COL781: Computer Graphics

21. Colour and Materials

kitti851, pixabay.com

Regarding assignments

Assignment 1 demos on Friday (probably)

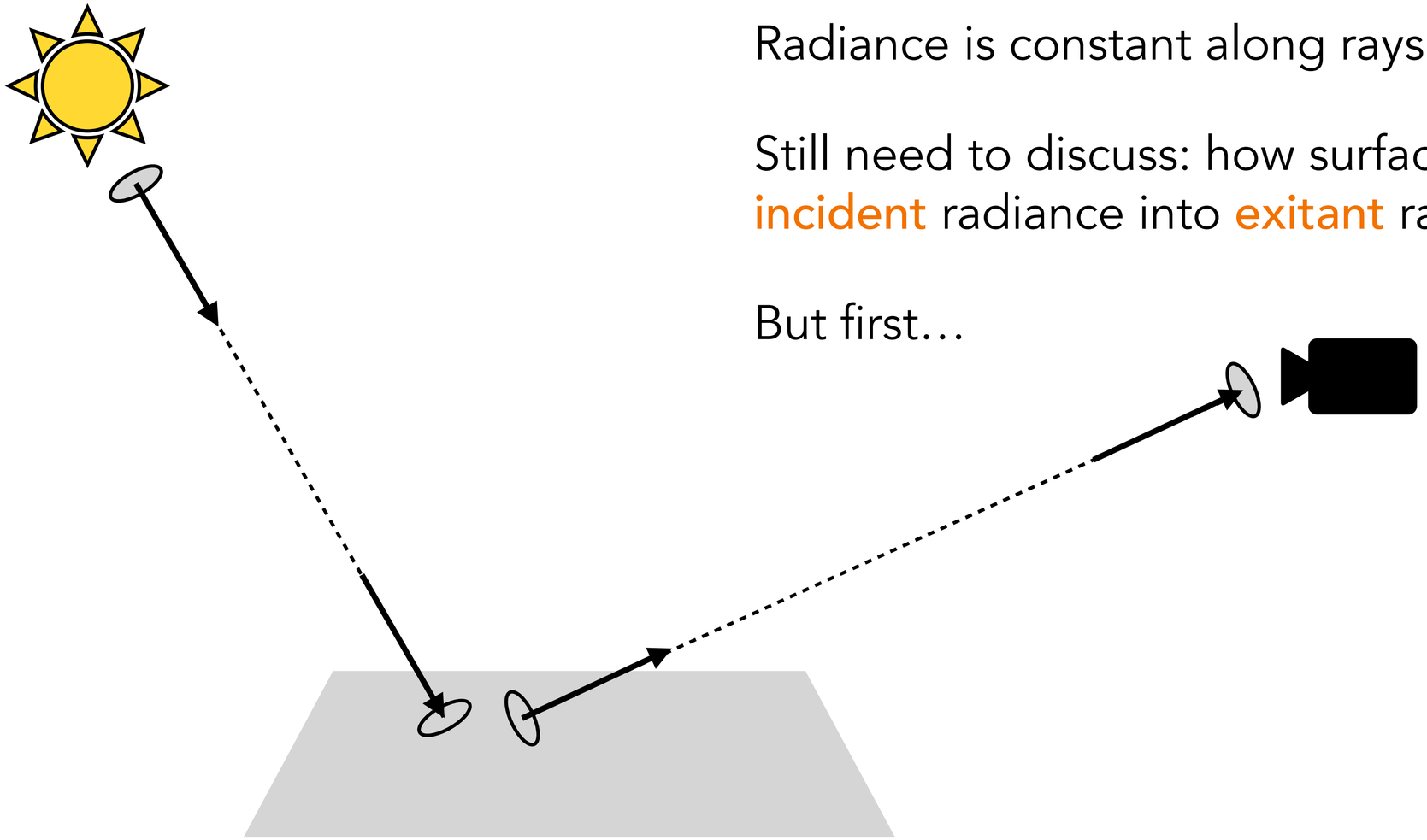
- To be scheduled by Rupesh

Assignment 2 also due on Friday!

- How is everyone’s progress?
- Need more time? Or prefer to enjoy semester break?

Assignment 3 out after semester break

Recap

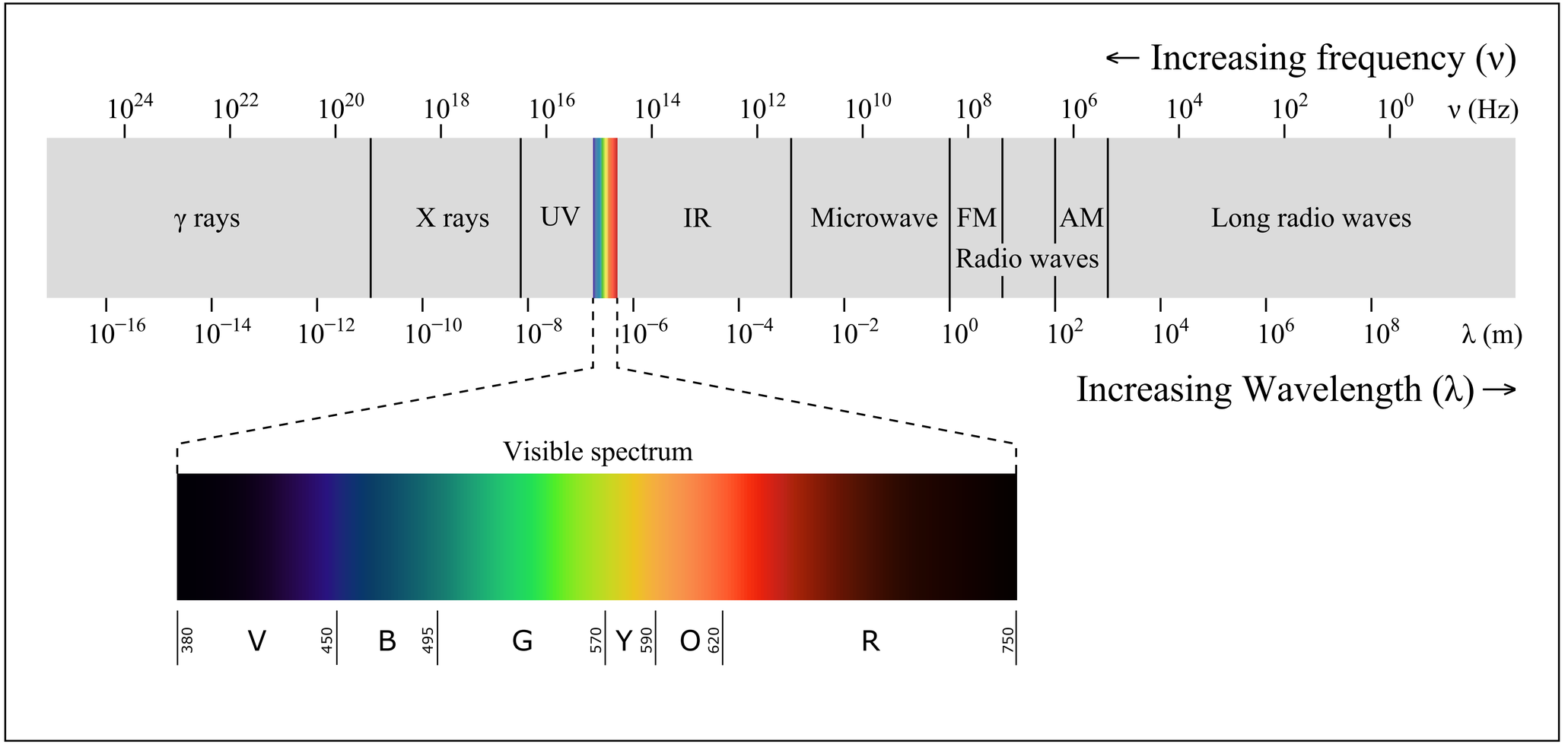


Radiance is constant along rays.

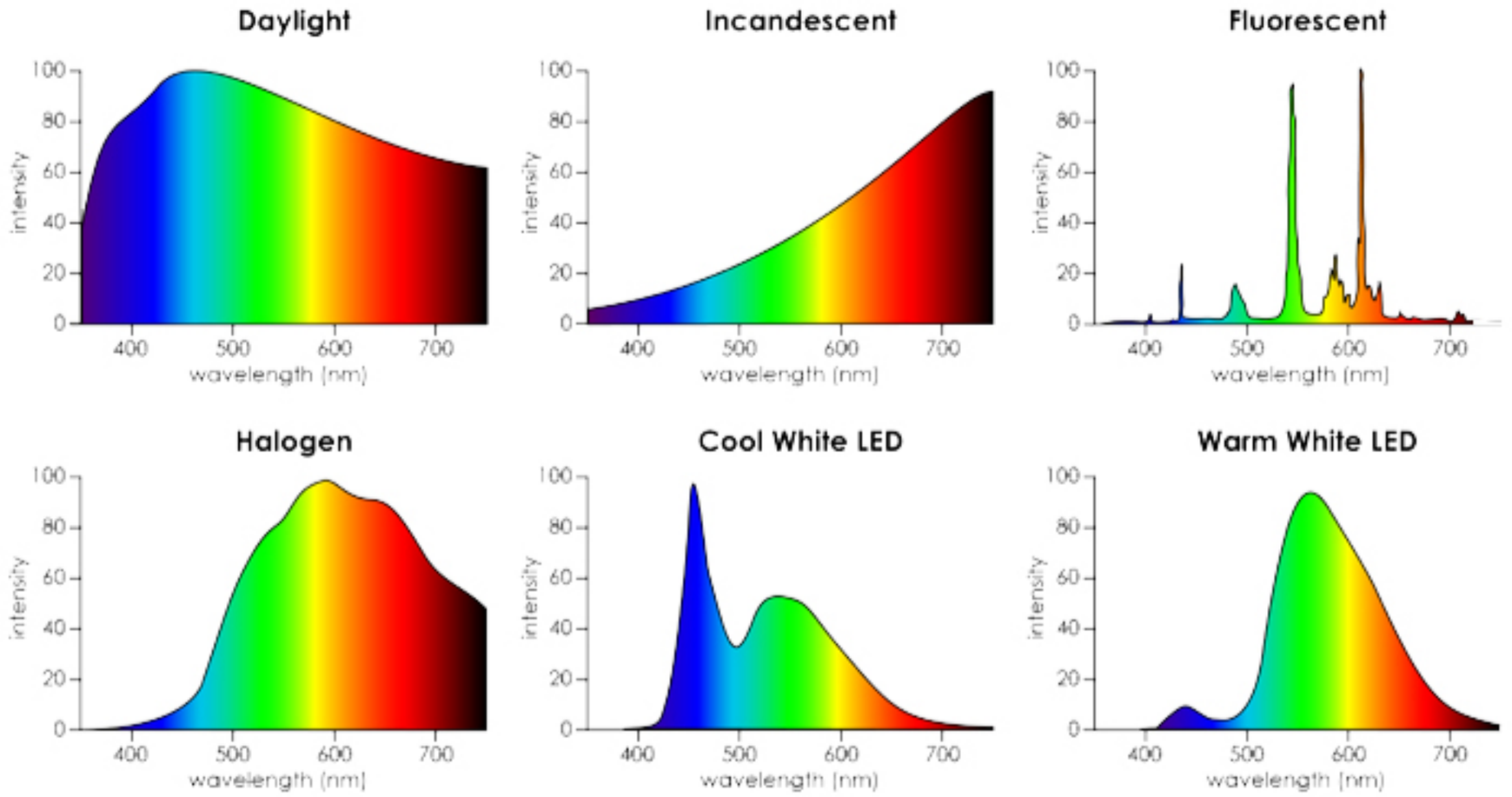
Still need to discuss: how surfaces transform incident radiance into exitant radiance

But first…

What is colour?

