Color Vision II

Lecture 11
Chapter 5, Part 2

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Sensation & Perception (PSY 345 / NEU 325)
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Trichromatic color vision:

(Young & Helmholtz theory)

- three lights needed to make a specific color percept, due to use of 3 distinct cones with different sensitivities

- colors uniquely defined by combinations of cone activations

However, this doesn't quite explain everything

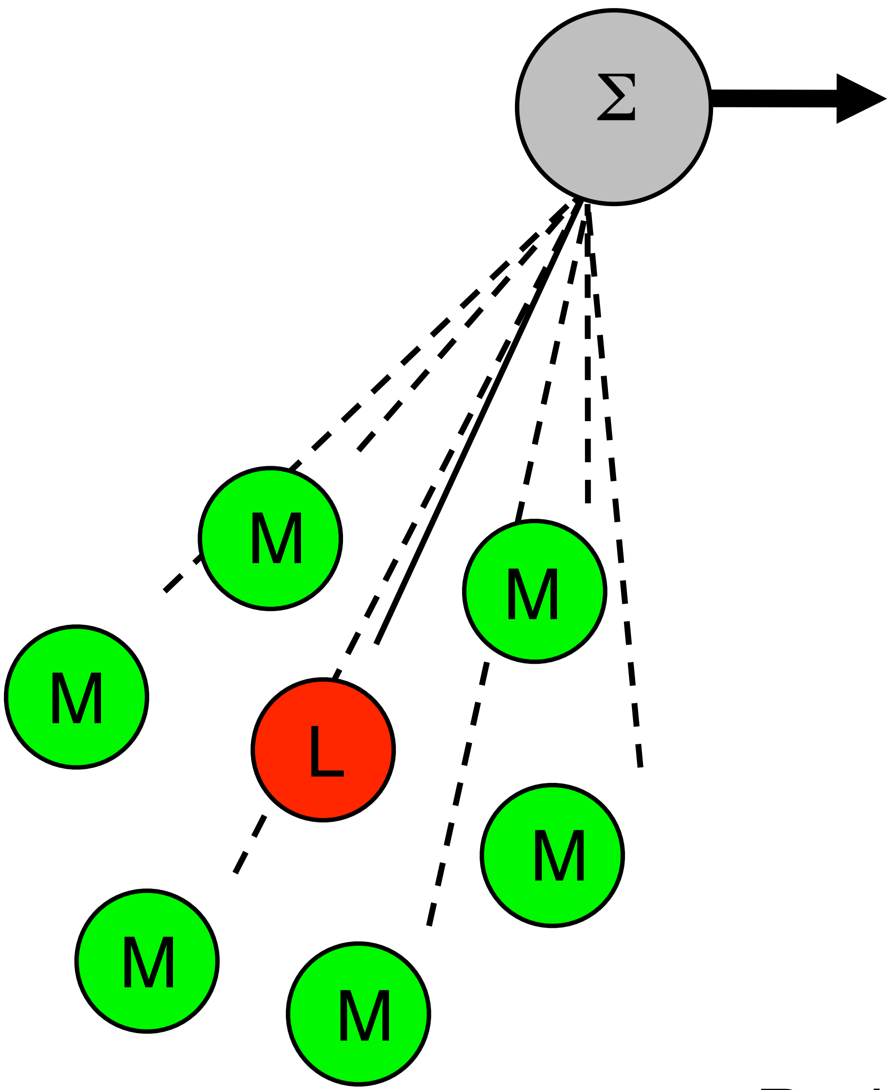
Opponent color theory:

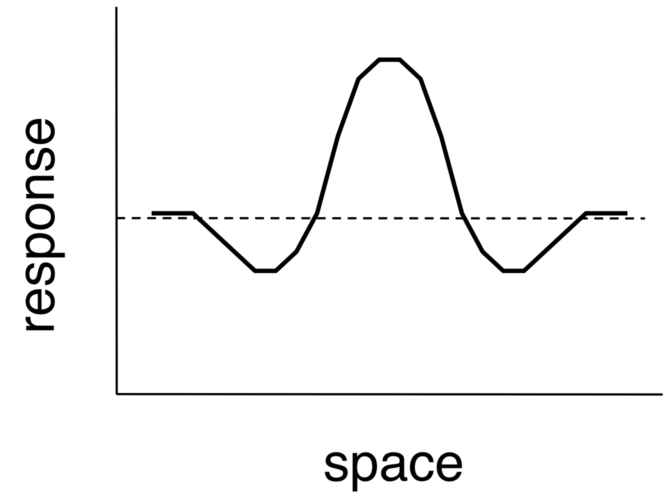
- perception of color is based on the output of three channels, each based on an *opponency* between two colors

Opponent Channels:

- L-M (red - green)
- S - (L+M) (blue -yellow)
- L+M - (L+M) (black - white)

Some Retinal Ganglion Cells have center-surround receptive fields with “color-opponency”





- Red-Green (L - M) Color-Opponent cell
- Carries info about red vs. green

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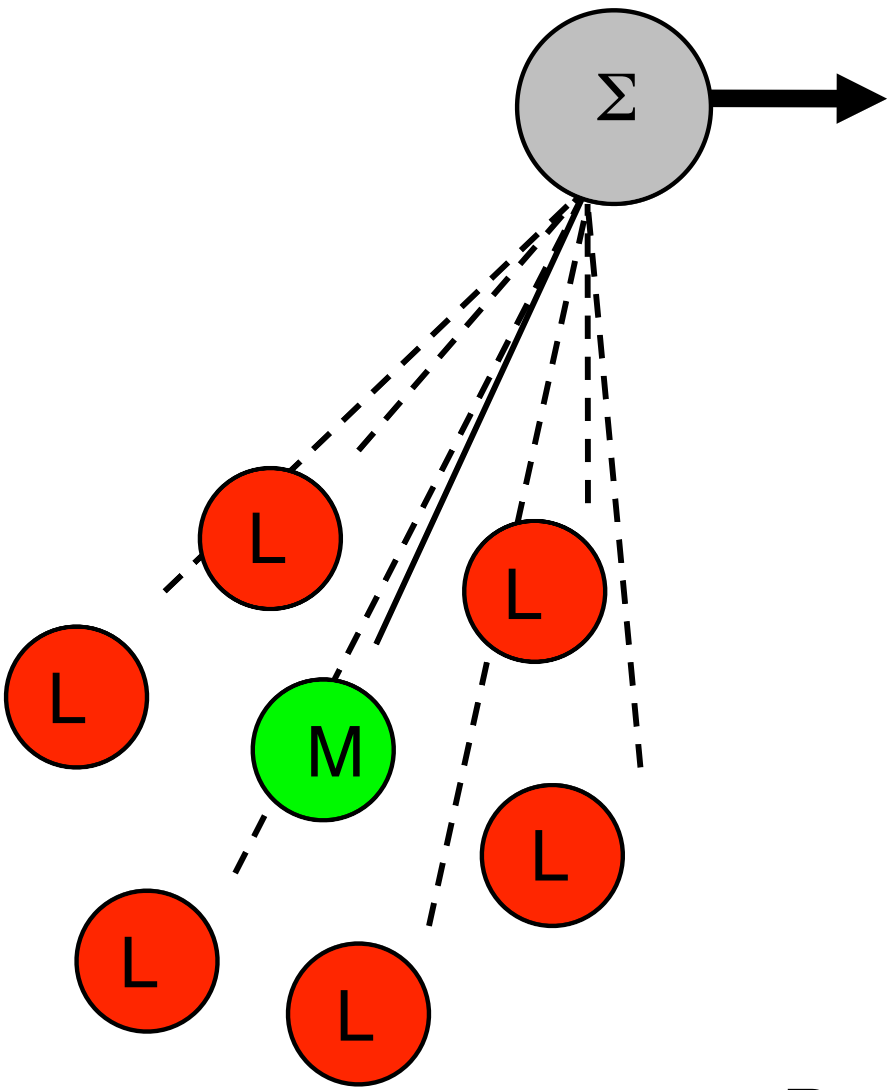

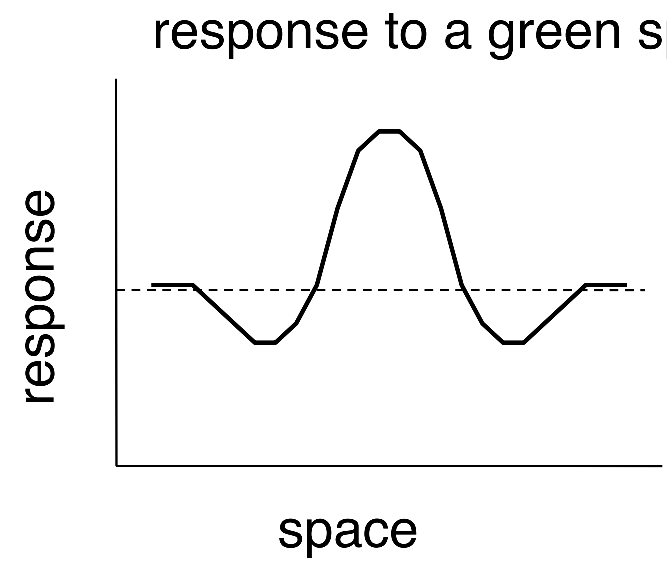

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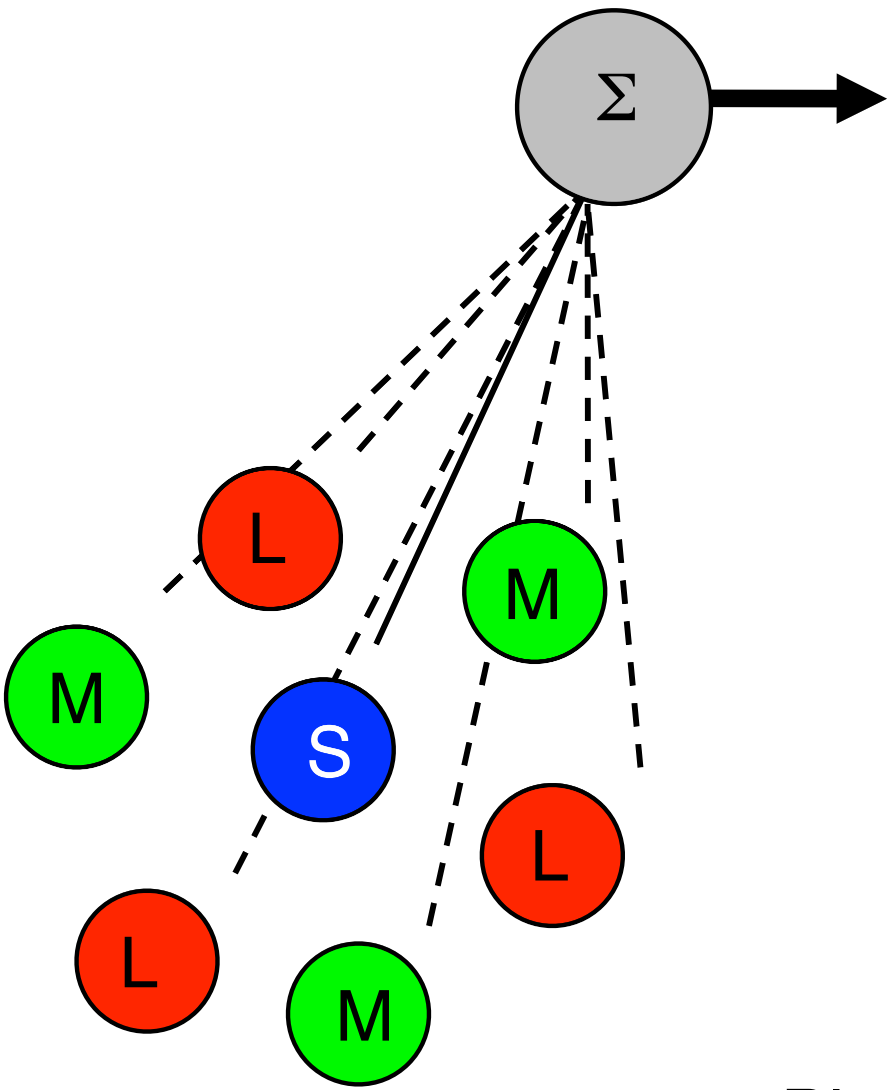
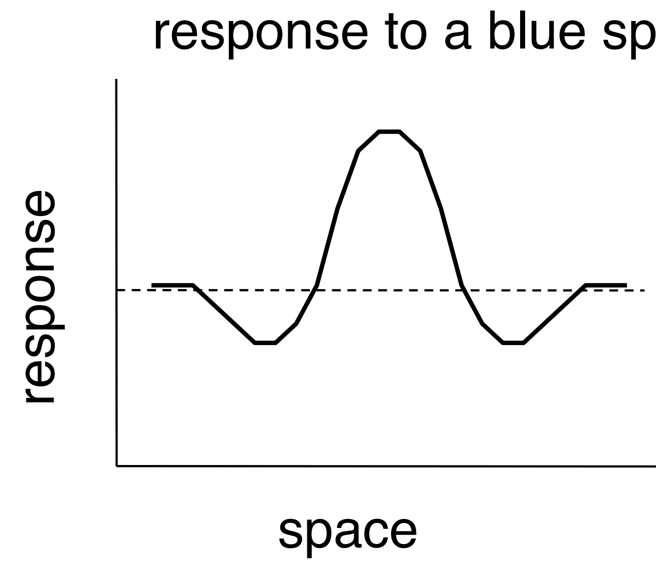




