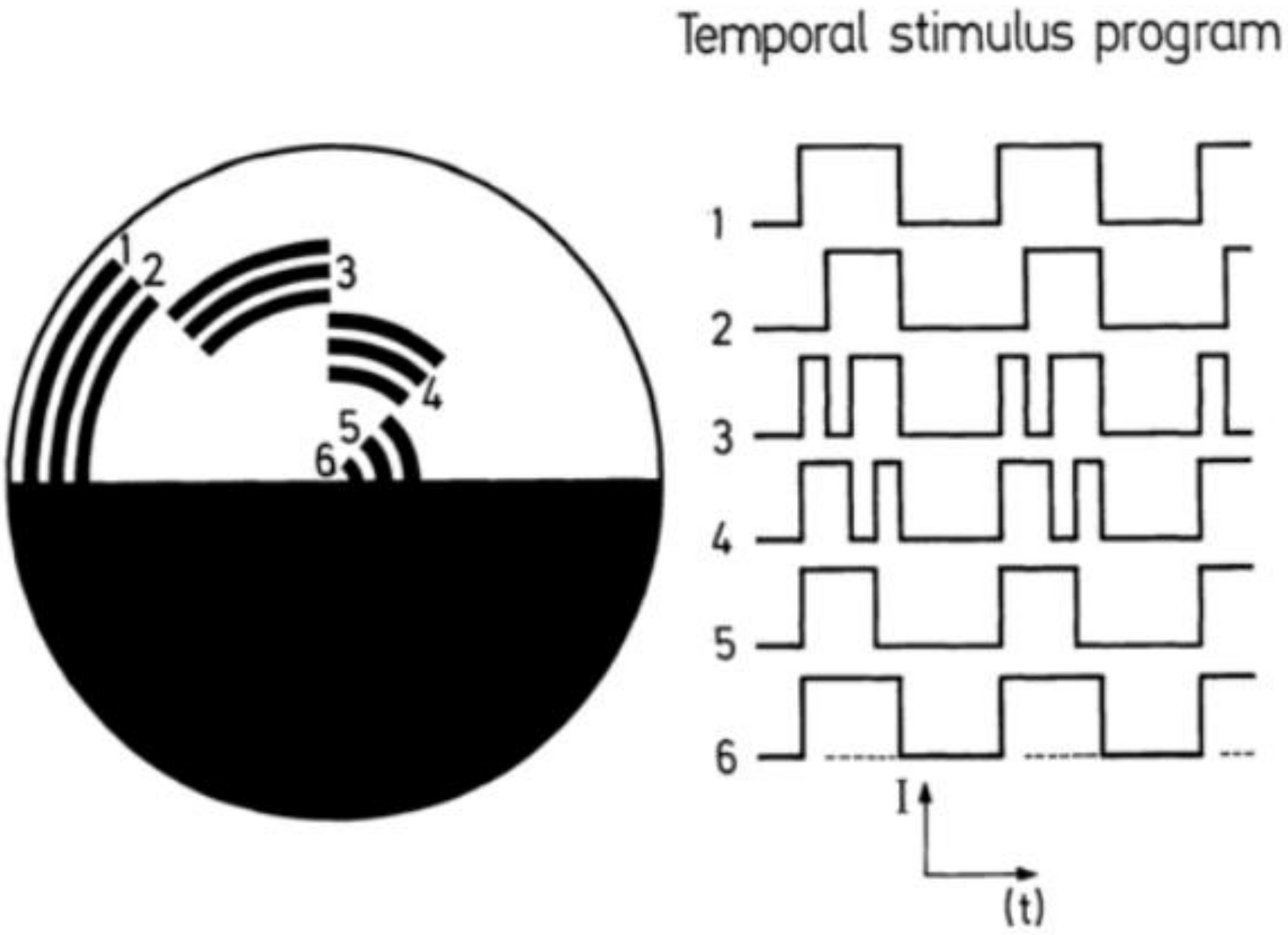


Fig. 11. *Benham top (A) and the temporal stimulus program (B)* of the different sector parts, when the disc is rotated clockwise

What Causes the Fechner Color Effect?

Scientists still aren't 100% sure about the exact causes

Definitely has to do with differing rates of stimulation for different color specific retinal ganglion cells and lateral inhibition.

The ganglion cells translate patterns of light into patterns of nerve firing.

Lateral inhibition is when an excited neuron reduces the activity of its neighbors, causing action potentials not to spread laterally.

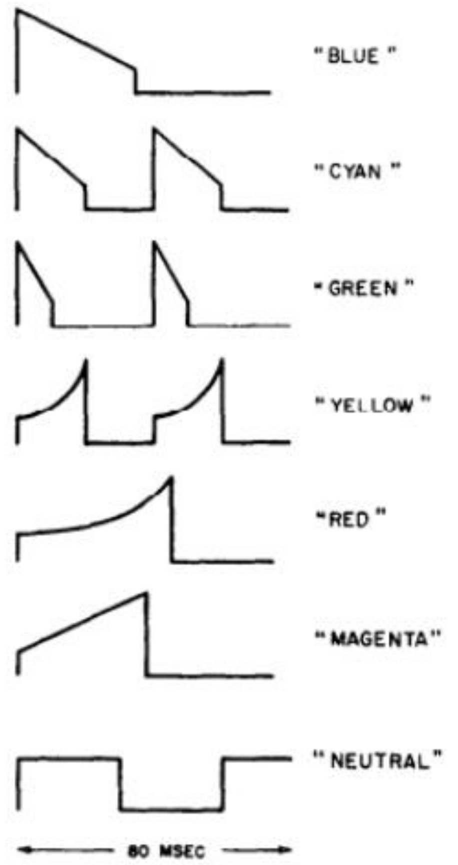
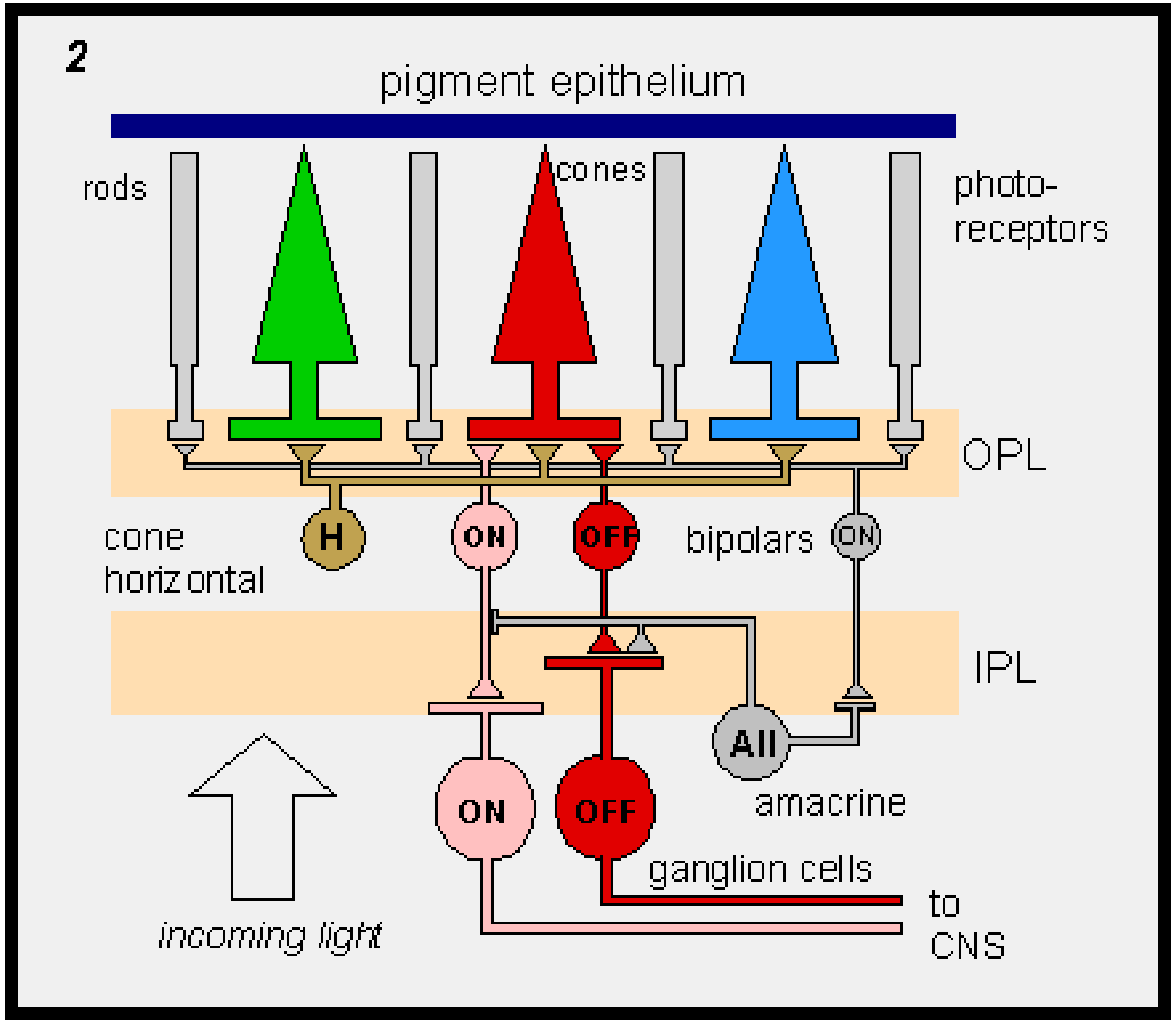


Fig. 11. Smoothed approximations to temporal signals used with constant background.

Rates of Stimulation for Different Color-Specific Ganglion Cells

The chemical reactions in the different color-specific cones happen at different rates, “red” reaction stops faster than blue and green.

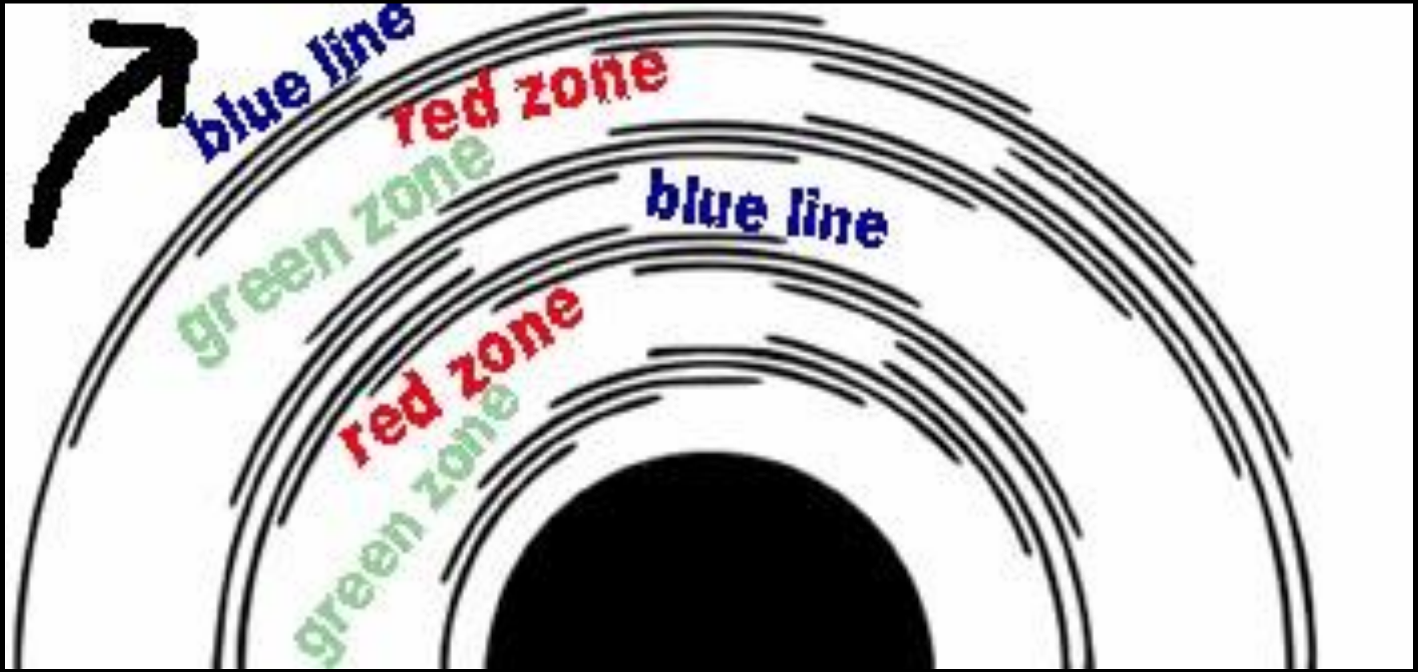
When white light goes away, “red” reactions stop first, but when white light appears, red appears quicker than blue and green.



Application to Benham's Disk

When the patterns move, white turning to black makes white light appear slightly blue-green, but black turning to white makes white light appear slightly red.

The different patterns make different colors appear at different times, creating different combinations of color.



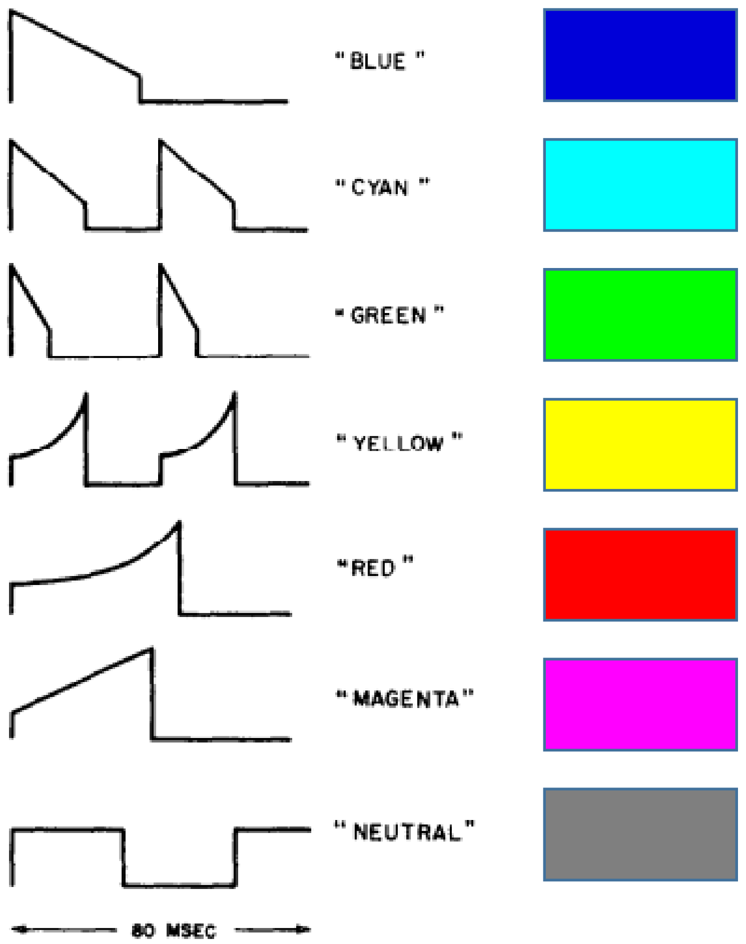


FIG. 11. Smoothed approximations to temporal signals used with constant background.

