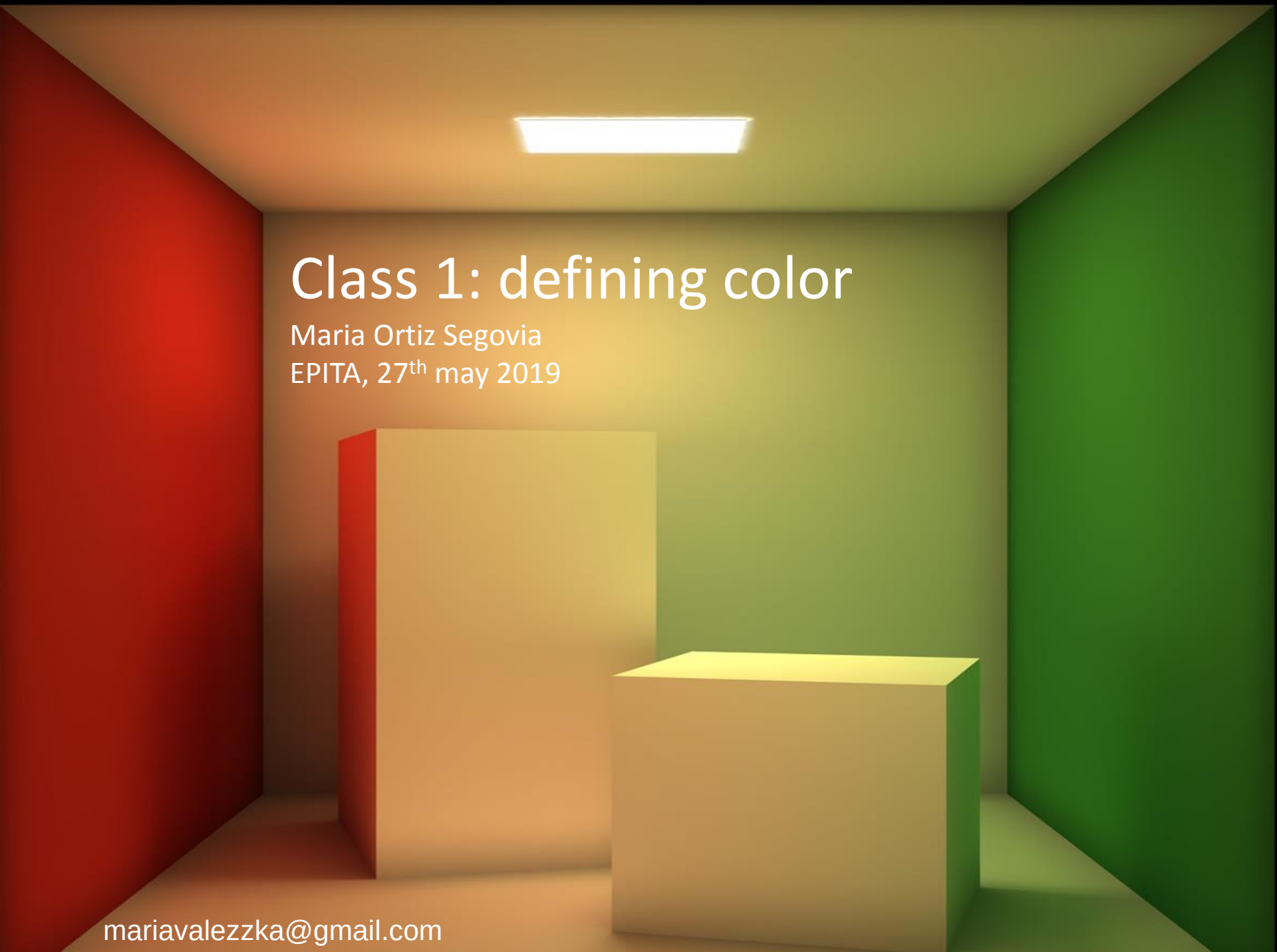

Class 1: defining color

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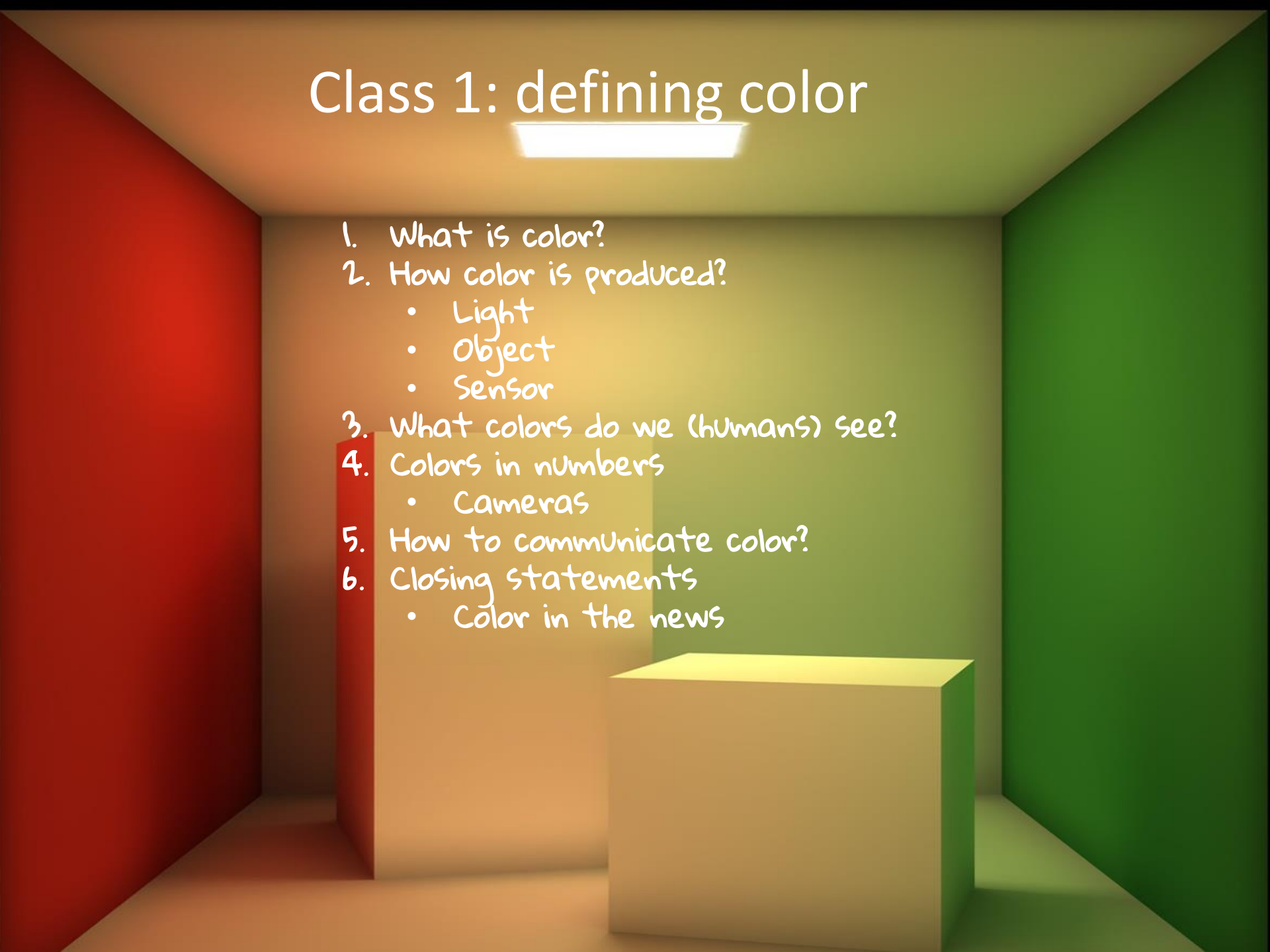
EPITA, 27th may 2019

mariavalezzka@gmail.com

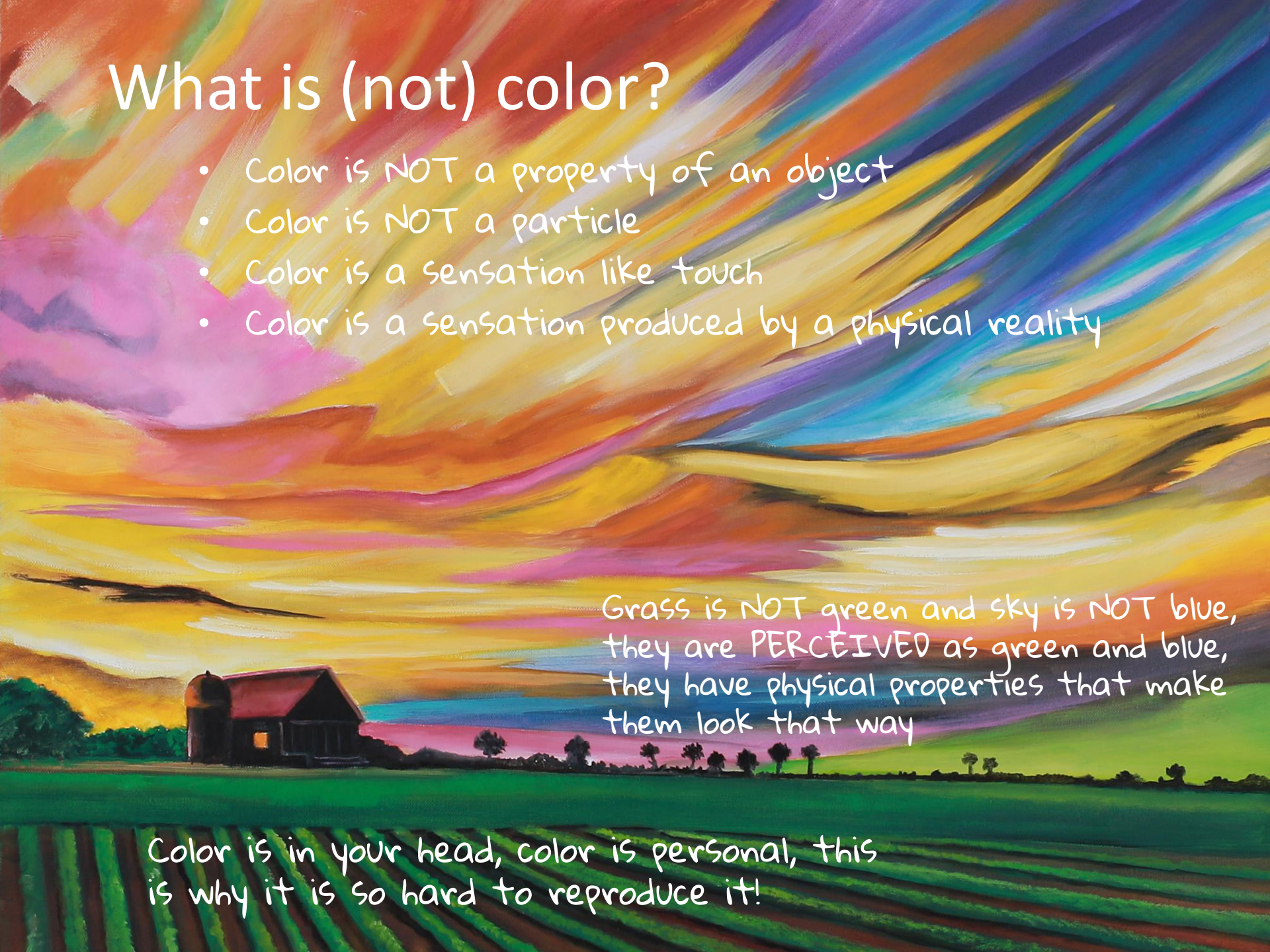
Class 1: defining color

1. What is color?
2. How color is produced?
   - Light
   - Object
   - Sensor
3. What colors do we (humans) see?
4. Colors in numbers
   - Cameras
5. How to communicate color?
6. Closing statements
   - Color in the news



What is (not) color?

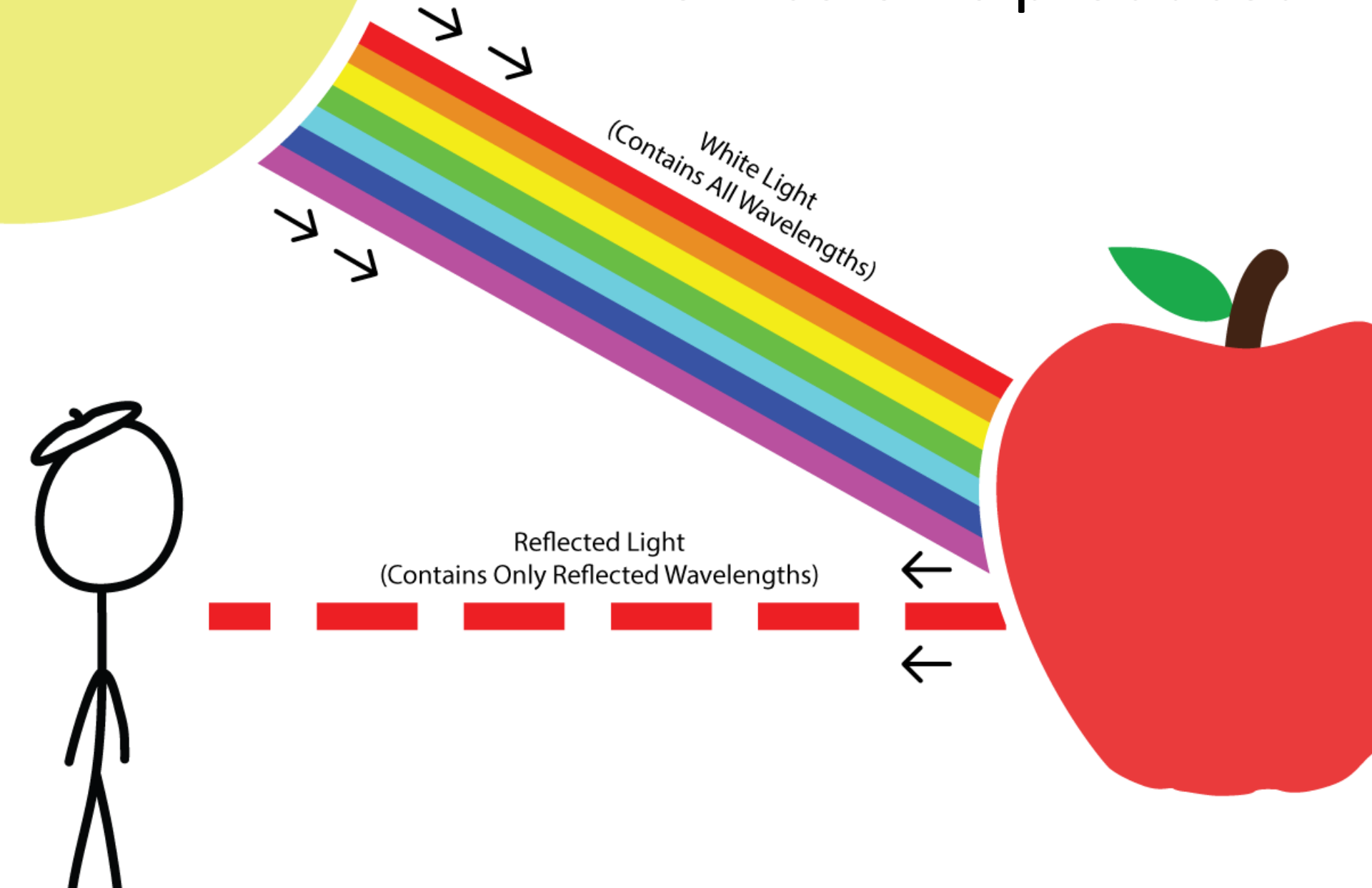
- Color is NOT a property of an object
- Color is NOT a particle
- Color is a sensation like touch
- Color is a sensation produced by a physical reality



Grass is NOT green and sky is NOT blue, they are PERCEIVED as green and blue, they have physical properties that make them look that way

Color is in your head, color is personal, this is why it is so hard to reproduce it!