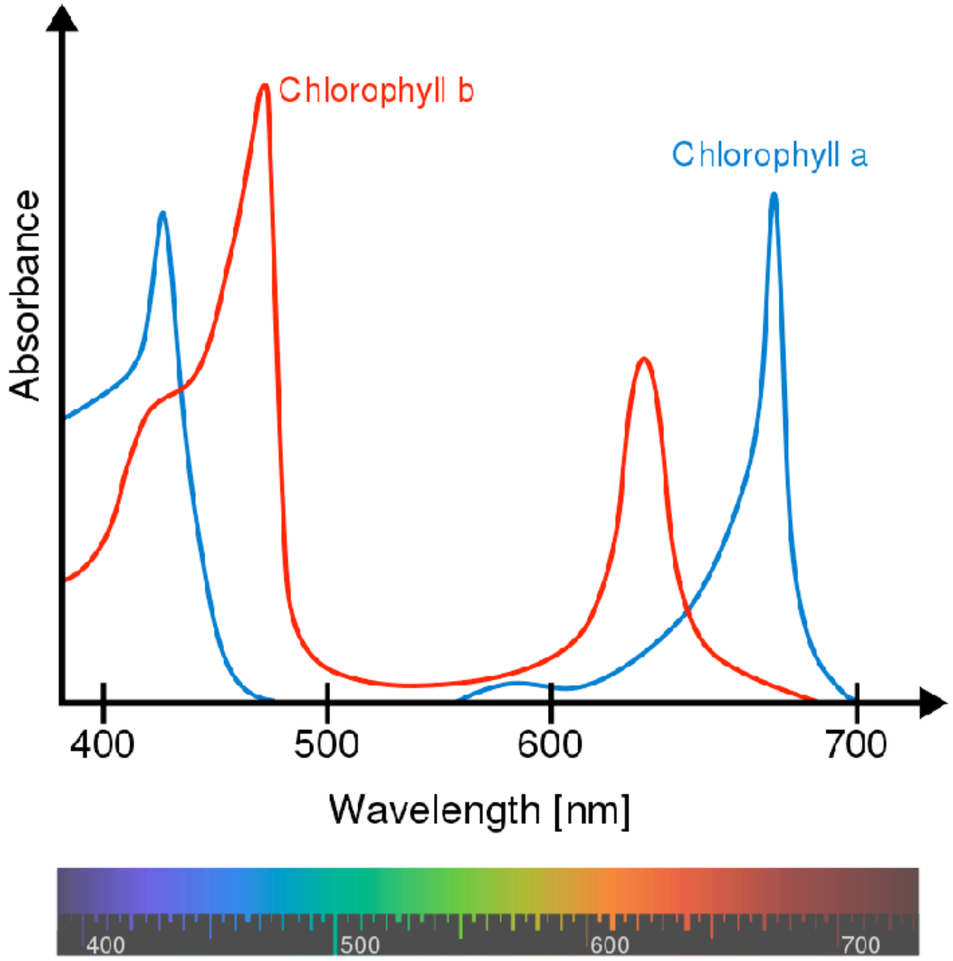


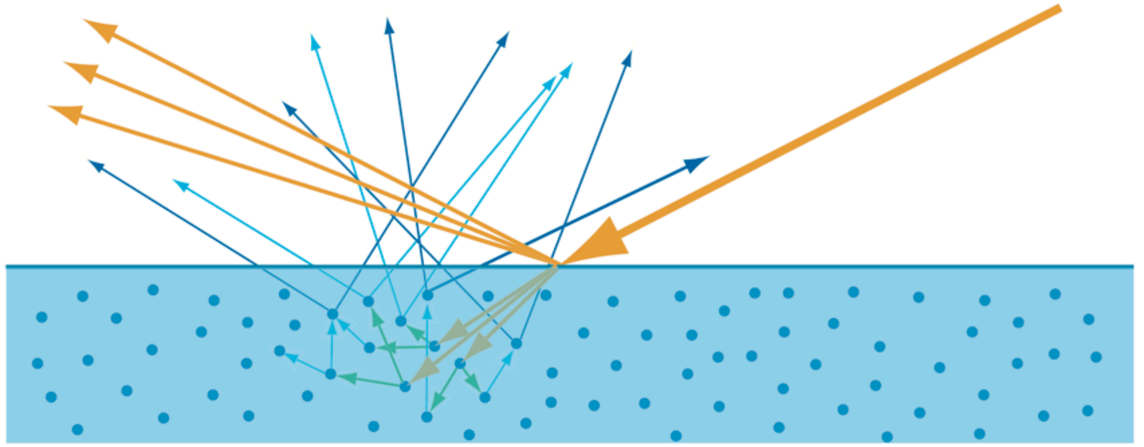
Emission spectra

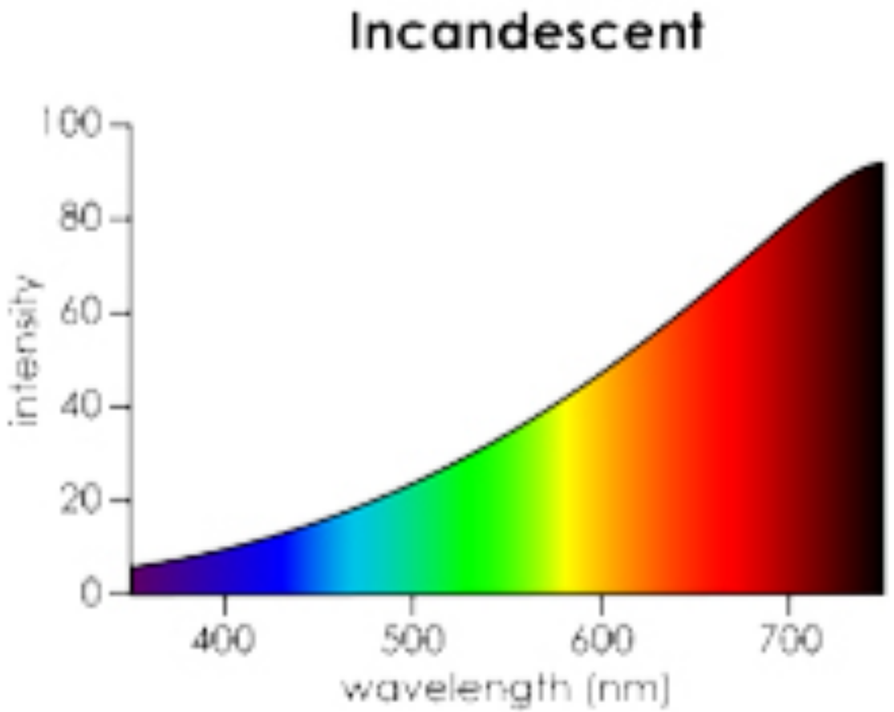


Admesy, via Ren Ng

Absorption spectra







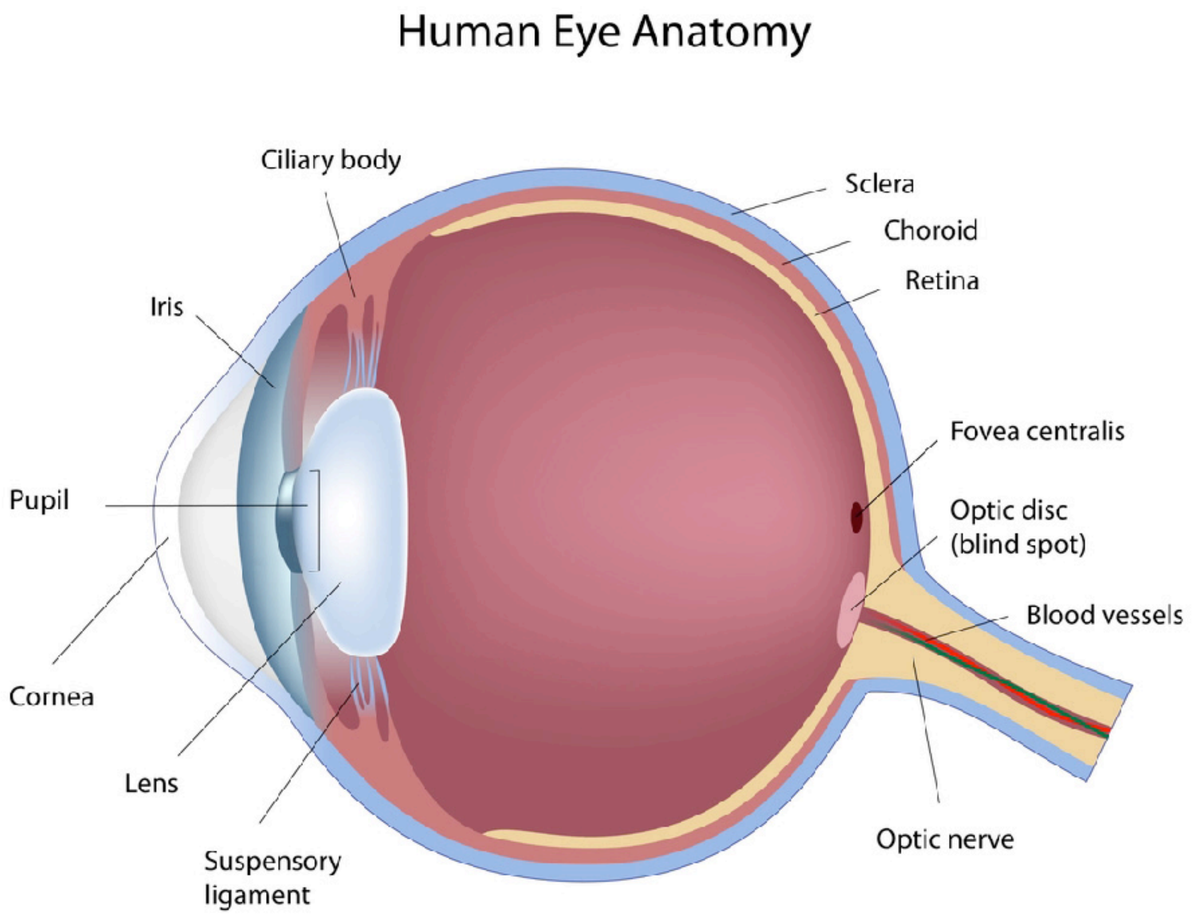
Spectral distribution

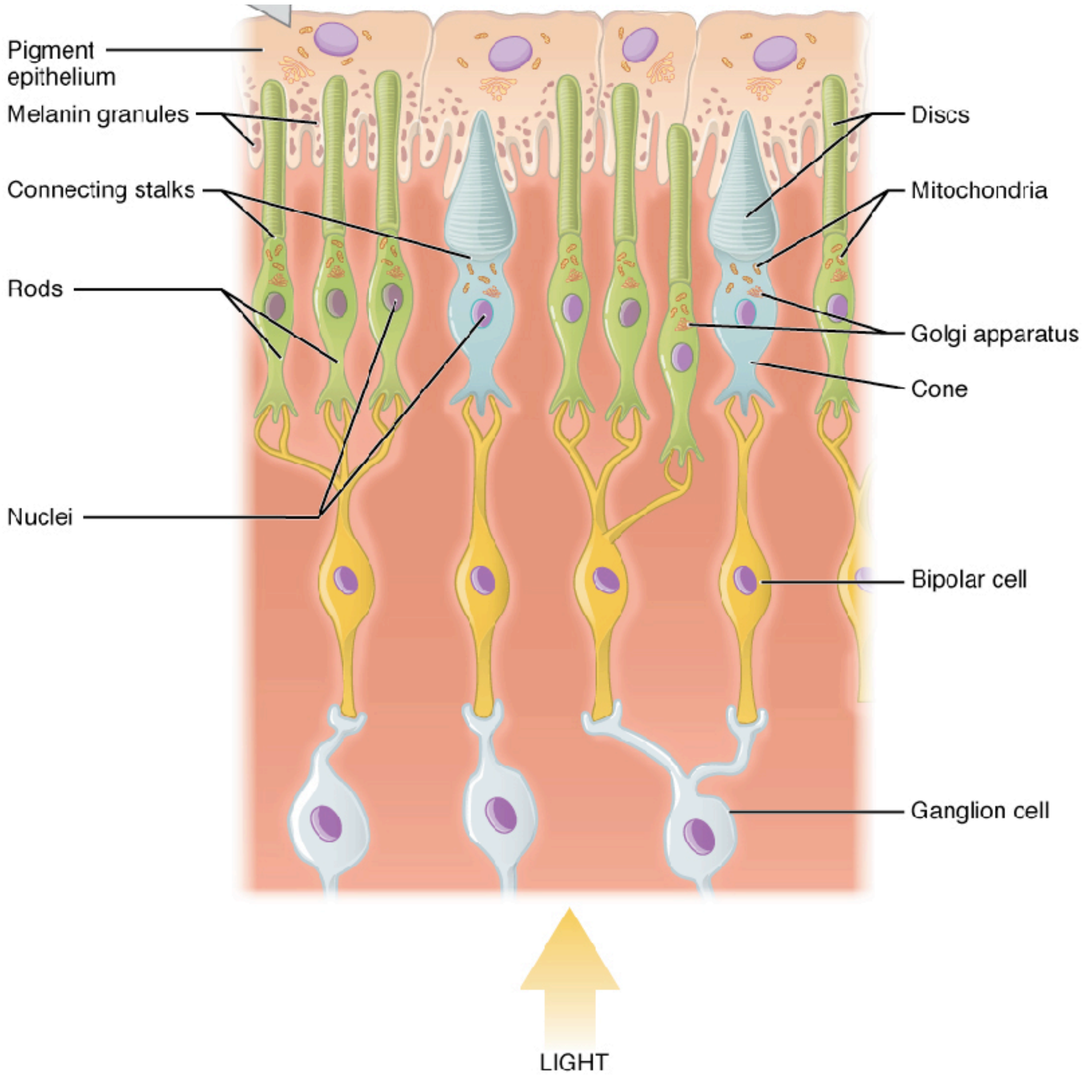
?

RGB (255, 220, 160)

