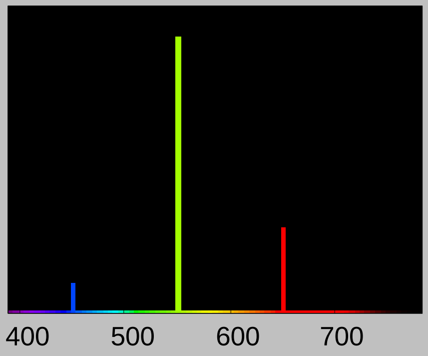
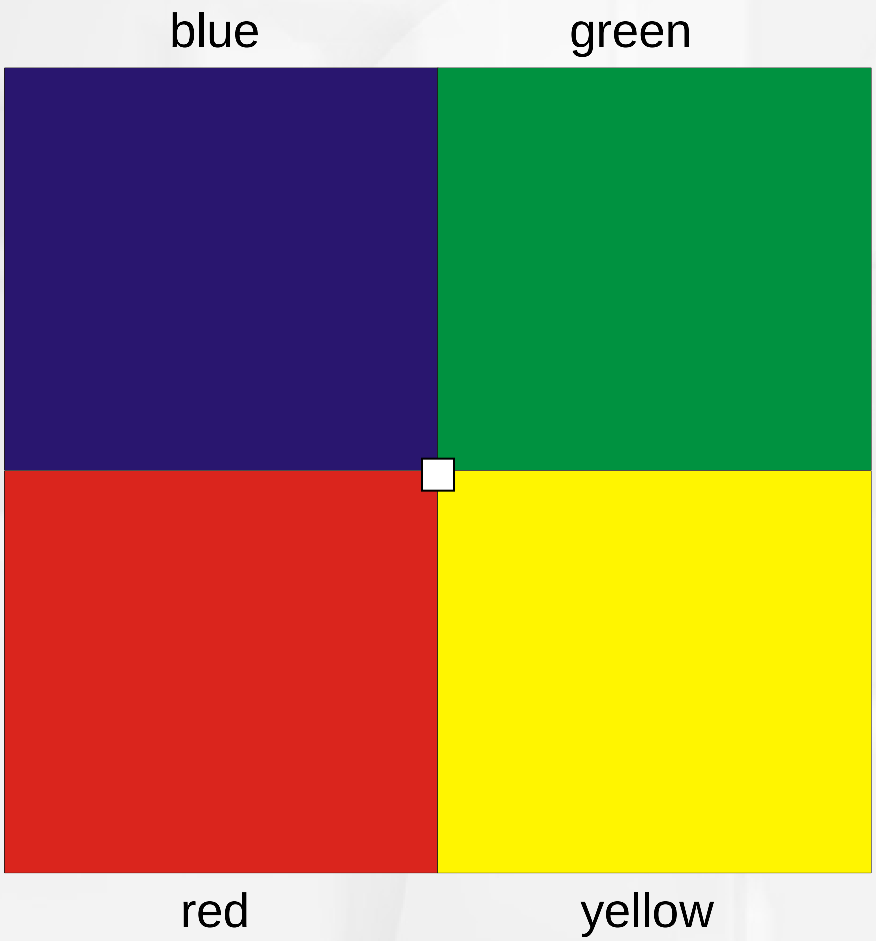
So the theory of trichromacy explains why we only need three primaries to produce a variety of colors. But what does an arbitrary sum of primaries *look* like?



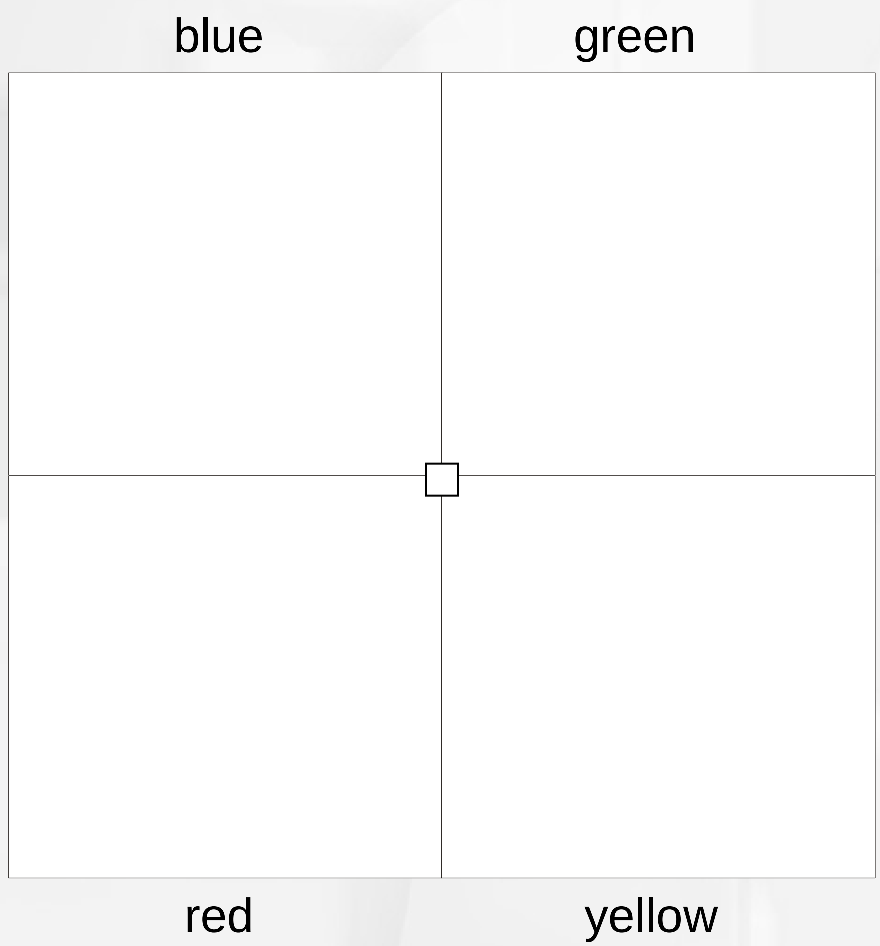
In 1878, Hering argued that trichromacy wasn't enough. He asked:

Why don't we ever see yellowish blues? Or reddish greens?

Color aftereffects



Color aftereffects

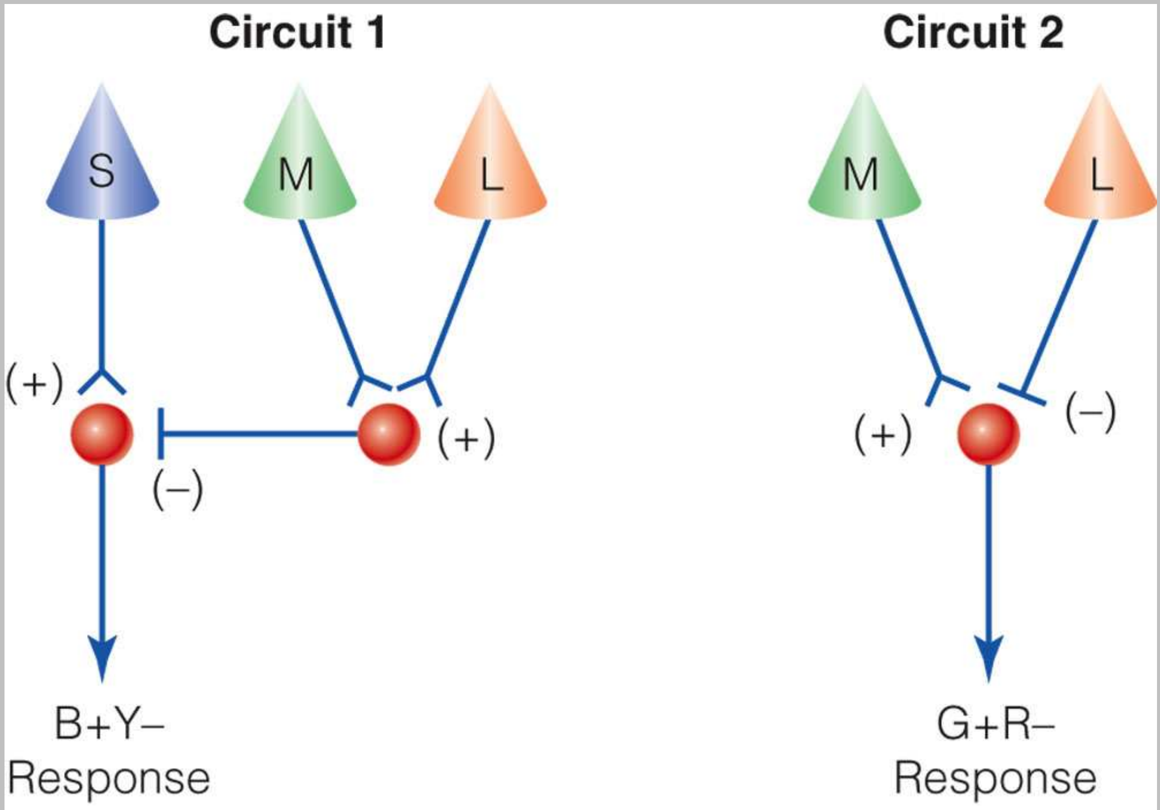


Why are red and green opposites? Why are yellow and blue opposites?