THE PERCEPTION OF COLOR WITH ACHROMATIC STIMULATION'
LEON FESTINGER, MARK R. ALLYN and CHARLES W. WHITE

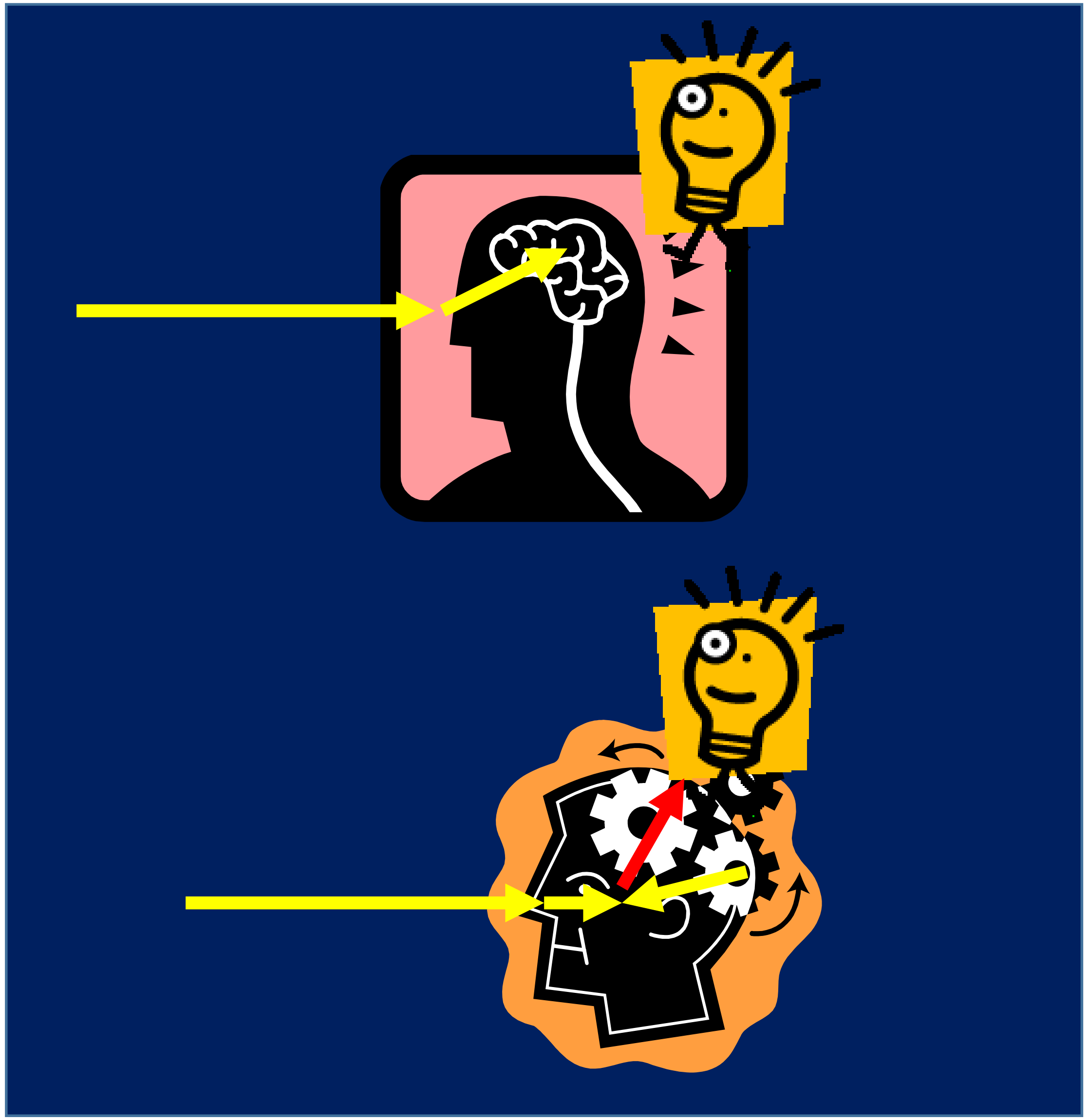
Yision Res. Vol. 11. pp. 591-612. Perpamon Press 1971.
Printed in Great Britain

13. Distinguish between bottom-up and top-down processing.

14. How are the following factors involved in various visual illusions?
    a. illusions with explicitly known physiological origins
    b. illusions consistent with perceptual overestimation of acute angles
    c. context or association including size constancy

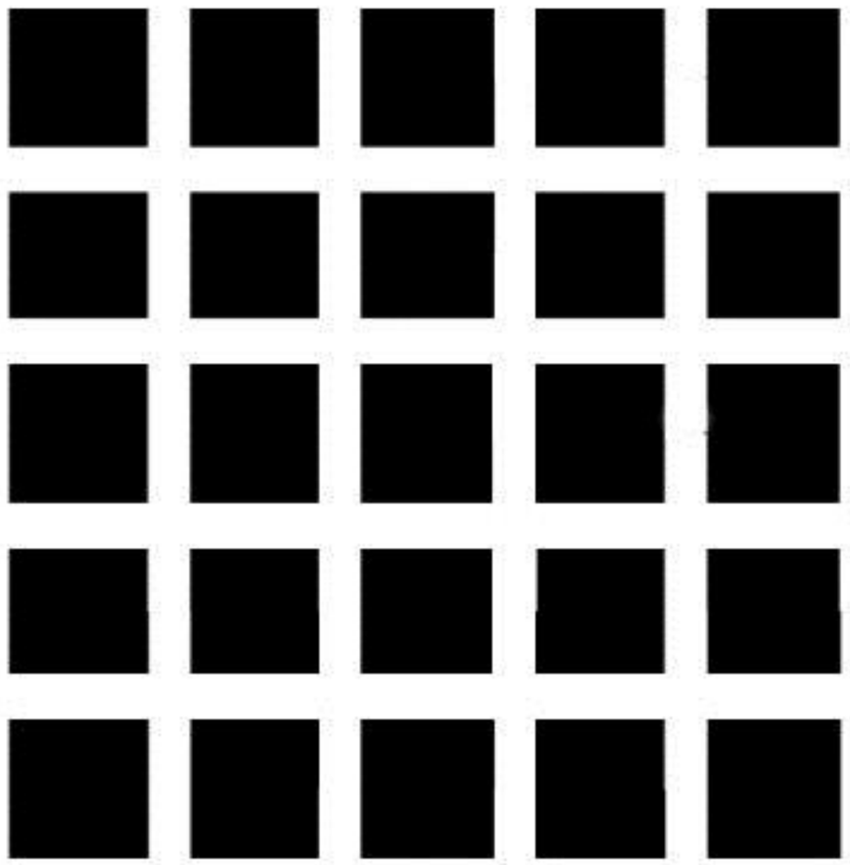
major classes of illusions

- **Physiological basis (mostly bottom up)**
- **Context and expectations (top down)**

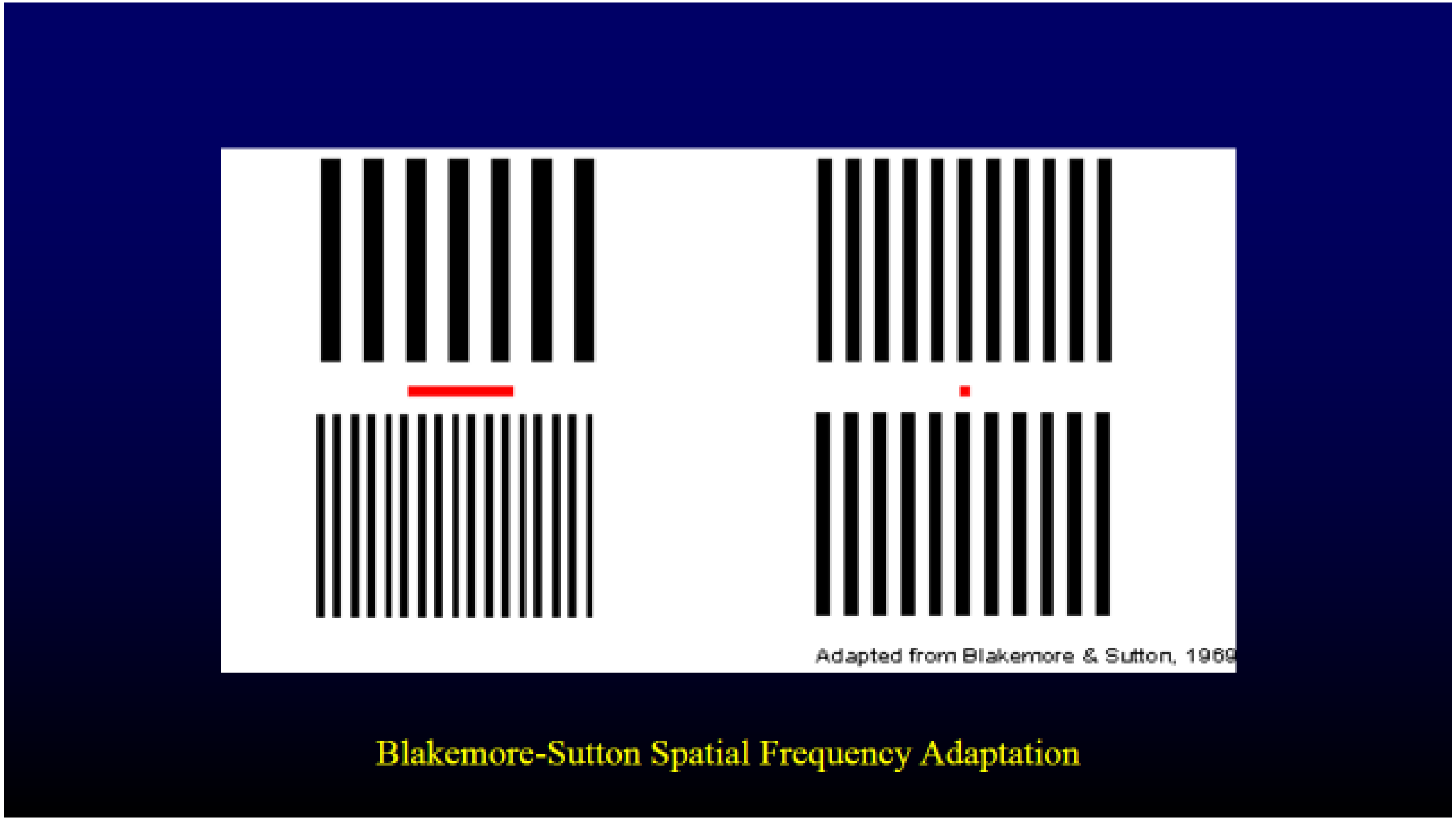


Visual Illusions

physiological explanations (concentric RF's, lateral inhibiition)



physiological explanation: spatial frequency tuned mechanisms



from outline

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14. How are the following factors involved in various visual illusions?

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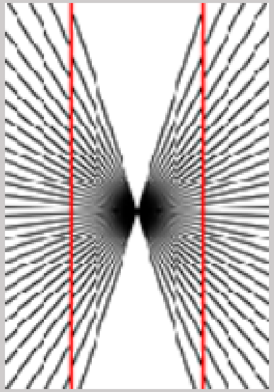
b. illusions consistent with perceptual overestimation of acute angles

c. context or association including size constancy *illusions consistent with overestimation of acute angles*



