Color

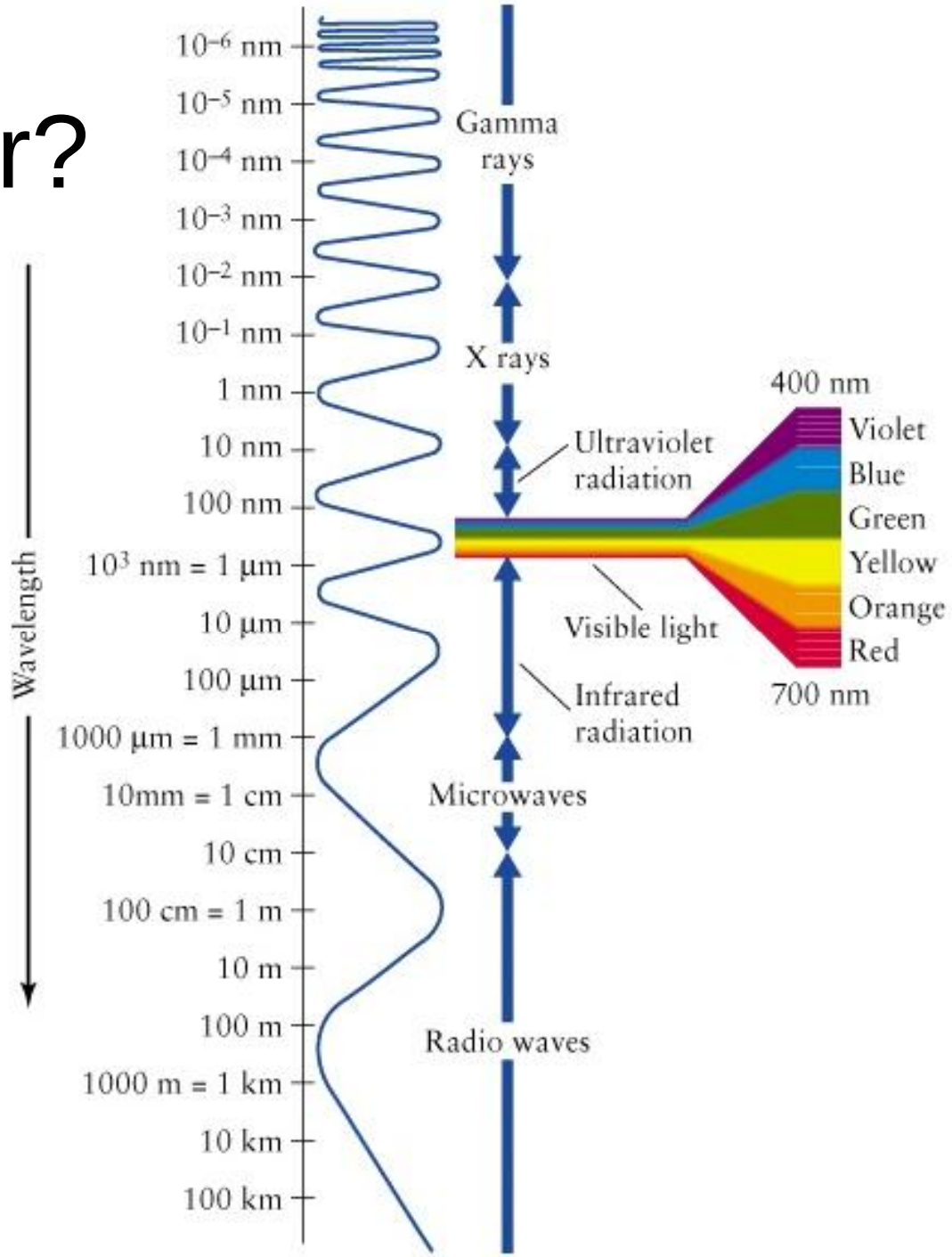
(colour)

Chapter 6

Digital Multimedia, 2nd edition

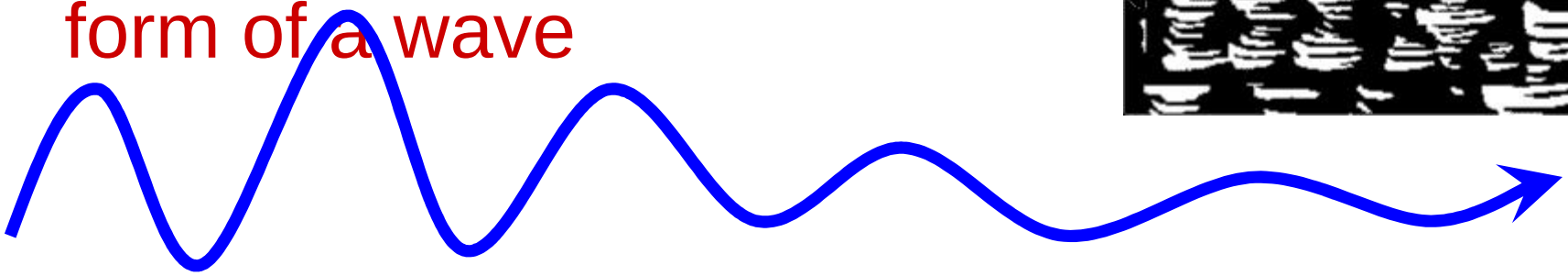
What is color?

- Color is how our eyes perceive different forms of energy.
- Energy moves in the form of waves.



What is a wave?

- Think of a fat guy (Dr. Breimer) doing a cannonball into a pool.
- The incredible energy created by my fat ass hitting the water is transfer and dispersed into the pool in the form of a wave



Why does energy move in waves?

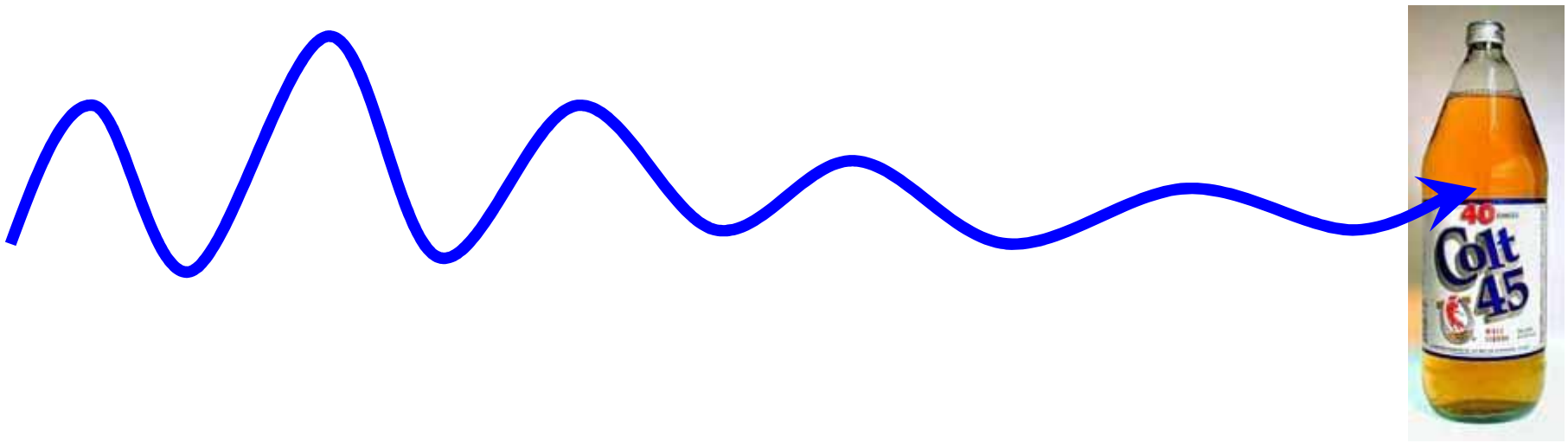
- I don’t f***ing know. Are you 4-years old? you have to ask a million stupid questions?
- Seriously, there is some complex physics behind the reason, but here is a simple way to explain it….