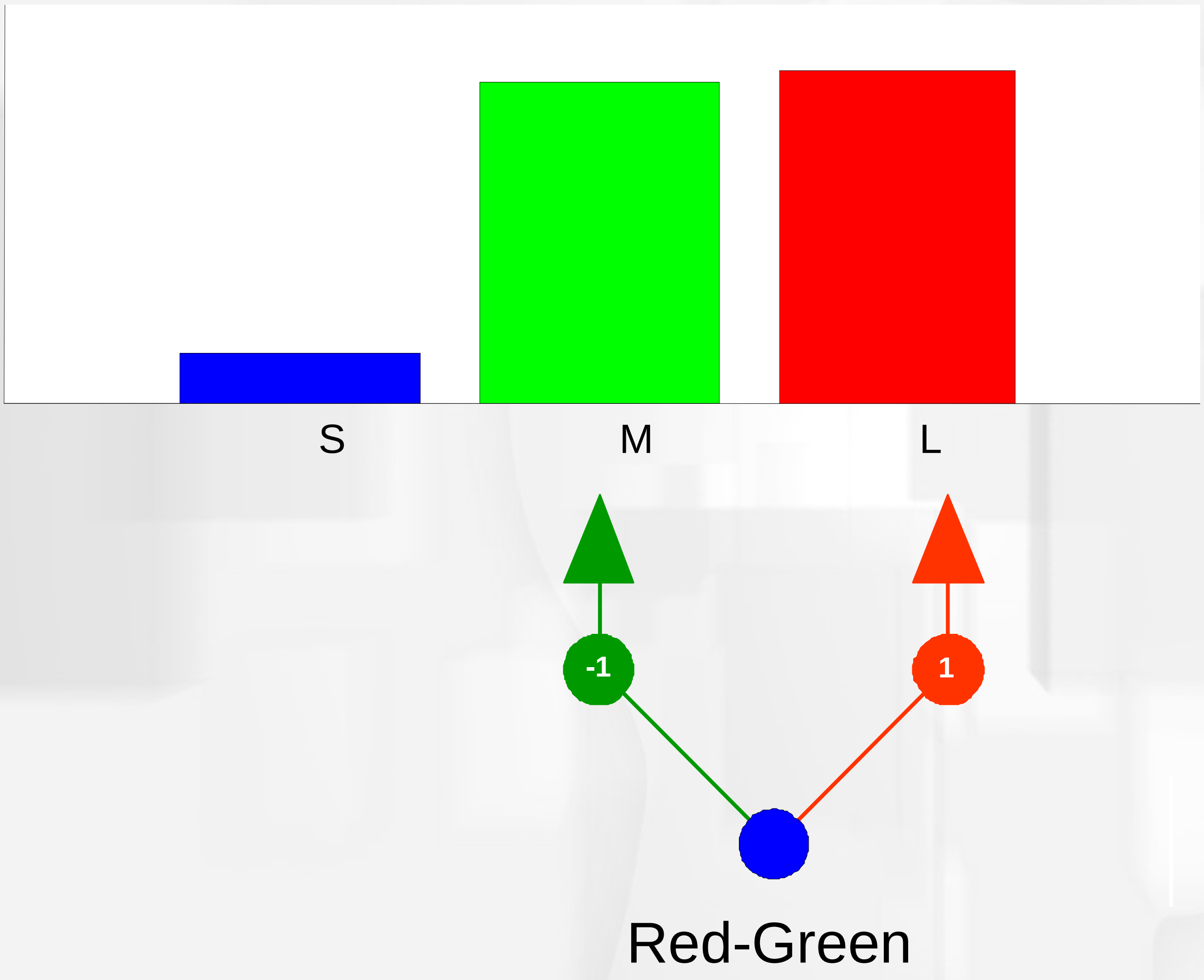
Hering proposed the *Opponent Process Theory*

Color vision is based on the activity of two opponent-process mechanisms:

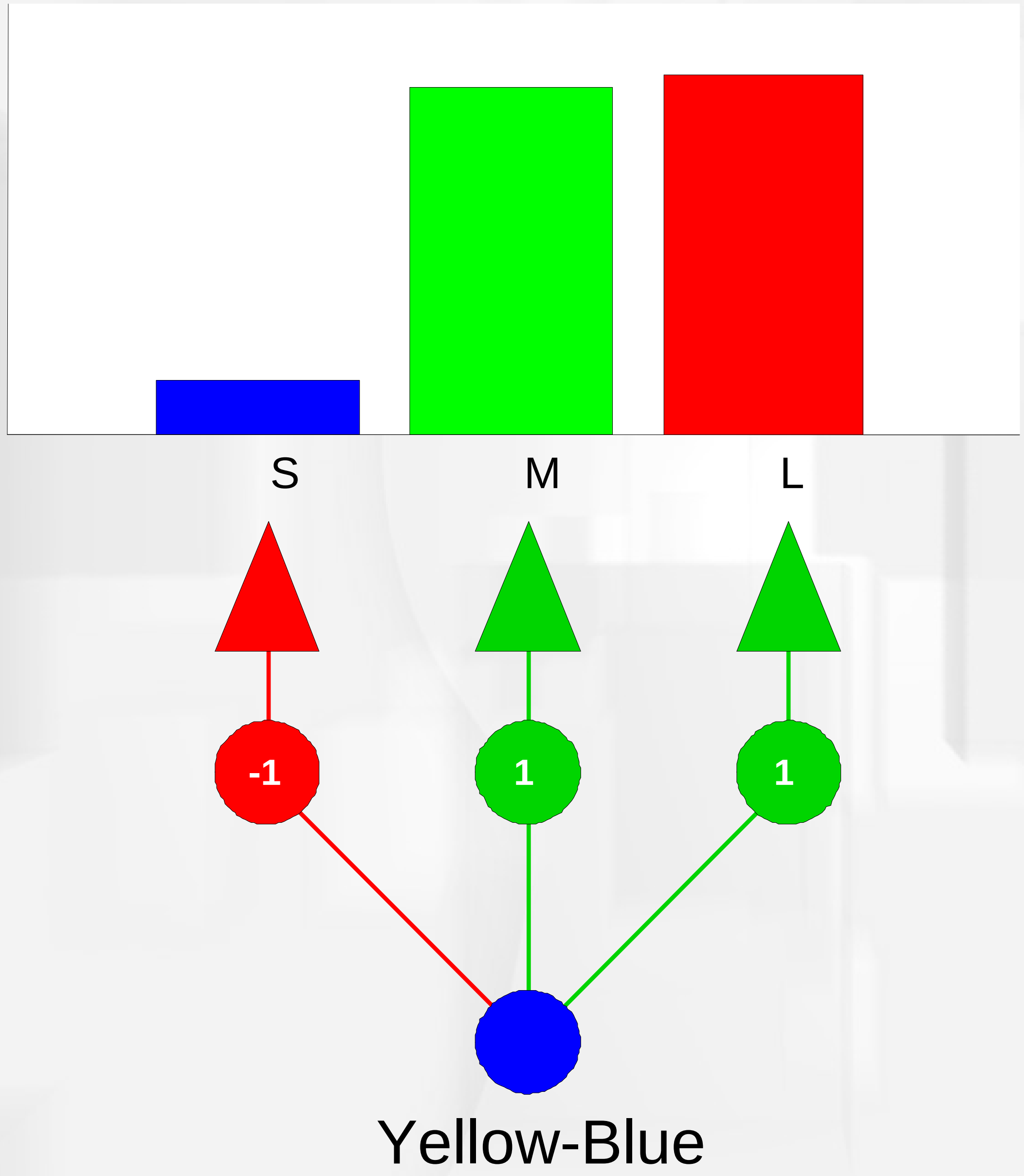
1. A RED/GREEN opponent mechanism.
2. A YELLOW/BLUE opponent mechanism



