Computer Vision for Visual Effects

CVFX 2015

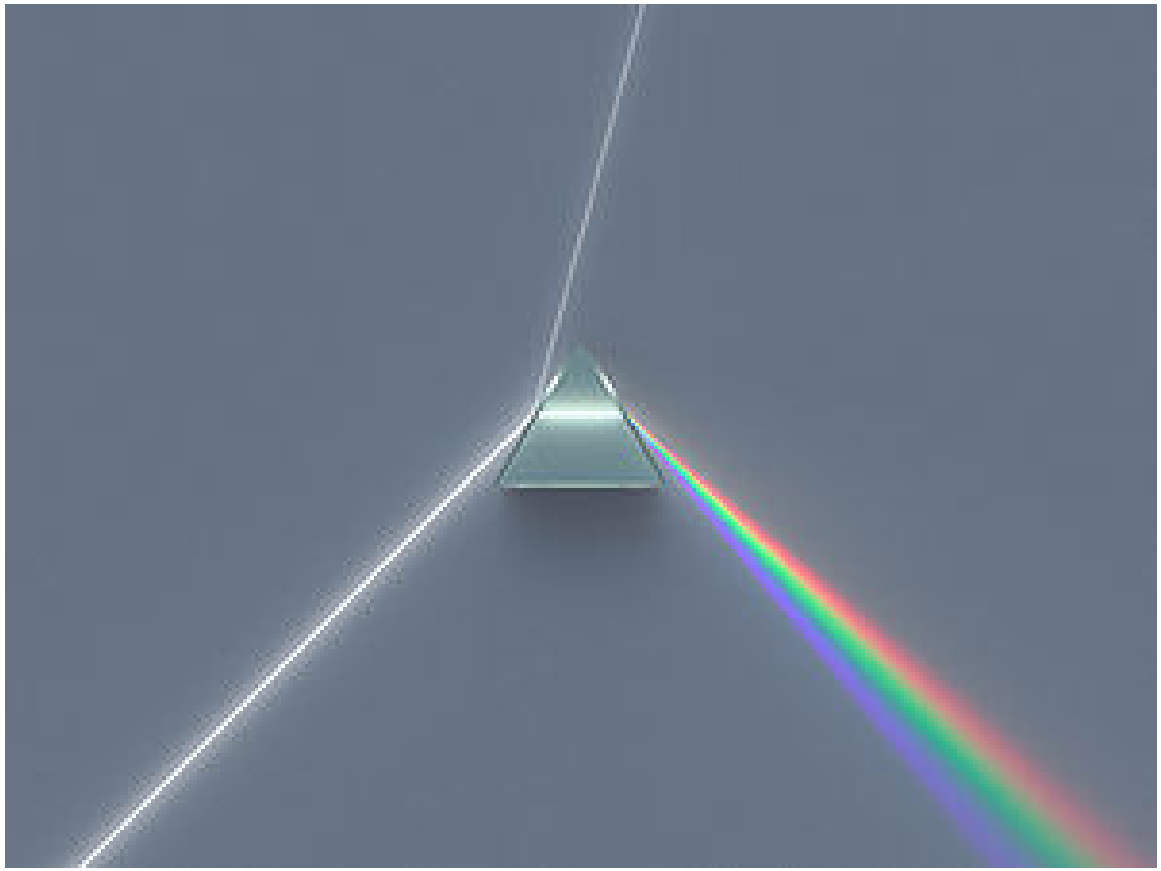
This lecture is based on the course materials of the Computational Photography courses given at MIT (Prof. Durand & Prof. Freeman) and CMU (Prof. Efros)

Computer Vision for Visual Effects

CVFX 2015

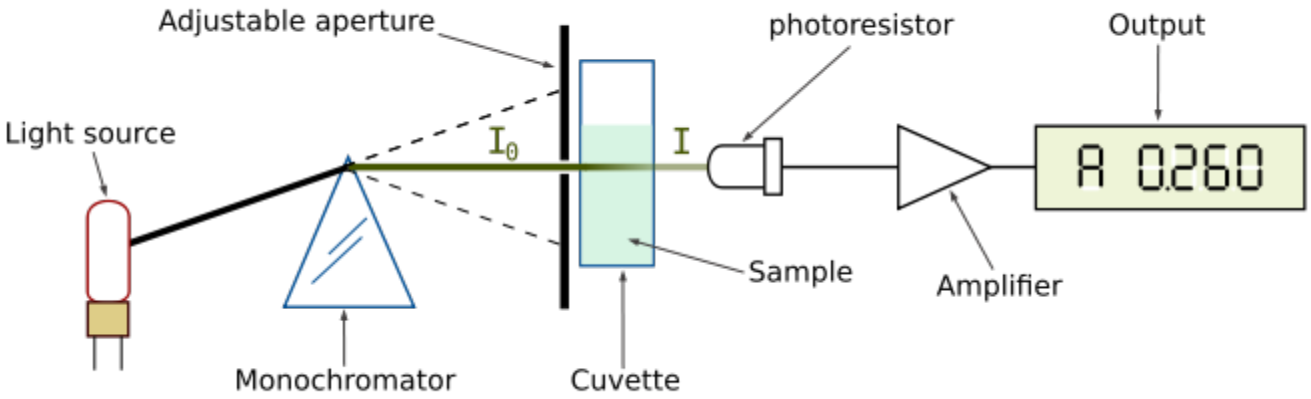
Color

Color



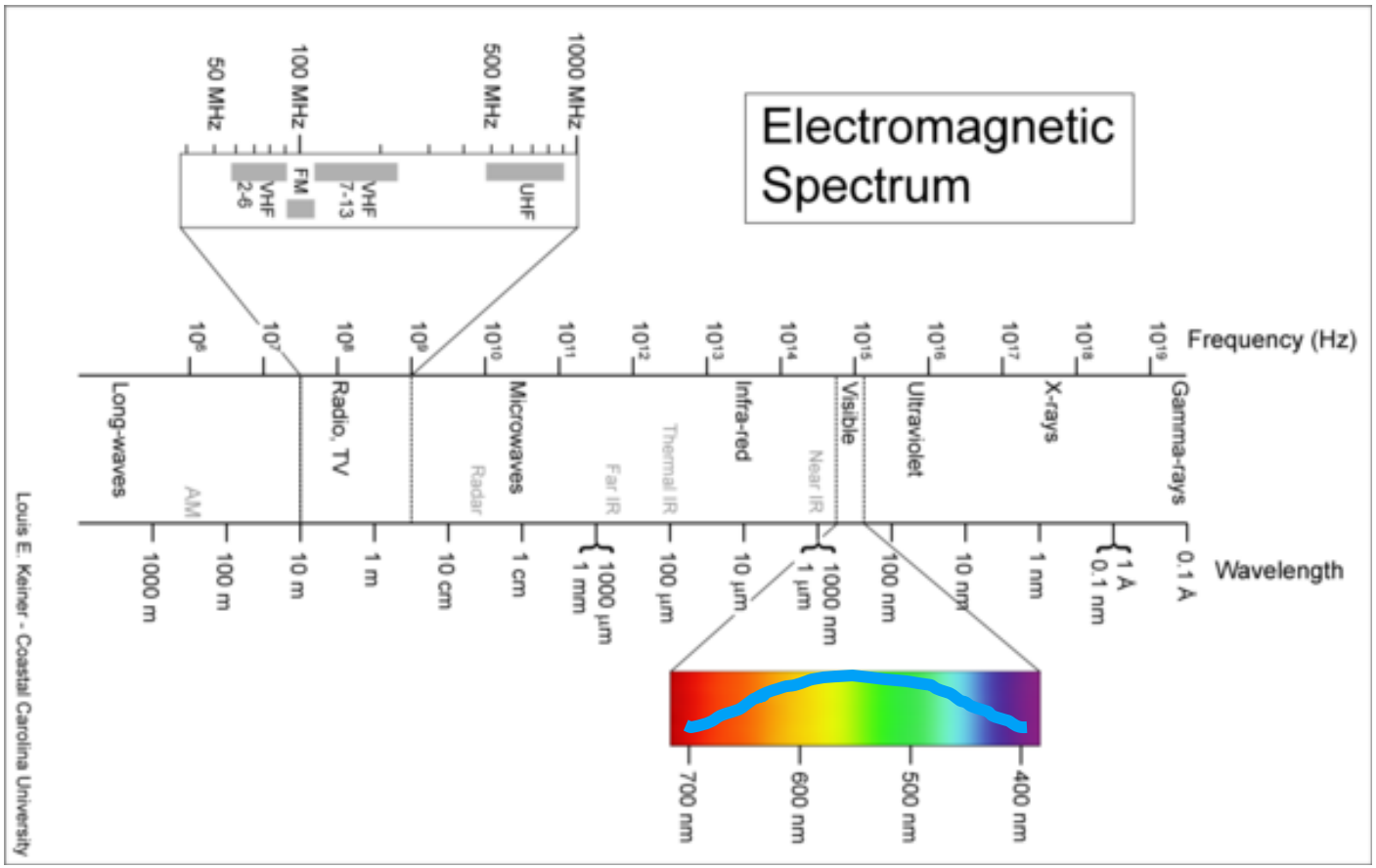
[Wikipedia]

Spectrophotometer



[Wikipedia]