Why does energy move in waves?

- Q: How does a snake move without legs?
- A: By going “swish swish”
- Similarly, the “swish swish” of a wave allows energy to move even in a vacuum.

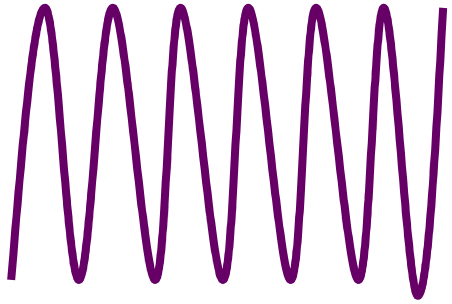
Why does energy need to move anyway?

- To get a 40oz beverage from the liquor store

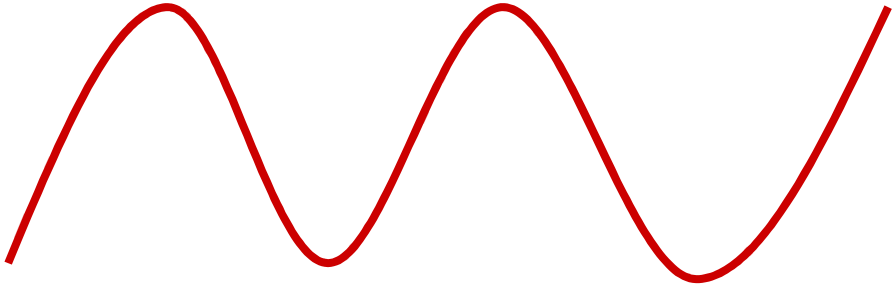


Where were we anyhow?

- Light is a form of energy that travels in a wave pattern.
- The length of the wave can vary



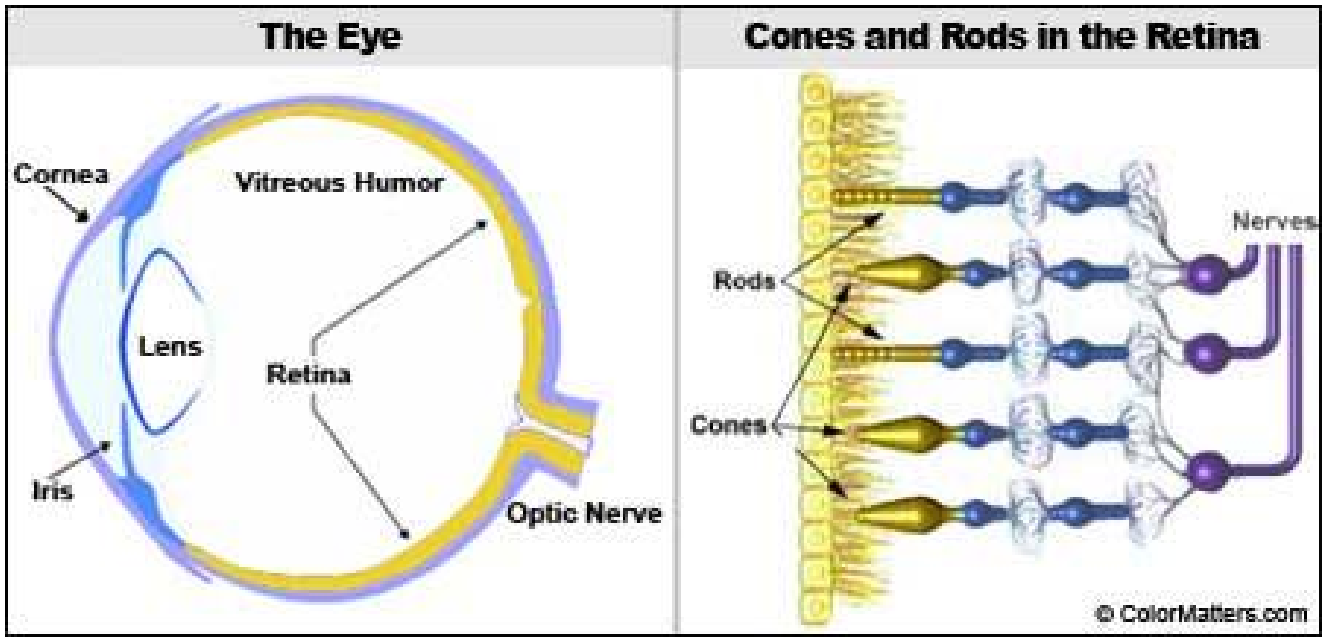
- Short wavelength



- Long wavelength

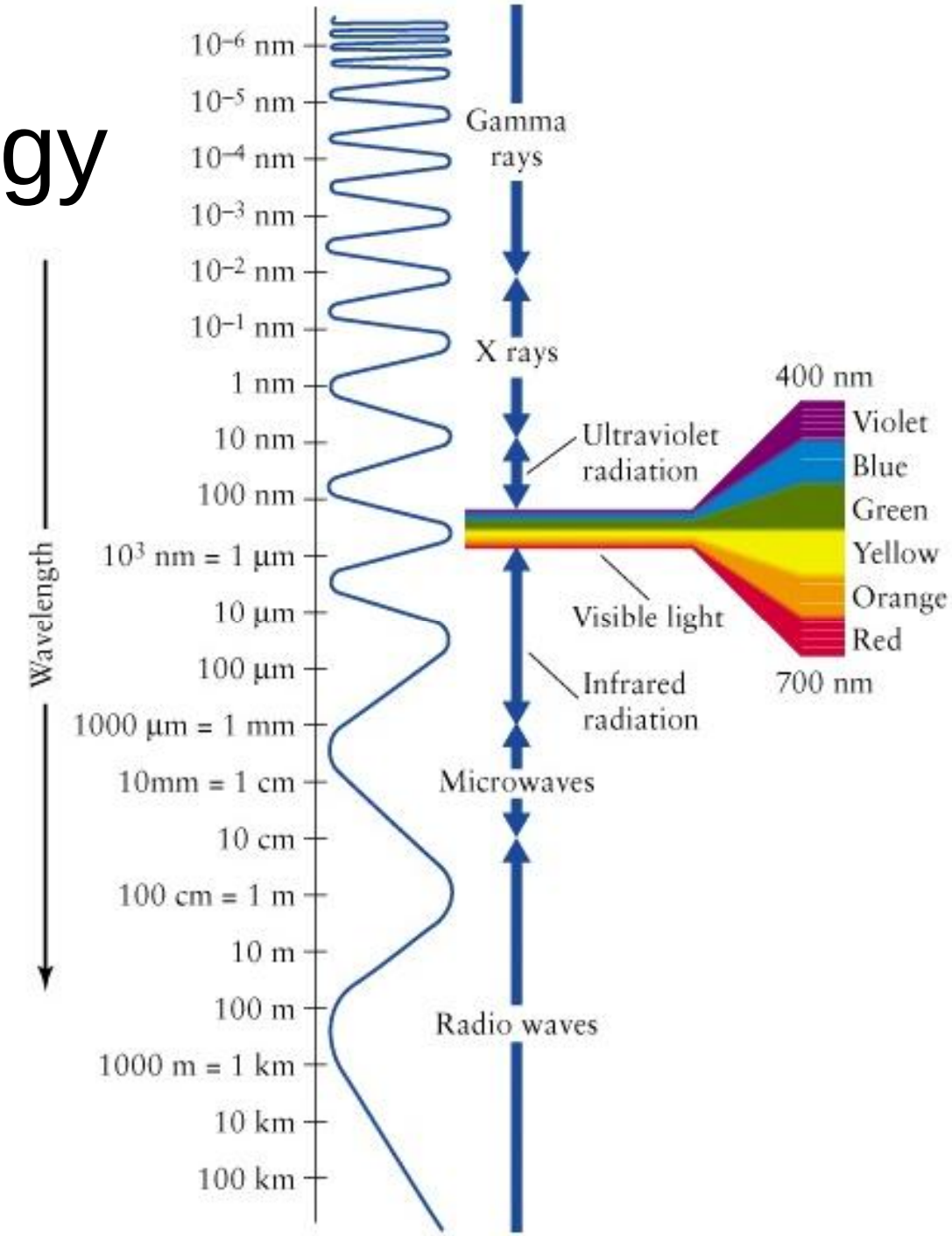
The Human Eye…

- has Cones and Rods (like nerves) that can detect different wavelengths of light…
- and send signals to the brain.