- Blue-Yellow (S-(M+L)) Opponent cell
- Carries info about blue vs. yellow

(Negative) Afterimage: visual image seen after a stimulus has been removed

polarity is the opposite of the original stimulus:

- Colors are complementary:
  - Red produces Green afterimages
  - Blue produces Yellow afterimages
  - Light stimuli produce dark negative afterimages

examine color after-effects

lilac chaser:

http://www.michaelbach.de/ot/col-lilacChaser/index.html

So far we've addressed:

1) Illuminant - power spectrum
2) Cones - absorption spectrum

Q: what's missing?

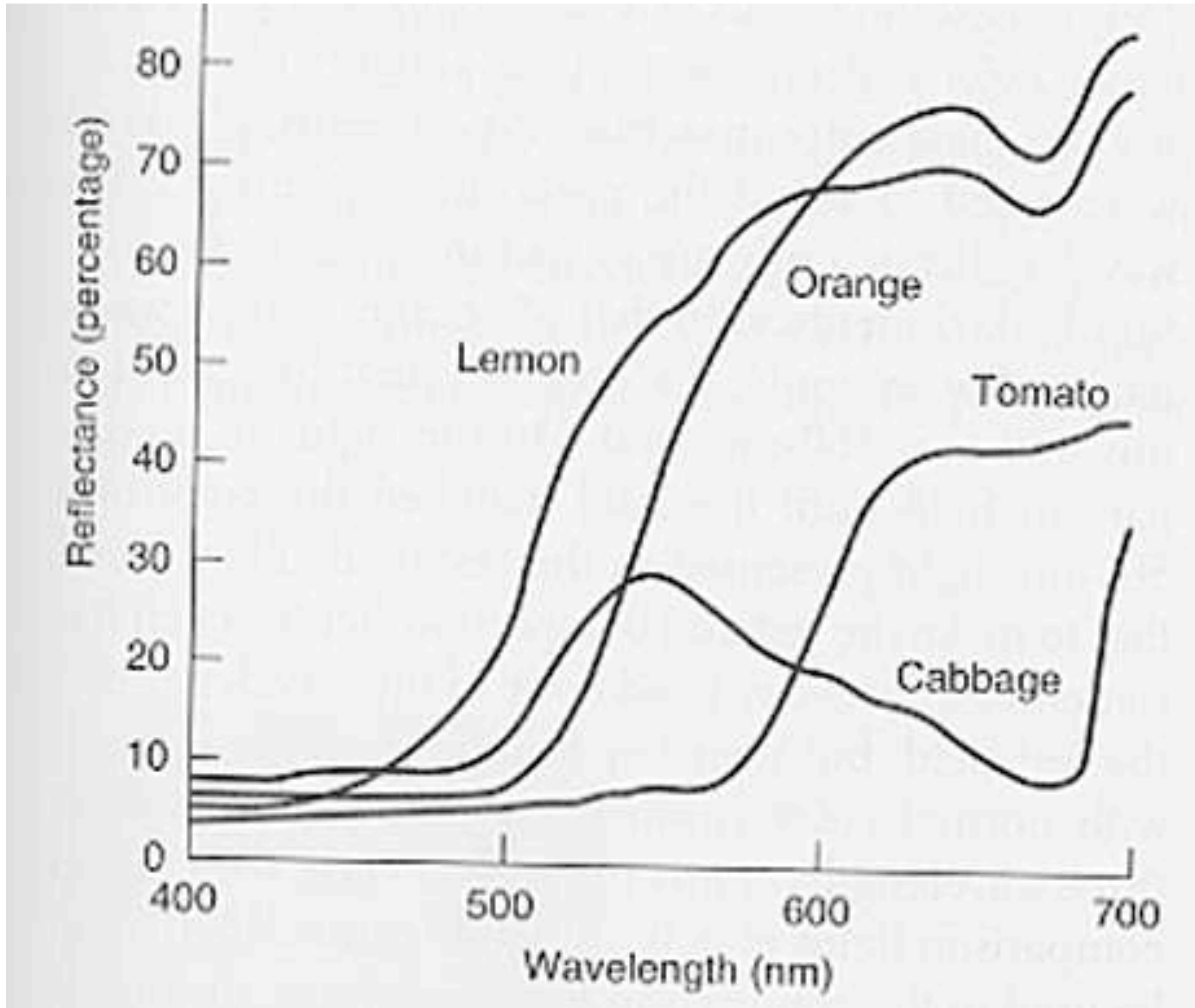
3) Objects in the world!

What properties of an object determine the properties of the reflected light that hits our eyes?

Surface reflectance function:

Describes how much light an object reflects, as a function of wavelength

Think of this as the *fraction* of the incoming light that is reflected back



By now we have a complete picture of how color vision works:

Illuminant

defined by power (or “intensity”) spectrum

amount of light energy at each wavelength

↓

Object

defined by its reflectance function

certain percentage of light at each wavelength is reflected

↓

Cones

defined by absorption spectrum

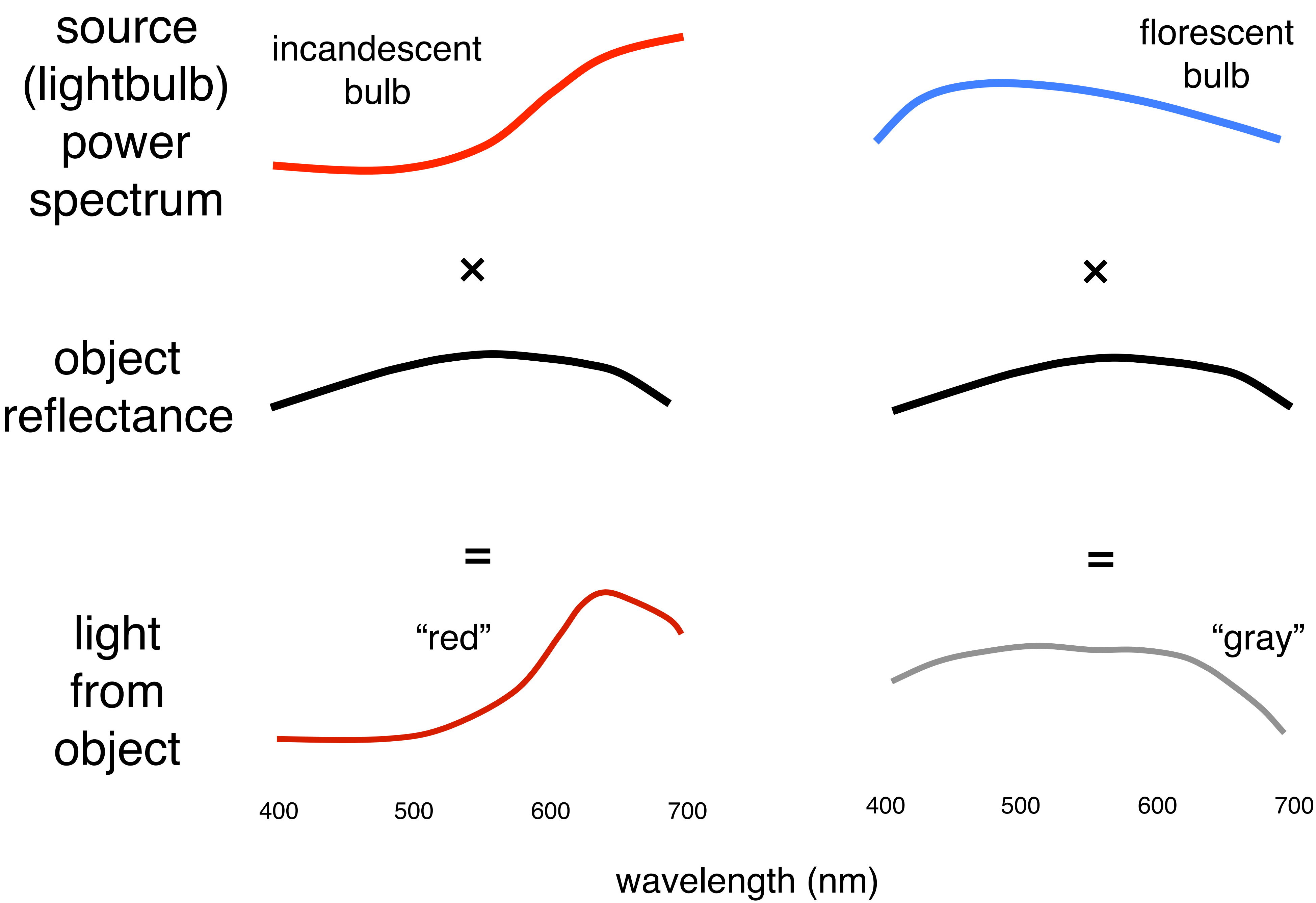
each cone class adds up light energy according to its absorption spectrum

↓

cone responses

three spectral measurements

convey all color information to brain via opponent channels


source
(lightbulb)
power
spectrum
incandescent
bulb
florescent
bulb
×
×
object
reflectance
=
=
light
from
object
“red”
“gray”
400
500
600
700
400
500
600
700
wavelength (nm)

But in general, this doesn’t happen:

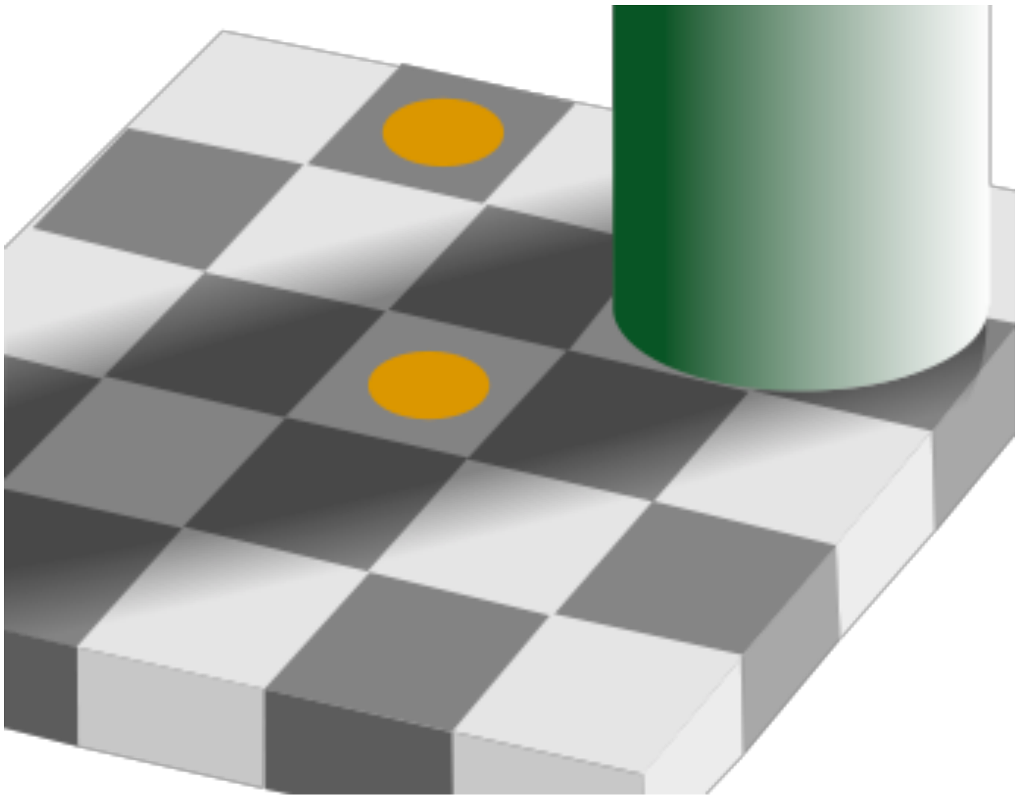
We don’t perceive a white sheet of paper as looking reddish under a tungsten light and blueish/grayish under a halogen light.

