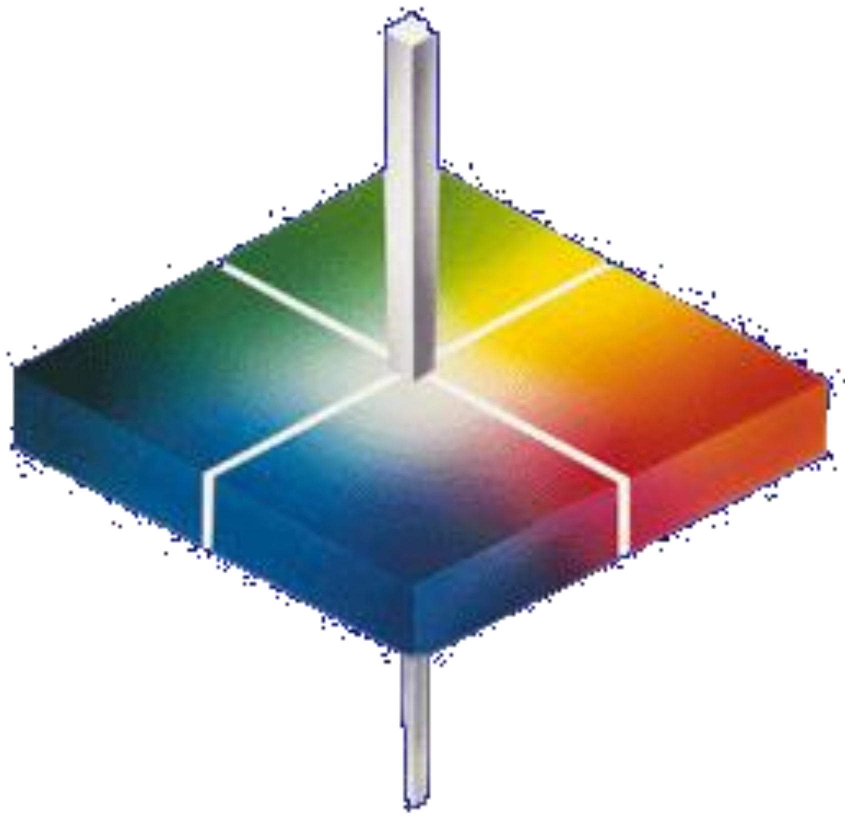
COLOR

The Basics Of Color Perception and Measurement



Contents

Learning Outcomes

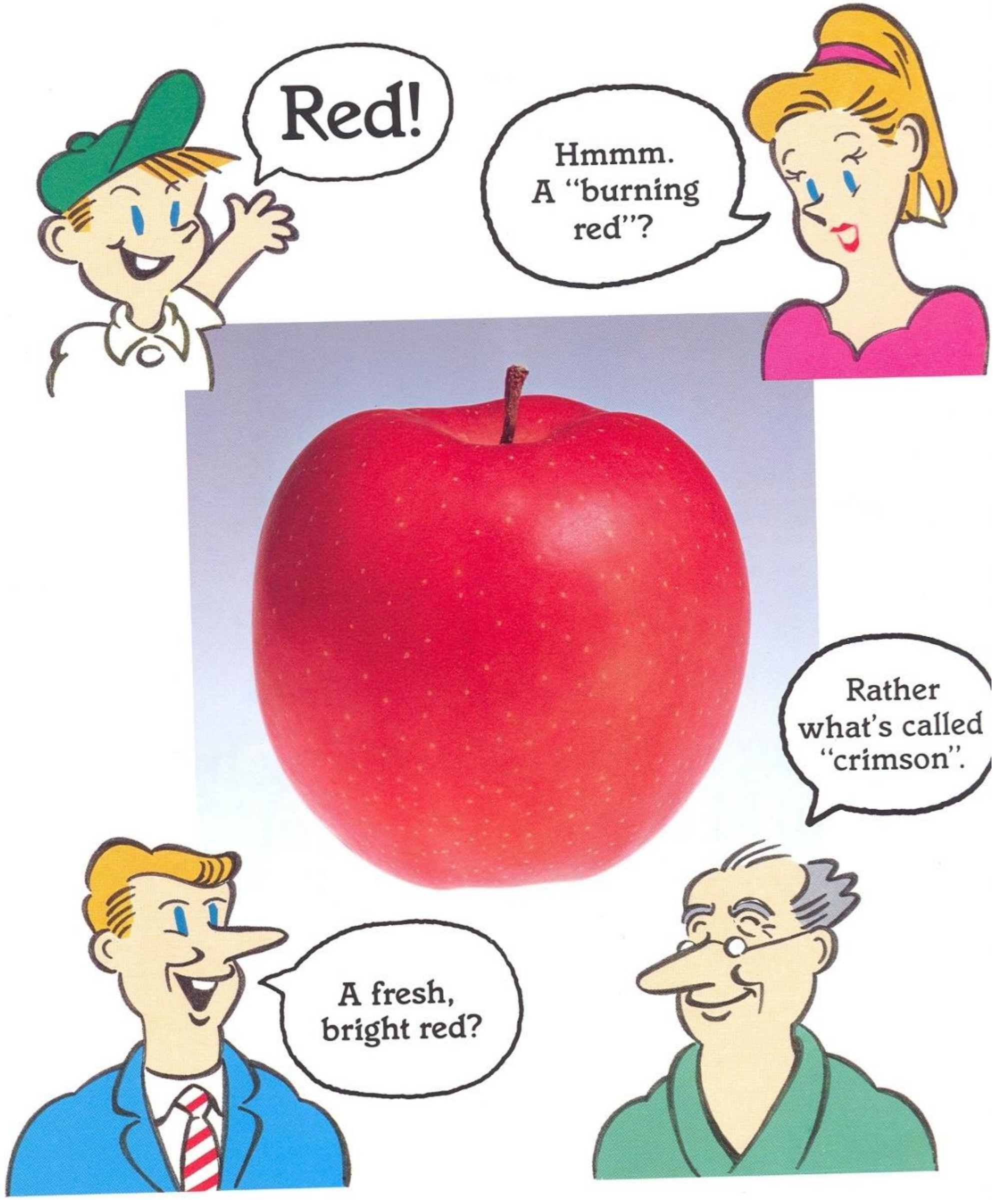
- To learn color principles
- To learn color measurement principles
- To learn why we measure food color

Why do we measure food color?

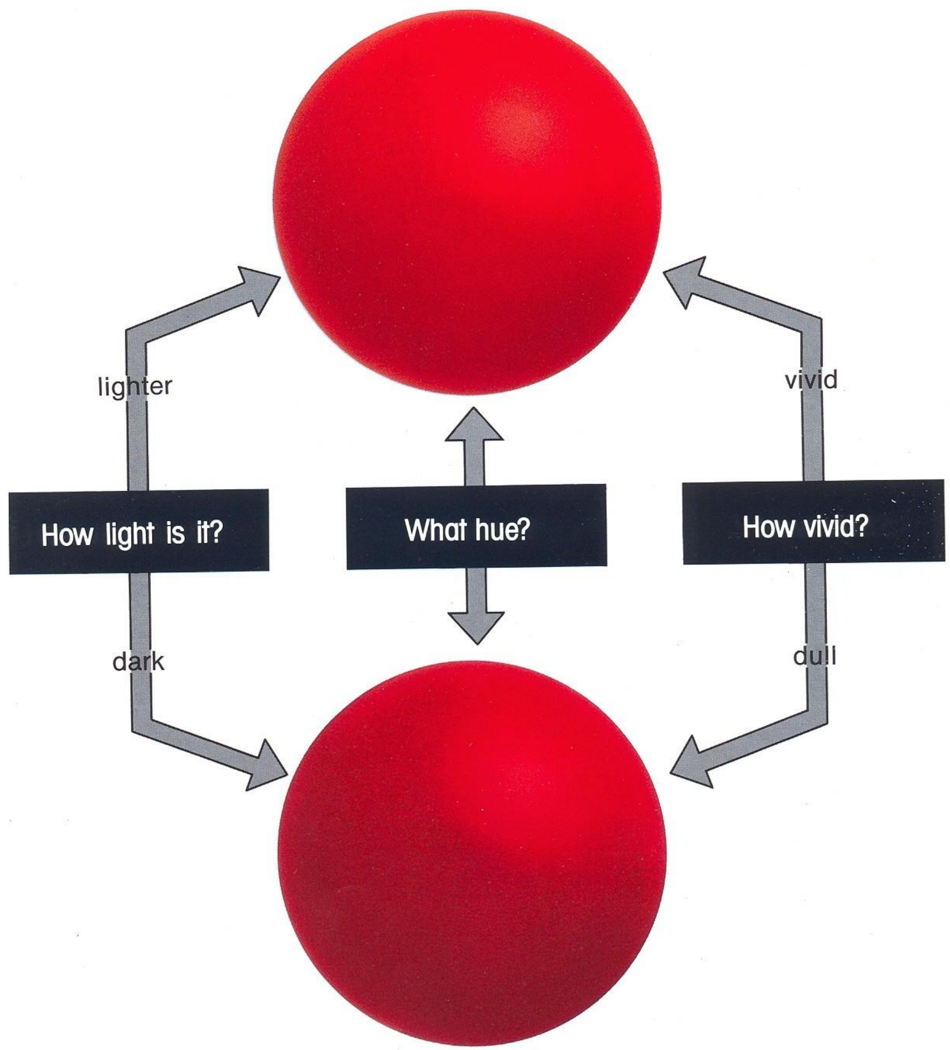
- It is an index of ripeness
- It is an index of spoilage
- It is an indicator of processing time;
  - Potatoes darken when they are fried
- It is an indicator of processing quality;
  - Tomato paste can get brown at high Temp.
- It is an indicator of storage quality;
  - Darkening of dried tomato reflect too high m.c.
  - Bleaching of dried tomato reflect too high O_2 level

Color Perception

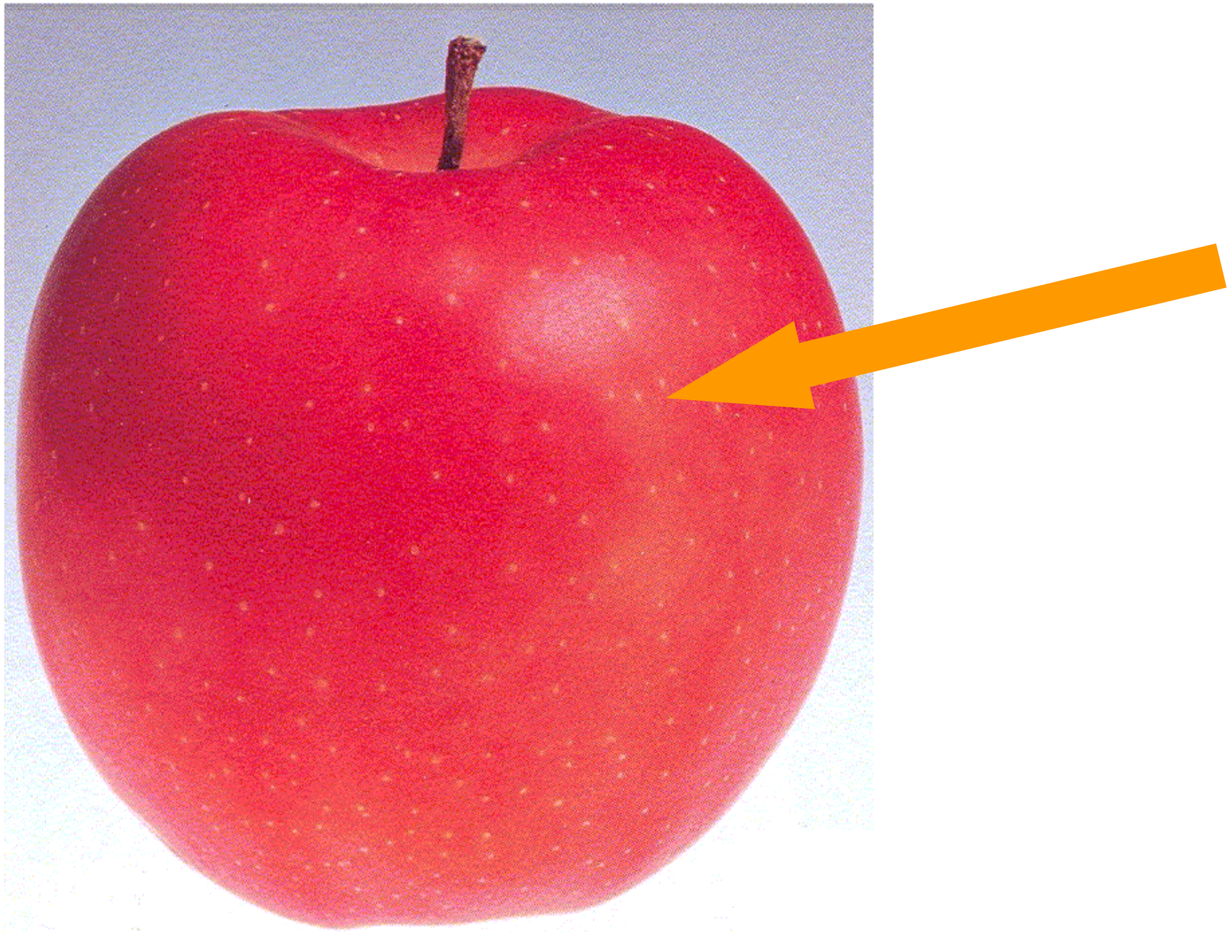
What color is this apple?



Two red balls.
Now tell someone the difference between them.