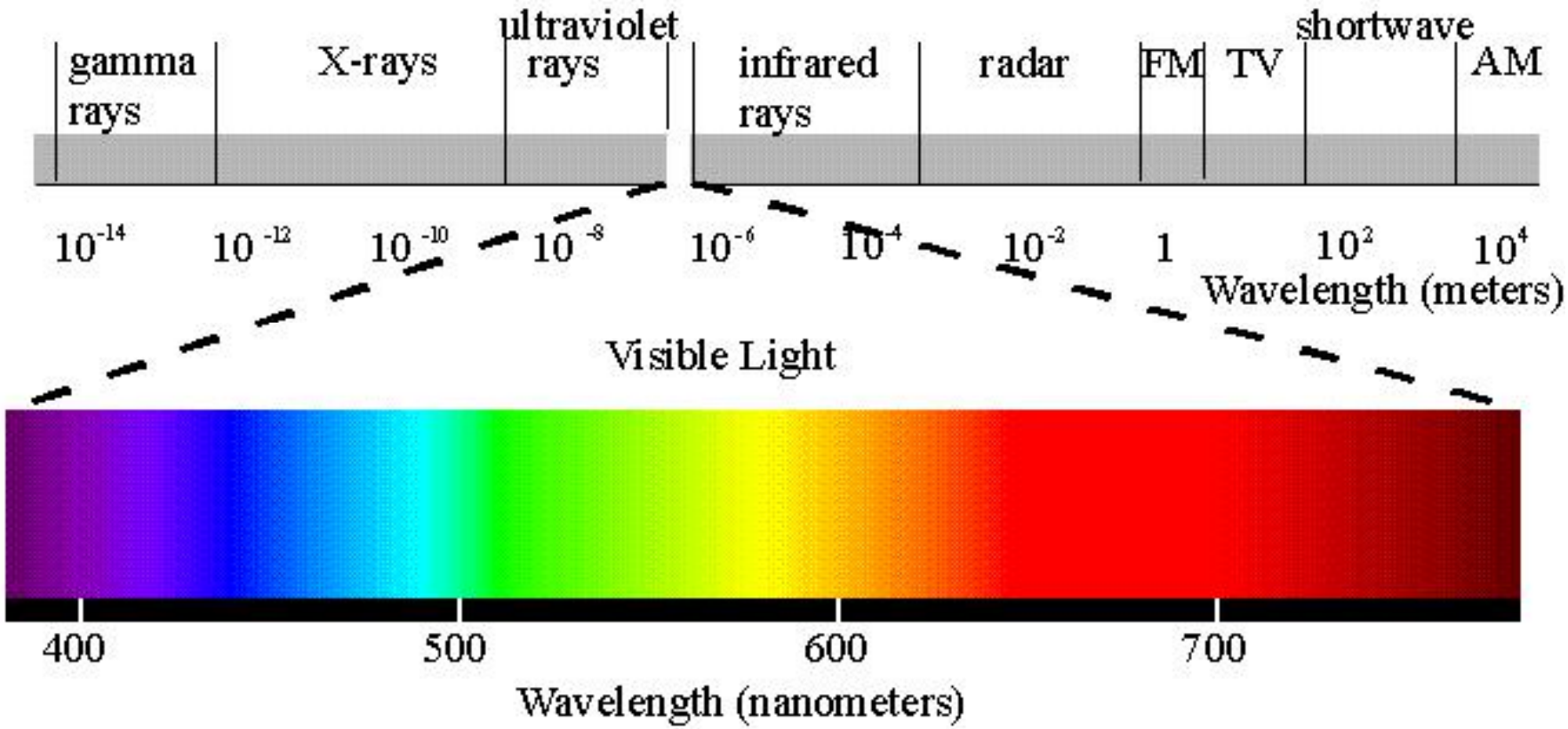
Visible Energy

- We can only see a very limited range of wave lengths.
- What would it be like if we could see microwaves?



What microwaves might look like

Spectrum of visible light

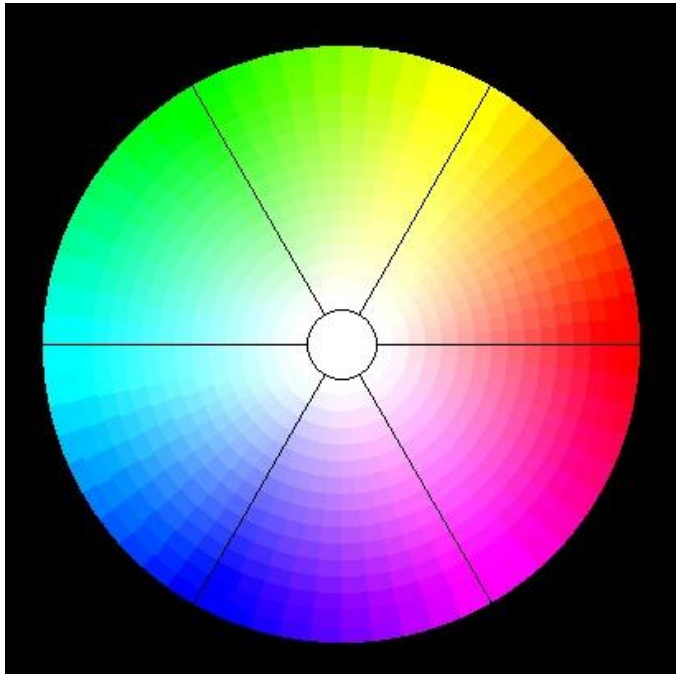


What is your favorite color?

