Introduction to Multimedia Technology (MM301)

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Lecture Rules

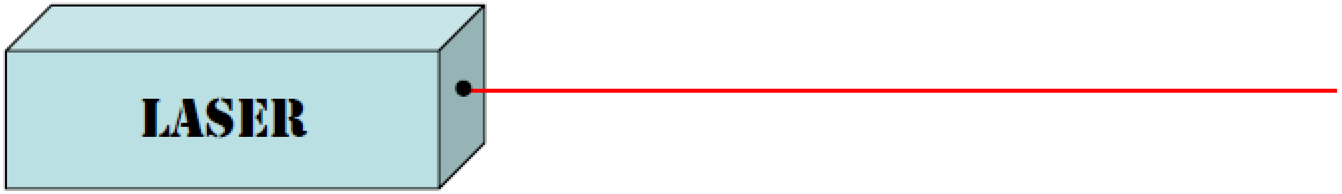
- Cellular phones' OFF
- No side talking
- No more than 10 min. delay

Outline

- Properties of Light
- Color Models in Images
  - RGB
  - CYM
  - YIQ
- Color Models in Video
  - YUV
  - YCbCr
- Colors Applications

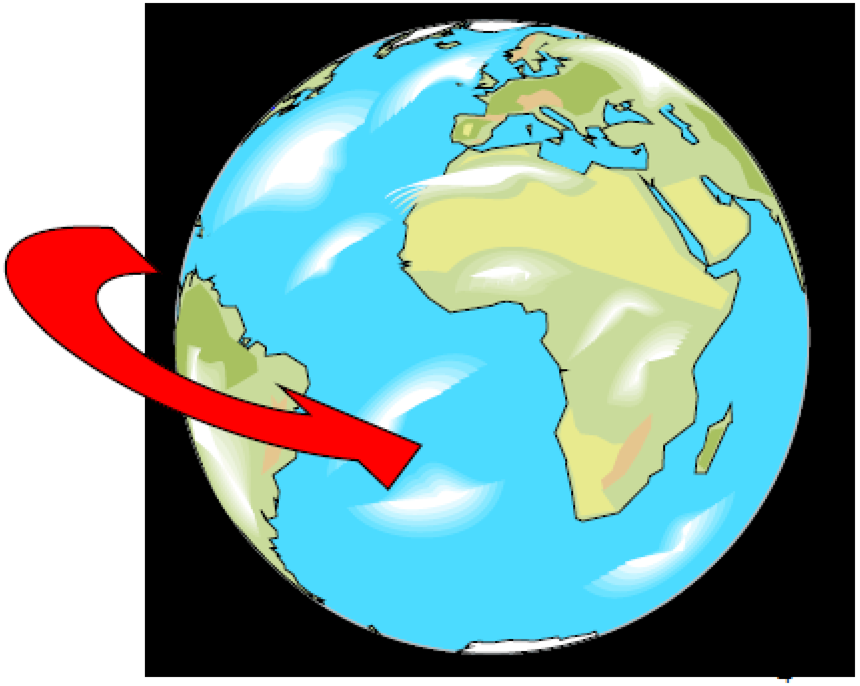
Properties of Light

- Light travels in straight lines:



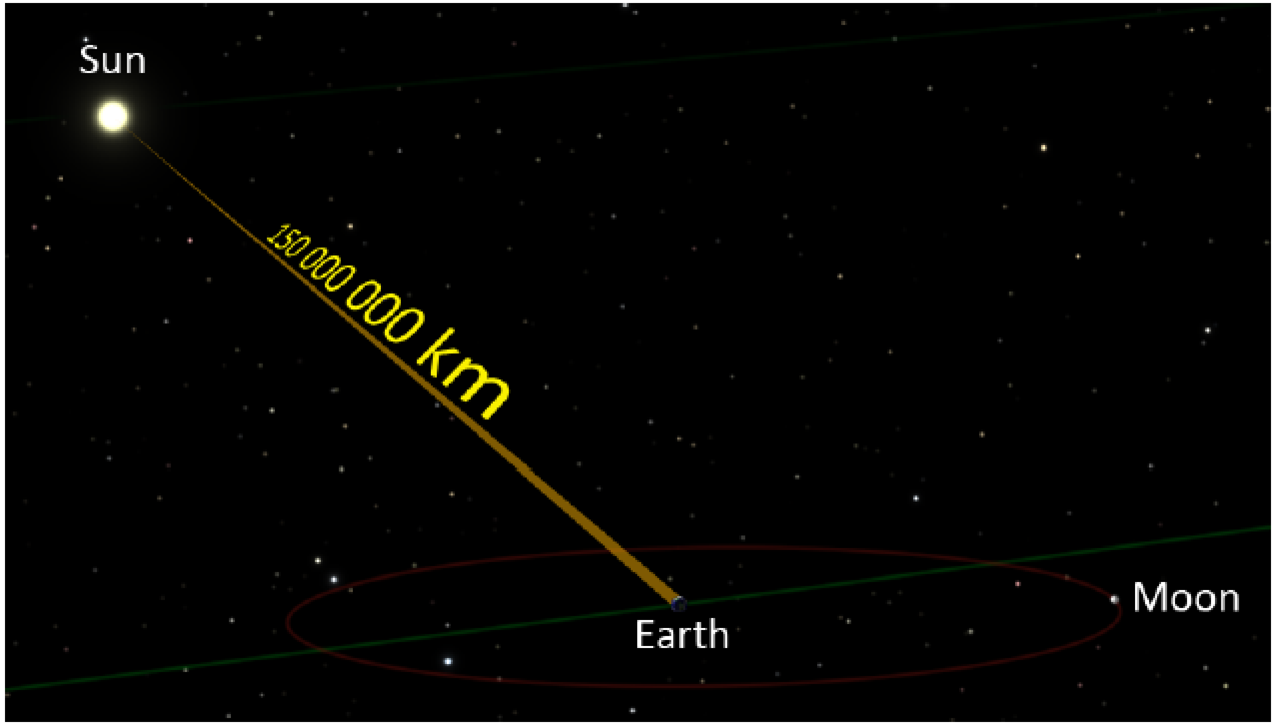
Properties of Light

- Light travels VERY FAST – around 300,000 kilometres per second.
- At this speed it can go around the world 8 times in one second.



Properties of Light

- Sunlight takes about 8 minutes 17 seconds to travel the average distance from the surface of the Sun to the Earth.

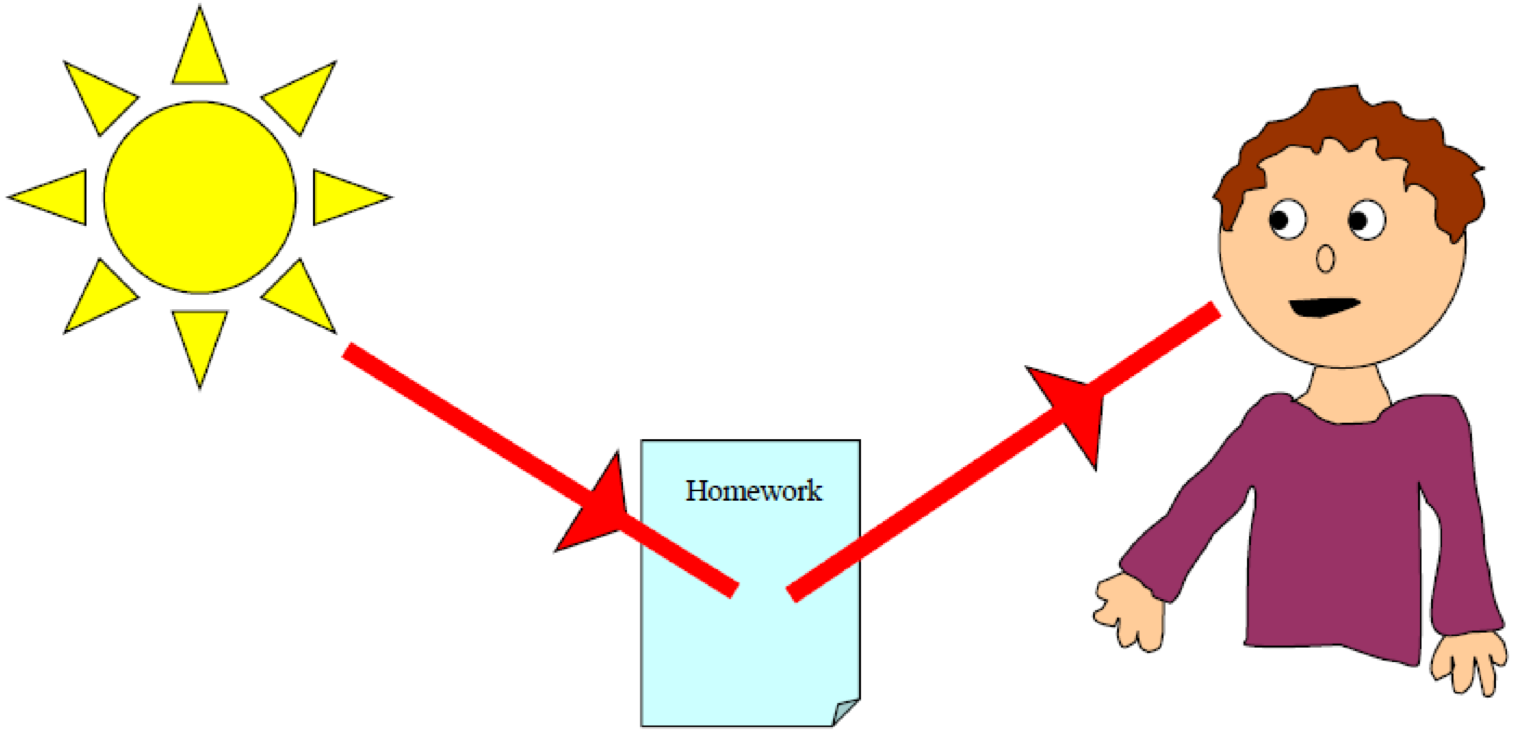


Properties of Light

- Thunder and lightning start at the same time, but we will see the lightning first.