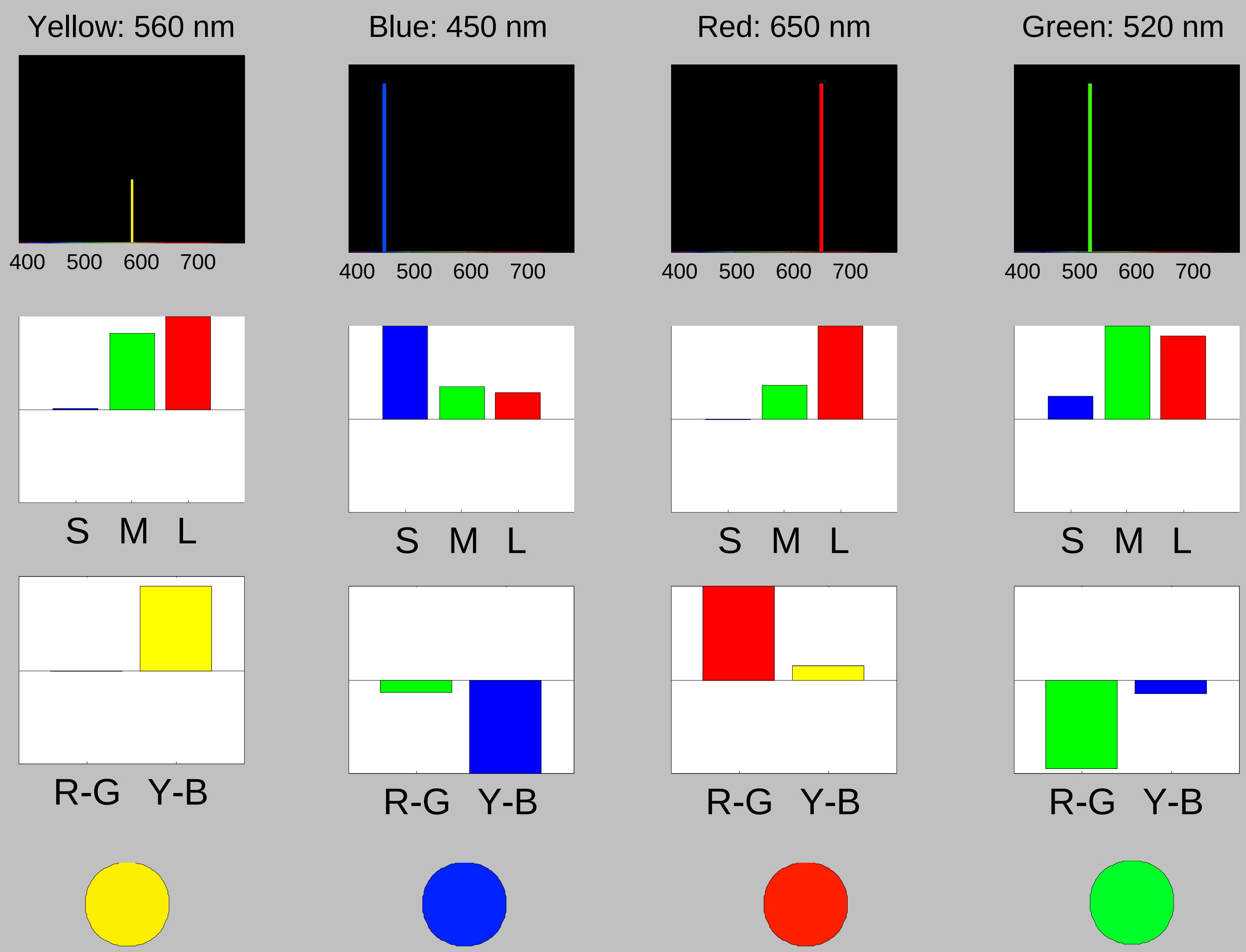
The Red-Green opponent system subtracts M from L cone responses



The Yellow-Blue opponent system subtracts S from L+M cone responses



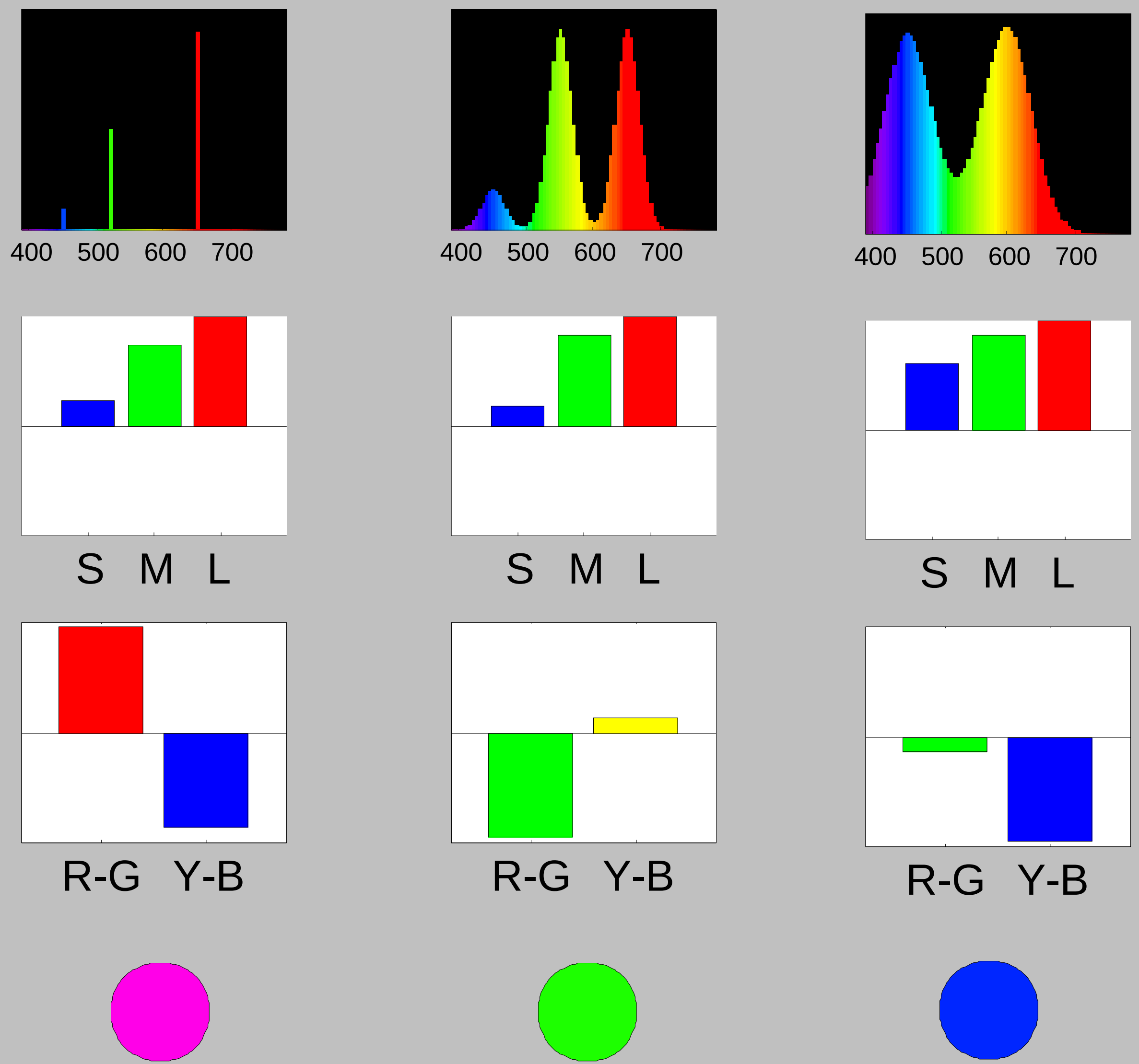
Now with RG = L-M and YB = (L+M) – S,
we can predict the appearance of any arbitrary spectrum of light.



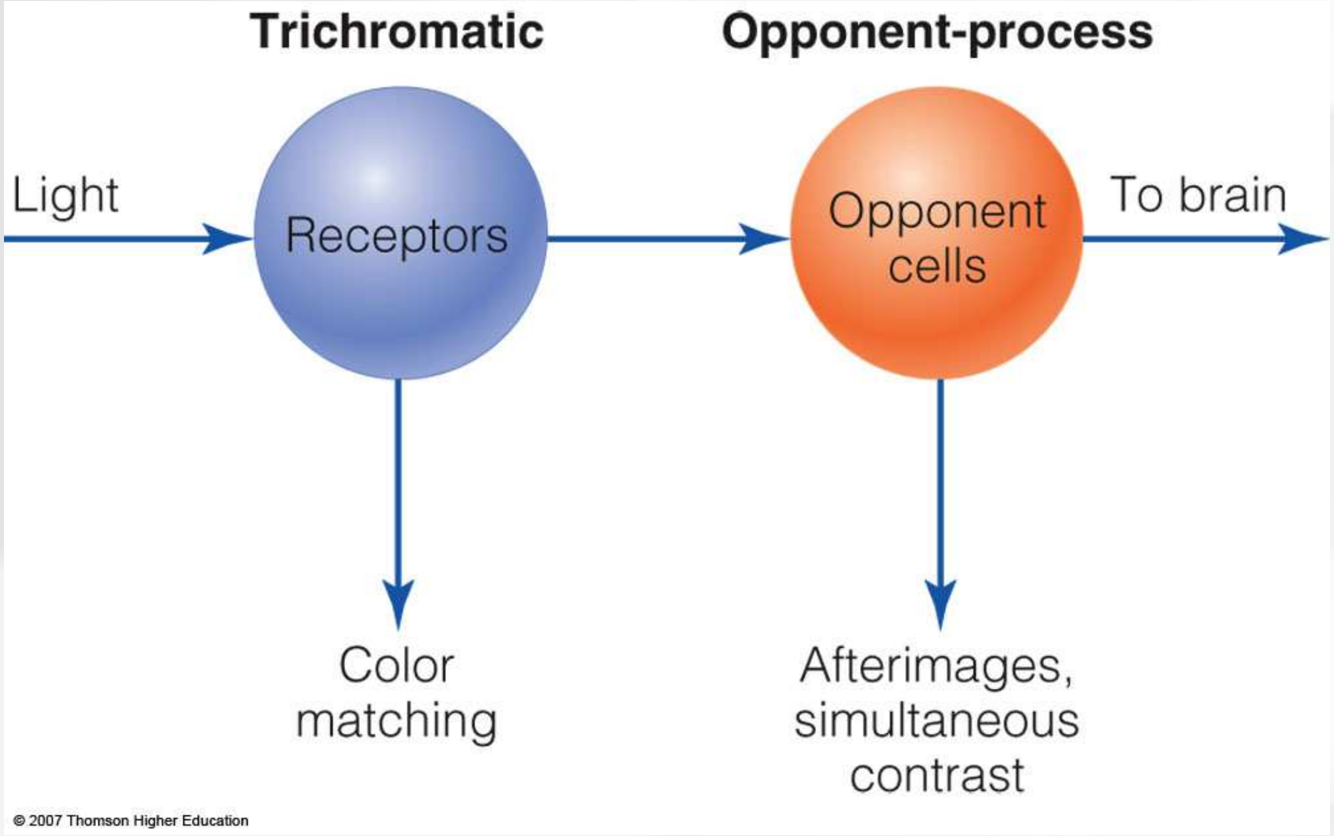
Now with RG = L-M and YB = (L+M) – S,
we can predict the appearance of any arbitrary spectrum of light.