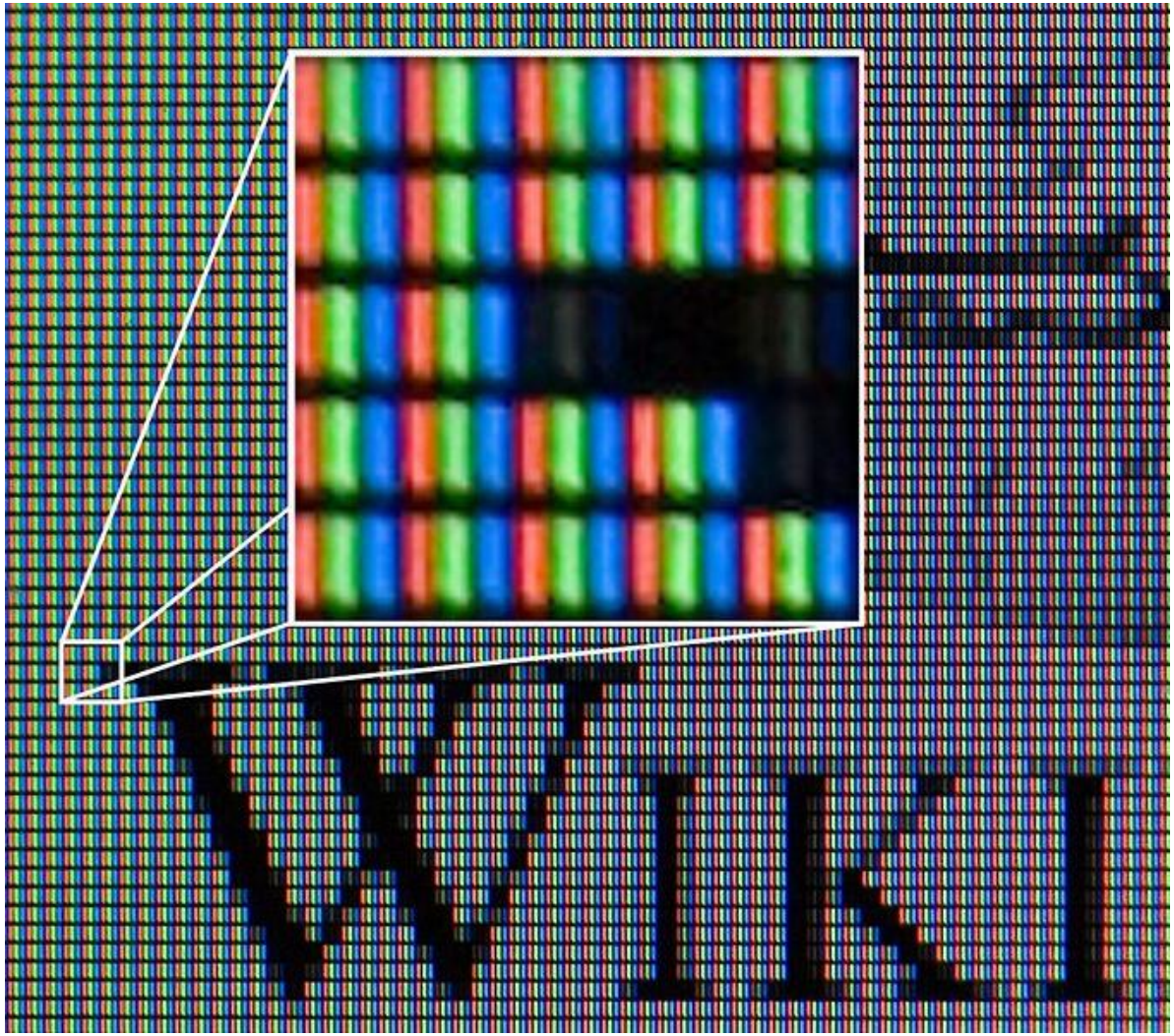
- Can you guess mine?
  - Infared
- My son's favorite color is yellow, red, black, white, blue, purple, brown (poop color), khaki (light poop color), and orange.
  - This is his way of saying he hates pink

Tristimulus Theory

- Any color can be produced by mixing different amounts of three additive primaries

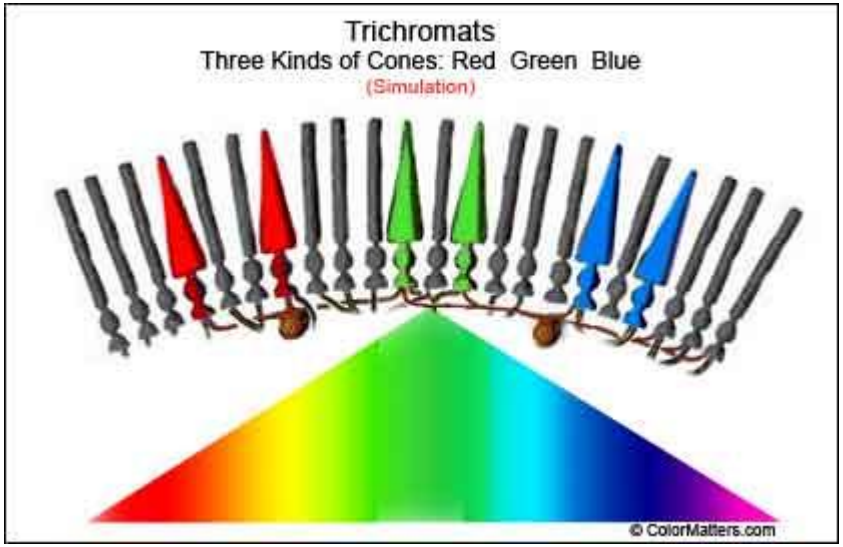


How do TVs and Computer Monitors create color?



How do TVs and Computer Monitors create color?

- The same way our eyes detect color.
- By mixing the three wavelengths your eyes can detect.

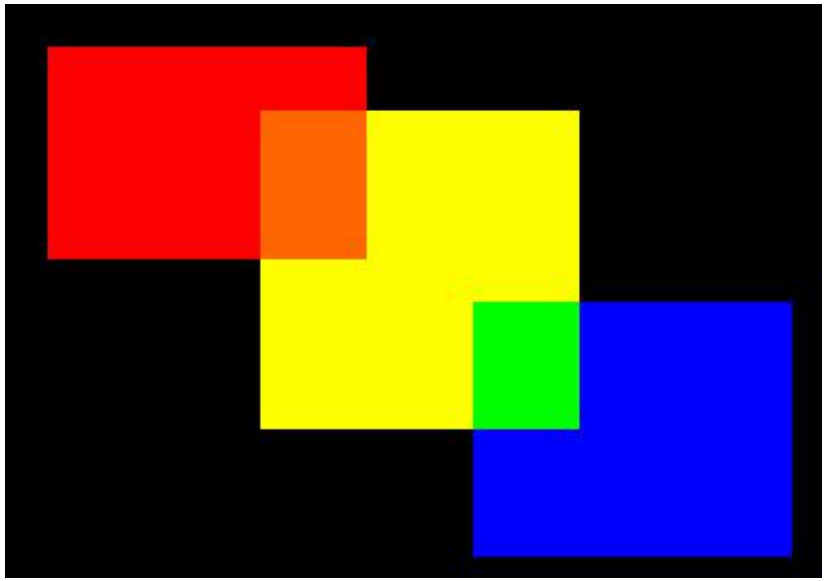


Red, Yellow and Blue (NOT!)

- In kindergarten, we all learned that the primary colors were:
- Red, Yellow, and Blue, right?
- Well, that was a lie.
- Just, like in 1st grade when they told you there was a giant vacuum in space.
- There is NO giant vacuum in space.
- Microwaves are NOT invisible.
- And, Yellow is NOT a primary color!

Yellow

- Yellow is ONLY considered primary when mixing paint or ink
- Mixing paint is different than mixing light
- More colors =
  darker color
- Red + Green is too dark (brownish, not yellow)



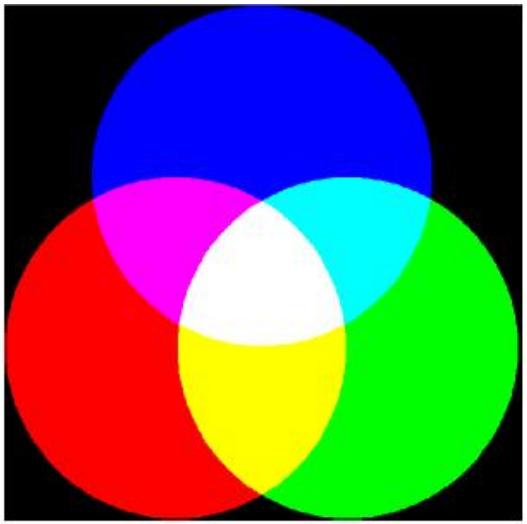
Green

- Mixing light is different than mixing paint.
- It is an additive and synergistic process

- More color = lighter color
- Red + Green = bright yellow
- Red + Green + Blue = white!

