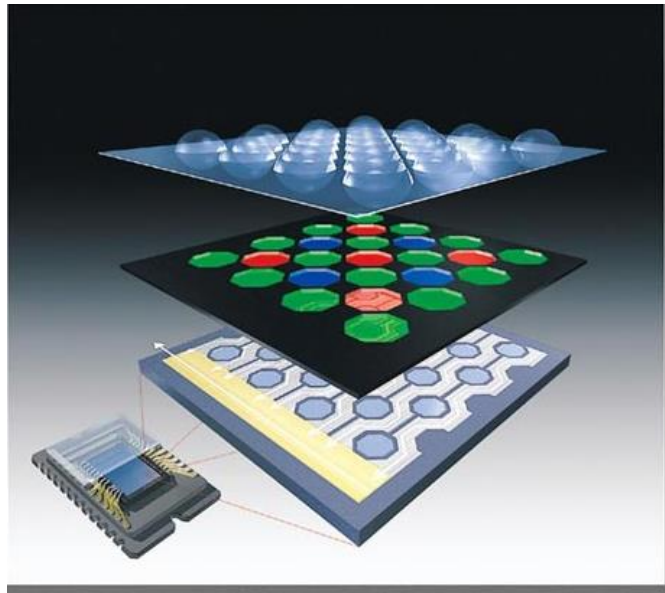
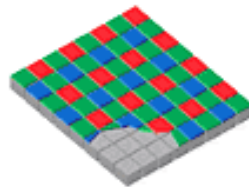


# **COLOR MODEL AND IMAGE FORMAT**

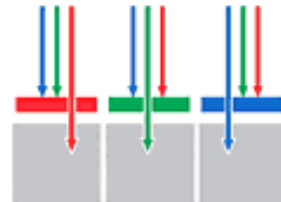
# Sensing Colors



## Mosaic Capture



In conventional systems, color filters are applied to a single layer of photodetectors in a tiled mosaic pattern.

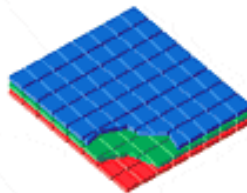


The filters let only one wavelength of light - red, green or blue - pass through to any given pixel, allowing it to record only one color.

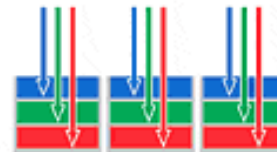


As a result, mosaic sensors capture only 25% of the red and blue light, and just 50% of the green.

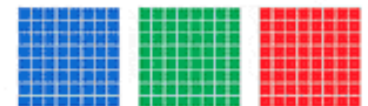
## Foveon® X3™ Capture



A Foveon® X3™ image sensor features three separate layers of photodetectors embedded in silicon.

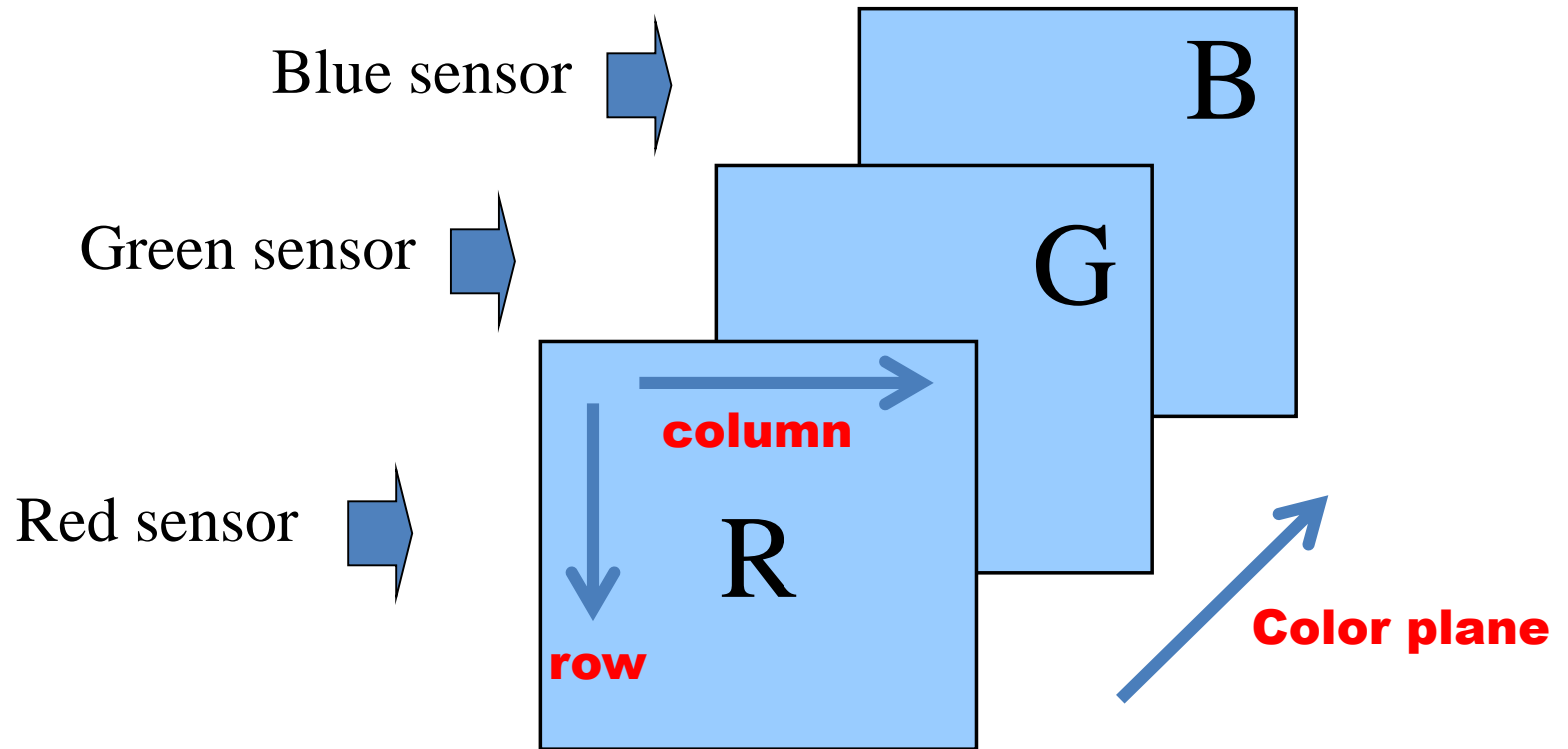


Since silicon absorbs different colors of light at different depths, each layer captures a different color. Stacked together, they create full-color pixels.