Color Constancy

The visual system uses a variety of tricks to make sure things look the same color, regardless of the illuminant (light source)

- **Color constancy** - tendency of a surface to appear the same color under a wide range of illuminants
- To achieve color constancy, we must discount the illuminant and determine the surface color, regardless of how it appears

Illusion illustrating Color Constancy

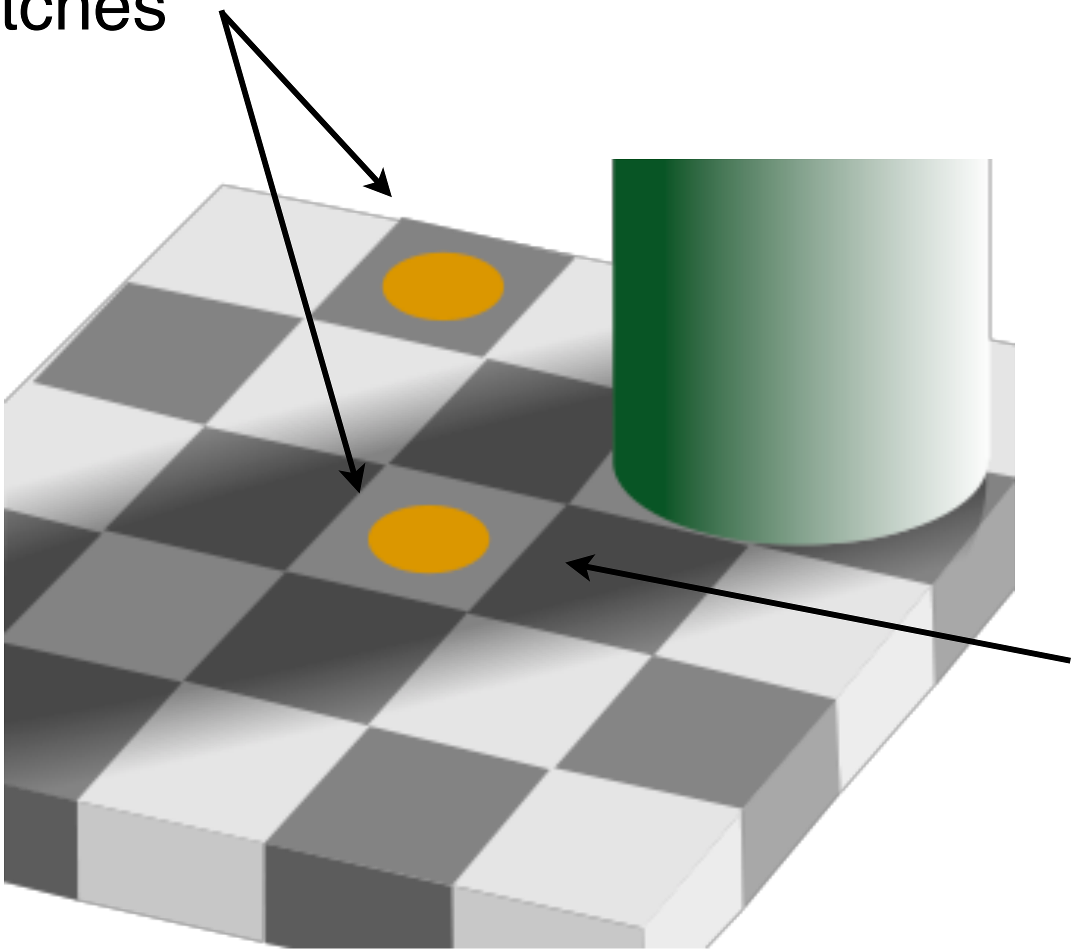


Same yellow in both patches

Same gray around yellow in both patches

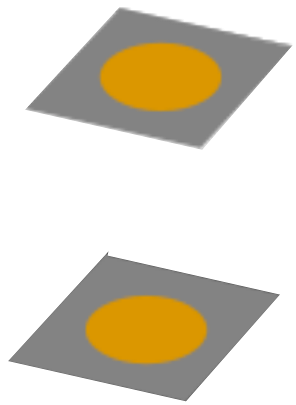
(the effects of lighting/shadow can make colors look different that are actually the same!)

Exact same light coming to your eye from these two patches

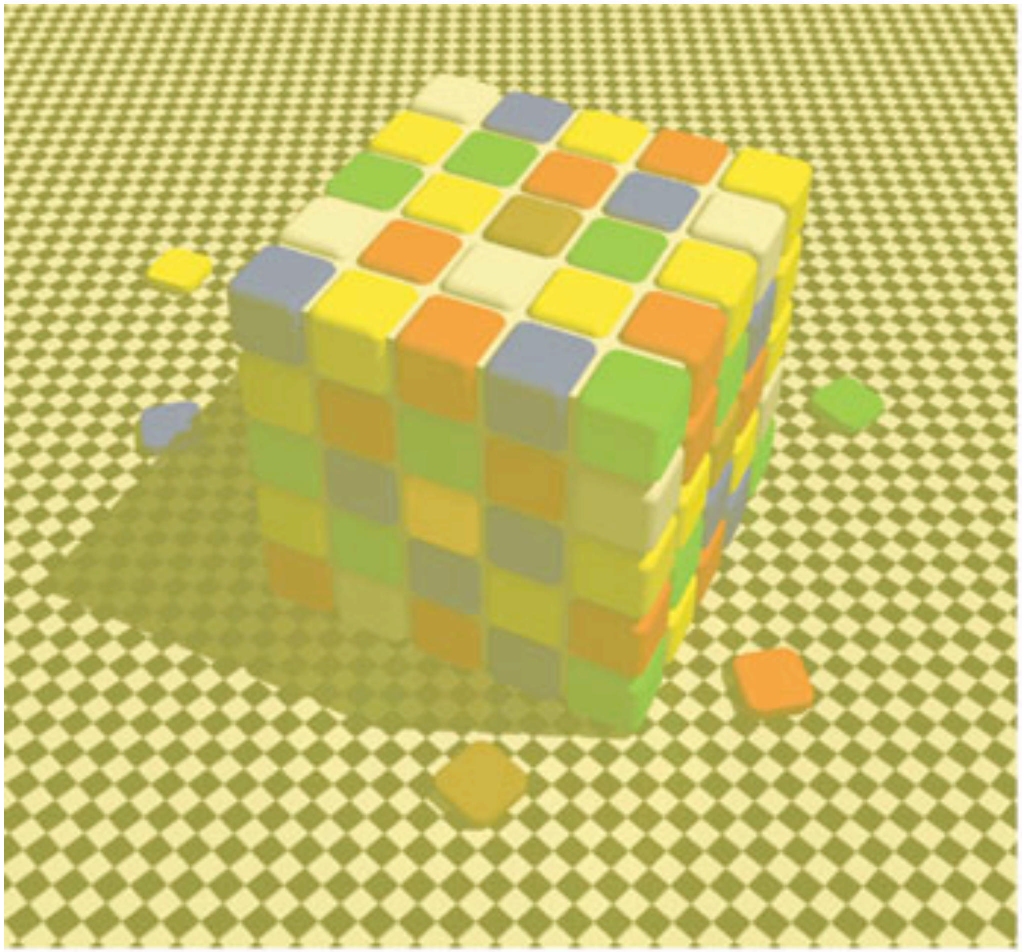


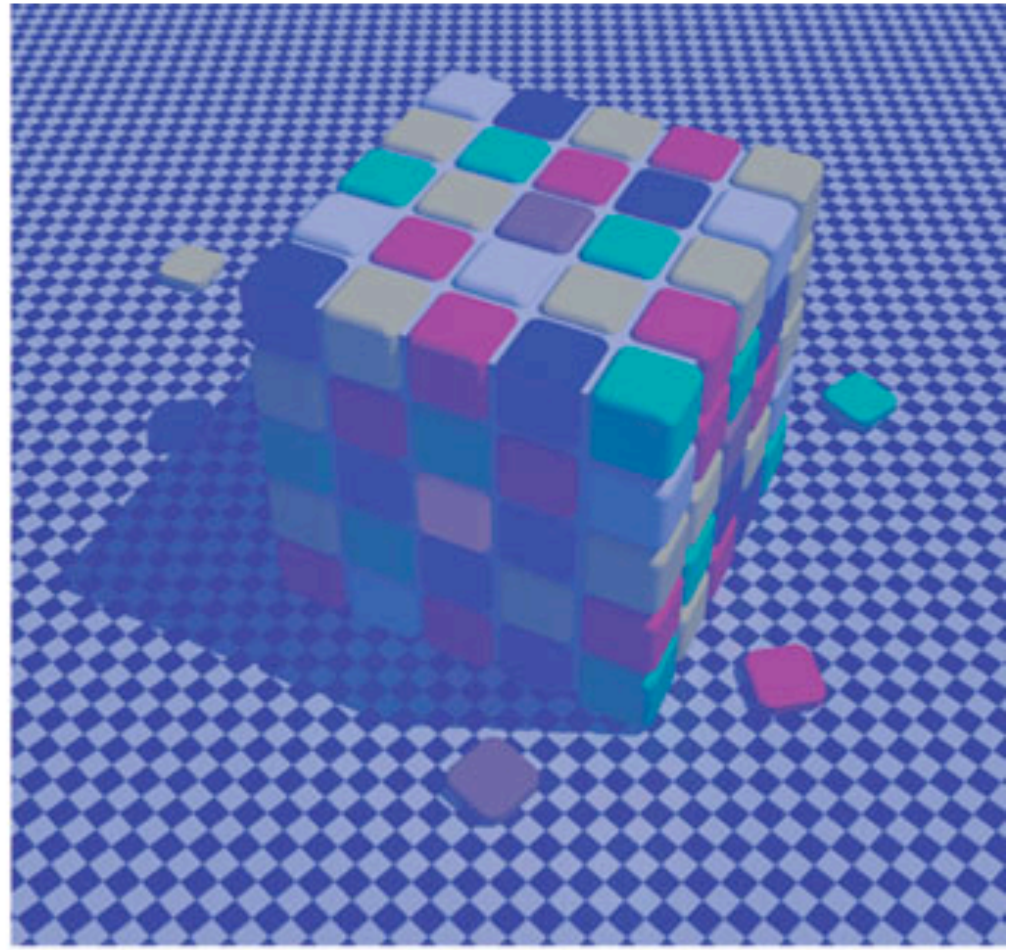
But the brain infers that less light is hitting this patch, due to shadow