Sum of primaries:

Or more complex spectra:



Our experience of color is shaped by physiological mechanisms, both in the receptors and in opponent neurons.

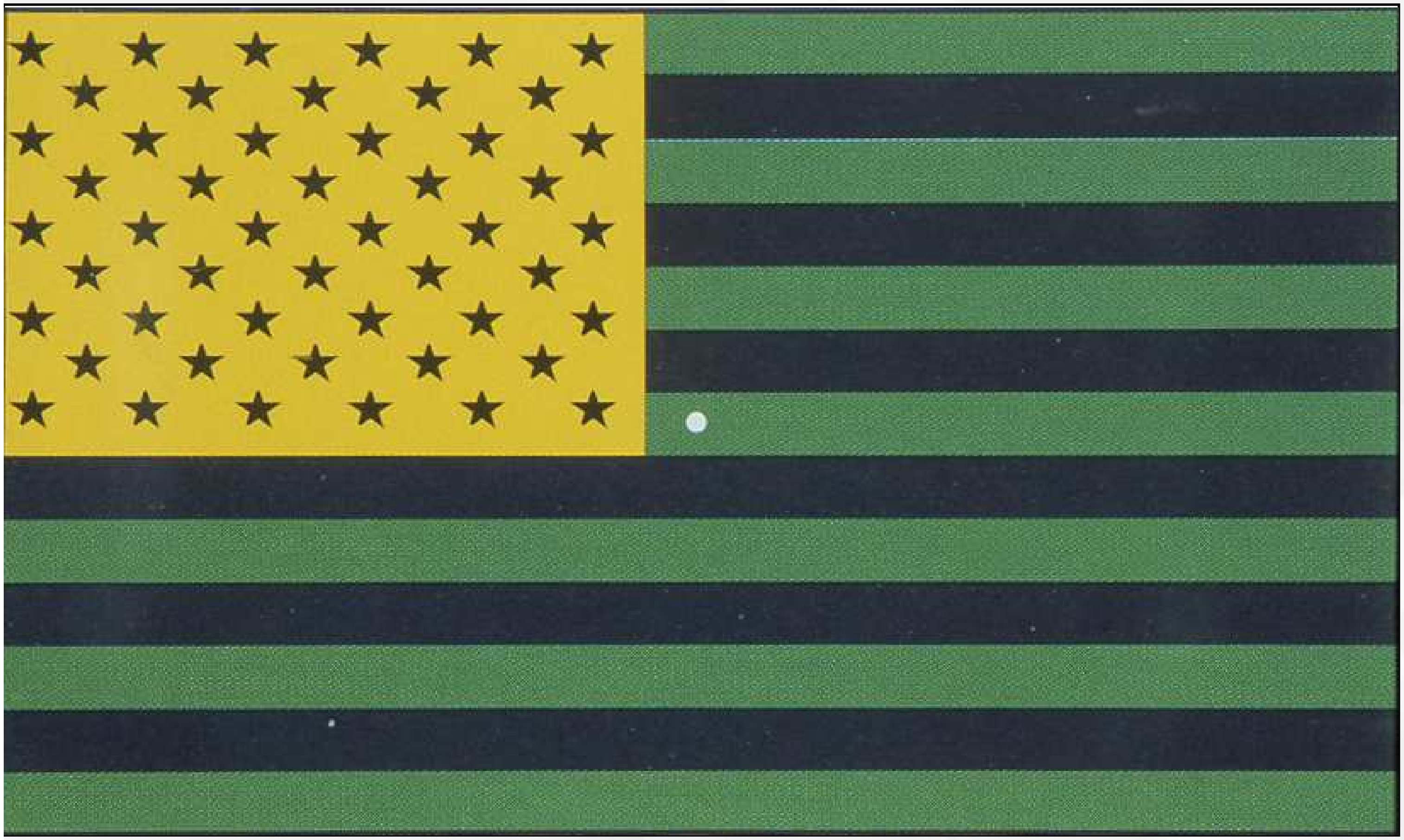


But, color perception depends on more than wavelength

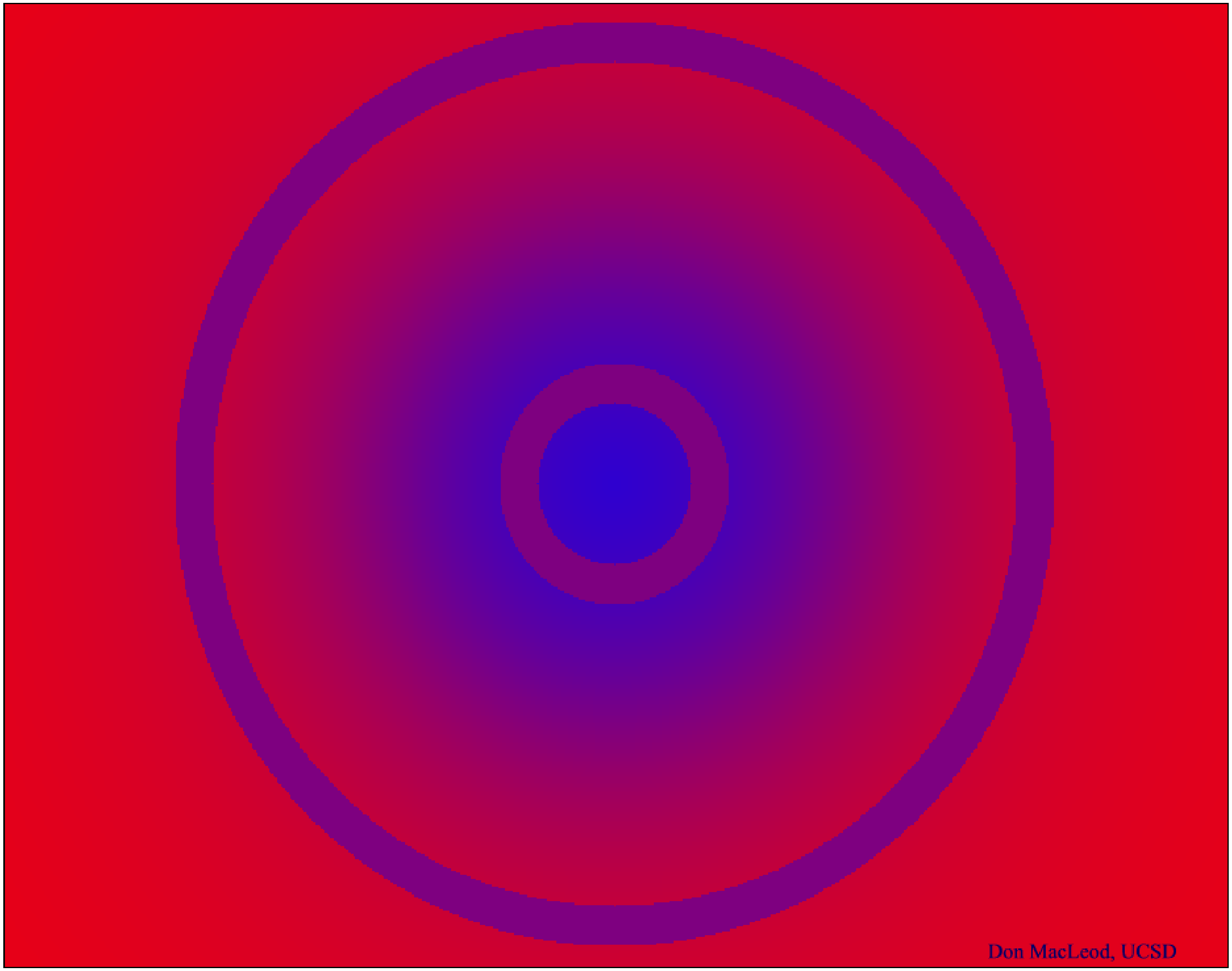
Examples:

- Light/dark adaptive state (Purkinje shift)
- Adaptation aftereffects
- Simultaneous contrast effects
- Color constancy