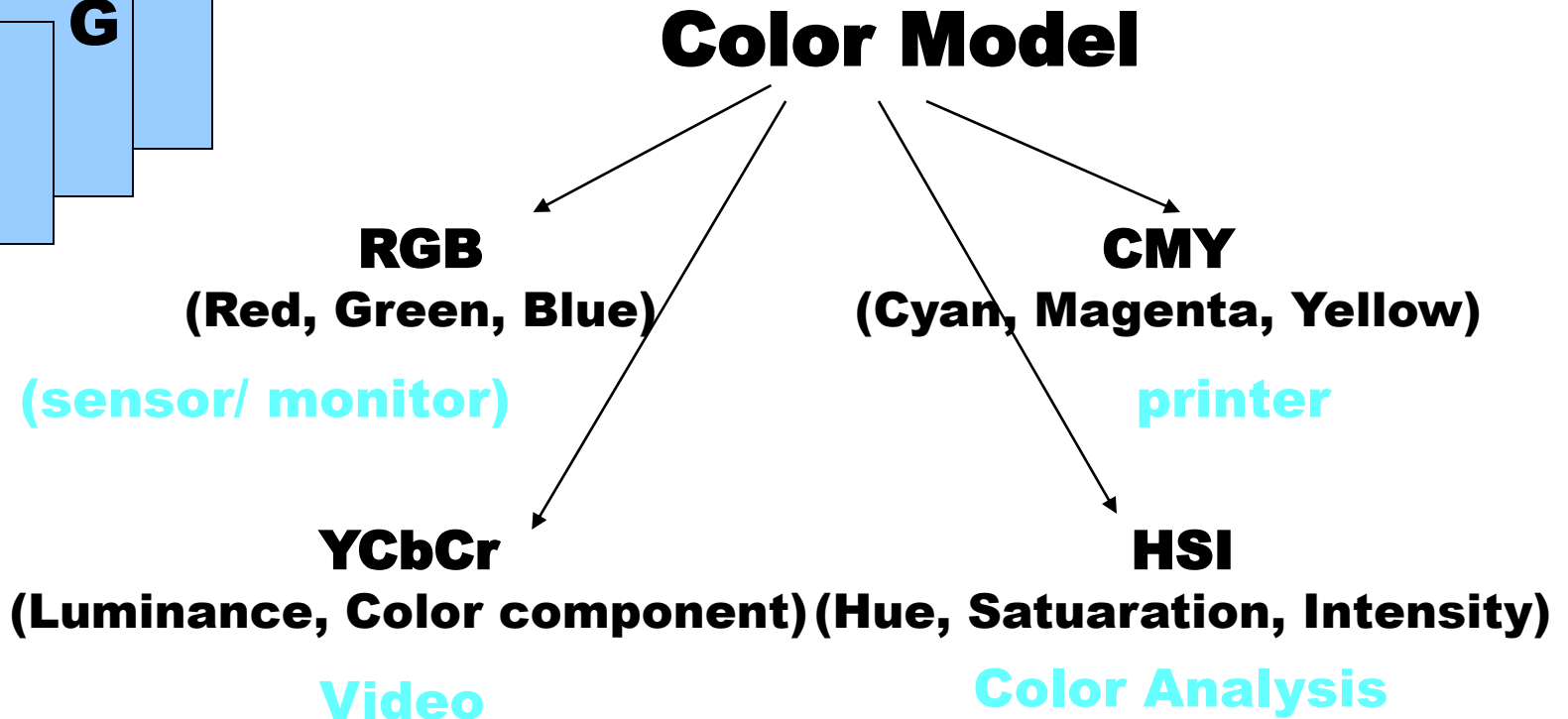
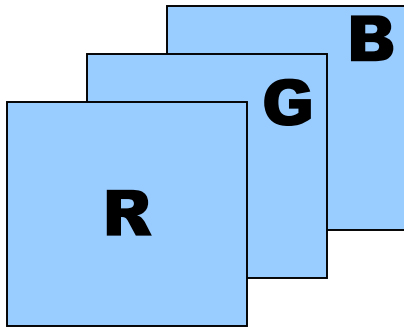
As a result, only Foveon X3 image sensors capture red, green and blue light at every pixel location.

# Color Digital Image



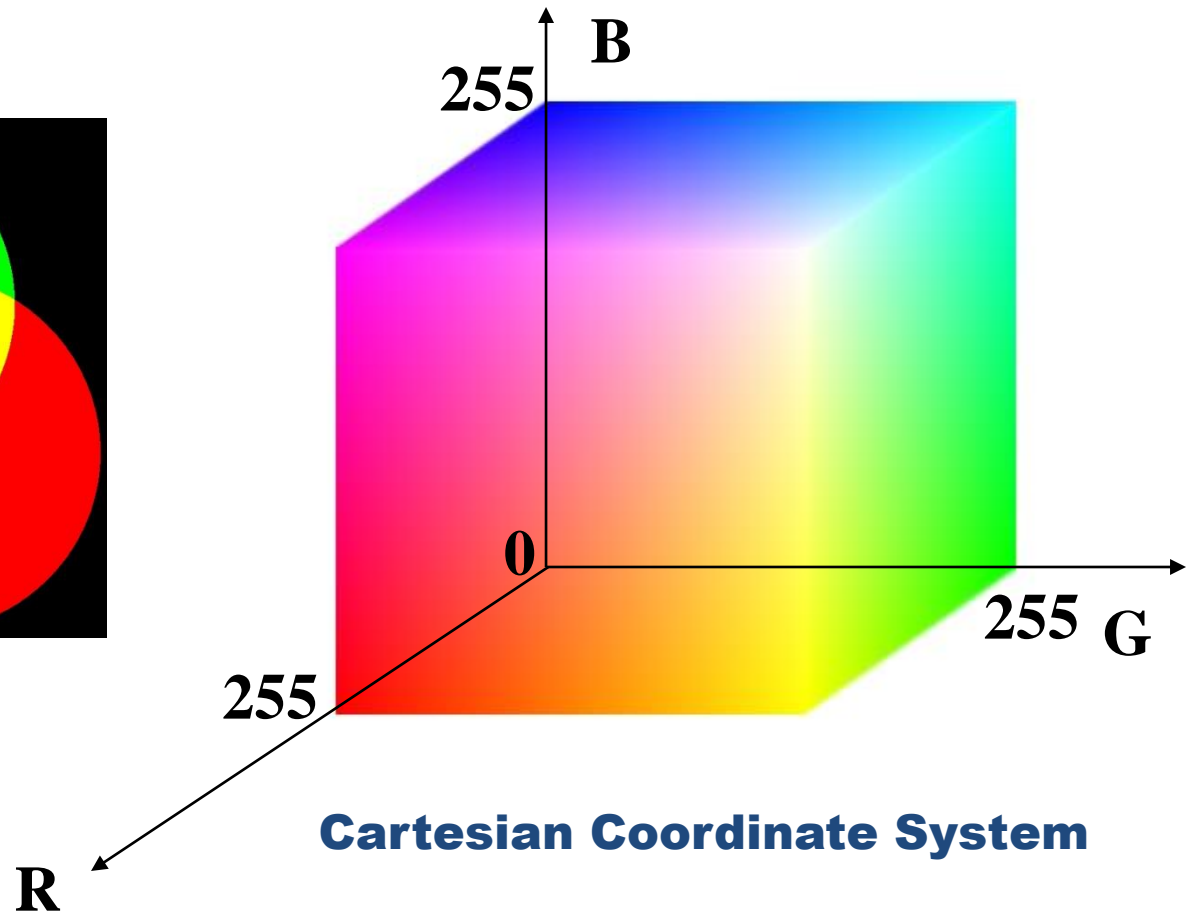
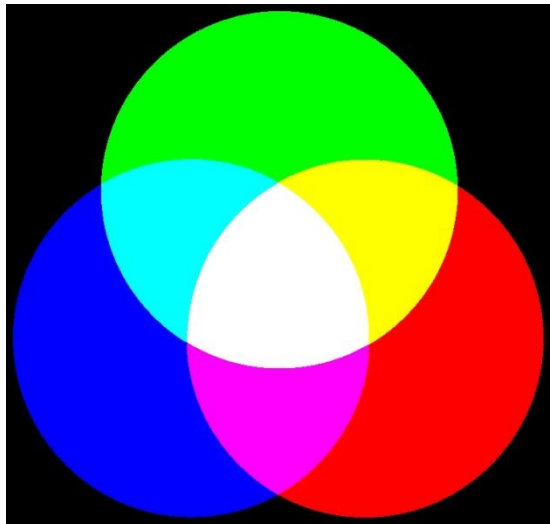
# Color Digital Image