Poggendorf, Herring and Zollner Illusions

Acute Angle Dilation Illusions Report

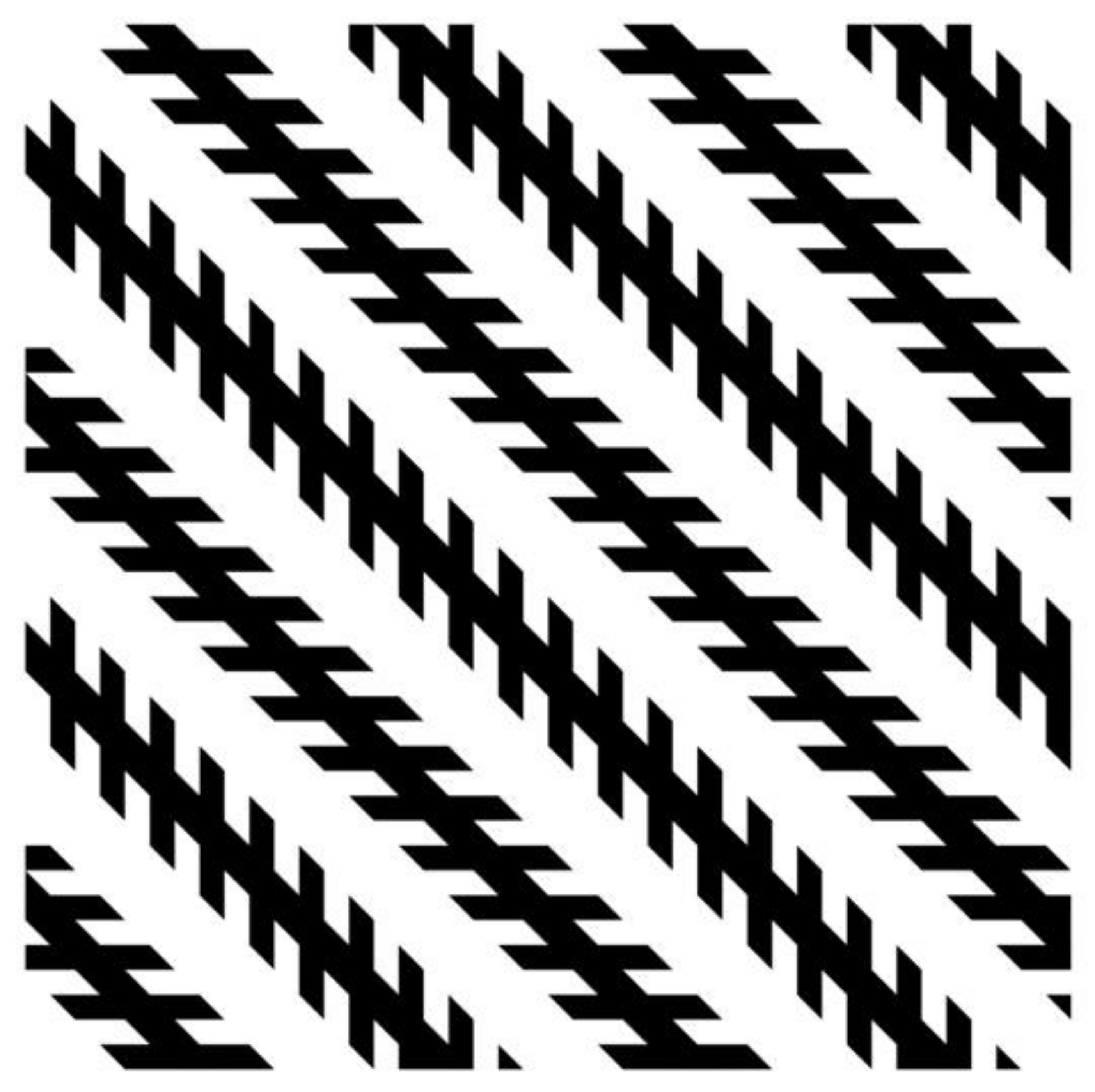
~February 9th

Acute Angle Dilation Illusions

Mikayla Dilbeck, Crown 85

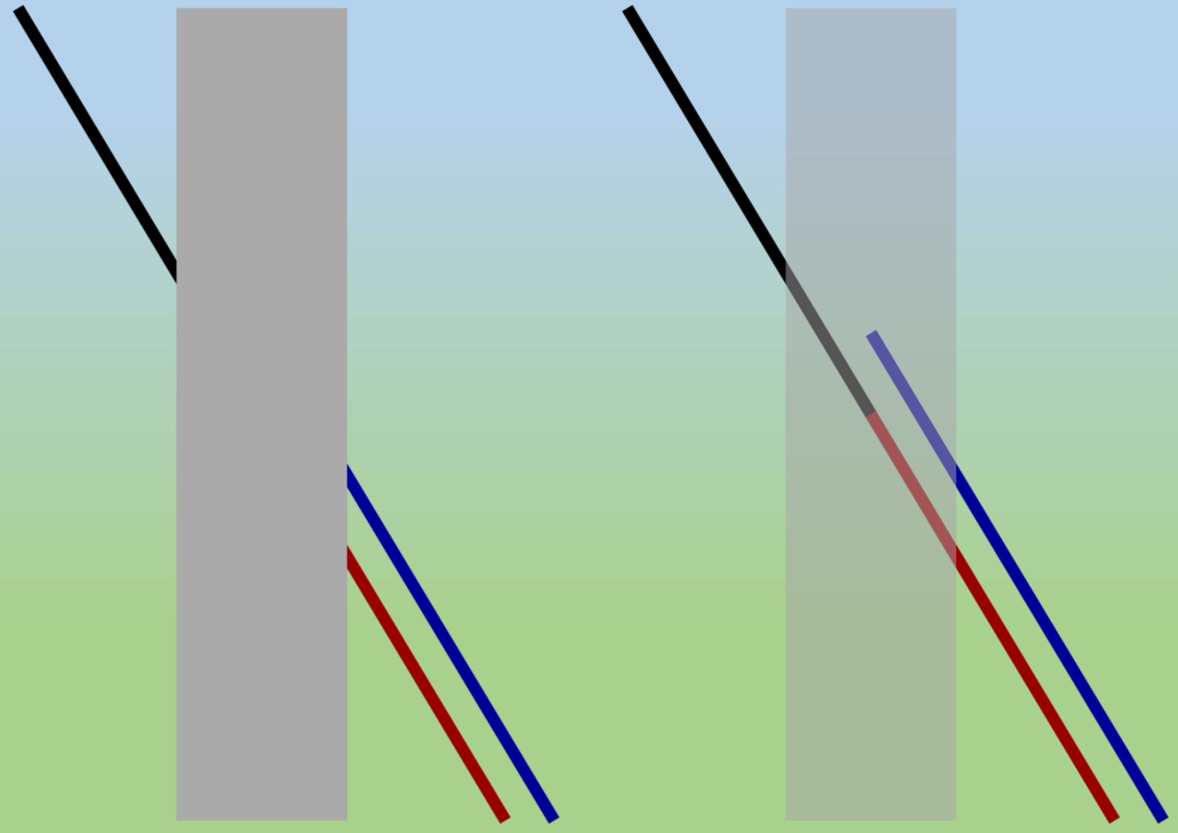
Zollner Illusions

Discovered 1860 by Zollner, an astrophysicist



More:
http://www.psy.ritsumei.ac.jp/~akitaoka/zollnere.html

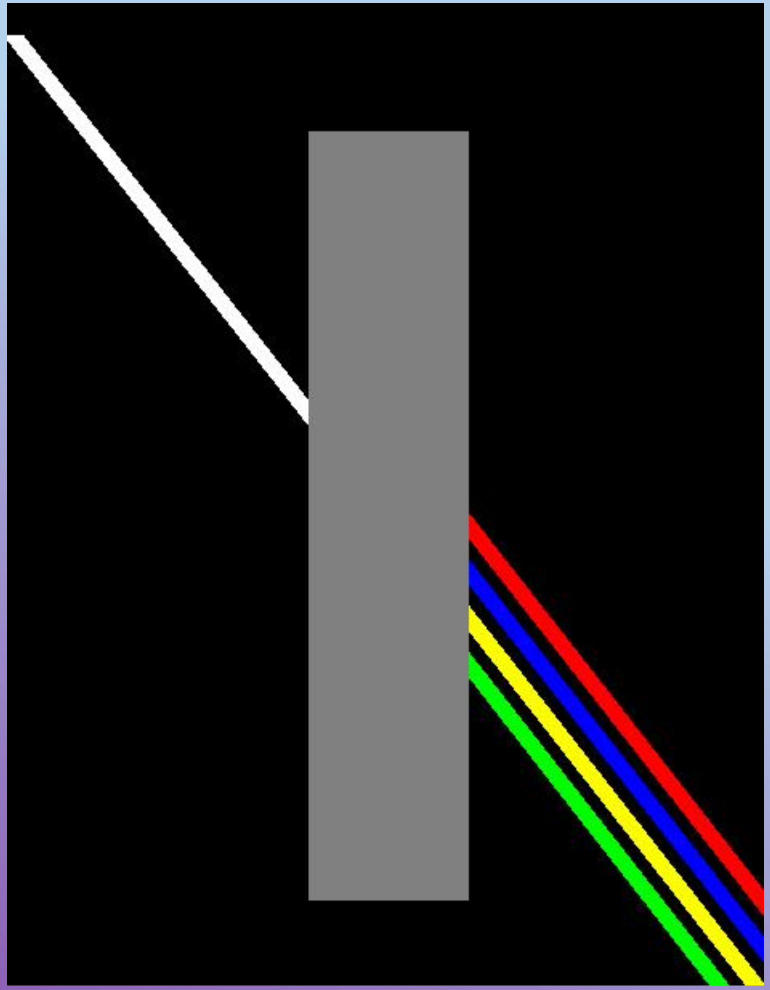
Poggendorff Illusion



Discovered 1860 by Poggendorff when Zollner wrote a letter to Poggendorff describing an illusion he saw on a fabric design (Zollner's illusion) → Poggendorff noticed another illusion of misaligning diagonal lines

More:
http://www.michaelbach.de/ot/ang-poggendorff/

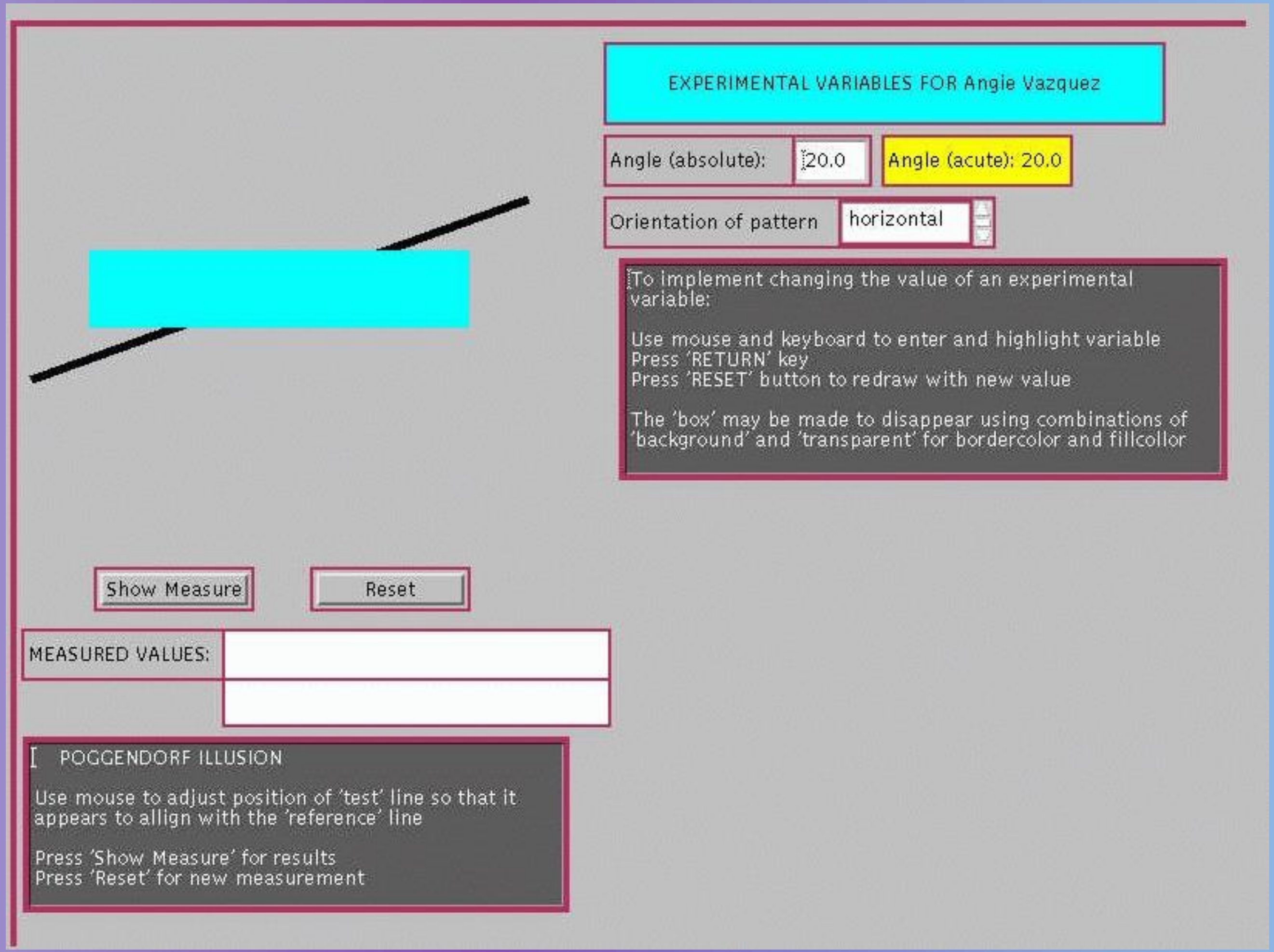
angle dilation illusion (Poggendorf)



http://switkes.chemistry.ucsc.edu/teaching/CROWN85/JAVA/POGGENDORF/poggendorf_2.htm

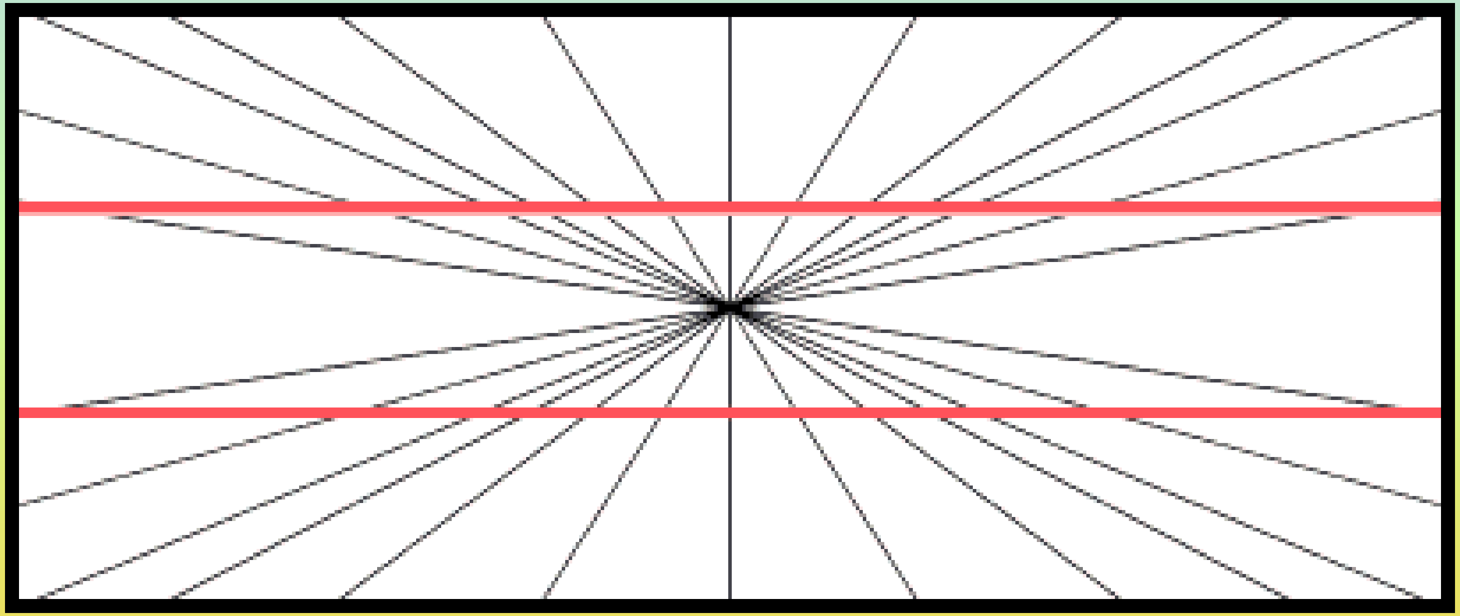
Java Chrome

Poggendorf illusion: acute angle overestimation)



Poggendorf Interactive Illusion (possible capstone)

Hering Illusion



http://www.michaelbach.de/ot/ang-hering/

Why does this happen?