Tristimulus values

The human eye

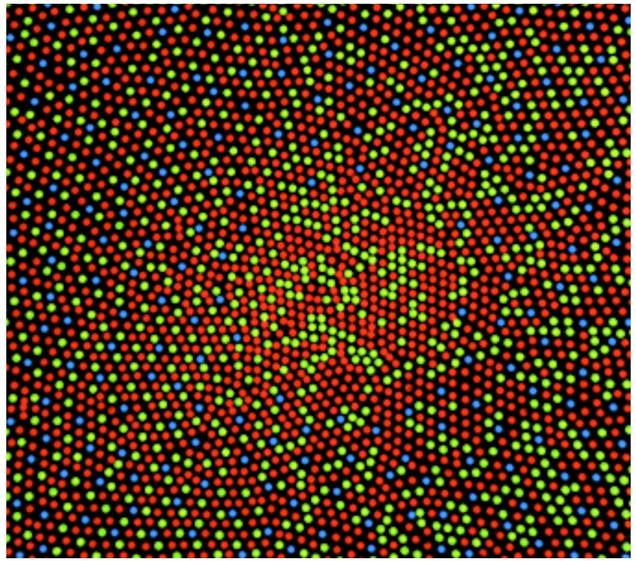


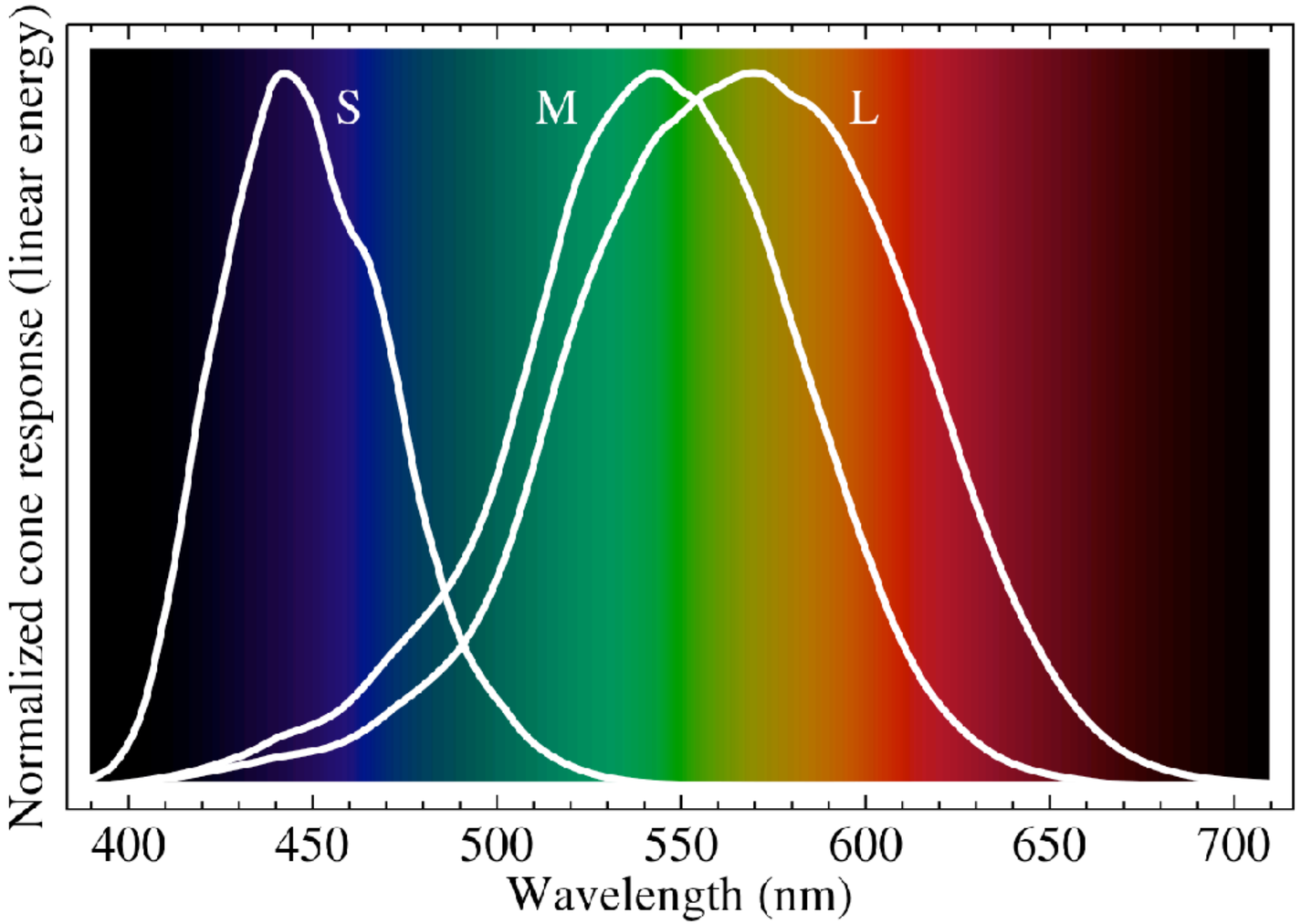


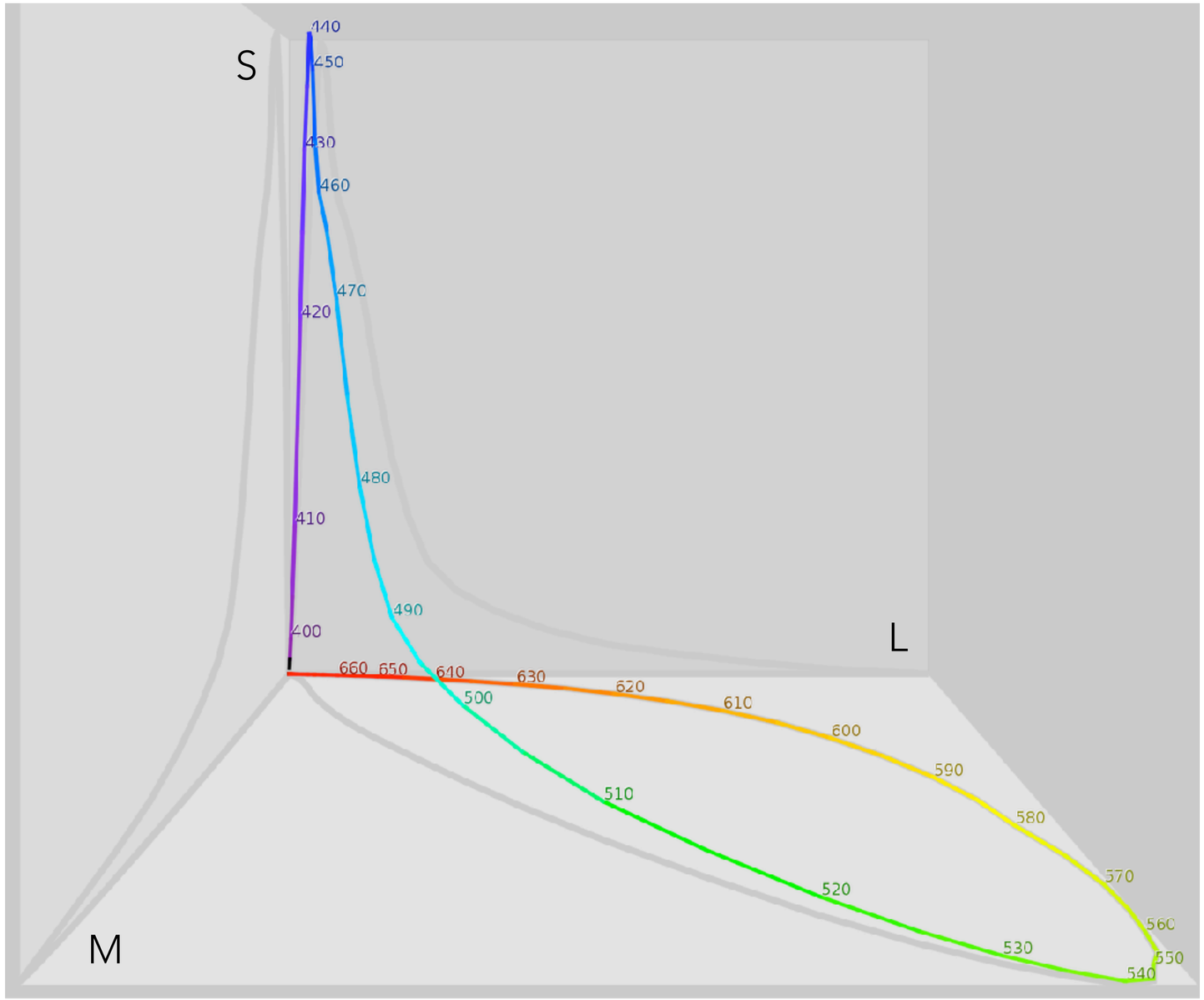
Cone cells

Three types of cone cells: sensitive to