Color has dimensions: Numbers

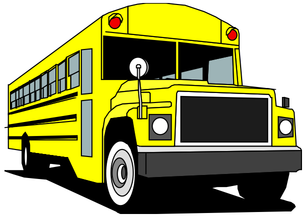
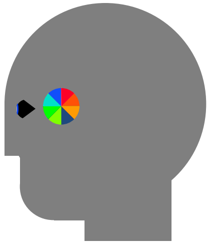


x = 13.05

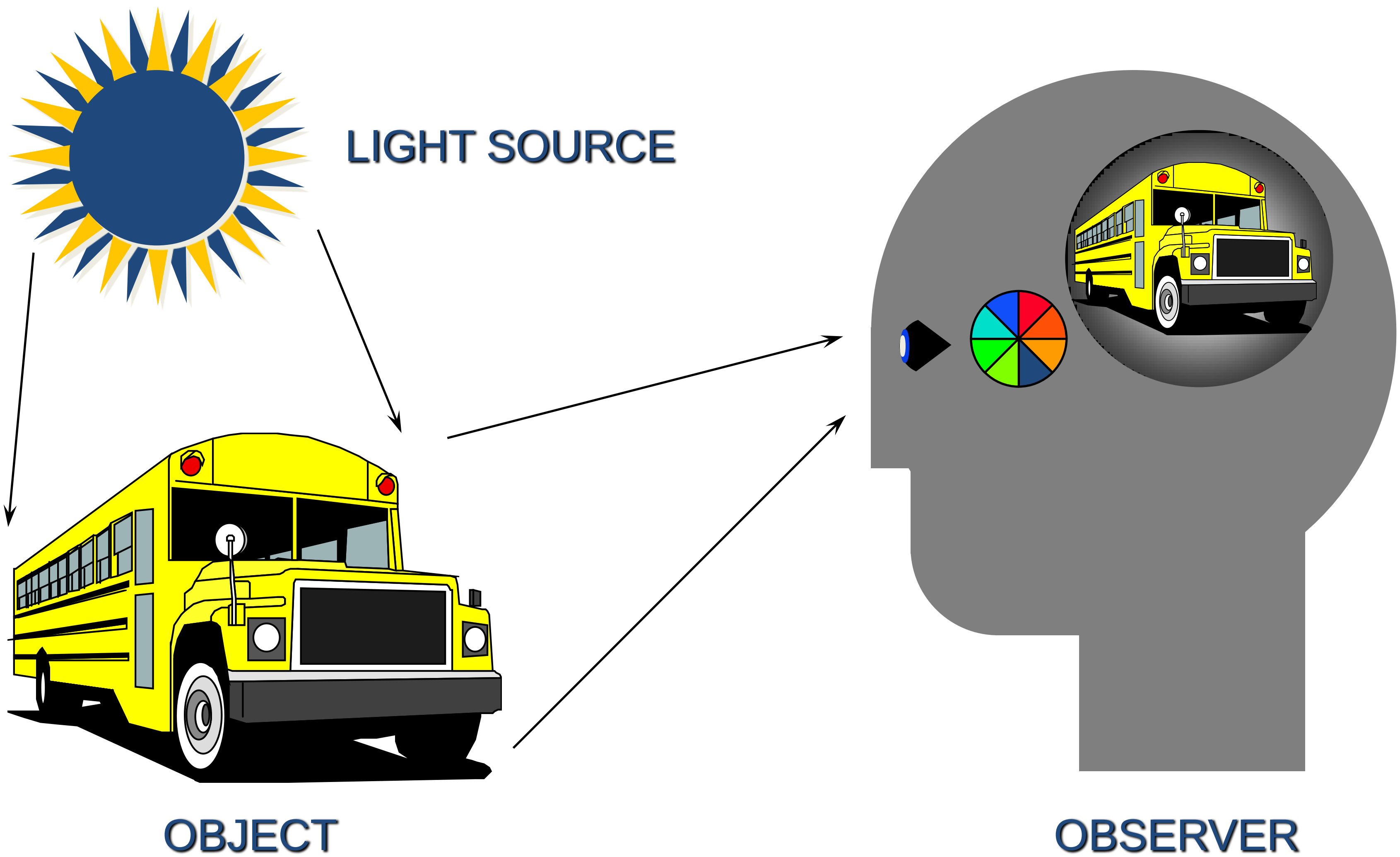
y = 0.4601

z = 0.2873

Things Required To See Color

- A Light Source 
- An Object 
- An Observer 

Visual Observing Situation

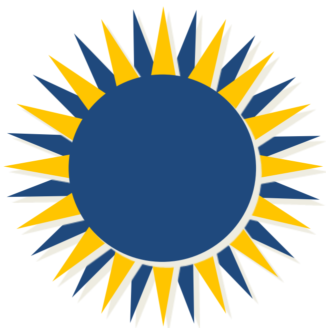


Visual Observing Situation

- The visual observing model shows the three items;
- 1- Light Source
- 2- An Object
- 3- Observer (EYE)

  that are necessary to perceive color.

- In order to build an instrument that will quantify human color perception, each item in the visual observing situation must be represented as a table of numbers.

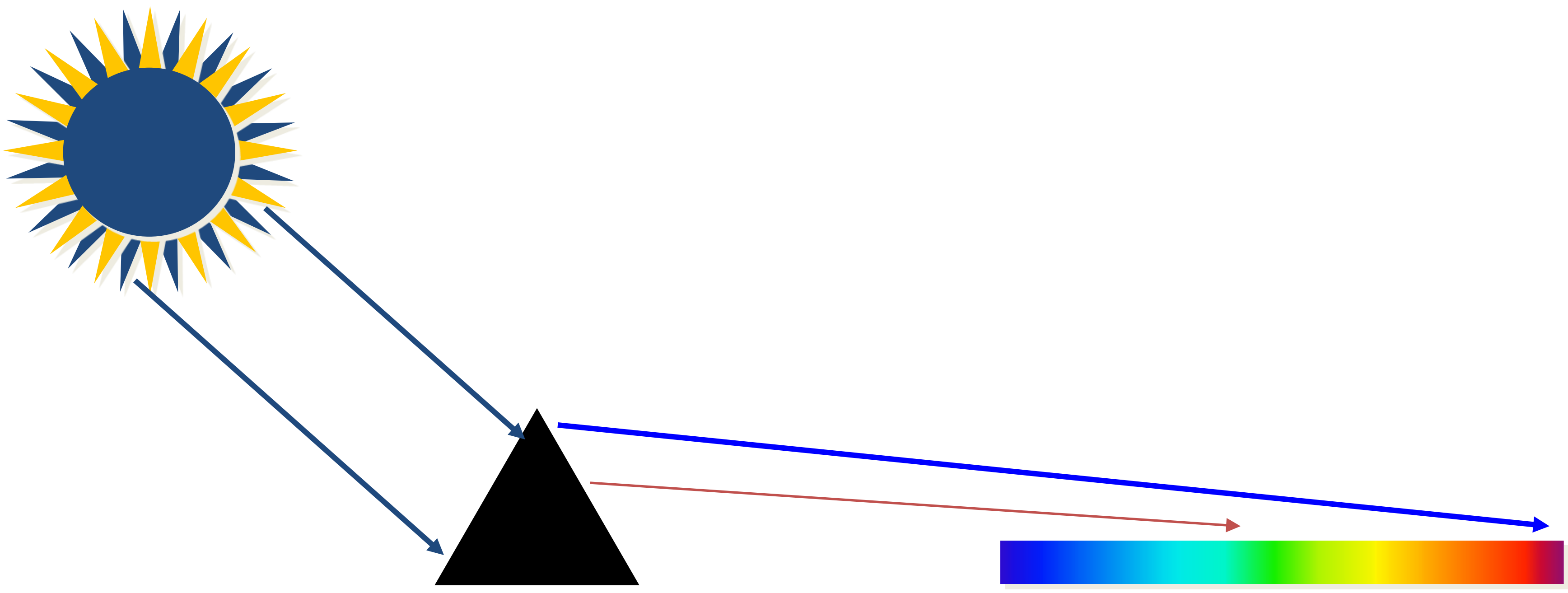


1- Light Source

Light Source

- A light source normally emits light that appears to be white.
- When the light is dispersed by a prism it is seen to be made up of all visible wavelengths.

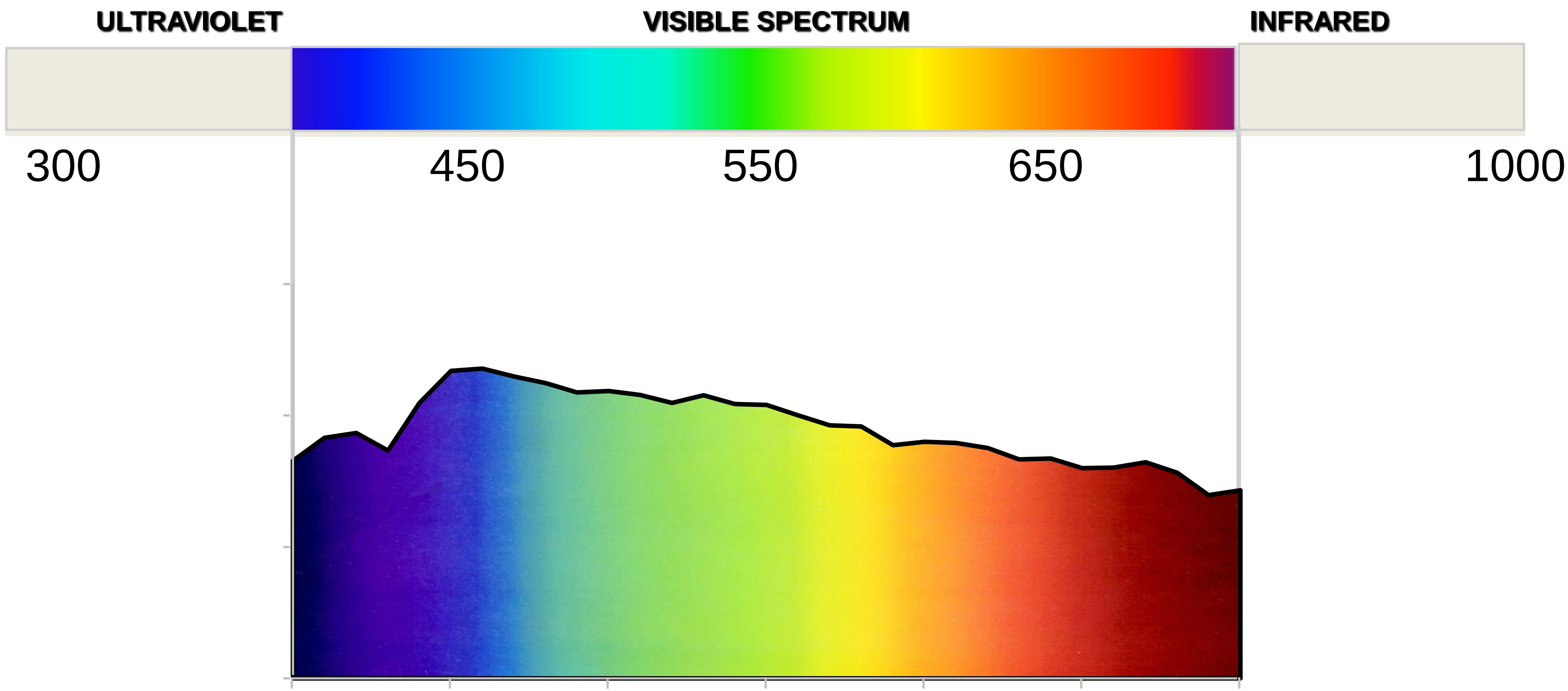
Sunlight Spectrum



Light Source

- Visible light is a small part of the electromagnetic spectrum.
- The wavelength of light is measured in nanometers (nm). One nanometer is one-billionth of a meter.
- The wavelength range of the visible spectrum is from approximately 400 to 700 nm.
- A plot of the relative energy of light at each wavelength creates a power distribution curve quantifying the spectral characteristics of the light source.

Spectral Power Distribution of Sunlight

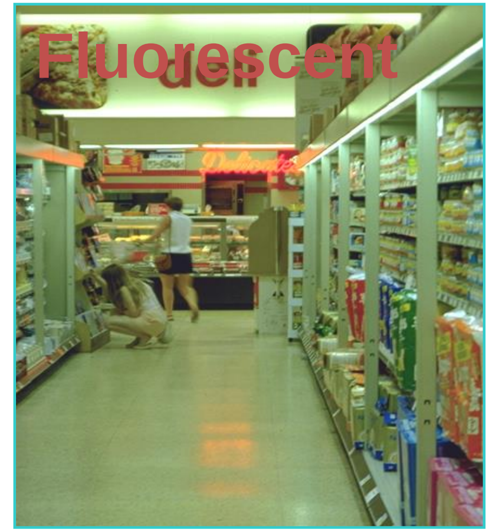


Light Source versus Illuminant

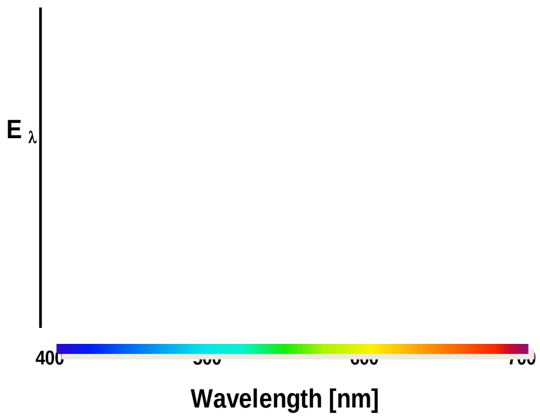
- A **light source** is a real physical source of light.
- An **illuminant** is a plot, or table, of relative energy versus wavelength that represents the spectral characteristics of different types of light sources.