## (Color Model)



# RGB

## (Color Model)



# An example of RGB Image



Red

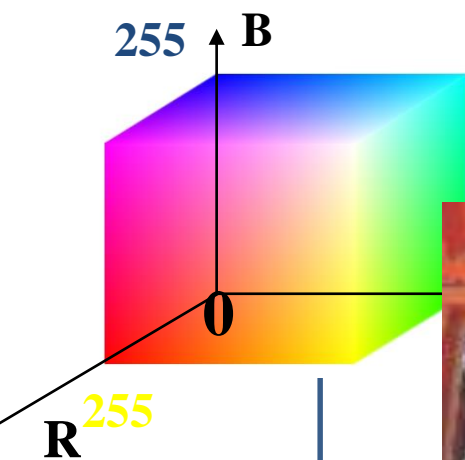


Green



Blue





Original



**R+G+B**

**R+0+0**

**0+0+B**

**R+G+0**

Red



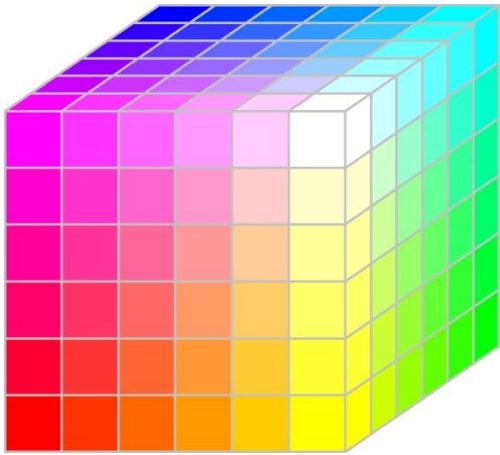
Green



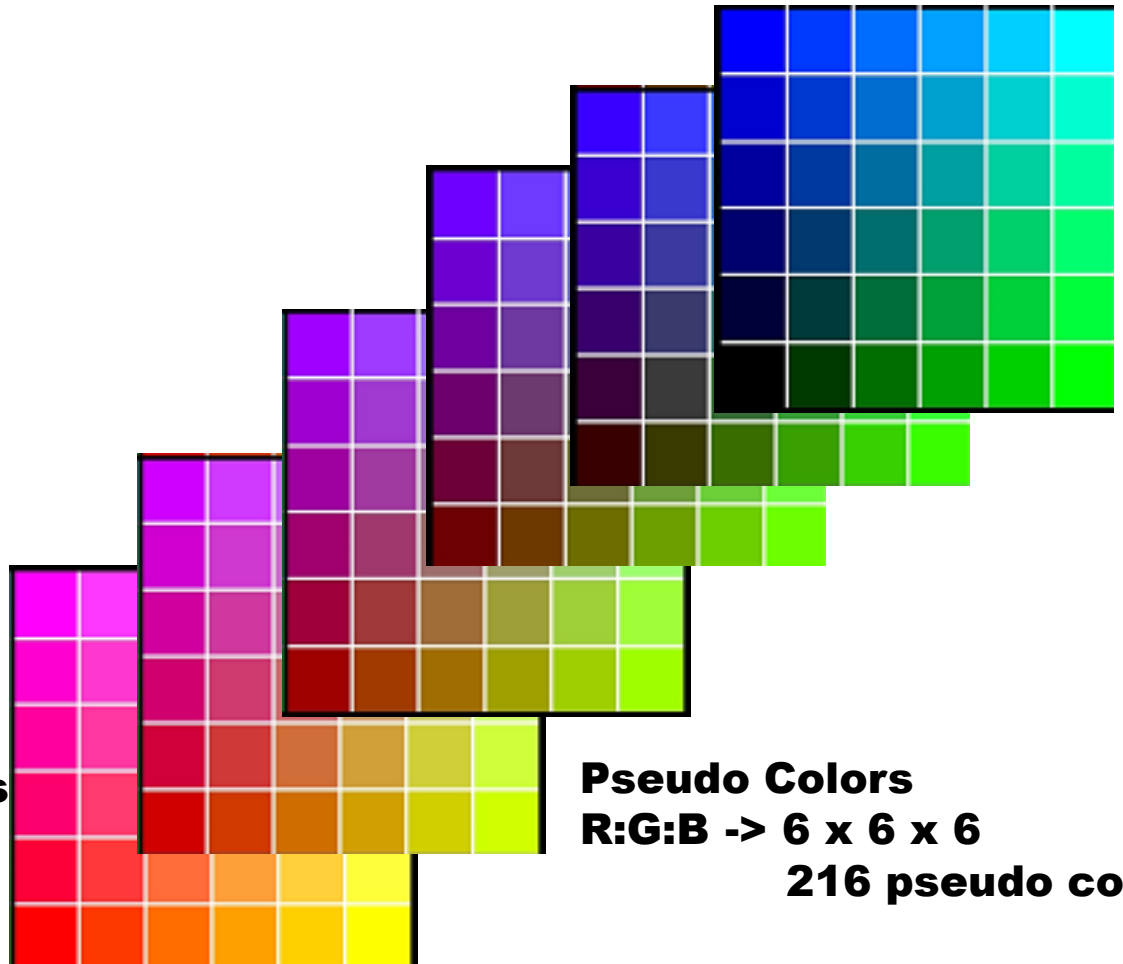
Blue



# RGB Pseudo Color (Quantized Color)



**True Colors**  
**R:G:B -> 8bits: 8bits: 8bits**  
**256 x 256 x 256**  
**~ 16 million colors**



**Pseudo Colors**  
**R:G:B -> 6 x 6 x 6**  
**216 pseudo colors**








































# Web Colors

FFF	CCC	999	666	333	000	FFC	FF9	FF6	FF3	SWITCH TO <a href="#">DECIMAL RGB</a>					
FFF	CCC	999	666	333	000	C00	900	600	300	COLOR CODES					
99C					CC9	FFC	FFC	FF9	FF6	CC3					CC0
C00					900	C33	C66	966	633	300					033
CCF	CCF	333	666	999	CCC	FFF	CC9	CC6	330	660	990	CC0	FF0	FF3	FF0
F00	F33	300	600	900	C00	F00	933	633	000	000	000	000	000	366	033
99F	CCF	99C	666	999	CCC	FFF	996	993	663	993	CC3	FF3	CC3	FF6	FF0
F00	F66	C33	633	933	C33	F33	600	300	333	333	333	333	366	699	066
66F	99F	66C	669	999	CCC	FFF	996	663	996	CC6	FF6	990	CC3	FF6	FF0
F00	F66	C33	900	966	C66	F66	633	300	666	666	666	033	399	6CC	099
33F	66F	339	66C	99F	CCC	FFF	CC9	CC6	CC9	FF9	FF3	CC0	990	FF3	FF0
F00	F33	900	C00	F33	C99	F99	966	600	999	999	399	066	066	3CC	0CC
00C	33C	336	669	99C	CCF	FFF	FFC	FF9	FFC	FF9	CC6	993	660	CC0	330
C00	C00	600	933	C66	F99	FCC	C99	933	CCC	9CC	699	366	033	099	033
33C	66C	00F	33F	66F	99F	CCF				CC9	996	993	990	663	660
C33	C66	F00	F33	F66	F99	FCC				9CC	699	399	099	366	066
006	336	009	339	669	99C				FFC	FF9	FF6	FF3	FF0	CC6	CC3
600	633	900	933	966	C99				CFP	9FF	6FF	3FF	0FF	6CC	3CC
003	00C	006	339	66C	99F	CCF	339	99C	CCC	CC9	996	663	330	990	CC0
300	C33	633	966	C99	FCC	FFF	9FF	CFP	CFP	9FF	6CC	399	066	0CC	0CC
00F	33F	009	00C	33F	99F	99C	006	669	999	999	993	660	660	CC3	CC0
F33	F66	933	C66	F99	FFF	CCC	6CC	9CC	9FF	9CC	3FF	0CC	099	3FF	0FF
00F	66F	33C	009	66F	66C	669	003	336	666	666	666	330	993	CC6	990
F66	F99	C66	966	FFF	CCC	999	366	699	6FF	6CC	699	099	3CC	6FF	0FF
00F	66F	33C	33F	33C	339	336	006	003	333	333	333	333	663	996	660
F99	FCC	C99	FFF	CCC	999	666	699	399	3FF	3CC	399	366	3CC	6FF	0FF