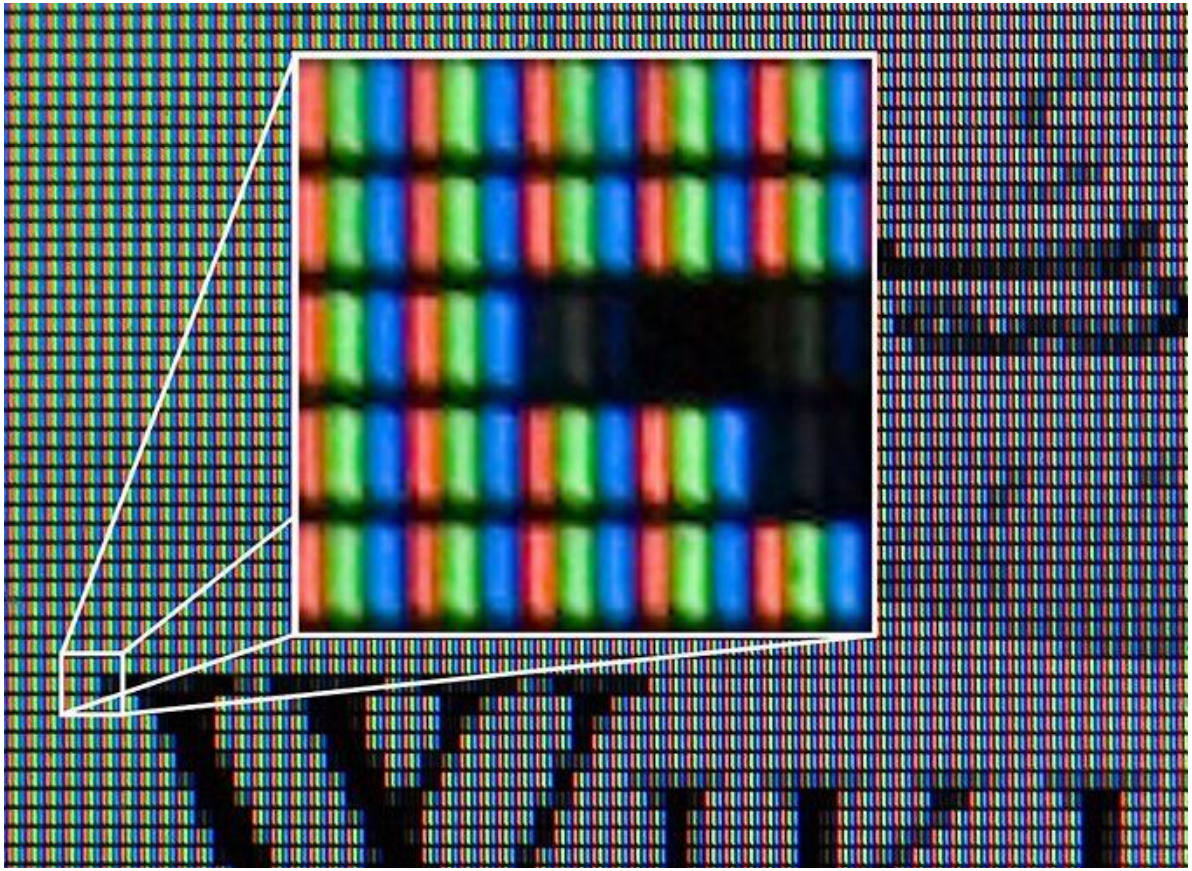
Back to TVs and Monitors

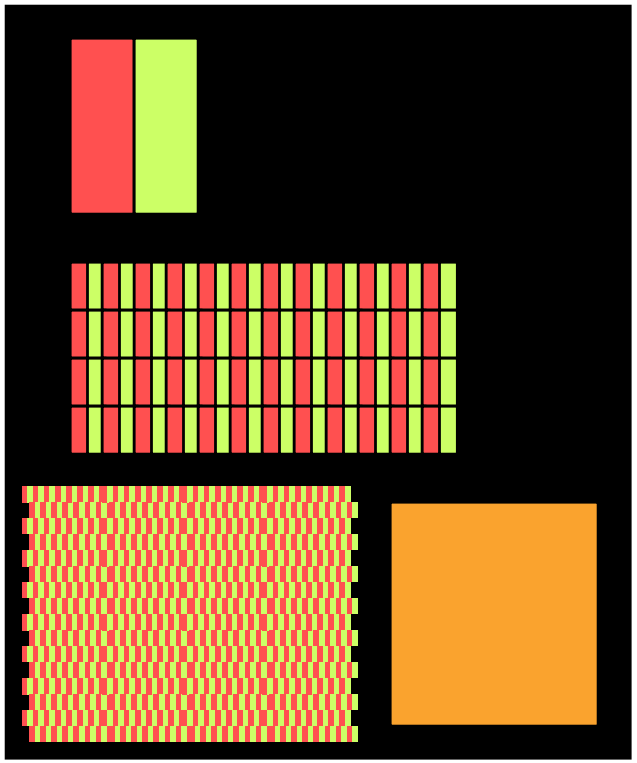
- The surface is black, no light equals black.
- Each pixel is created from three separate light signals.
- **Two models:**
  - **RGB**: Red, Green, Blue
  - **CMYK**:
    - Cyan
    - Magenta
    - Yellow
    - Key (level of intensity – bright to dark)



Pixel Components

- If you put colors close enough together, the eye perceives them as one color.