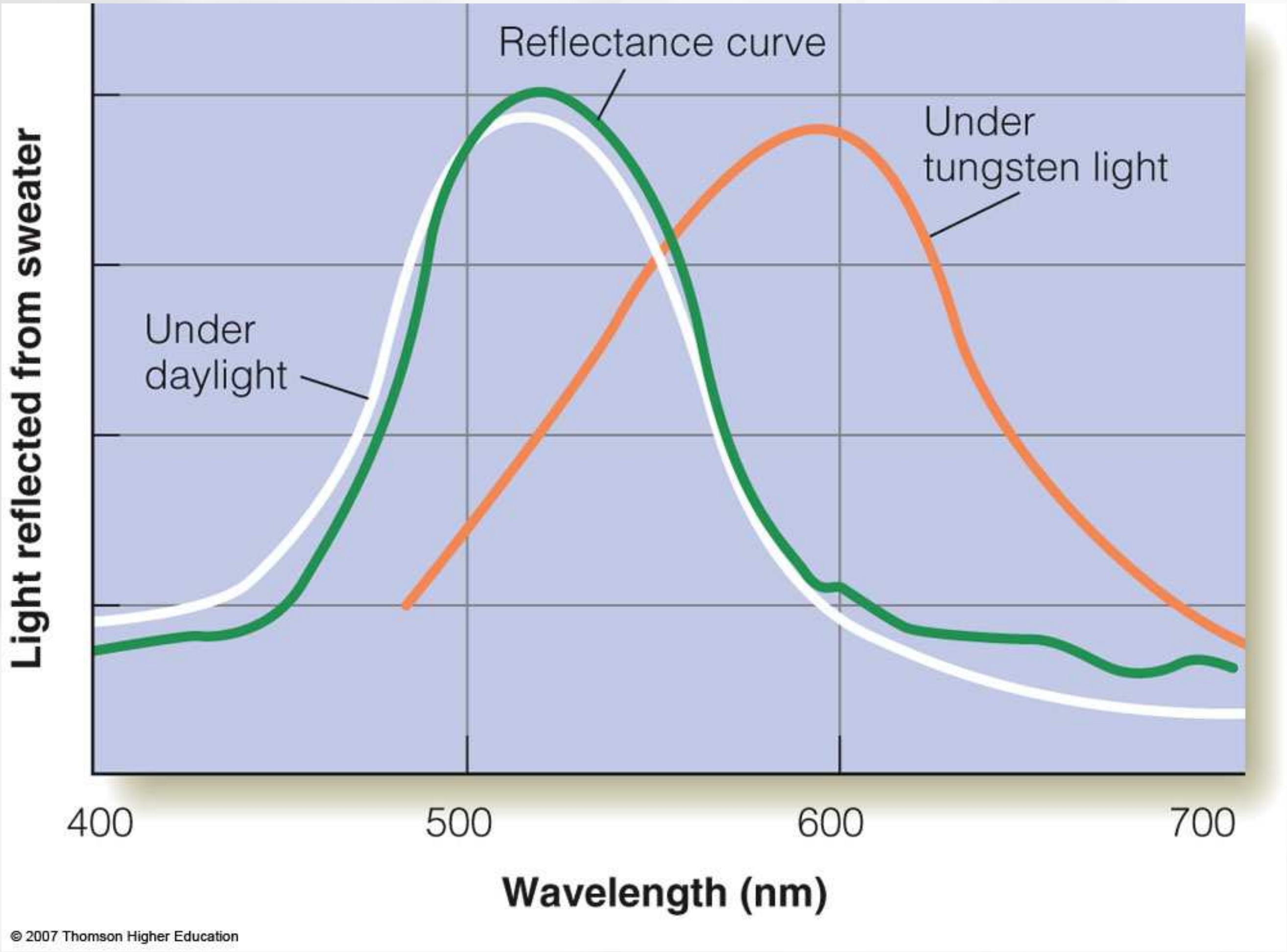
Adaptation aftereffects



Simultaneous contrast effects



‘**Color Constancy**’, is when the perceived color of objects does not vary much with changes in the illumination, even though these changes cause huge changes in the spectral light entering the eye.

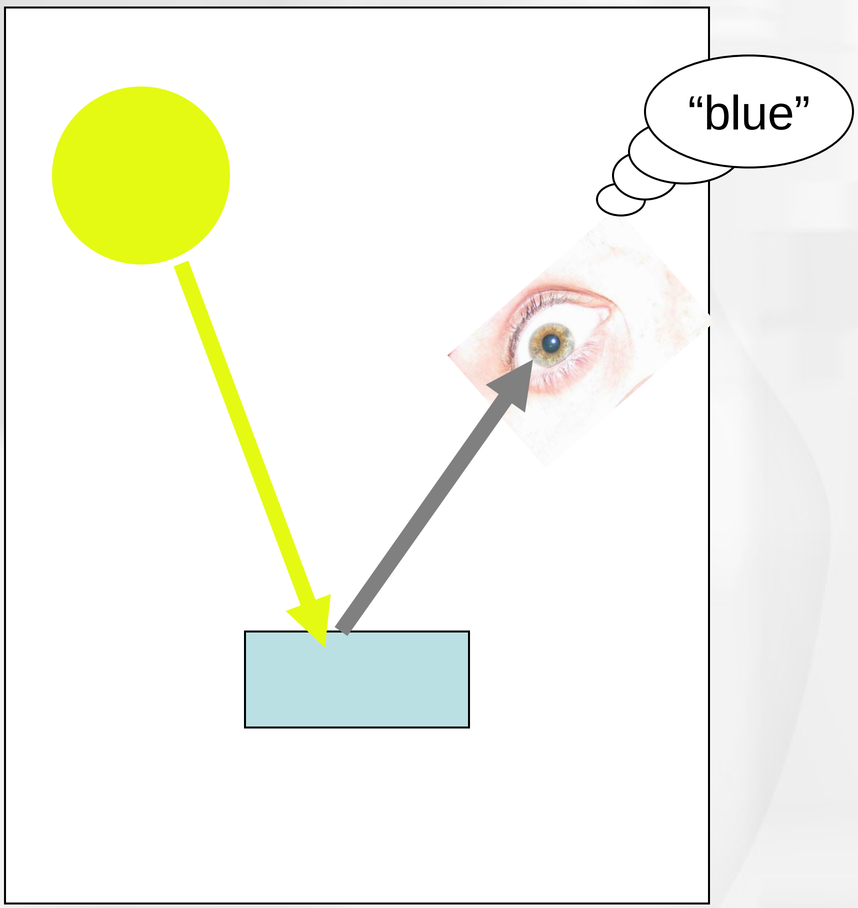


The reflectance curve of a sweater (green curve) and the wavelengths reflected from the sweater when it is illuminated by daylight (white) and by tungsten light (yellow).

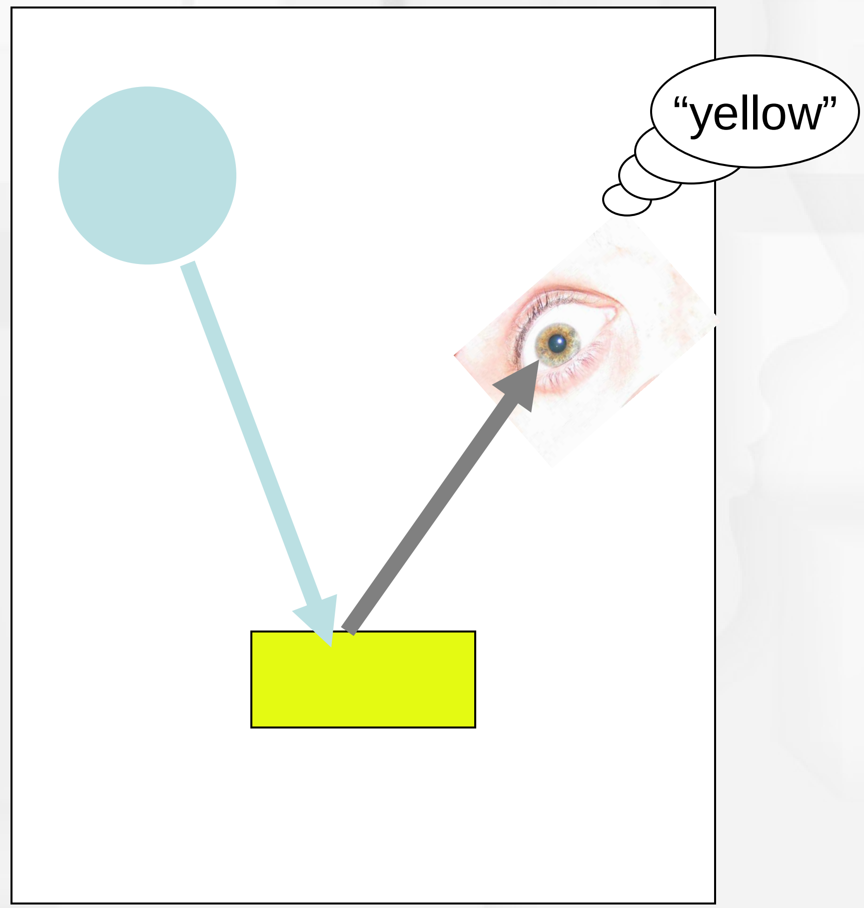
‘**Color Constancy**’, is when the perceived color of objects does not vary much with changes in the illumination, even though these changes cause huge changes in the spectral light entering the eye.