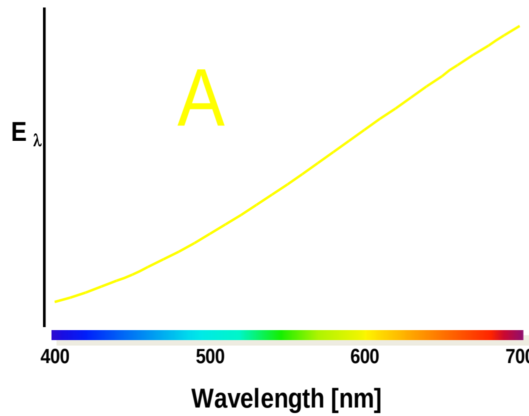
Light Source versus Illuminant

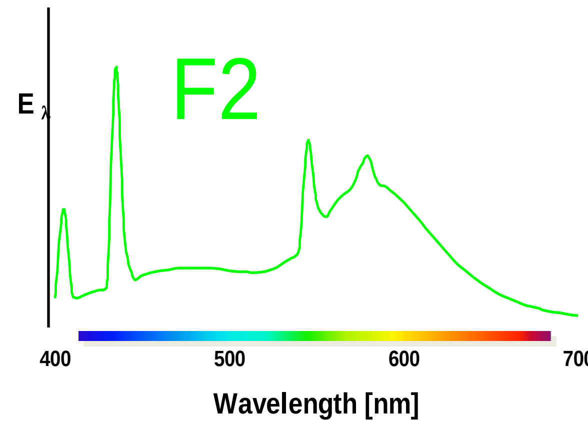
Source



Illuminant





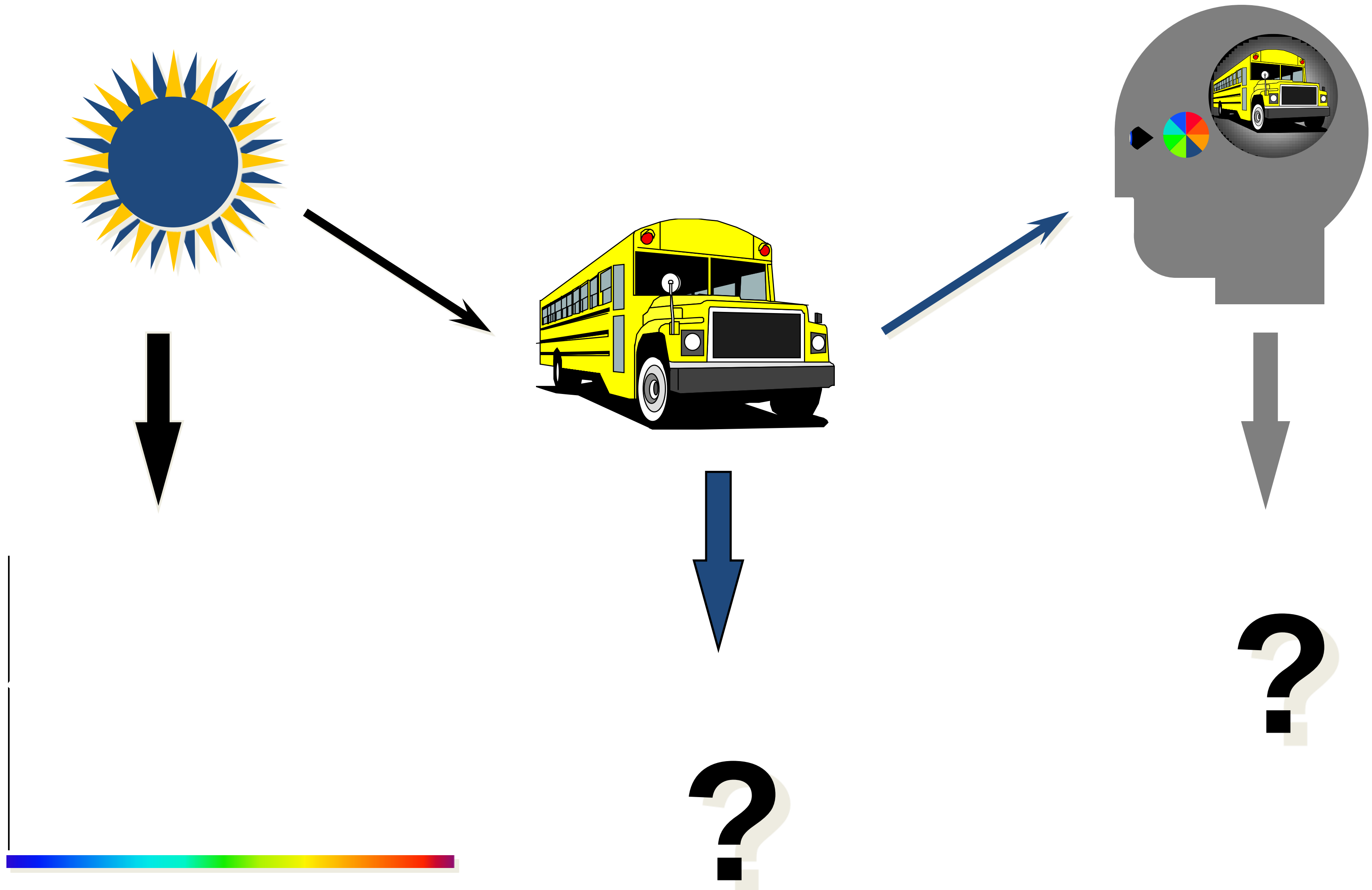


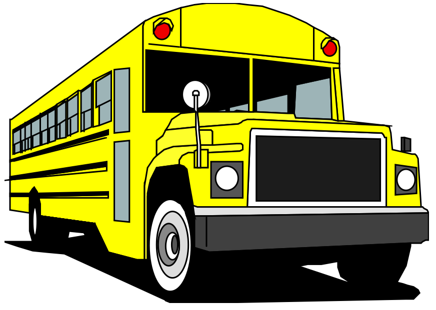
Some Common Illuminants

A	Incandescent
C	Average Daylight
D_{65}	Noon Daylight
F2	Cool White Fluorescent
U30	Ultralume

Light Source versus Illuminant

- By representing a light source as an illuminant, the spectral characteristics of the first element of the Visual Observing Situation have been **quantified** and **standardized.**



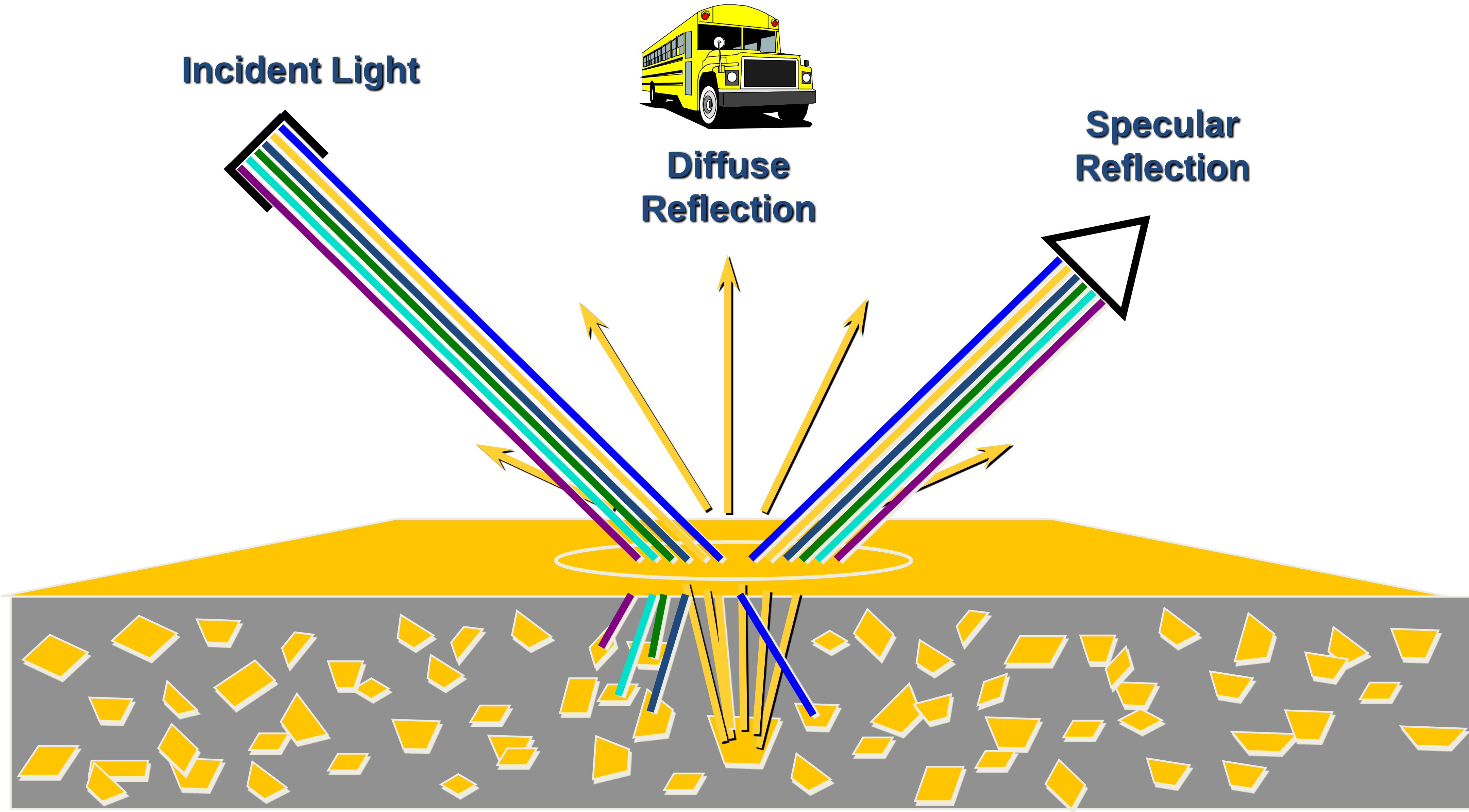


2- Object

Object

- Objects modify light. Colorants such as pigments or dyes, in the object, selectively absorb some wavelengths of the incident light while reflecting or transmitting others.

Light Interaction with School Bus Paint



If all light is reflected object appears WHITE

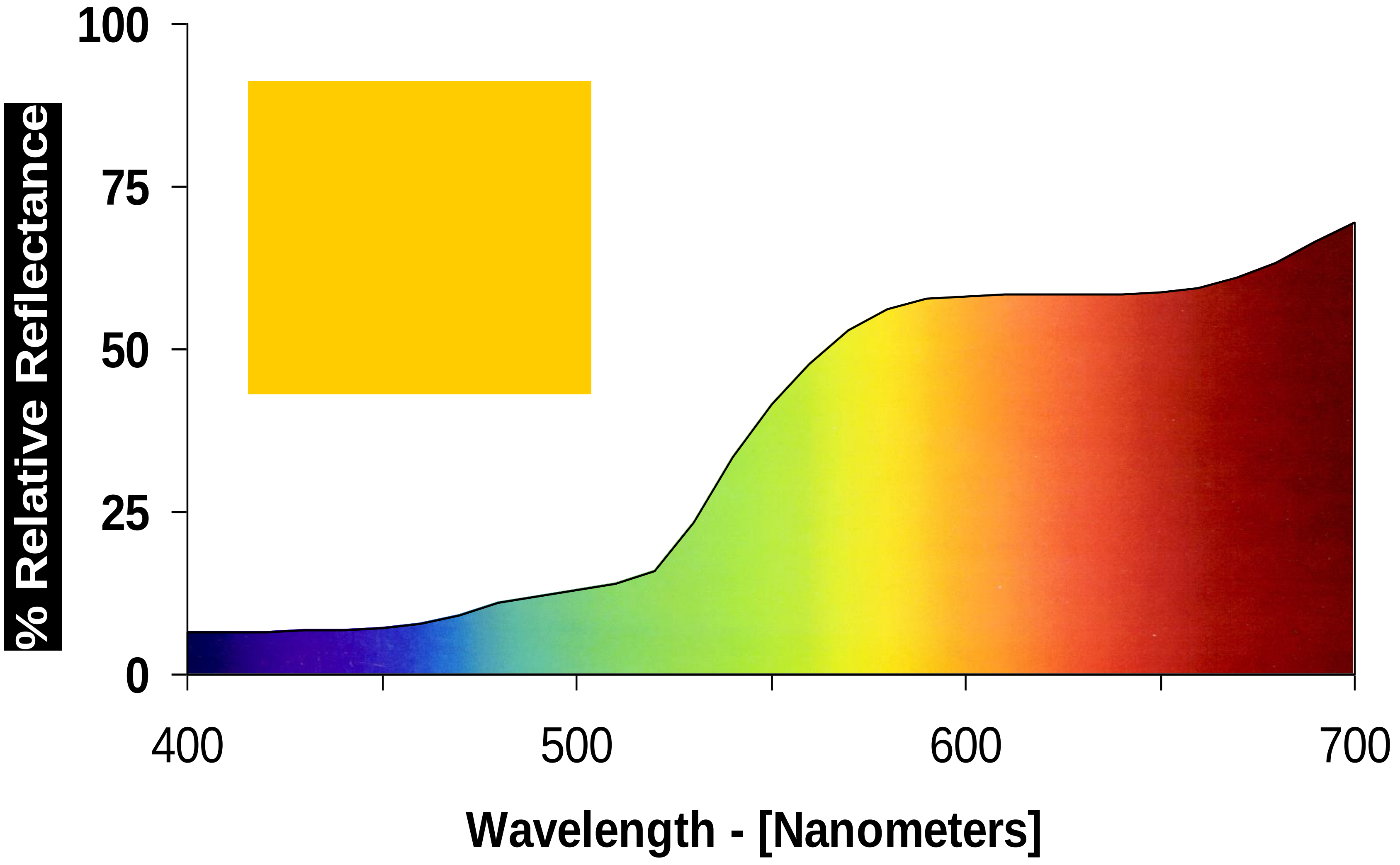
If all light is absorbed object appears BLACK