- most modern investigators have proposed theories based on the receptive field properties of orientation-selective neurons in V1 of subhuman primates, lateral inhibitory interactions typically playing a central part in these accounts
- **Blakemore and Carpenter** propose that inhibitory interactions among orientationally tuned neurons that respond to bars of similar orientation would result in over estimation of acute angles
- When two spatially contiguous lines of neighboring orientations are exposed simultaneously, the activity peaks in the population of orientation detectors are shifted away from each other because of the inhibitory interactions → the orientations of the lines comprising the angle are perceived wrongly

"physiological" explanation

Orientationally tuned neurons in V1:

- in V1 one finds neurons that respond to a bar of a specific orientation *(old stuff; previous lecture)*
- there are inhibitory connections among neurons with similar (nearby) preferred orientations
- bars with similar orientations form **acute angles**
- the inhibition among nearby orientations leads to an over estimate of an acute angle

Exp. Brain Res. 18, 287—303 (1973)

Interactions Between Orientations in Human Vision

R. H. S. Carpenter and Colin Blakemore
The Physiological Laboratory, University of Cambridge, Cambridge (England)

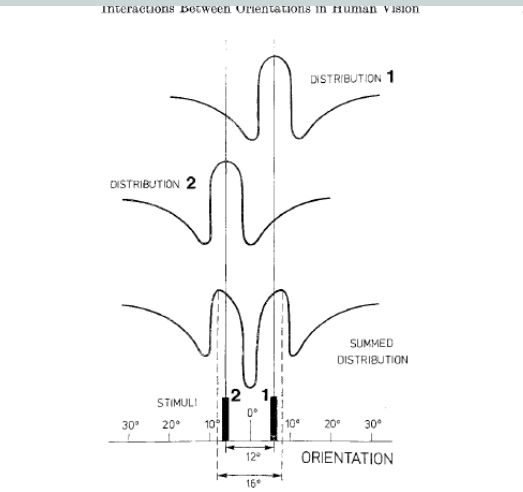


Fig. 1. *Illustrating an explanation for angle-expansion.* For full description, see text

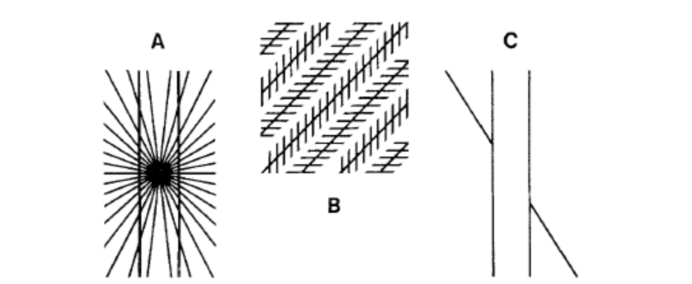


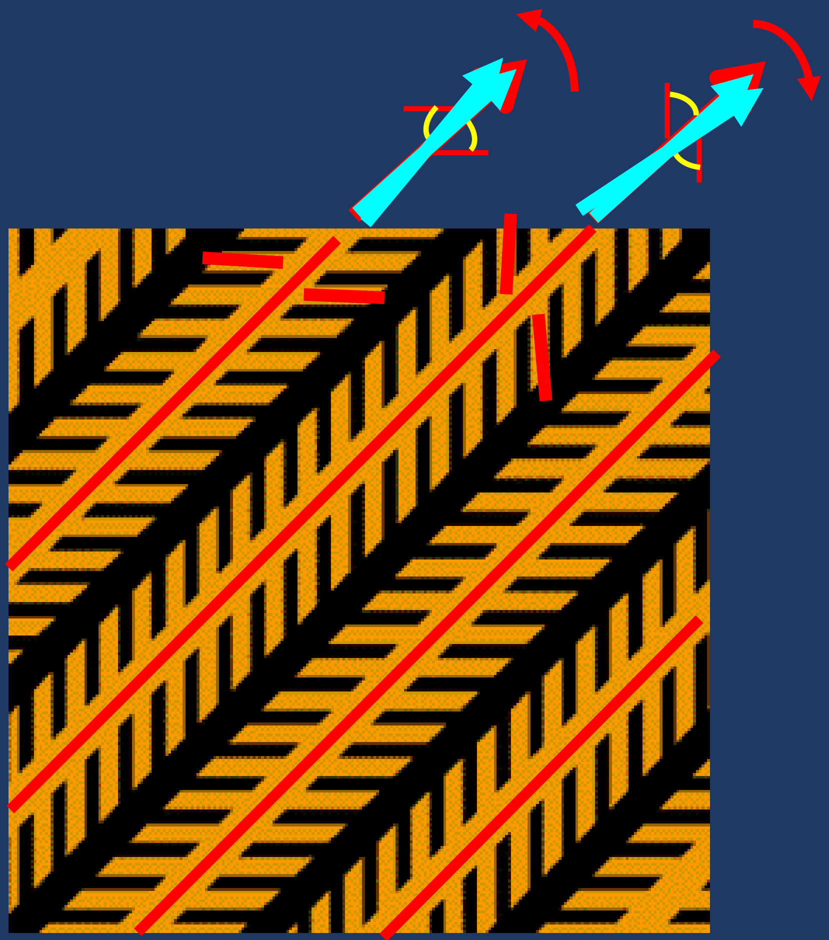
Fig. 2. *Three geometric illusions that probably involve the misperception of angles.* From left to right they are: A. Hering's illusion, B. Zöllner's illusion, C. Poggendorff's illusion

Citations

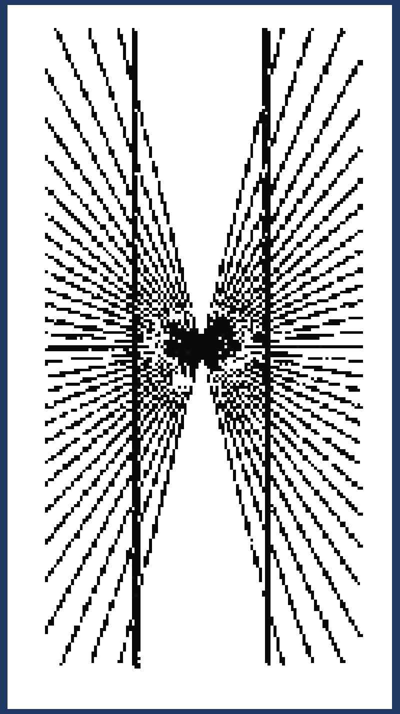
Nundy, Surajit, Beau Lotto, David Coppola, Amita Shimpi, and Dale Purves. "Why Are Angles Misperceived?" *Proceedings of the National Academy of Sciences of the United States of America*. The National Academy of Sciences, n.d. Web. 07 Feb. 2016.4

Parker, Denis M. "Evidence for the Inhibition Hypothesis in Expanded Angle Illusion." *Nature* (1974): 250. *Nature.com*. Nature Publishing Group. Web. 07 Feb. 2016.

overestimation of acute angles (physiological, perhaps)

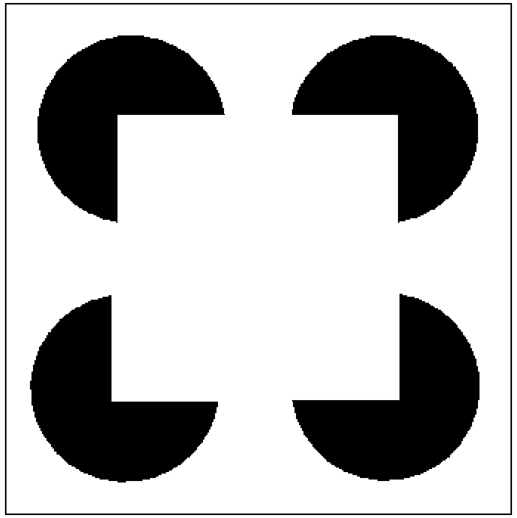


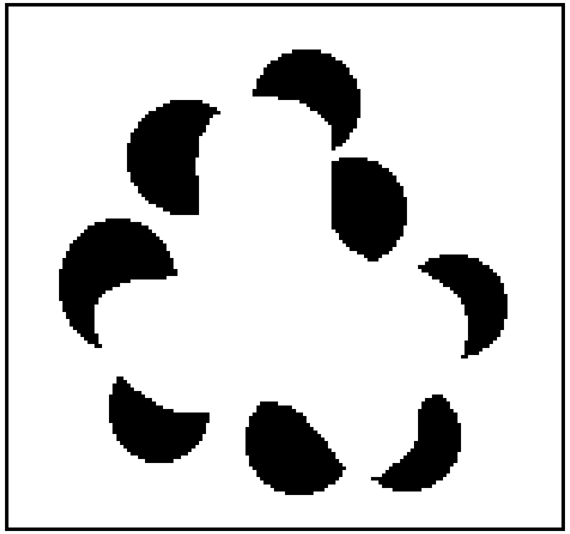
Zollner

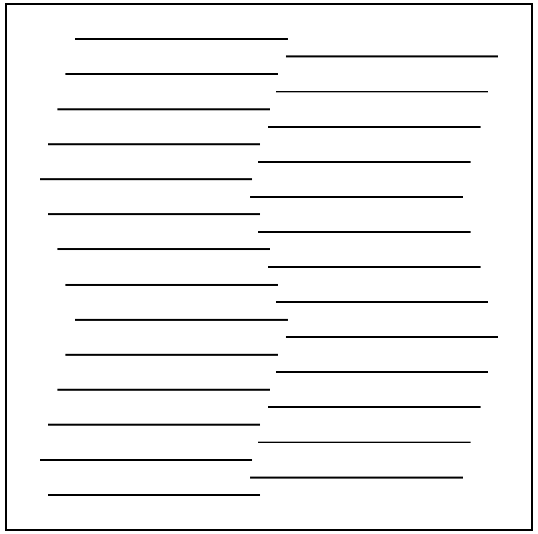


Herring

subjective Contours (expectation; top-down effect)

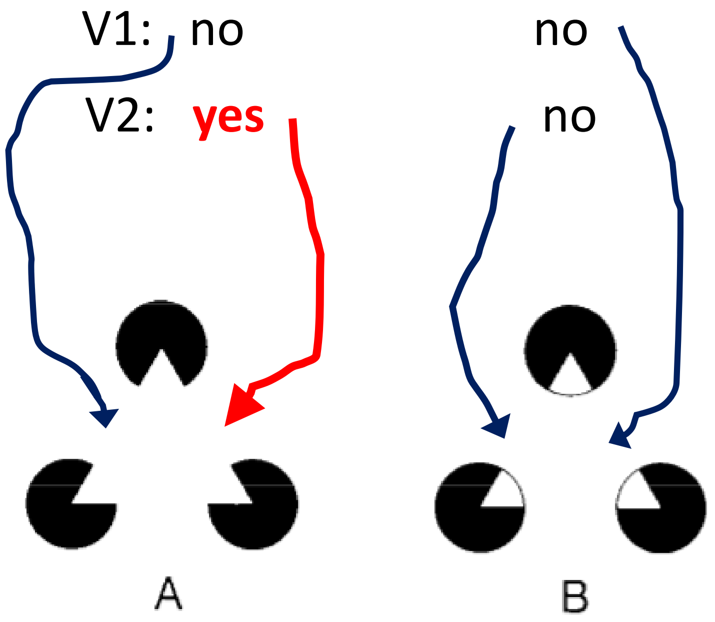


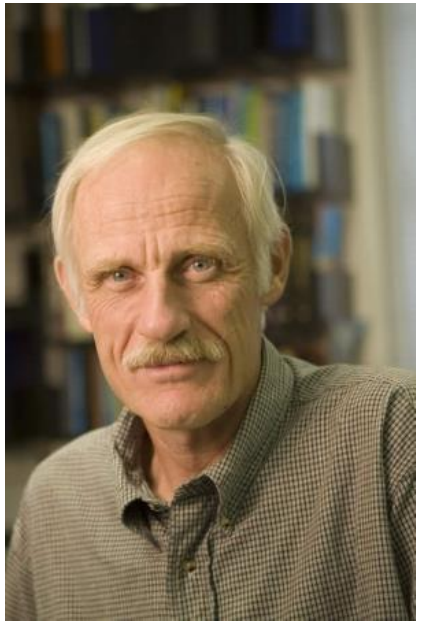




do neurons that respond to actual contours also respond to illusory contours ?

Testing figures below on cells previously shown to be responsive to **actual** lines:





more "top-down" vision

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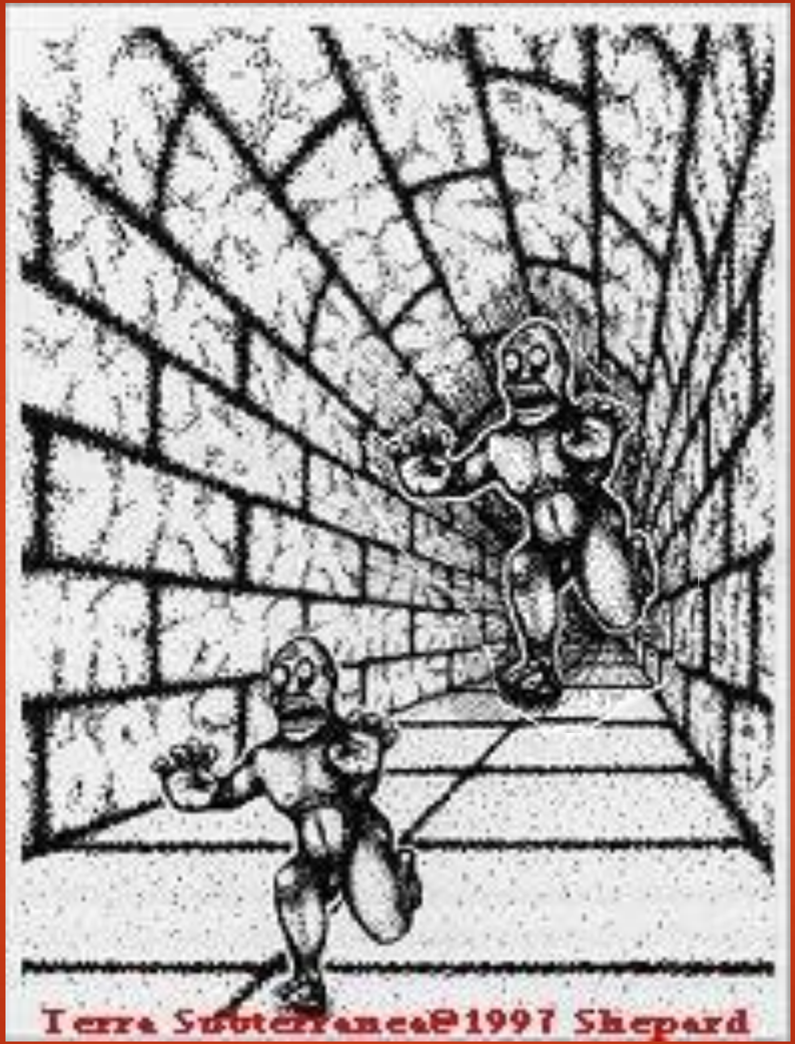
c. context or association including size constancy

	Muller–Lyer, Ponzo and Ames Room Illusions	Size Constancy Illusions Report	~February 9th