long, medium, and short wavelengths

(not red, green, and blue!)



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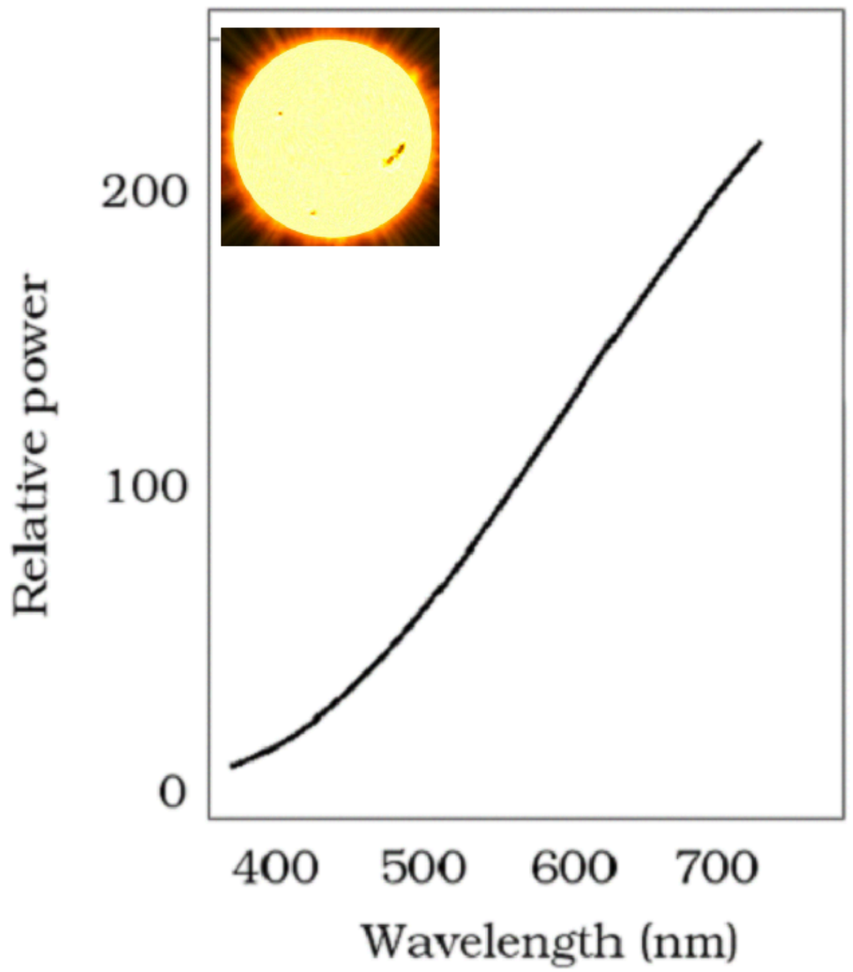
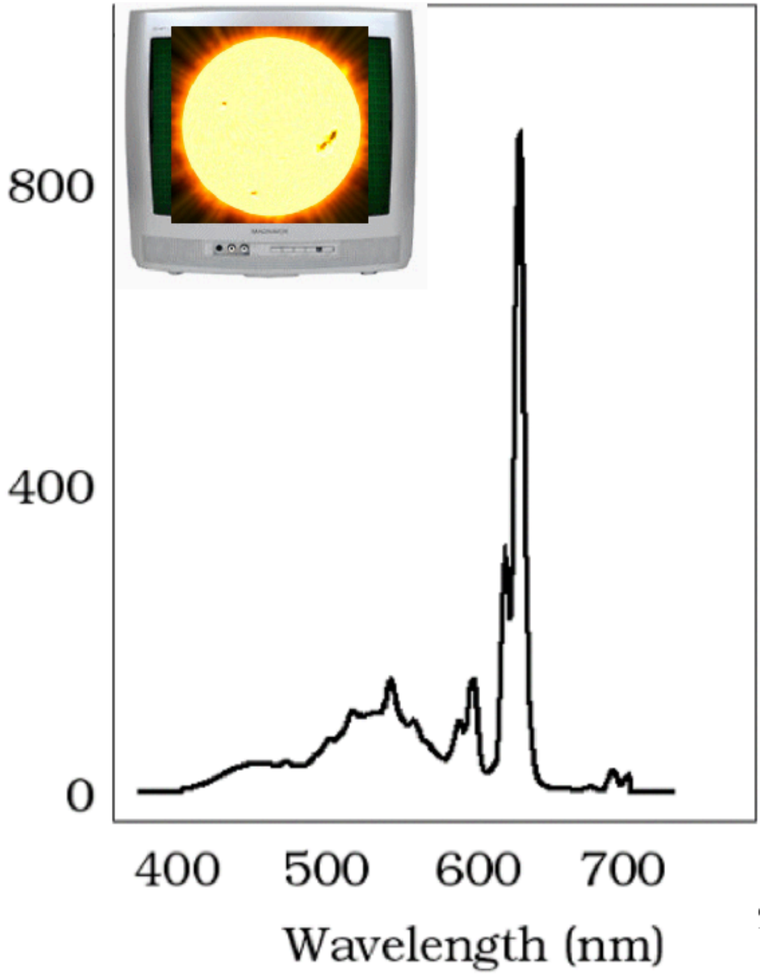
Metamers