00F	33F	00F	00C	009	006	003	339	336	000	000	000	000	000	663	330
FCC	FCC	FFF	CCC	999	666	333	9CC	6CC	0FF	0CC	099	066	033	3FF	0FF
00C	C99	© 2011 <a href="#">VisiBone</a>				009	33C	66C	669	336	003				330
					9CC	CFP	CFP	9FF	6FF	3CC					0CC
						00C	009	006	003						
						CFP	9FF	6FF	3FF						

Using HTML color codes for web site background color:

```
<body style="background:#80BFFF">
```

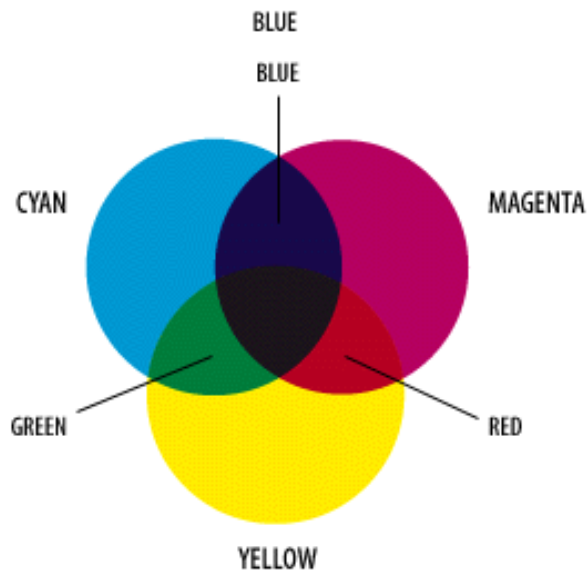
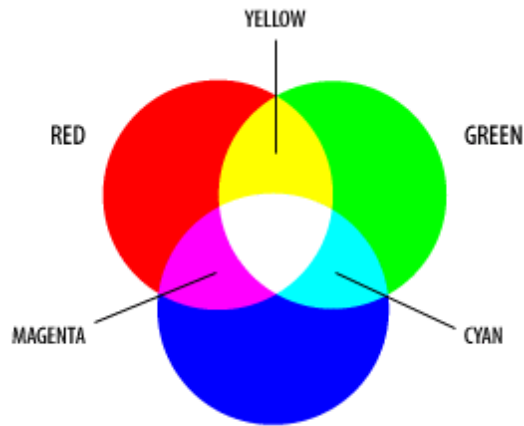
- 6 digit color code
  - 216-HEX decimal code
  - RRGGBB

	rgb(233,150,122)	#E9967A		rgb(154,205,50)	#9ACD32
	rgb(220,20,60)	#DC143C		rgb(107,142,35)	#6B8E23
	rgb(255,248,220)	#FFF8DC		rgb(128,128,0)	#808000
	rgb(255,235,205)	#FFEBDC		rgb(85,107,47)	#556B2F
	rgb(255,228,196)	#FFE4C4		rgb(143,188,143)	#8FBC8F
	rgb(255,222,173)	#FFDEAD		rgb(102,205,170)	#66CDAA
	rgb(245,222,179)	#F5DEB3		rgb(32,178,170)	#20B2AA
	rgb(222,184,135)	#DEB887		rgb(0,139,139)	#008B8B
	rgb(210,180,140)	#D2B48C		rgb(0,128,128)	#008080
	rgb(189,183,107)	#BDB76B		rgb(0,255,255)	#00FFFF
	rgb(218,165,32)	#DAA520		rgb(127,255,212)	#7FFFD4
	rgb(184,134,11)	#B8860B		rgb(175,238,238)	#AFEEEE
	rgb(205,133,63)	#CD853F		rgb(64,224,208)	#40E0D0
	rgb(210,105,30)	#D2691E		rgb(72,209,204)	#48D1CC
	rgb(160,82,45)	#A0522D		rgb(0,206,209)	#00CED1
	rgb(165,42,42)	#A52A2A		rgb(95,158,160)	#5F9EA0
	rgb(178,34,34)	#B22222		rgb(70,130,180)	#4682B4
	rgb(139,69,19)	#8B4513		rgb(176,196,222)	#B0C4DE
	rgb(139,0,0)	#8B0000		rgb(176,224,230)	#B0E0E6
	rgb(128,0,0)	#800000		rgb(173,216,230)	#ADD8E6
	rgb(250,164,96)	#FAA460		rgb(135,206,235)	#87CEEB
	rgb(255,127,80)	#FF7F50		rgb(135,206,250)	#87CEFA
	rgb(255,99,71)	#FF6347		rgb(0,191,255)	#00BFFF
	rgb(255,0,0)	#FF0000		rgb(30,144,255)	#1E90FF
	rgb(255,69,0)	#FF4500		rgb(100,149,237)	#6495ED
	rgb(255,140,0)	#FF8C00		rgb(65,105,225)	#4169E1
	rgb(255,165,0)	#FFA500		rgb(0,0,255)	#0000FF
	rgb(255,215,0)	#FFD700		rgb(0,0,205)	#0000CD

# CMY

## (Printing Color Model)

### Display color model



### Normalized RGB

$$r = \frac{R}{R + G + B}$$

$$g = \frac{G}{R + G + B}$$

$$b = \frac{B}{R + G + B}$$

### Normalized RGB-to-Normalized CMY

$$\begin{bmatrix} c \\ m \\ y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