- When a starting pistol is fired we see the smoke first and then hear the bang.

We see things because they reflect light into our eyes:

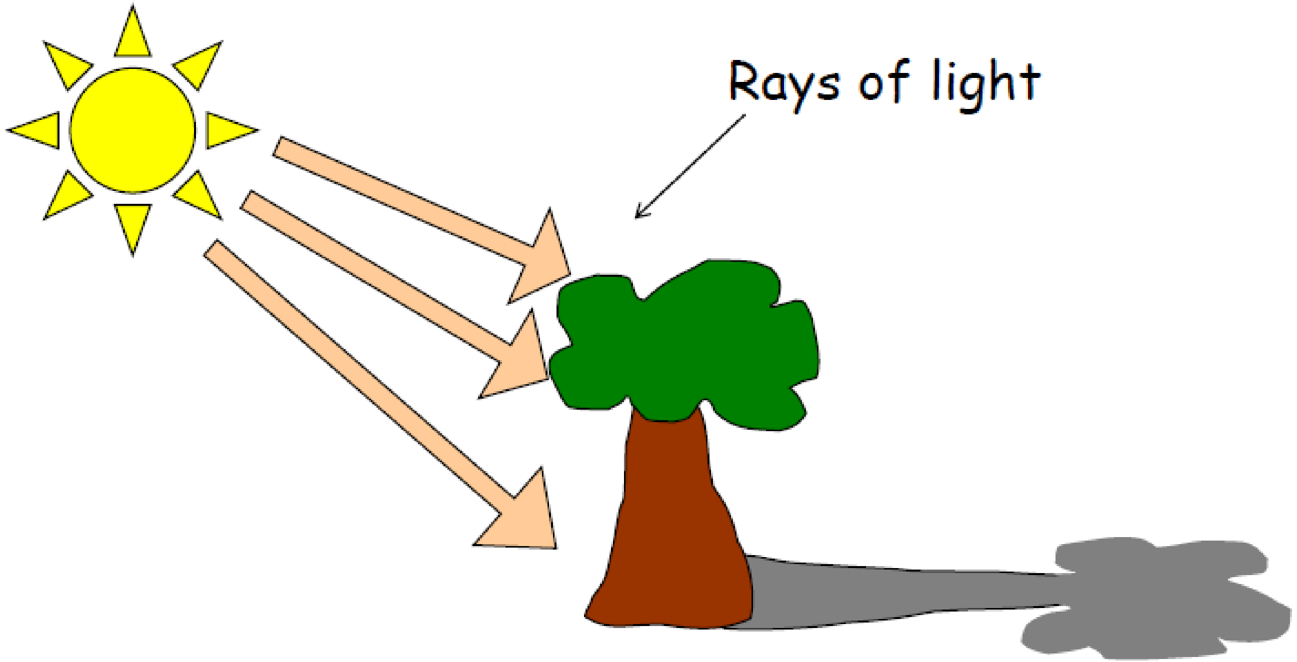


Luminous and non-luminous objects

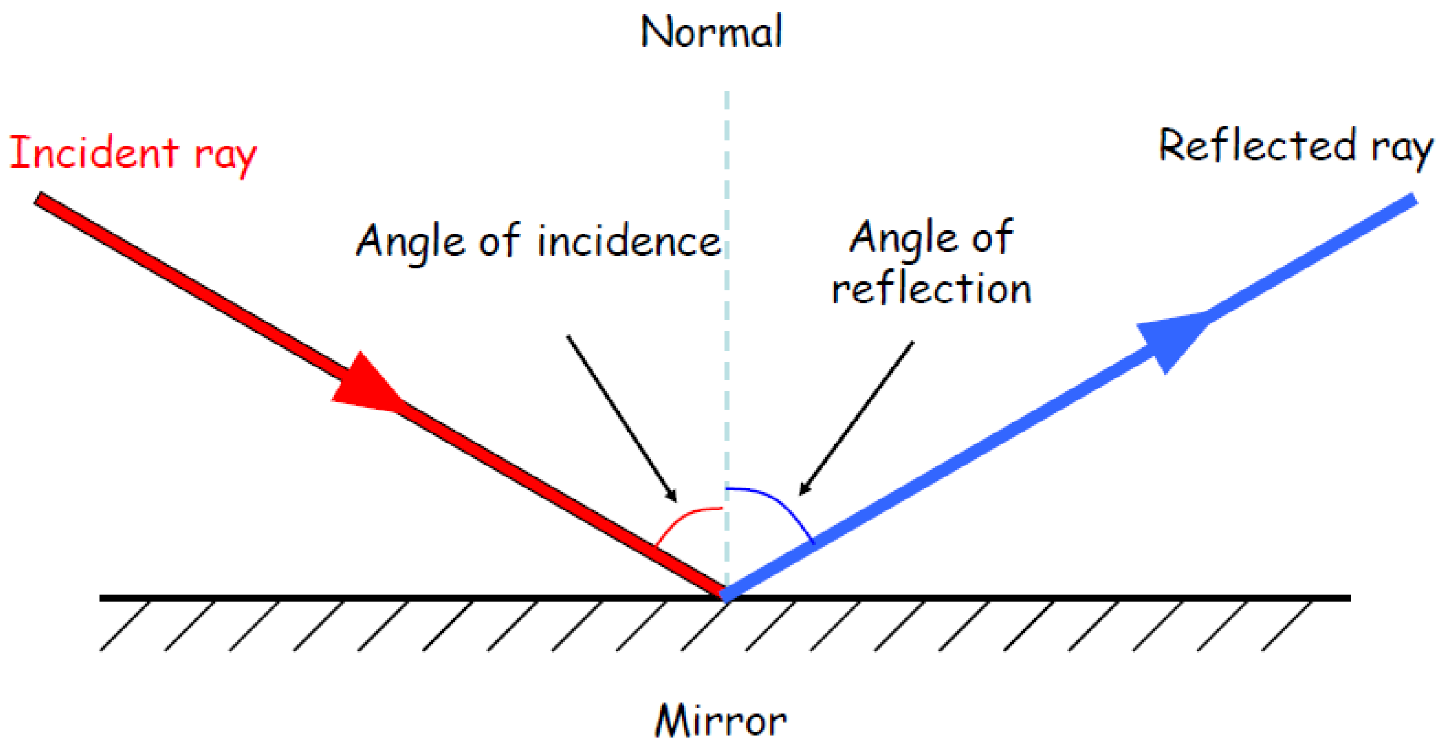
- A **luminous object** is one that produces light.(sun)
- A **non-luminous** object is one that reflects light.

Shadows

- Shadows are places where light is “blocked”: darken area where lights fall on opaque object



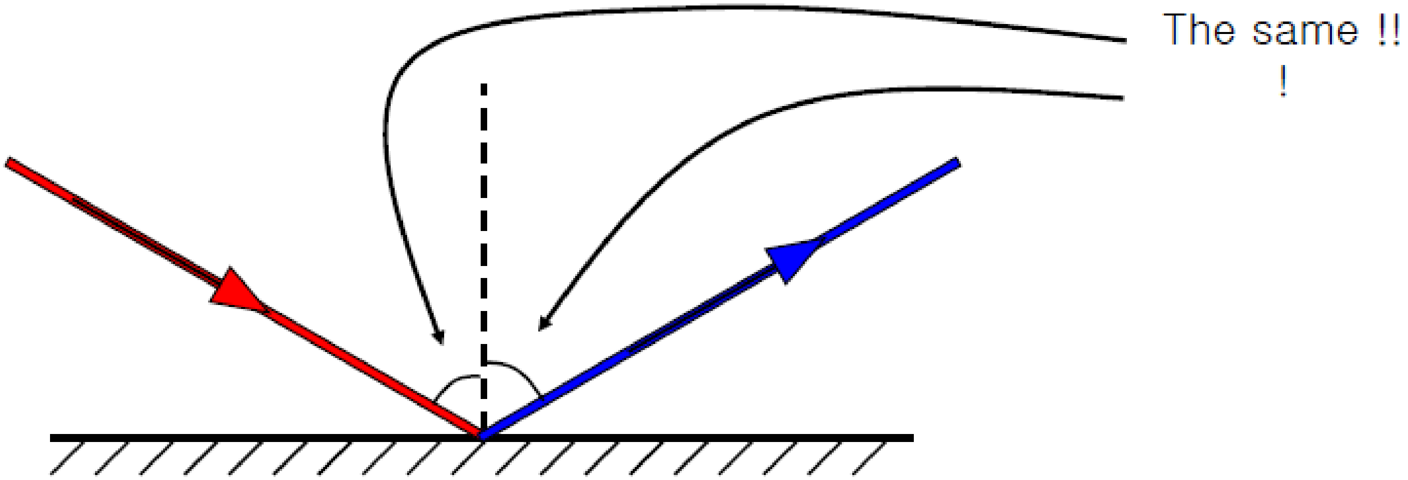
Reflection: (Clear-Regular Reflection from a mirror)



The Law of Reflection

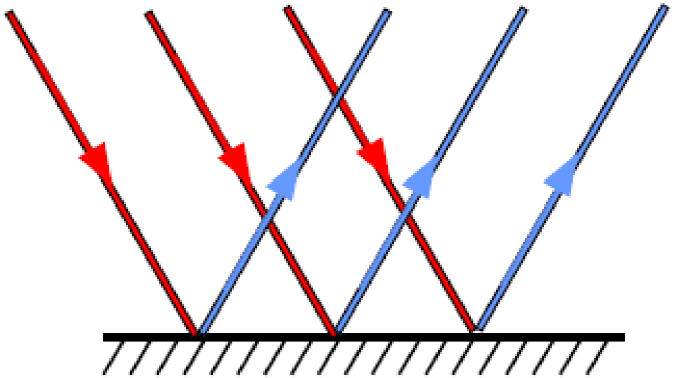
Angle of incidence = Angle of reflection

In other words, light gets reflected from a surface at angle it hits it.