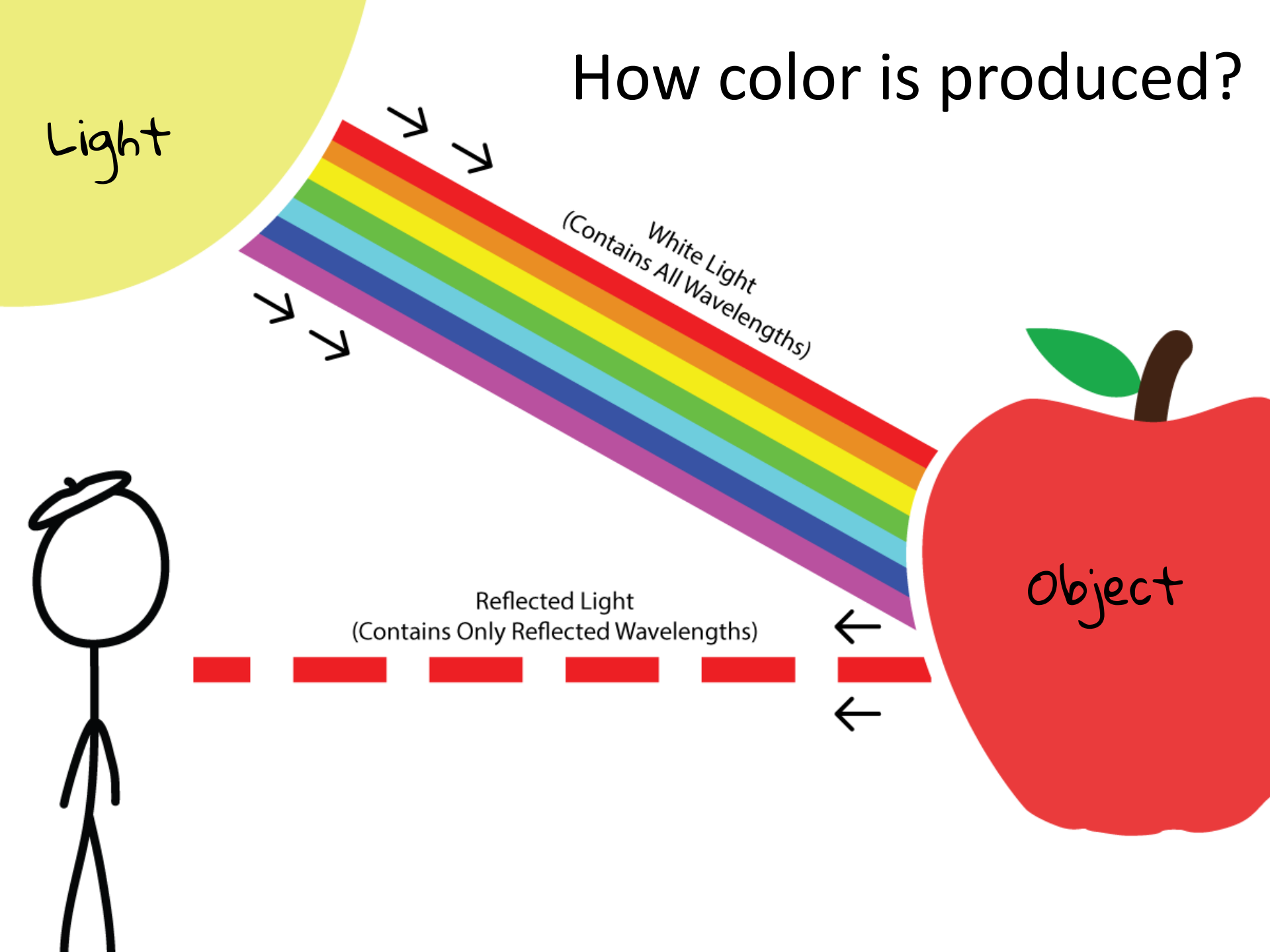
How color is produced?



How color is produced?

Light

How color is produced?



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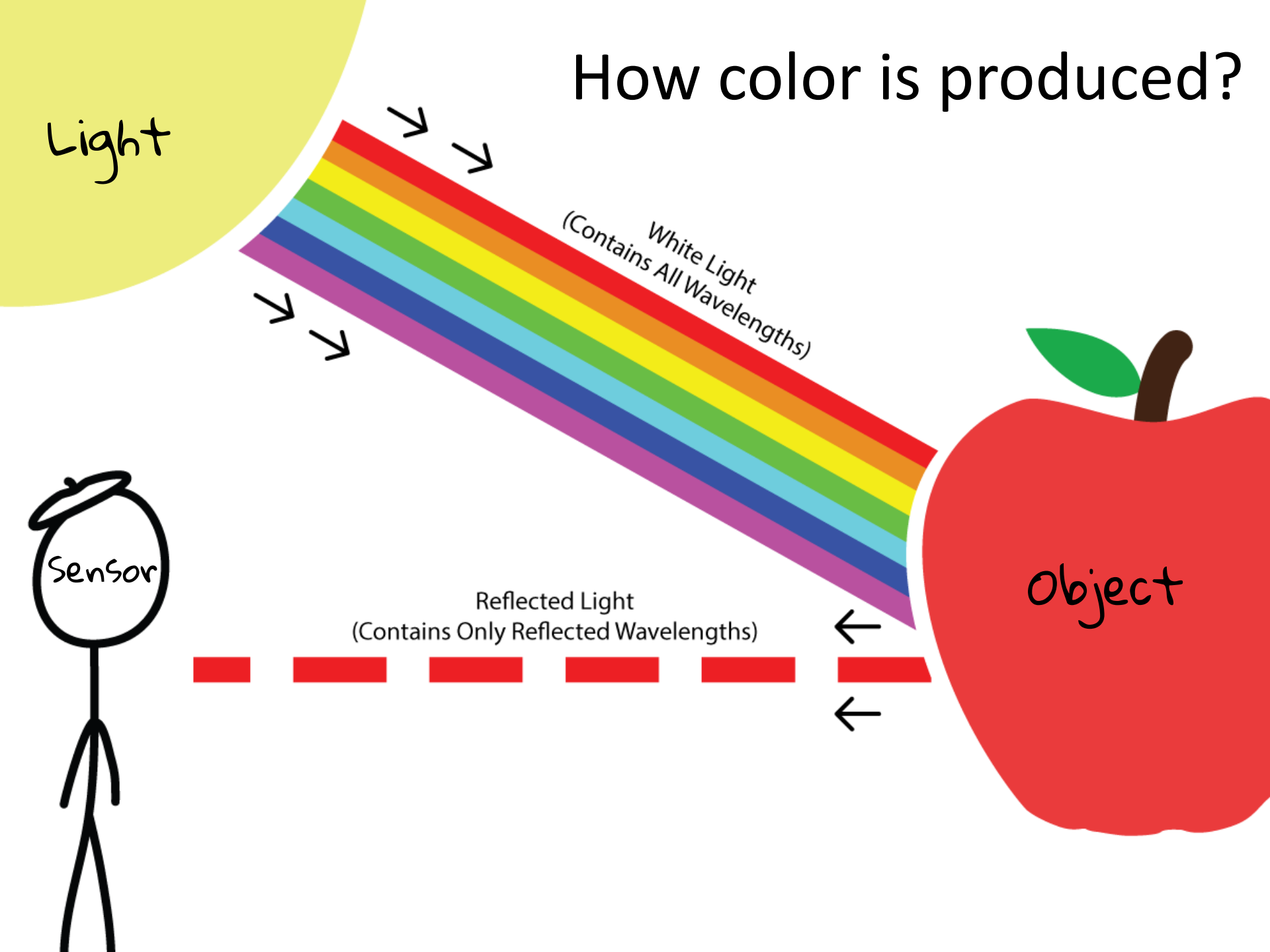
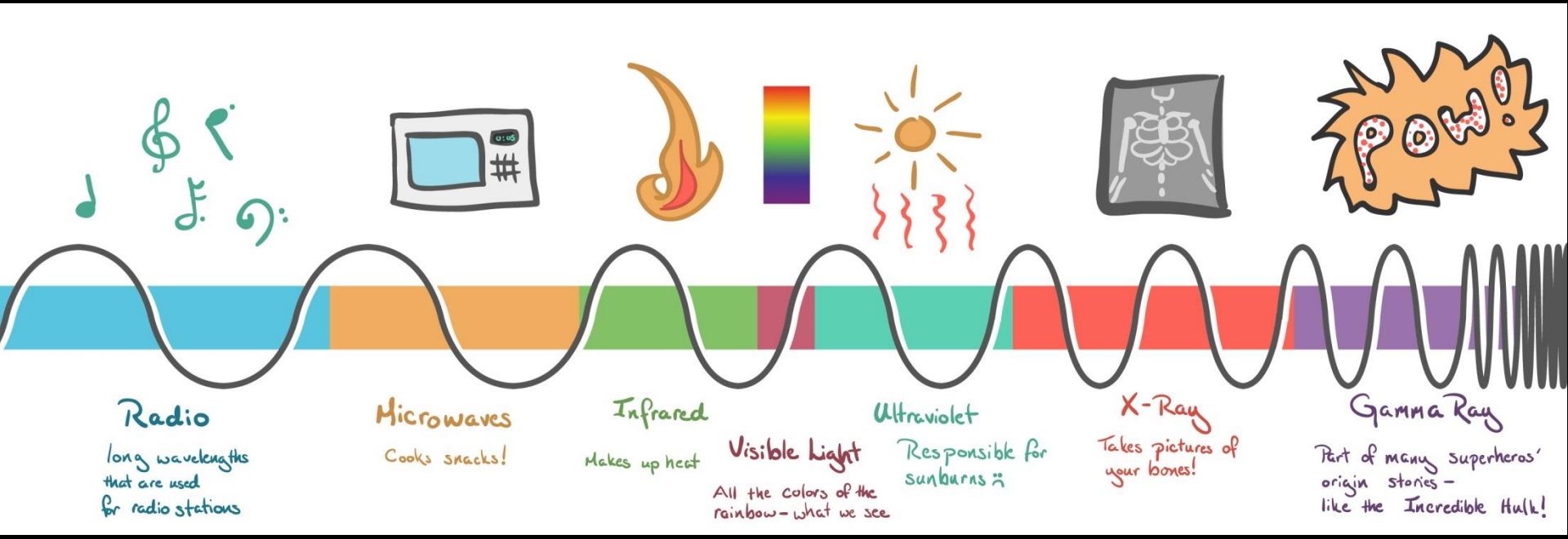
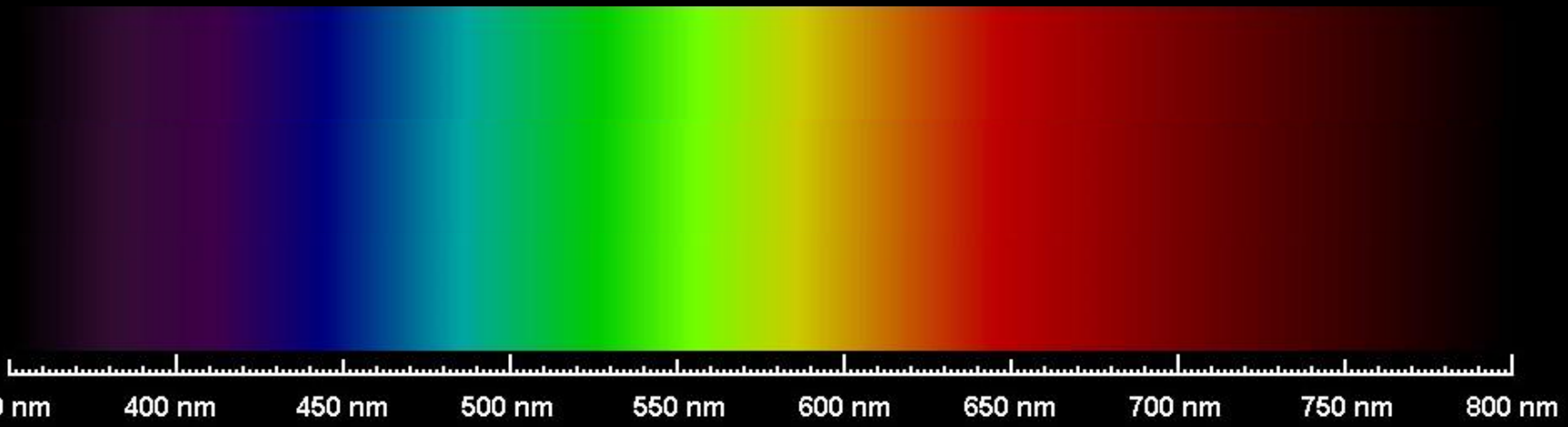


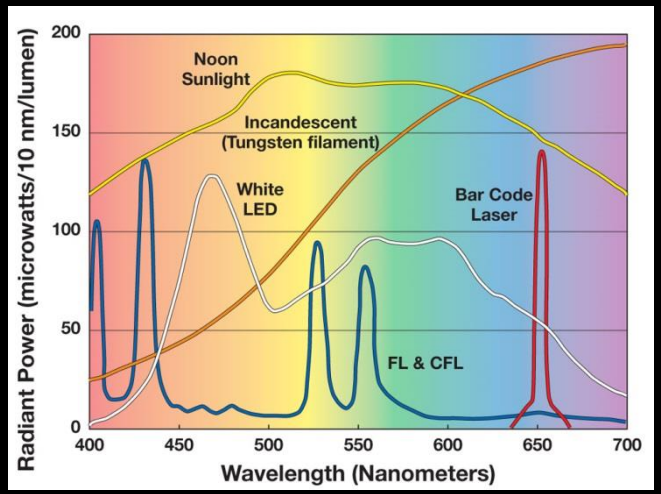
1. Light

Electromagnetic spectrum



Visible light





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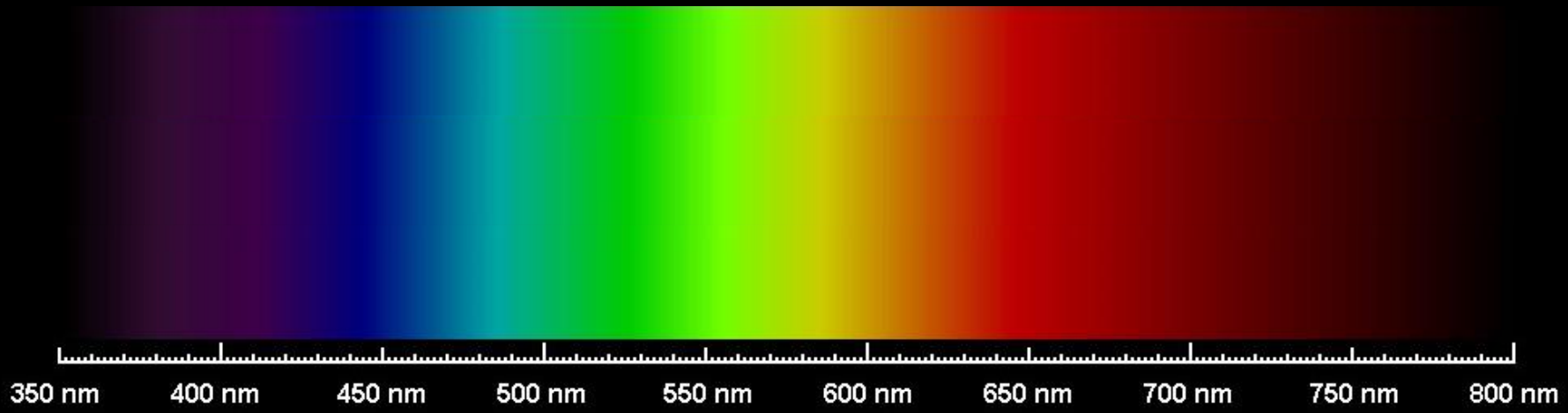

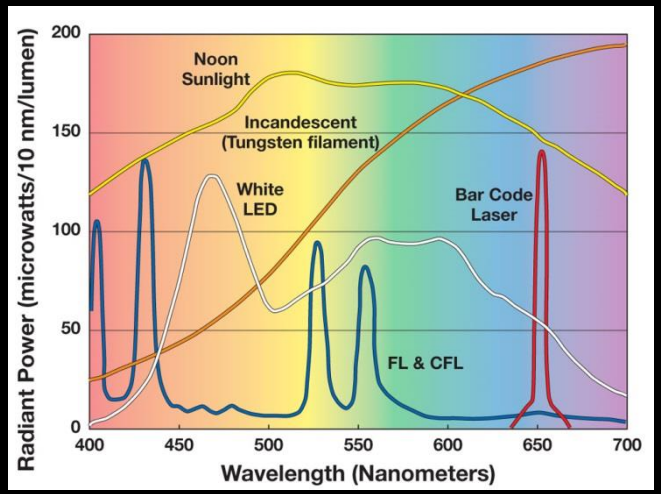

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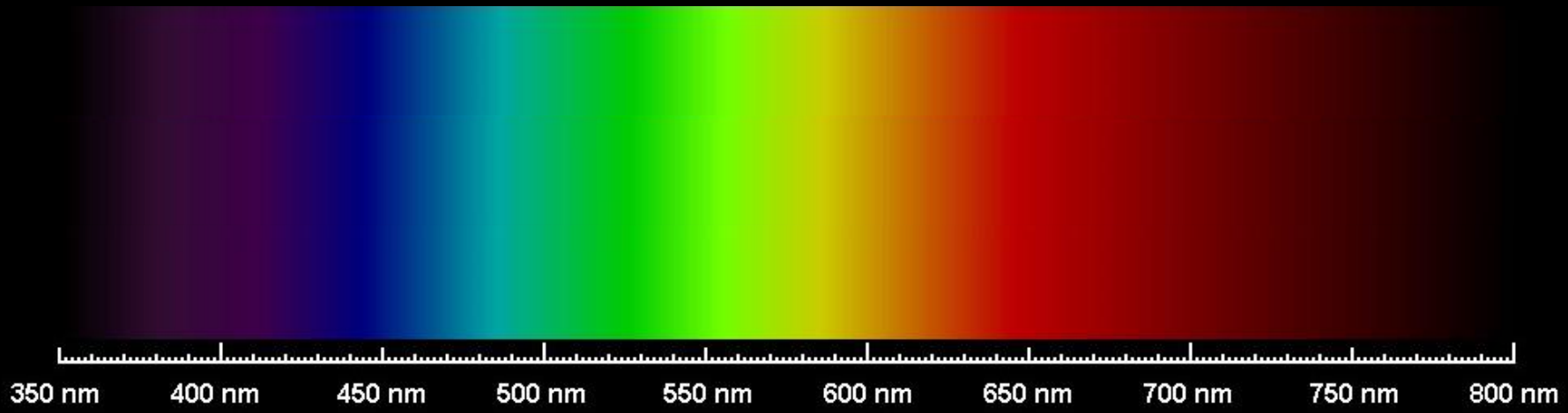