Electromagnetic Spectrum



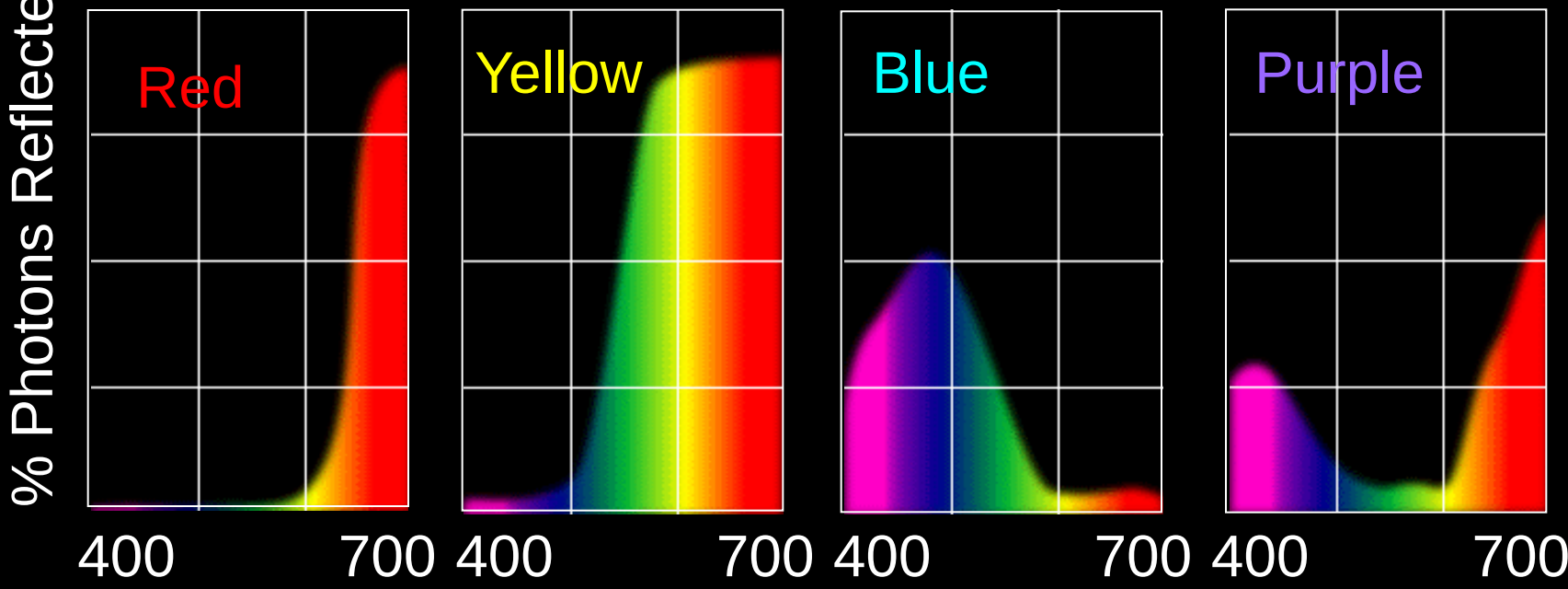
Human Luminance Sensitivity Function

[Wikipedia]

The Physics of Light

Some examples of the reflectance spectra of surfaces

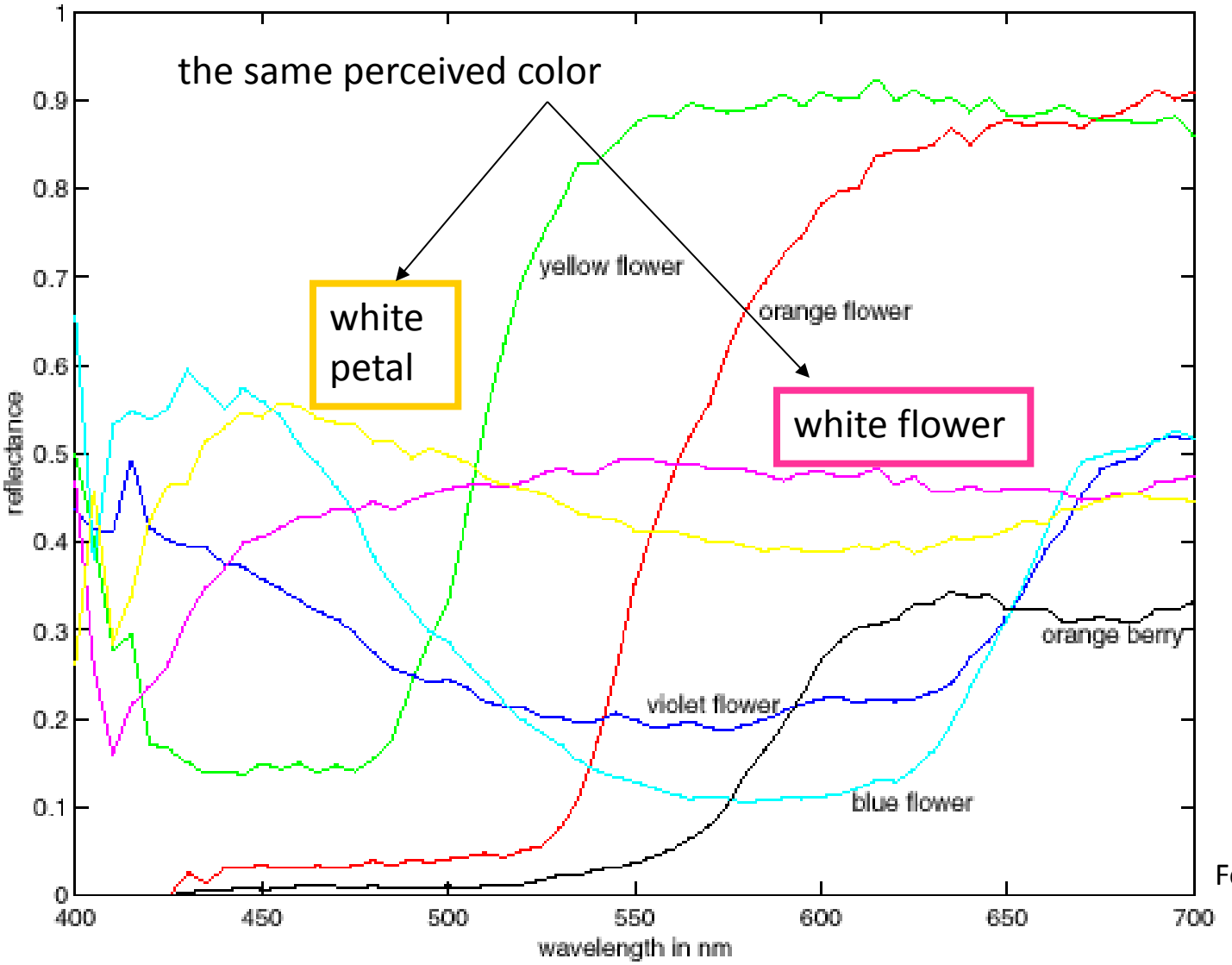


問題

- 如果兩個物體反射的光線，具有不同的光譜分布，那麼對人眼來說，這兩個物體有可能看起來顏色一樣嗎?

Different colors normally have different spectral reflectance, but different spectral reflectance may cause the same perceived color.



Forsyth, 2002

問題

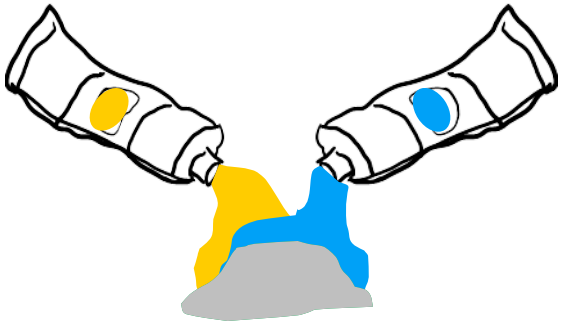
- 兩個物體反射的光線，雖然具有不同的光譜分布，但是對人眼來說有可能看起來是相同的顏色

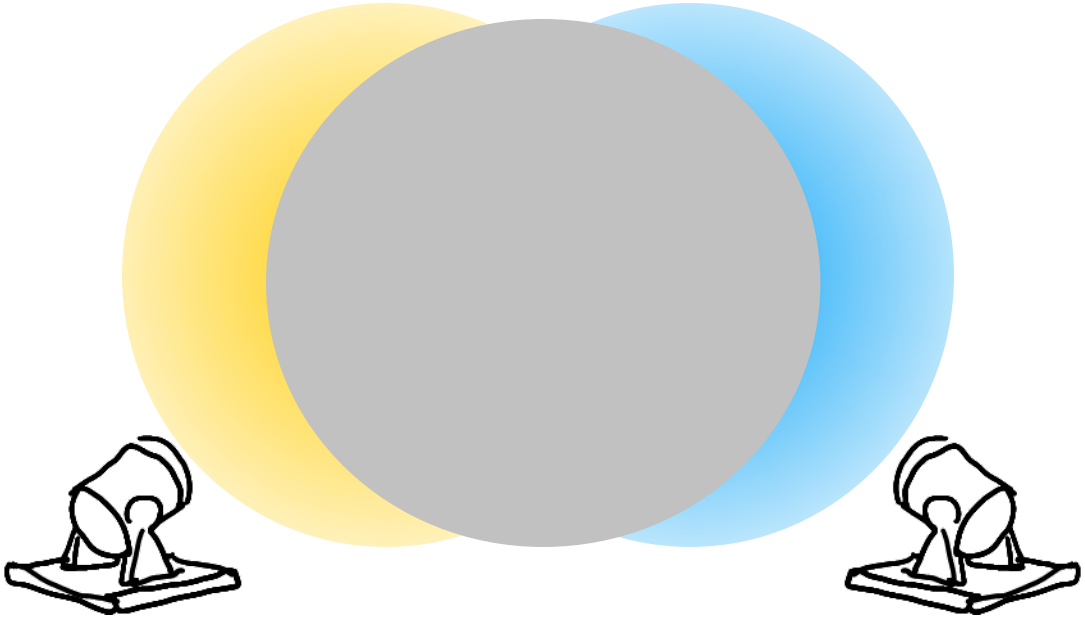
- 這樣的特性有甚麼缺點?
- 有甚麼優點?
- 如何利用這項特性?