# CMY









## Normalized CMY-to-CMY

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} c \\ m \\ y \end{bmatrix} * 255 = \begin{bmatrix} c * 255 \\ m * 255 \\ y * 255 \end{bmatrix}$$

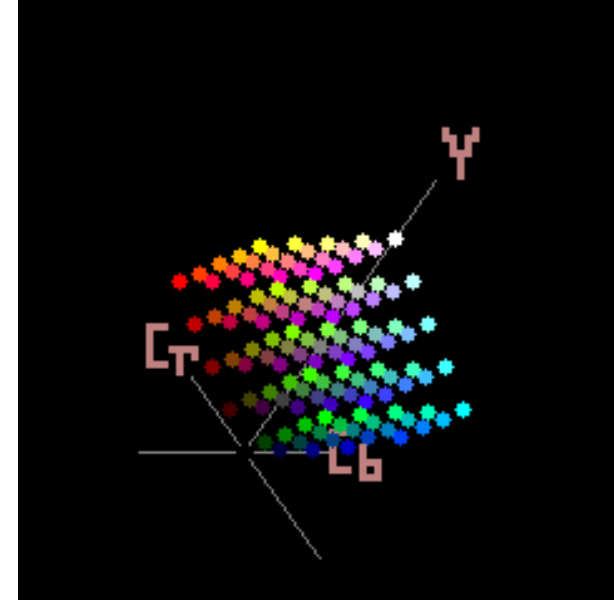
## CMY-to-RGB

$$\begin{bmatrix} r \\ g \\ b \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} c \\ m \\ y \end{bmatrix} \Rightarrow \begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} r \\ g \\ b \end{bmatrix} * 255$$

RGB to CMYK table

Color	Color name	(R,G,B)	Hex	(C,M,Y,K)
	Black	(0,0,0)	#000000	(0,0,0,1)
	White	(255,255,255)	#FFFFFF	(0,0,0,0)
	Red	(255,0,0)	#FF0000	(0,1,1,0)
	Green	(0,255,0)	#00FF00	(1,0,1,0)
	Blue	(0,0,255)	#0000FF	(1,1,0,0)
	Yellow	(255,255,0)	#FFFF00	(0,0,1,0)
	Cyan	(0,255,255)	#00FFFF	(1,0,0,0)
	Magenta	(255,0,255)	#FF00FF	(0,1,0,0)

# YCbCr (YUV) (Color Model)



**Y,Cb,Cr** → **Y-Luminance**  
                     → **Cb,Cr – Color component**

## RGB-to-YCbCr

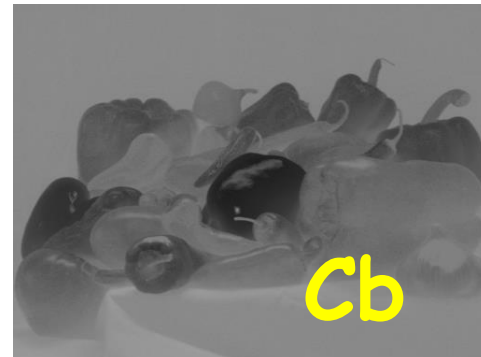
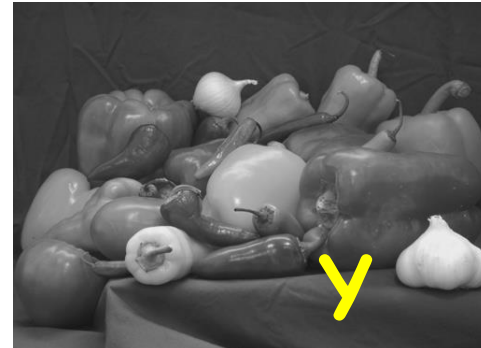
$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.257 & 0.504 & 0.098 \\ -0.148 & -0.291 & 0.439 \\ 0.439 & -0.368 & -0.071 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix}$$

## YCbCr-to- RGB

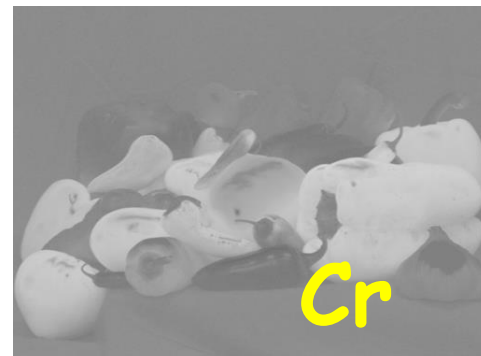
$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.164 & 0 & 1.596 \\ 1.164 & -0.392 & -0.813 \\ 1.164 & 2.017 & 0 \end{bmatrix} \begin{bmatrix} Y-16 \\ Cb-128 \\ Cr-128 \end{bmatrix}$$

**Analog Video (PAL), Digital Video (MPEG)**

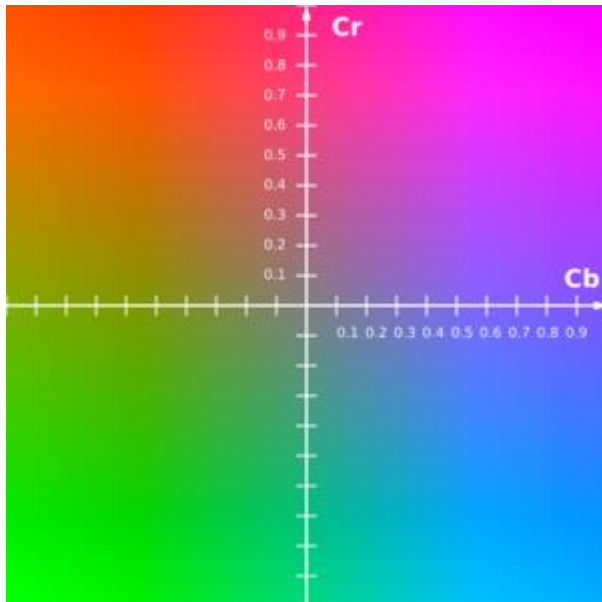
# YCbCr (YUV) decomposition



**B & G**  
or B-Y



**R & G**  
or R-Y

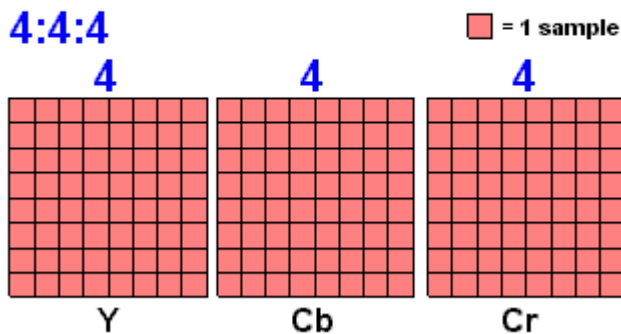


# Video Representation

- Digital TV using YCbCr
  - Standard conversion equation??
  - What type of digital interface for YCbCr of each standard

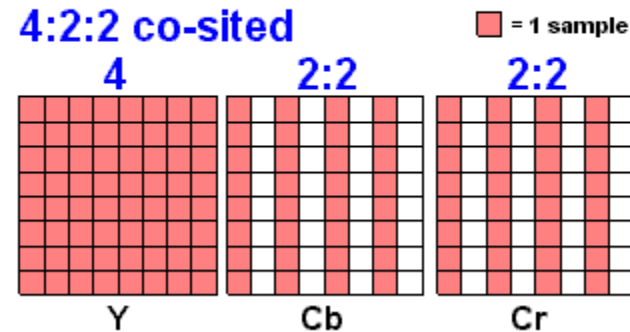
# Color Subsampling

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**4:4:4** -> color is a platinum standard for color, and it's extremely rare to see a recording device or camera that outputs 4:4:4 color.