Terra Subterranea©1997 Shepard

Size Constancy Illusions

Demonstrations

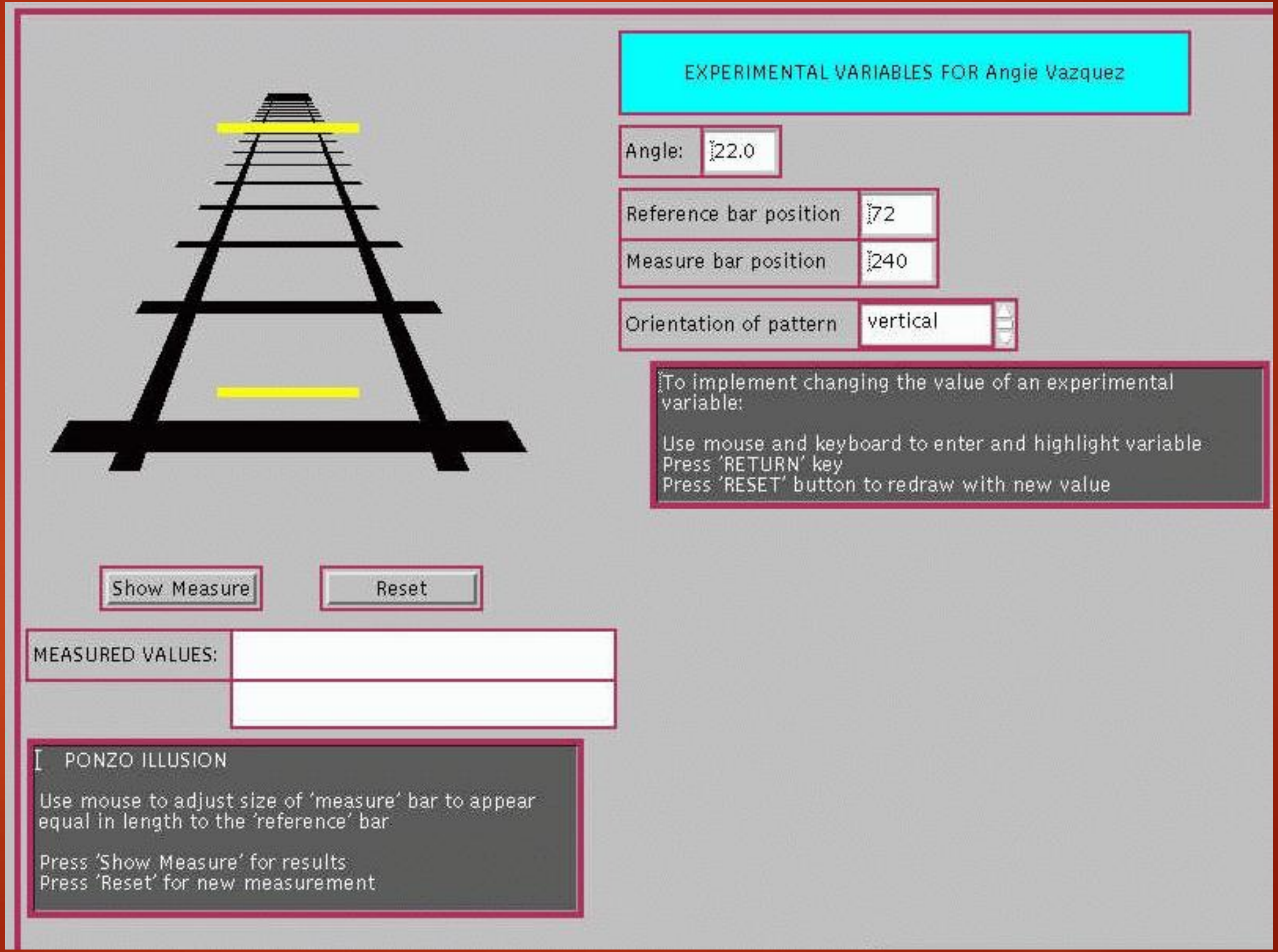
Ponzo Illusion

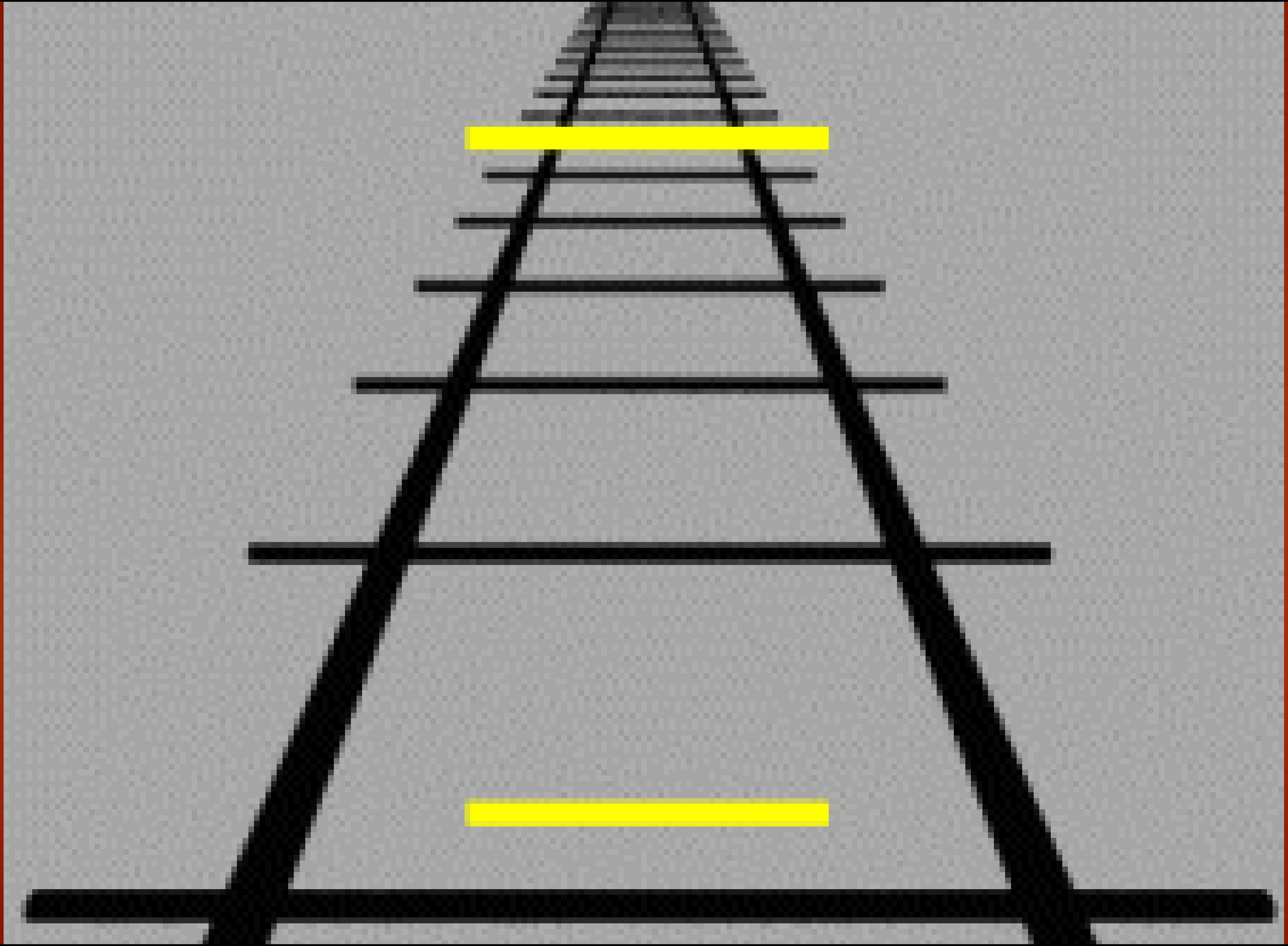
Müller-Lyer Illusion

Ames Room

Ponzo Illusion Image

Interactive Demo

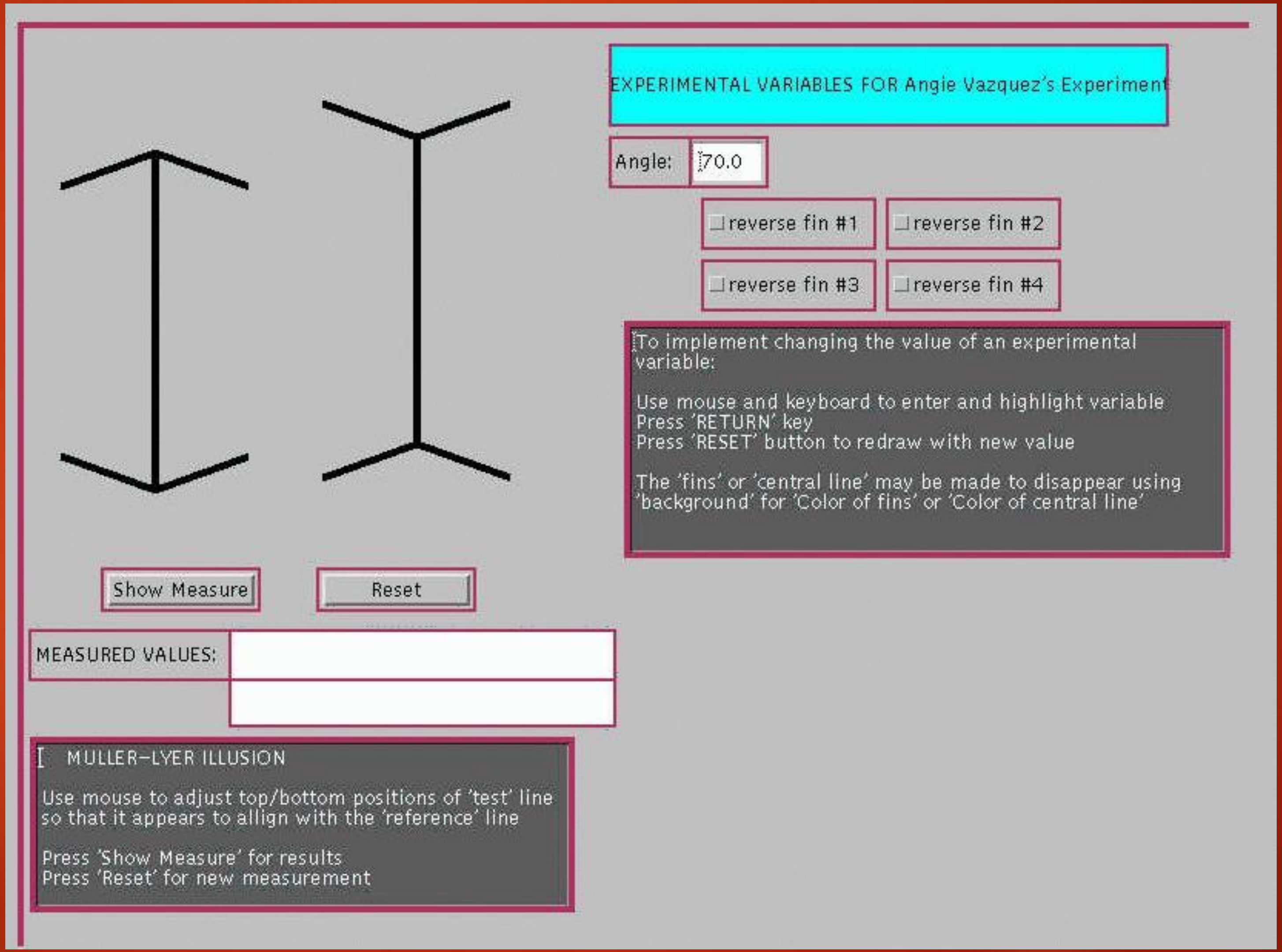




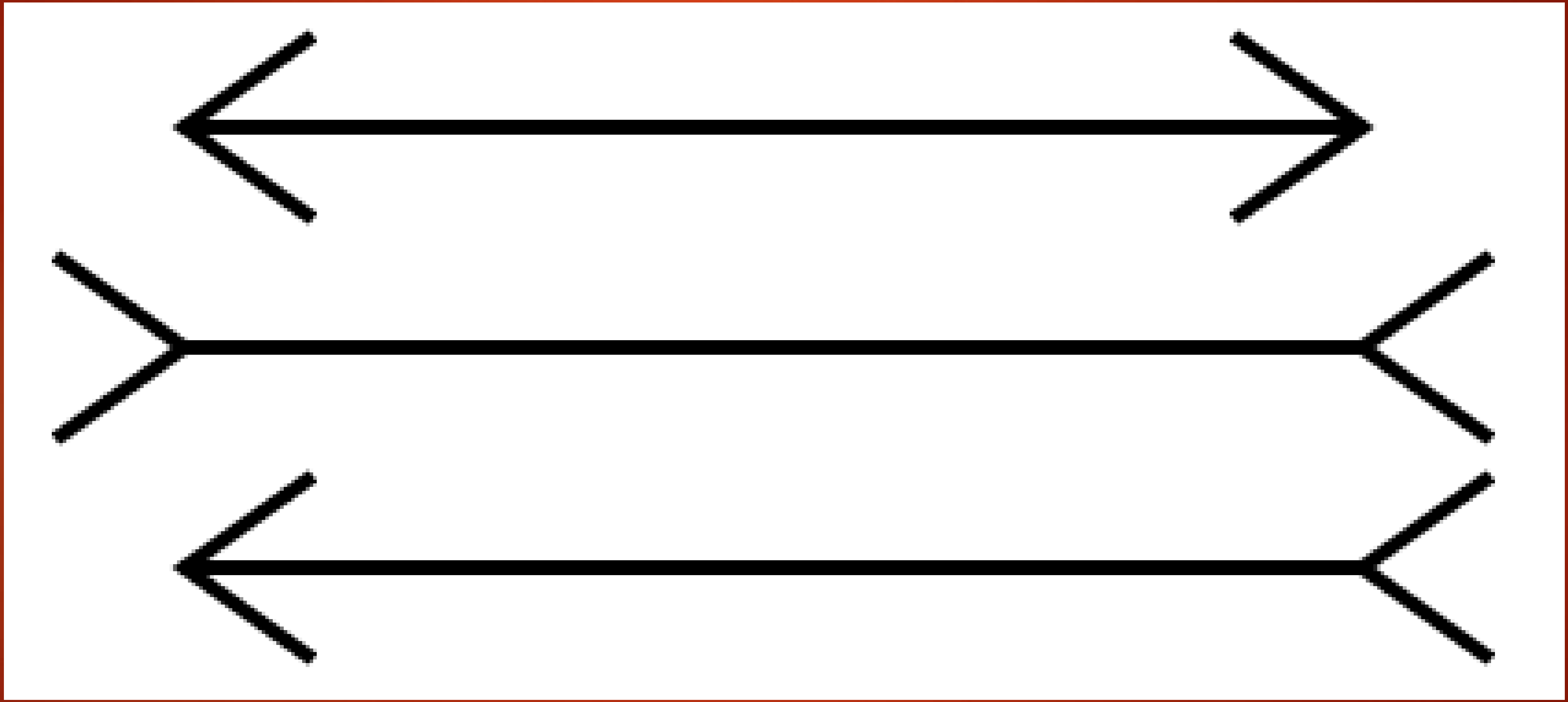
Müller-Lyer Illusion Image

Interactive

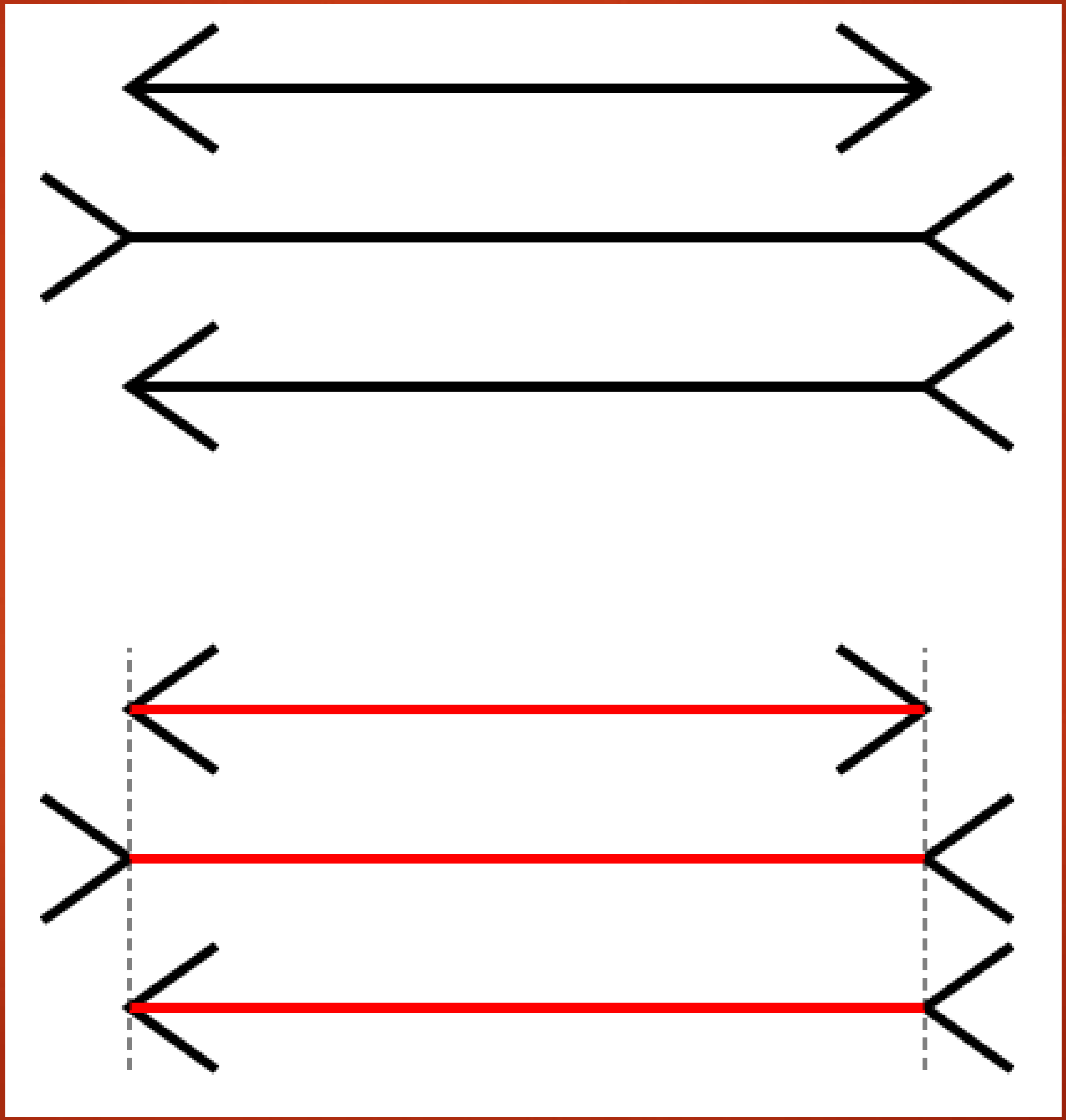
Demo



Müller-Lyer Illusion



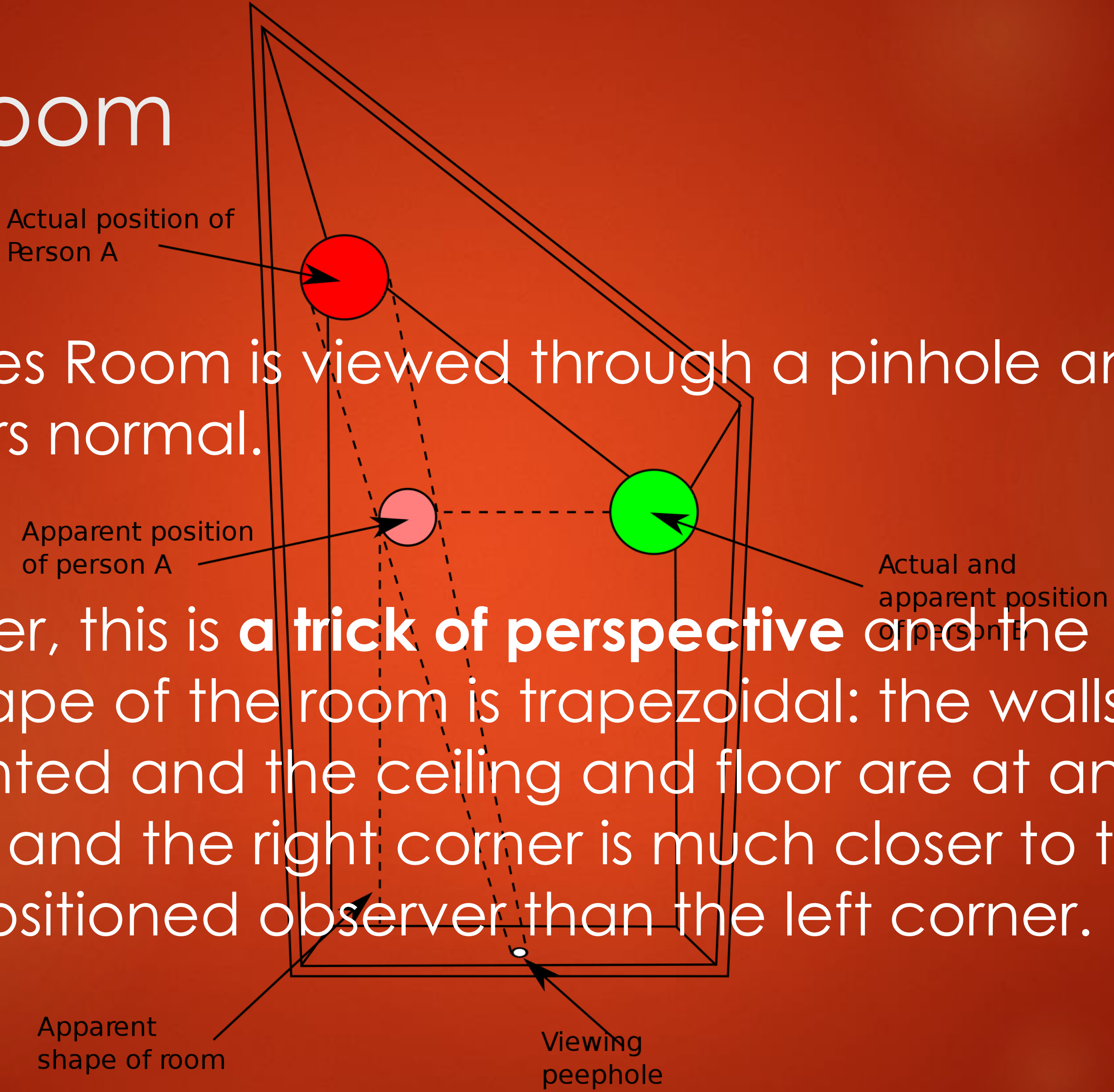
Müller-Lyer Illusion



Ames Room Video

Demonstration Video

Ames Room



- An Ames Room is viewed through a pinhole and appears normal.
- However, this is **a trick of perspective** and the true shape of the room is trapezoidal: the walls are slanted and the ceiling and floor are at an incline, and the right corner is much closer to the front-positioned observer than the left corner.

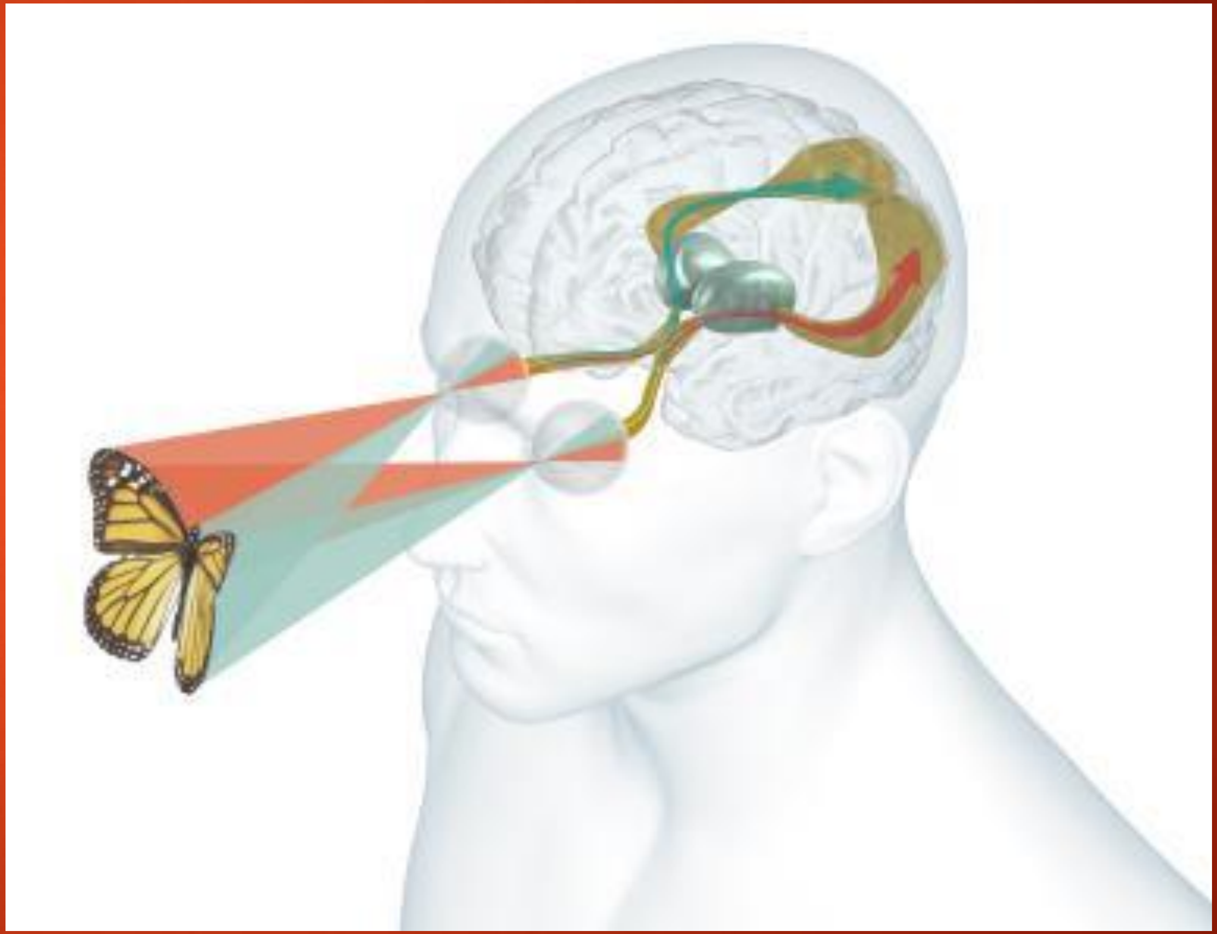
Ames Room

- The brain has "built in" assumptions that the walls of a room are parallel, and it overrides the fact that people are changing sizes in this room, even though we *know* that people don't just change size.

- Fun Fact: The Lord of the Rings movies used an Ames Room on set to make the hobbits appear smaller than Gandalf!

Top-Down Processing