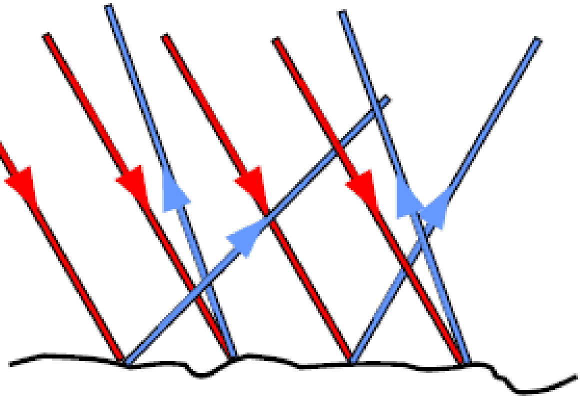


Clear-Regular vs. Diffuse-Unregularly Reflection

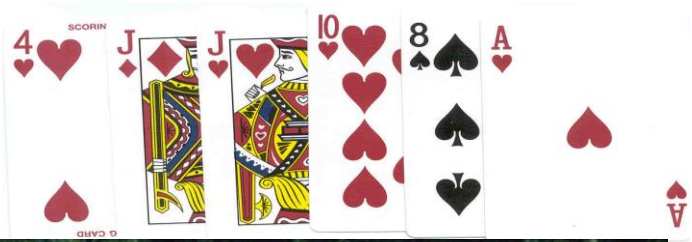
- Smooth, shiny surfaces have a clear reflection:

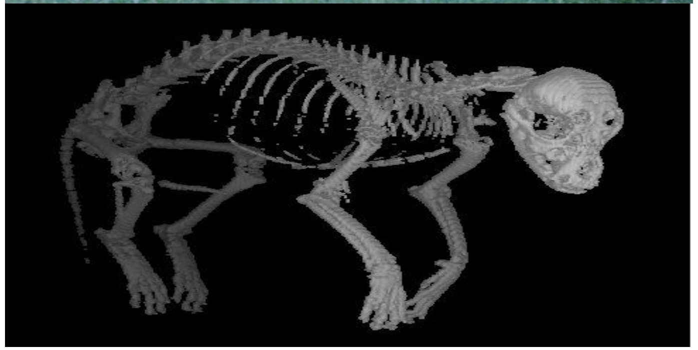


- Rough, dull surfaces have a diffuse reflection.
- Diffuse reflection is when light is scattered in different directions



Color



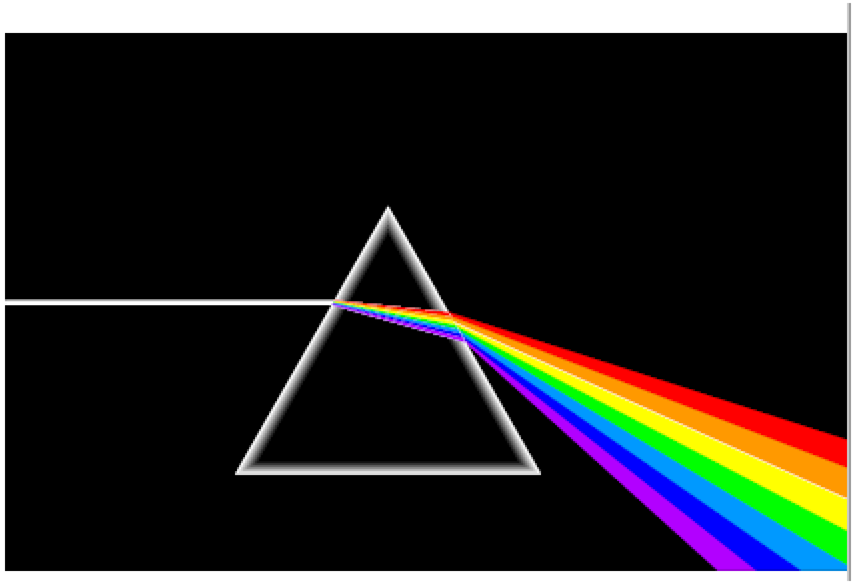


- Used heavily in human vision
- Color is a pixel property, making some recognition problems easy
- Visible spectrum for humans is 400nm (blue) to 700 nm (red)
- Machines can “see” much more; ex. X-rays, infrared, radio waves

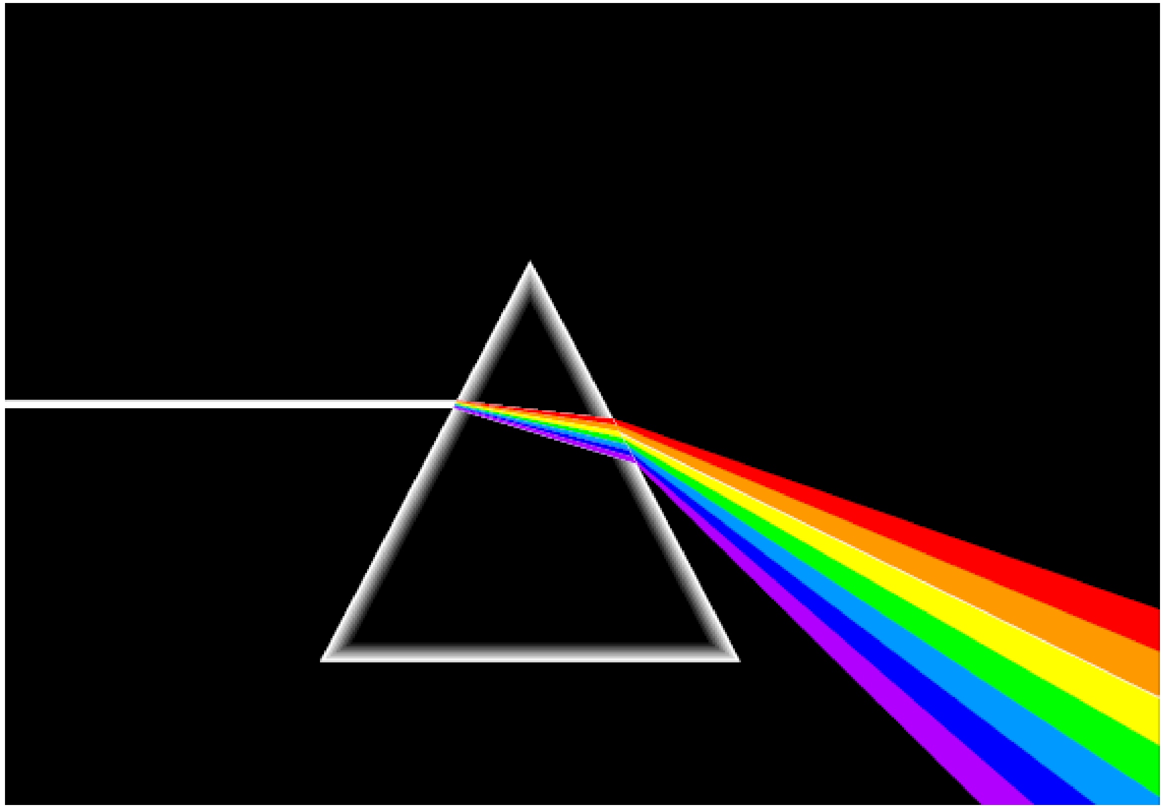
Color

- White light is not a single color; it is made up of a mixture of the seven colours of the rainbow.