If some light is absorbed object appears GRAY

Object

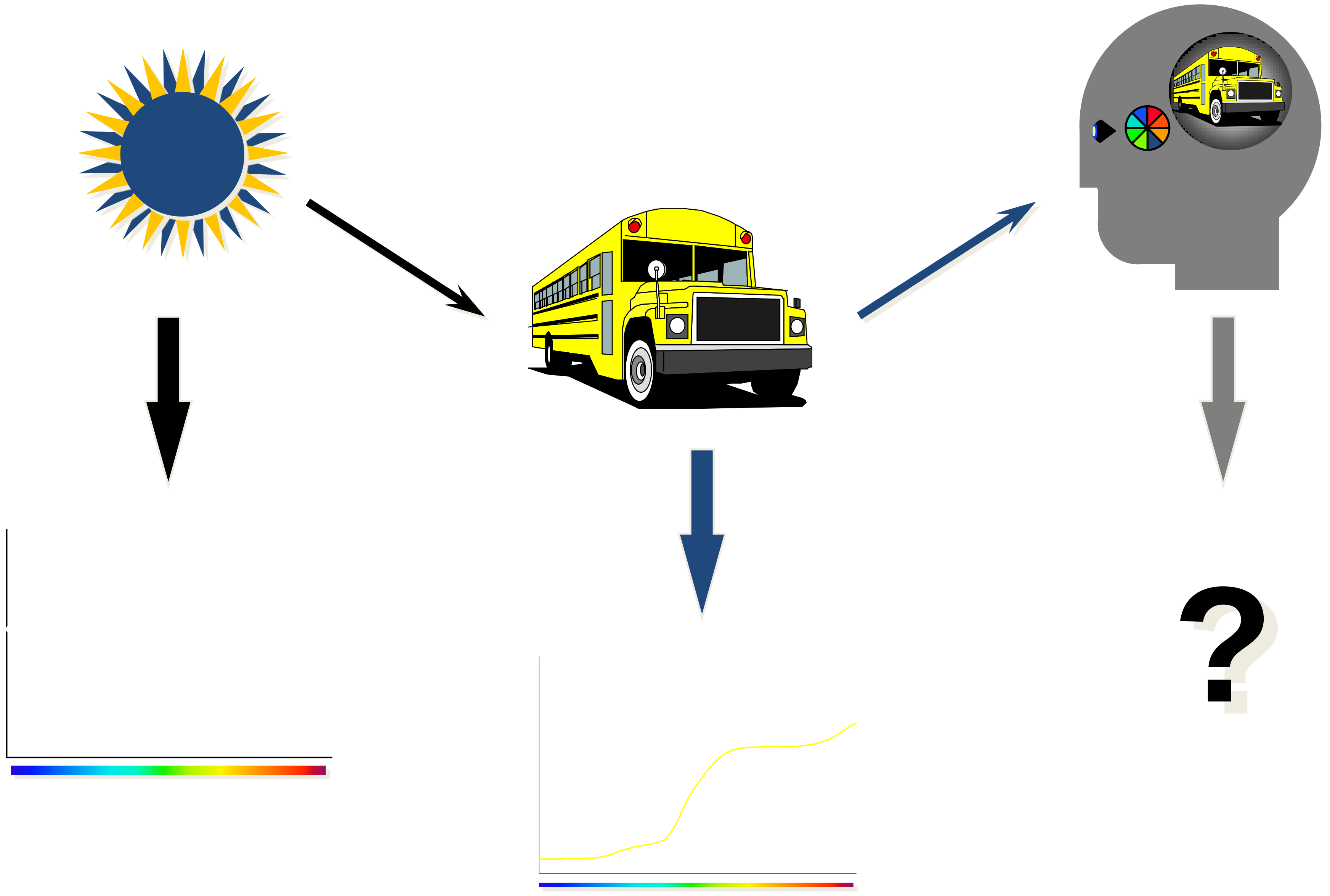
- The amount of reflected or transmitted light at each wavelength can be quantified. This is a spectral curve of the object's color characteristics.

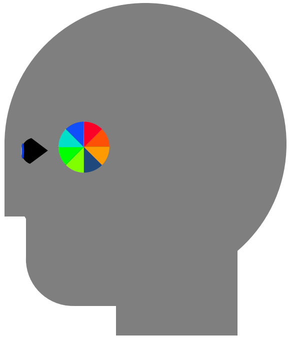
Spectrophotometric Curve for “School Bus Yellow”



Object

- By measuring the relative reflectance or transmission characteristics of an object, the second element of the Visual Observing Situation has been quantified.



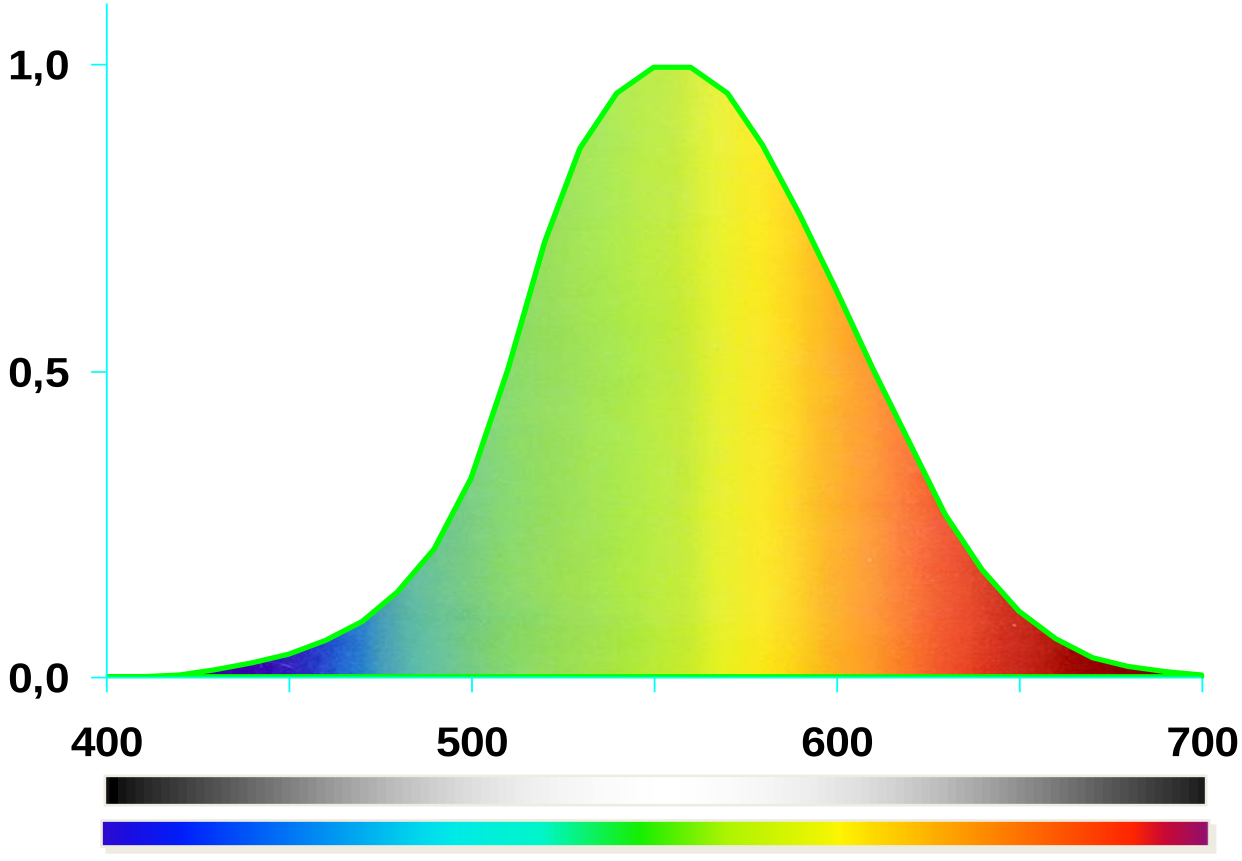


3- Observer

Observer

- Luminosity is the relative sensitivity of the human eye to various wavelengths of light.

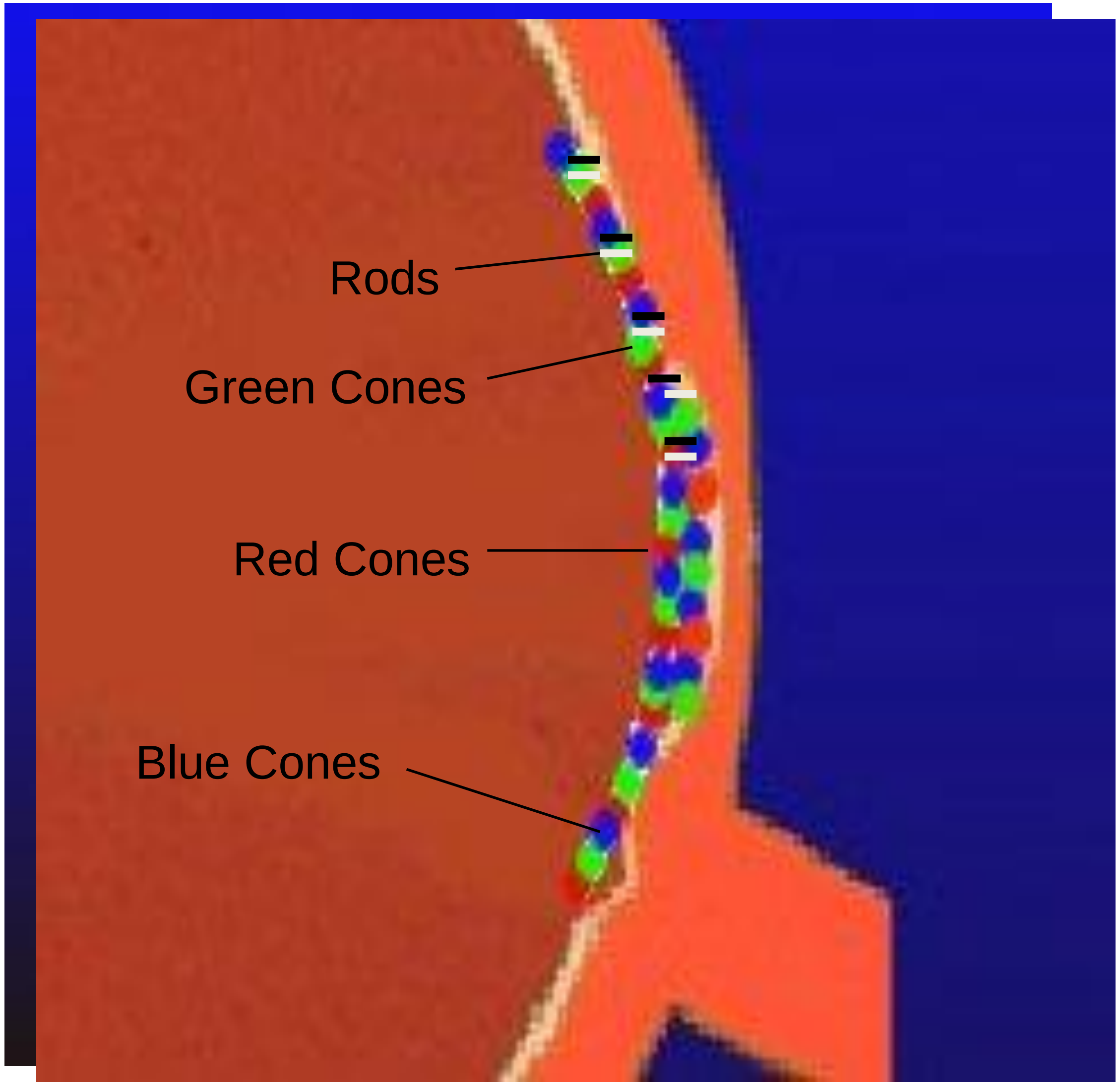
Human Eye Sensitivity to Spectral Colors



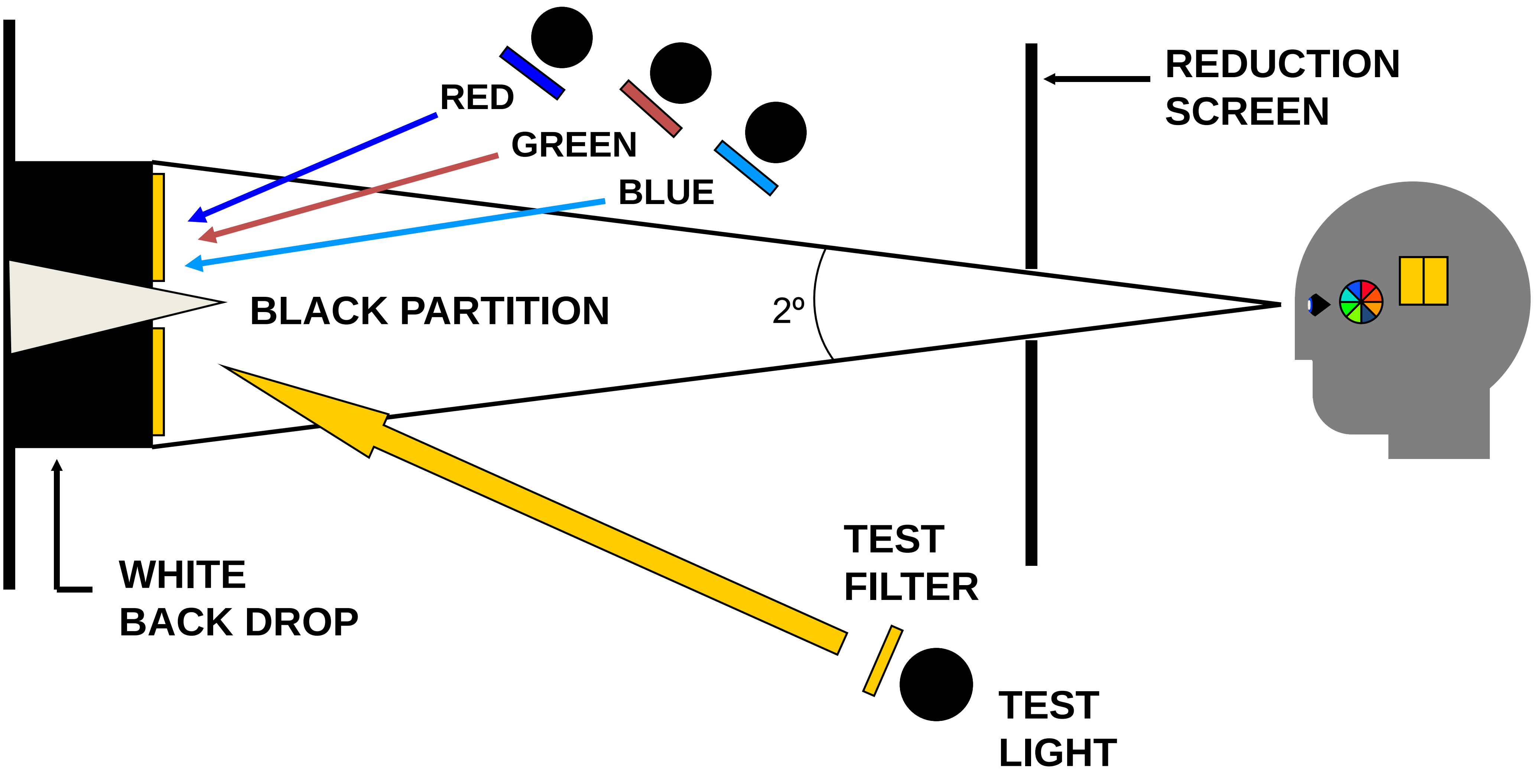
Observer

- **Rod** shaped receptors in the eye are responsible for night vision.
- **Cone** shaped receptors are responsible for daylight and color vision.
- There are three types of cone shaped receptors sensitive to **red**, **green** and **blue**.