- We form our perceptions starting with a larger object, concept or idea before working our way toward more detailed information.



Top-Down Processing

- Also known as conceptually-driven processing, since your **perceptions are influenced by expectations, existing beliefs and cognitions.**

- In some cases you are aware of these influences, but in other instances this process occurs without conscious awareness.

Description

- The Muller-Lyer and Ponzo illusions and the Ames Room demonstration are examples of 'top-down' processing where the **relative size of an object is misconstrued due to its placement among distance cues.**

- If objects of constant size are placed in an environment where there are strong perspective cues, these objects can appear larger at greater distances.

Resources Cited

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- Kindersley, Dorling. Top-Down Processing. Digital image. Getty Images, n.d. Web. 9 Feb. 2016.

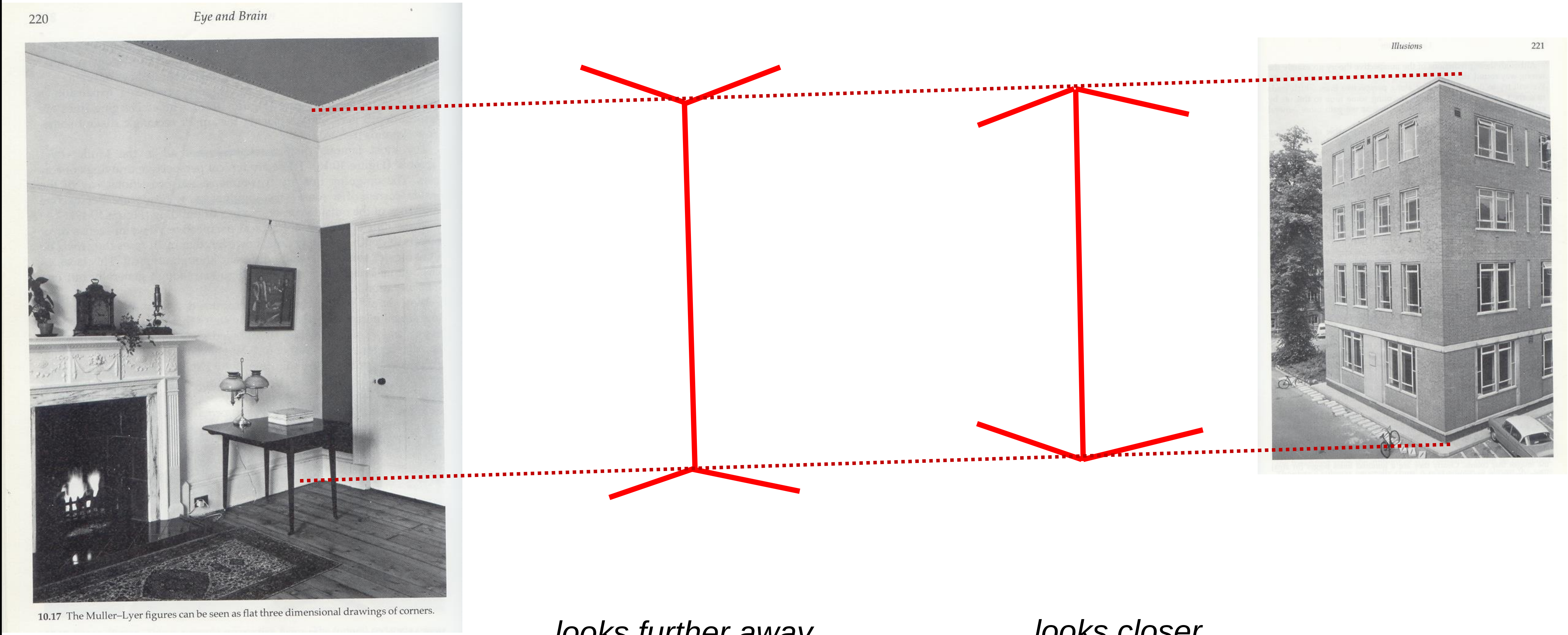
size constancy

demo

http://psych.hanover.edu/krantz/SizeConstancy/

J. Krantz, many excellent WWW demos !!

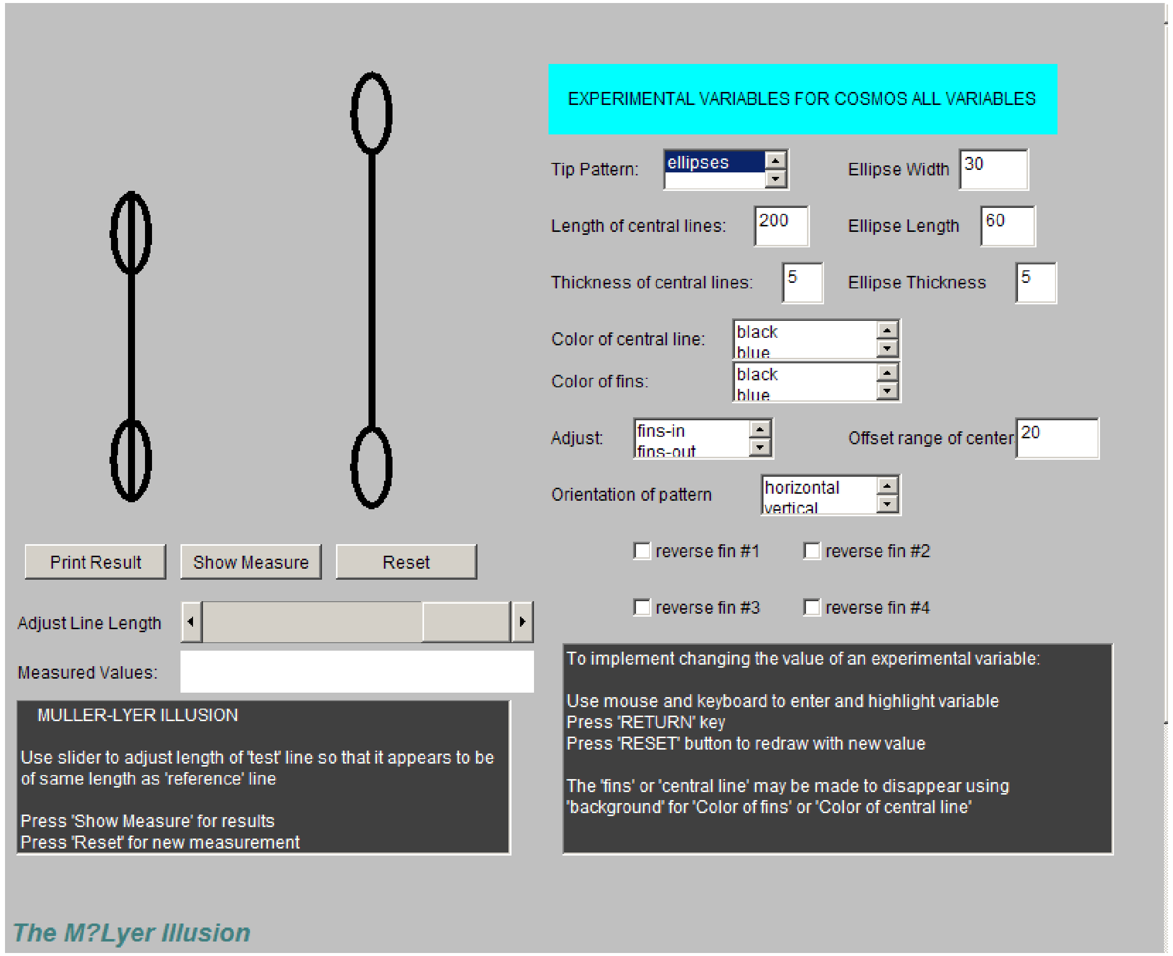
Gregory’s ‘corners’ and size constancy



looks further away
same size appears larger

looks closer
same size appears smaller

Muller-Lyer Illusion [centroid (blur) at end of vertical line]