- We can demonstrate this by splitting white light with a prism:



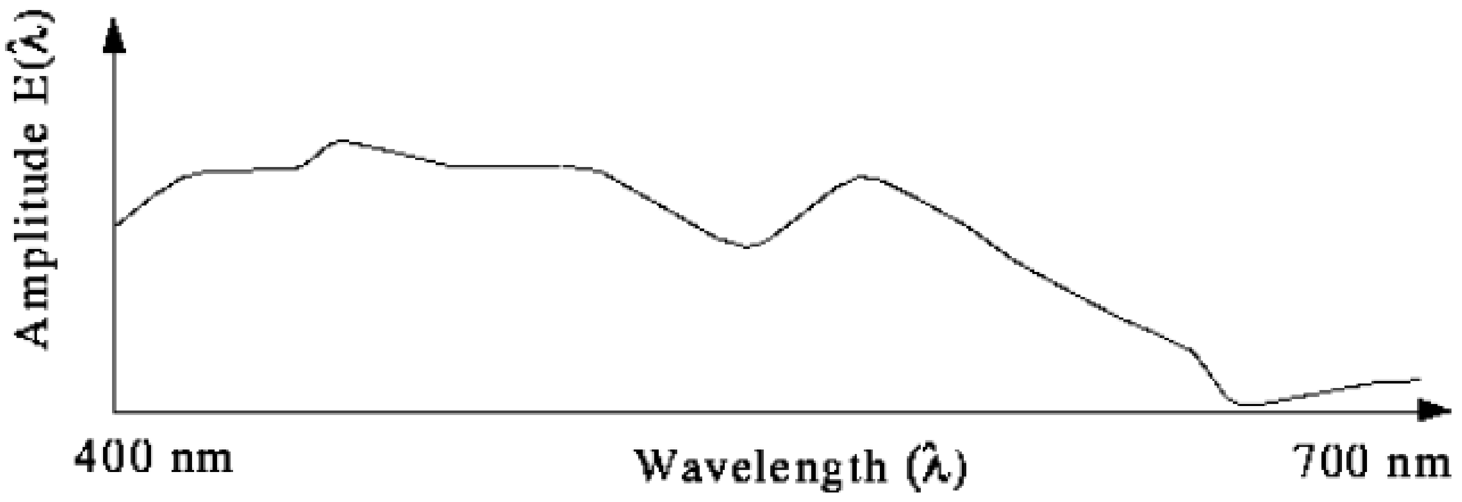
The colors of the rainbow:



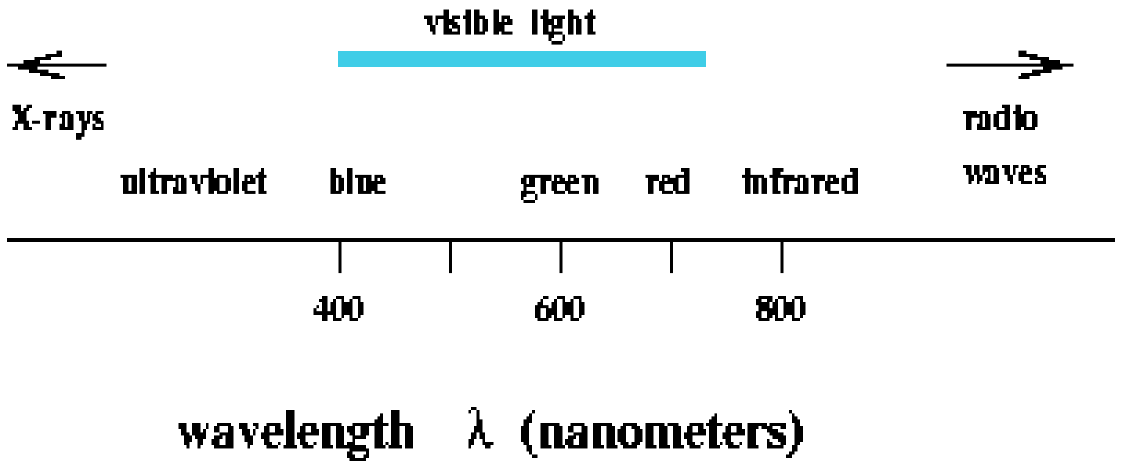
- Red
- Orange
- Yellow
- Green
- Blue
- Indigo
- Violet

The colors of the rainbow:

Light and Spectra Visible light is an electromagnetic wave in the 400 nm - 700 nm (nanometres) range. Most light we see is not one wavelength, it's a combination of many wavelengths.



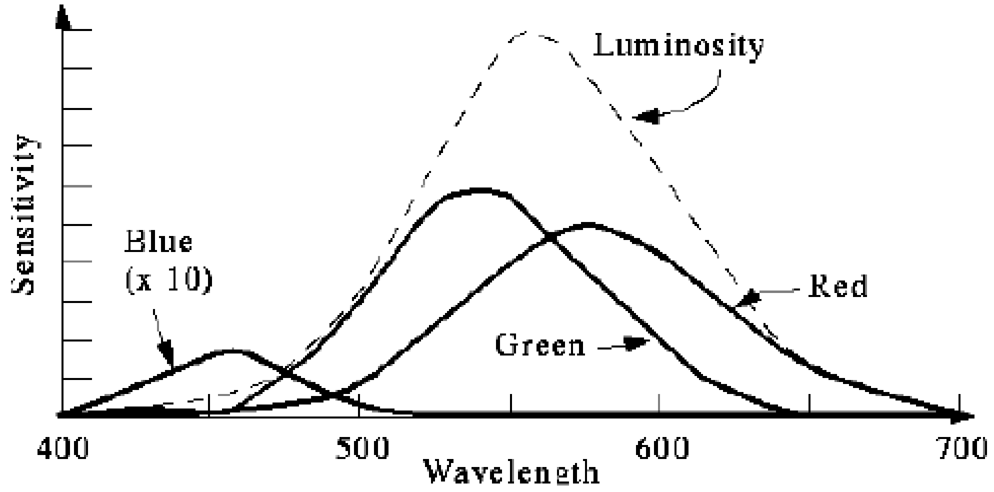
Some physics of color



- White light is composed of all visible frequencies (400-700)
- Ultraviolet and X-rays are of much smaller wavelength
- Infrared and radio waves are of much longer wavelength

The colors of the rainbow:

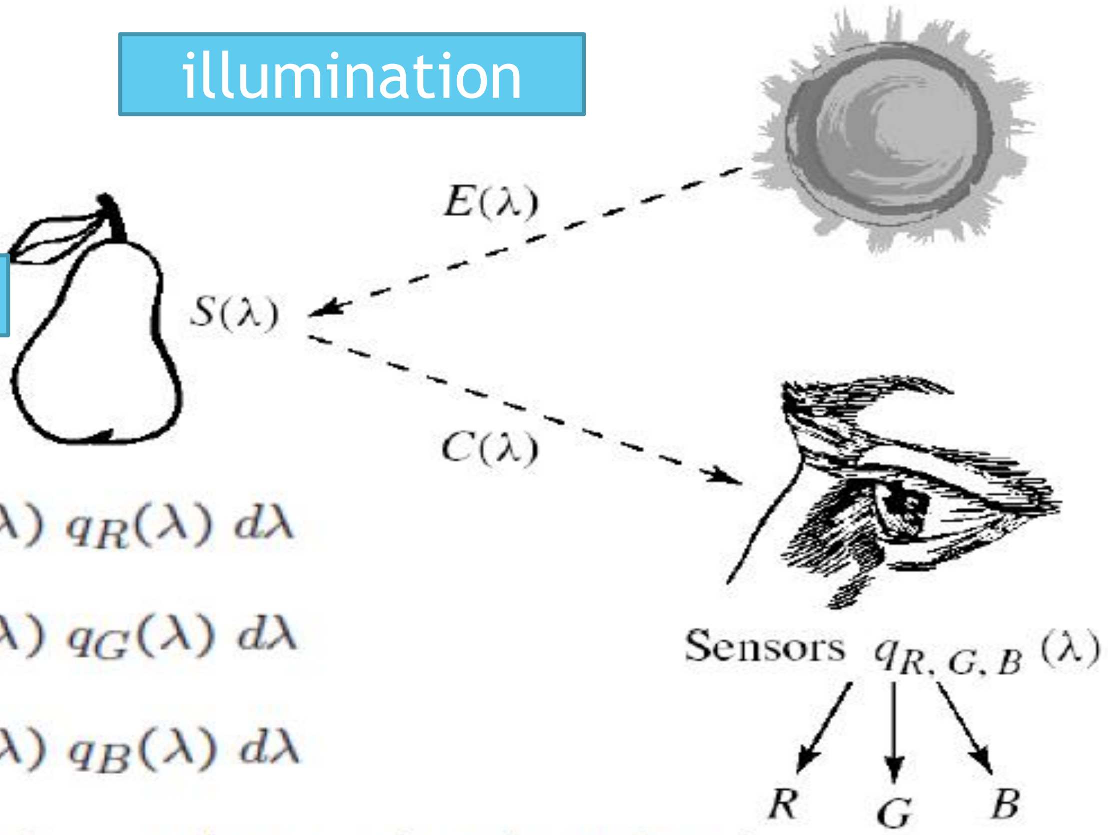
- The Human Retina
  - The eye is basically just a camera
  - The retina contains two types of photoreceptors, rods (120 million) and cones (6-7 million).
  - The rods are not sensitive to color. The cones provide the eye's color sensitivity
- Cones and Perception



The colors of the rainbow:

illumination

Reflection



$$R = \int E(\lambda)\, S(\lambda)\, q_R(\lambda)\, d\lambda$$

$$G = \int E(\lambda)\, S(\lambda)\, q_G(\lambda)\, d\lambda$$

$$B = \int E(\lambda)\, S(\lambda)\, q_B(\lambda)\, d\lambda$$

where E is the light (spectral power distribution) and S are the spectral sensitivity functions.