Example 1: same wavelengths entering the eye, different perceived color

Yellow light X blue surface =
gray light entering eye



Blue light X yellow surface =
gray light entering eye

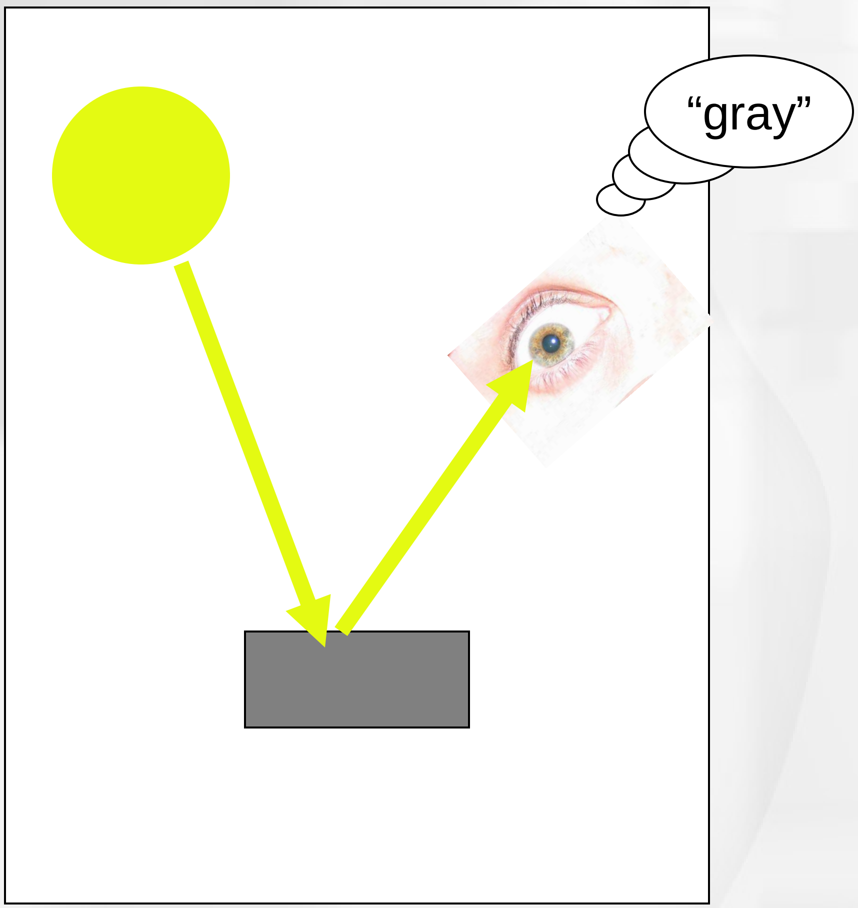


Color Constancy

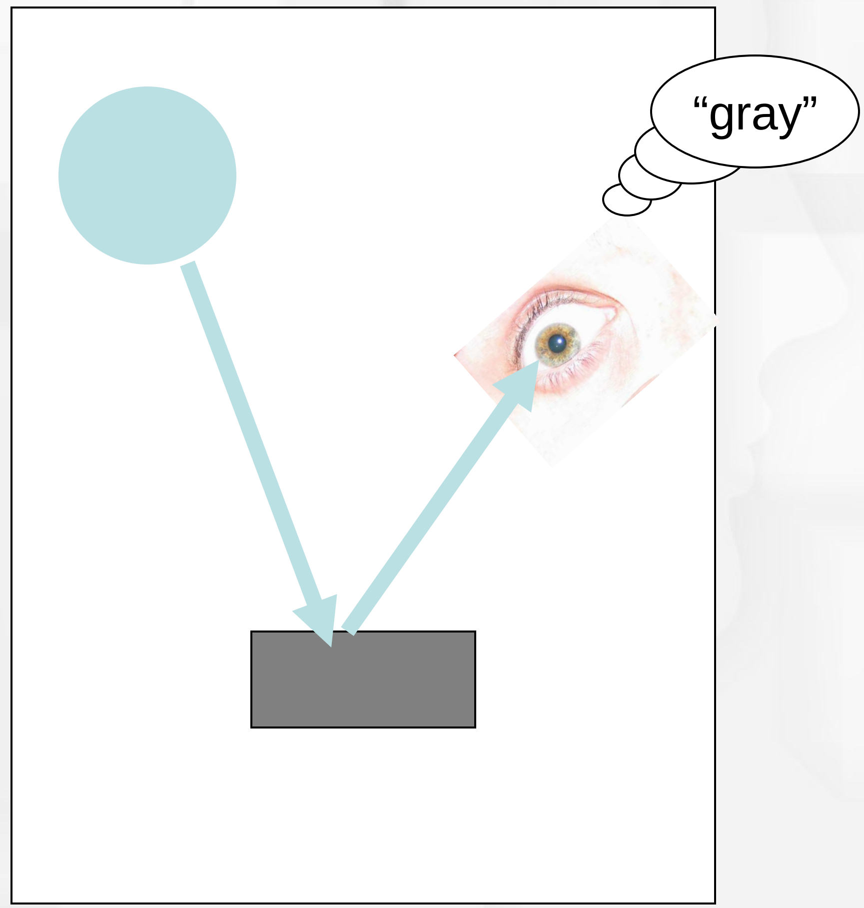
Somehow, the visual system knows the spectrum of the light source, and takes that into account when determining the reflectance properties of a surface.

Example 2: different wavelengths entering the eye, same perceived color

Yellow light X gray surface =
yellow light entering eye



Blue light X gray surface =
blue light entering eye



Blue squares on the left are physically the same as the yellow squares on the right!

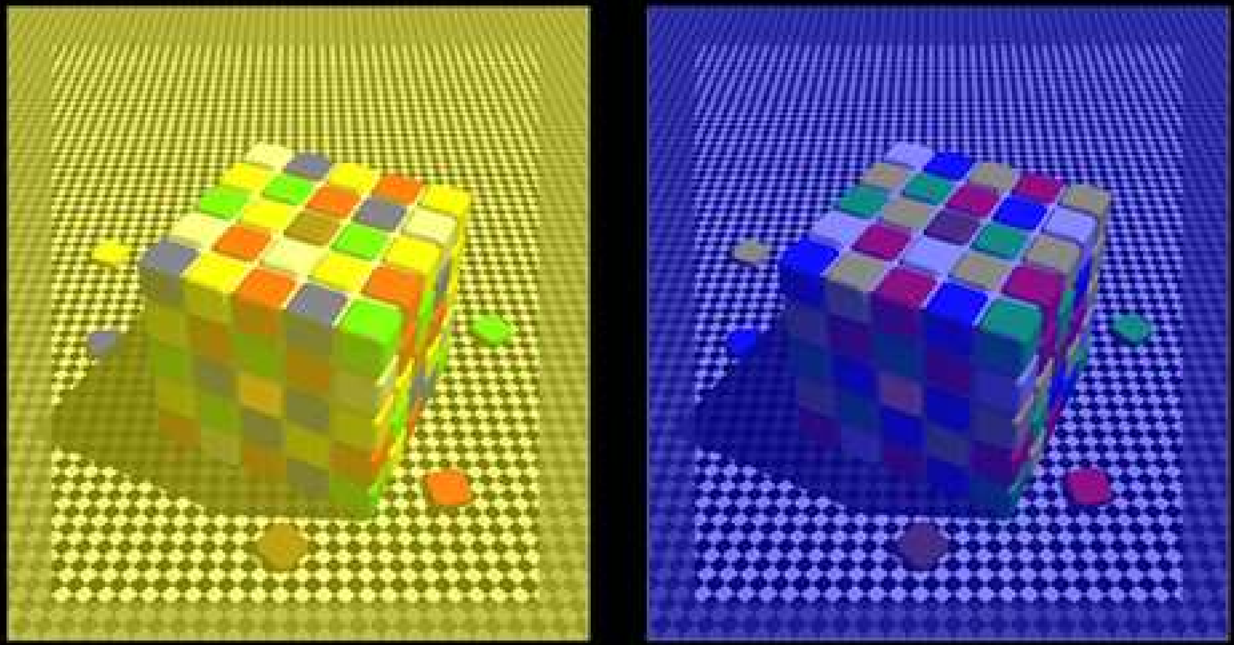


Image by R. Beau Lotto

Blue squares on the left are physically the same as the yellow squares on the right!

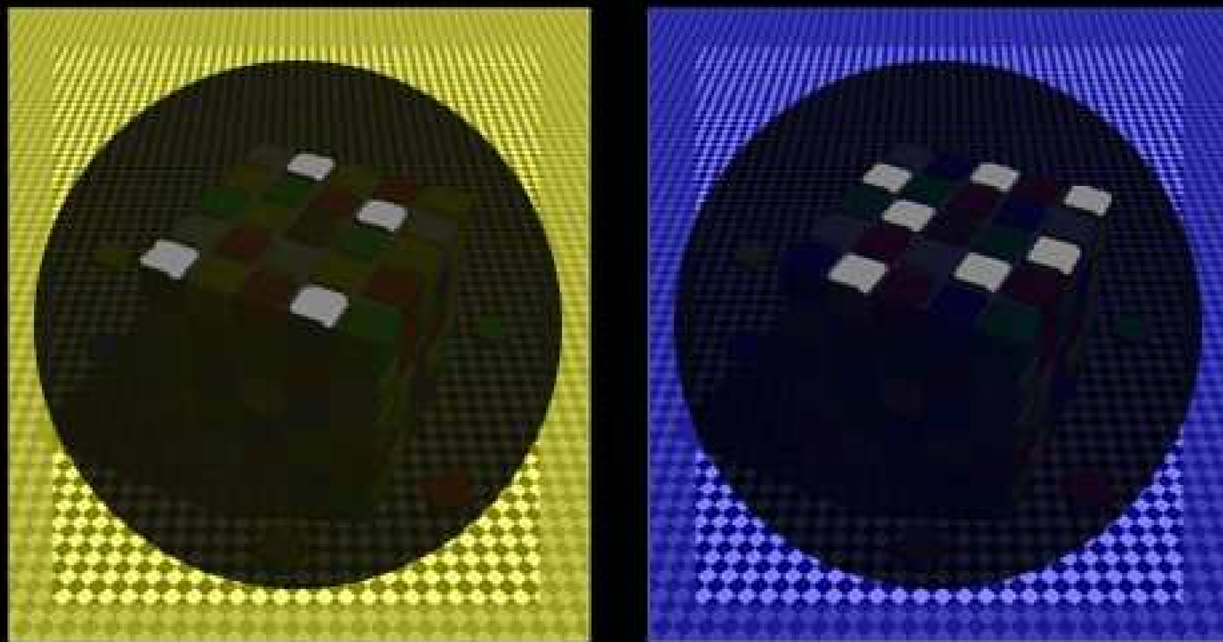


Image by R. Beau Lotto

Blue squares on the left are physically the same as the yellow squares on the right!