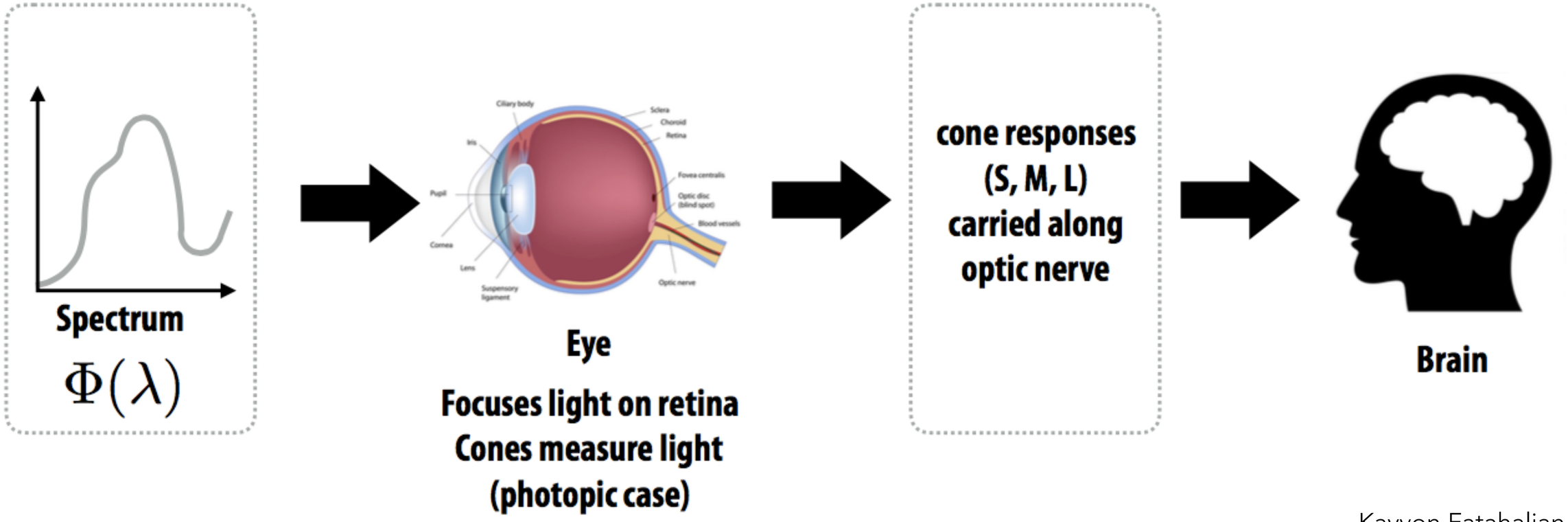




Brian Wandell

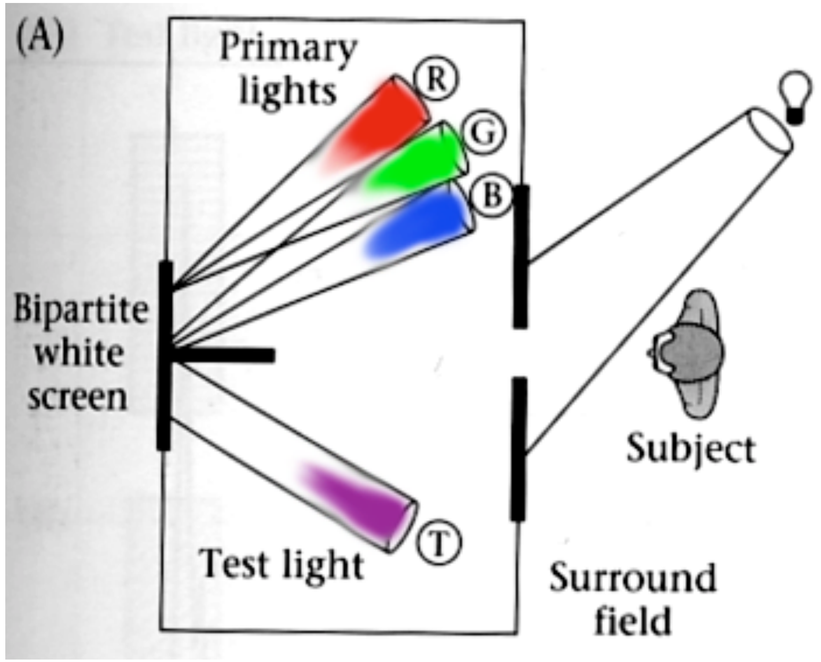
Colours are entirely a product of the human visual system!

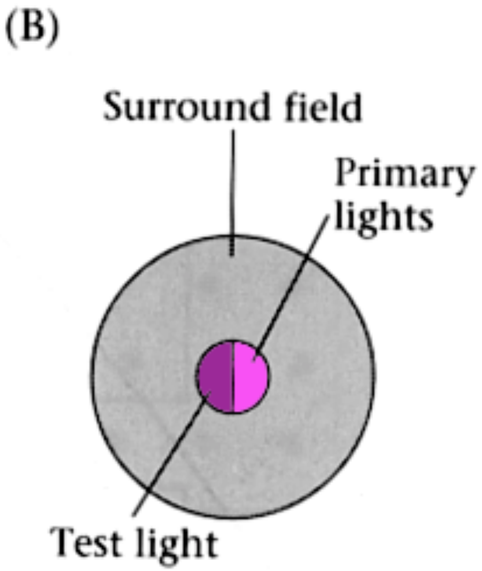
Physically, only spectra exist.

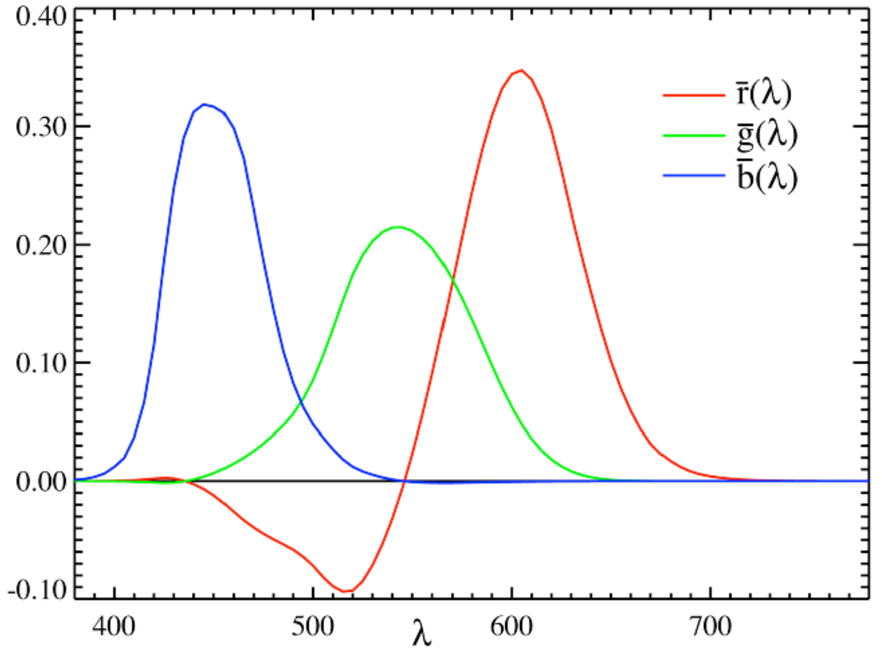


Kayvon Fatahalian

Colour matching experiments







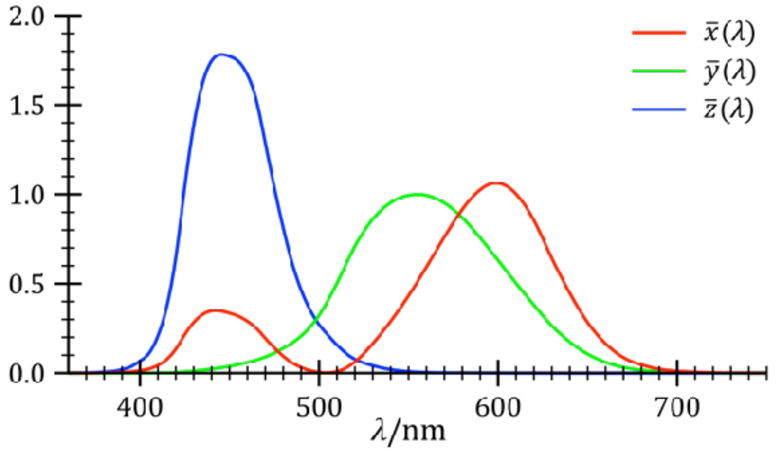
Primaries: 700 nm (red),
546.1 nm (green), 435.8 nm (blue)

Colour spaces

A **colour space** is a choice of coordinate system for the 3D space of colours.

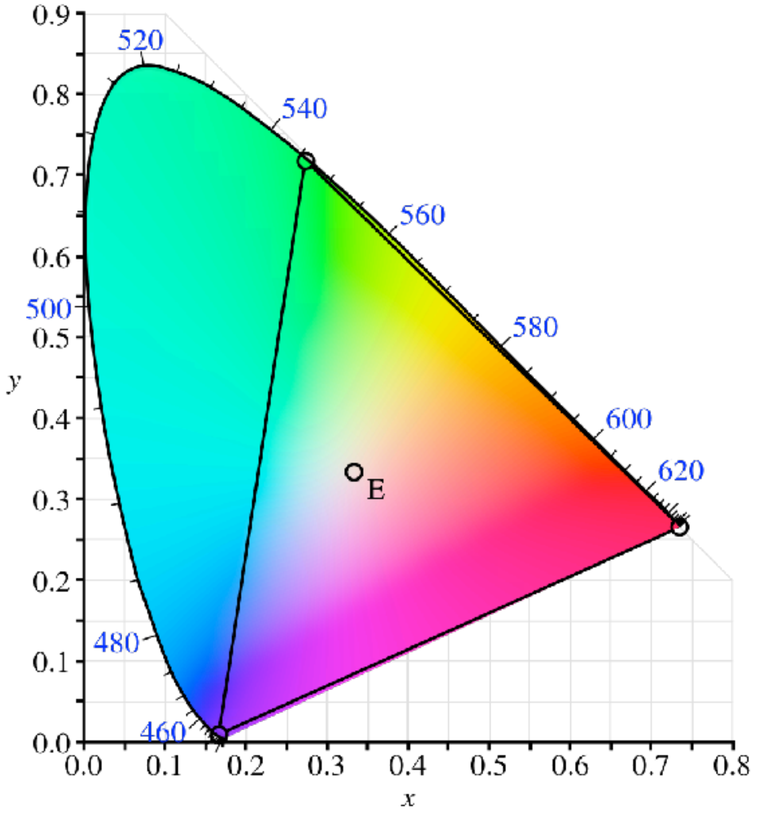
CIE 1931 XYZ colour space:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.490\,00 & 0.310\,00 & 0.200\,00 \\ 0.176\,97 & 0.812\,40 & 0.010\,63 \\ 0.000\,00 & 0.010\,00 & 0.990\,00 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$