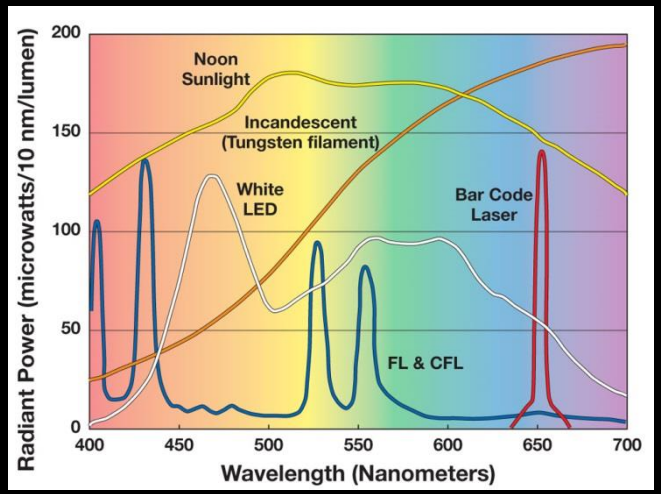

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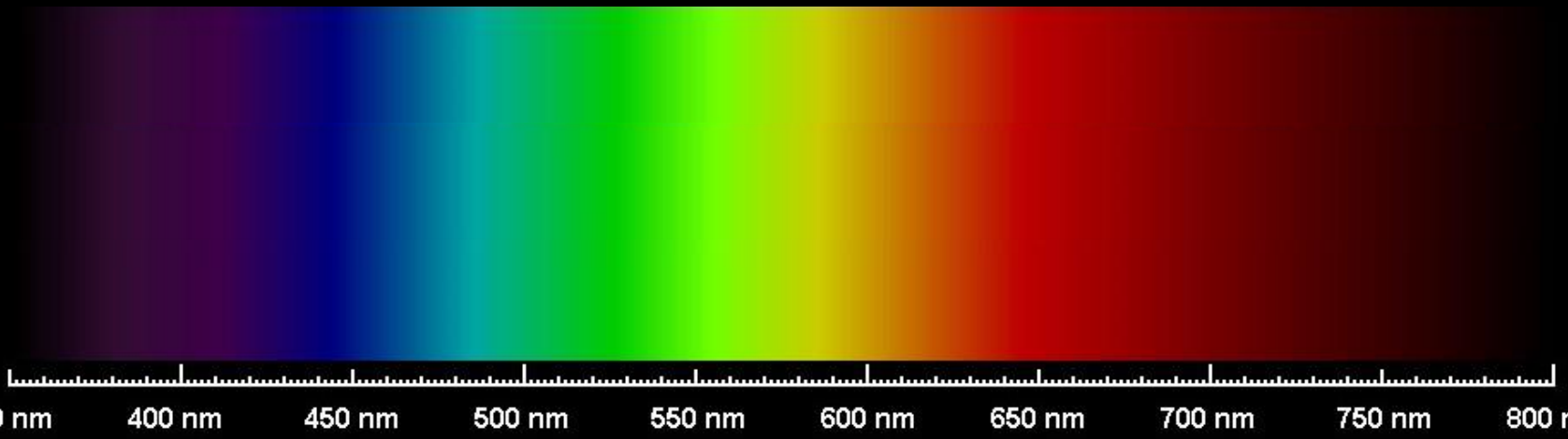

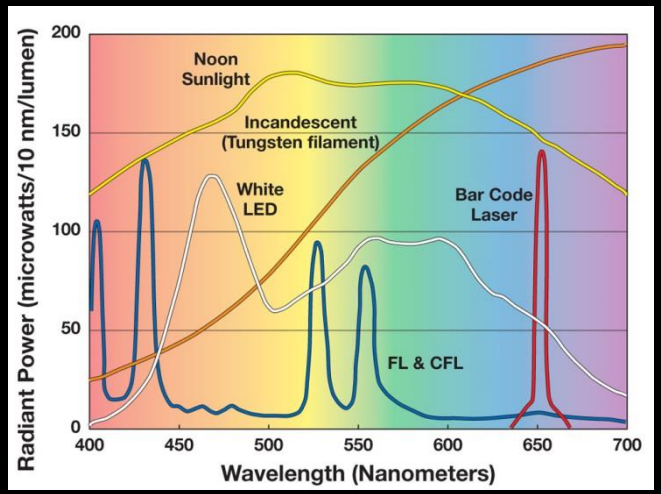

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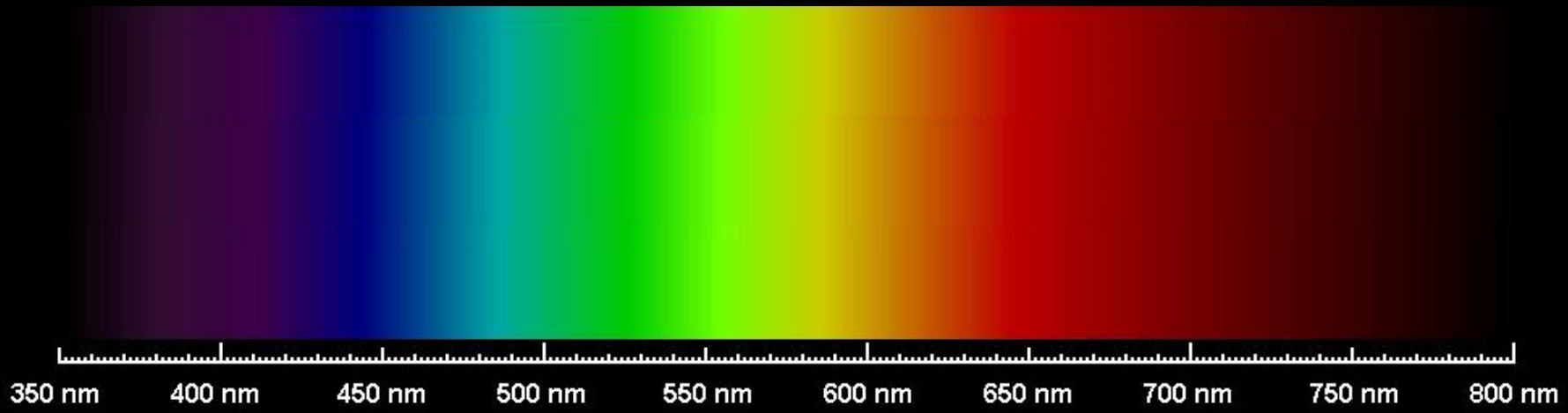

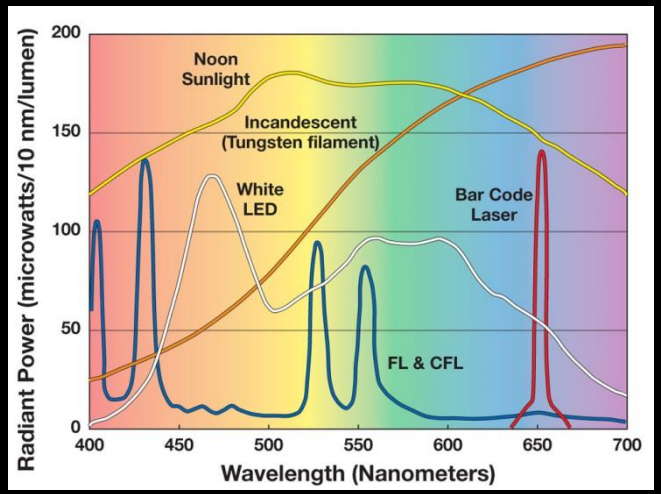

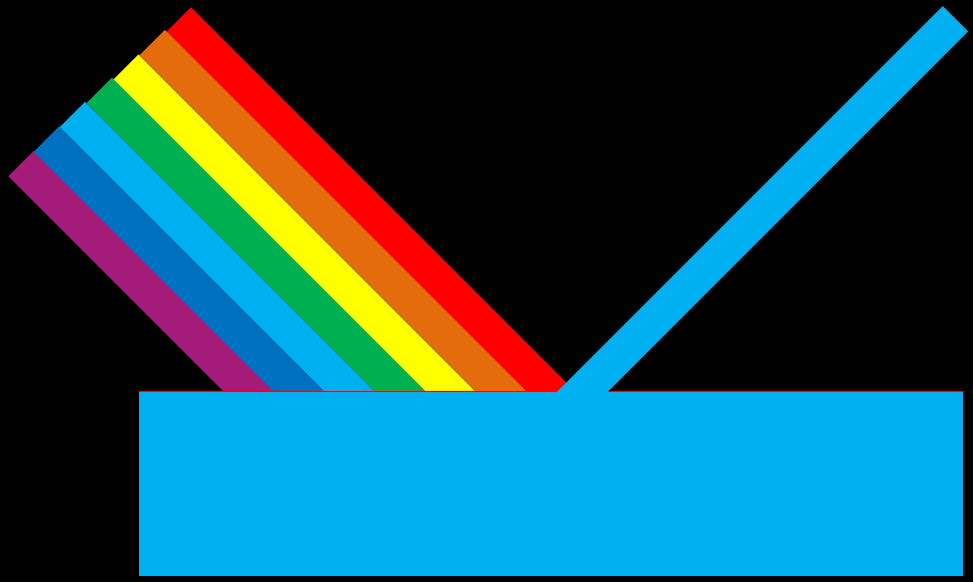

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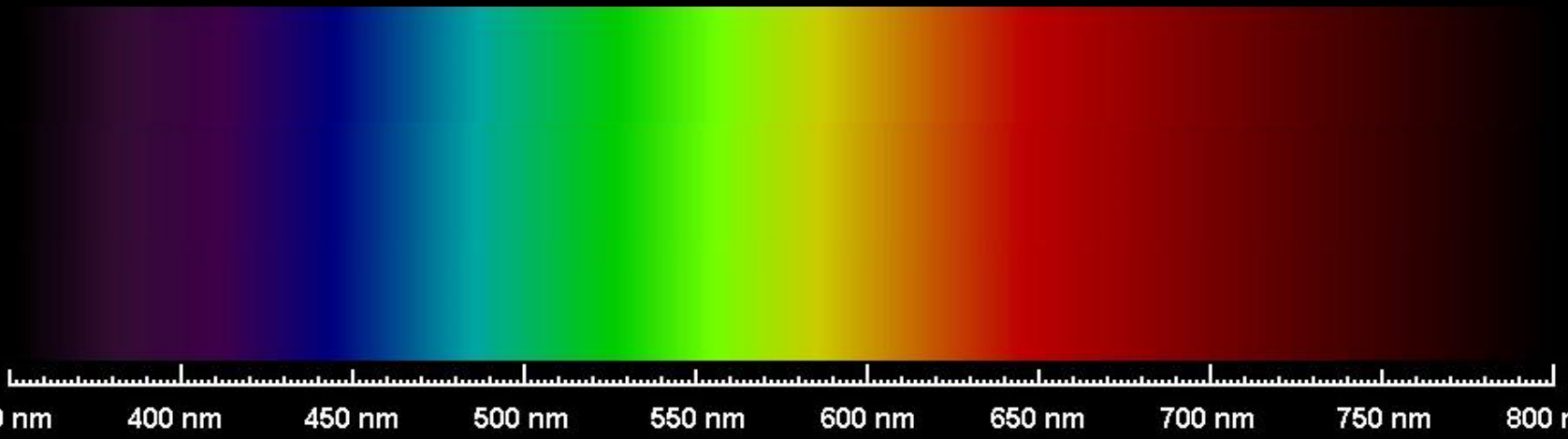

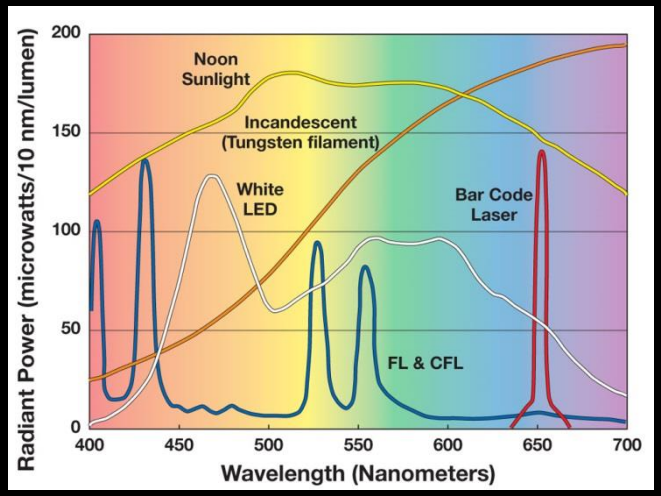

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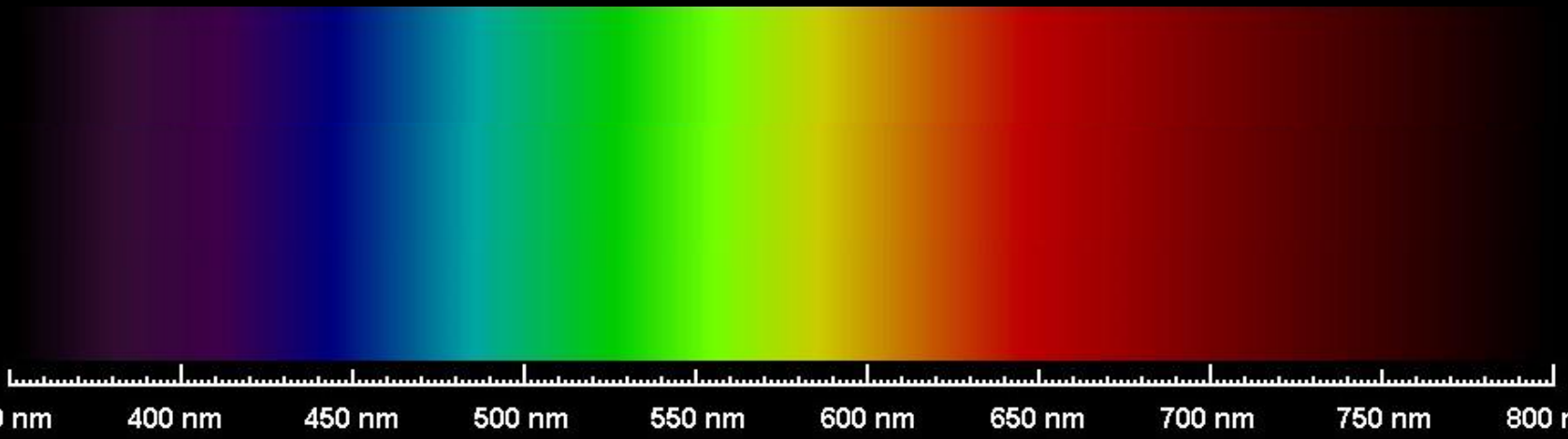

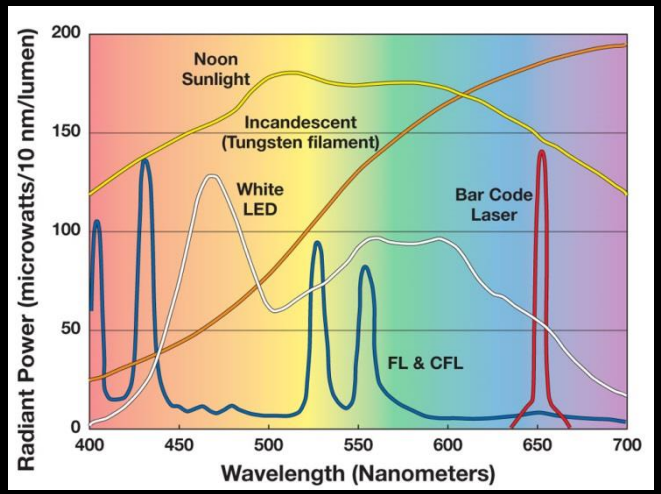

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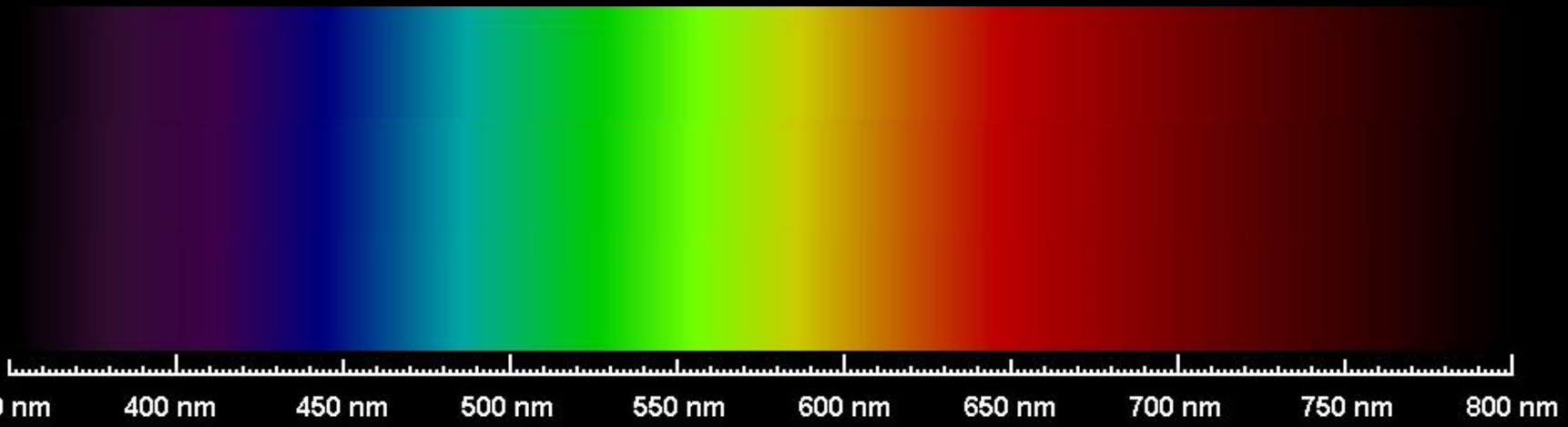