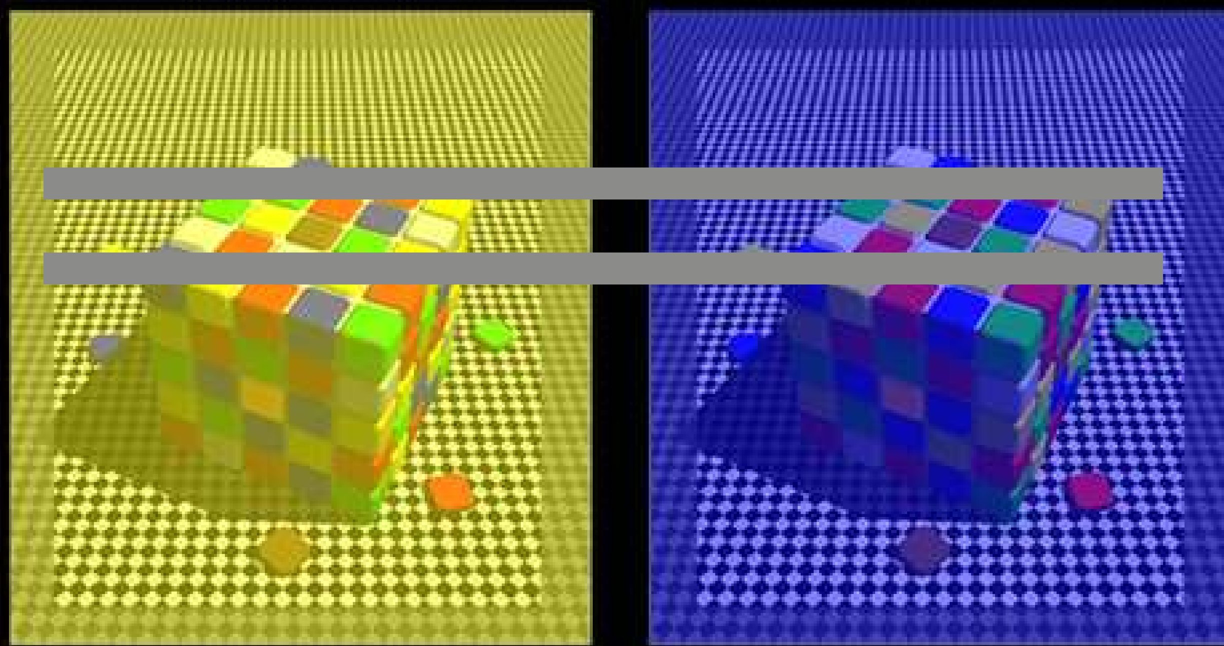


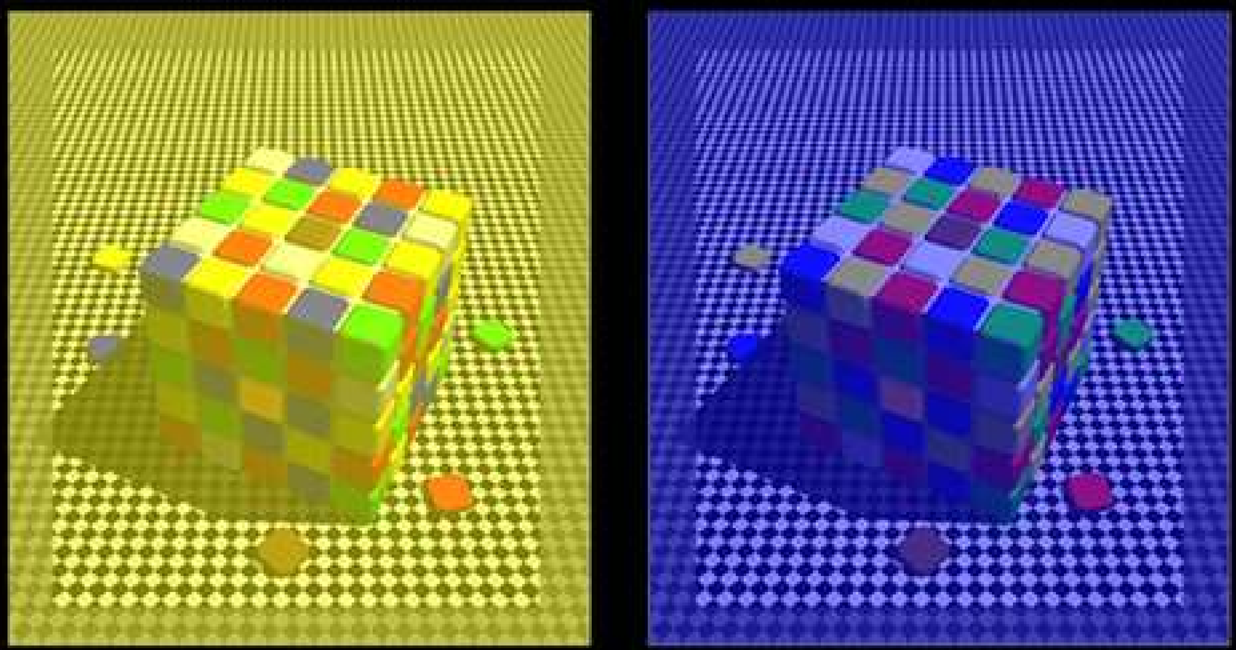
Image by R. Beau Lotto

What's going on with this illusion?

Remember, the light entering your eye is a combination of the light source and the reflectance properties of the object.

What's important to you is the reflectance properties, not the light source.

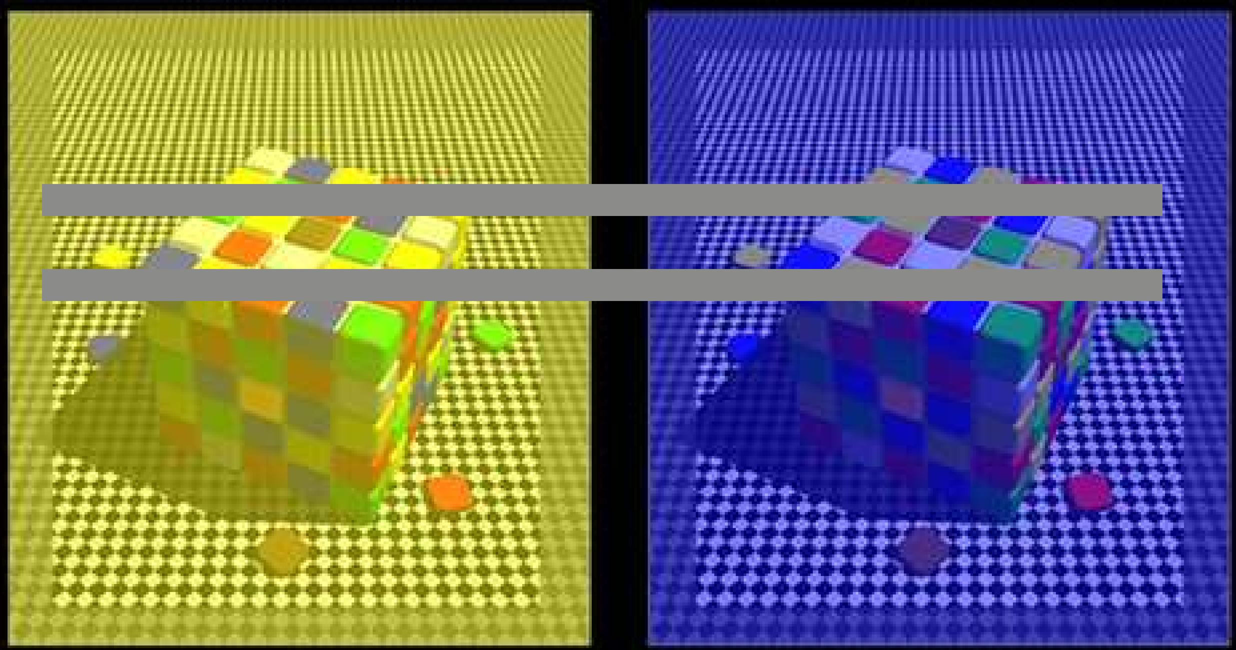
The images on the left and right are drawn to look like the same object, just illuminated by two different lights (yellow on left, blue on right).



The blue checks on the left and the yellow checks on the right are both physically gray.