The Human Eye



Determination of Standard Colorimetric Observer

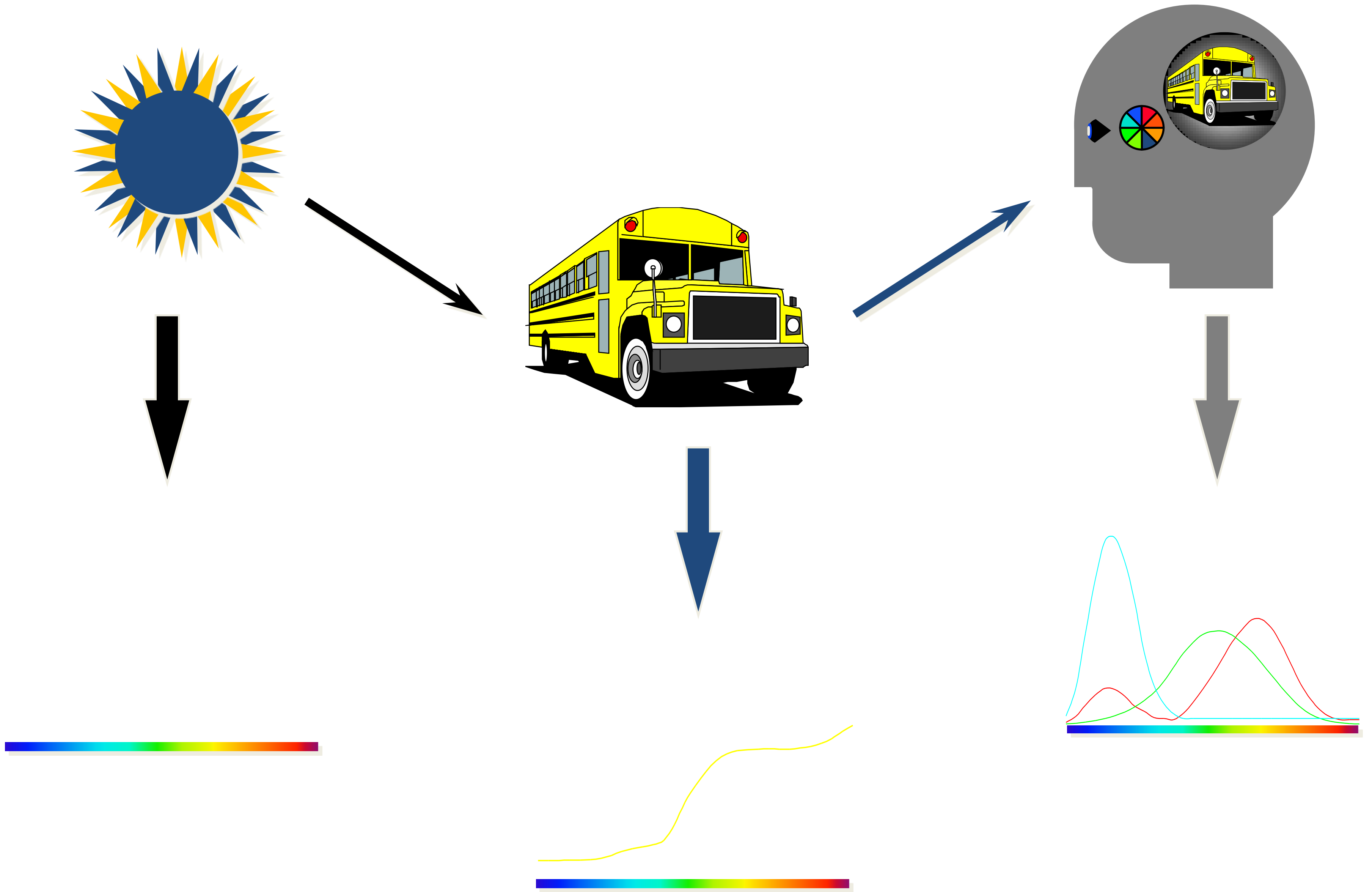


Observer

- The experimentally derived $\bar{x}$, $\bar{y}$, and $\bar{z}$ functions became the CIE 1931 2º Standard Observer. These functions quantify the red, green and blue cone sensitivity of the average human observer.

Observer

- The three elements of the Visual Observing Situation have now been modeled as tables of numbers.
  - The **Source** is quantified as a user selected illuminant
  - The **Object** is quantified by measuring the reflectance or transmission curve
  - The **Observer** is quantified by the selected CIE Standard Observer Functions

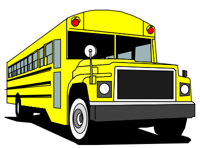


Color Measurement

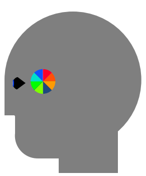
Things Required:

<u>To See Color</u>

Light Source



Object

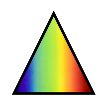


Observer

<u>To Measure Color</u>

Defined Light Source

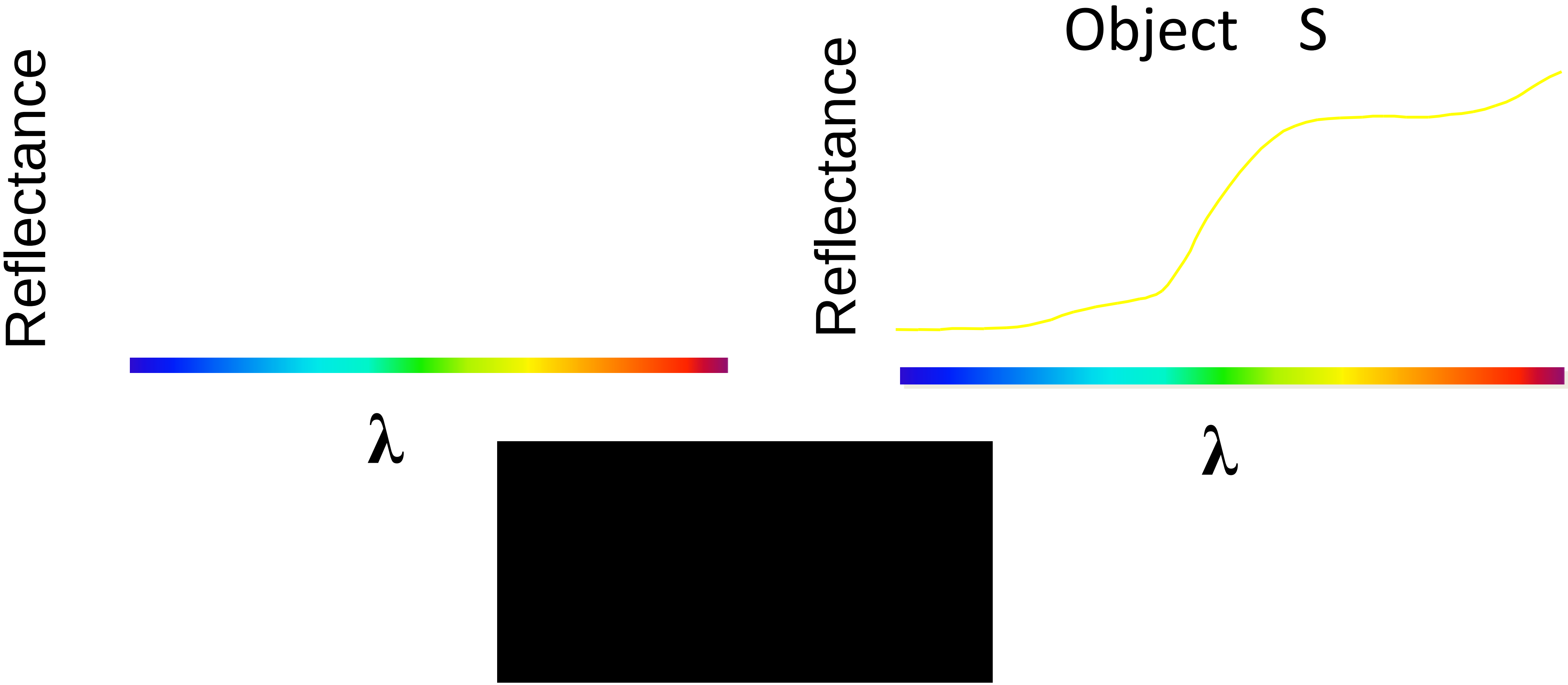
Specimen

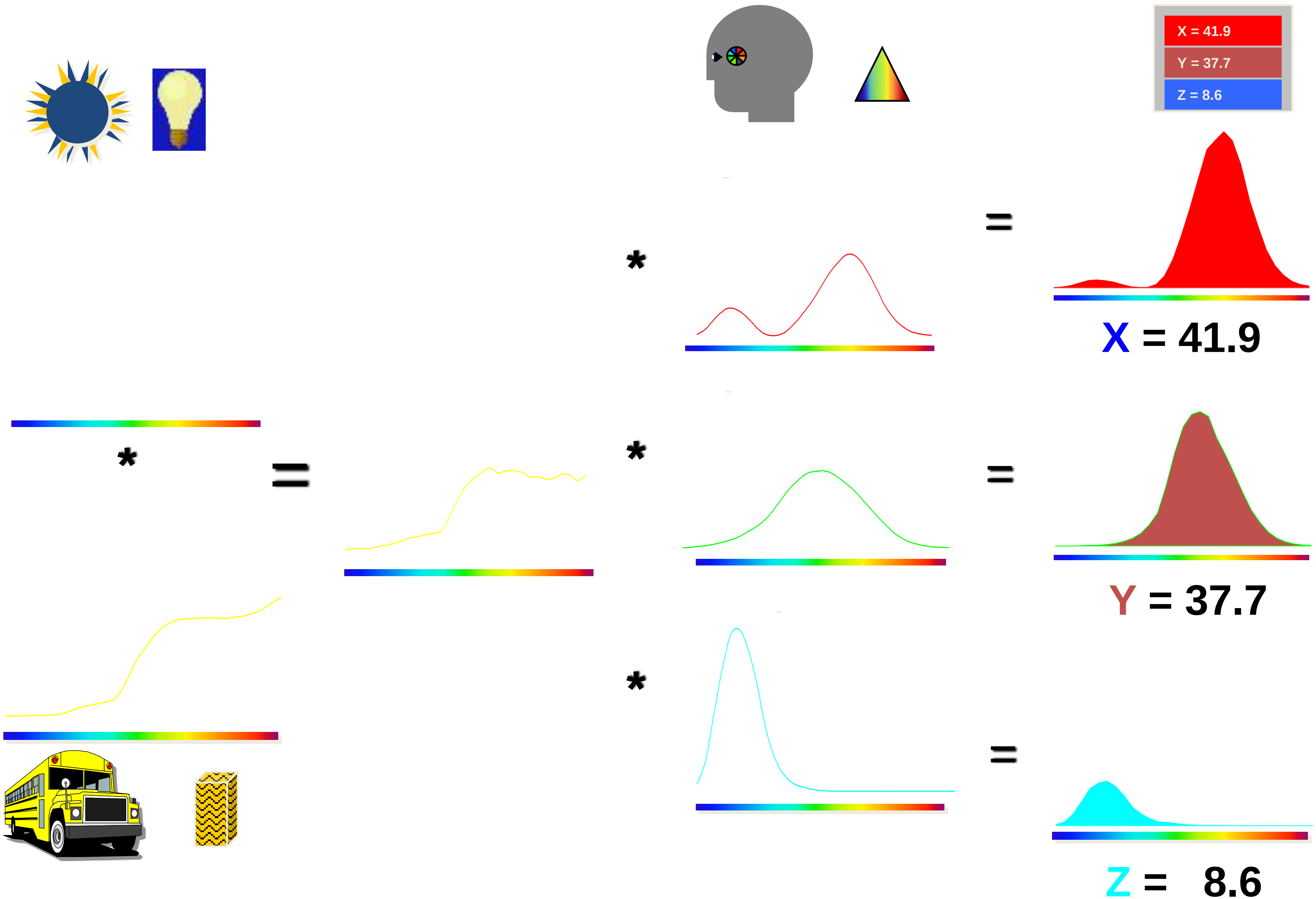


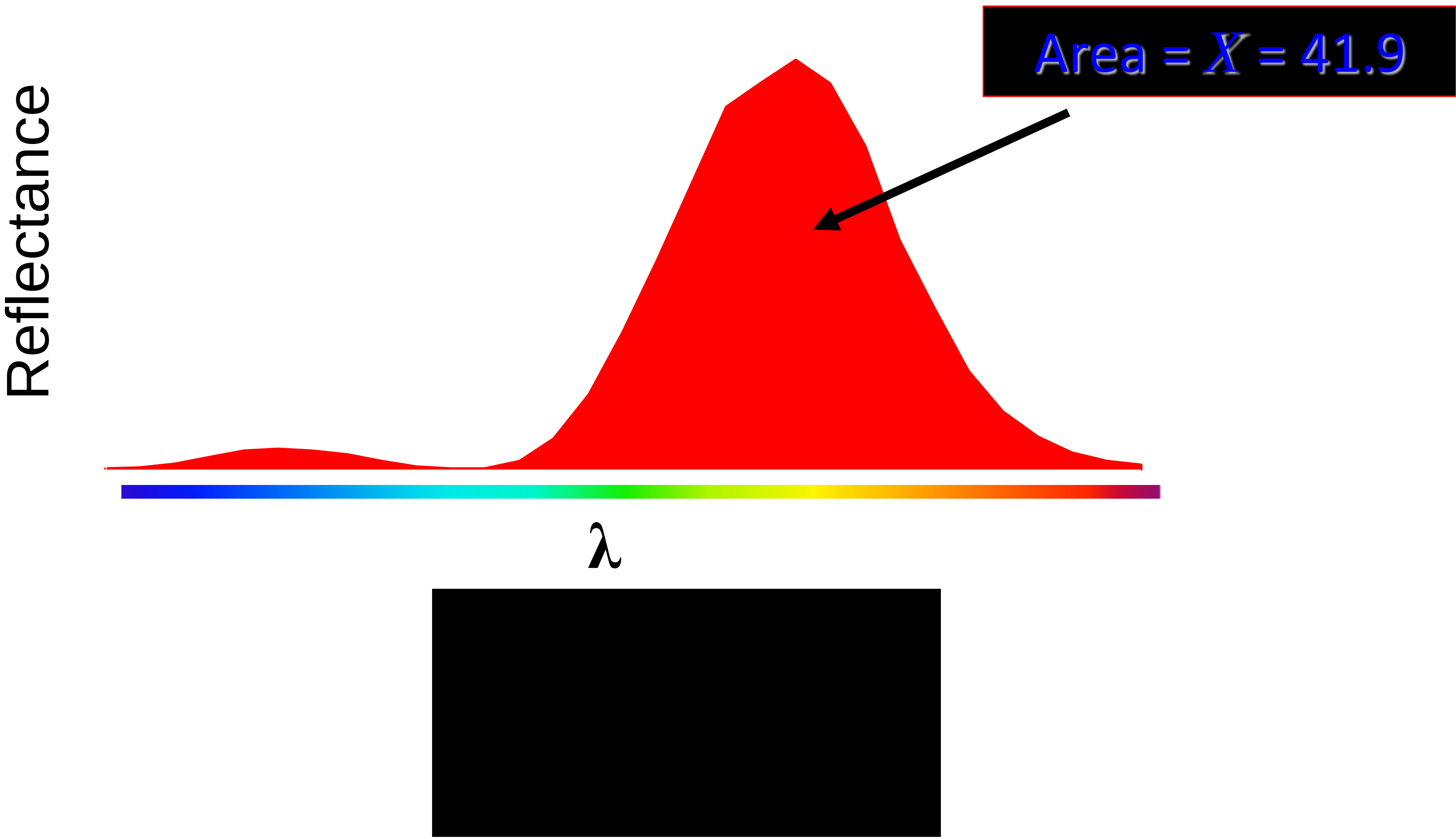
Spectrometer

Color Measurement

- The **CIE Tristimulus color values X, Y, Z** of any color are obtained by multiplying together the data values for the illuminant, the reflectance or transmittance of the object, and the standard observer functions. The product is then summed for the wavelengths in the visible spectrum to give the resulting X, Y, Z tristimulus values.


Reflectance
λ
Reflectance
Object S
λ


X = 41.9
Y = 37.7
Z = 8.6
*
=
*
=
*
=
*
=
X = 41.9
Y = 37.7
Z = 8.6


Area = X = 41.9
Reflectance
λ

Measuring Color

- A **Tristimulus Colorimeter** or **Colorimeter** uses a light source to light the specimen being measured. The light reflected off of the object then passes through a red, green and blue glass filter to simulate the standard observer functions for a particular illuminant (typically C). A photodetector beyond each filter then detects the amount of light passing through the filters. These signals are then displayed as X, Y and Z values.

Measuring Color

Tristimulus Colorimeter

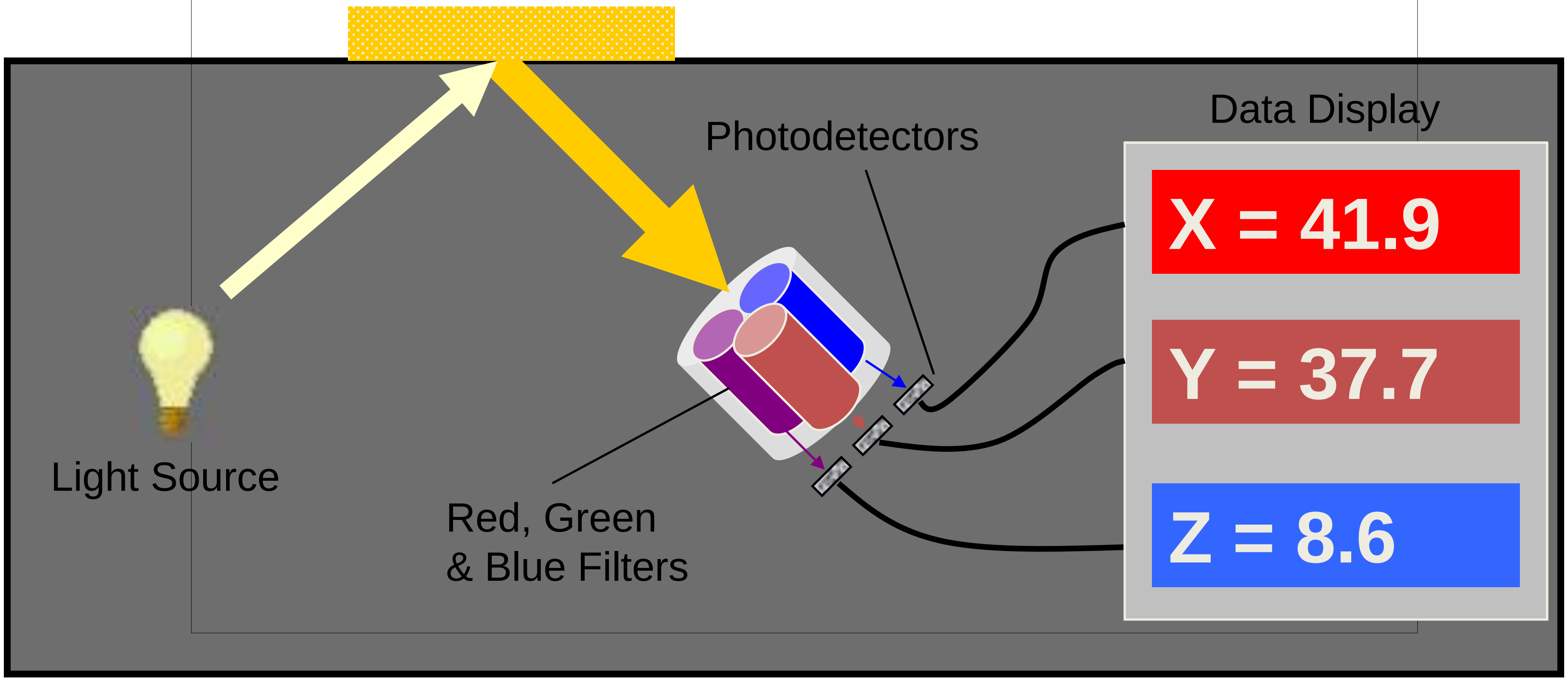
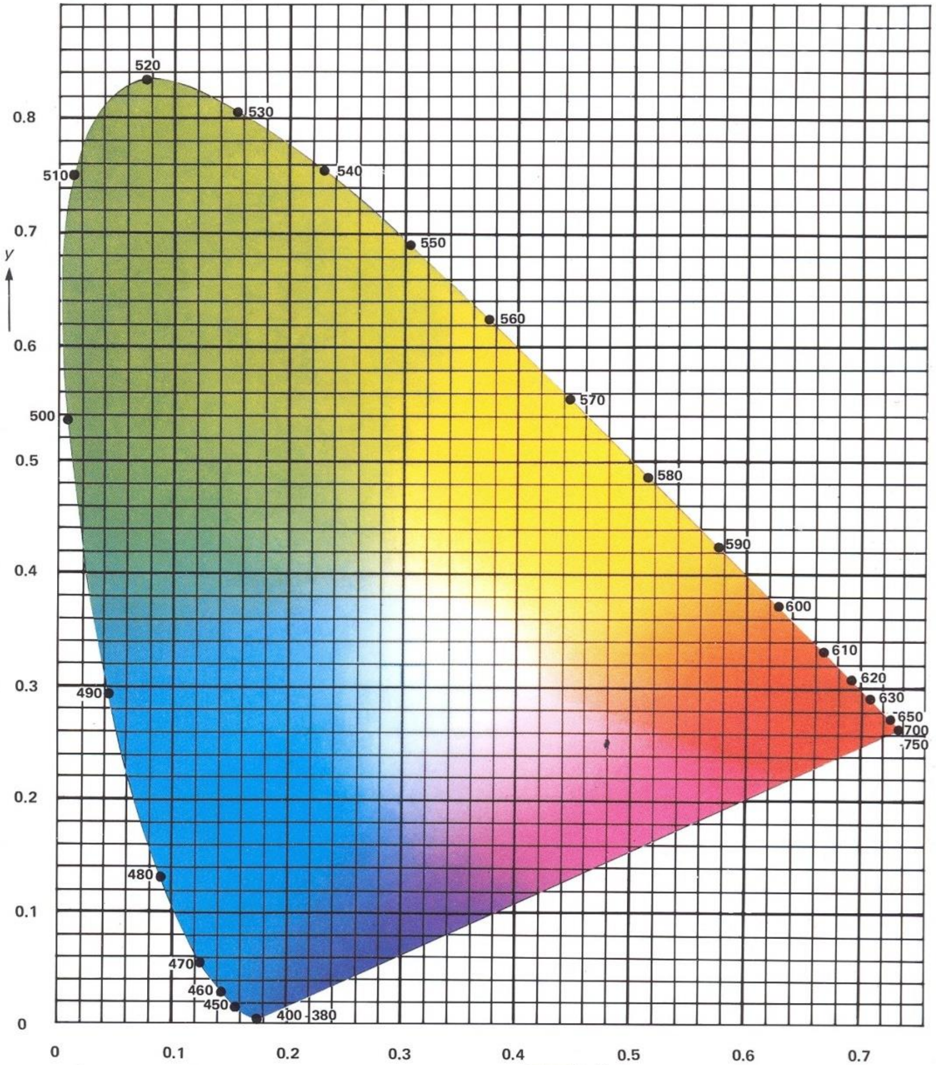
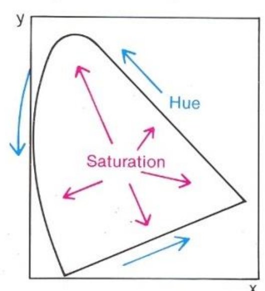


Fig. 12: CIE 1931 (x,y)-Chromaticity Diagram





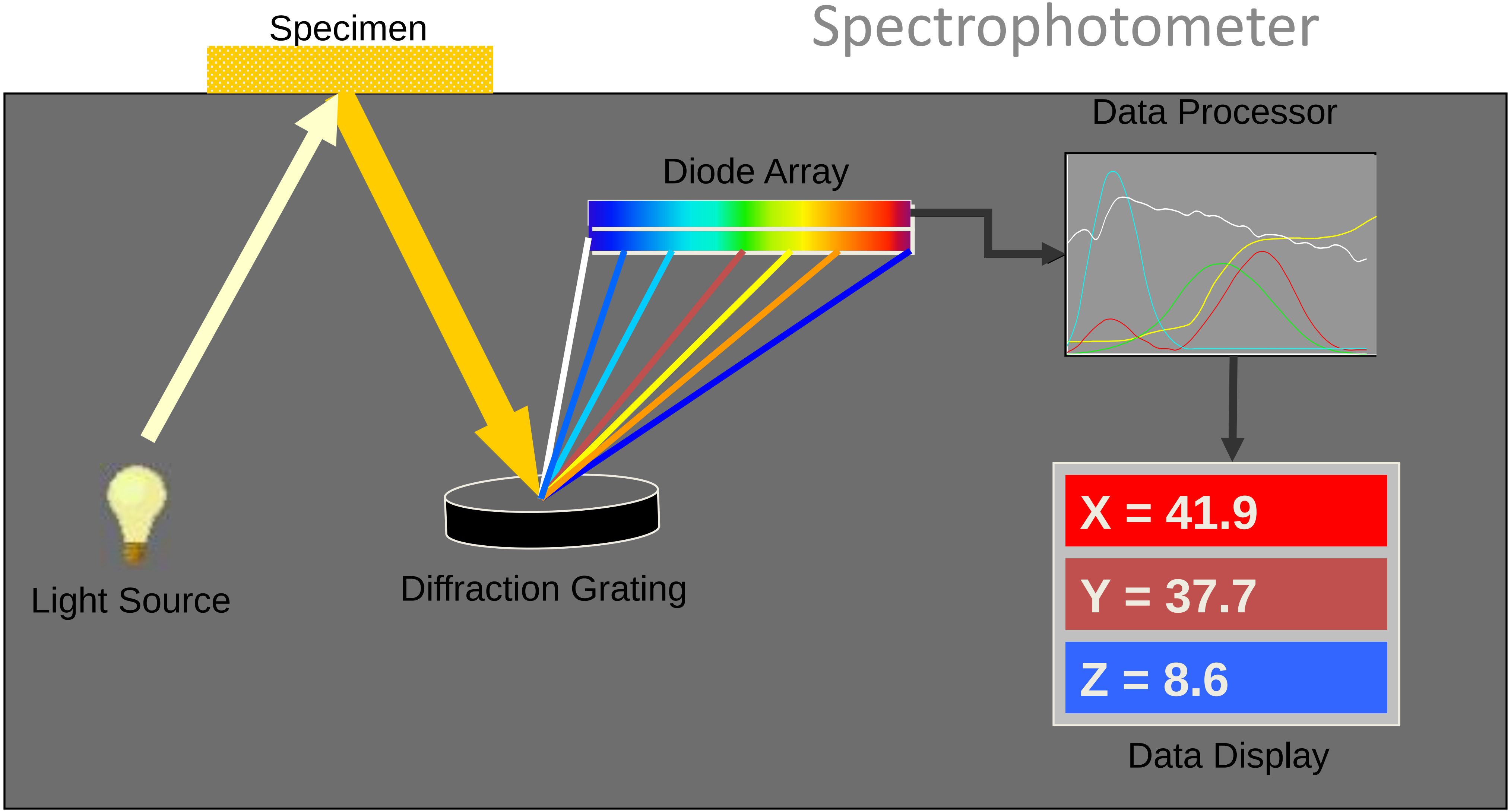
Some Colorimeter Systems

Measuring Color

- A **Colorimetric Spectrophotometer** or **Spectrophotometer** uses a light source to light the specimen being measured. The light reflected by the object then passes to a grating which breaks it into the spectrum. The spectrum falls onto a diode array which measures the amount of light at each wavelength. This spectral data is then sent to the processor where it is multiplied together with data table values for the selected CIE illuminant and the 2º or 10º standard observer functions to obtain the X, Y, Z values.