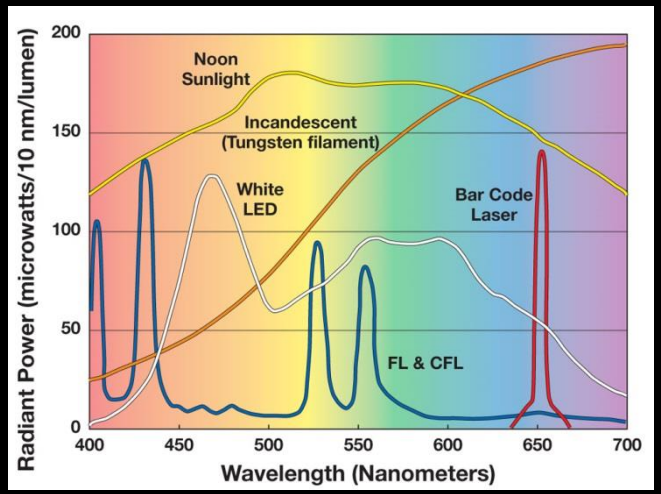

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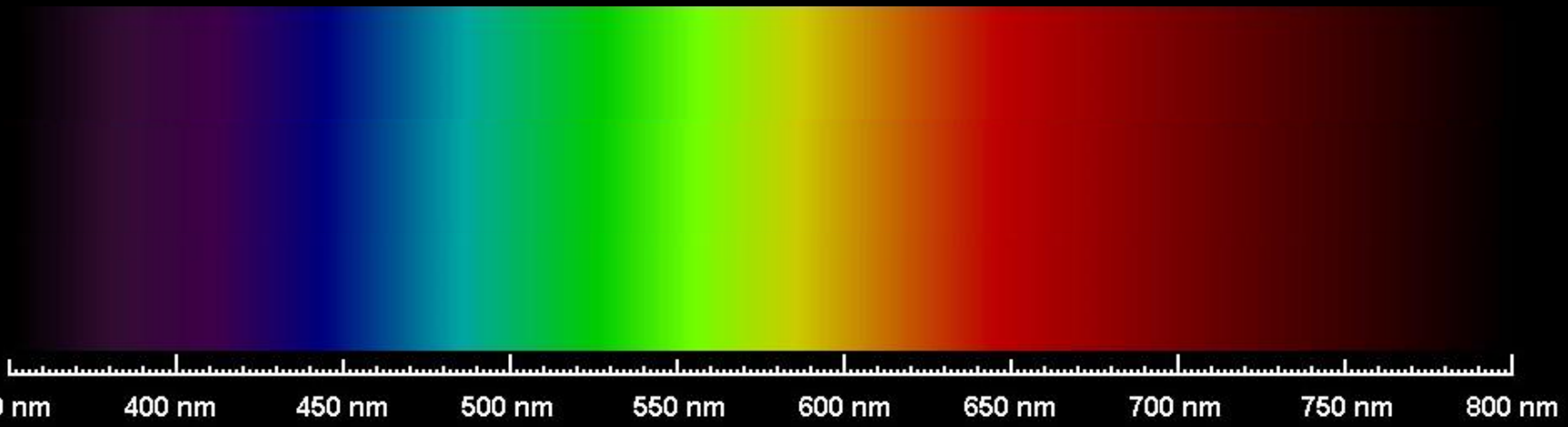

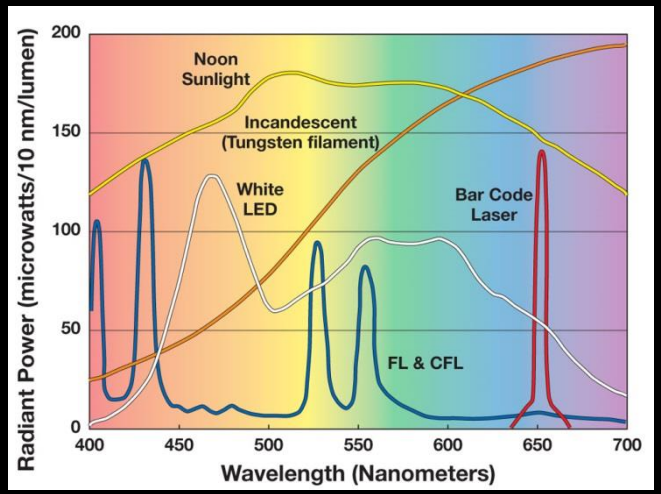

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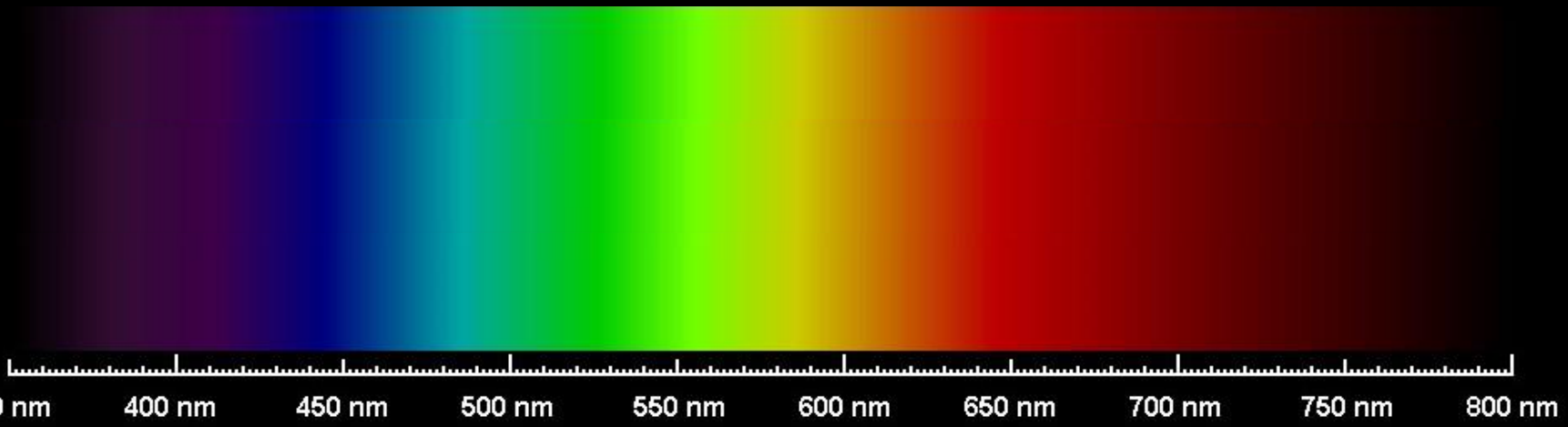

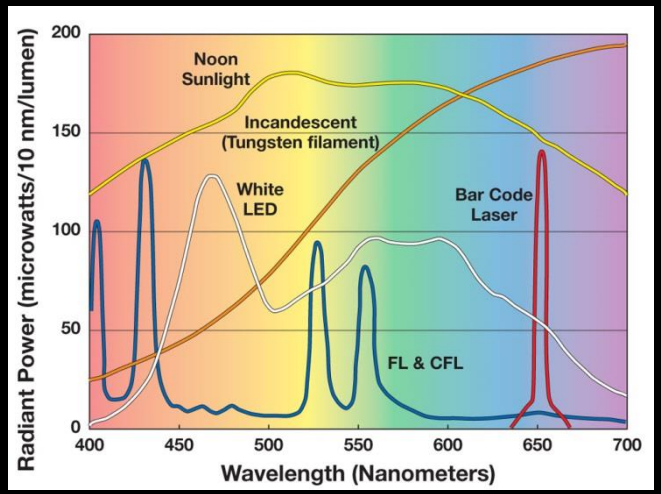

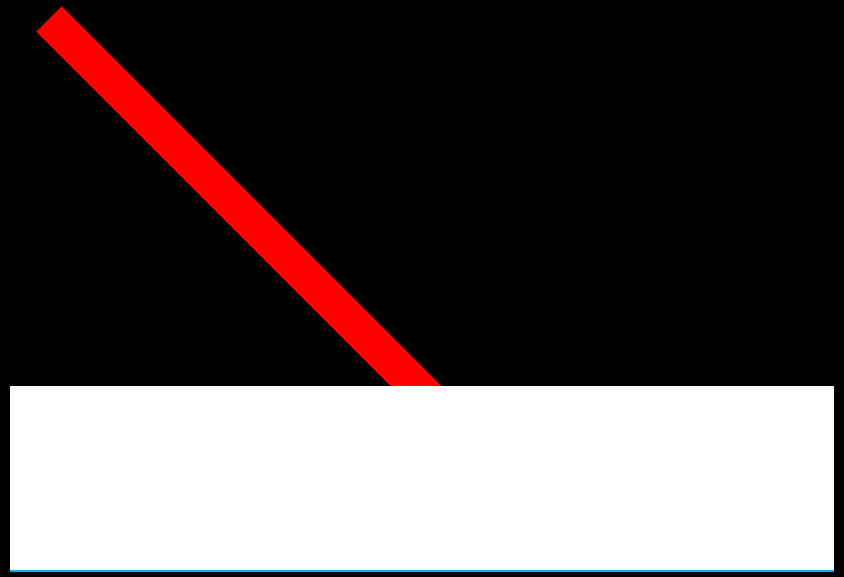

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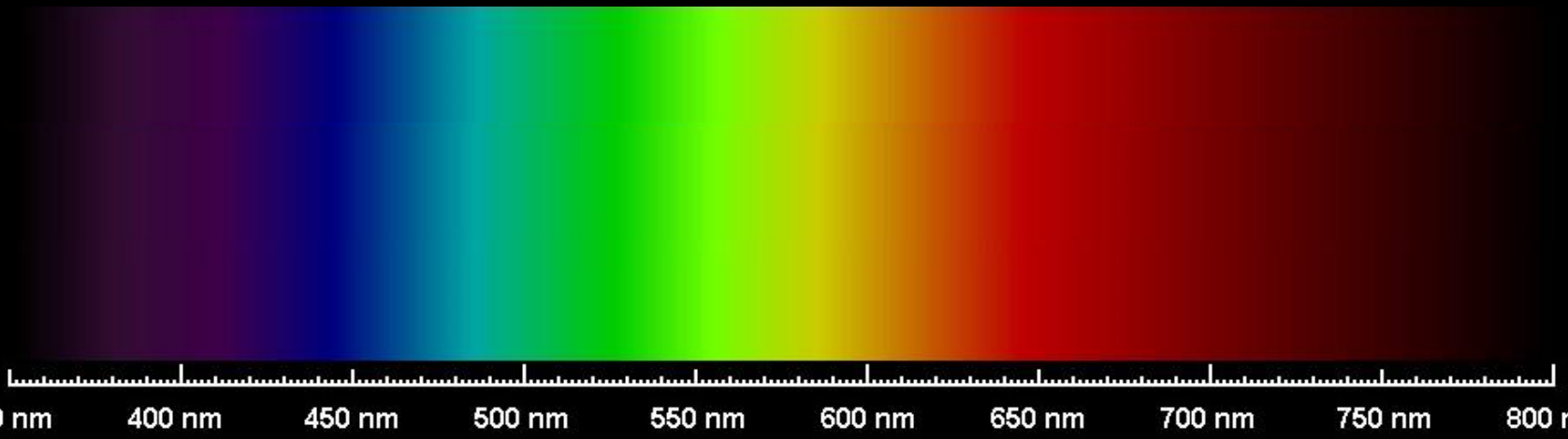
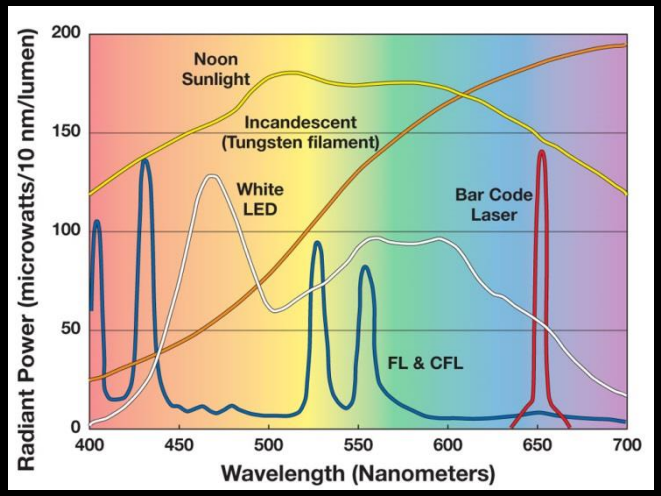
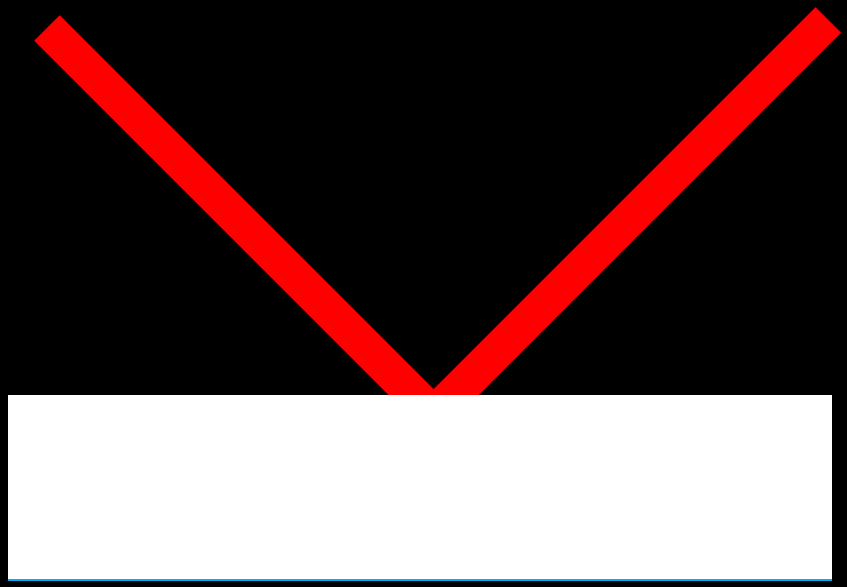
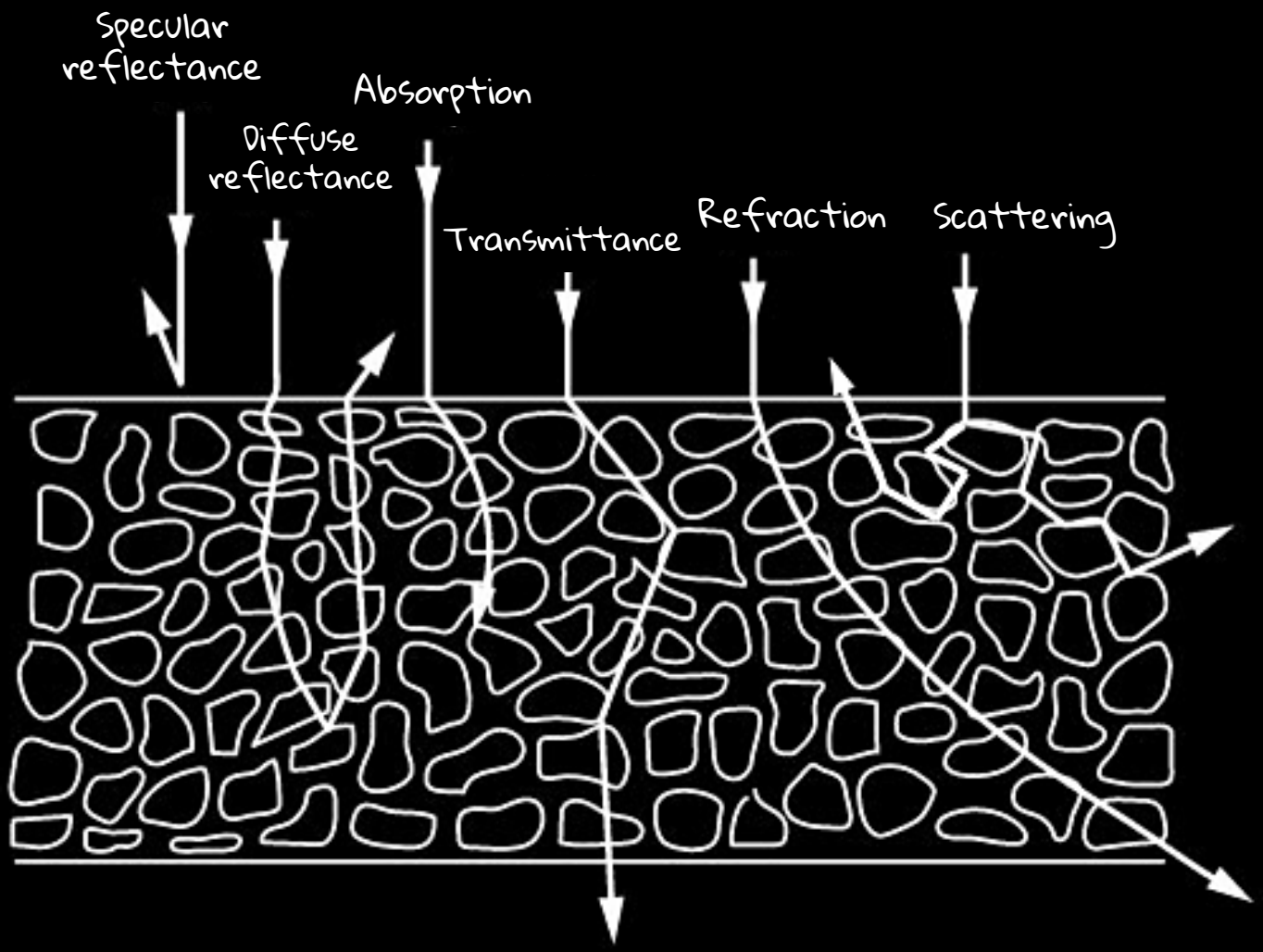