色彩的重現

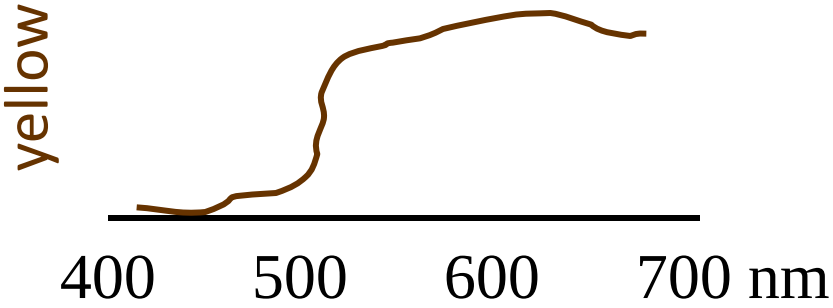
- 為什麼螢幕和投影機，能夠重現我們所看到的顏色?
- 投影機需要發出各種不同波長的光線嗎?

Additive and Subtractive Color Mixing

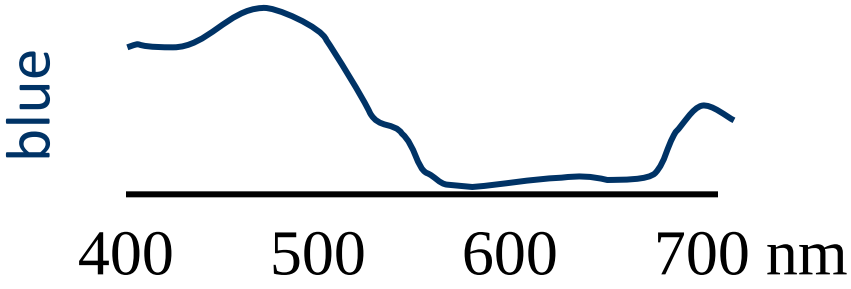


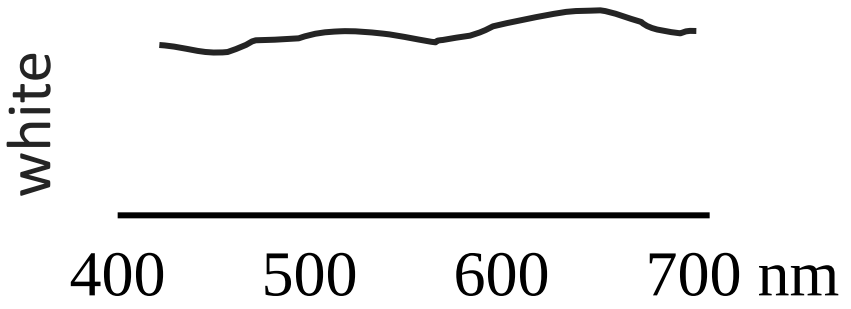


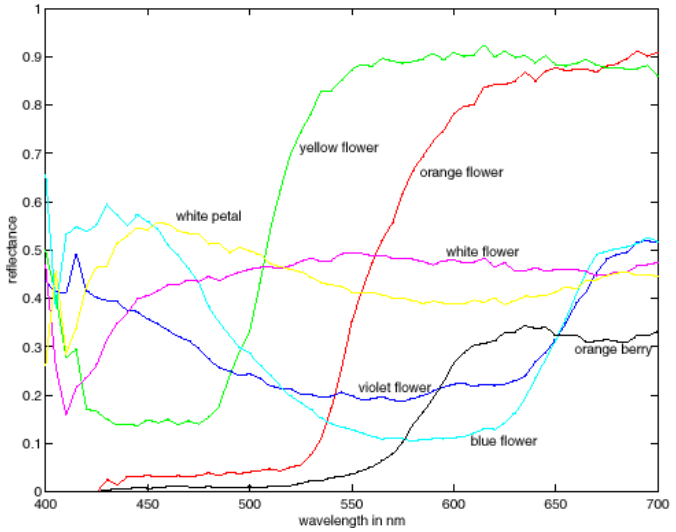
Additive Color Mixing



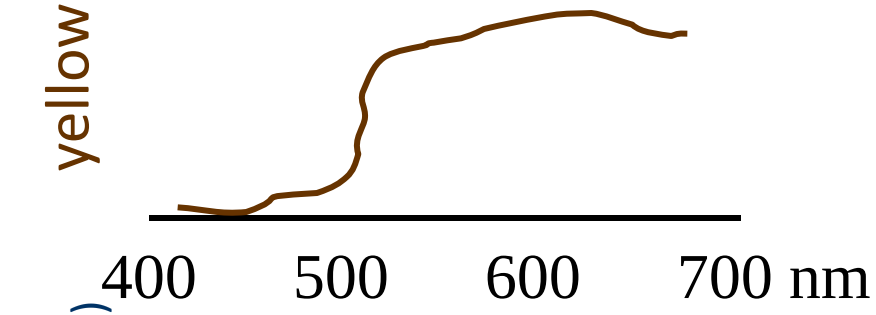
When colors are combined by *adding* the color spectra, e.g., three-color projectors.

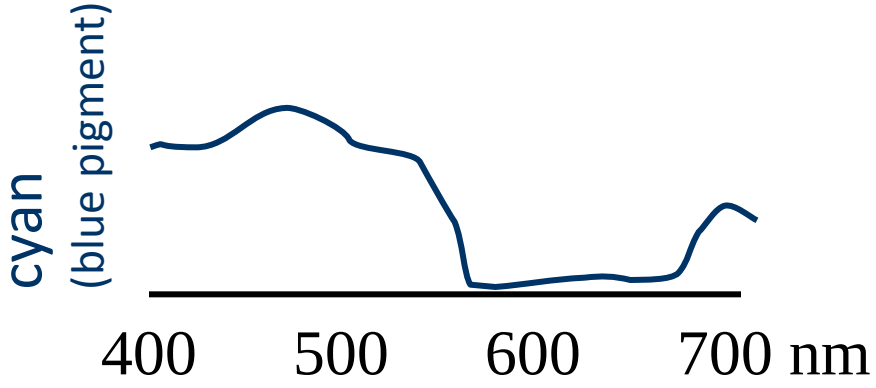


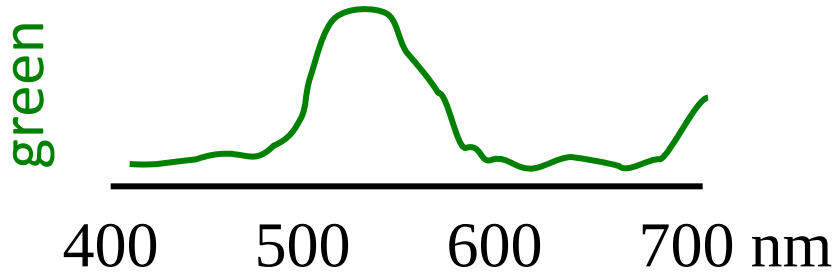




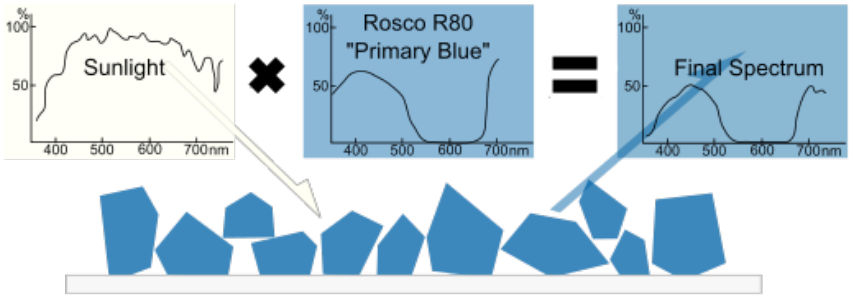
Subtractive Color Mixing





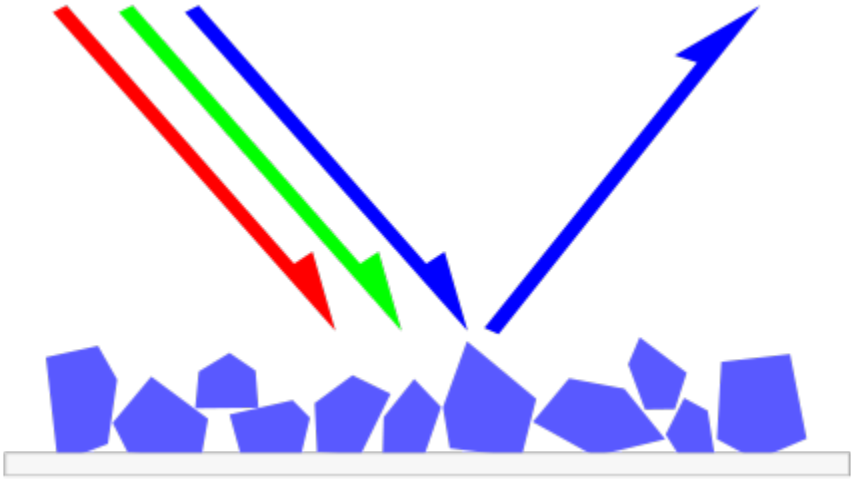


When colors are combined by *multiplying* the color spectra, e.g., pigments.



[Wikipedia]

藍色的顏料吸收偏紅和偏綠的光，反射藍光



[Wikipedia]

Color Science

- 如何讓投影機或螢幕重現我們所看到的顏色?