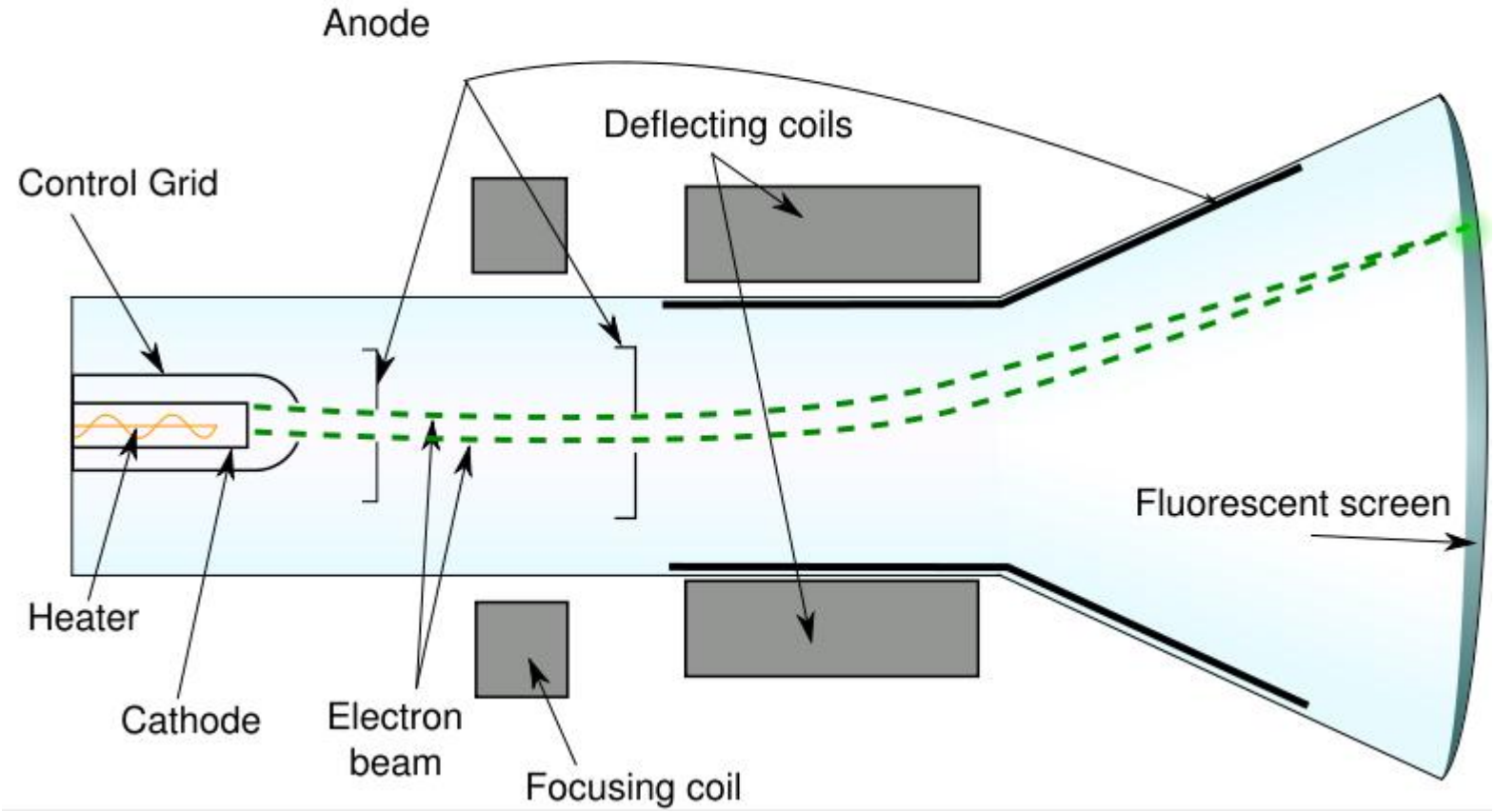


TVs and Monitors

- Light signals can be generated in many different ways
- The key is that you want the pixel to be very small and bright.
- **Three technologies:**
  1. CRT: Cathode Ray Tube
  2. LCD: Liquid Crystal Display
  3. Plasma

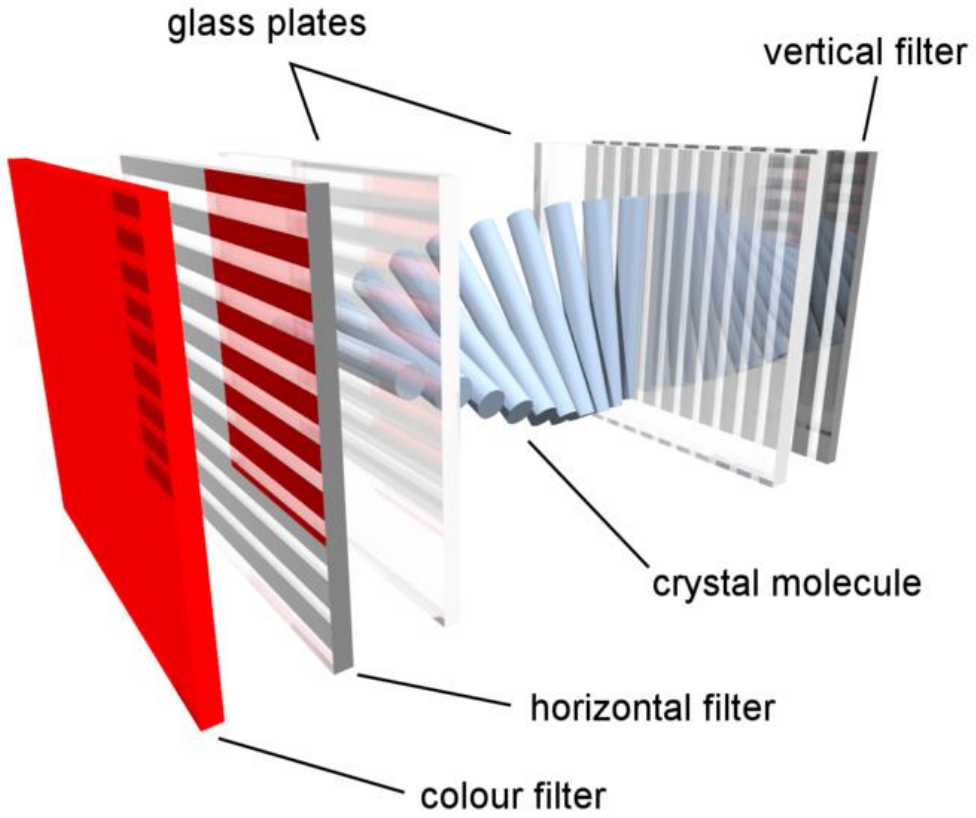
CRT: Cathode Ray Tube

- Glass tube containing an electron gun and a fluorescent screen



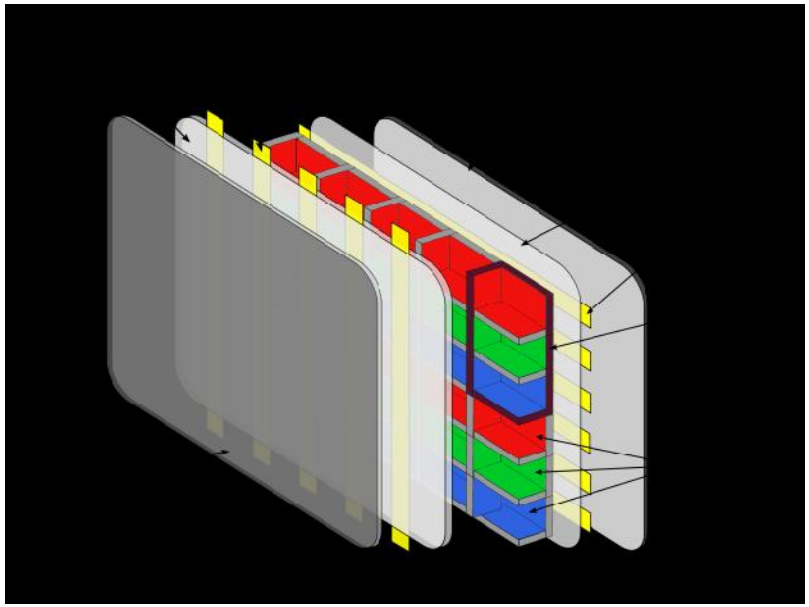
LCD: Liquid Crystal Display

- Each pixel consists of a layer of molecules aligned between transparent electrodes, and polarizing filters



Plasma TV

- Cells between two panels of glass hold neon and xenon gas. Gas is electrically turned into a plasma which excites phosphors to emit light.