CONCLUSION: the lower patch must be reflecting a higher fraction of the incoming light (i.e., it’s brighter)

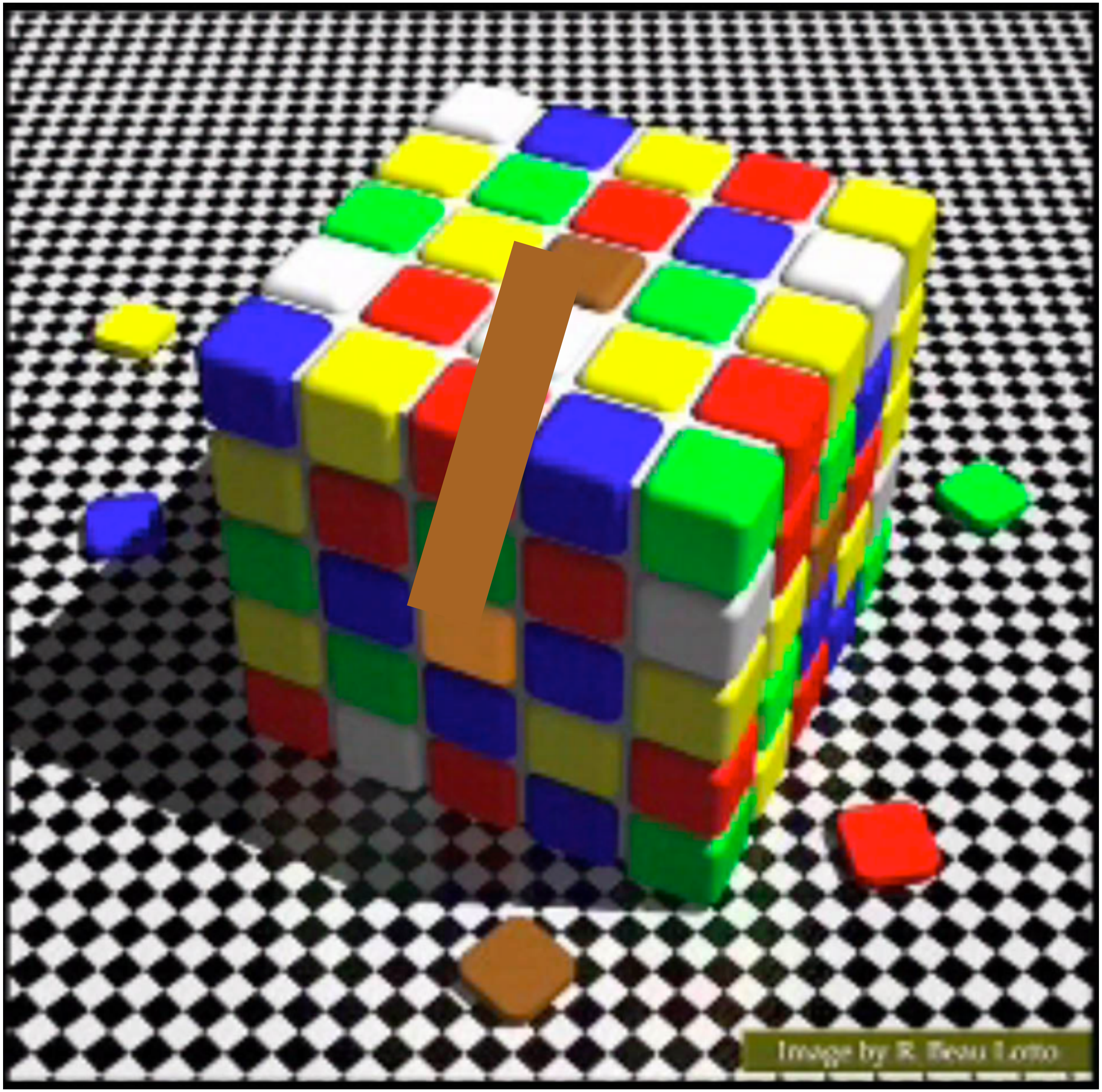


Color Computations





Beau Lotto



Beau Lotto

- Visual system tries to discount the effects of the illuminant: it cares about the properties of the *surface*, not the *illuminant.*

- still unknown how the brain does this: believed to be in cortex (V1 and beyond).

- *but*: color-constancy is not perfect

- possible to fool the visual system:

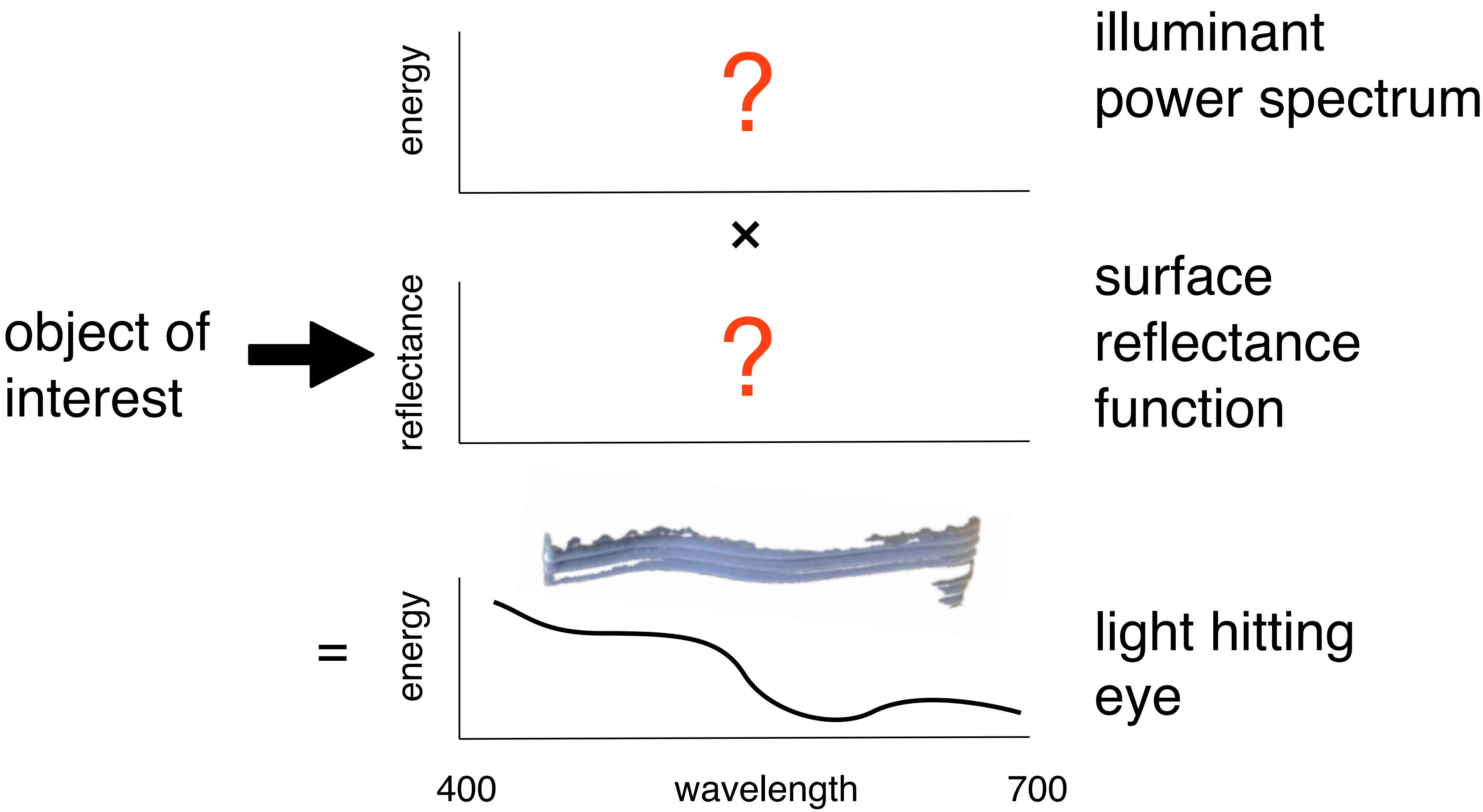
  – using a light source with unusual spectrum (most light sources are broad-band; narrow-band lights will make things look very unusual)

  – showing an image with little spectral variation (e.g., a blank red wall).

the dress incident

"guys please help me - is this dress white and gold, or blue and black? Me and my friends can't agree and we are freaking the fuck out."

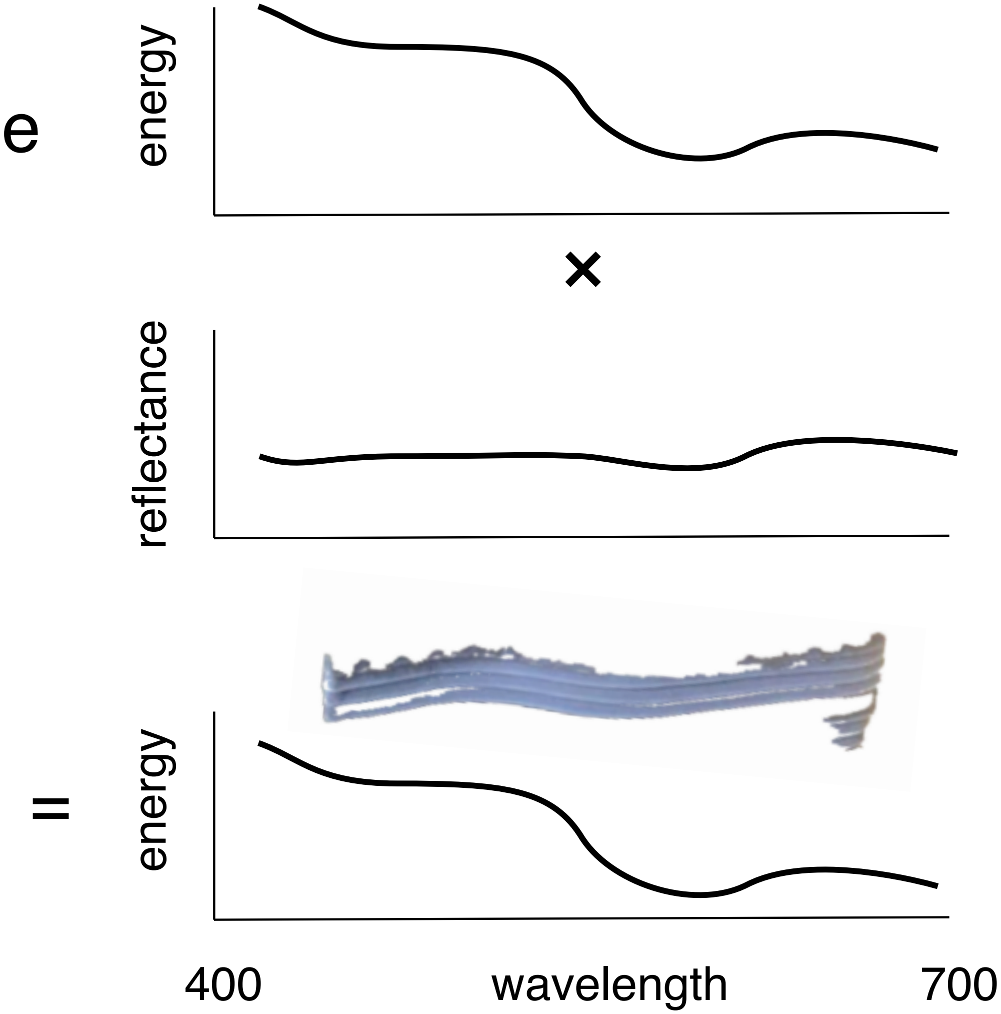
So what's going on?



Possibility #1: dress in blueish light (or shadow)

blueish
light source

white stripe!