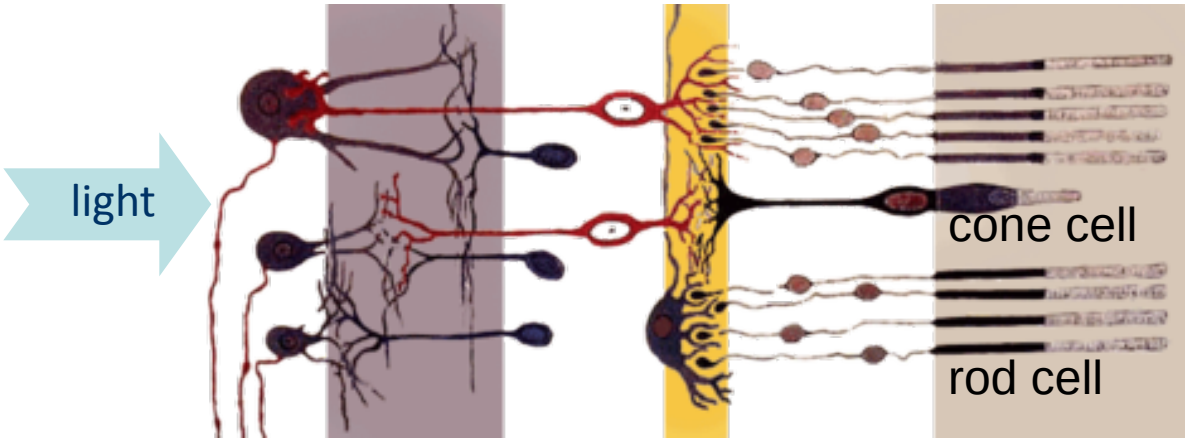
人眼的感光構造

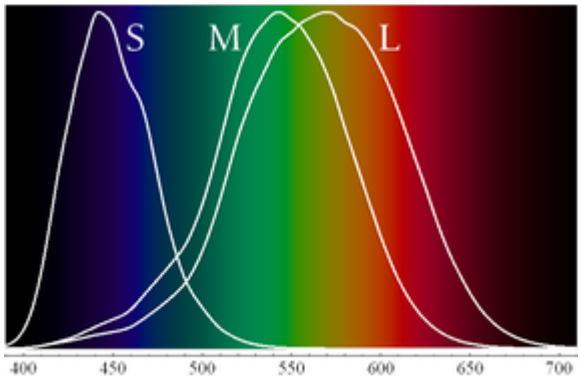
Cone cells function in relatively bright light.

There are three types of cones responding to different wavelengths of light.

Rod cells can function in less intense light than cone cells.

Rod cells are more light-sensitive, thus responsible for night vision.

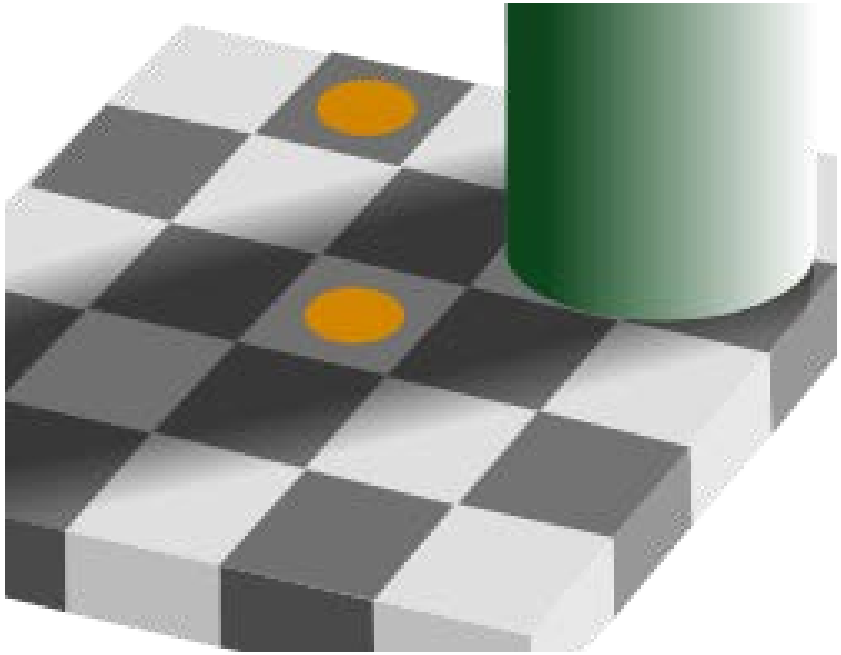




[Wikipedia]

Human Perception

Human Perception



[Wikipedia]

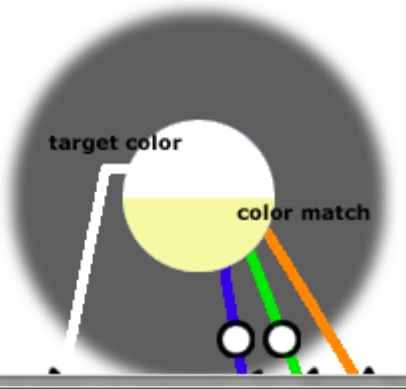
handprint : do "primary" c

www.handprint.com/HP/WCL/color6.html

violet wavelengths).

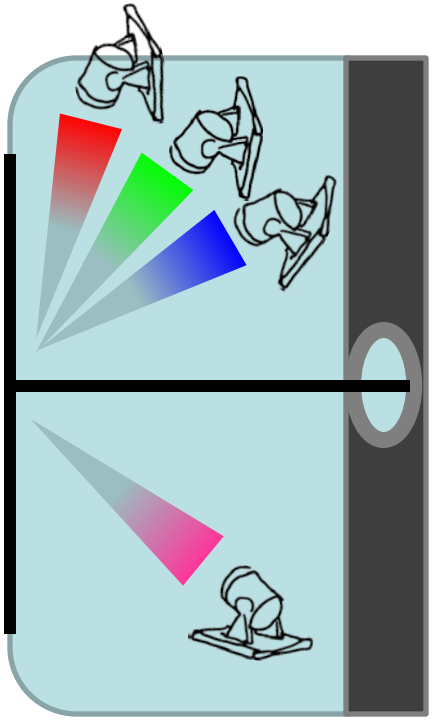
Maxwell's Trichromatic Measurements. The Young-Helmholtz primaries were used in the first precise, quantitative **color matching experiments**, conducted in the 1850's by both Helmholtz and the brilliant Scottish physicist **James Clerk Maxwell** (1831-1879, right). Maxwell created **additive color mixtures** in two ways: by mixing colored lights through a system of prisms, mirrors and neutral filters enclosed in a long, flat box (a *Maxwell box,* the first modern colorimeter), or — the method he found more practical and accurate — by visually mixing circular wedges of colored papers on a rapidly spinning disk (a **color top** or *Maxwell disk,* shown at right). He demonstrated that any color of light could be matched by a specific combination of just three primaries, which he represented on his color top with the pigments vermilion (scarlet, **PR106**), emerald green (bluish green, **PR21**), and ultramarine blue (blue violet, **PB29**), and in his prism box by the wavelengths 650 nm ("scarlet"), 510 nm ("green") and 480 nm ("blue"). His colorimeter became the most widely used apparatus in modern color research.

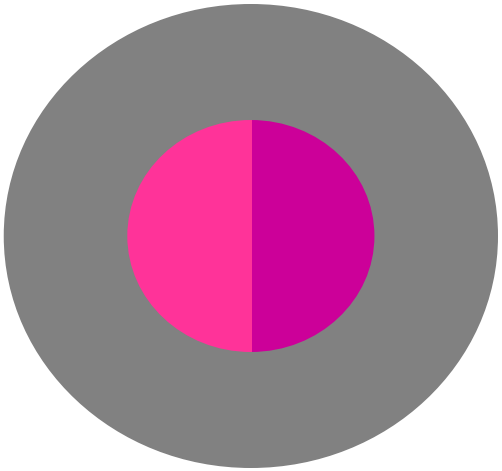
the young James Clerk Maxwell holding his color top (c.1860)



In the original version of Maxwell's color matching experiments, the viewer looked through a small lens or eyepiece to see a