Chromaticity diagram

vs. $(x, y) = \dfrac{(X, Y)}{X + Y + Z}$



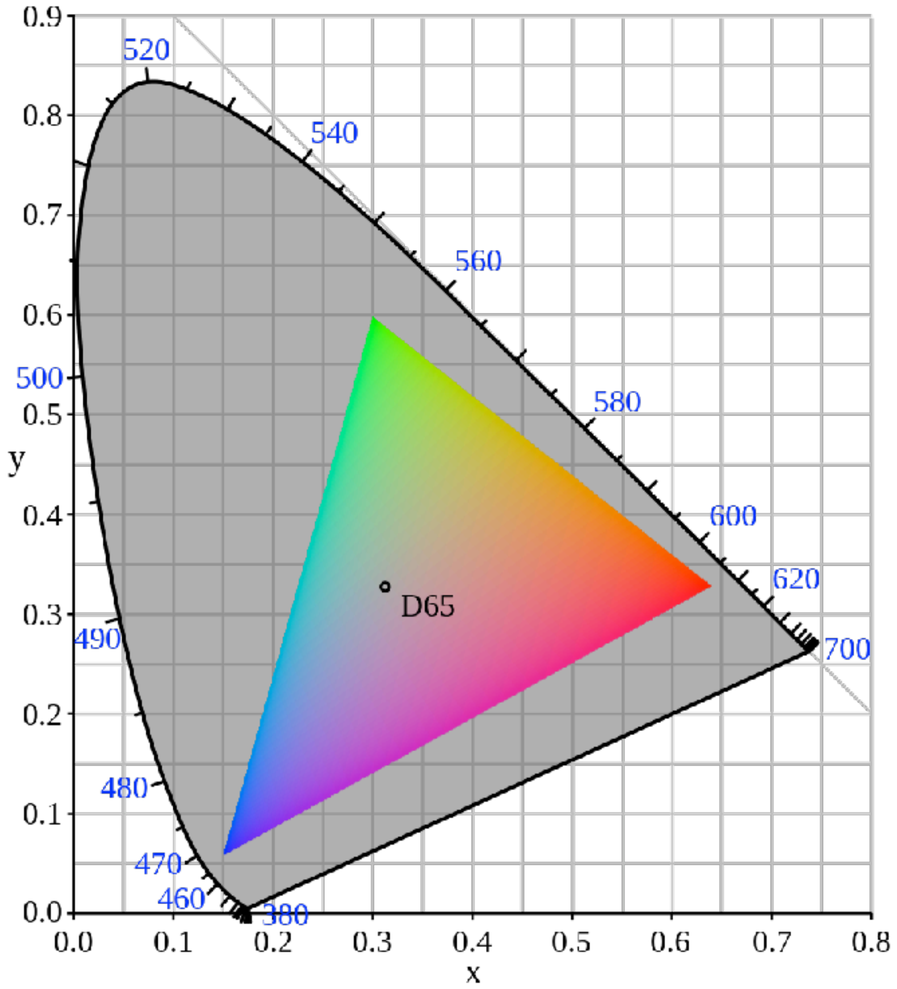
sRGB

Standard colour space for most monitors, printers, and the web

$$\begin{bmatrix} R_{\text{lin}} \\ G_{\text{lin}} \\ B_{\text{lin}} \end{bmatrix} = \begin{bmatrix} +3.2406 & -1.5372 & -0.4986 \\ -0.9689 & +1.8758 & +0.0415 \\ +0.0557 & -0.2040 & +1.0570 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Then for $C = R, G, B$:

$$C = \begin{cases} 12.92C_{\text{lin}}, & C_{\text{lin}} \leq 0.0031308 \\ 1.055C_{\text{lin}}^{1/2.4} - 0.055, & C_{\text{lin}} > 0.0031308 \end{cases}$$



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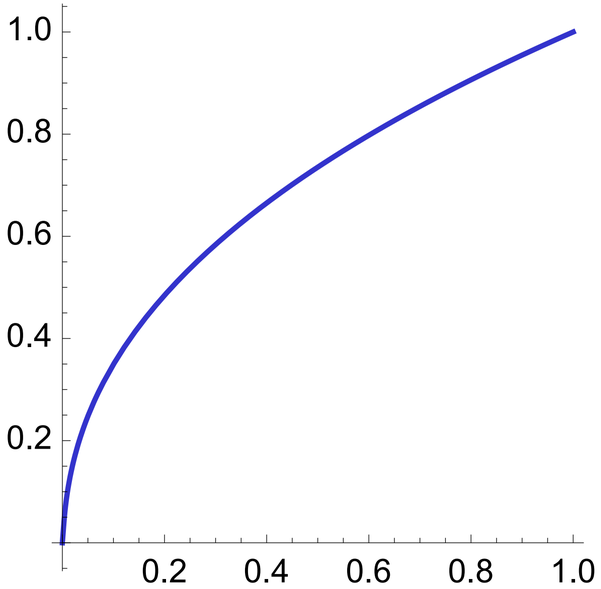
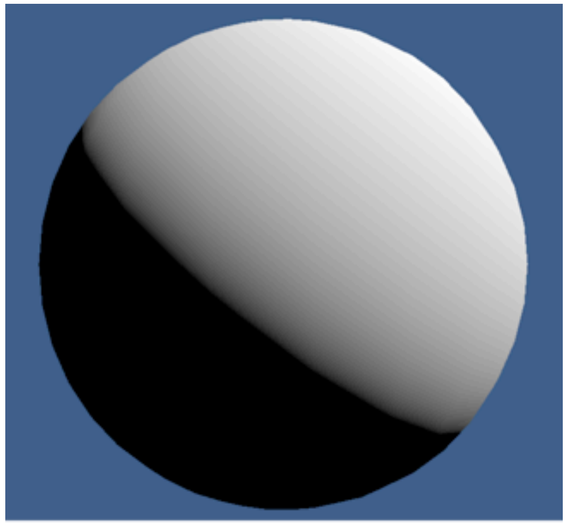


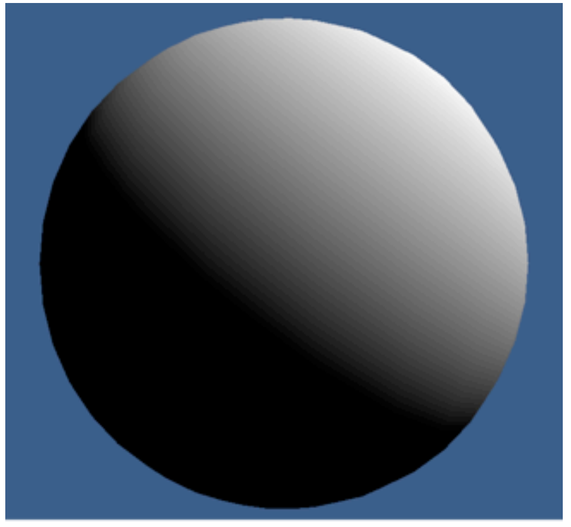
Gamma correction: component values are transformed by a nonlinear function

Why? Better quantization of dark values

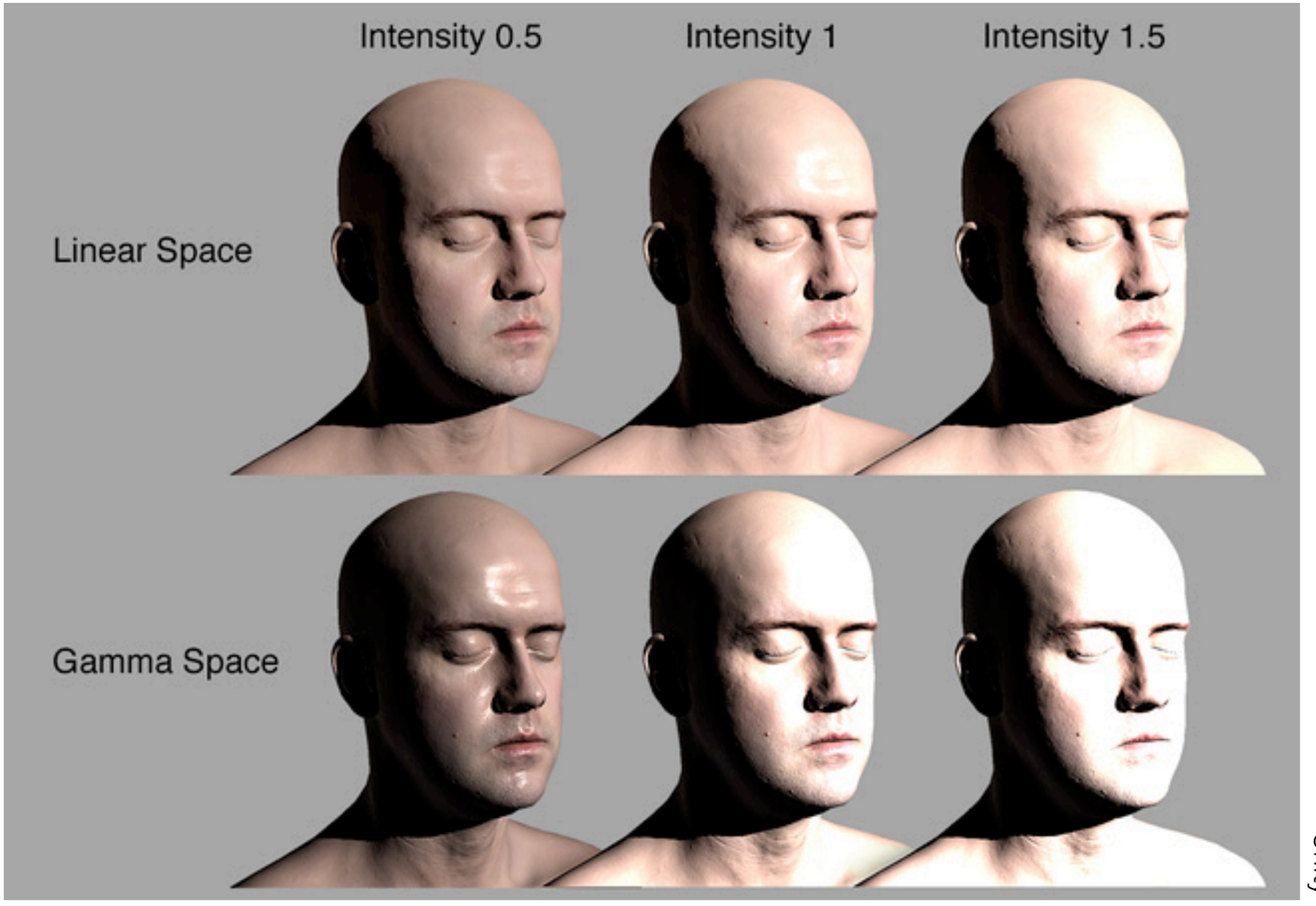
Linear encoding V_S =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Linear intensity I =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0