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**4:2:2**-> Since the human eye doesn't really notice when color is removed, most of the higher-end devices output something called 4:2:2. :

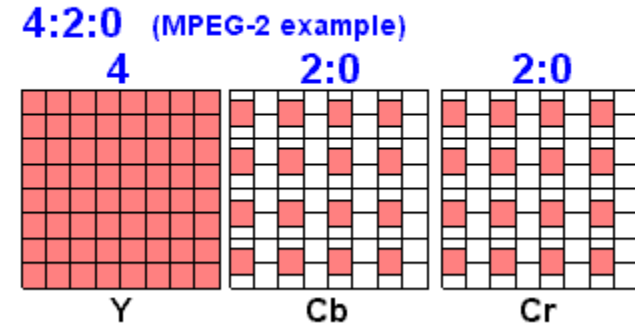
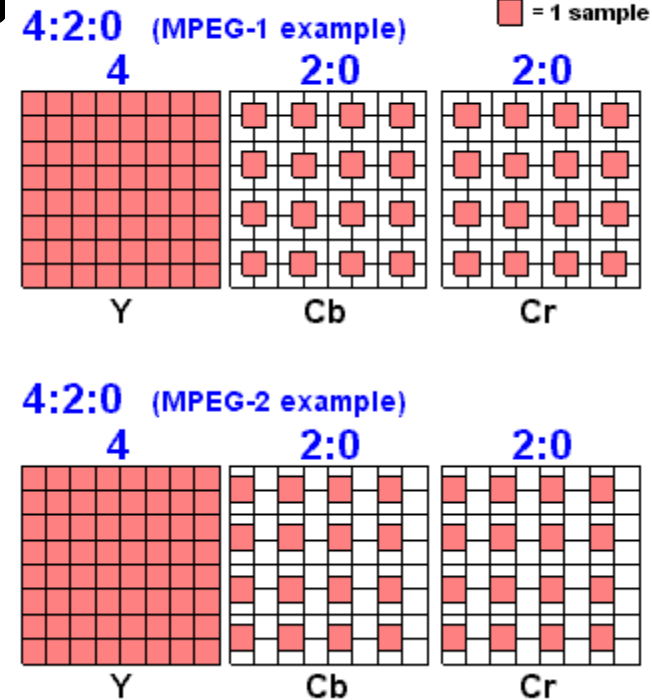
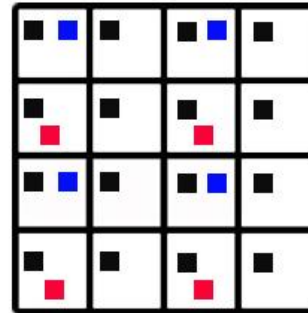
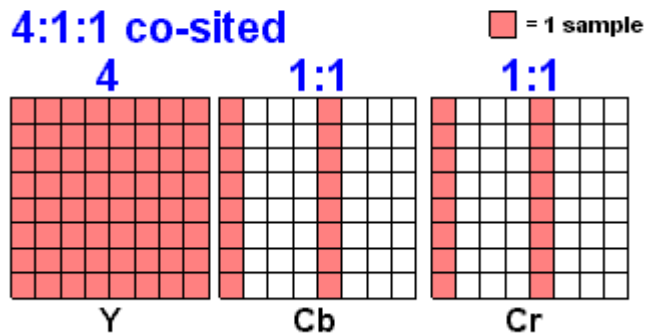
Most computer software can use the neighboring color values and average in the values of the missing color values.

DV (at 50 Mbps), Digital Betacam and DVCPRO 50 and is an option in MPEG-2.

# Color Subsampling

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**4:1:1->75% of the color for each pixel is tossed away!**

With bigger “gaps” between color information, it’s even harder for software to “rebuild” the missing values, but it happens. This is one of the reasons that re-compressing DV can cause color smearing from generation to generation.

**4:2:0->** With a color subsampled image, it’s up to the program decoding the picture to estimate the missing pixel values, using the surrounding intact color values, and providing smoothing between the averaged values.

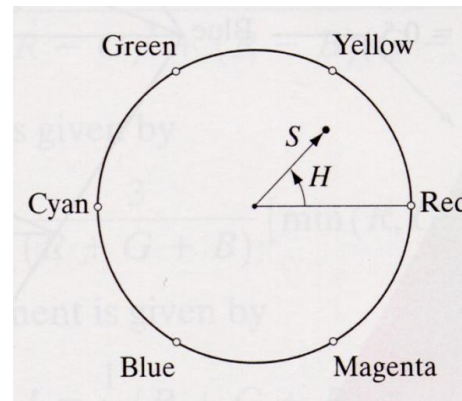
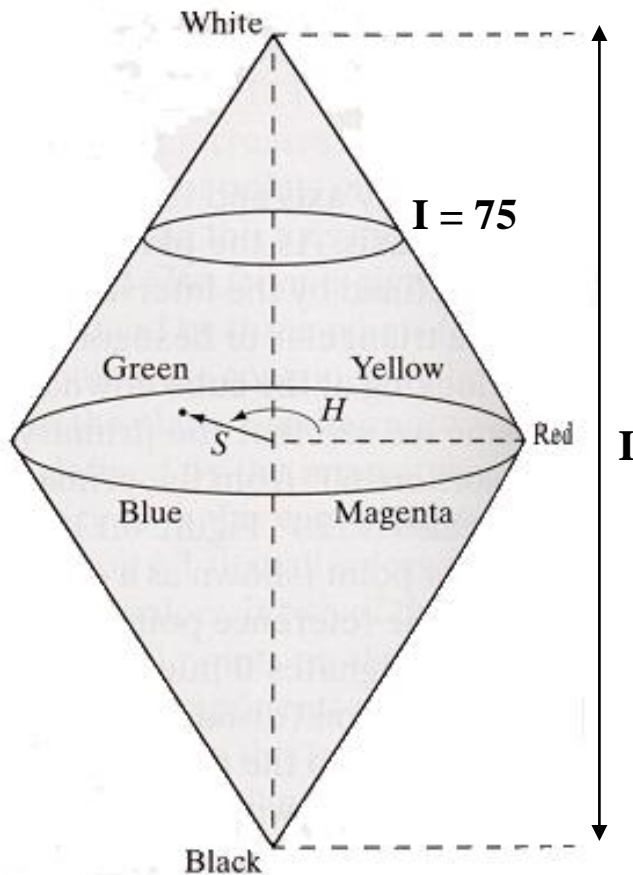
**PAL DV, PAL DVCAM, DVD, and HDV**