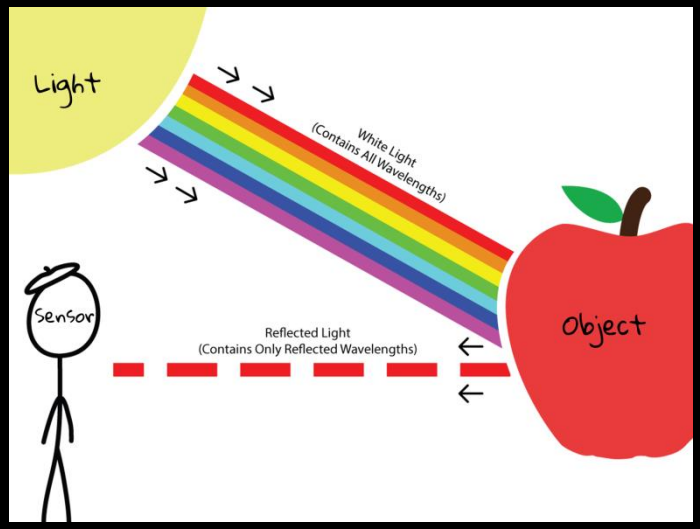
2. Object

Surface and subsurface Interactions with light



2. Object
Color is not 'part' of an object

- Dimension, shape, made of (material), volume, density, porosity
- Color happens because certain objects absorb a certain portion of the visual spectrum of light and reflects others



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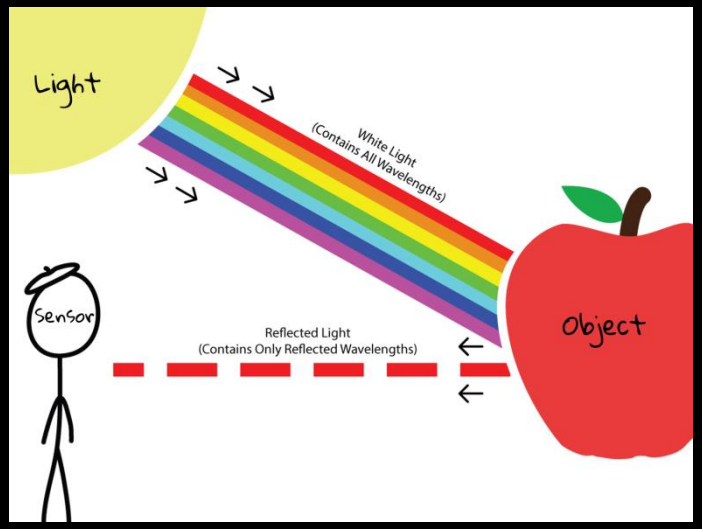
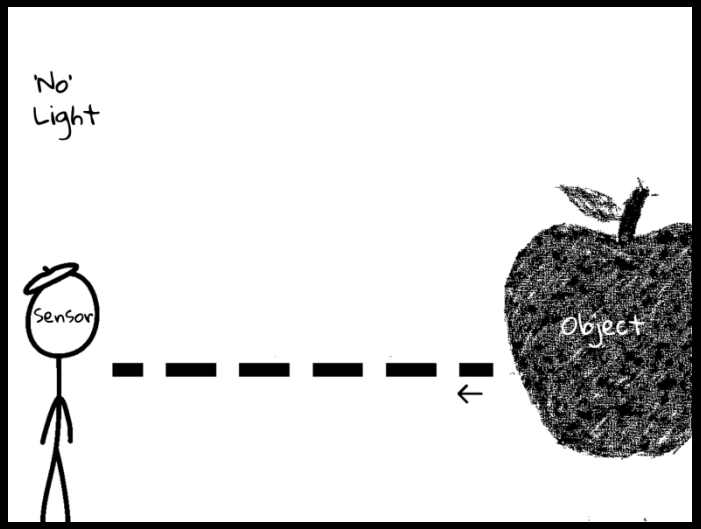
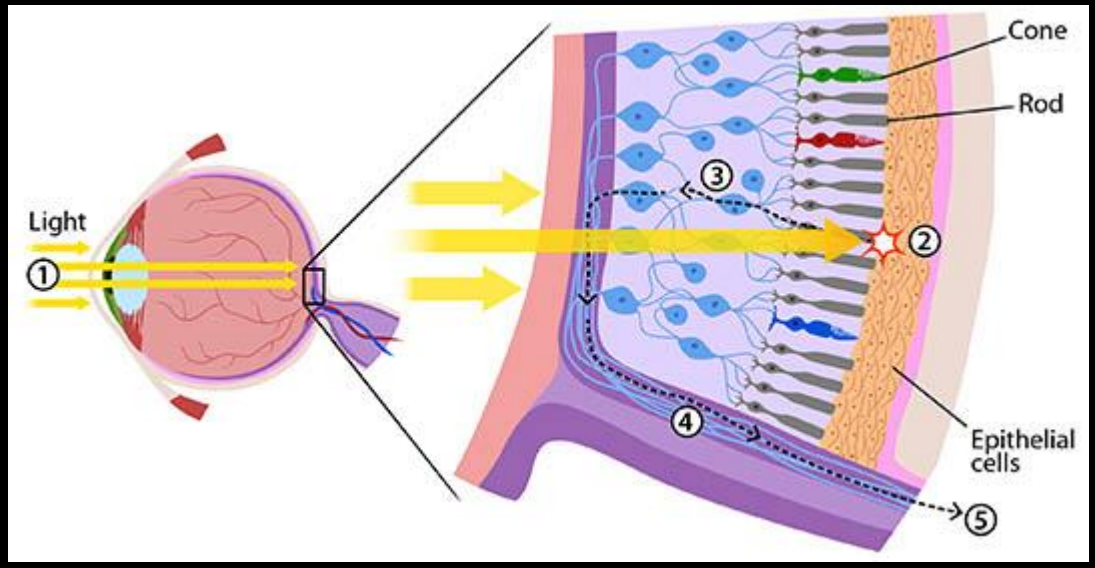
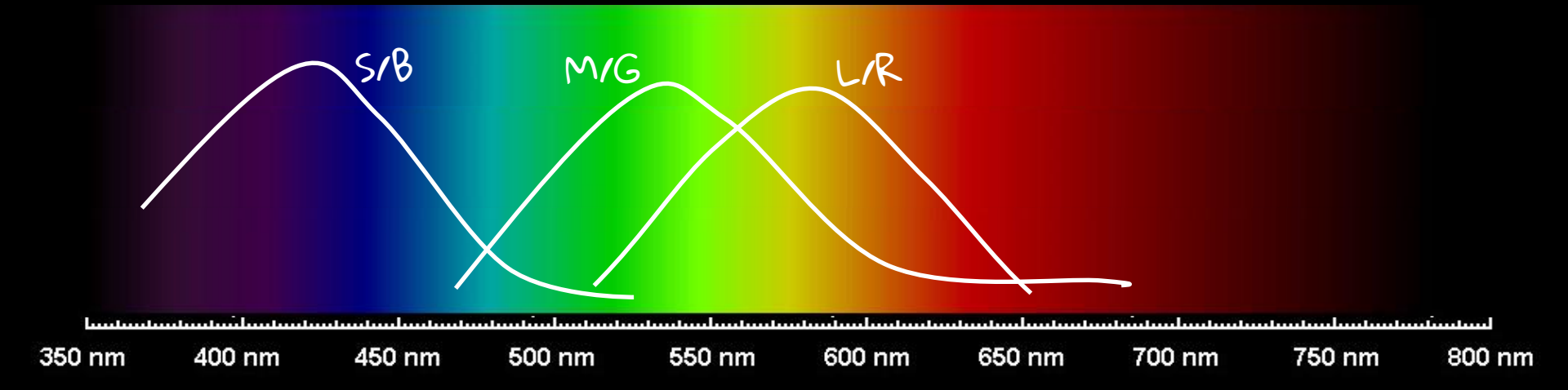




3. Sensor

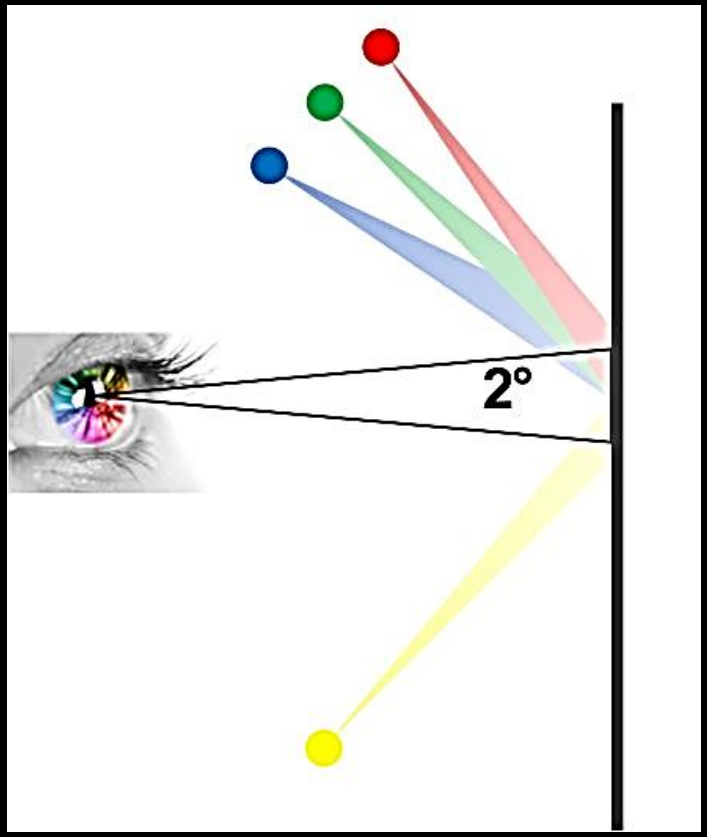
Human spectral sensitivity functions

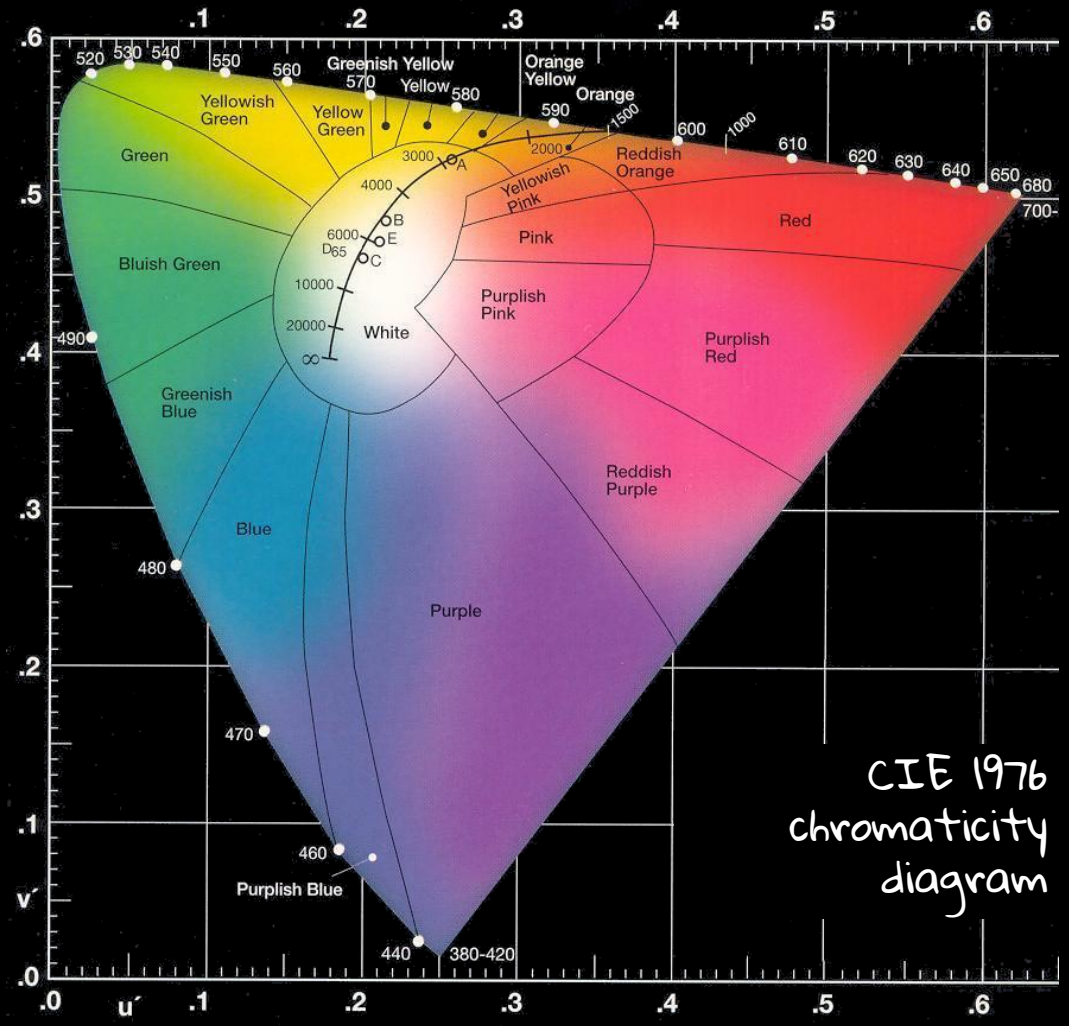




What colors do we see?

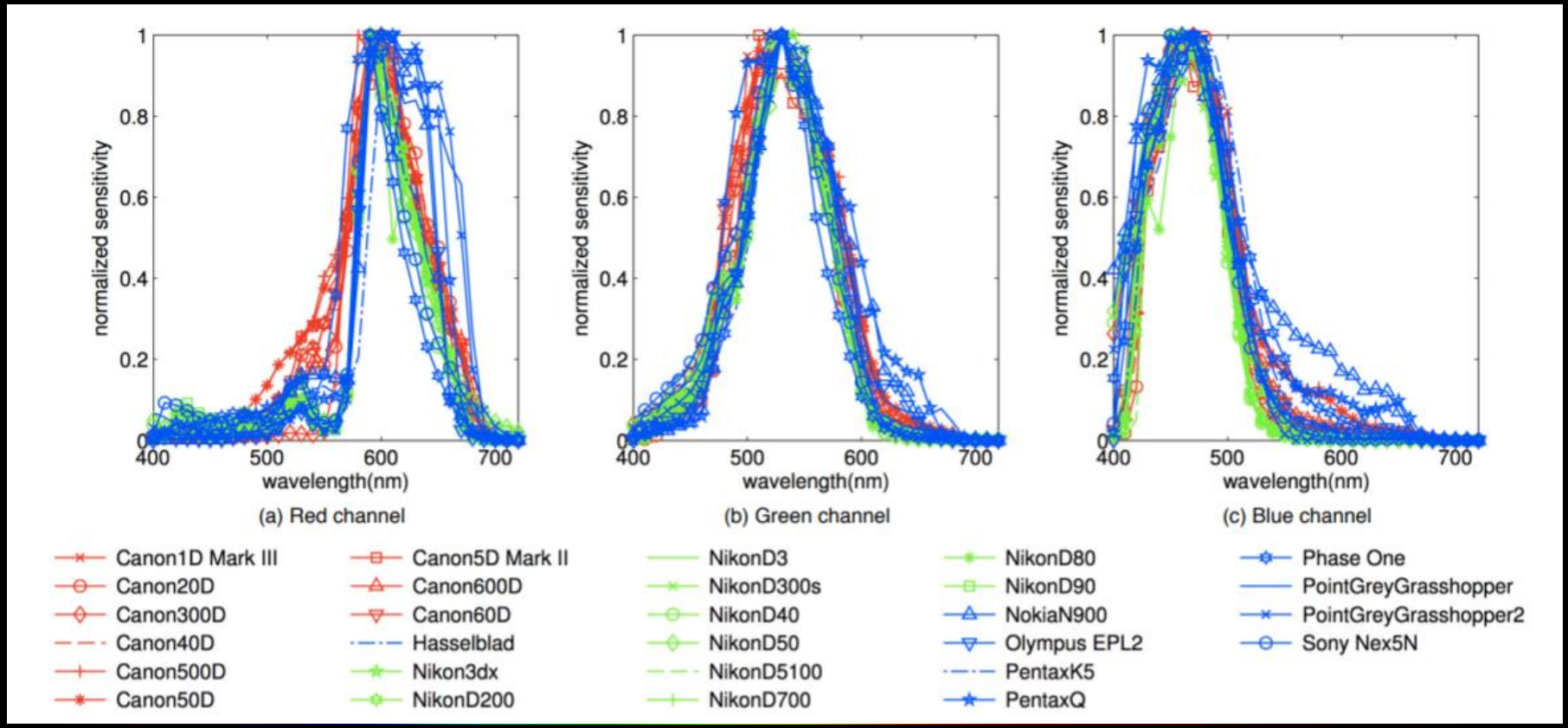
Color matching experiments

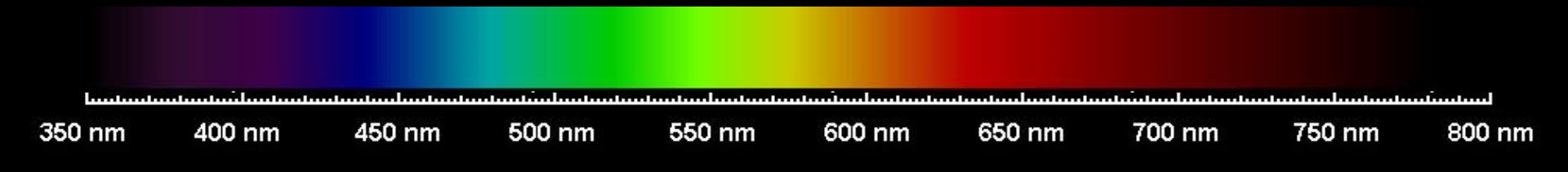




3. Sensor

Camera spectral sensitivity functions

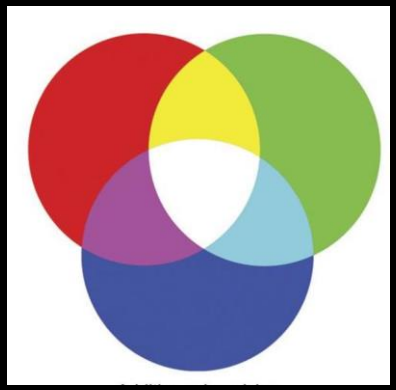




How to (re)produce color?