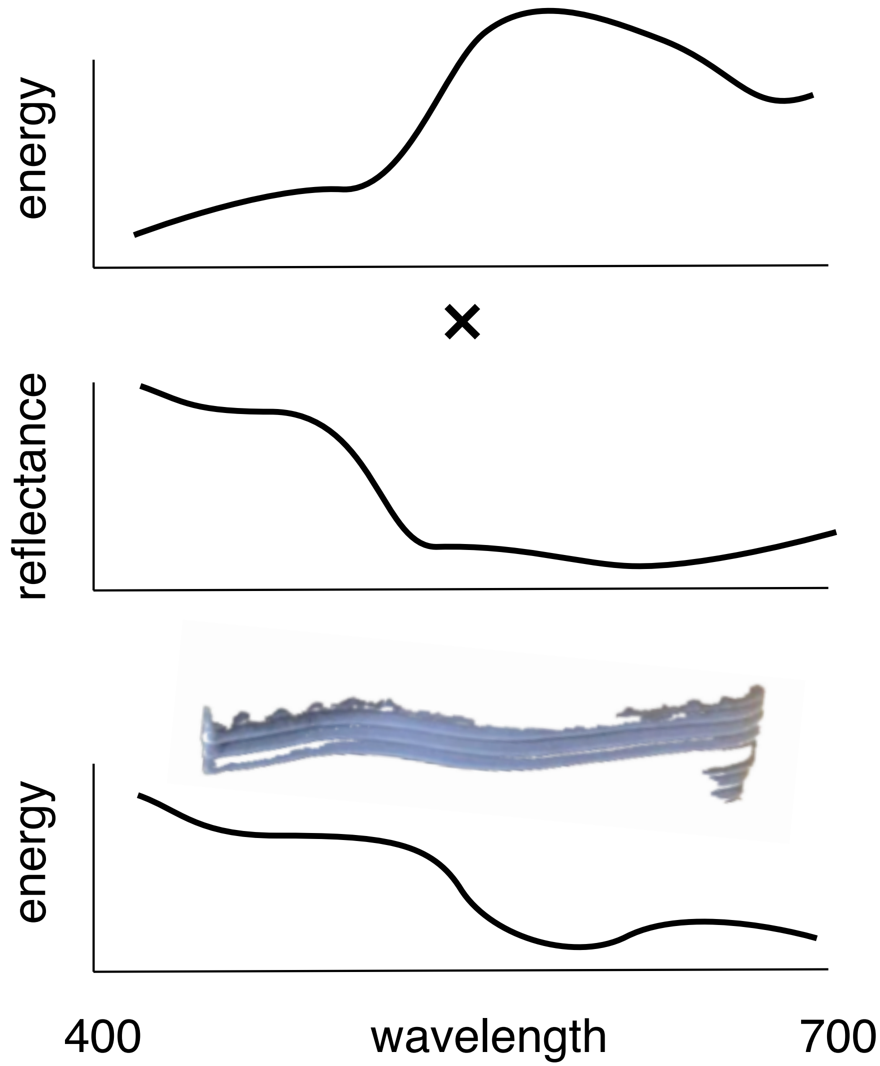


Possibility #2: dress in yellow light

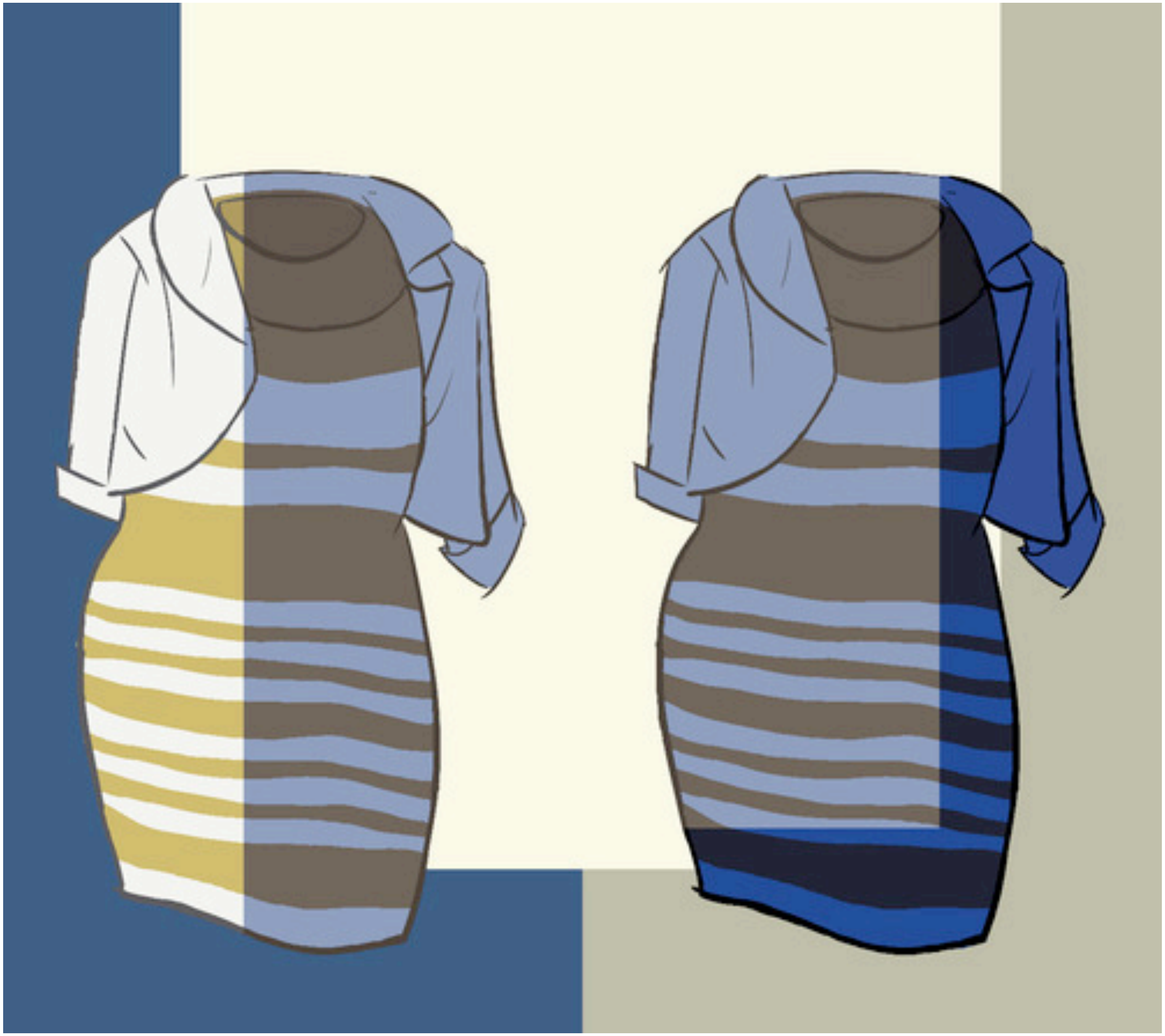
yellowish
light source

blue
stripe!

=



So: percept depends on inferences about the light source!



So: percept depends on inferences about the light source!

Rosa Lafer-Sousa

Of course: we have no idea (so far) why people are making such radically different inferences about light

And reborn in 2017:

Grey-and-green, or pink-and-white?

alisha 🎃
@dolansmalik

Follow

THE REAL SHOE IS PINK & WHITE OKAY⁉️
The second pic was with flash & darkened, so it looks teal & gray. (depends on what lighting ur in)

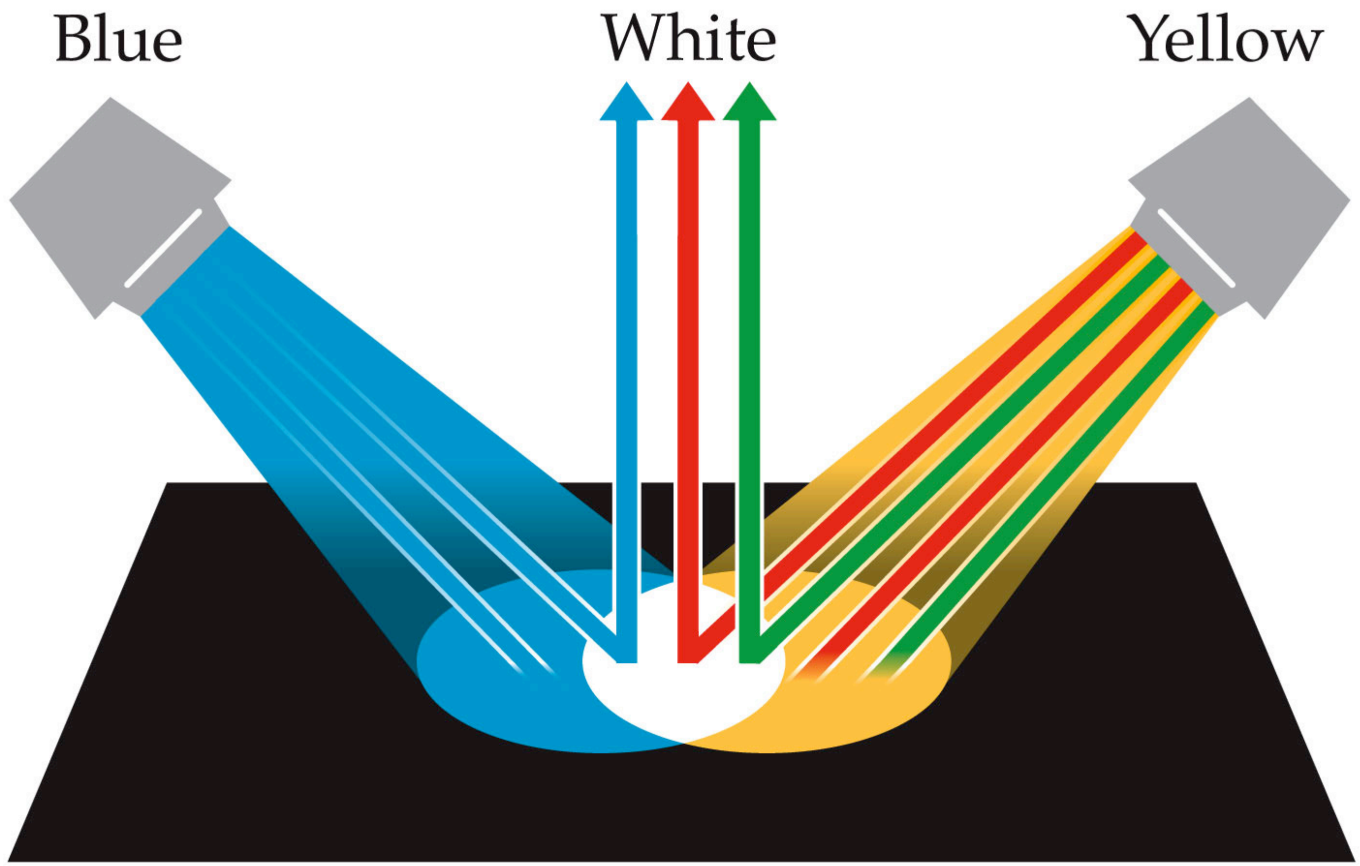
6:00 PM - 11 Oct 2017

Color mixing

- Mixing of lights (additive) vs Mixing of paints (subtractive)