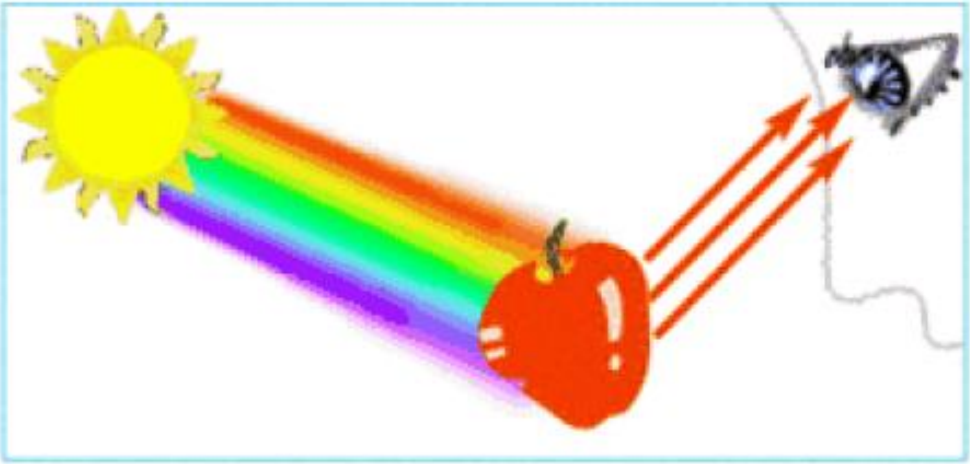
Factors that Affect Perception

- Light: the spectrum of energy that illuminates the object surface
- Reflectance: ratio of reflected light to incoming light
- Specularity: highly specular (shiny) vs. matte surface
- Distance: distance to the light source
- Angle: angle between surface normal and light source
- Sensitivity how sensitive is the sensor

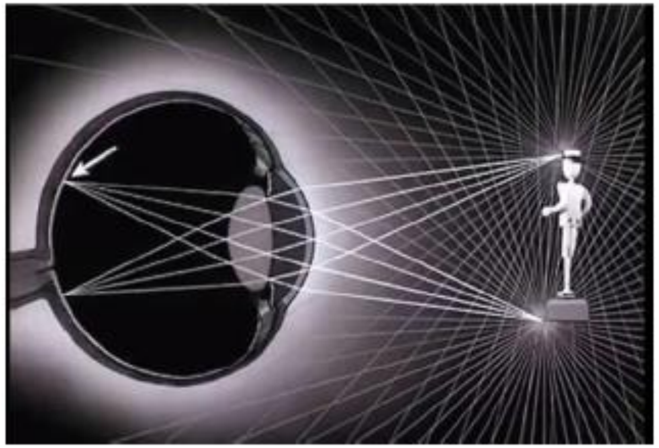
The colors of the rainbow:

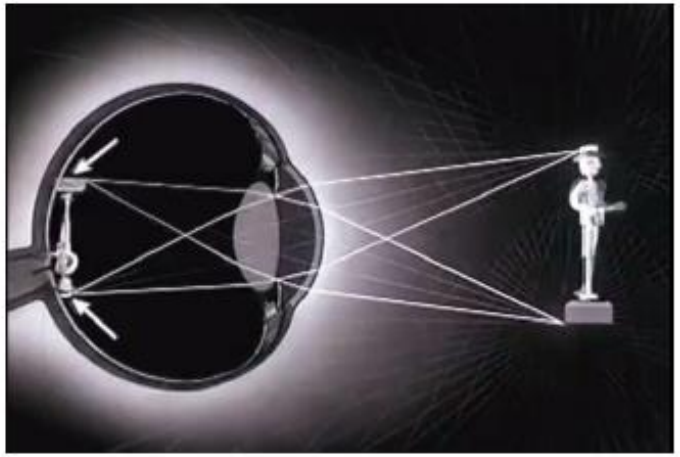
– The function $C(\lambda)$ is called the *color signal* and consists of the product of $E(\lambda)$, the illuminant, times $S(\lambda)$, the reflectance:

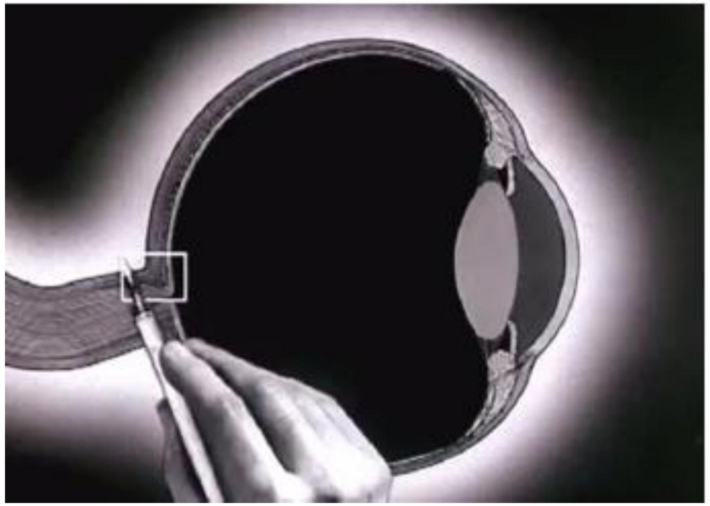
$$C(\lambda) = E(\lambda)\, S(\lambda).$$

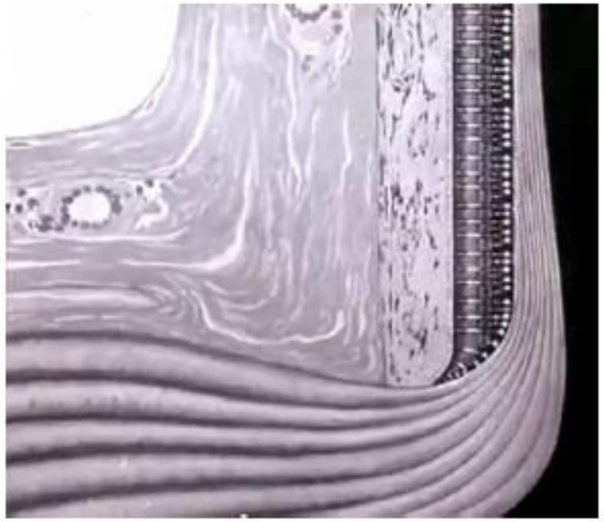


How we see things and colours



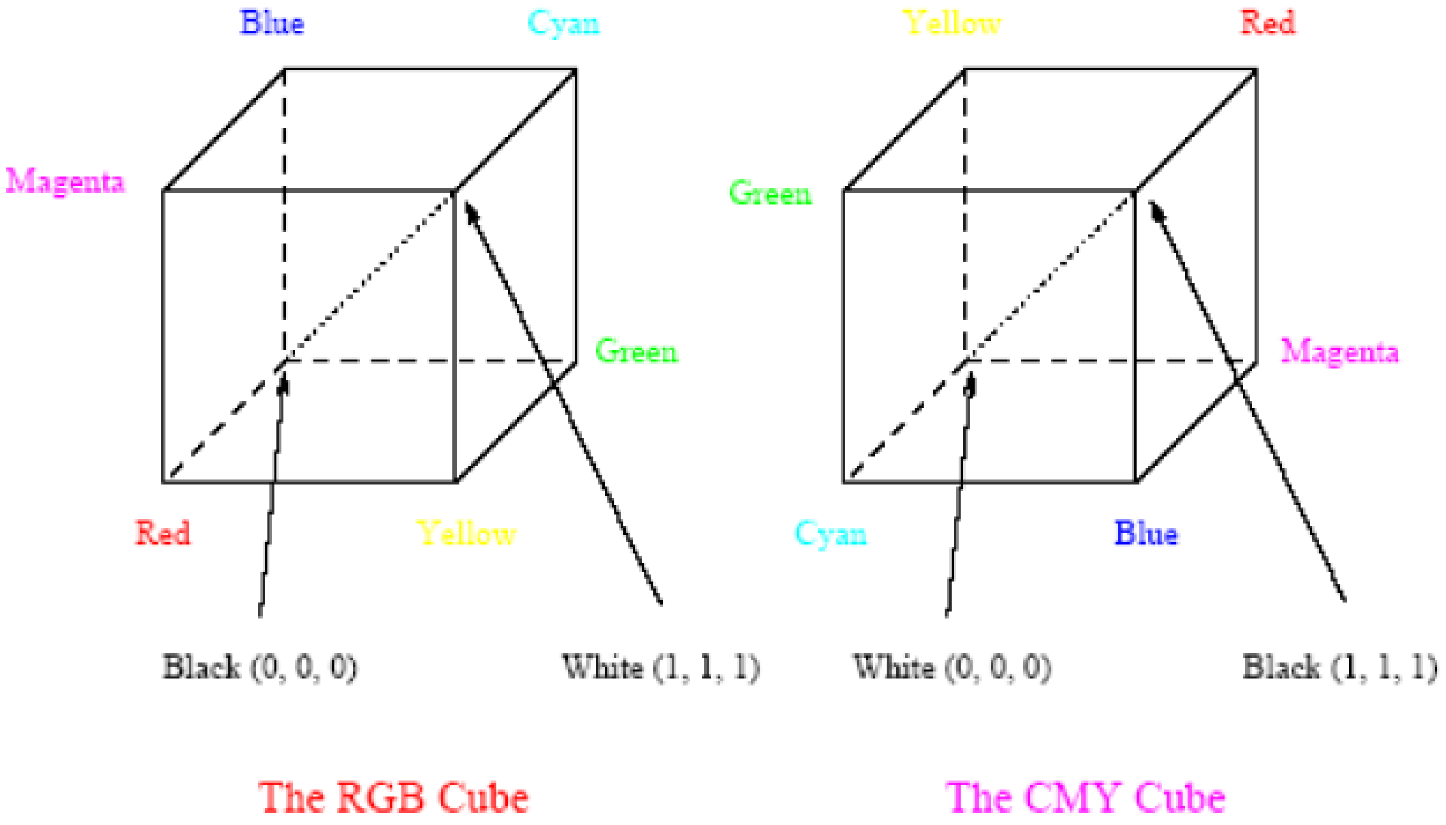






Reflected light ray are minimized and Inverted

Color Models in Images

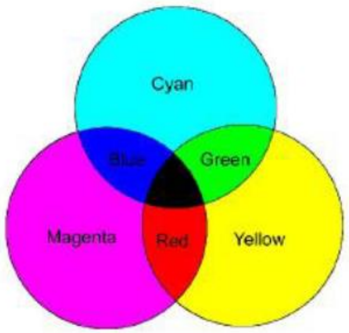


RGB and CMY color cubes

Additive and Subtractive Color

- **Additive color**:
  When two light beams impinge on a target,
  their colors add.
  When two phosphors on a CRT screen are turned on,
  their colors add. (red + green = yellow)