Color Matching

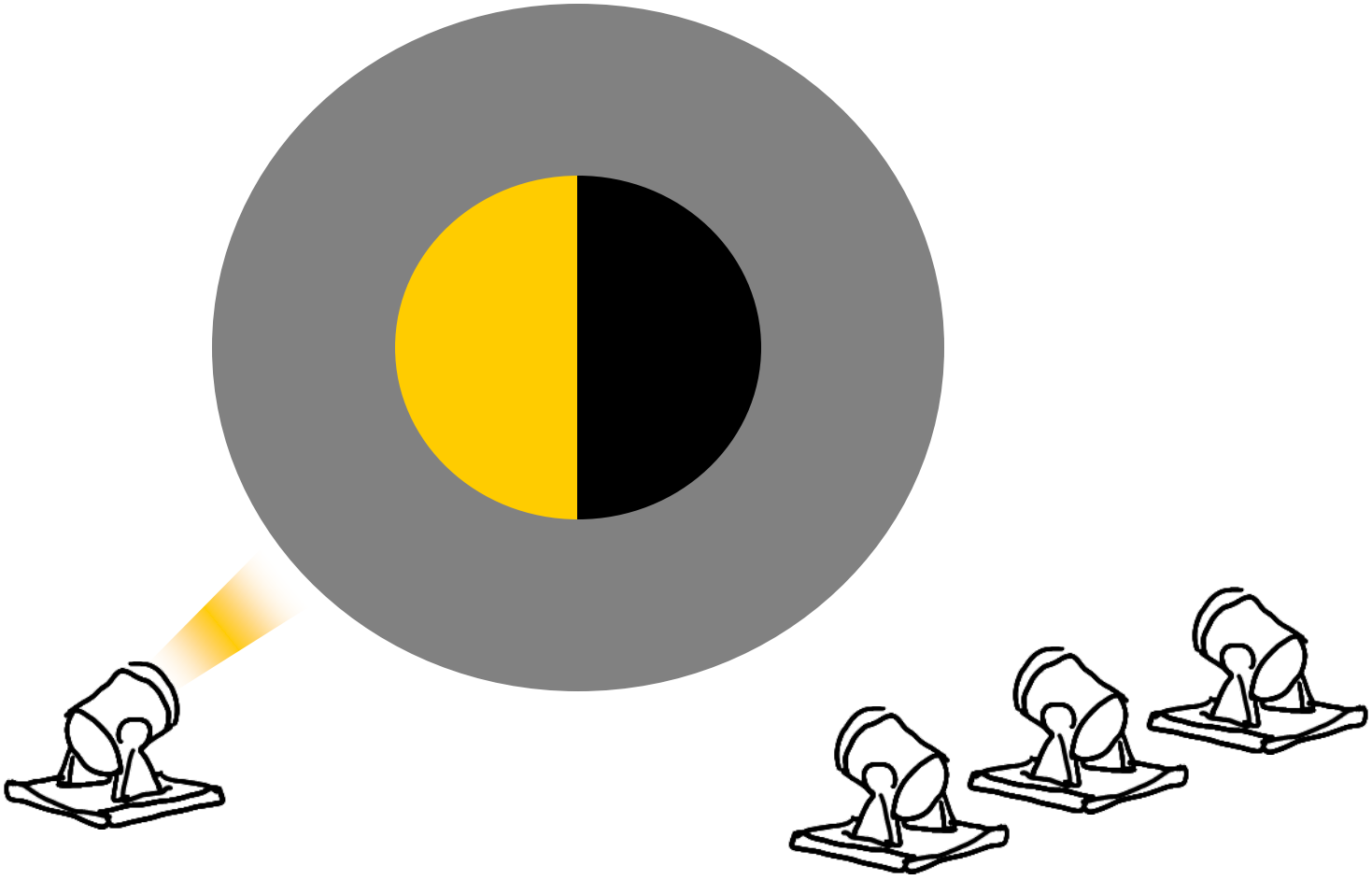




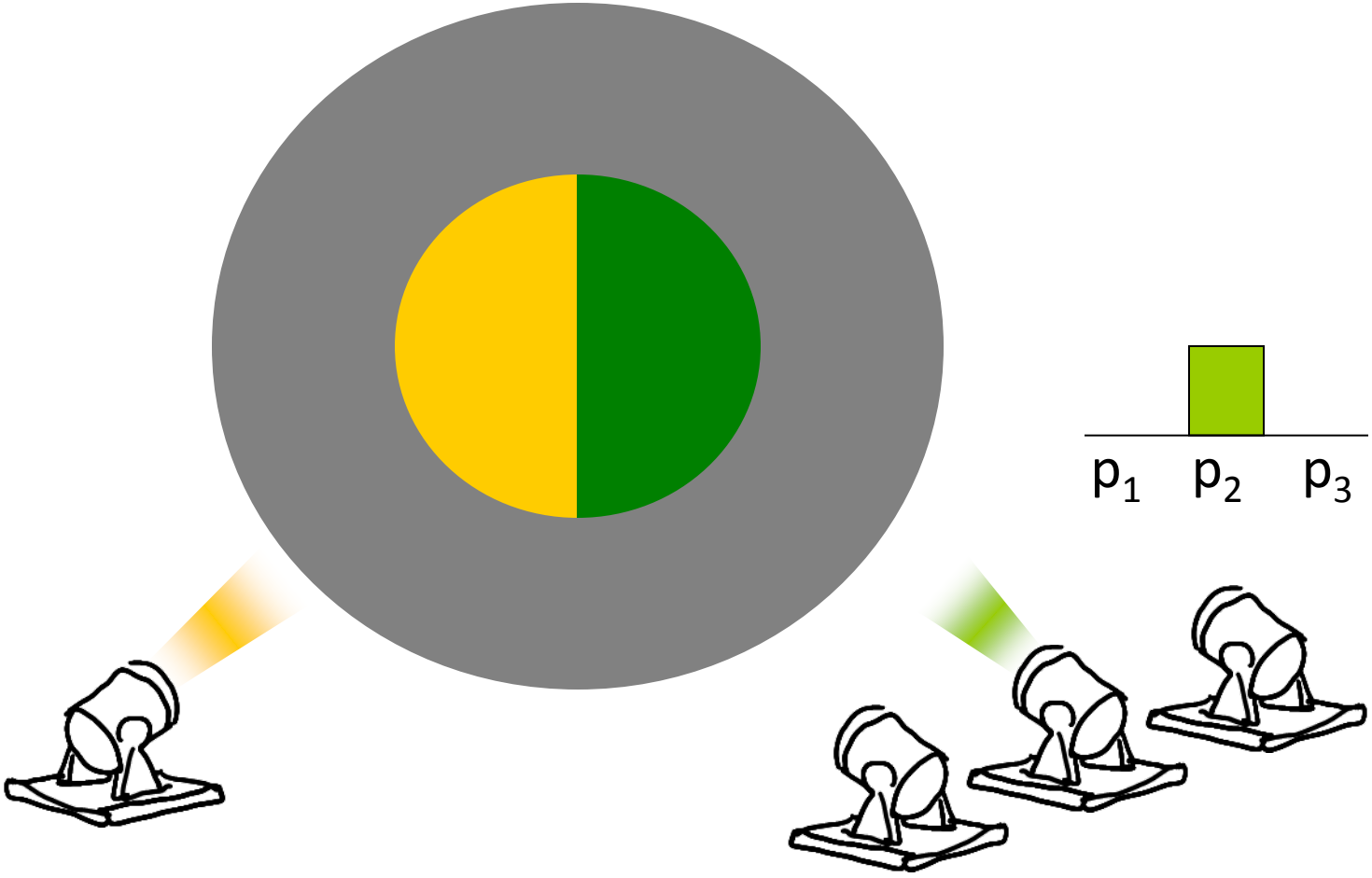
三色原理 (或是四色)

- 經由實驗發現:
  - 對大多數人來說，只需要三種固定波長的光，藉由調整它們的強度，就能組合出我們想要看到的顏色 (但是必須允許"負"的光)
  - 對大多數人來說，組合的係數幾乎相同