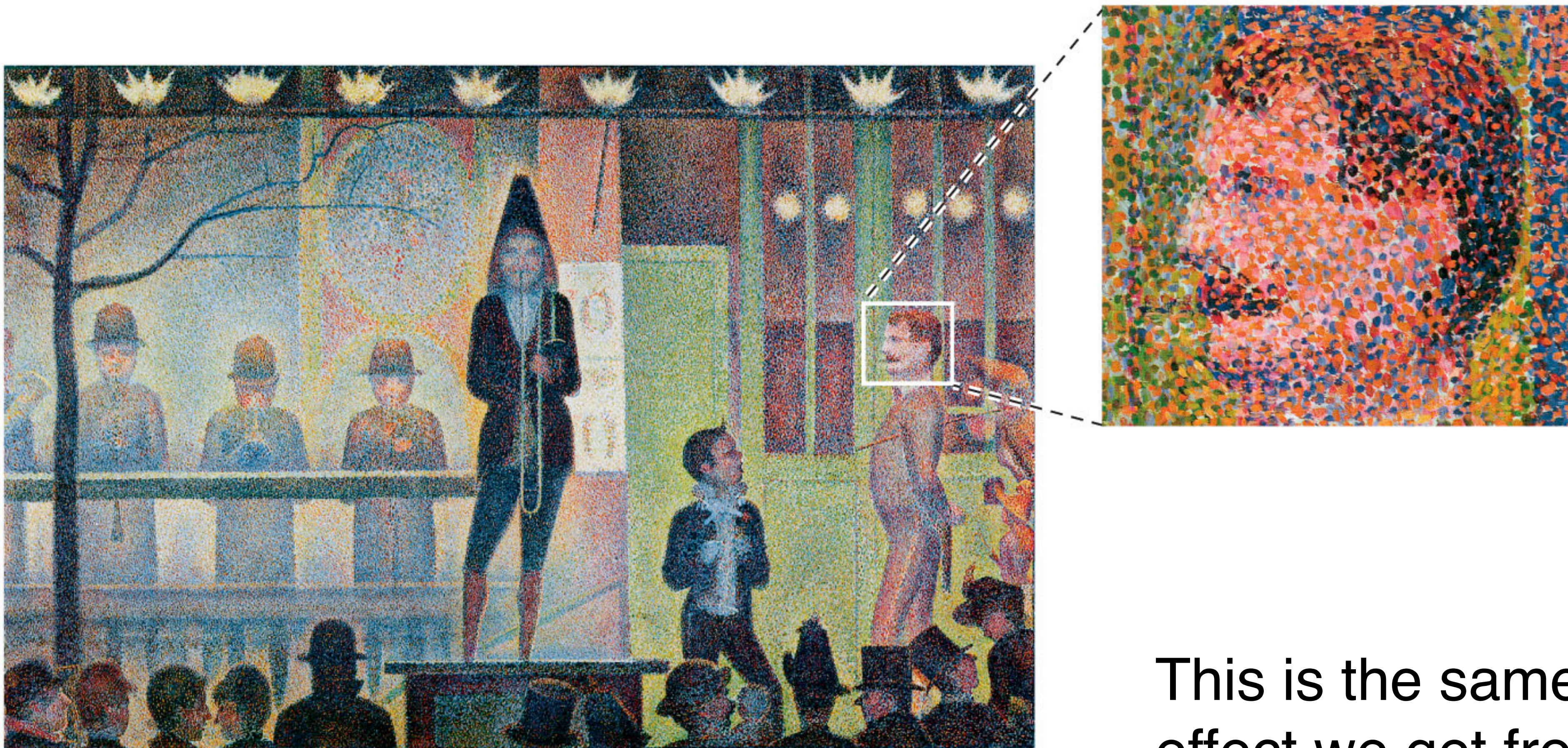
Mixing of lights:

- **Additive color mixing**
- If light A and light B both arrive at the eye, the effects of those two lights add together
- (that is, the power spectra add)



Georges Seurat's painting *La Parade* (1888)

- illustrates the effect of *additive* color mixture
- reflected light from nearby dots adds together when blurred by the eye



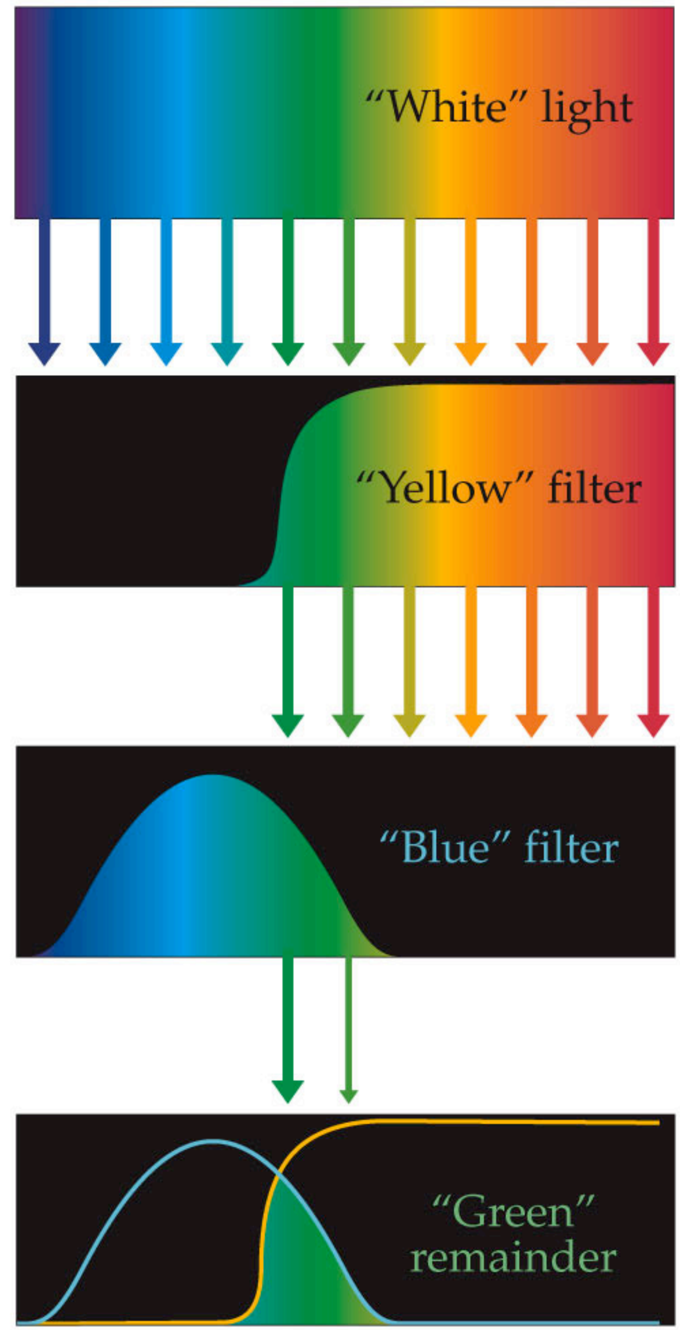
This is the same effect we get from a TV monitor with 3 kinds phosphors

Mixing of paints:

- **Subtractive color mixing**
- If pigment A and B mix, some of the light shining on the surface will be subtracted by A and some by B. Only the remainder contributes to the perception of color

Example of ***subtractive*** color mixture:
"white"—broadband—light is passed through two filters

1. Take "white" light that contains a broad mixture of wavelengths.
2. Pass it through a filter that absorbs shorter wavelengths. The result will look yellowish.
3. Pass that through a bluish filter that absorbs all but a middle range of wavelengths.
4. The wavelengths that make it through both filters will be a mix that looks greenish.



This is the same result we'd get from mixing together yellow & blue paints.

color blindness

- About 8% of male population, 0.5% of female population has some form of color vision deficiency: Color blindness
- Mostly due to missing M or L cones (sex-linked; both cones coded on the X chromosome)

Types of color-blindness:

dichromat - only 2 channels of color available (contrast with "trichromat" = 3 color channels).

Three types, depending on missing cone:

	Frequency: M / F
• **Protanopia**: absence of L-cones	2% / 0.02%
• **Deuteranopia**: absence of M-cones	6% / 0.4%
• **Tritanopia**: absence of S-cones	0.01% / 0.01%

includes true dichromats and color-anomalous trichromats


Scene Viewed by
Protanope
Same Scene Viewed by
Normal Trichromat

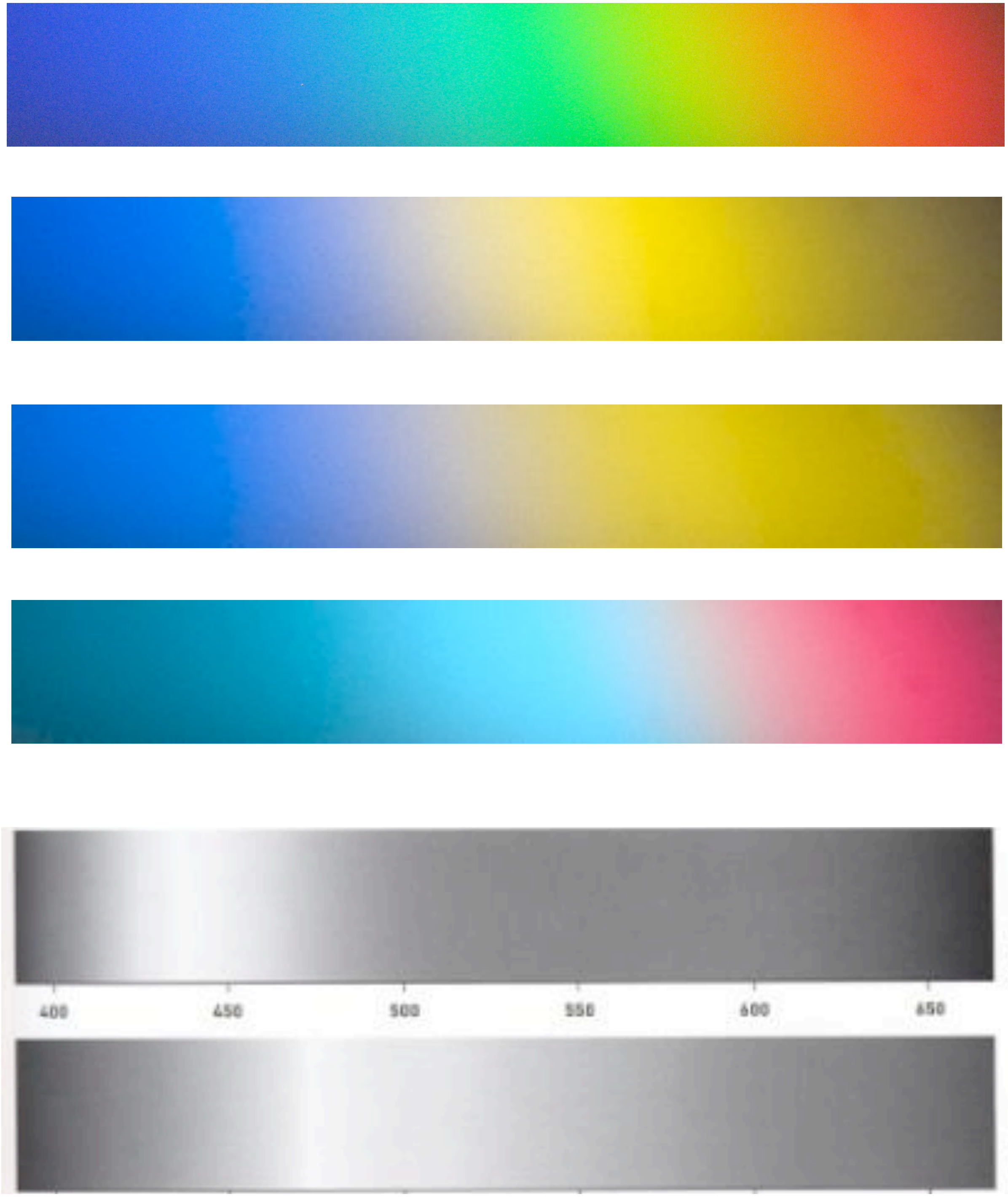

Scene Viewed by
Deuteranope
Same Scene Viewed by
Normal Trichromat


Scene Viewed by
Tritanope
Same Scene Viewed by
Normal Trichromat

Other types of color-blindness:

- **Monochromat:** true “color-blindness”; world is black-and-white
- **cone monochromat** - only have one cone type (vision is truly b/w)
- **rod monochromat** - visual in b/w AND severely visually impaired in bright light

Rod monochromacy



normal trichromat

protanope

deuteranope

tritanope

monochromat

scotopic light levels

Color Vision in Animals

- most mammals (dogs, cats, horses): dichromats
- old world primates (including us): trichromats
- marine mammals: monochromats
- bees: trichromats (but lack "L" cone; ultraviolet instead)
- some birds, reptiles & amphibians: tetrachromats!