**NTSC DV, NTSC DVCAM, and DVCPRO**



# HSI (Hue, Saturation , Intensity)

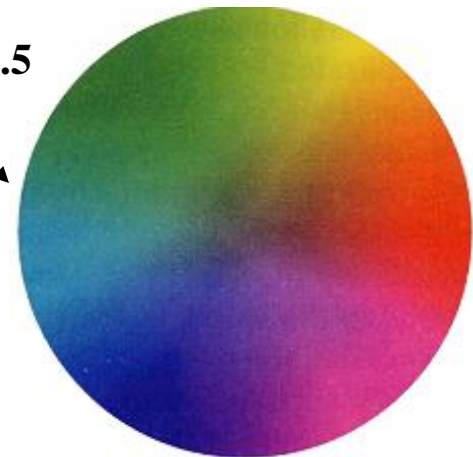
## (Color model)



$I = 75$



$I = 0.5$

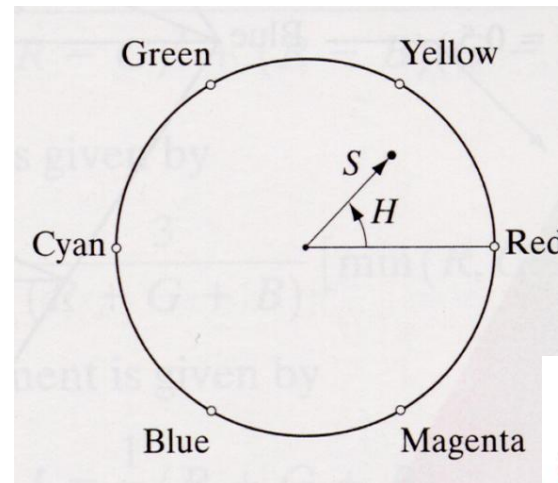


# RGB-to-HIS

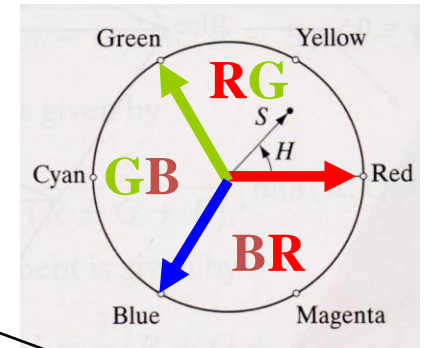
$$H = \begin{cases} \theta & B \leq G \\ 360 - \theta & B > G \end{cases} \quad \Rightarrow \quad \theta = \cos^{-1} \left\{ \frac{\frac{1}{2}[(R-G) + (R-B)]}{\sqrt{(R-G)^2 + (R-B)^2 + (G-B)^2}} \right\}$$

$$S = 1 - \frac{3}{R+G+B} [\min(R, G, B)]$$

$$I = \frac{1}{3} [R + G + B]$$



# HIS-to-RGB



$$0 \leq H < 120 \text{ (RG)}$$

$$120 \leq H < 240 \text{ (GB)}$$

$$240 \leq H \leq 360 \text{ (BR)}$$

$$H = H - 120$$

$$H = H - 240$$

$$R = I \left[ 1 + \frac{S \cos(H)}{\cos(60 - H)} \right]$$

$$G = I \left[ 1 + \frac{S \cos(H)}{\cos(60 - H)} \right]$$

$$B = I \left[ 1 + \frac{S \cos(H)}{\cos(60 - H)} \right]$$

$$G = 1 - (R + B)$$

$$B = 1 - (R + G)$$

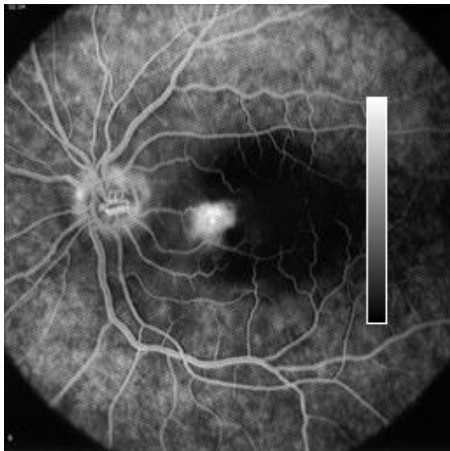
$$R = 1 - (G + B)$$

$$B = I(1 - S)$$

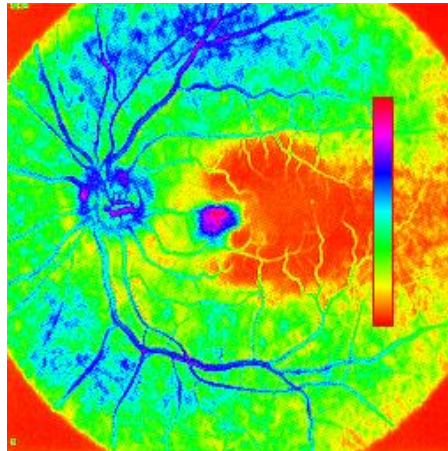
$$R = I(1 - S)$$

$$G = I(1 - S)$$

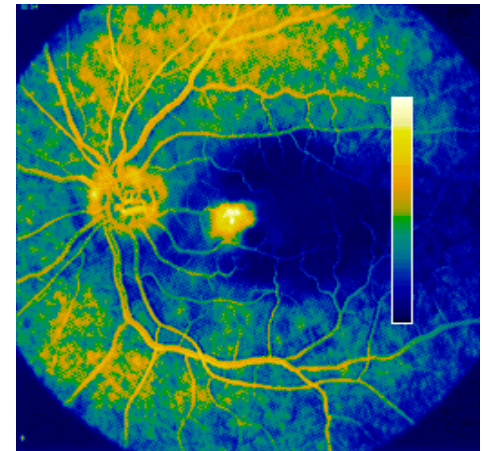
# Color Map (1)



**Gray scale display**

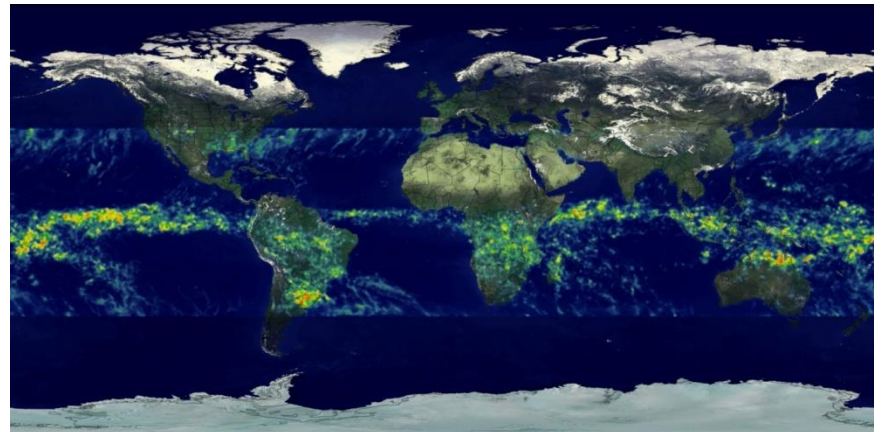
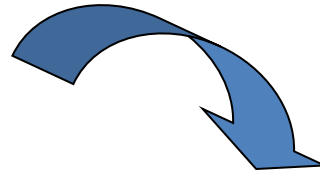
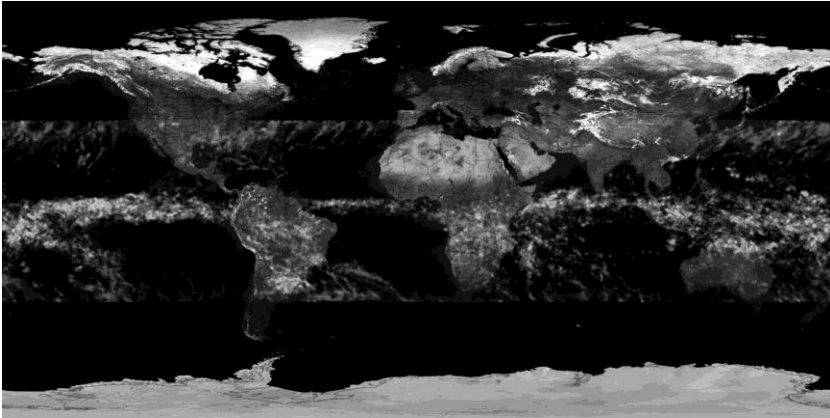