How to (re)produce color?

Additive process
(Primaries R,G,B)



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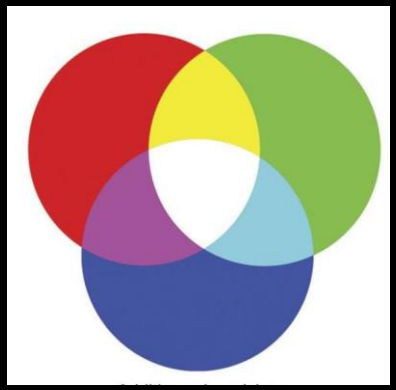
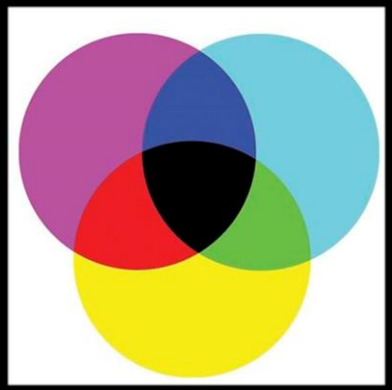
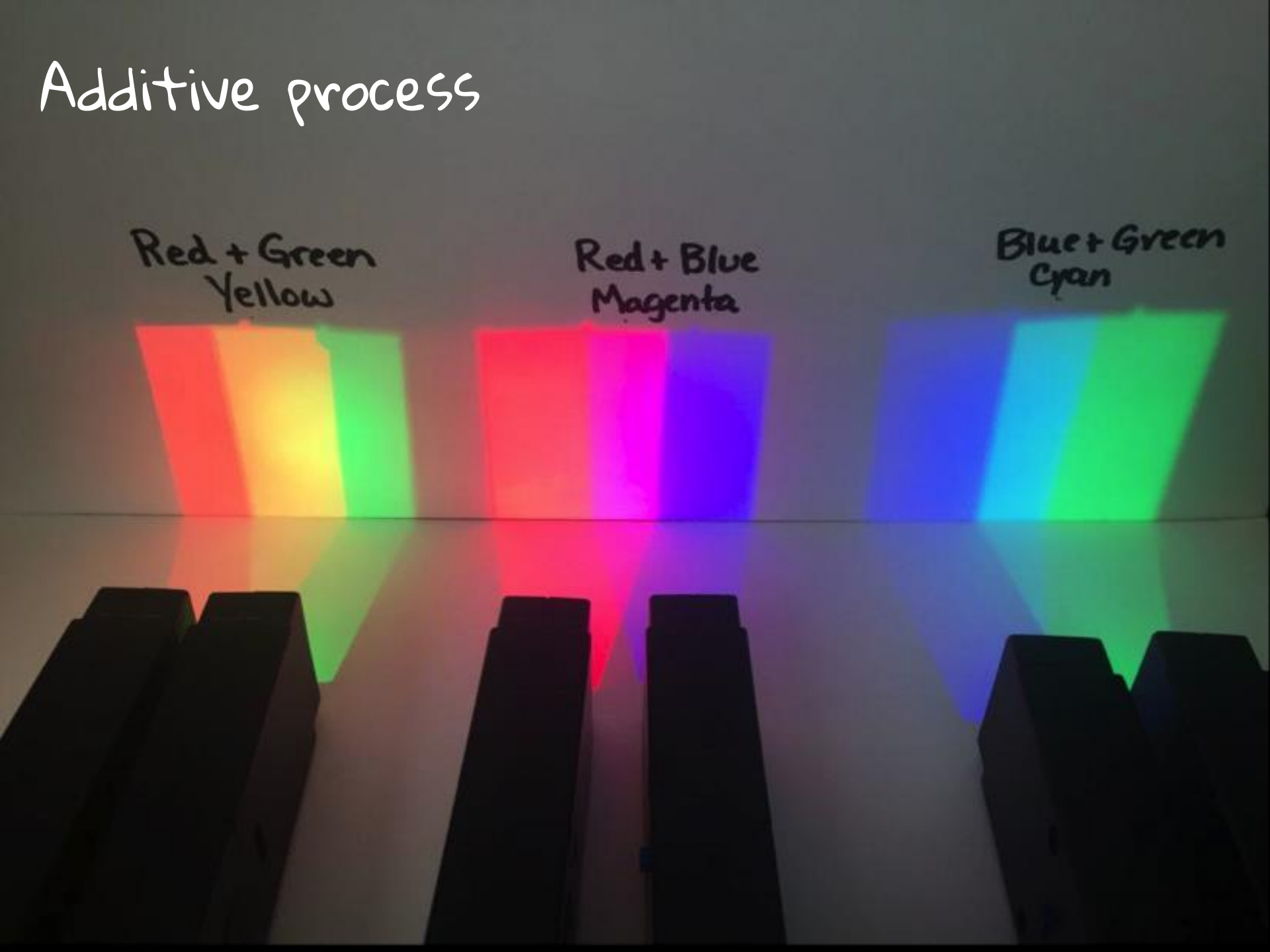


Subtractive process
(Primaries CMY)

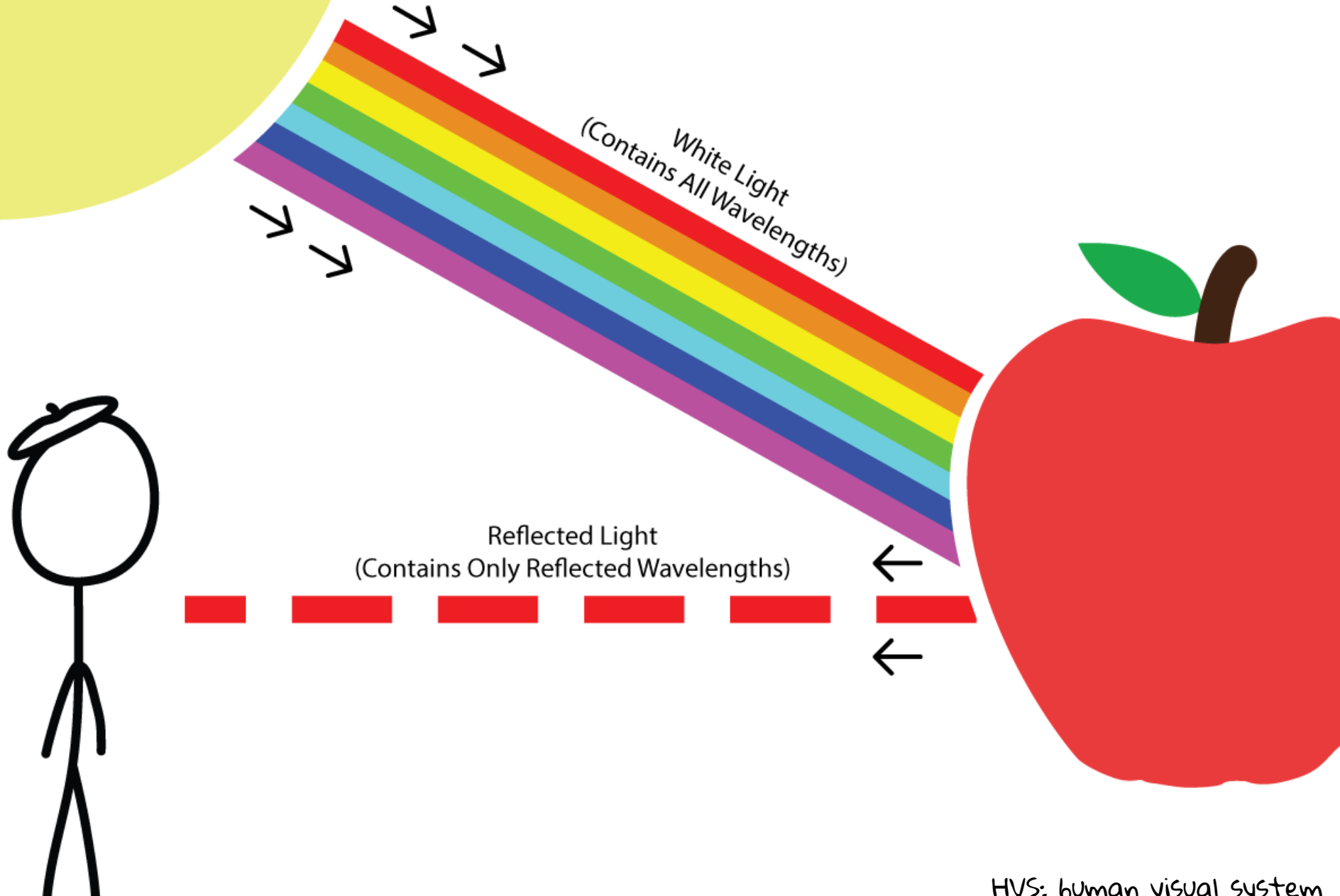


Additive process




Subtractive
Process

Let's put them all together!

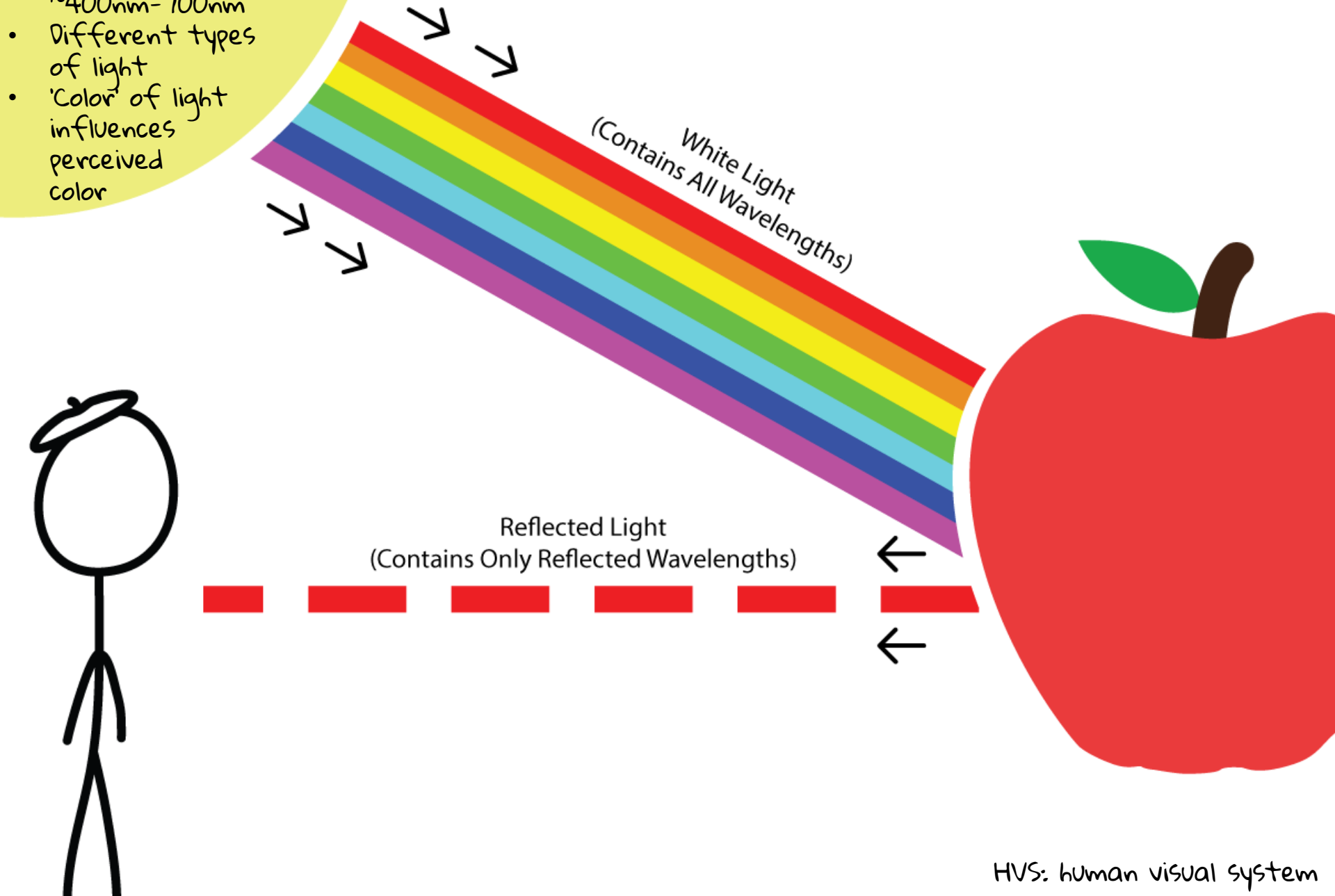


HVS: human visual system

1. Light

- Visible spectrum ~400nm-700nm
- Different types of light
- 'Color' of light influences perceived color

Let's put them all together!



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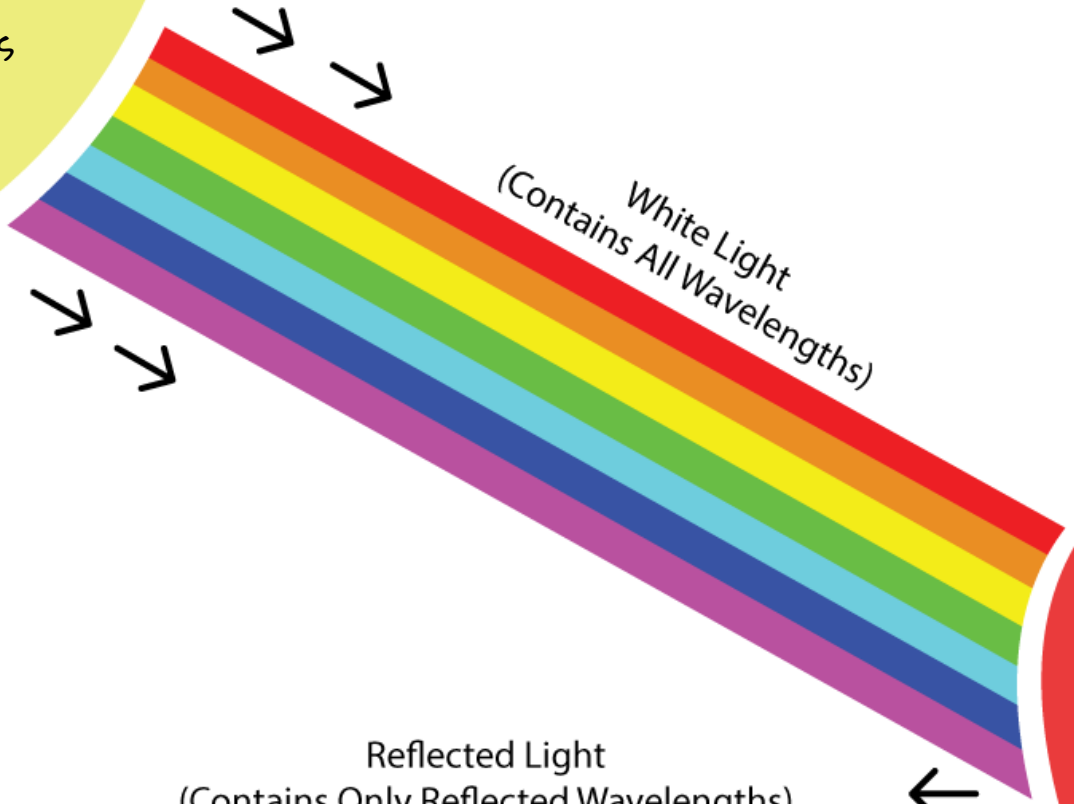

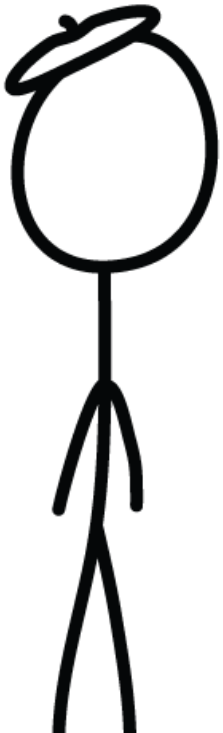

Reflected Light
(Contains Only Reflected Wavelengths)

2. Object

- Light interacts with the particles of the object (it bounces inside, goes through, bounces back...)
- Color is NOT a property of the object

HVS: human visual system

Let's put them all together!