Color vision doesn't work at low light levels!

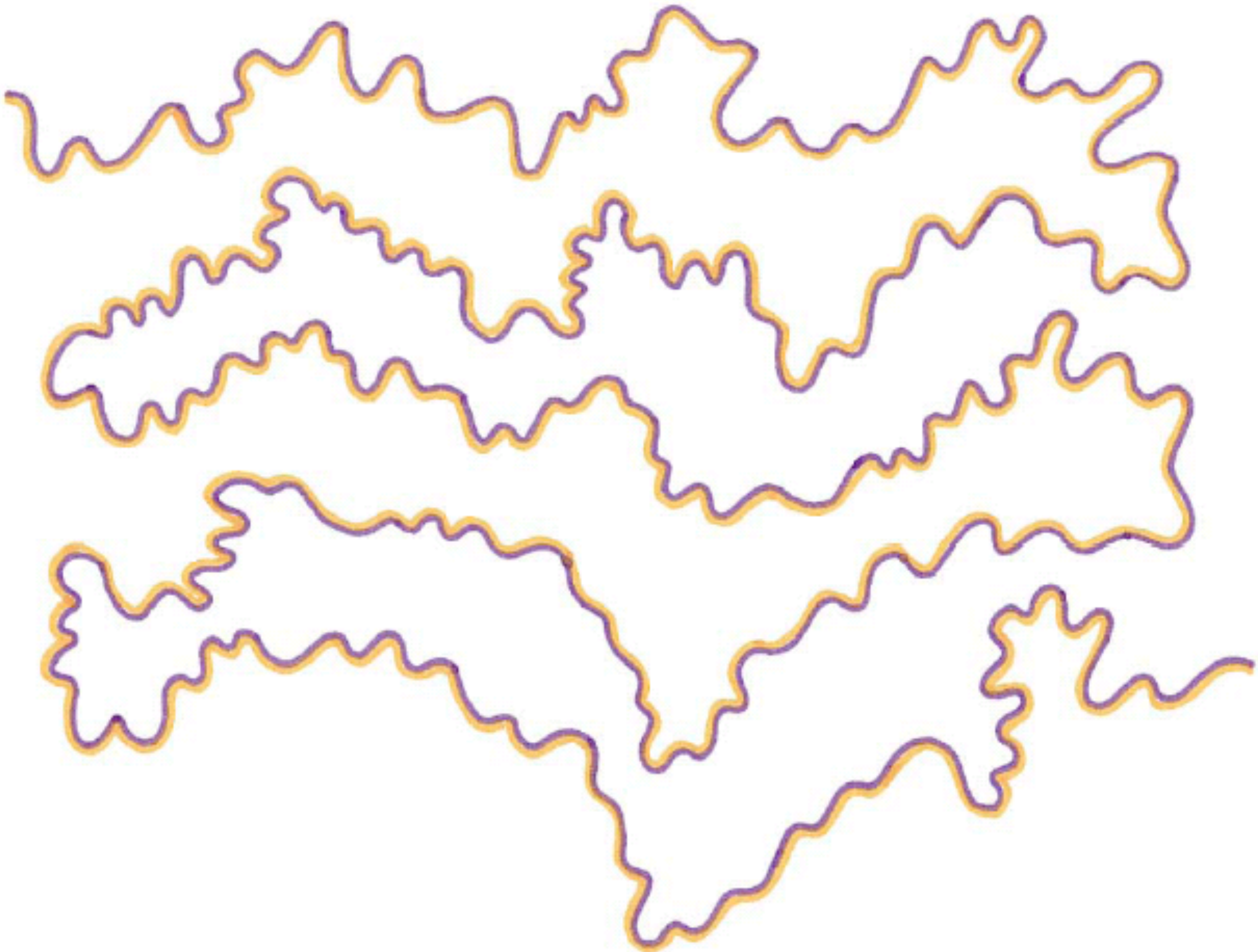
Two Regimes of Light Sensitivity

- **Photopic**: Light intensities that are bright enough to stimulate the cone receptors and bright enough to "saturate" the rod receptors
    - Sunlight and bright indoor lighting

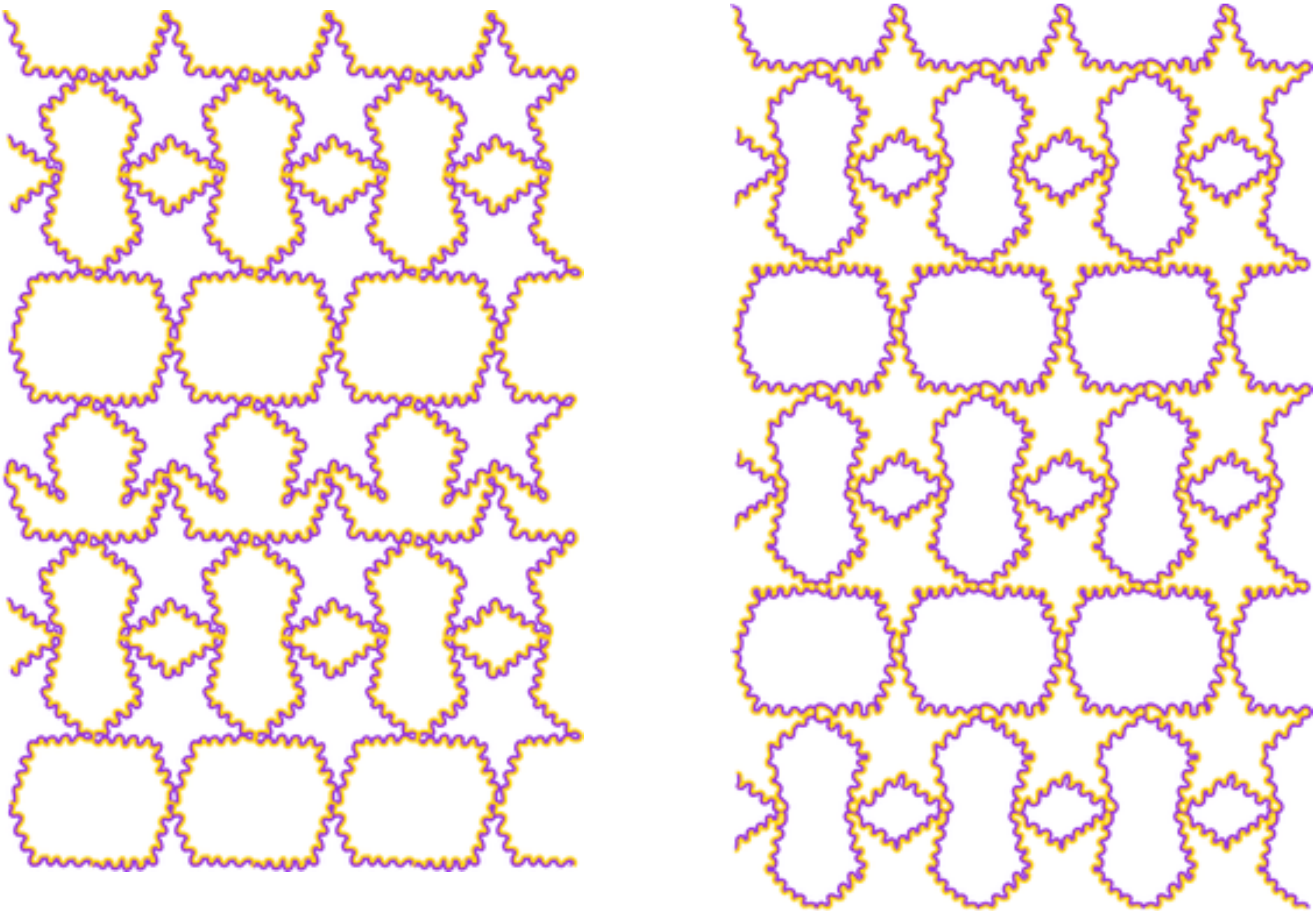
- **Scotopic**: Light intensities that are bright enough to stimulate the rod receptors but too dim to stimulate the cone receptors
    - Moonlight and extremely dim indoor lighting

Other (unexplained) color phenomenon:

- watercolor illusion
- neon color spreading
- motion-induced color: *Benham's top*



Watercolor illusion



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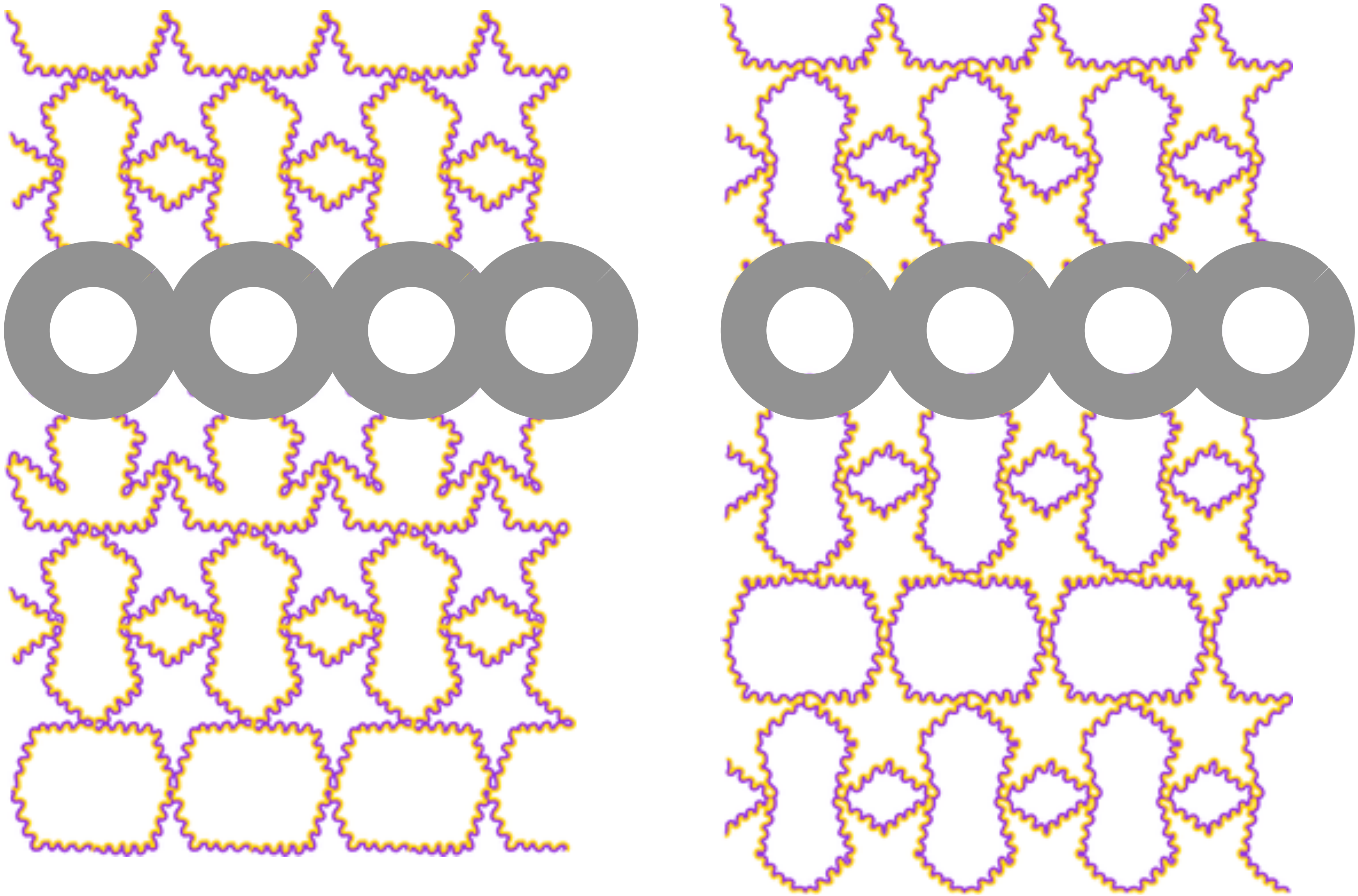