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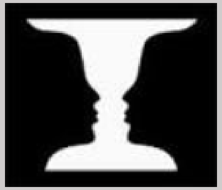
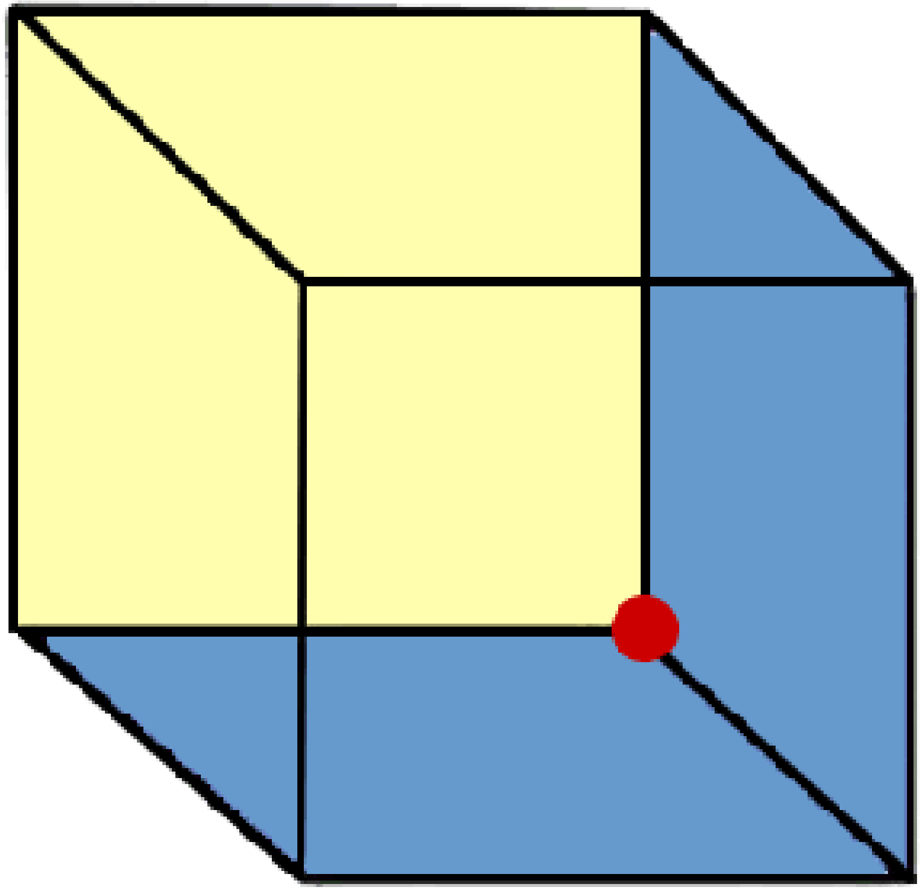
✓ c. context or association including size constancy

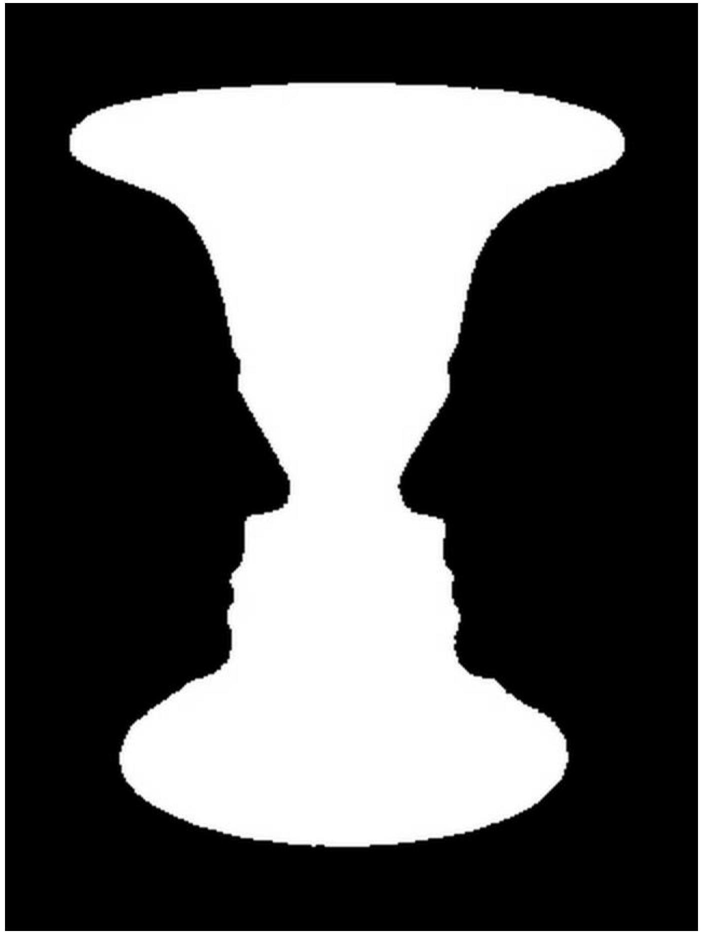
More top down illusions

15. Give examples of the visual system "making bets" or "filling in" and understand how these can lead to illusions.



	Bistable Perception	Bistable Perception Report	~February 9th





Bistable Perception

What is bistable perception?

- When an image is able to provide multiple, but stable perceptions
- Because ambiguous figures like the Necker cube and Rubin vase can be experienced in two different ways, they are called bistable.
- When there are two or more percepts, it would be called multisable.

Sensory Inputs: Binocular Rivalry

- a type of perceptual rivalry, where two different images are presented to the two eyes simultaneously but you are only conscious of one image at a time
    i. Also called ambiguous or rivalrous
    ii. One image is dominant, whereas the other is suppressed
    iii. Dominance will shift
    iv. All/part of one image appears totally suppressed

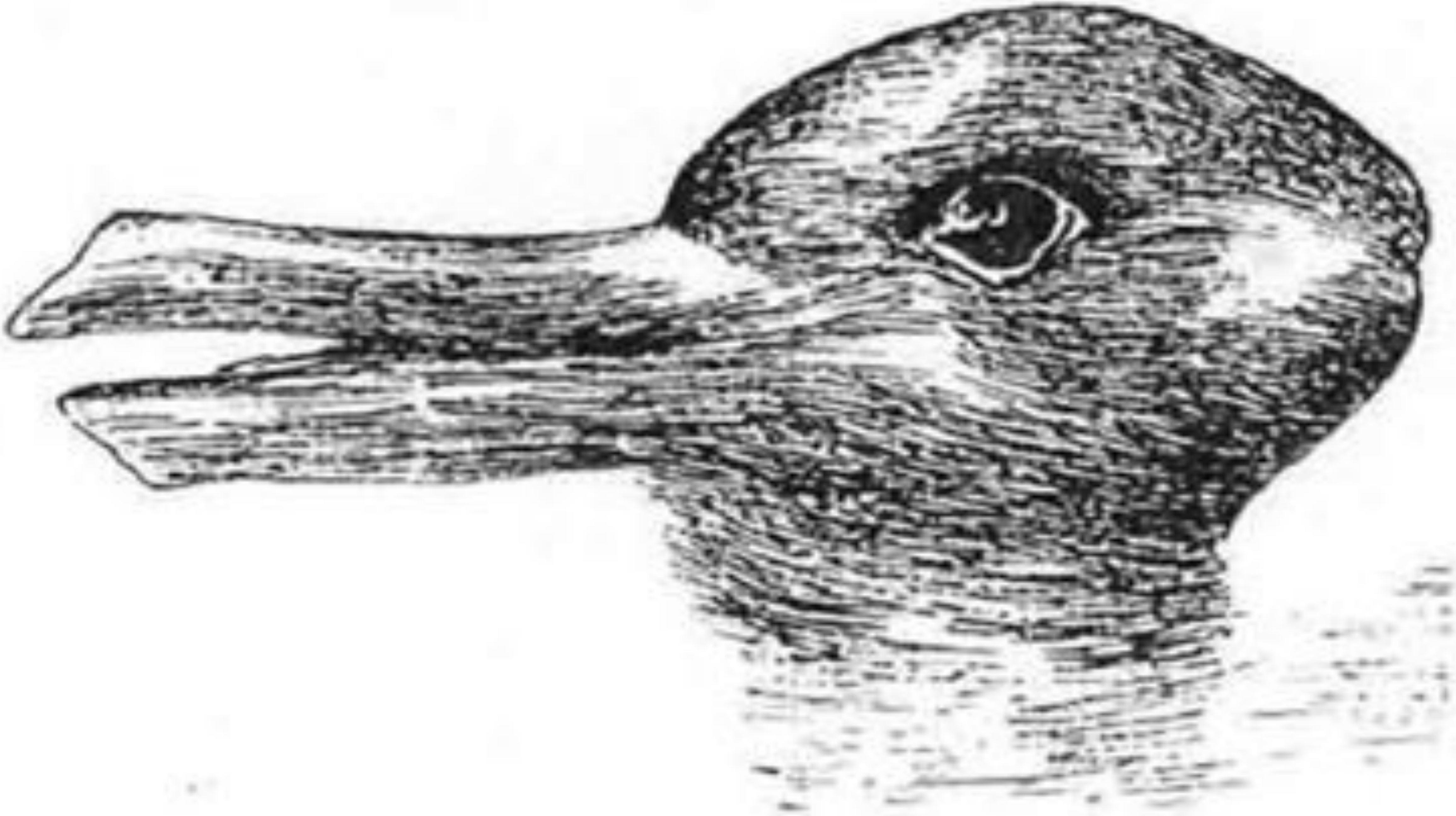
- Increasing the strength of one stimulus, by adding motion or contrast etc, will increase its dominance by decreasing the duration of its suppression

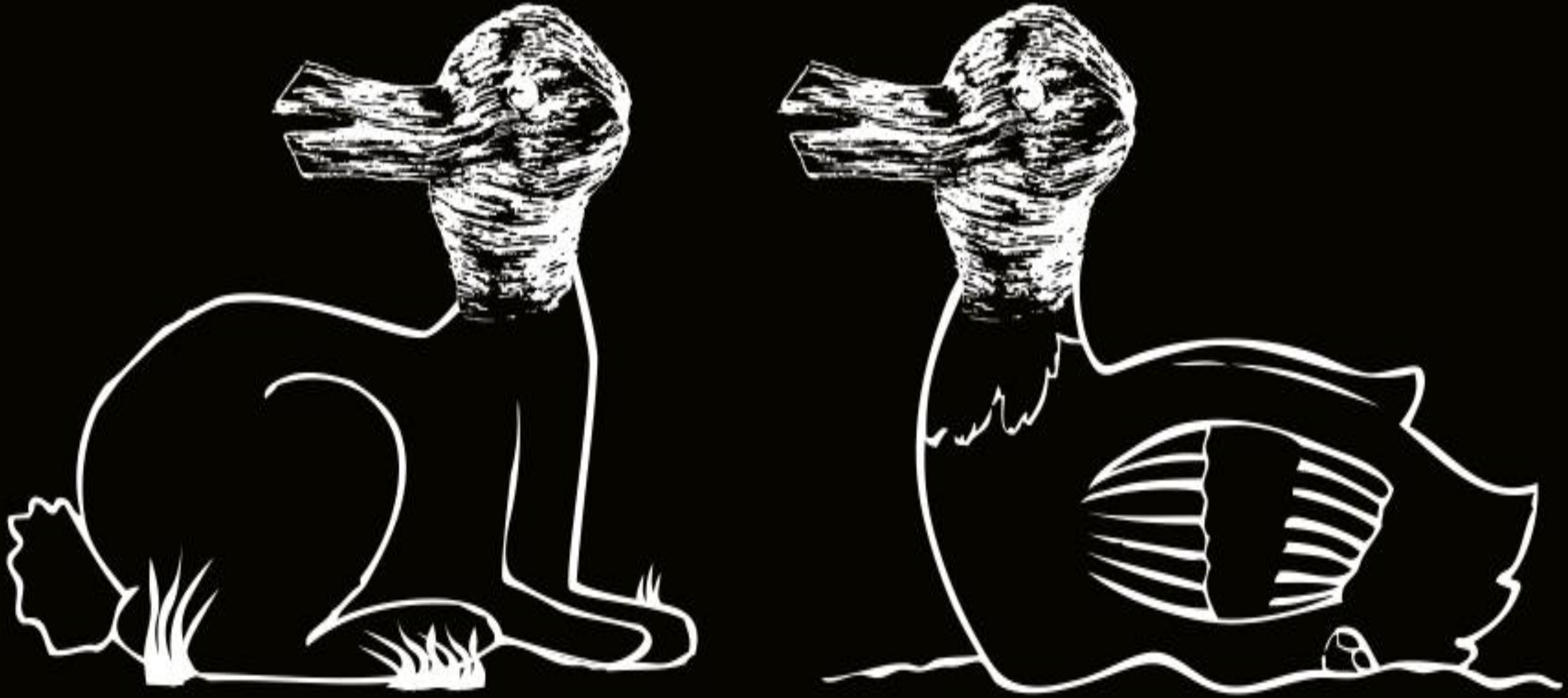
Sensory Inputs: Higher order interpretative bistability

- Bistable/multistable perception is a product of continuous interactions between ‘low-level’ (sensory) and ‘high-level’ (frontal and parietal) brain regions

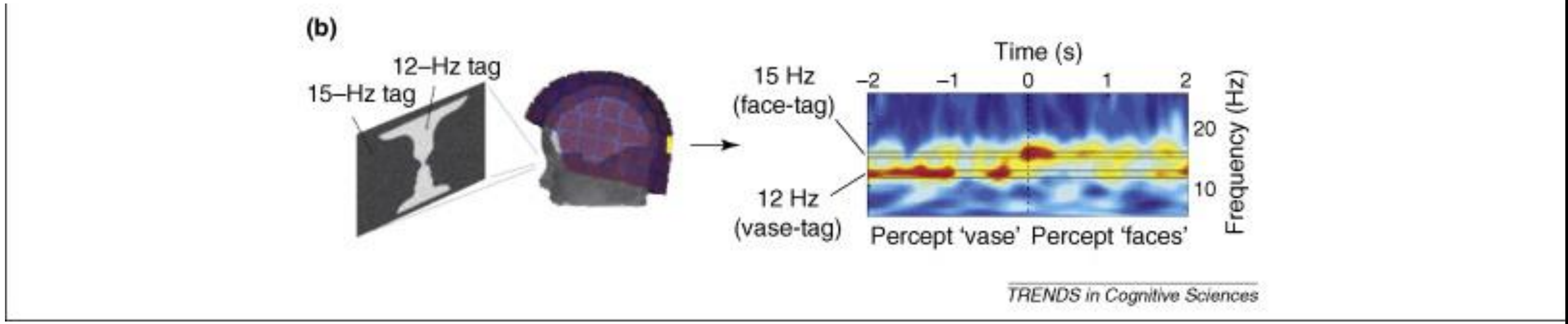
- Where the visual system adds information to the one contained in retinal projections.