Measuring Color

Spectrophotometer



Some Spectrophotometer Systems

Color Scales

Visual Organization of Color

- Color has a degree of **Lightness** or **Value**
- **Hue** is the color from the rainbow or spectrum of colors.
- Colorant can be added to increase the amount of **Chroma** or **Saturation**.

Munsell Color System

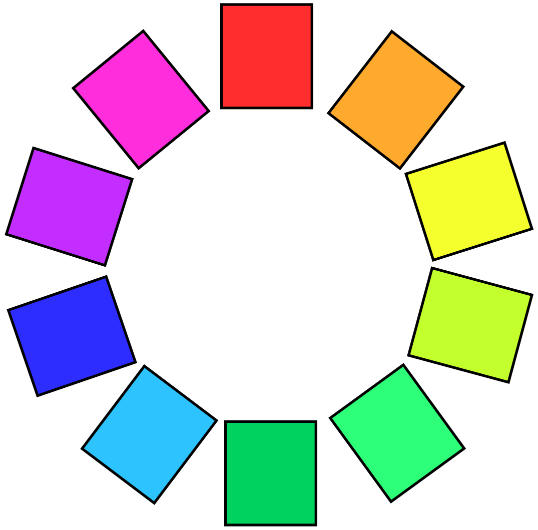
Color is “Hue”,
Lightness is “Value”
Saturation is “Chroma”

This is the word of color

Hue : “Red”, “yellow”, “green”, “blue”…
“Color” forms the color wheel.

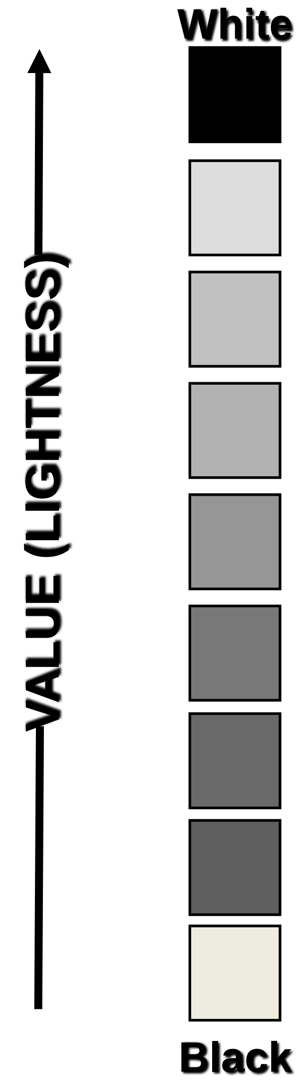
Apples are red,
Lemons are yellow,
Sky is blue-
that’s how we all perceive color in everyday language.

The term used to distinguish these red, yellow, and blue colors is called ***HUE***.



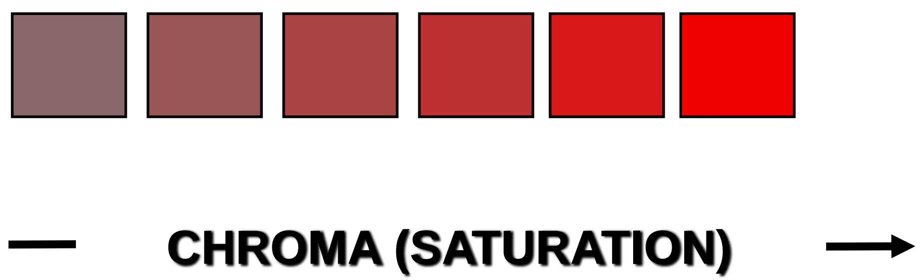
Value: Light colors, dark colors.
The “lightness” of colors changes vertically.

Colors can be separated into “light” and “dark” colors when their values are compared. Take for instance the yellow of a lemon and that of a grapefruit. Without a doubt, the lemon is yellow is much lighter. The lightness, which can be independently of color hue, is “value”.

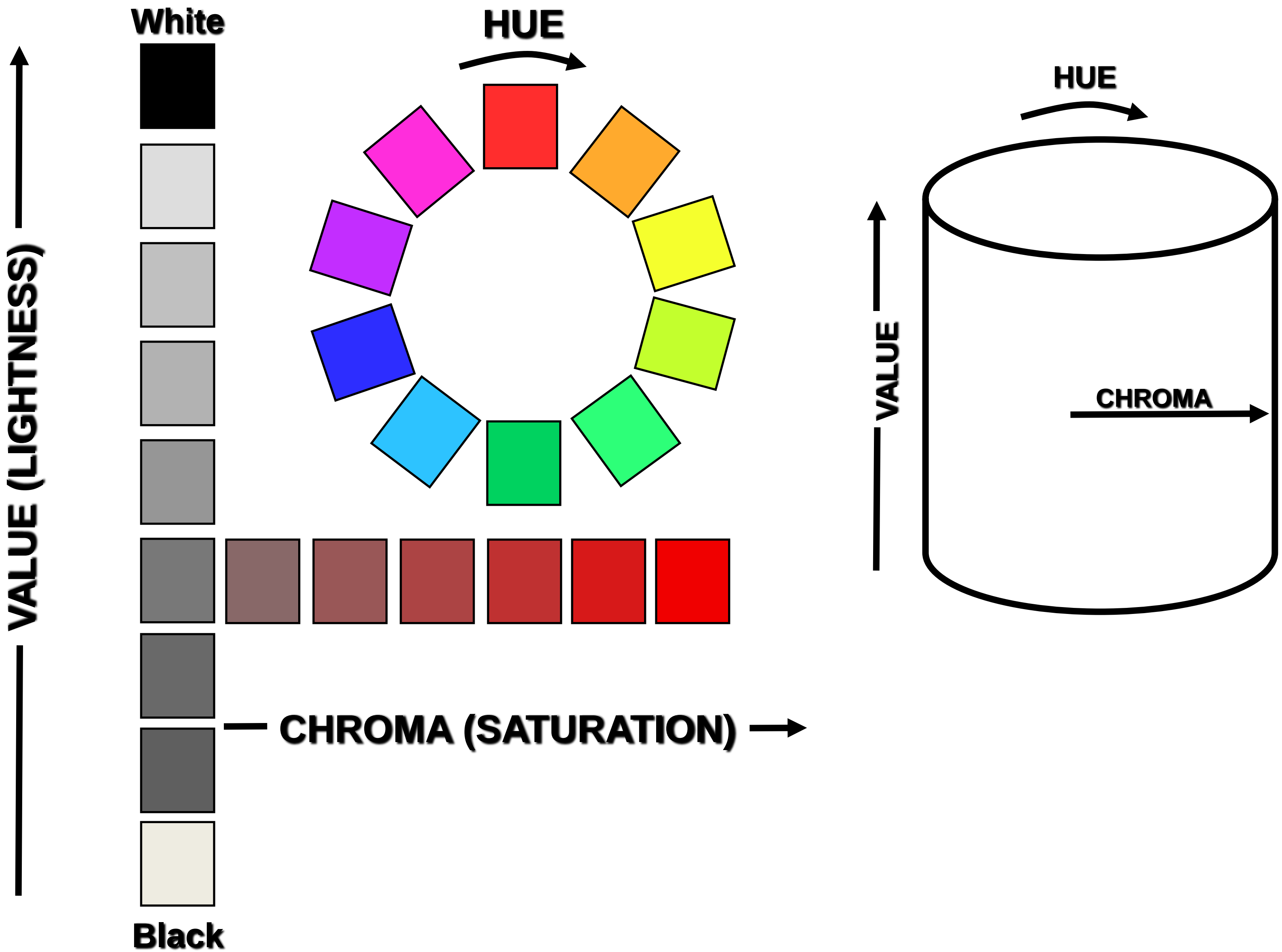


Chroma : Vivid colors, dull colors.
“Saturation” varies horizontally.

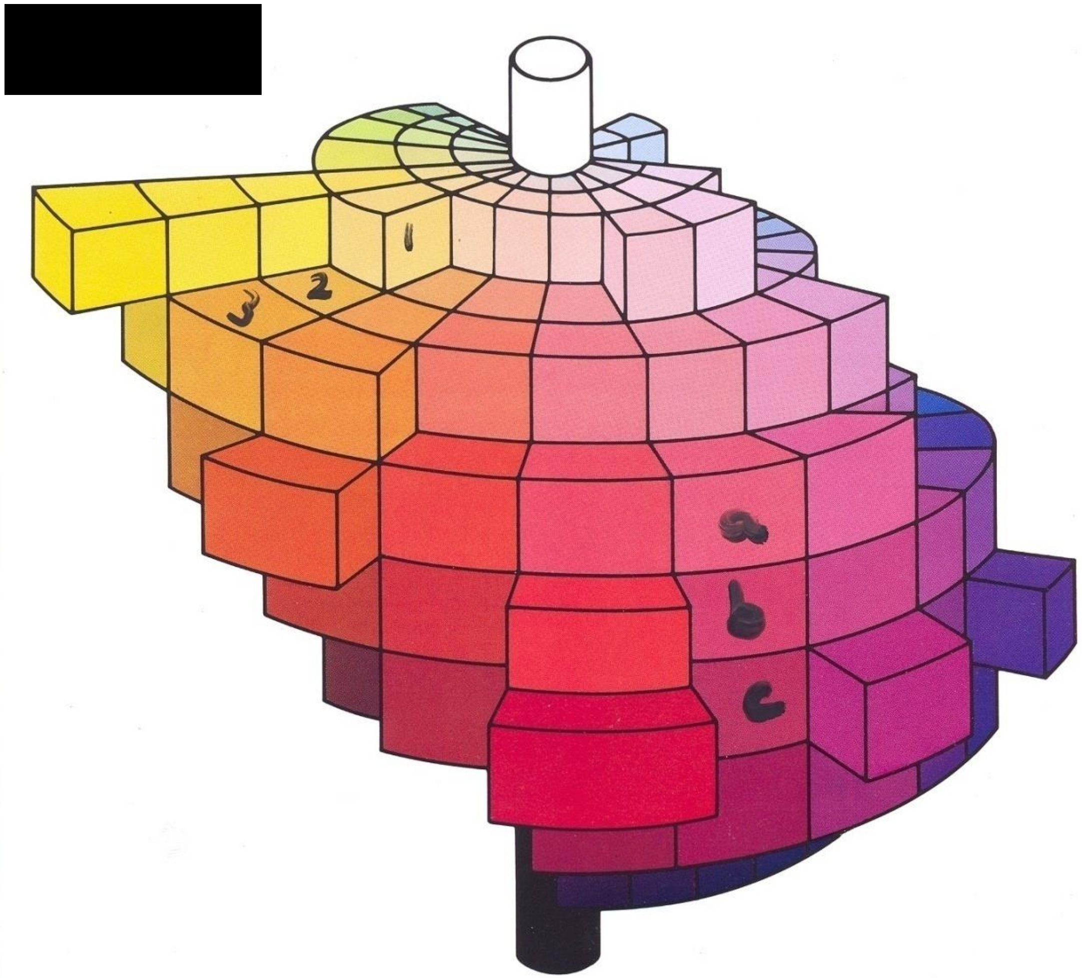
How do you compare the colors in a lemon and banana? You might say the lemon is “light”, “vivid” while that of banana is “dull”- another big difference, but this time one of color intensity, or strength. This third property of color that is distinguishable from both value and hue is called “chroma”.



Visual Organization of Color



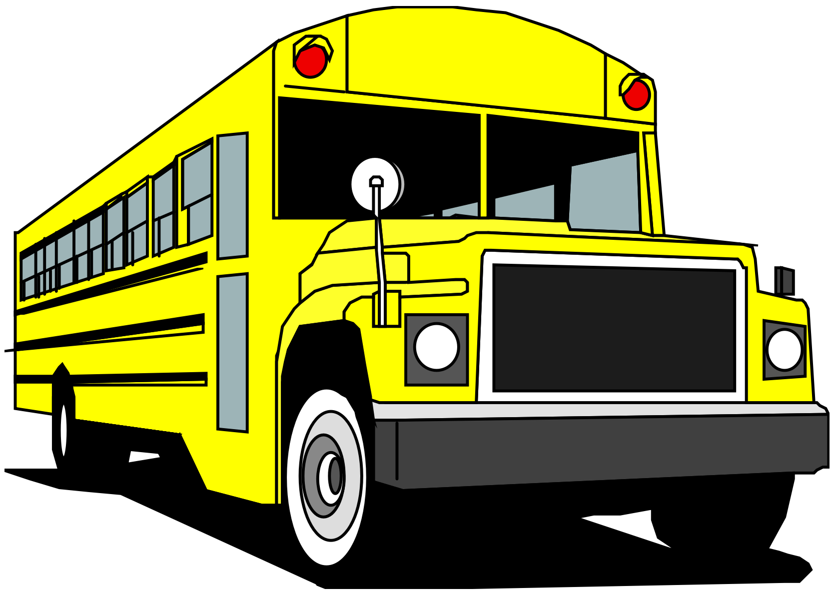
Three dimensional representation of color



Measured Color Values

- Visual methods of specifying color are **subjective**.
- Measuring color using an instrument gives **objective** results.