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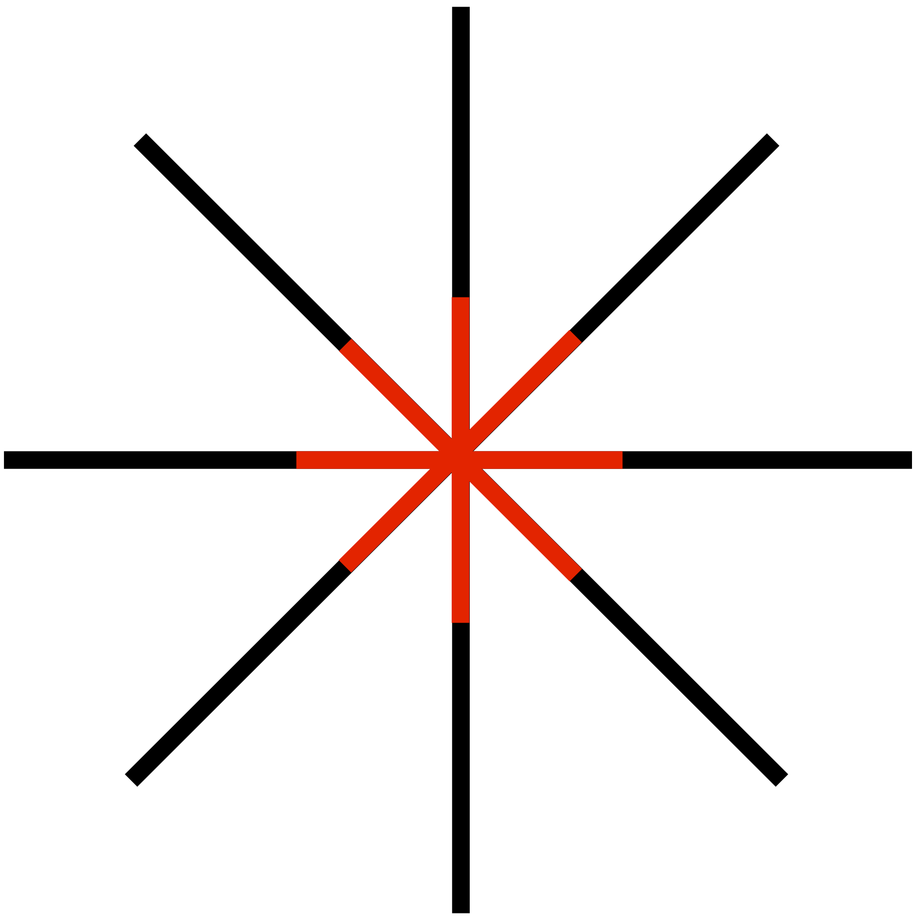
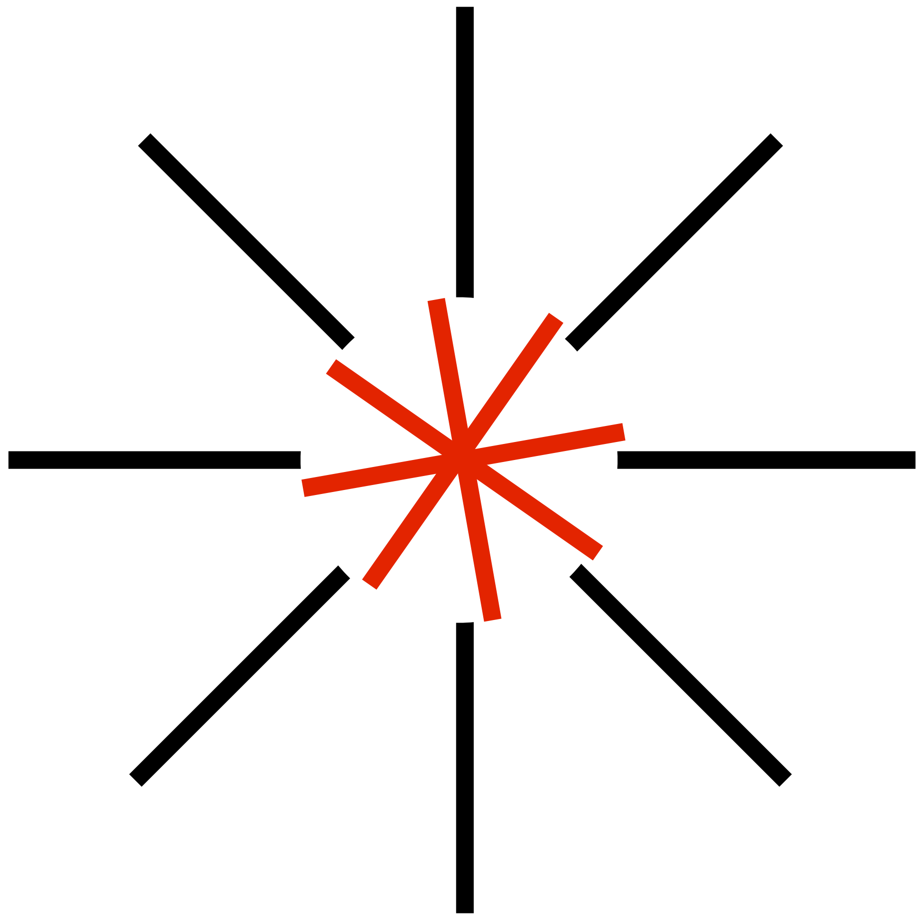


Neon Color-Spreading



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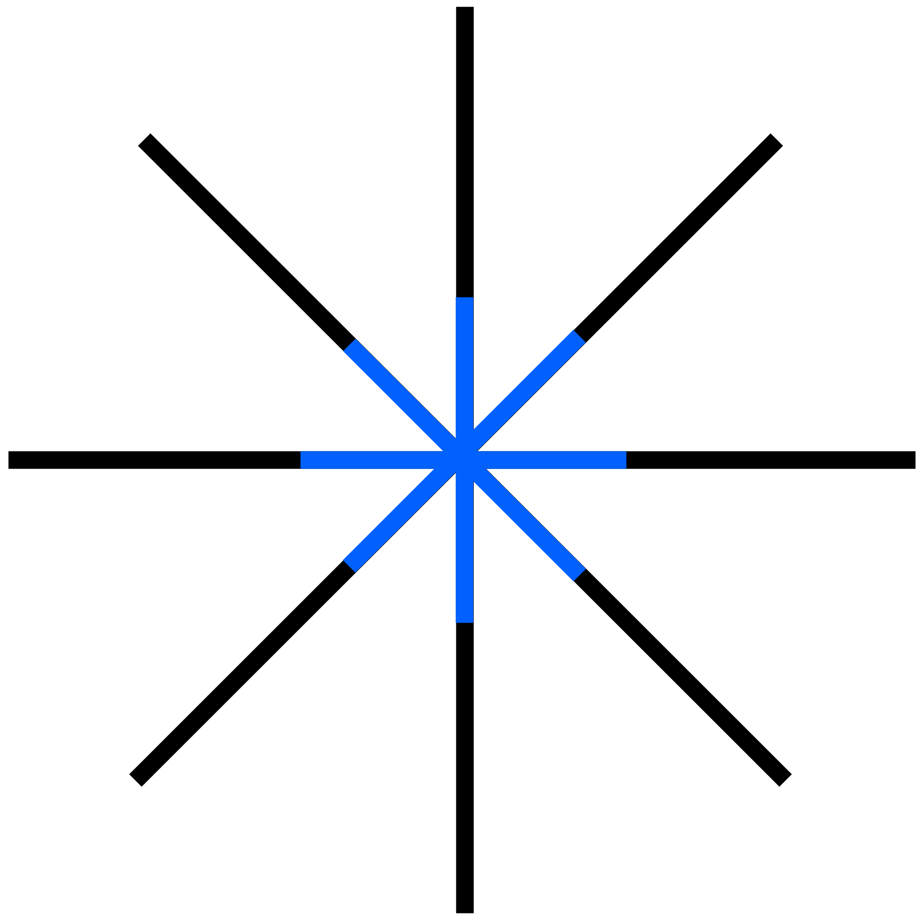

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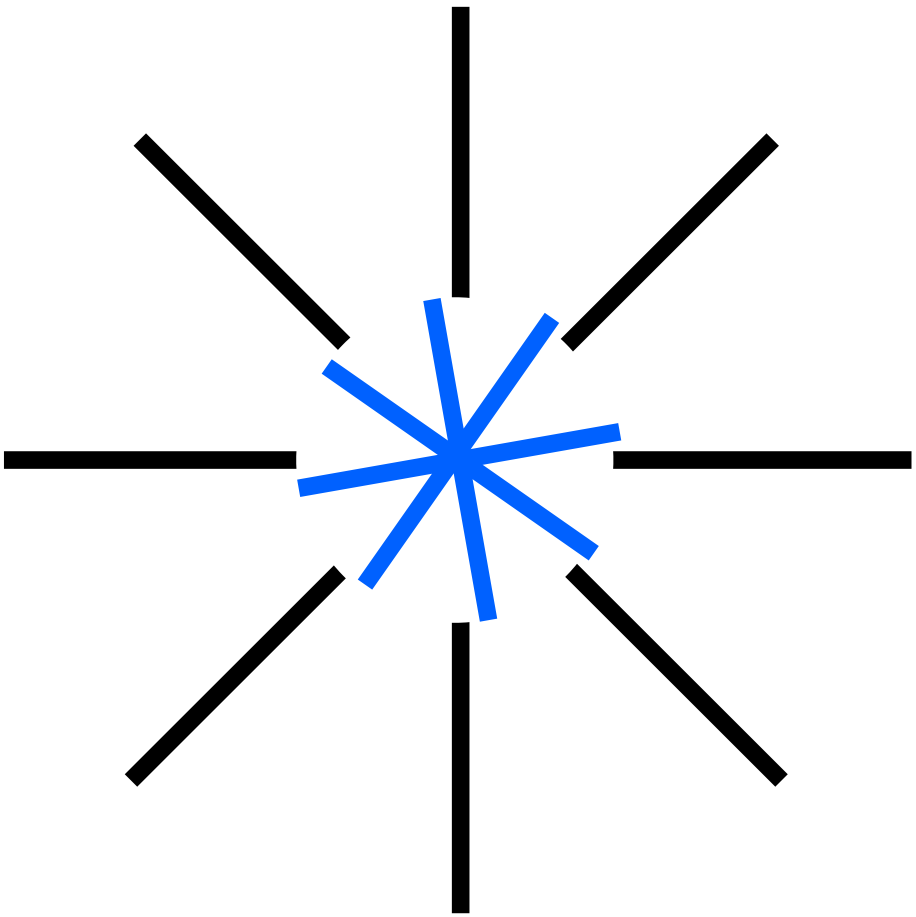

Neon Color-Spreading

Benham's top:

motion-induced color perception

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

- not well-understood; believed to arise from different color-opponent retinal ganglion cells having different temporal latencies.
- the flickering pattern stimulates the different color channels differently (although this is admittedly a crude theory)

Summary

- trichromacy: 3-dimensional color vision (vs. hyper-spectral cameras!)
- metamers
- color-matching experiment
- color space (RGB, HSB)
- non-spectral hues
- opponent channels, negatives & after-images
- color-opponent channels
- surface reflectance functions
- color constancy
- photopic / scotopic light levels
- additive / subtractive color mixing
- color blindness