Linear Space



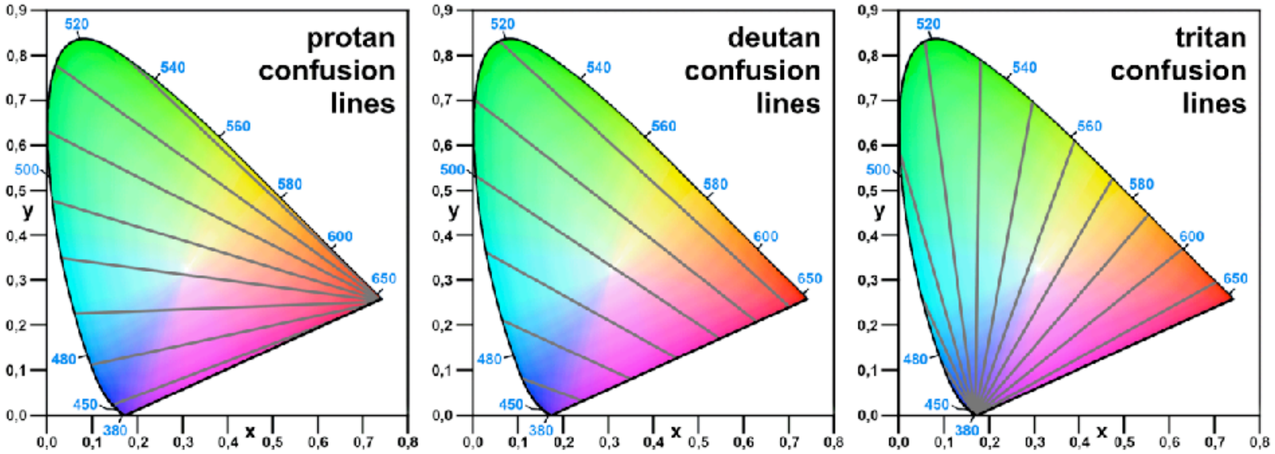
Gamma Space



Unity

Colour blindness

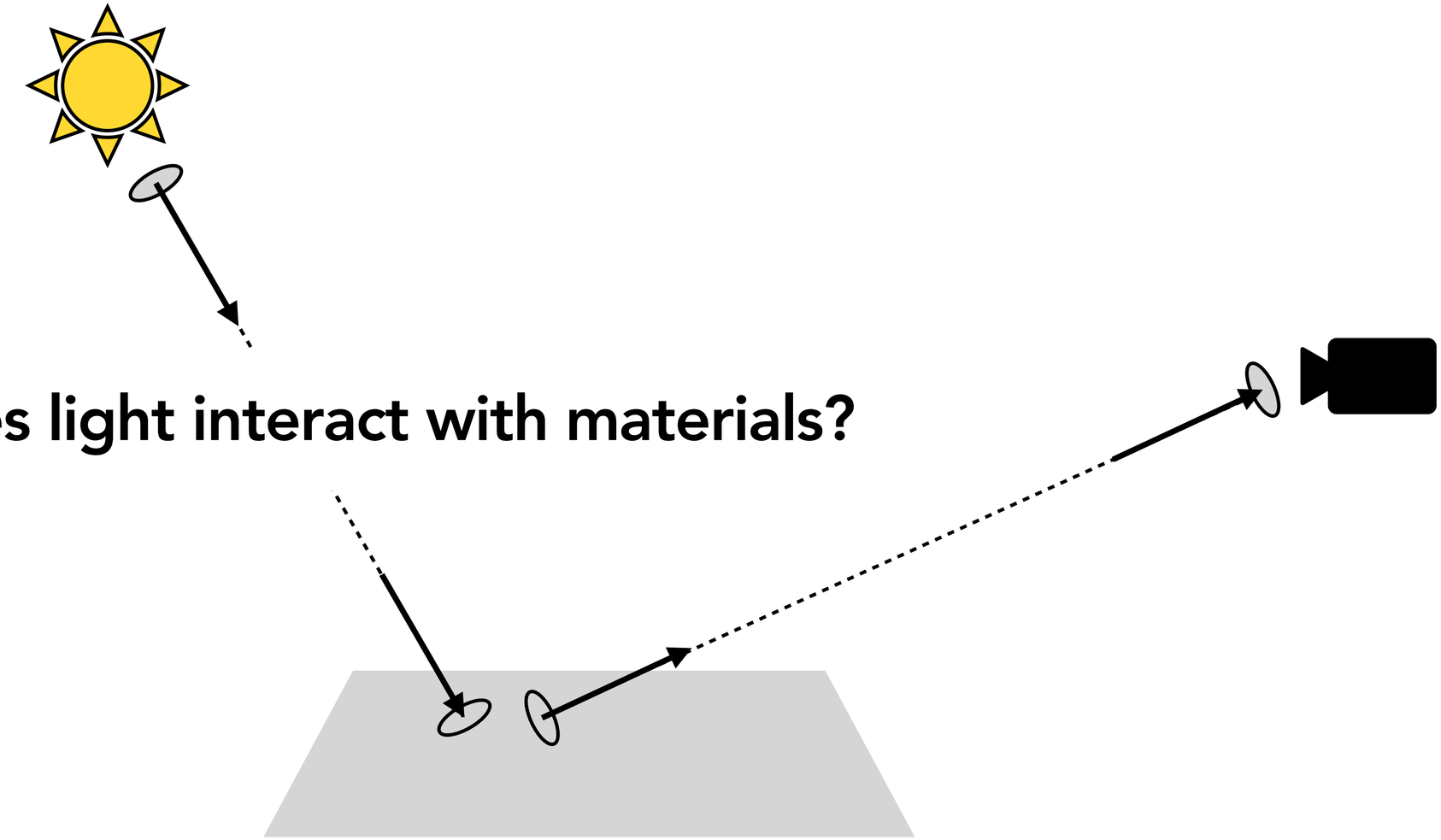
Reduced or no functionality in one (or more) of the three types of cones



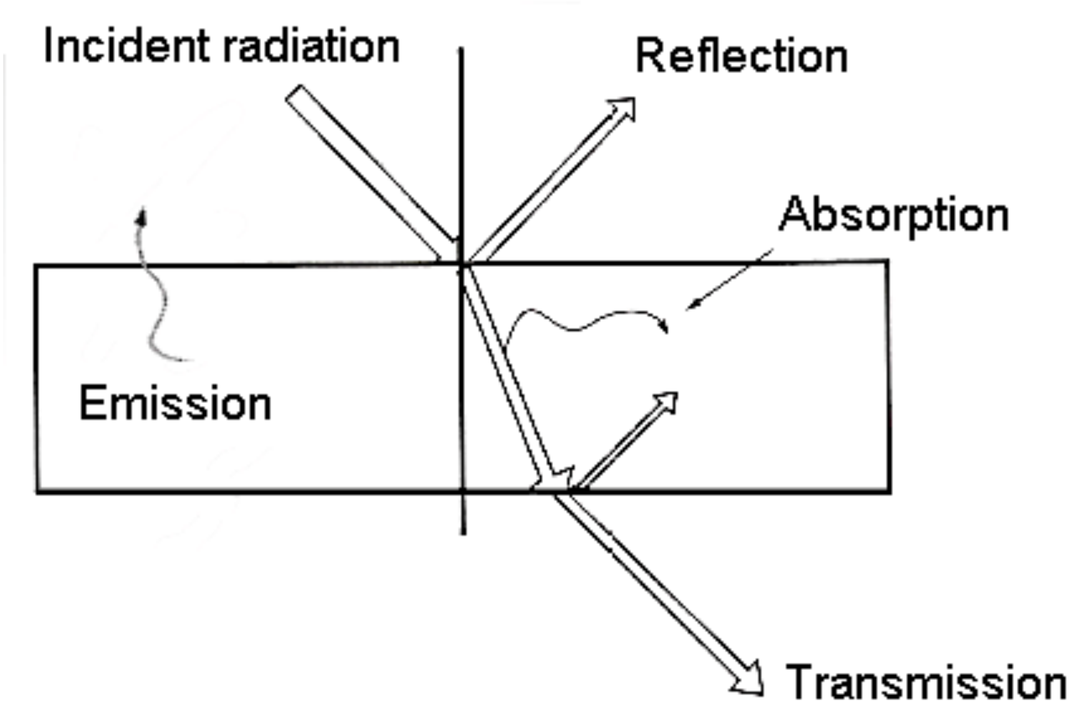
Normal vision

Deuteranopia

Tritanopia



How does light interact with materials?

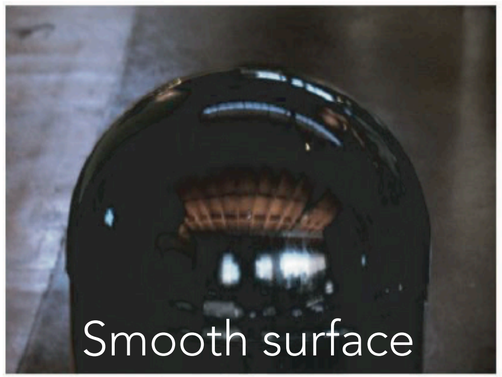

Incident radiation
Reflection
Absorption
Emission
Transmission

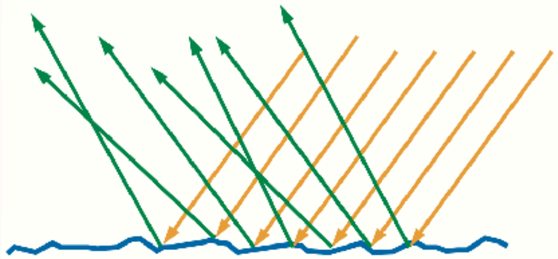
Puzzle:

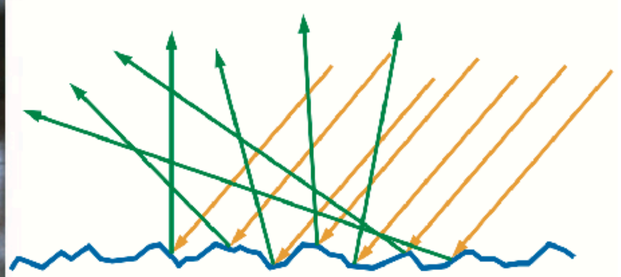
An object looks white if it reflects (almost) all incident light regardless of frequency.