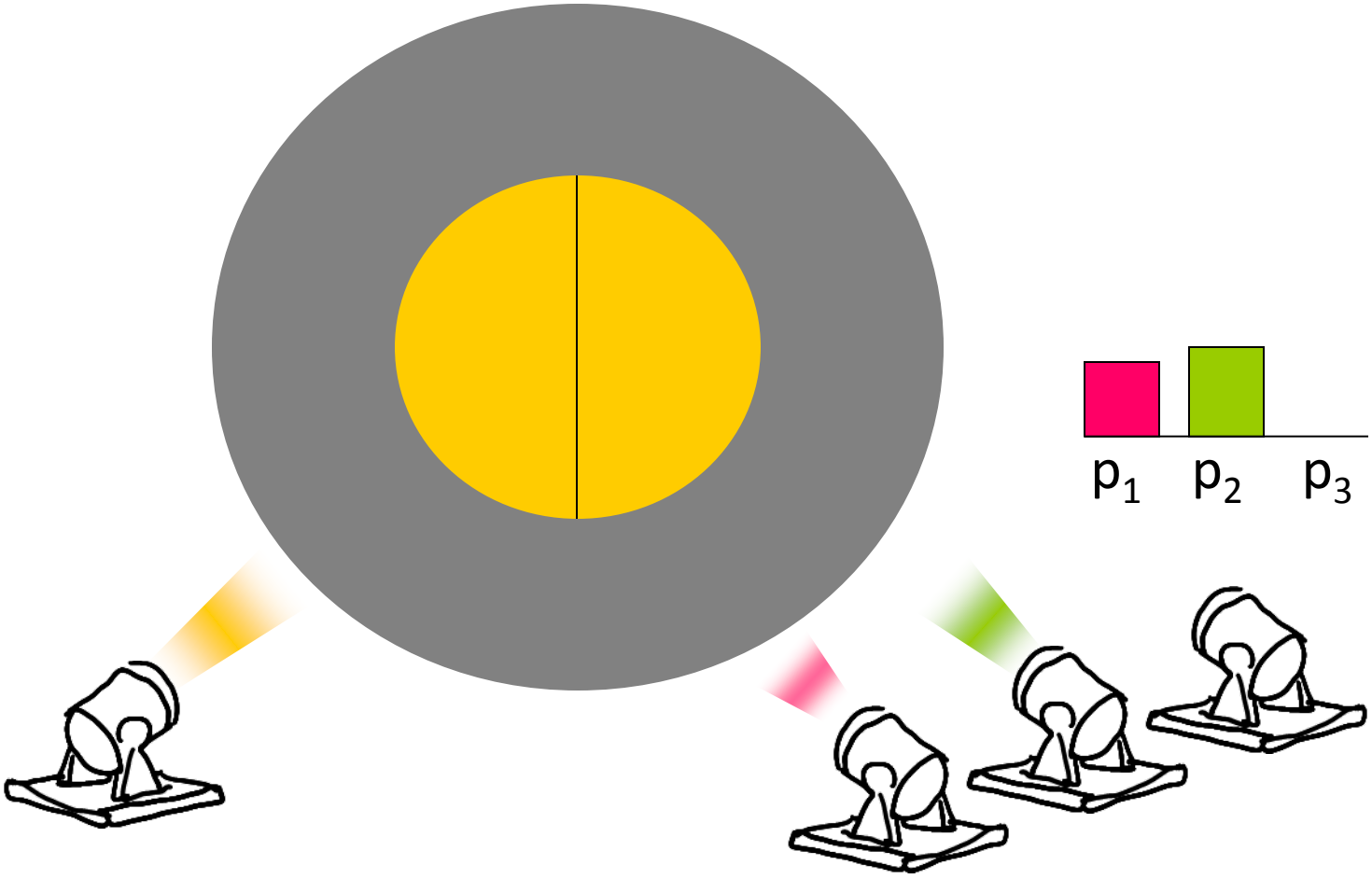
Color Matching Experiment 1



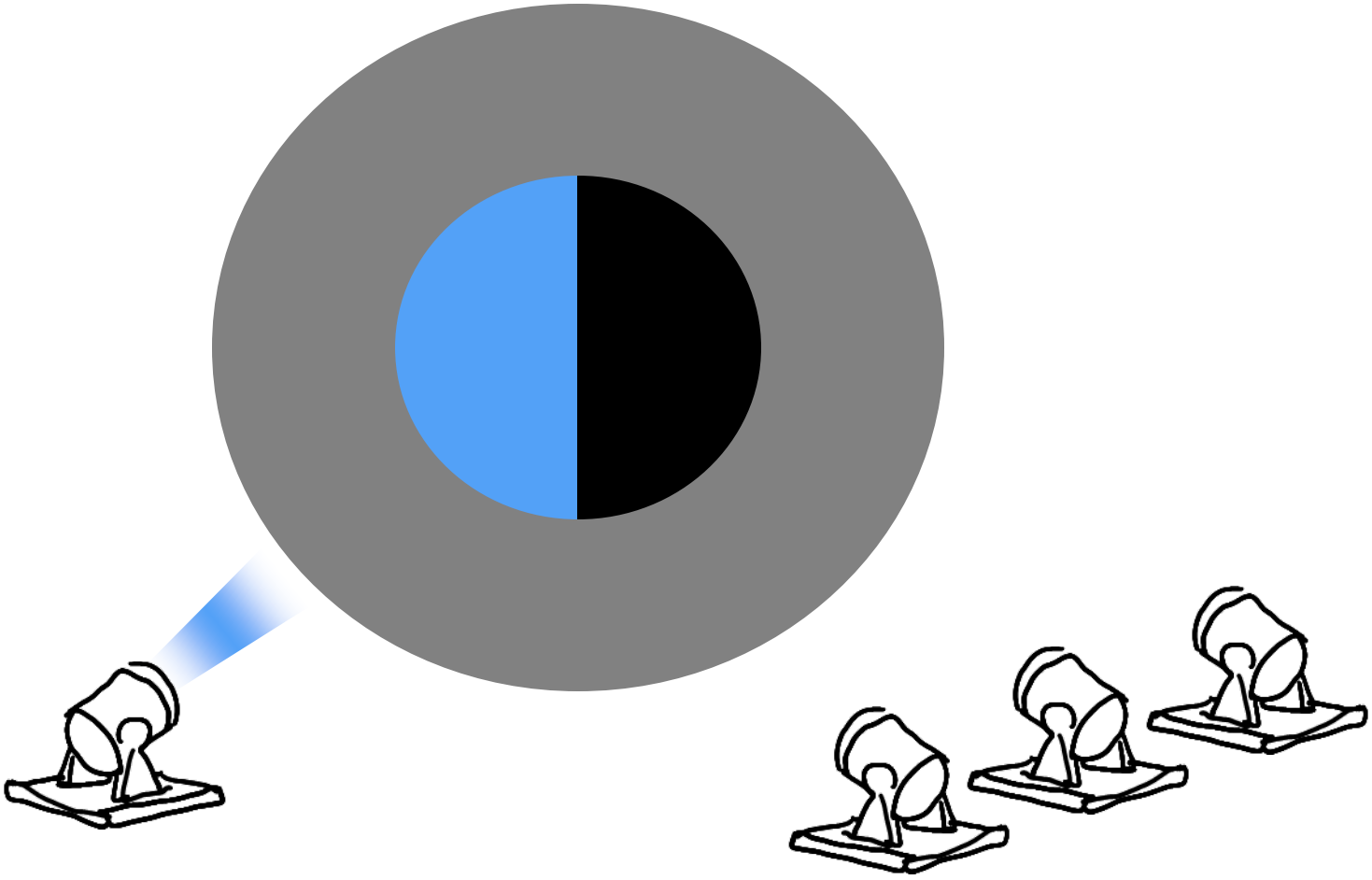
Color Matching Experiment 1



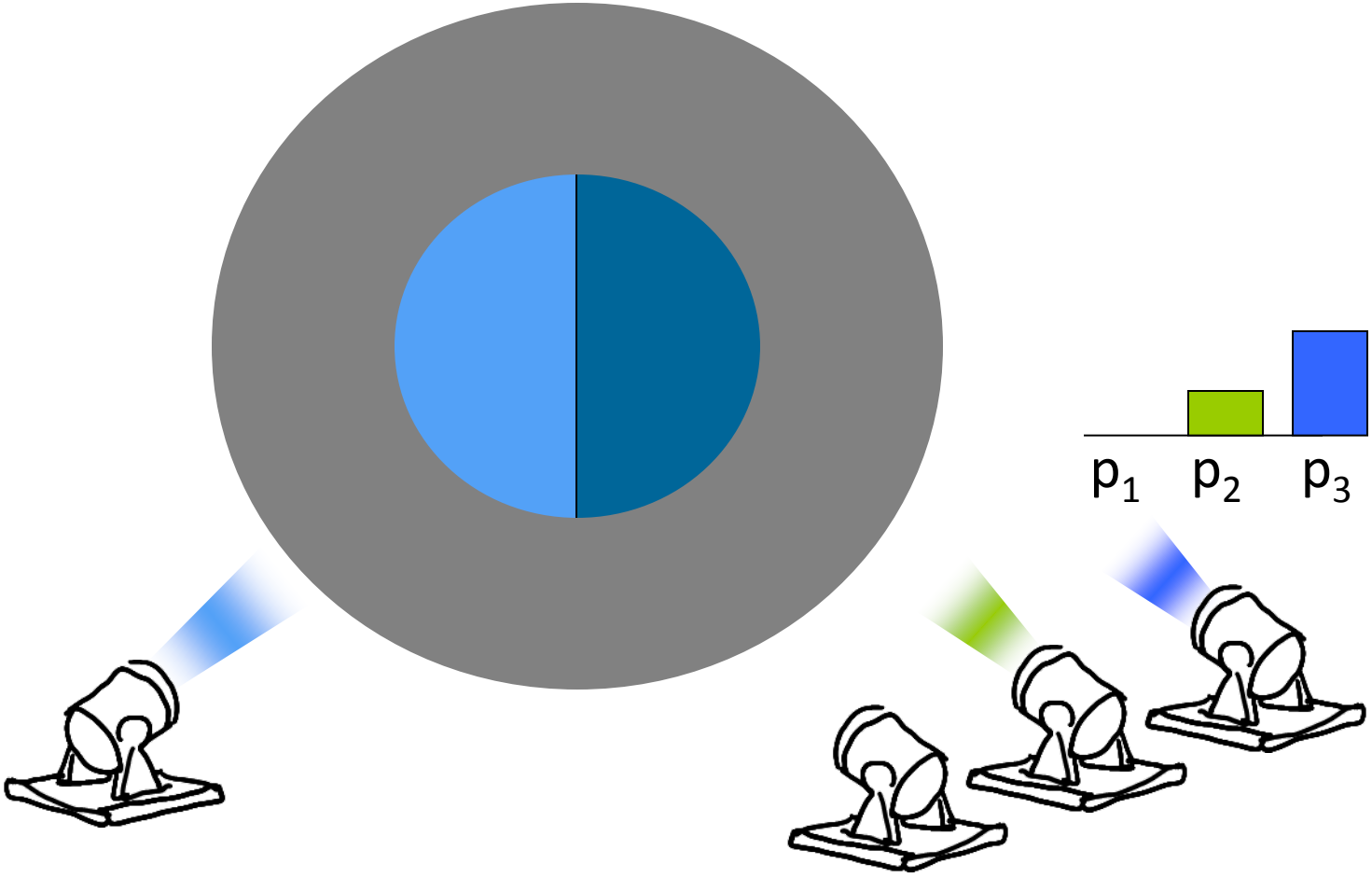
Color Matching Experiment 1



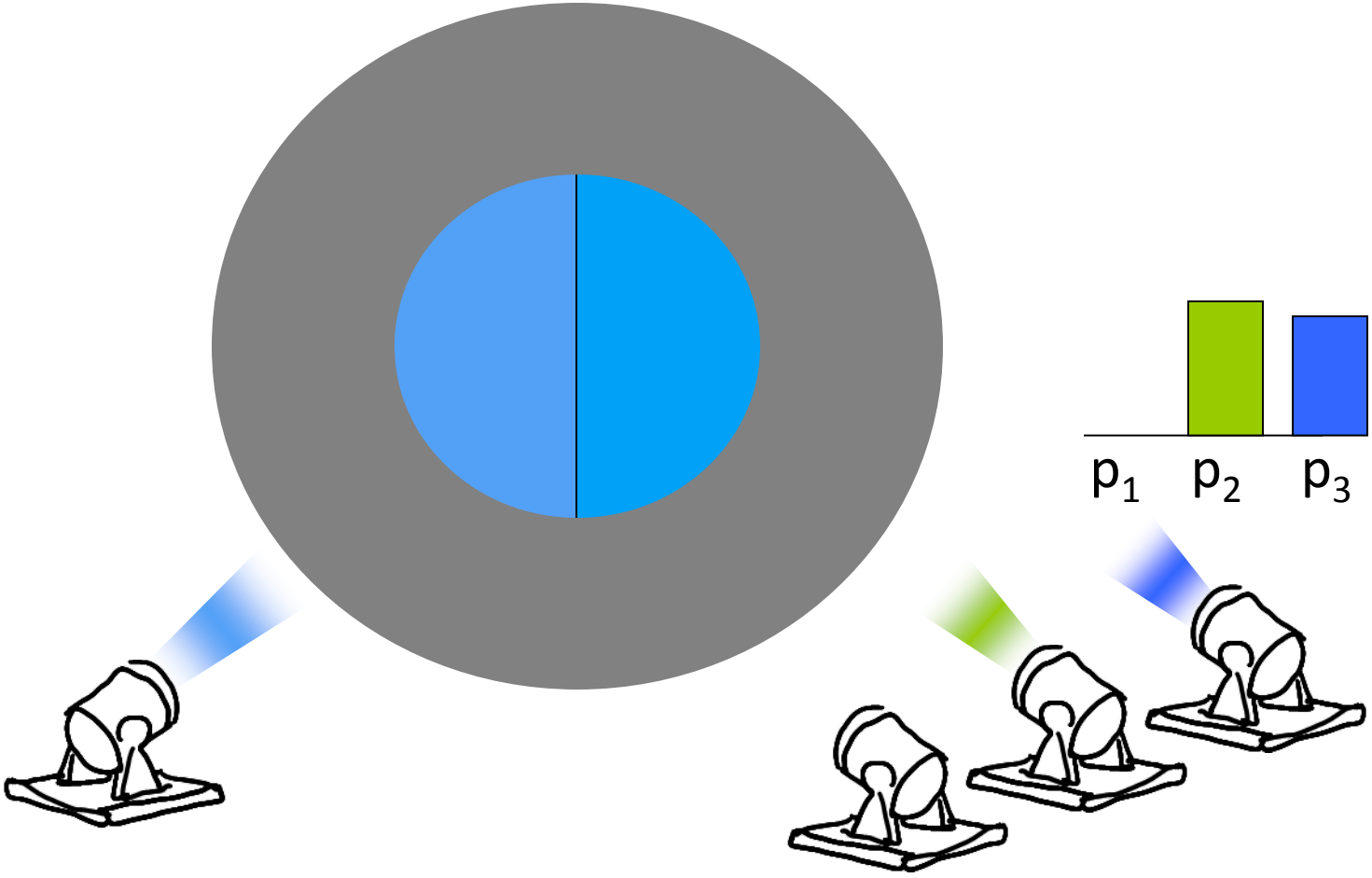
Color Matching Experiment 2