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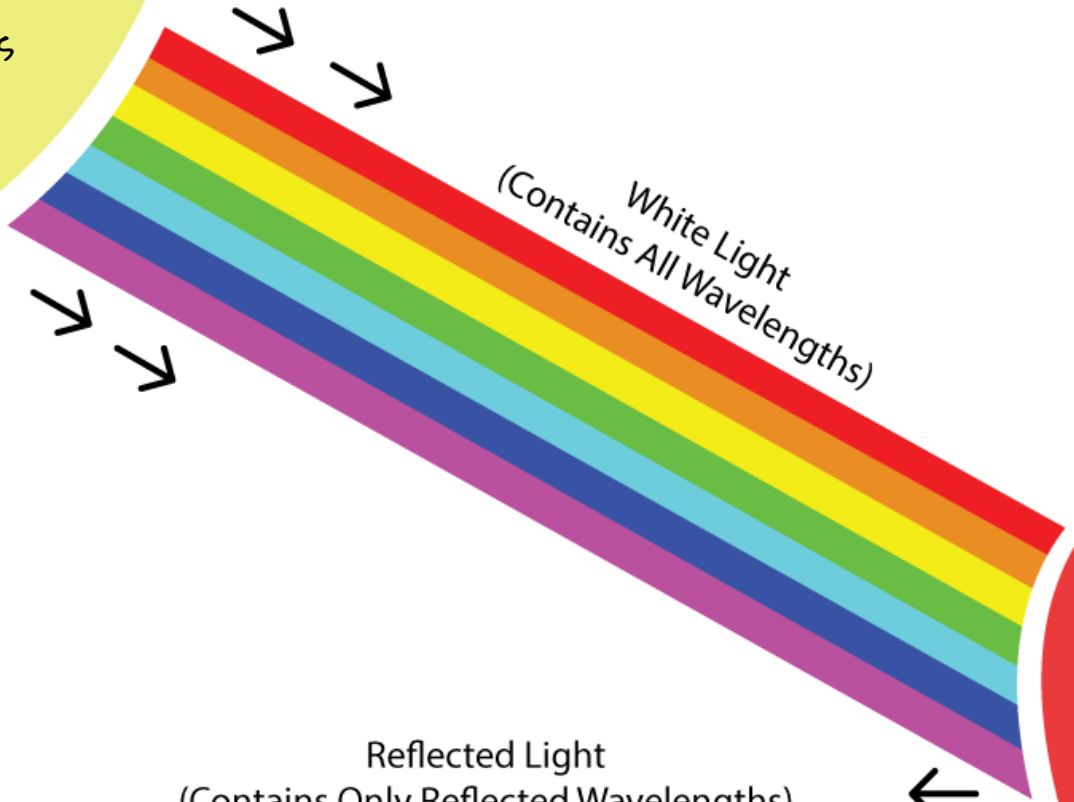

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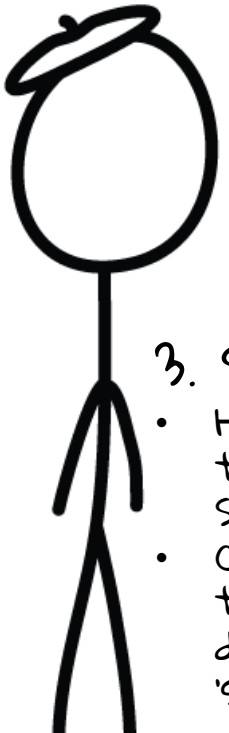

3. Sensor

- HVS is composed of three sensors (cones) SML
- CIE has characterized the HVS (chromatic diagram) to obtain a 'standard observer'

HVS: human visual system

Let's put them all together!

1. Light

- Visible spectrum ~400nm-700nm
- Different types of light
- 'Color' of light influences perceived color

Color can be produced by:

- Additive process (light mixing)
- Subtractive process (paint mixing)

2. Object

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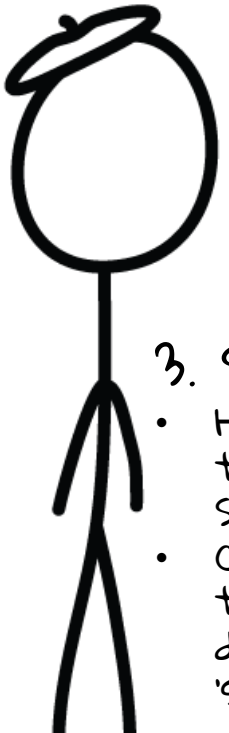
- Color is NOT a property of the object



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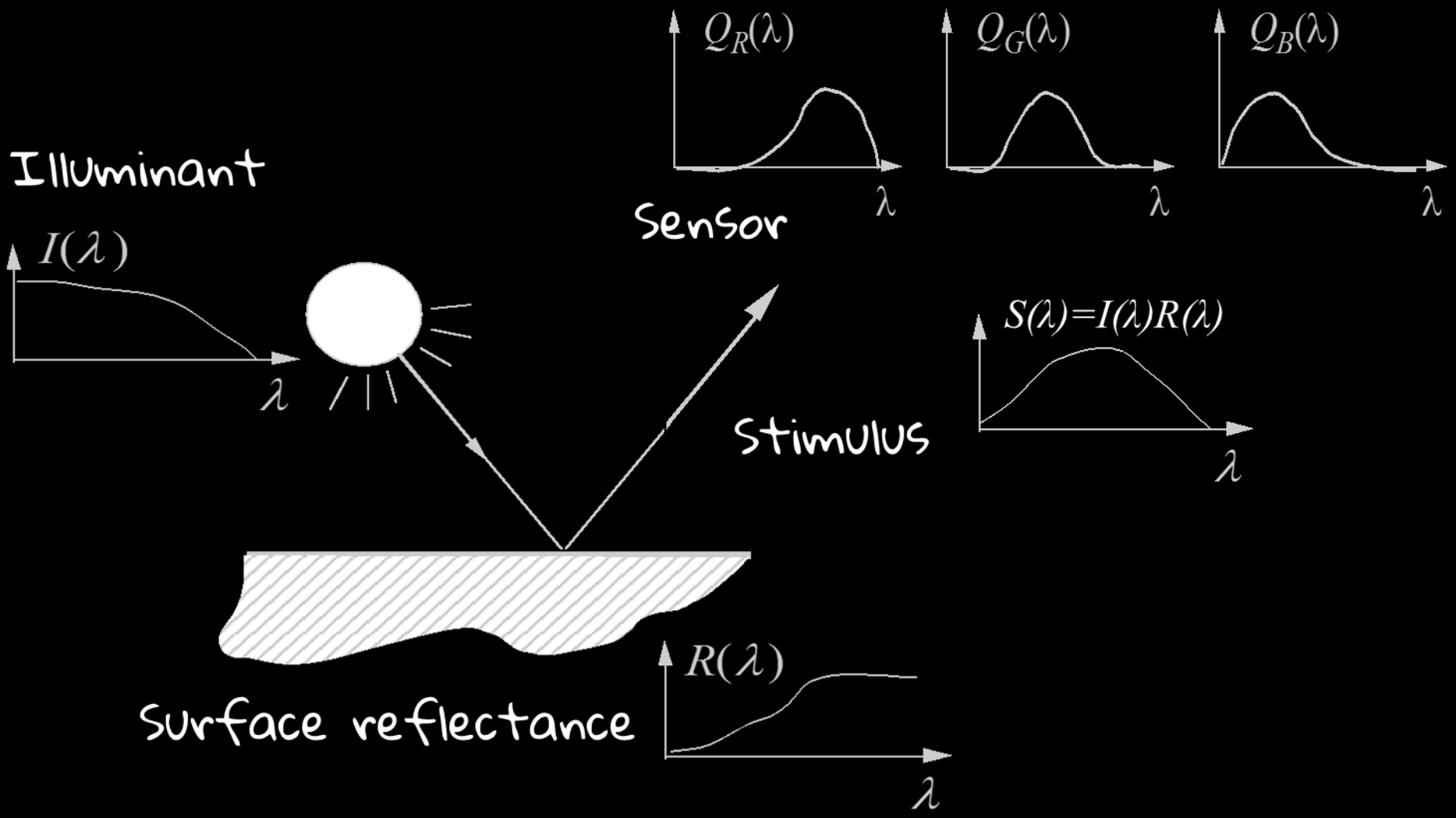
HVS: human visual system

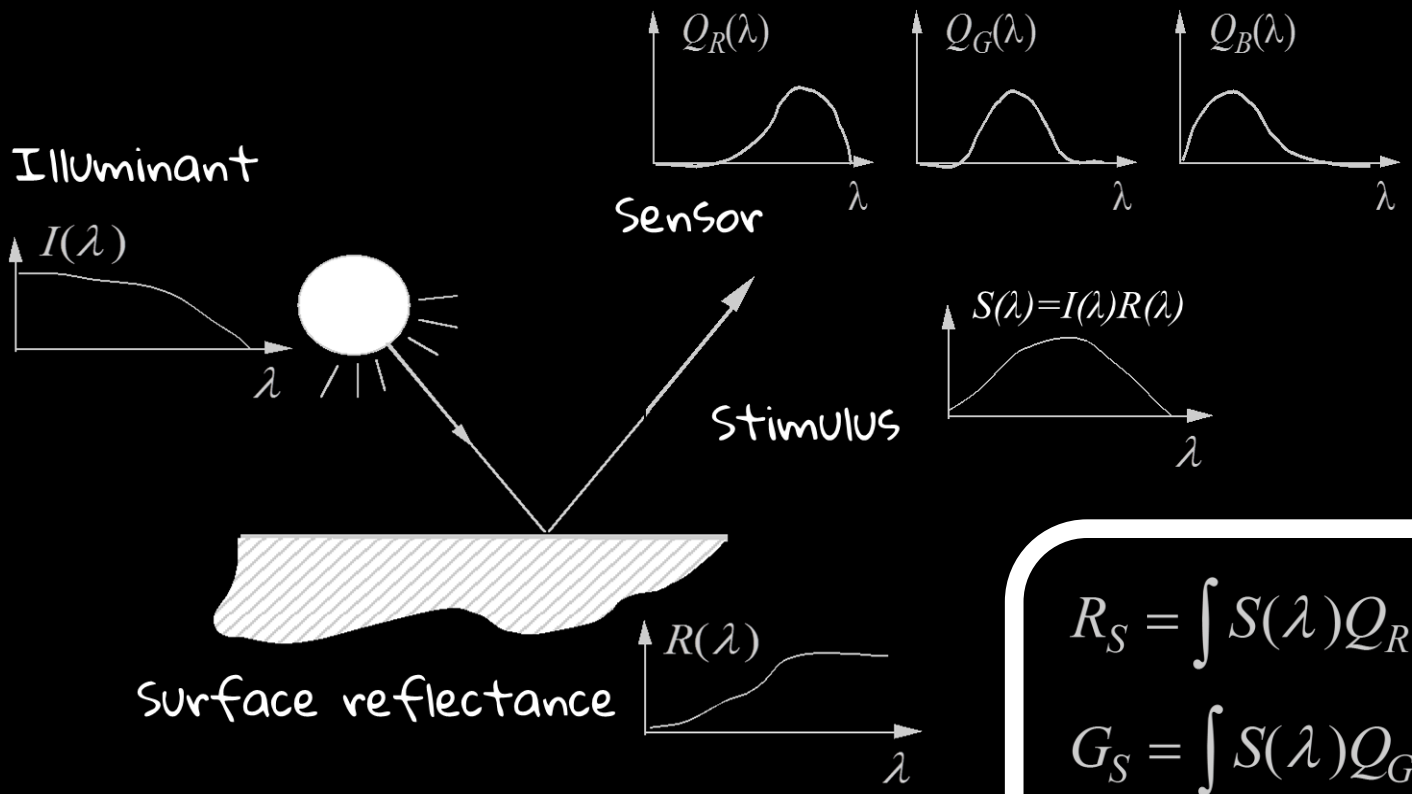
Colors in numbers

trichromatic theory



Colors in numbers

trichromatic theory



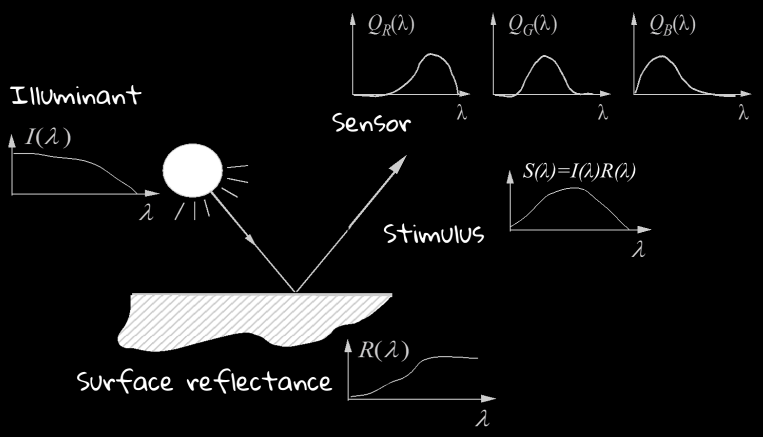
$$R_S = \int S(\lambda) Q_R(\lambda) d\lambda$$

$$G_S = \int S(\lambda) Q_G(\lambda) d\lambda$$

$$B_S = \int S(\lambda) Q_B(\lambda) d\lambda$$

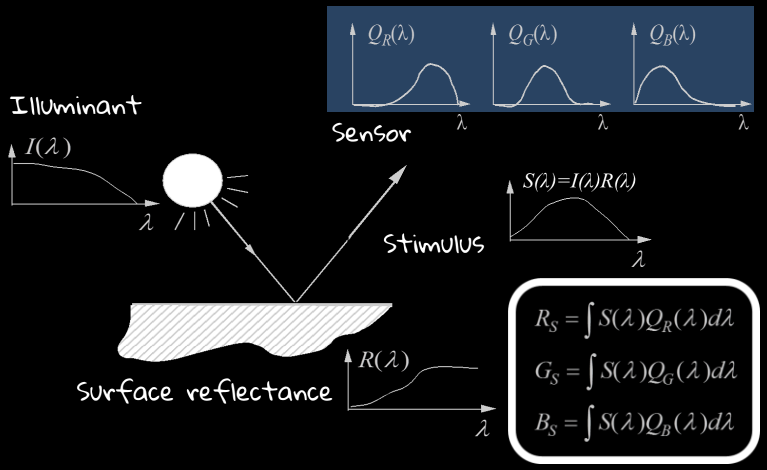
And what does that mean in practice?

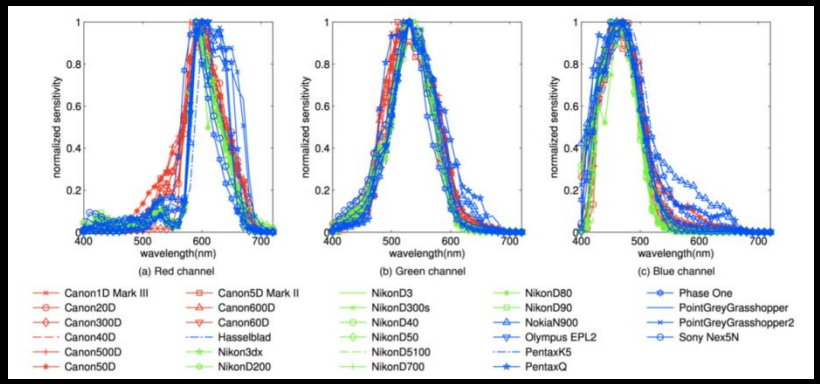
case study: cameras



And what does that mean in practice?

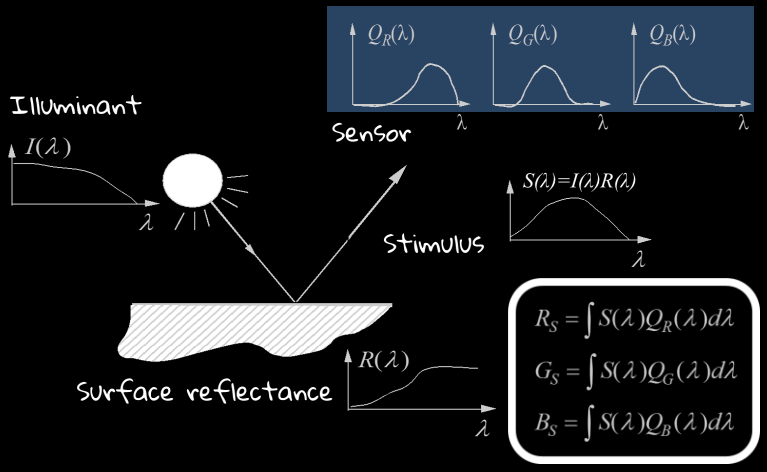
case study: cameras

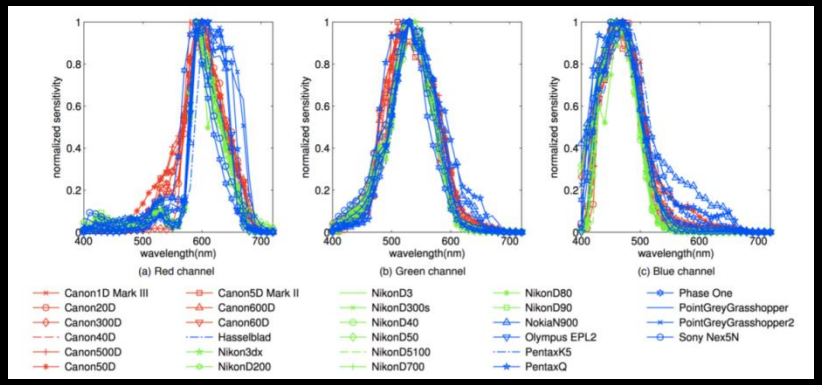




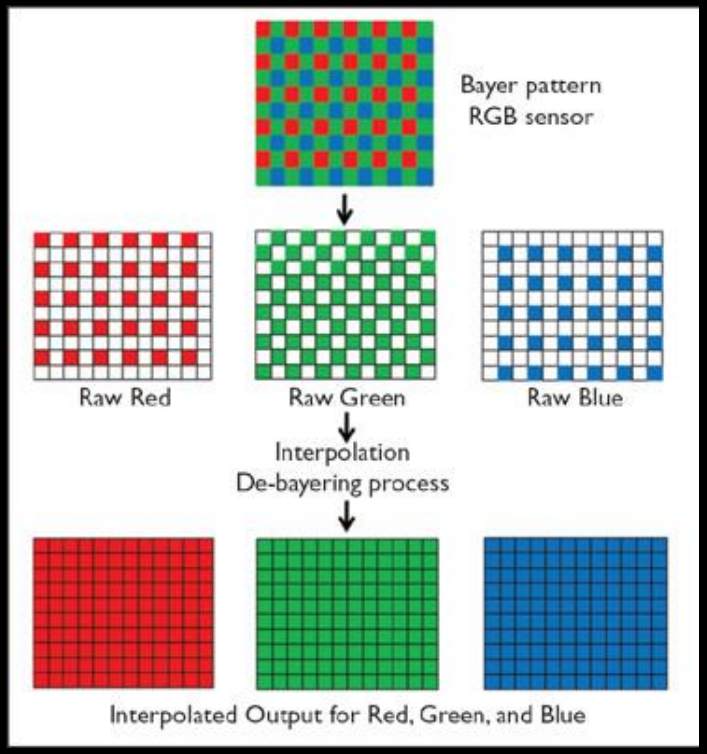
And what does that mean in practice?

case study: cameras





Camera outputs TIF or JPEG file that contains 3 channels: RGB

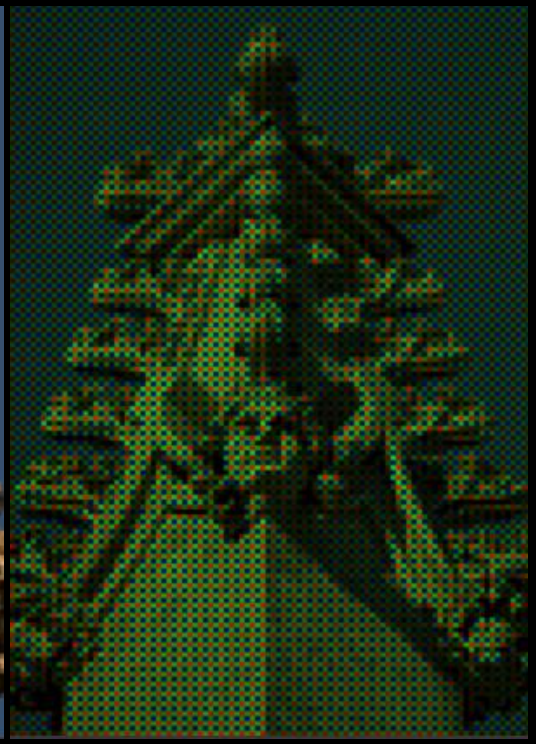


And what does that mean in practice?