- **Subtractive color**:
  For ink on paper, the opposite situation holds:
  yellow ink *subtracts* blue from white illumination,
  but reflects red and green; it appears yellow.
  (white - blue = yellow)



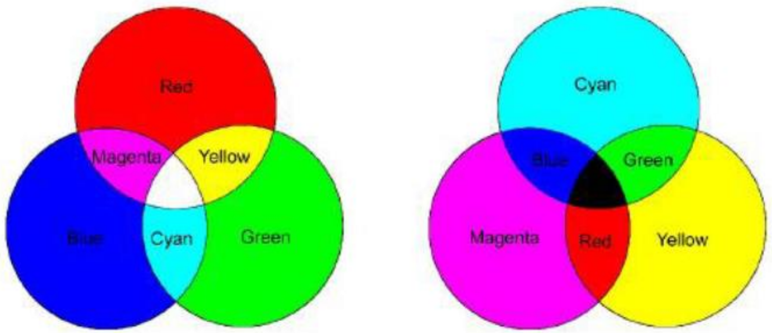
Additive and subtractive color.
(a): RGB is used to specify additive color.
(b): CMY is used to specify subtractive color

Subtractive Color: CMY Color Model

- Instead of red, green, and blue primaries, we need primaries that amount to -red, -green, and -blue. I.e., we need to *subtract* R, or G, or B from White (W).

- These subtractive color primaries are Cyan (C), Magenta (M) and Yellow (Y) inks.

C = W - R, (0, 1, 1) = (1, 1, 1) - (1, 0, 0)
M = W - G, (1, 0, 1) = (1, 1, 1) - (0, 1, 0)
Y = W - B, (1, 1, 0) = (1, 1, 1) - (0, 0, 1)



Additive and subtractive color.
(a): RGB is used to specify additive color.
(b): CMY is used to specify subtractive color

Transformation from RGB to CMY

- Simplest model we can invent to specify what ink density to lay down on paper, to make a certain desired RGB color:

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- Then the inverse transform is:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$

CMYK System

- **Sharper and cheaper printer colors:**
- Calculate that part of the CMYmix that would be black, remove it from the color proportions, and add it back as real black (K).
- when equal components of cyan, magenta, and yellow inks are mixed, the result is usually a dark brown, not black. Adding black ink to the mix solves this problem.

CMYK System

Why are RGB inks not used when printing?

- the paper is already White(which is a mix of all other base colors), so it needs to 'turn off' some light components and 'leave on' those representing the desired color
- Monitors emit light, paper reflects light. When emitting light

The YIQ Color Model

- This is used for color TV. Here is the luminance (the only component necessary for B&W-TV). The conversion from RGB to YIQ is given by

$$\begin{pmatrix} Y \\ I \\ Q \end{pmatrix} = \begin{pmatrix} 0.30 & 0.59 & 0.11 \\ 0.60 & -0.28 & -0.32 \\ 0.21 & -0.52 & 0.31 \end{pmatrix} \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

- The chrominance information is contained in the *I*(orange-blue) and *Q*(purple-green) axes, which are roughly orthogonal.

Conversion from RGB to YIQ

- An approximate linear transformation from RGB to YIQ is

$$
\begin{array}{rcl}
luminance \quad Y & = & 0.30R + 0.59G + 0.11B \\
R - cyan \quad I & = & 0.60R - 0.28G - 0.32B \\
magenta - green \quad Q & = & 0.21R - 0.52G + 0.31B
\end{array}
$$

We often use this for color to gray-tone conversion.

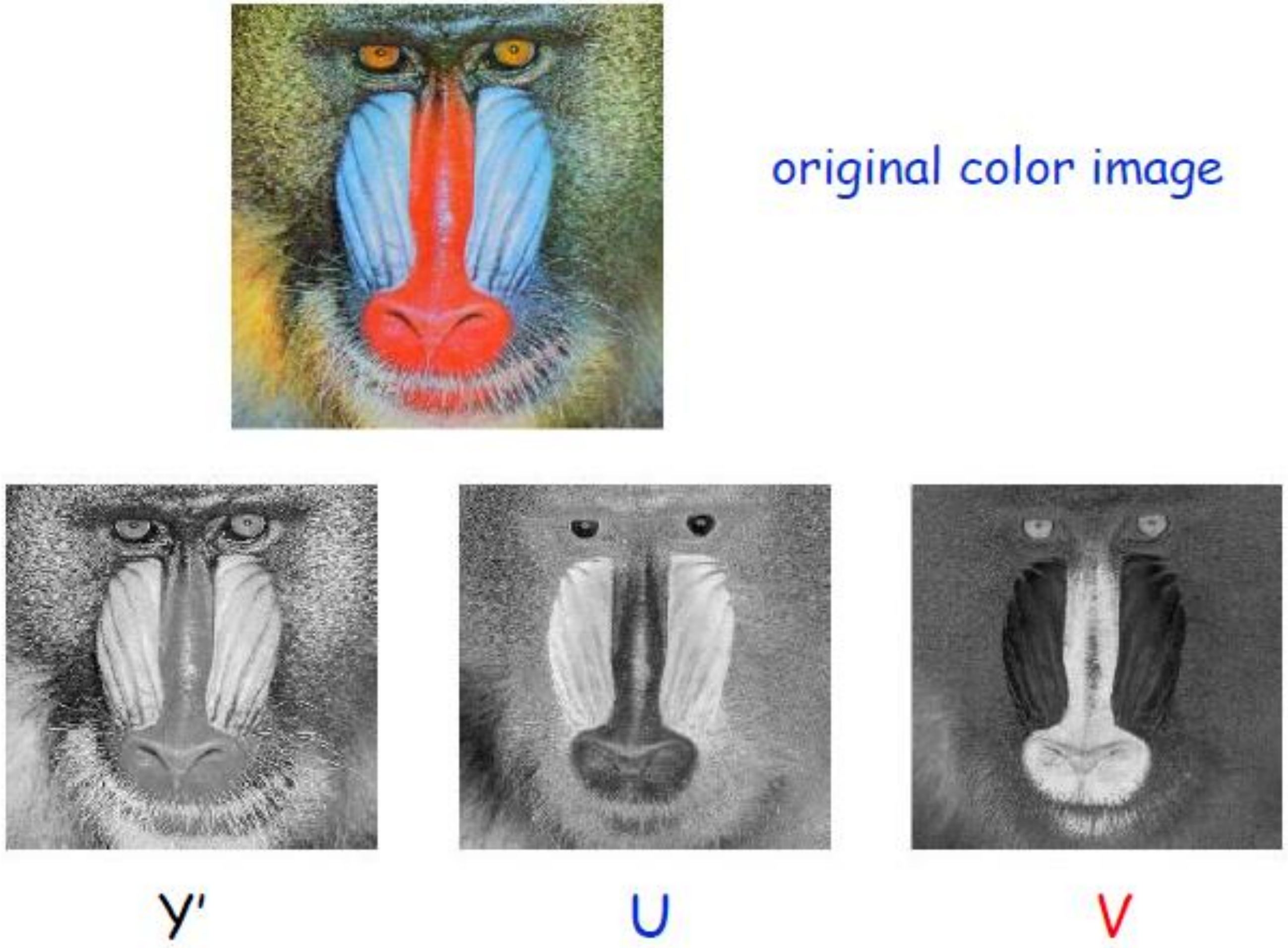
Color Models in Video

- Largely derive from older analog methods of coding color for TV.
  Luminance is separated from color information.
- YIQ is used to transmit TV signals in North America and Japan (NTSC).
- In Europe, video tape uses the PAL or SECAM(encoding system for analogue television),
  which are based on TV that uses a matrix transform called YUV.
- Digital video mostly uses a matrix transform called YCbCr that is closely related to YUV

YUV Color Model

- The color information is separated out into 2 channels –one for Blue information minus the brightness, and one for Red info minus the brightness.
- In this image, the Blue channel is showing *purple/yellow colors*, and the Red channel has more *red/cyan* colors in this particular image.
- Y stands for intensity. U stands for blue and V stands for red.