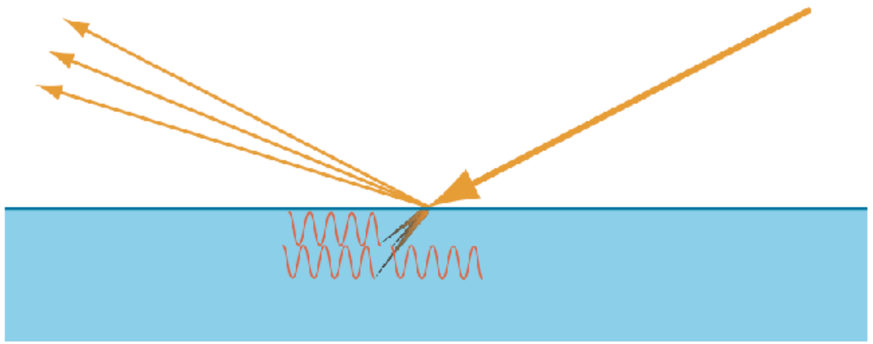
A mirror reflects (almost) all incident light (regardless of frequency).

So what's the difference between a white object and a mirror?

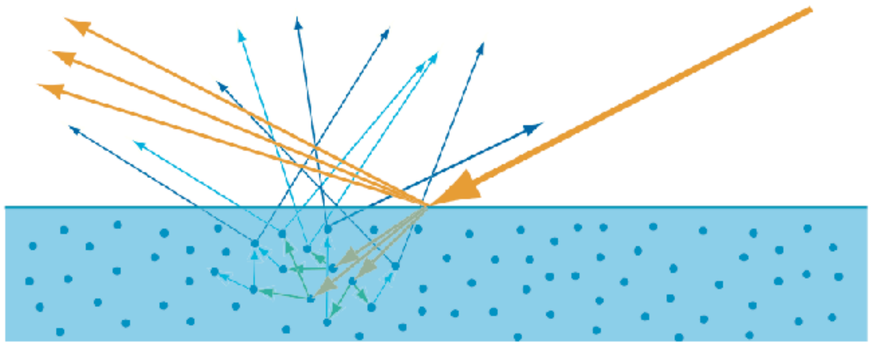






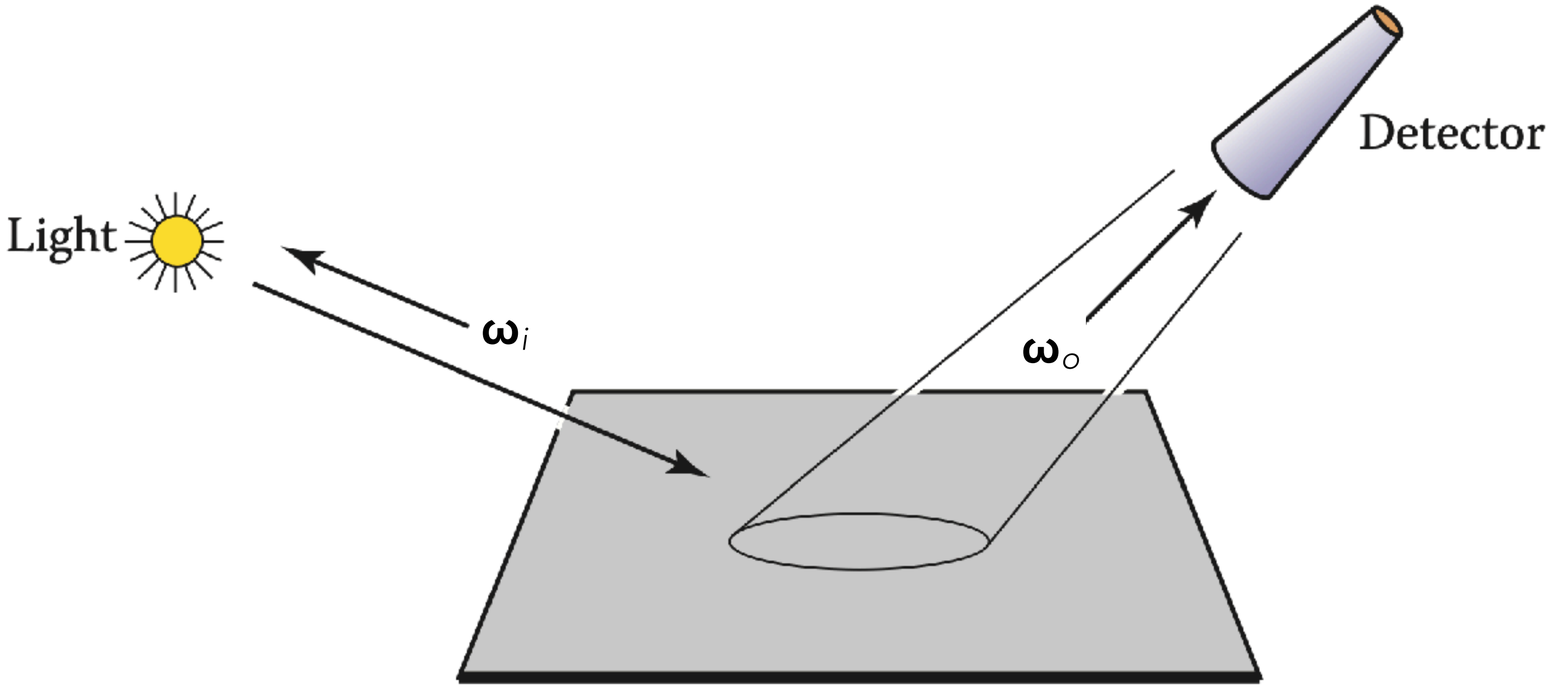


Metals



Non-metals

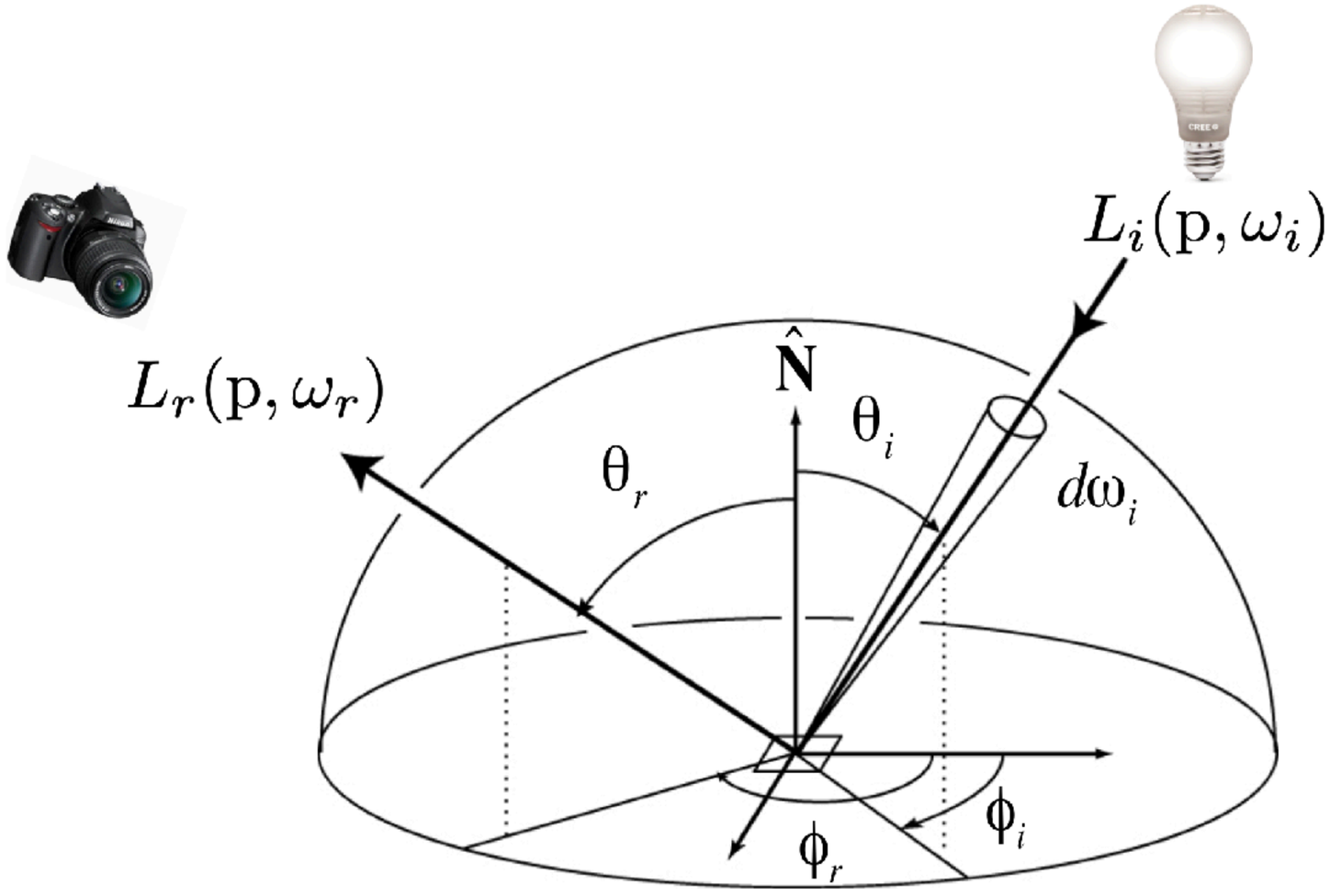
The BRDF



Fundamentals of Computer Graphics

Bidirectional Reflectance Distribution Function

$$f_r(\omega_i \rightarrow \omega_o) = L_o(\mathbf{x}, \omega_o)/E(\mathbf{x})$$



$$L_r(\mathbf{x}, \boldsymbol{\omega}_r) = \int_{H^2} f_r(\boldsymbol{\omega}_i \rightarrow \boldsymbol{\omega}_r)\, L_i(\mathbf{x}, \boldsymbol{\omega}_i) \cos(\theta_i)\, \mathrm{d}\boldsymbol{\omega}_i$$

Diffuse

Plastic

Red semi-gloss paint

Ford “Mystic Lacquer” paint

Mirror

Gold