RGB vs. Wavelength

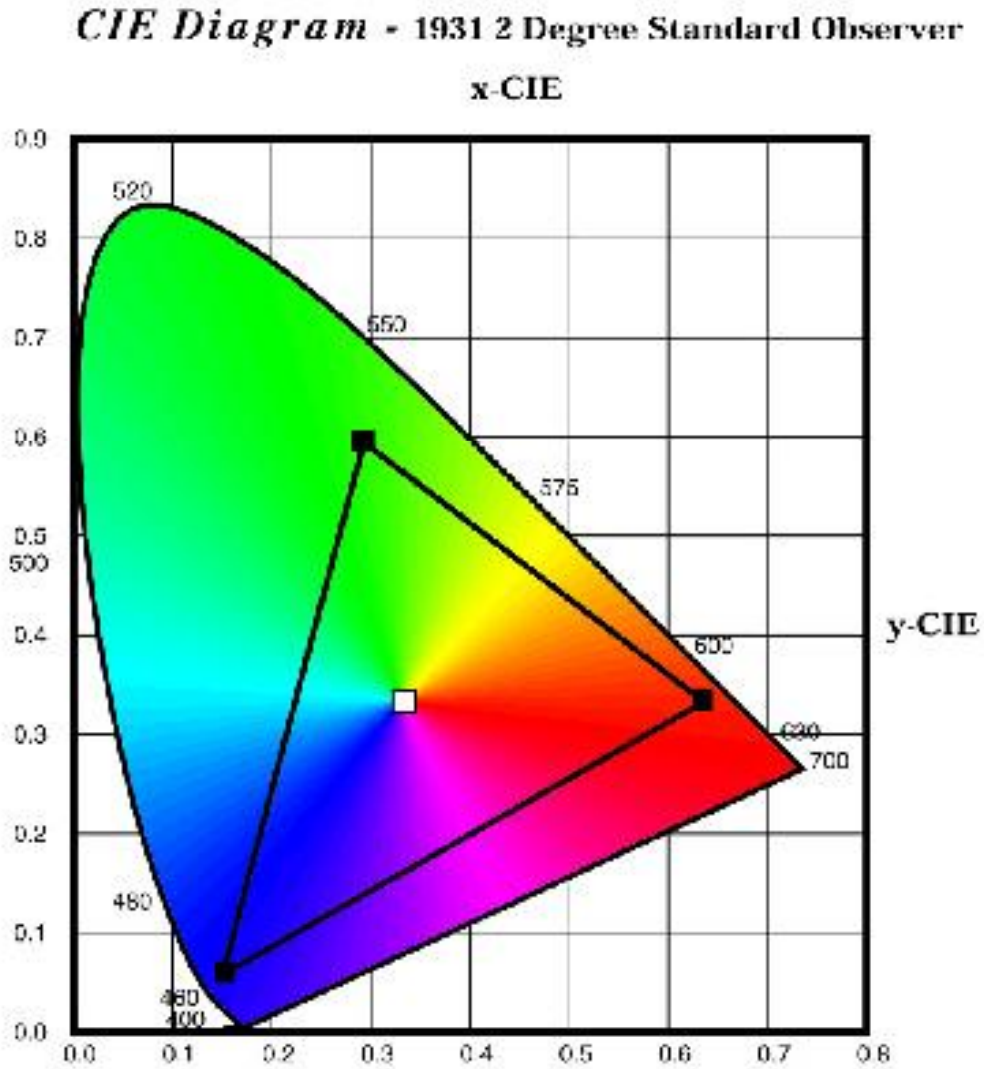
- Technologically, it is easier to control color by emitting three different colors RGB, rather than vary the wavelength to create a “pure” color.
- **Similar to Binary**
  - Can encode any number in binary
  - Can encode any color with RGB combination

RGB vs. Wavelength

- In fact, the cones and rods in the eyes detect only three colors.
- We see more than three because the cones and rods send “mixed” or synergistic signals to the brain.
- Humans have a hard time distinguishing RGB mixtures from “pure colors” because we sense color as RGB mixtures anyway.

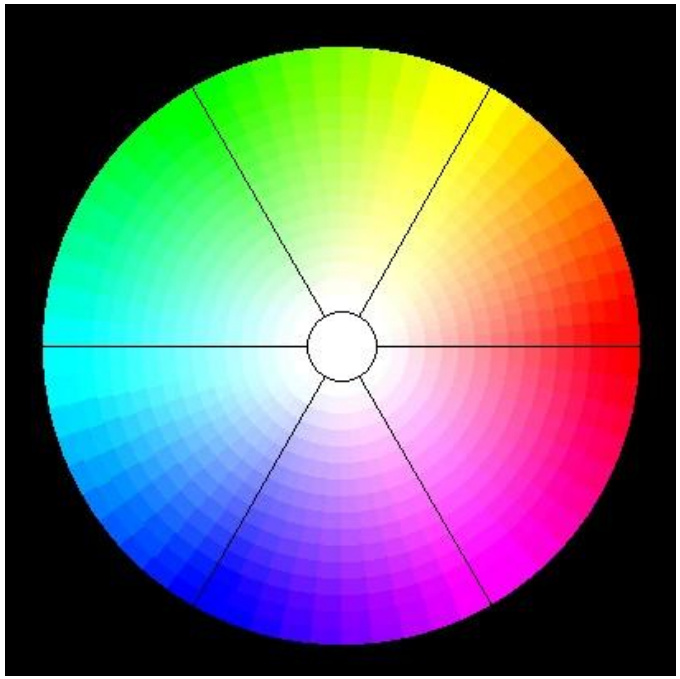
RGB is great but not perfect

- You can NOT reproduce all the visible color wavelengths using RGB combinations
- But, you can get pretty close.



RGB vs. CMYK

- RGB is NOT suitable for printing on paper.
- Color printers can NOT produce Yellow (Red+Green) because ink does not have the same synergistic properties of light.
- Thus, Yellow has to be a primary pigment.
- The color wheel gets turned.



RGB vs. CMYK

- **CMYK**: *Cyan, Magenta, Yellow, and K (Key) which is really black.*
- RGB is used almost exclusively for TVs/Monitors (where the surface is Black), you don’t need Key/Black
- Because CMYK is also for print (where paper is typically white), you need Black (C+M+Y = purplish brown).
- *How do you get White with RGB?*