YUV Color Model



YUV Color Model

- YUV codes a luminance (luma) signal equal to Y'
  (for gamma-corrected signals)
- gamma-corrected is used to code and decode luminance

$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & -0.51499 & -0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.13983 \\ 1 & -0.39465 & -0.58060 \\ 1 & 2.03211 & 0 \end{bmatrix} \begin{bmatrix} Y' \\ U \\ V \end{bmatrix}$$

Gamma Correction

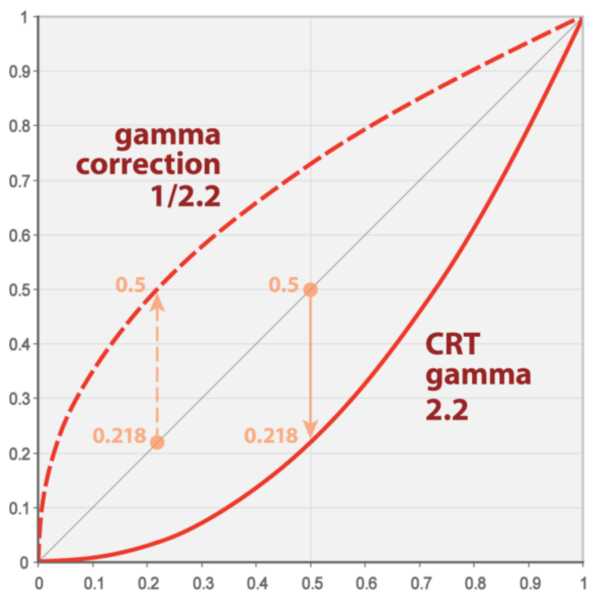
- Most display device’s brightness is not linearly related to the input.

$$I' = I^{\gamma}$$

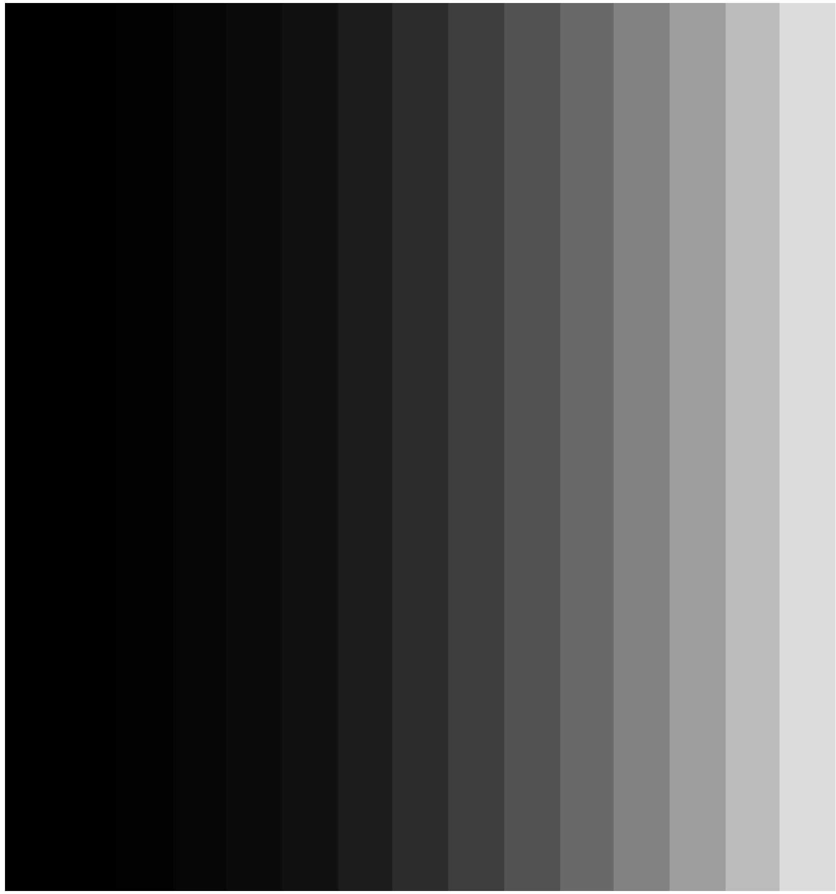
- To compensate for the nonlinear distortion we need to raise it to a power again

$$(I')^{1/\gamma} = I$$

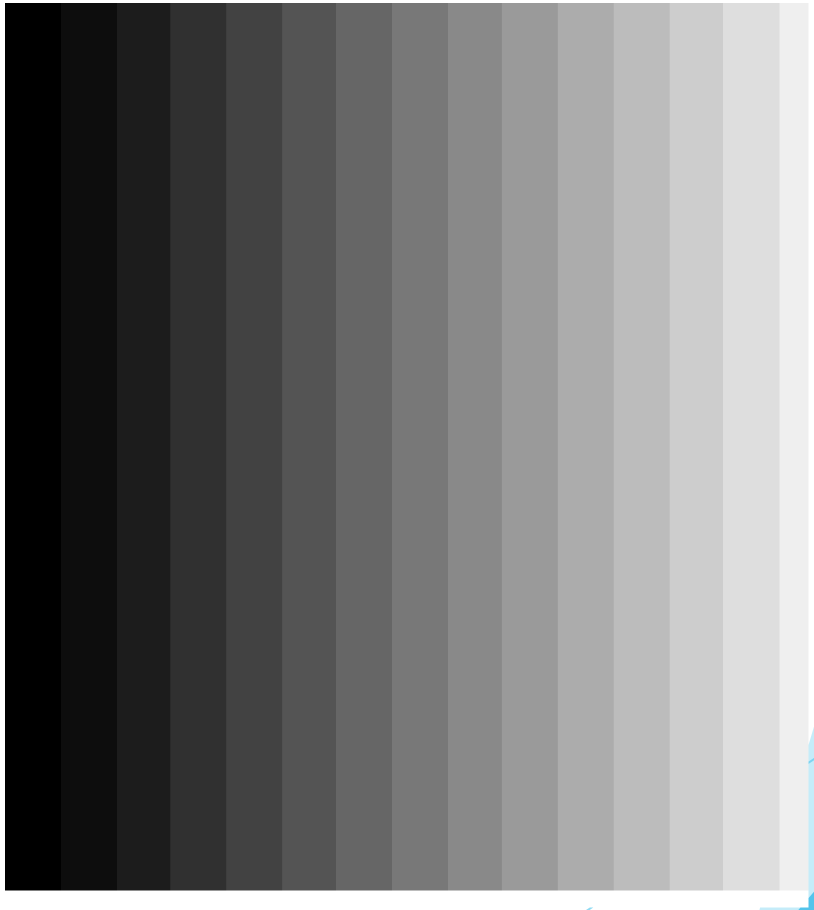
γ for CRT is about 2.2.



Gamma Correction



Linearly increasing intensity
Without gamma correction



Linearly increasing intensity
with gamma correction

YIQ Color Model

- YIQ is used in analog NTSC color TV broadcasting
- I and Q are rotated version of U and V
- I stands for in-phase, while Q stands for quadrature

Here is the RGB -> YIQ conversion:

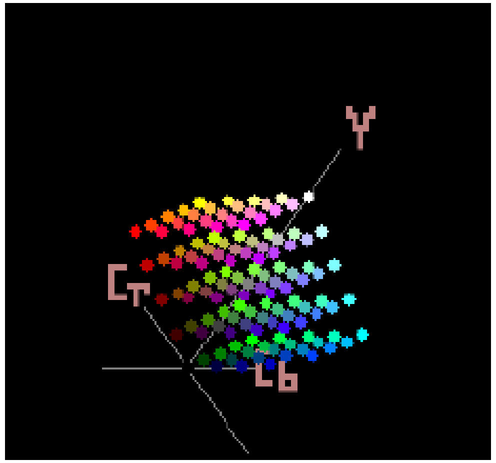
$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Here is the YIQ -> RGB conversion:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0.956 & 0.621 \\ 1 & -0.272 & -0.647 \\ 1 & -1.105 & 1.702 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix}$$

YCbCr Color Model

- Digital video uses YCbCr model – closely related to YUV
- YUV is changed to YCbCr by scaling.
- also written as YCBCR or Y′CBCR, is a family of color.
- Y′ is the luma component and CB and CR are the blue-difference and red-difference chroma components.



$$Y = 0.257R' + 0.504G' + 0.098B' + 16$$
$$Cb = -0.148R' - 0.291G' + 0.439B' + 128$$
$$Cr = 0.439R' - 0.368G' - 0.071B' + 128$$

YIQ and YUV for TV signals

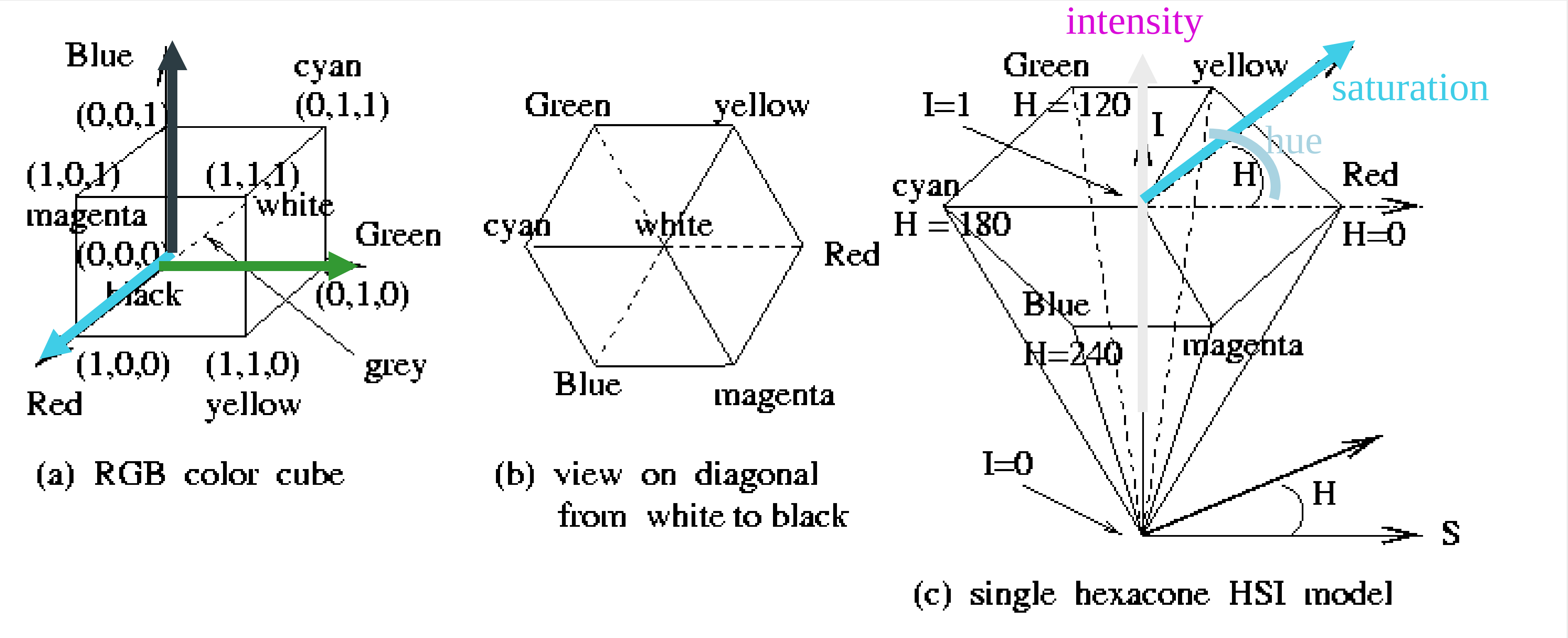
- Have better compression properties
- Luminance Y encoded using more bits than chrominance values I and Q; humans more sensitive to Y than I,Q
- **NTSC TV** uses luminance Y; chrominance values I and Q
- Luminance used by black/white TVs
- All 3 values used by color TVs
- YUV encoding used in some digital video and JPEG and MPEG compression