Color Matching Experiment 2

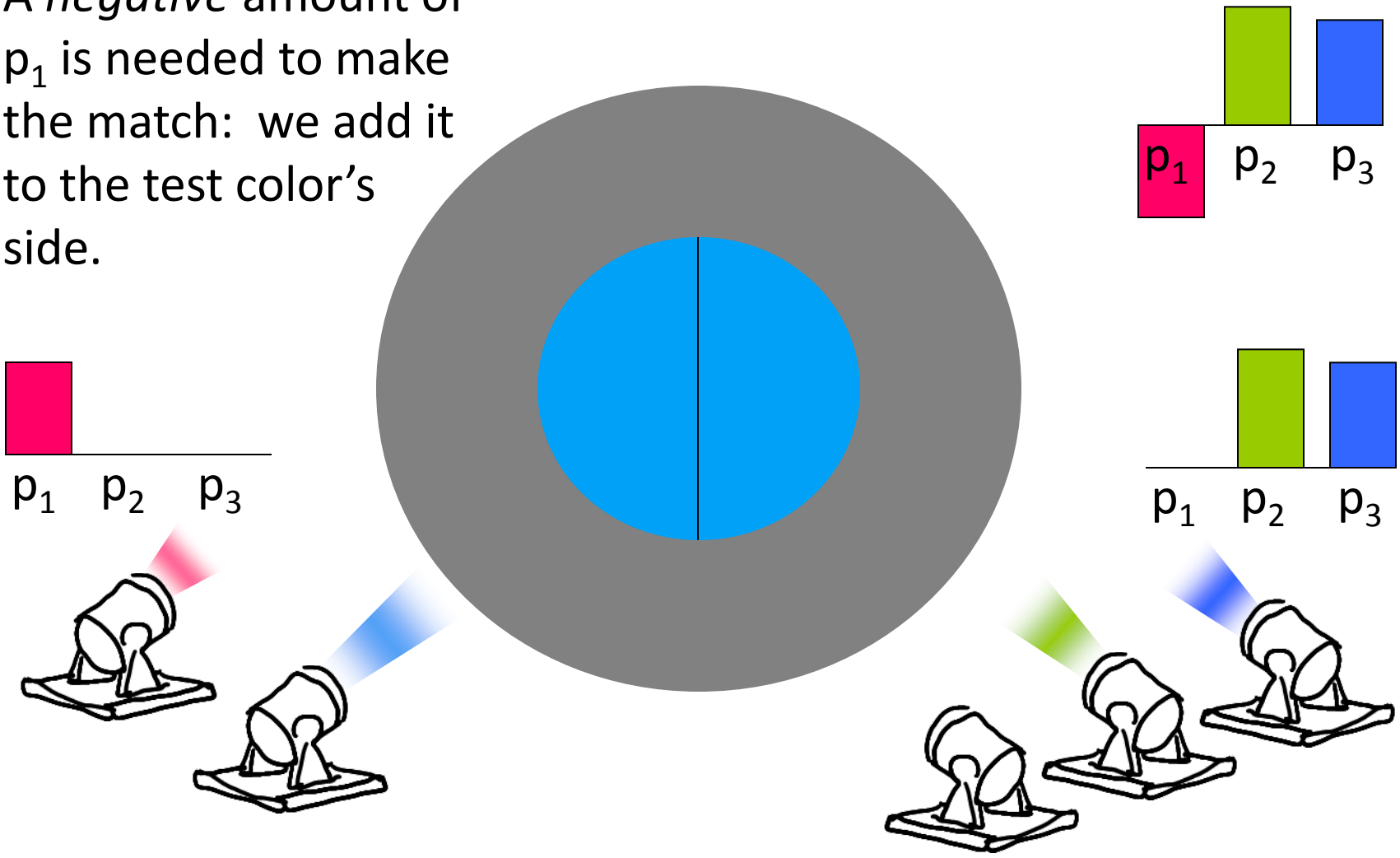


Color Matching Experiment 2

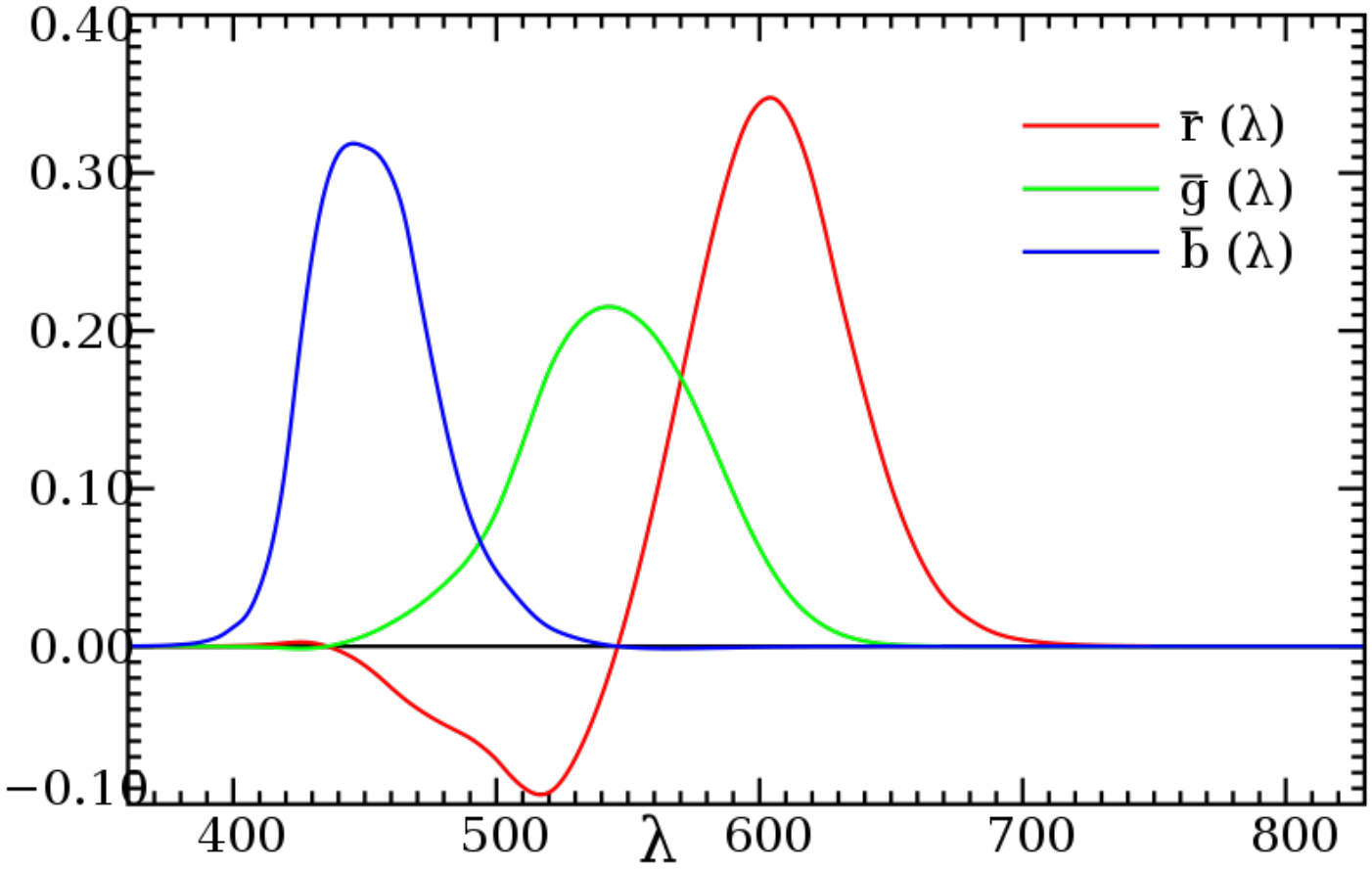


Color Matching Experiment 2

A *negative* amount of p_1 is needed to make the match: we add it to the test color's side.