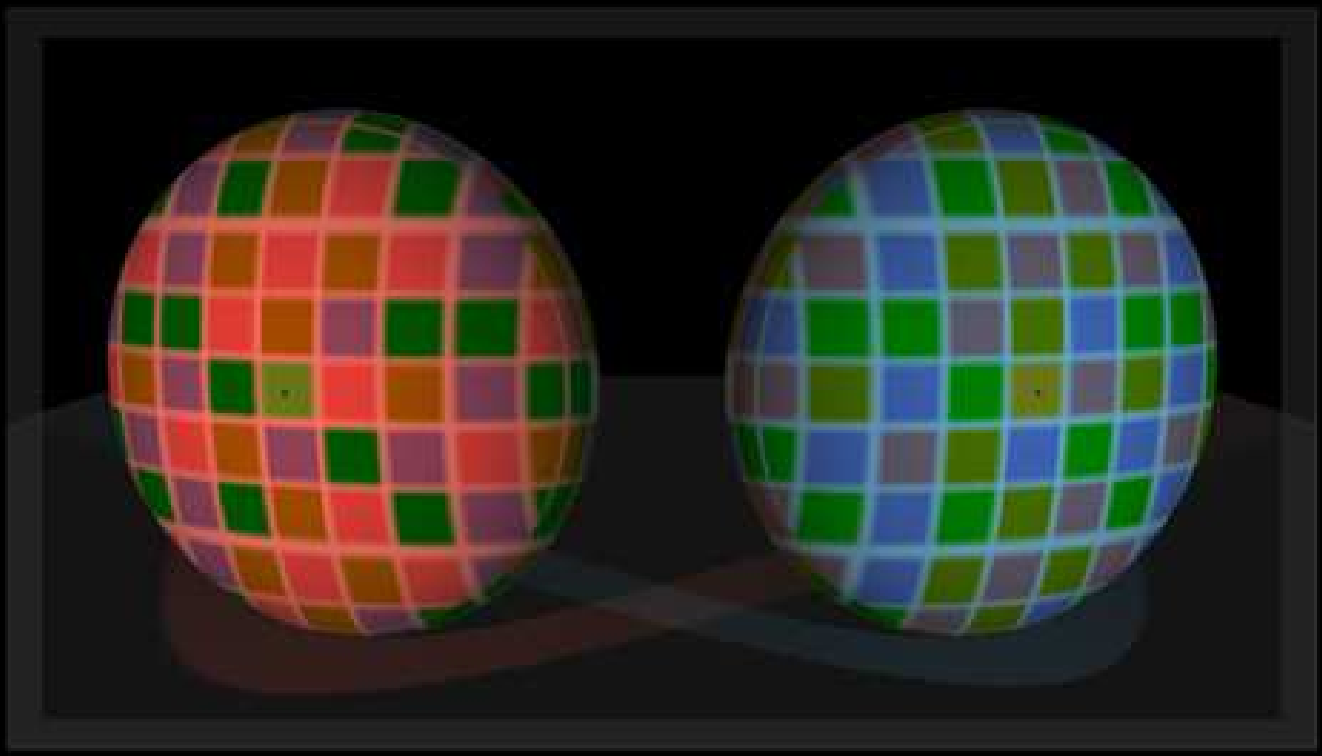
But with color constancy, the visual system knows that gray light under yellow illumination must be caused by a blue surface (left),

and the gray light under blue illumination must be caused by a yellow surface (right).

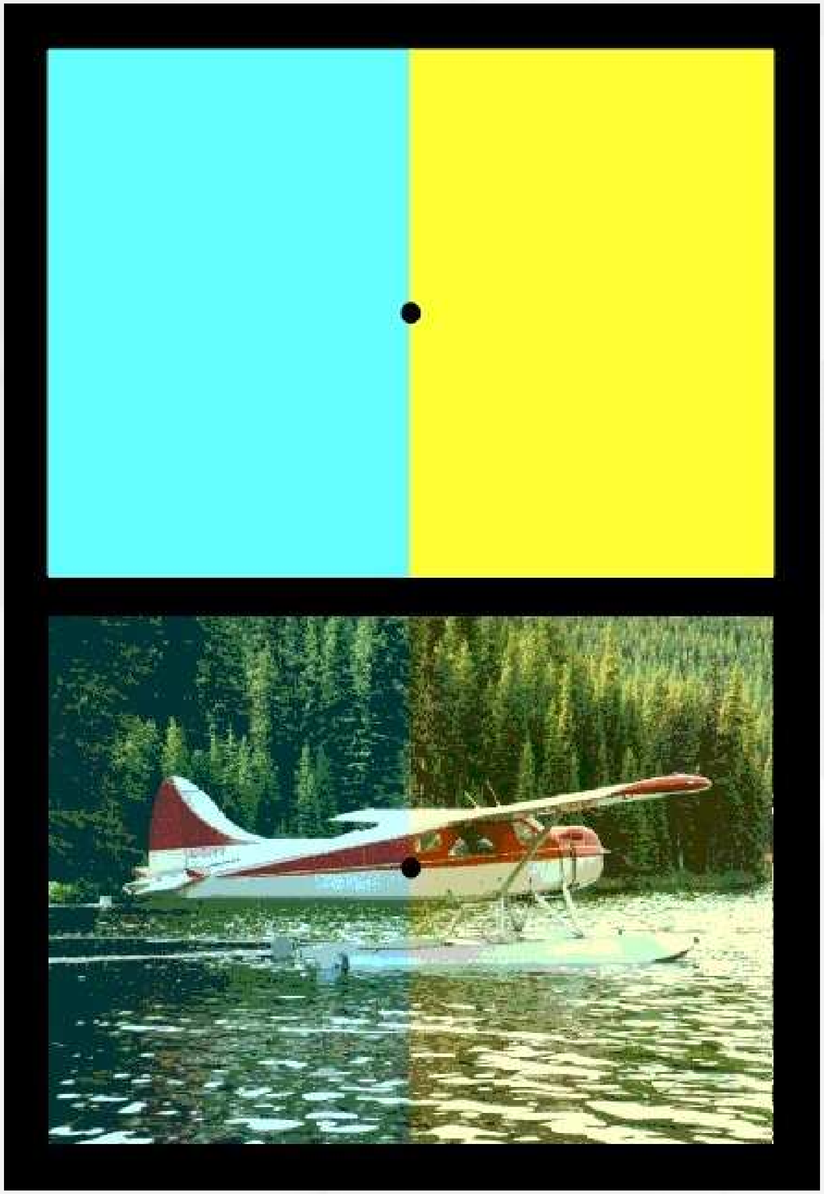


Another similar example. Center squares are physically the same, but look different.

The image is rendered to look like the two objects are illuminated by different colored lights.

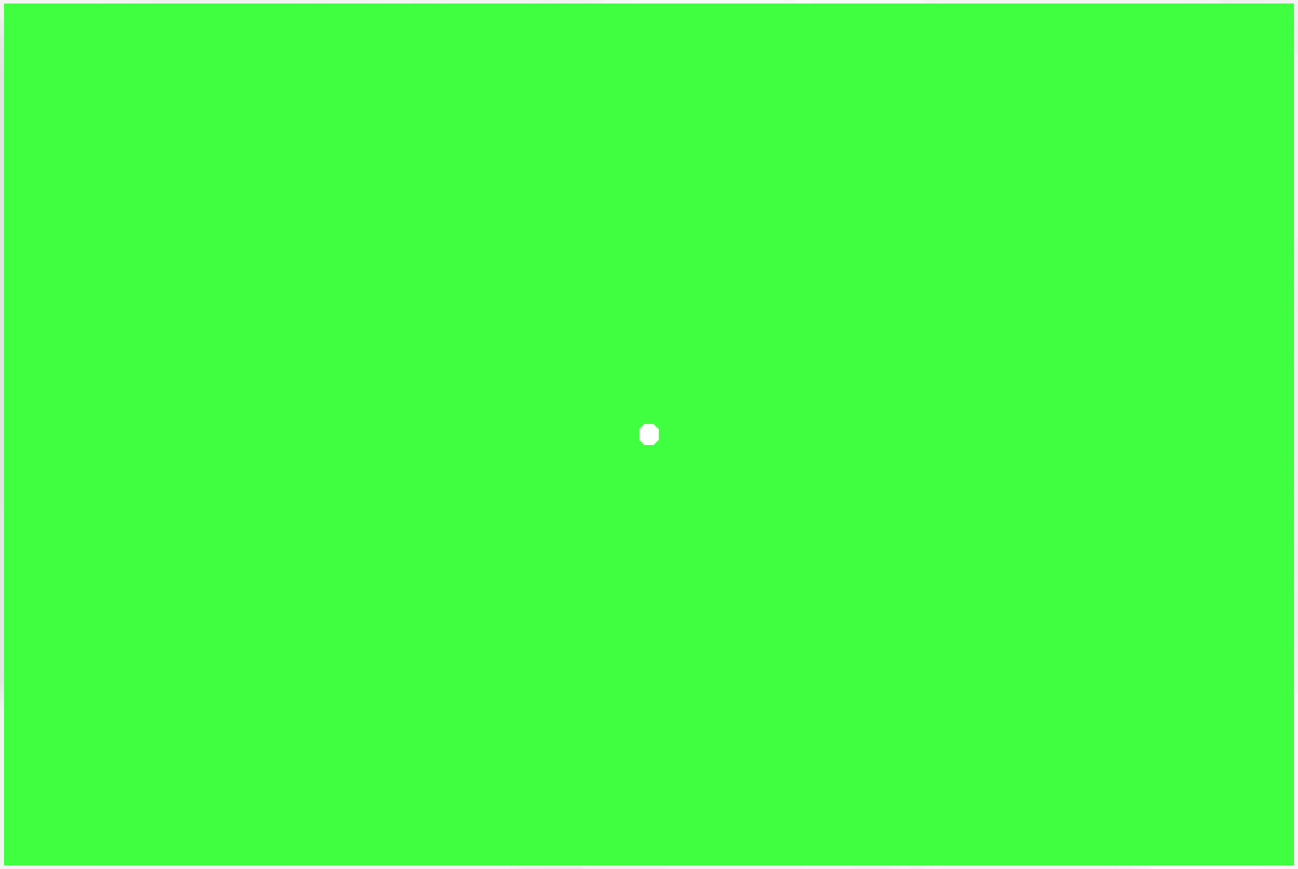


Chromatic adaptation supports color constancy



Chromatic adaptation supports color constancy

Chromatic adaptation supports color constancy



Chromatic adaptation supports color constancy

Chromatic adaptation supports color constancy