Coding methods for humans

- RGB is an additive system (add colors to black) used for displays
- CMY[K] is a subtractive system for printing
- HSV is good a good perceptual space for art, psychology, and recognition
- YIQ used for TV is good for compression

Color hexagon for HSI (HSV)

Color is coded relative to the diagonal of the color cube. Hue is encoded as an angle, saturation is the relative distance from the diagonal, and intensity is height.



Editing saturation of colors

(Left) Image of food originating from a digital camera;

(center) saturation value of each pixel **decreased** 20%;

(right) saturation value of each pixel **increased** 40%.

Properties of HSI (HSV)

- Separates out intensity **I** from the coding
- Two values (H & S) encode *chromaticity*
- Convenient for *designing* colors

- Hue H is defined by an angle

- Saturation S models the *purity* of the color
- S=1 for a completely pure or saturated color
- S=0 for a shade of “gray”

Color Applications

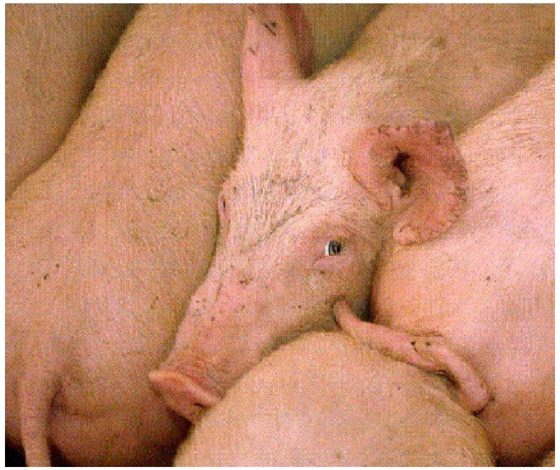
Finding a face in video frame

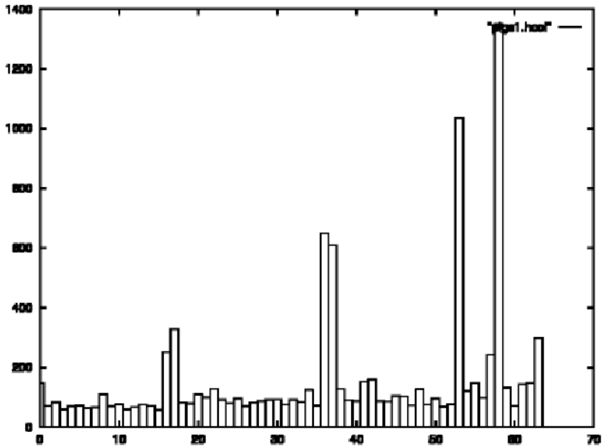
- (left) input video frame
- (center) pixels classified according to RGB space
- (right) largest connected component with aspect similar to a face (all work contributed by Vera Bakic)

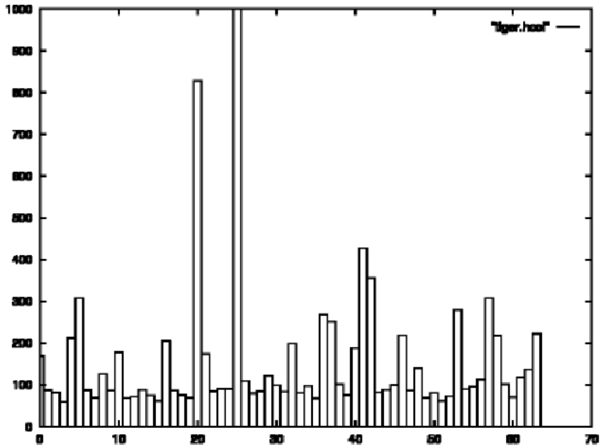
Color histograms can represent an image

- Histogram is fast and easy to compute.
- Size can easily be normalized so that different image histograms can be compared.
- Can match color histograms for database query or classification.

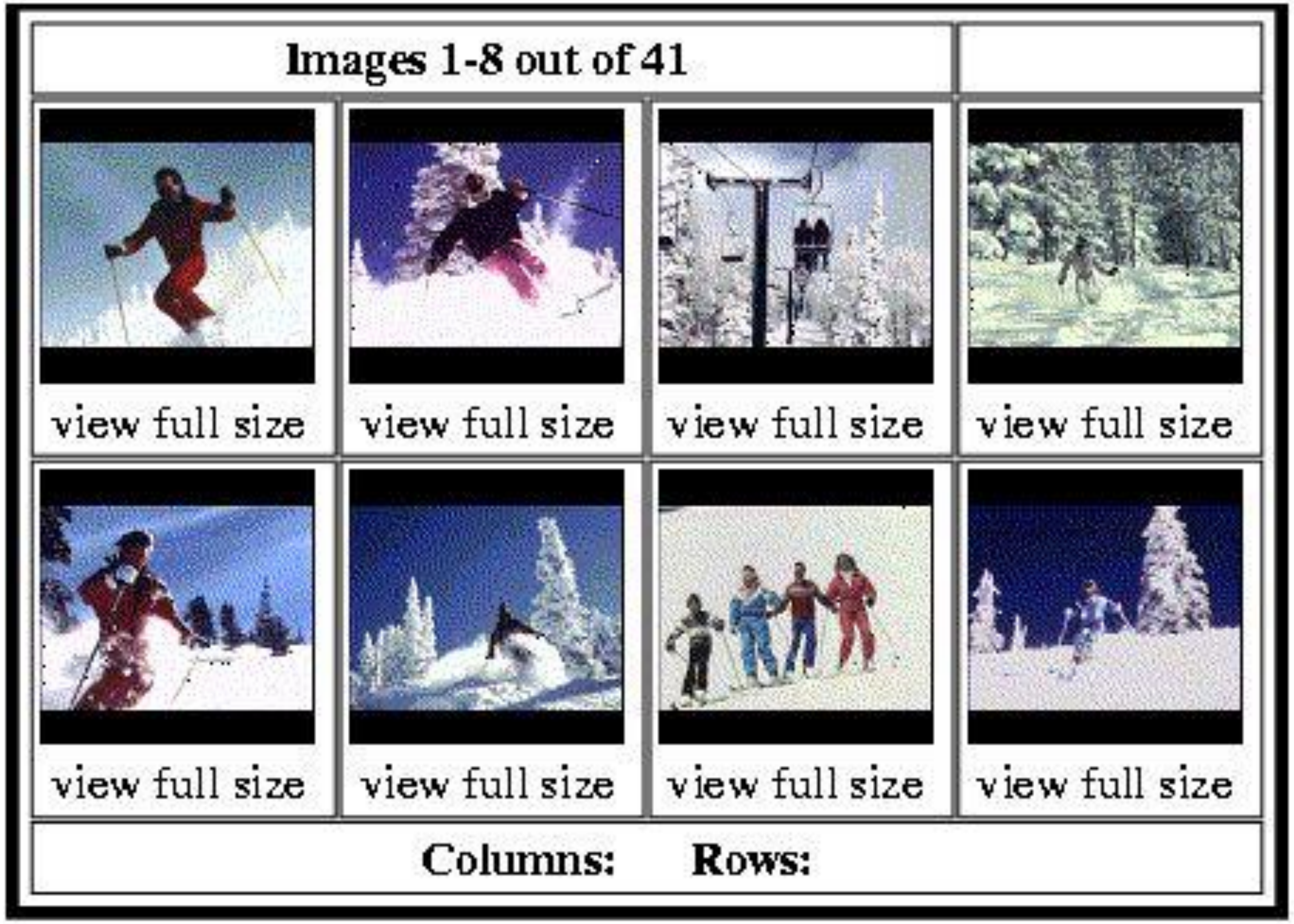
Histograms of two color images







Retrieval from image database



Top left image is query image.

The others are retrieved by having similar color histogram.