Measured Value of School Bus Yellow



X = 41.9

Y = 37.7

Z = 8.6

Color Scales

- Because XYZ values are not easily understood in terms of object color, other color scales have been developed to:
  - Relate better to how we perceive color
  - Simplify understanding
  - Improve communication of color differences
  - Be more linear throughout color space

HUNTER COLOR METER

- It has an advantages over spectrophotometric methods;
  - Relative inexpensive
  - Simple equipment
  - Well adapted to routine experiments

- Hunter Rd (Diffuse reflectance)
- Hunter L (Lightness)

} comparable Y of CIE or Value of Munsell

- Hunter a (Redness, greeness) → X,Y
- Hunter b (Yellowness, blueness) → Z, Y

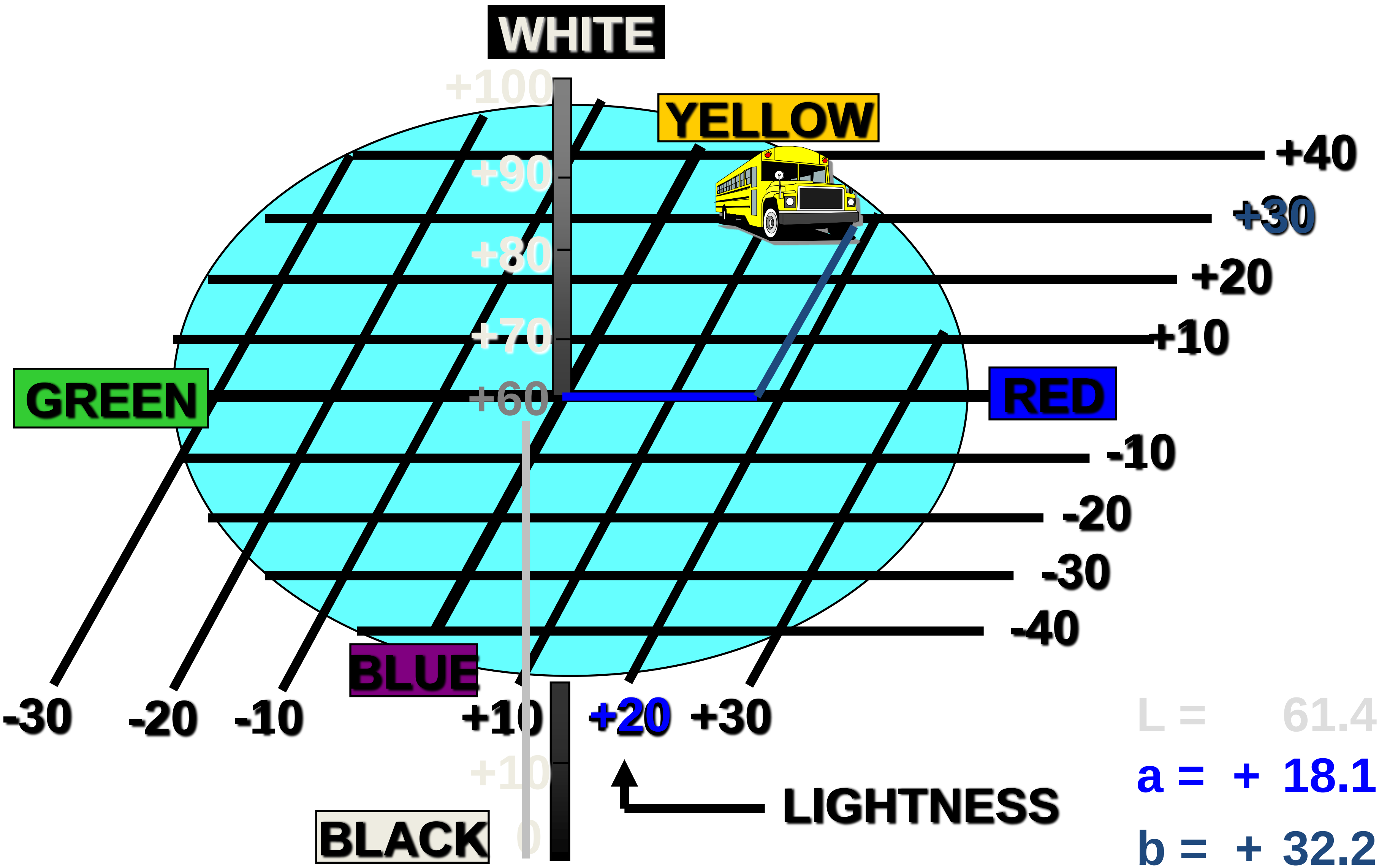
Hunter L,a,b Color Space

- The Hunter L,a,b color space is a 3-dimensional **rectangular** color space based on the opponent-colors theory.
  - **L** (lightness) axis - 0 is black, 100 is white
  - **a** (red-green) axis - positive values are red; negative values are green and 0 is neutral
  - **b** (blue-yellow) axis - positive values are yellow; negative values are blue and 0 is neutral

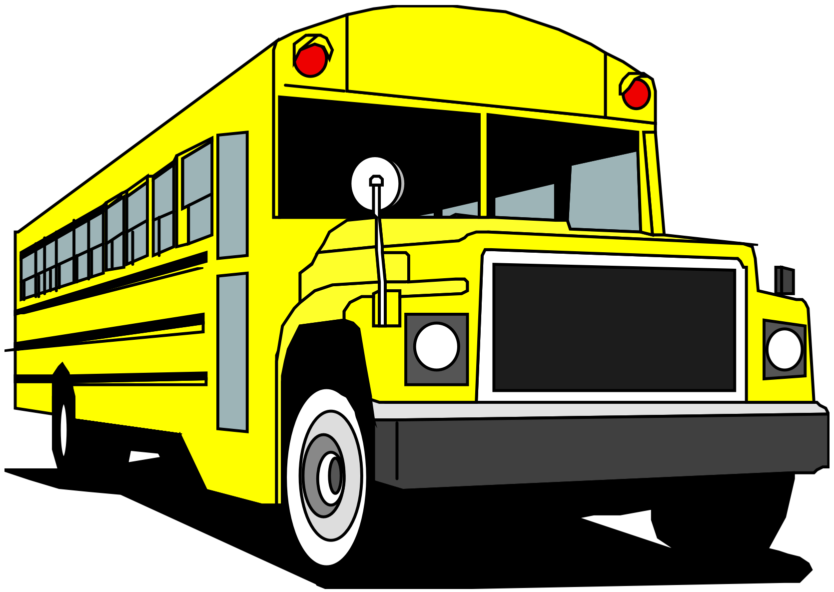
Hunter L,a,b Color Space

Hunter L,a,b Color Space

- All colors that can be visually perceived can be plotted in this L,a,b rectangular color space.
- The following slide shows where the “school bus yellow” falls in Hunter L,a,b color space.


WHITE
+100
+90
+80
+70
+60
YELLOW
+40
+30
+20
+10
GREEN
RED
-10
-20
-30
-40
BLUE
-30
-20
-10
+10
+20
+30
+10
BLACK
0
LIGHTNESS
L = 61.4
a = + 18.1
b = + 32.2

Hunter L,a,b Values for School Bus Yellow



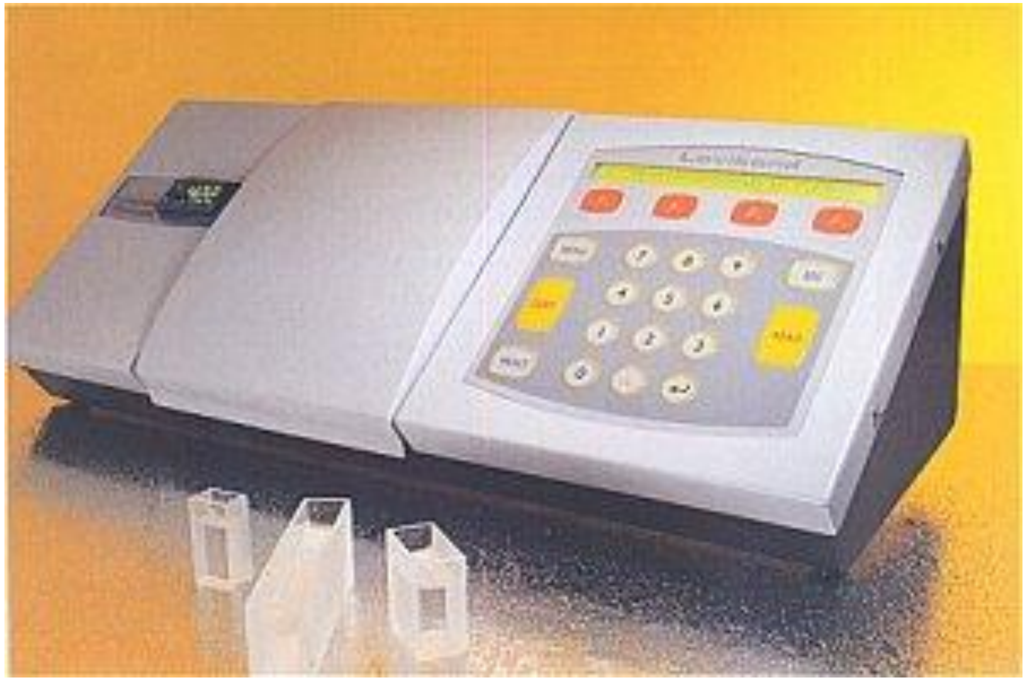
L = 61.4

a = + 18.1

b = + 32.2

LOVIBOND TINTOMETER

- Used in oil industry
- Has red, blue, yellow filters with numbers
- Color of oils is measured with transmitted light



What is an Acceptable Color Difference?

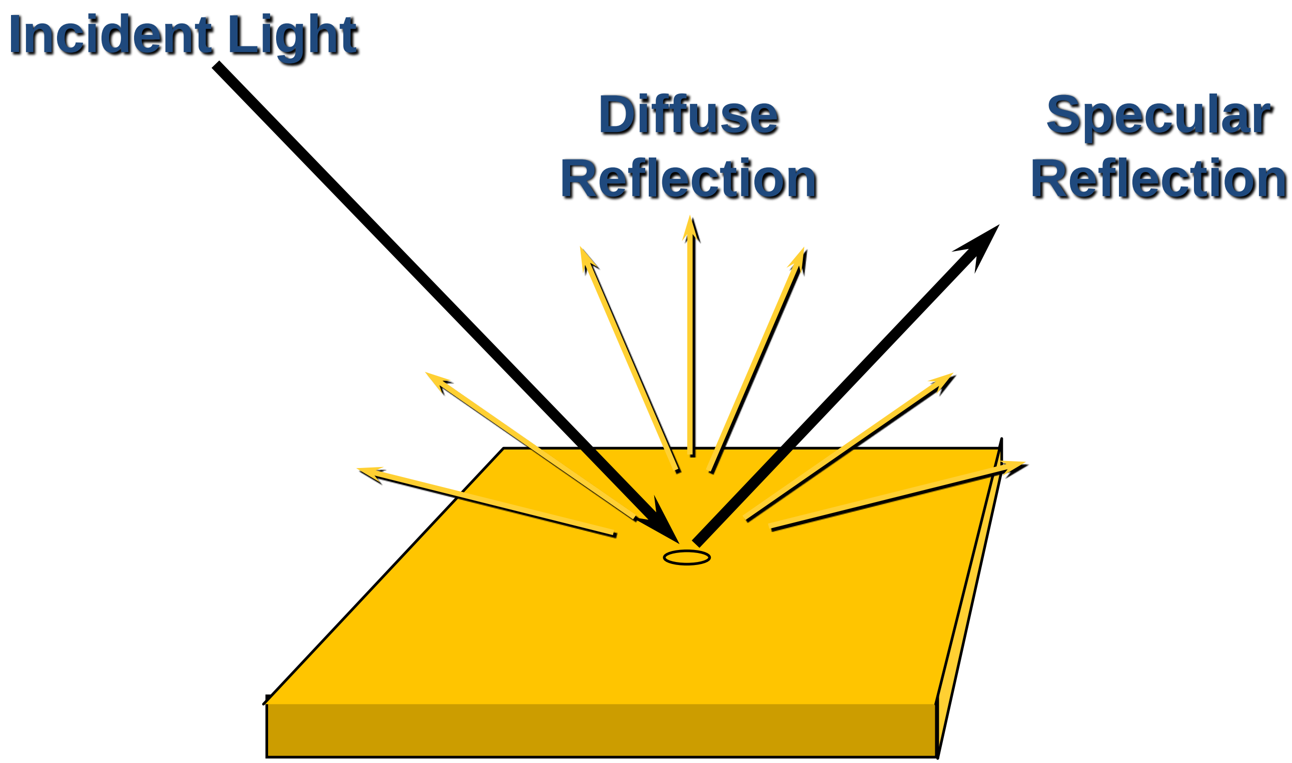
Maximum Acceptable

Minimum Perceptible

Reflectance of Light

- For opaque materials most of the incident light is reflected. Color is seen in the diffuse reflection and gloss is seen in the specular reflection. The reflection at the specular angle is generally the greatest amount of light reflected at any single angle. However specular reflection only represents less than 4% of the total reflected light. The remaining reflection is in the diffuse reflection.

Reflectance of Light



Sample Preparation and Presentation

Ideal Sample For Color Measurement

- Flat
- Smooth
- Uniform
- Non-directional
- Opaque or transparent

Sample Preparation and Presentation

- Choose samples that are representative of the product.
- Prepare the sample in a way to best approximate the ideal sample characteristics.
- Prepare samples in the same way each time.
- Present the samples to the instrument in a repeatable manner.
- Make multiple preparations of the sample and average measurements.

Some Examples of Preparation and Presentation