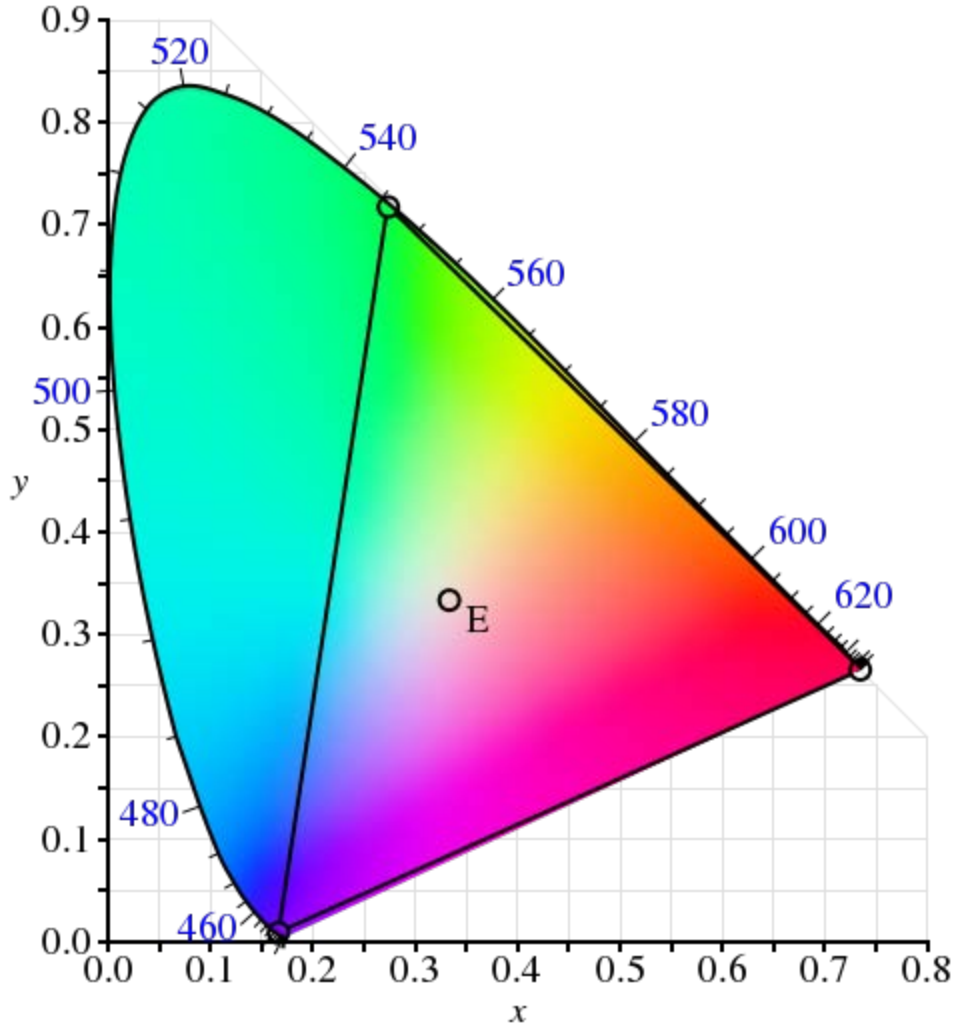
CIE 1931 RGB Color Matching Functions



700 .0nm
546.1 nm
435.8 nm

[Wikipedia]

The CIE 1931 xy Chromaticity Diagram with CIE RGB

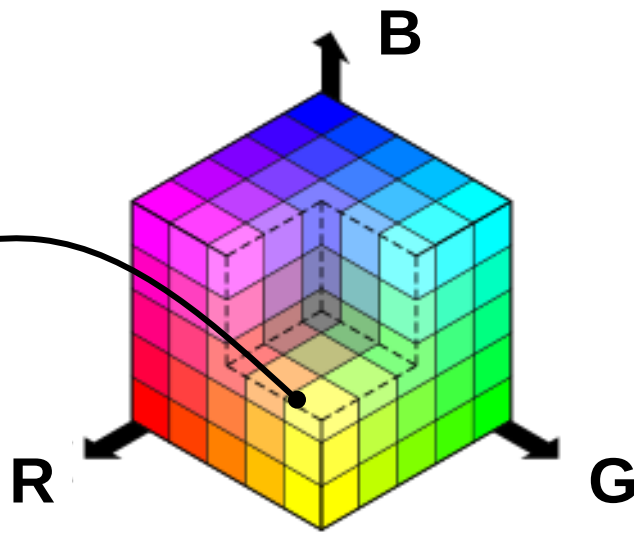


[Wikipedia]

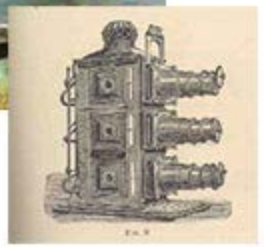
RGB

- 32-bit mode
  - Only 24 bits are used
  - 8 bits each channel

(c_1, c_2, c_3)



Early Color Photography

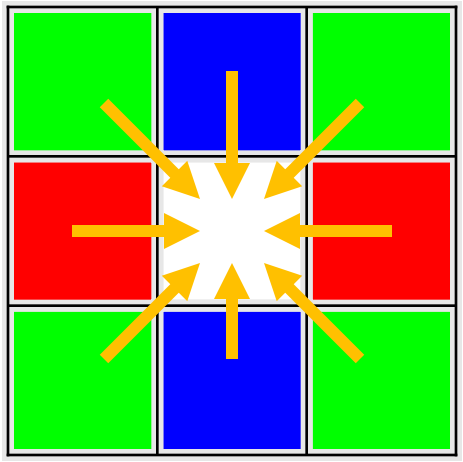


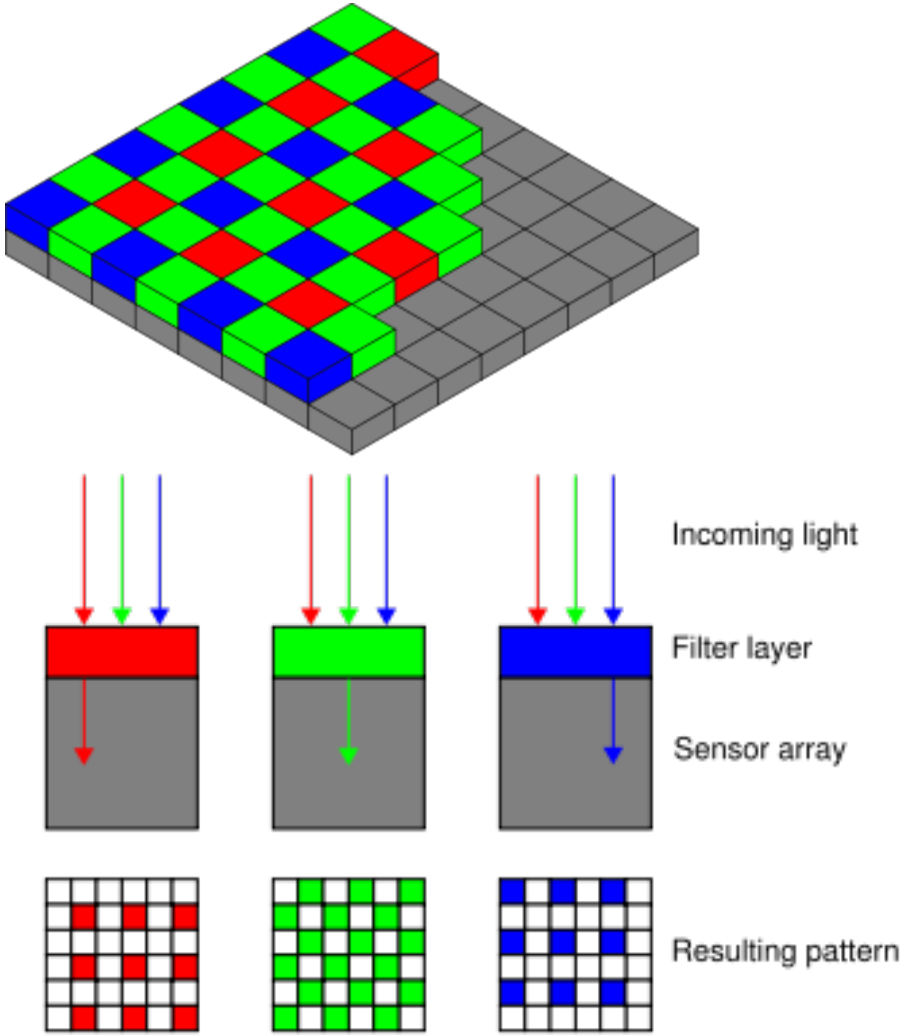
- Sergey Prokudin-Gorsky
- Optical color projections (1905)

- http://en.wikipedia.org/wiki/Prokudin-Gorskii

- Also check out Prof. Lewin's demonstration of color projections on YouTube
  http://www.youtube.com/watch?v=FJVvtOy-ukE&feature=related

Color Sensing in Digital Camera (RGB) -- Bayer Filter





- Estimate RGB at ‘G’ cells from neighboring cells

[Wikipedia]

Color Sensing in Digital Camera (RGB)

- 3-chip vs. 1-chip: quality vs. cost
- Why more green?
- Why three colors?

http://en.wikipedia.org/wiki/Bayer_filter

Rethinking Color Cameras

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Abstract

Digital color cameras make sub-sampled measurements of color at alternating pixel locations, and then "demosaick" these measurements to create full color images by up-sampling. This allows traditional cameras with restricted processing hardware to produce color images from a single shot, but it requires blocking a majority of the incident light and is prone to aliasing artifacts. In this paper, we introduce a computational approach to color photography, where the sampling pattern and reconstruction process are co-designed to enhance sharpness and photographic speed. The pattern is made predominantly panchromatic, thus avoiding excessive loss of light and aliasing of high spatial-frequency intensity variations. Color is sampled at a very sparse set of locations and then propagated throughout the image with guidance from the un-aliased luminance channel. Experimental results show that this approach often