**Rainbow display**

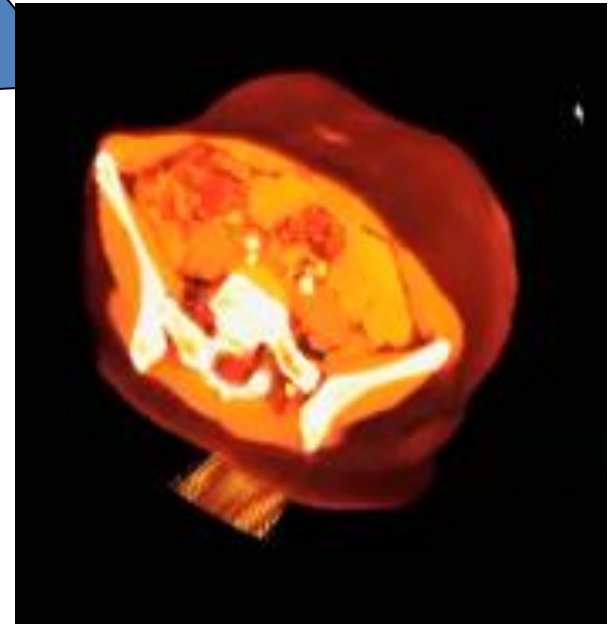
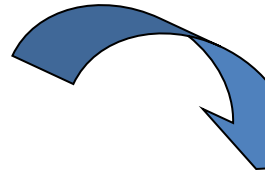
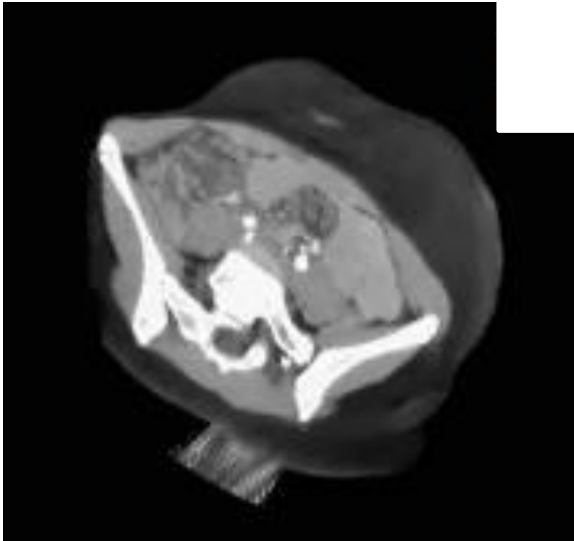


**B-G-Y-W display**

## Color Map (2)



## Color Map (3)





# Question

- Select color for detecting an orange ball

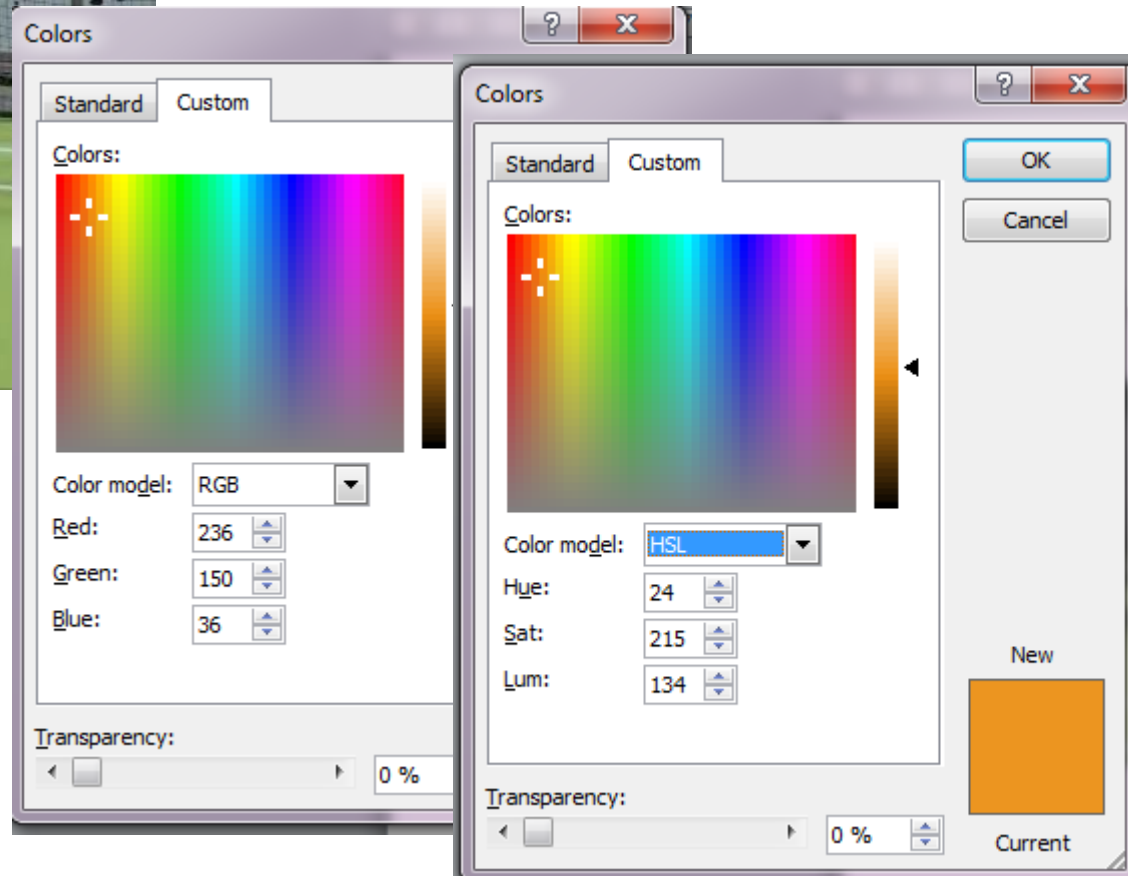


RGB range:

r : \_\_\_\_ g : \_\_\_\_ b : \_\_\_\_

HSL range:

h : \_\_\_\_ s : \_\_\_\_ l : \_\_\_\_



Let's play kahoot