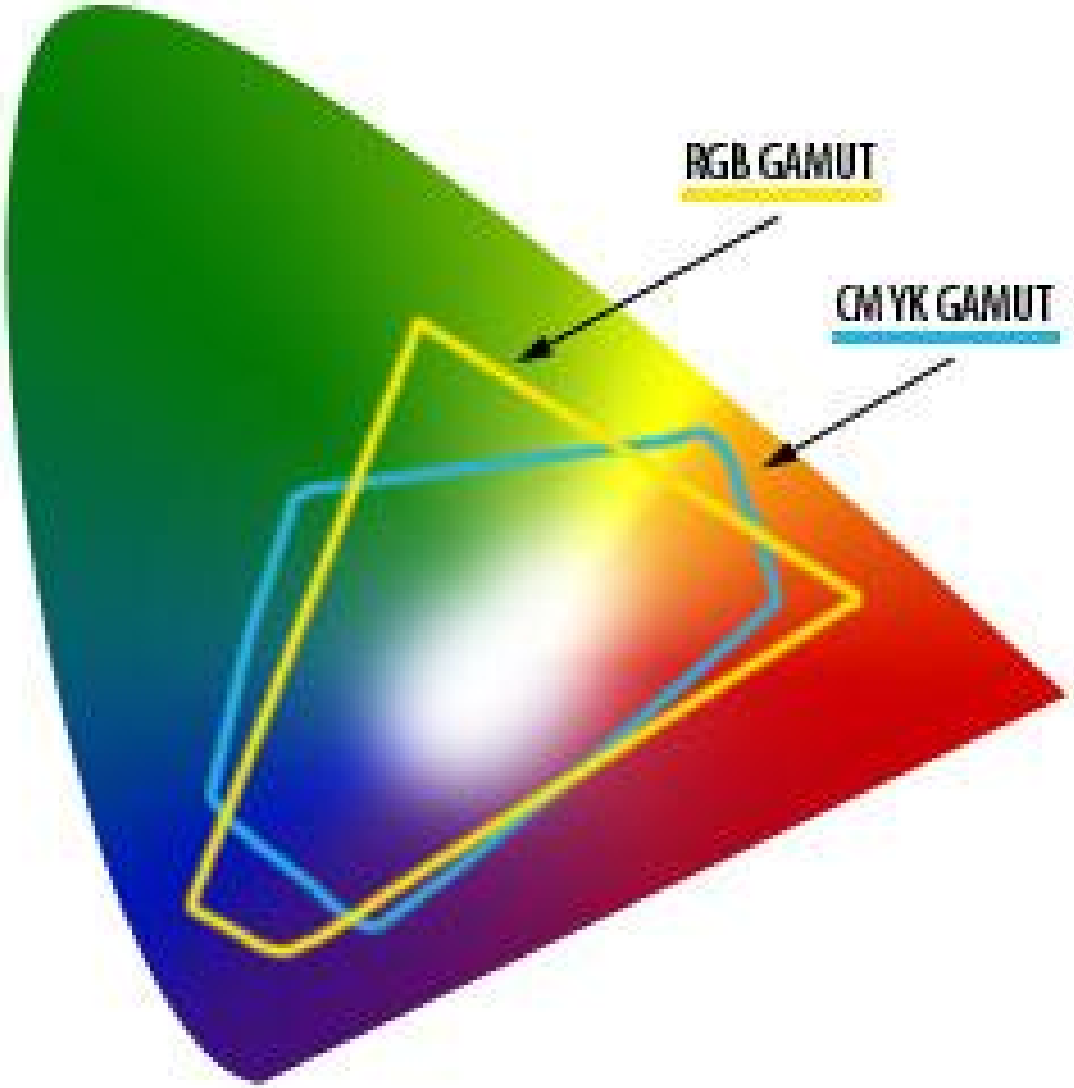
Complementary Colours

- Subtract additive primary from white gives its *complement*
  - Equivalently, add other two additive primaries
- $C = G+B = W-R$
- $M = R+B = W-G$
- $Y = R+G = W-B$
- *Cyan*, *magenta* and *yellow* are *subtractive* primary colours (mixing ink/paint)

CMYK

- CMYK encoding is used for applications that focus on printing: Photo Developing software and publishing software like QuarkXpress, Framemaker, etc.
- Applications that use RGB must convert to CMYK for printing
- Some RGB colors (on the monitor) can be perfectly matched using CMYK.

RGB vs. CMYK



Digital Color

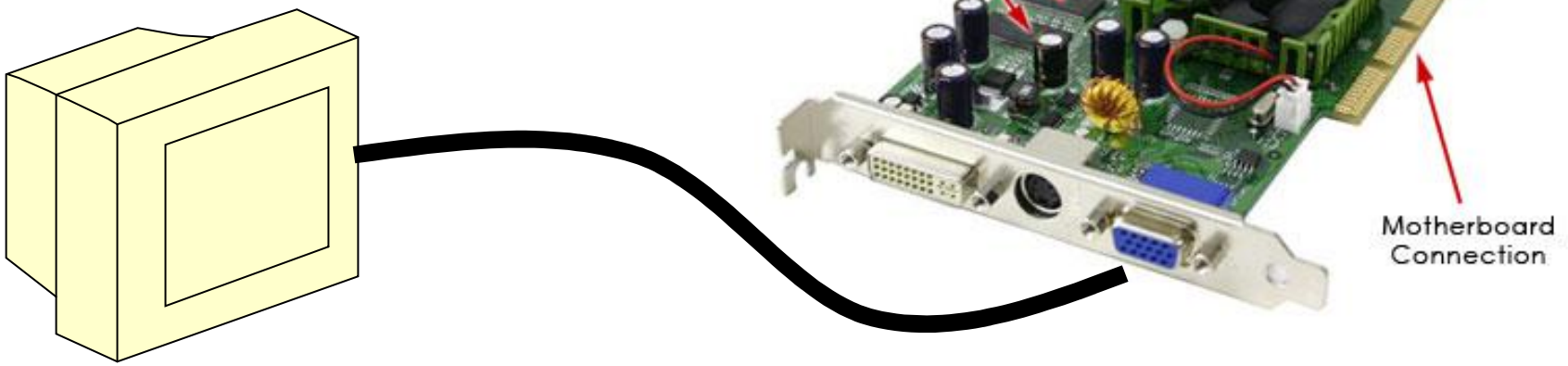
- Operating Systems and applications encode color using bits.
- Very early color systems only used 2 bits (4 colors).
- Dr. B’s first computer (IBM 8086) supported only 4 colors CMYK.
- As process speeds increased and graphics hardware improved
- 8 bit color and 16 bit color became the standard (1988-1994)

Data → Color

- Assume a four color encoding (2 bits)
- Assume a monitor with 640 X 480 pixels
- Monitor refreshes 60 times per second
  - (60 Hertz)
- The operating system must send…
- 640 X 480 X 2 X 60 bits per second.
- = 36 million bit per second.

Data → Color: Hardware

- Monitor plugs into a video/graphics card.
- The video card converts the bit pattern into an electrical signal.
- Monitors and graphics cards work together because of international standards.
  - For example, VGA standard



Monitor

- The electrical signal triggers the pixel color.
- CRT and LCD technology has a limit on
  - How small a pixel can be.
  - How bright it can be
  - How often it can be refreshed
    - 60-90 Hertz is the typical range

Data → Color: Software

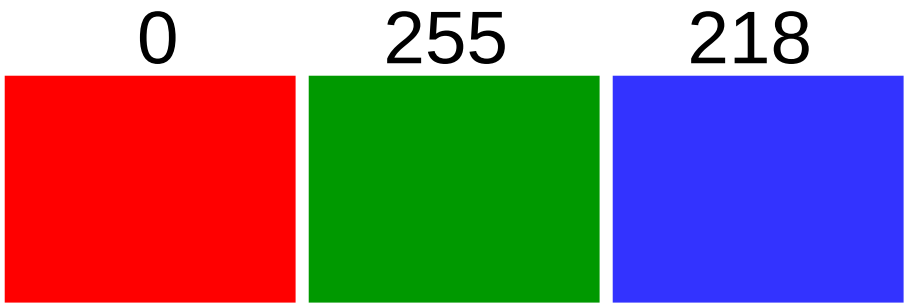
- The **graphics card** actually plugs into the mother board of the computer.
- The bit pattern travels across the **motherboard**.
- A **device driver** is used so that the operating system can communicate with the graphics card.
- A device driver is just small program…still written directly in assembly language.

Graphics Cards

- Old graphics card were just signal converters
- New graphics cards have memory (RAM) and processors
  - Takes the burden off of the computer's processor.
  - Enables 24-bit color at resolutions as high as 2560x1600.
  - Plus graphics card can also do things like render vectors (geometry computations).
- http://www.nvidia.com/page/geforce_8800.html

RGB Color Depth

- Choose number of bits for each of R, G and B
- More bits per color means more total colors, but image files will be larger
- 8 bits per color is not the standard: 24-bit color, 16.7 million colors



RGB Color Depth

- 8 bits (1 byte) per component means that you have 256 different “levels”
- If R = G = B, color is a shade of gray.
- Human eye can distinguish 256 shades of gray
- So, while 16.7 million colors is beyond what the human eye can distinguish.
- 24-bit RGB is under quantized for gray.
- But for Gray only.

Practical Technique: Color Palettes

- Choose 256 most important colors in an image to store in its palette
- When 24-bit image is reduced to indexed color, some colors may be missing form the palette
  - Replace missing color by nearest, may lead to *posterization*
  - *Dither* – use pattern of dots and optical mixing
- *Web-safe palette* – 216 colors guaranteed to reproduce accurately on all platforms and browsers

HSV

- Alternative way of specifing colour
- *Hue* (roughly, dominant wavelength)
- *Saturation* (purity)
- *Value* (brightness)
- Model HSV as a cylinder: *H* angle, *S* distance from axis, *V* distance along axis
- Basis of popular style of *colour picker*