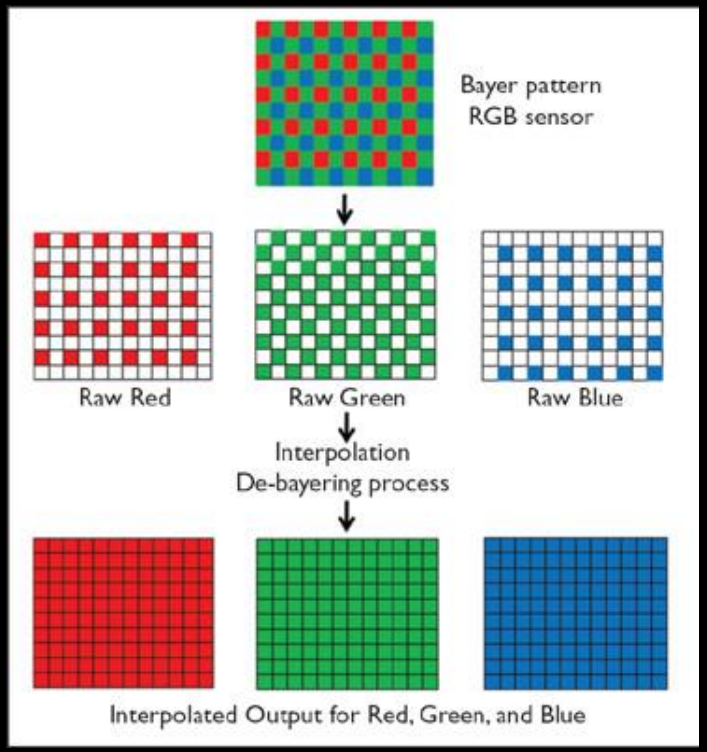
case study: cameras

Camera outputs TIF or JPEG file that contains 3 channels: RGB

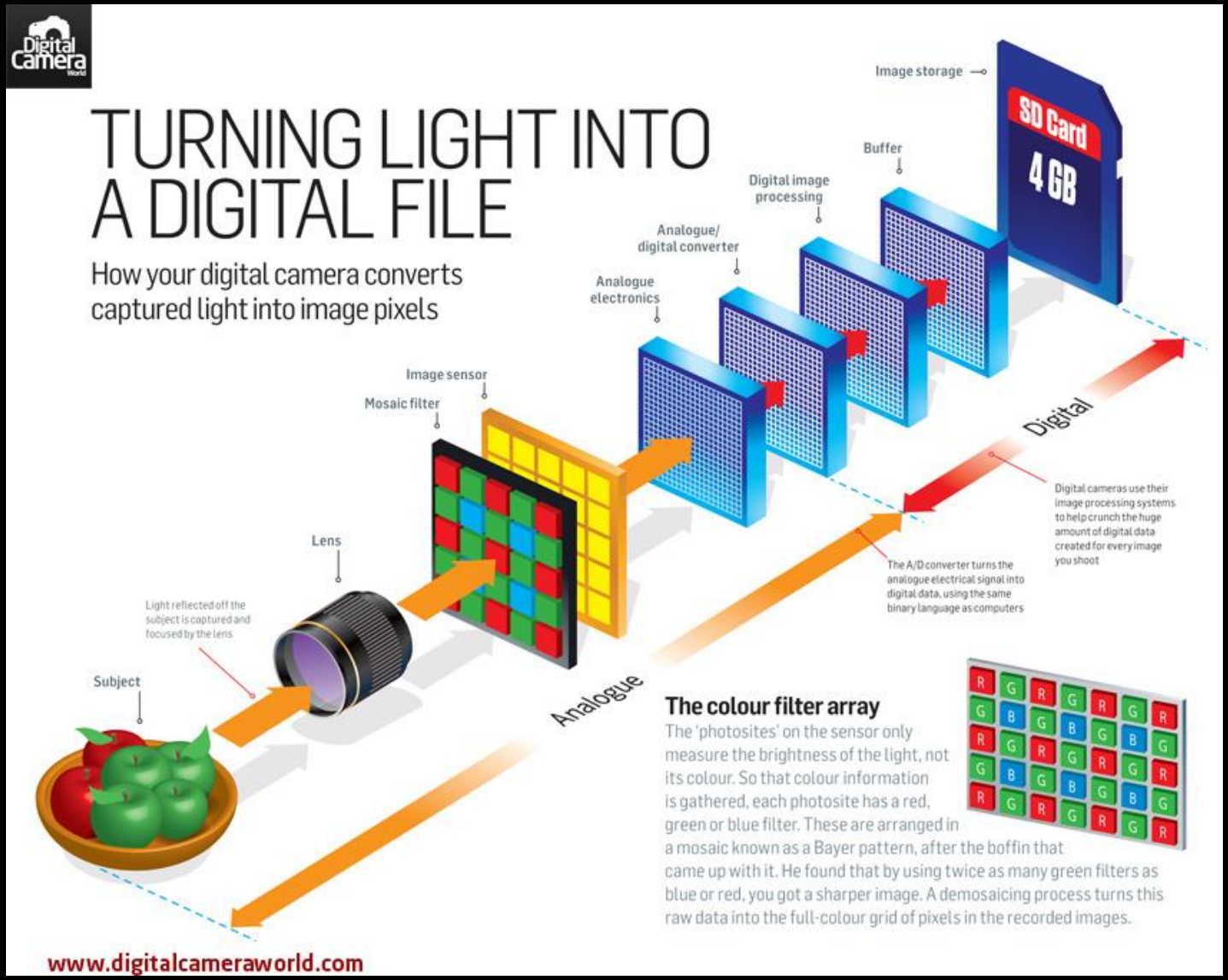
Original



What your camera sees



Case study: cameras JPEG vs RAW

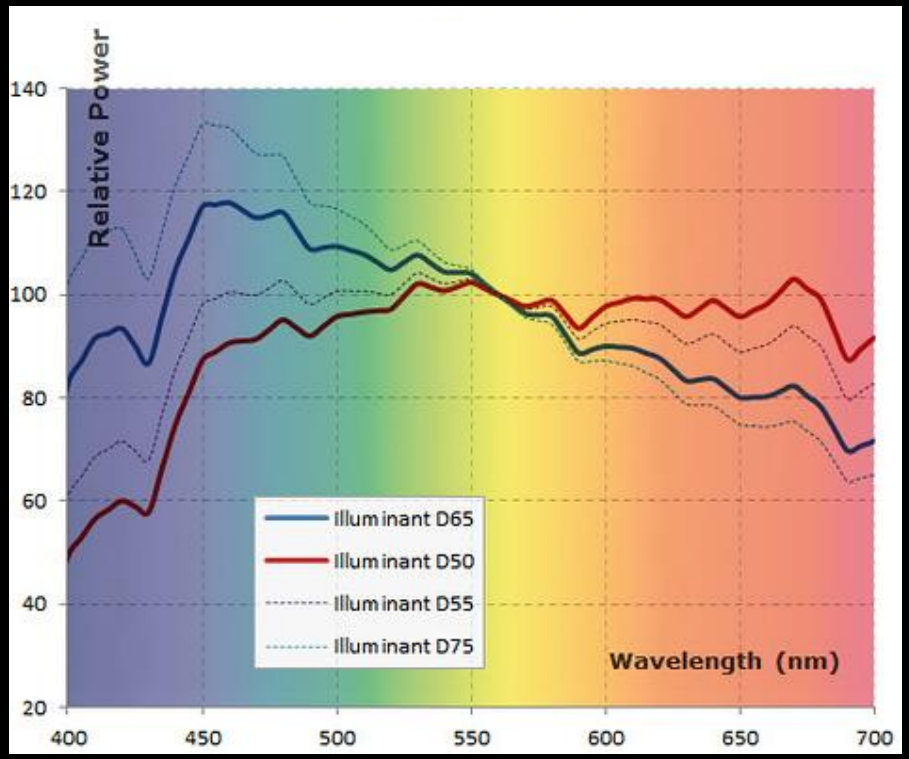


How to communicate color?

CIE (Commission internationale de l'éclairage)

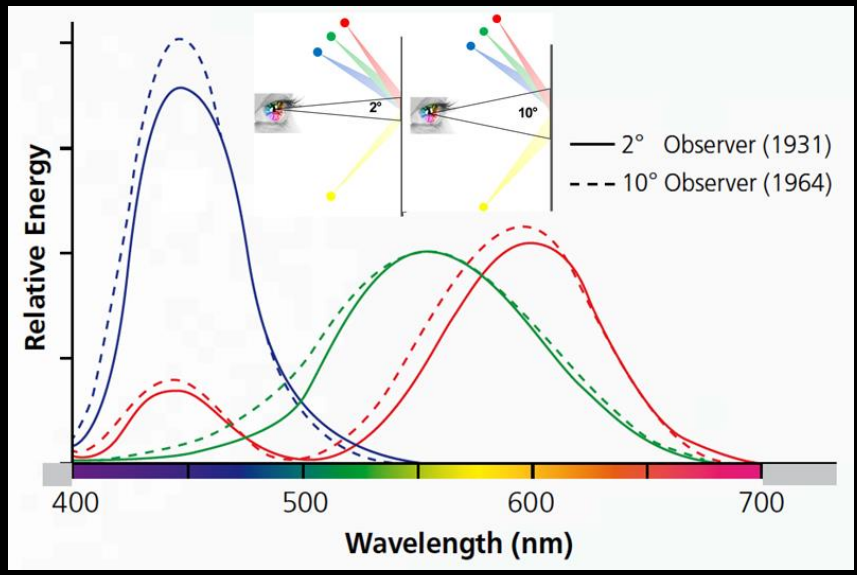
Standard illuminants

definition of spectral power distributions (SPD) for some typical light sources



Standard observers

how an average person sees colors across the visible spectrum



How to communicate color?

Pantone and other organizations

cie

International Color Consortium®

ISO

Idealliance

fogra

ISO 12646: Displays for color proofing - Characteristics and viewing conditions.
ISO 3664: Graphic technology and photography - Viewing conditions.
ISO 13655: Spectral measurement and colorimetric computation for graphic arts images.
ISO14861: Requirements for color soft proofing systems.
ISO 2846-1: Color and transparency of printing ink sets for four-color printing – Part 1: Sheet-fed and heat-set web offset lithographic printing.
ISO 12647-1-8: Process control for production of half-tone color separations, proof and production prints.
ISO/PAS 15399: Printing from digital data across multiple technologies.
ISO 15311-X (In progress): Graphic Technology – Requirements for printed matter for commercial and industrial production

A recap…

- Color is a sensation
- Three components: illumination, sensor, object
- Color mixing processes: additive and subtractive
- CIE provides standards for illuminants and observers
- Take away message:
  - color is difficult!!!!!
  - all that has been done is approximative, based on standards (conventions)
  - results from research are "only" around 100 years old

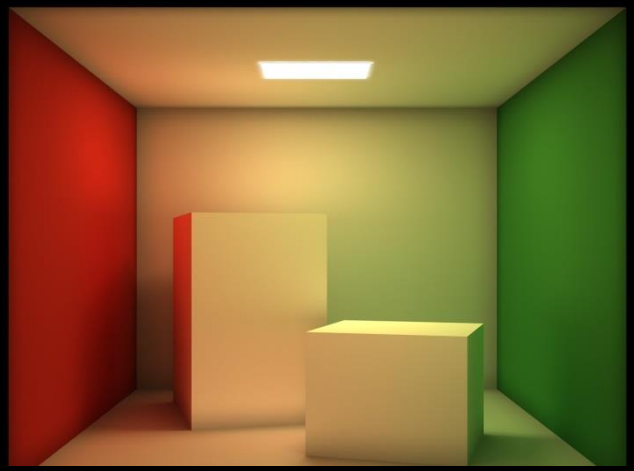
"Colors are light's suffering and joy"
-Johann Wolfgang von Goethe

To think over

What is fluorescence?

Why a banana stays yellow to us under two different light sources?

What is going on here?



Fun facts

Consulter le journal

Le Monde

Se connecter

ACTUALITÉS ÉCONOMIE VIDÉOS OPINIONS CULTURE M LE MAG SERVICES

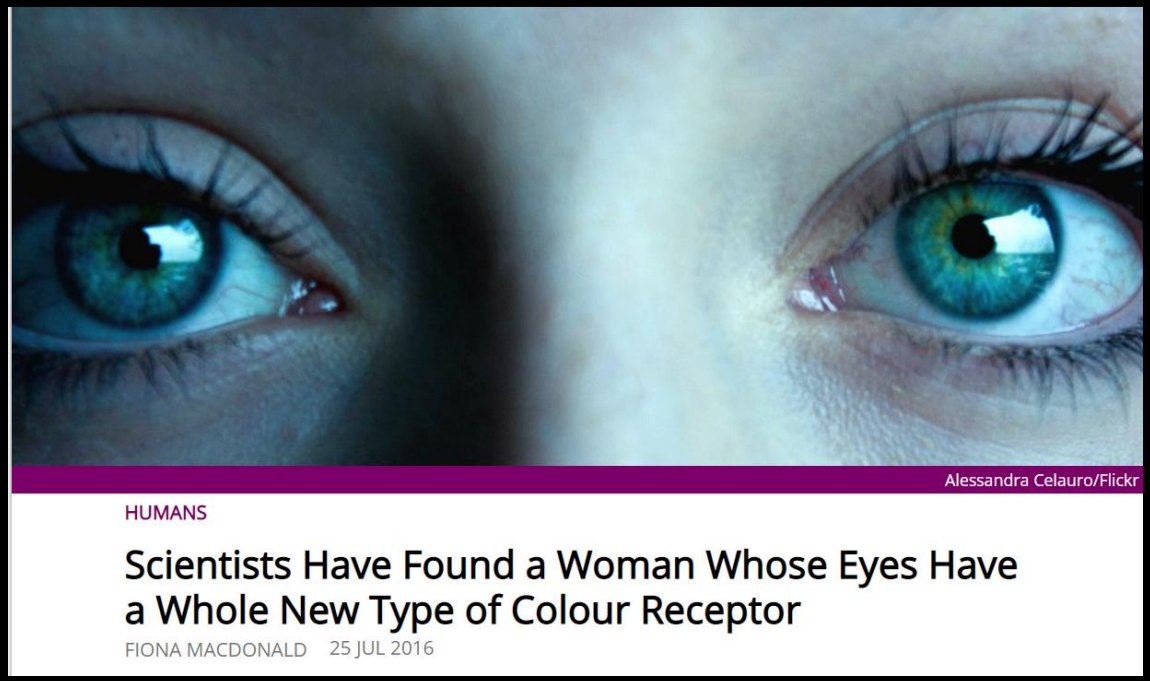
SCIENCES • ZOOLOGIE

La dirette argentée, ce poisson des abysses qui voit l'invisible en couleurs

Pour percevoir le moindre rayon lumineux à plus de 2 000 mètres de profondeur, la dirette argentée dispose d'un système visuel exceptionnel.

Par Nathaniel Herzberg • Publié le 12 mai 2019 à 17h00 - Mis à jour le 15 mai 2019 à 12h01

La dirette argentée dispose sur la rétine de quatorze types de bâtonnets photorécepteurs pour percevoir la couleur malgré la quasi absence de lumière au fond des océans. Pavel Riha, université de Bohème du Sud



- color blind men only possess two normal cone cells and one mutant cone that's less sensitive to either green or red light
- mothers and daughters of color blind men had one mutant cone and three normal cones
- around 12 percent of the female population should be tetrachromats.