  - In this sense, vision is interpretive, a process similar to higher-order intellectual activities, such as reasoning, in being mediated by representations and informed by implicit knowledge.



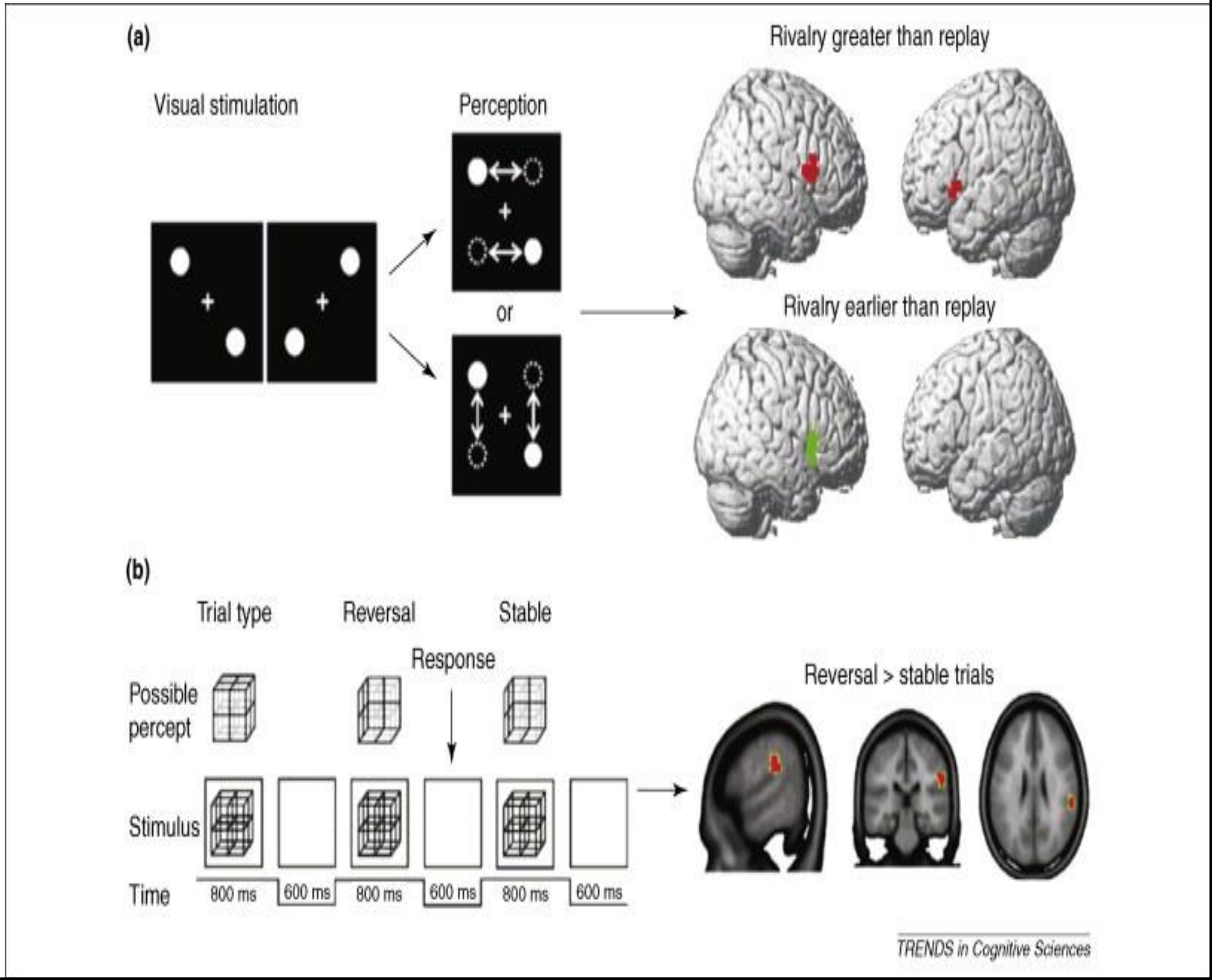


Neural Studies



- Multistable perception was tested using binocular rivalry, ambiguous figures, and ambiguous grouping of motion. Brain activity was measured with fMRI, EEG and MEG.

- As the percept shifted from one interpretation to the other, researchers found changes in activity at both low levels (V1, V2) and at higher levels of the visual system (inferior parietal cortex)



References

Philipp Sterzer, et. al, **The neural bases of multistable perception,** Trends in Cognitive Science, Volume 13, Issue 7, 2009, 310–318

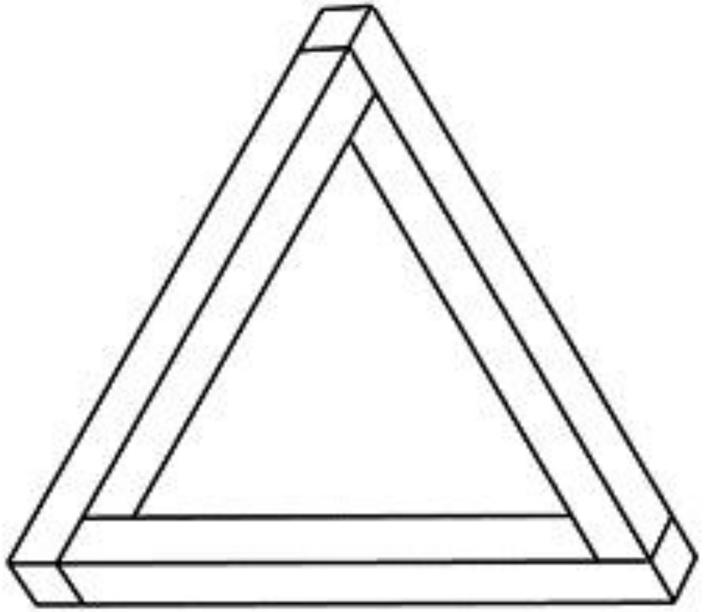
http://blog.pascallisch.net/wp-content/uploads/2015/02/Rubin-vase.png

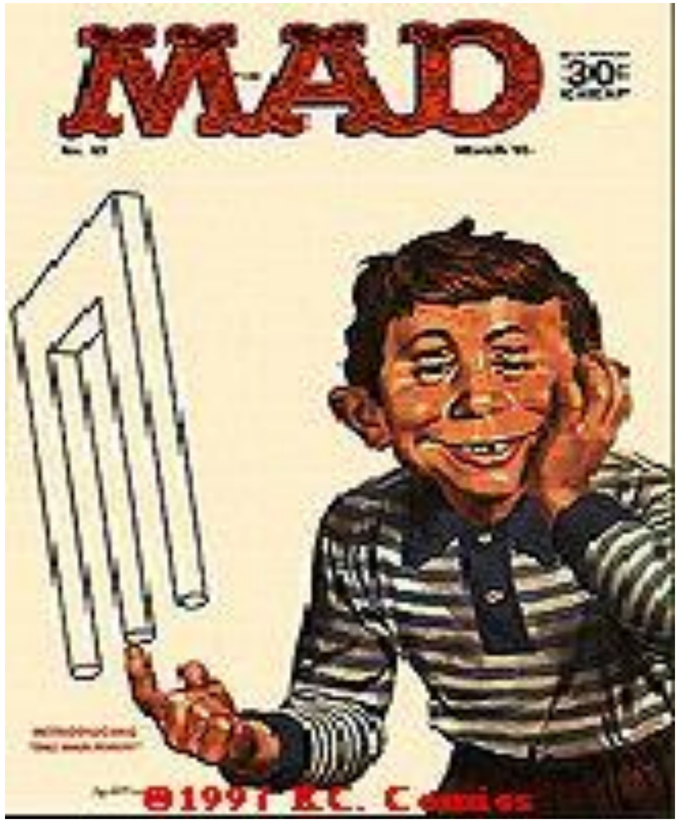
http://nordhjem.net/the-where-and-the-what-of-bistable-perception/

http://www.youramazingbrain.org/supersenses/necker.htm

the visual system attempts to make 3-D ‘sense’ out
of 2-D figures that may not have a consistent 3-D interpretation or
may correspond to a 2-D image of a ‘not-ordinary’ object as viewed
from a unique viewpoint.

impossible figures

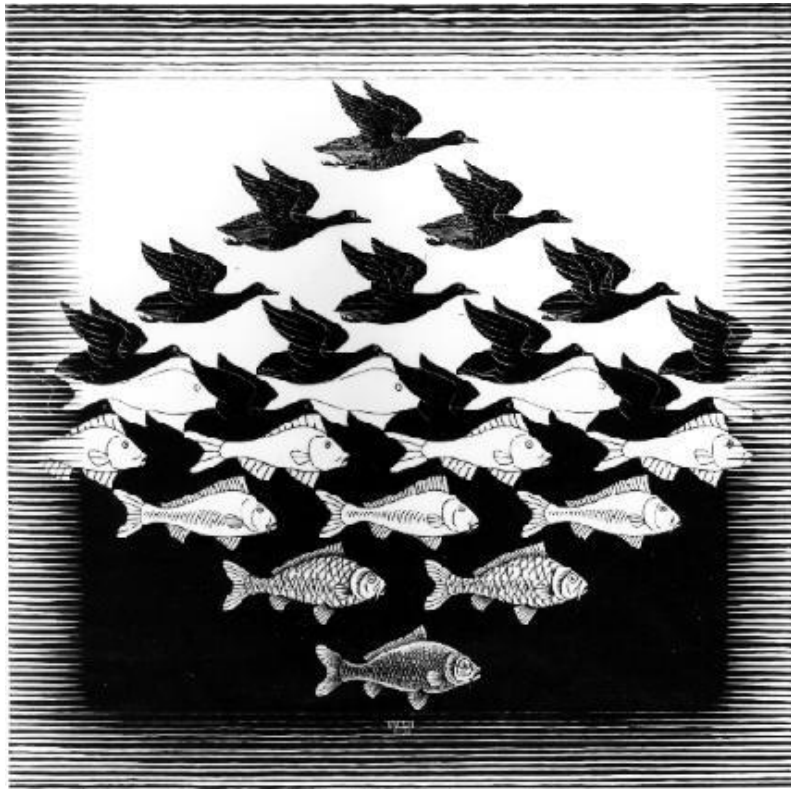




Escher -- Belvedere

https://www.youtube.com/watch?v=7dMjhhpCQFo

Escher



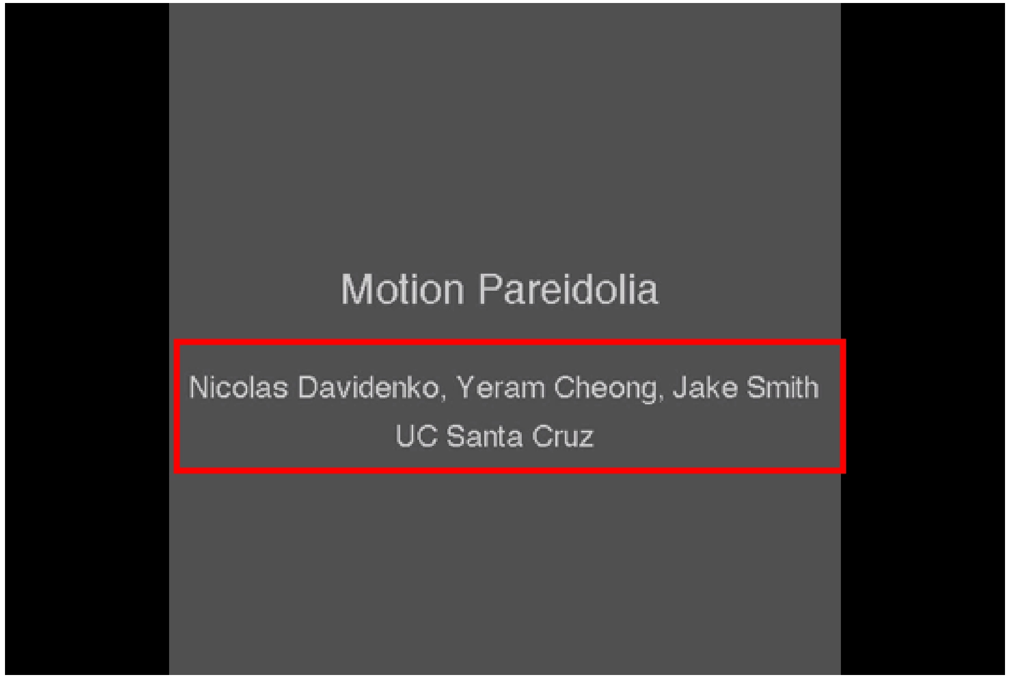
https://www.youtube.com/watch?v=2cjU5LQgu7M

https://www.youtube.com/watch?v=Kcc56fRtrKU

http://illusionoftheyear.com/?cat=184

Motion Pareidolia

Mind-controlled motion



- Nicolas Davidenko, Yeram Cheong, and Jacob Smith, University of California, Santa Cruz (USA)

Which way does the motion go? Is it up and down, or right and left? The truth is, the motion is entirely in your mind! In this demonstration, you first see a random texture moving up and down for 5 frames. After those priming frames, the remaining frames are completely random, but you will continue seeing up and down motion for several more frames. To convince yourself that this is all in your mind, try thinking to yourself "right left right left". The same sequence of random textures will appear to move whichever way your mind decides.

Rating: 6.2/10 (69 votes cast)

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https://www.youtube.com/watch?v=TYdQiP-b7Uw&feature=youtu.be

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