Color Mixing

Ver.3

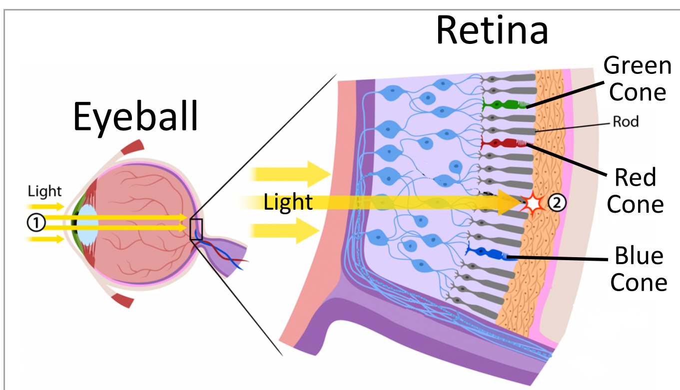
The Big Idea

1) The human eye mainly senses Red, Green and Blue, and the brain interprets combinations of these into all the colors we see. We can use Red/Green/Blue alone to reproduce any color.

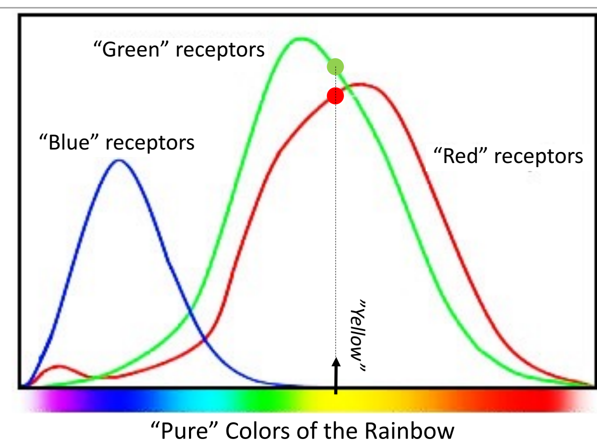
2) Printing/Dyes use Cyan/Magenta/Yellow because these *subtract* only Red/Green/Blue, respectively. We can thus use C/M/Y to reproduce any color via subtractive color mixing.

Background – for Leaders

- The human eye is primarily responsive to Red, Green and Blue light.
- We can control **just Red/Green/Blue light** to trick the brain into seeing any color.
- Main Question being posed/answered by the activity:
  How do printers and dyes use Cyan/Magenta/Yellow/Black (CMYK) inks to reproduce every color?
- Cyan/Magenta/Yellow each subtract only Red/Green/Blue, respectively.
- CMYK can be mixed to choose how much R/G/B reaches the eye, thus reproducing any color.



The eye has three types of color-sensors: red, green and blue. Each actually senses a range of colors →

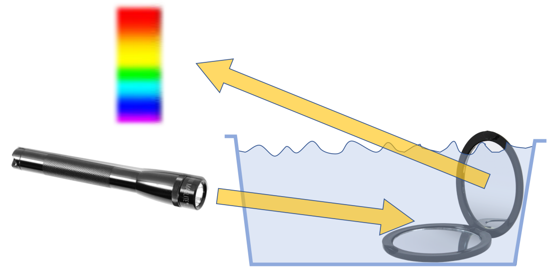


The brain interprets different ratios of Red/Green/Blue as each color in the rainbow.

The Hook   Intro + Rainbow (5 min)

Rainbow Demo
• Transparent container of water
• Compact mirror
• White wall or board

• Turn off lights



- **Here's an easy way to make a rainbow at home.**
  1. Turn off lights
  2. Shine flashlight into edge of water-filled container, hitting angled mirror, producing rainbow on wall.
  3. **Ask audience**: What colors do you see?
     – Explain that the angle/water is splitting the white light up into the different colors of light that make up white light.
  4. What colors DON'T you see?
  5. Is black in the rainbow?
     – Black is the *absence* of light.
- Isaac Newton was the first to prove that white light is made up of other colors
  – Previously it was thought that, like clothes or fabrics, white light was pure, and it got "dirty" when it got colored.

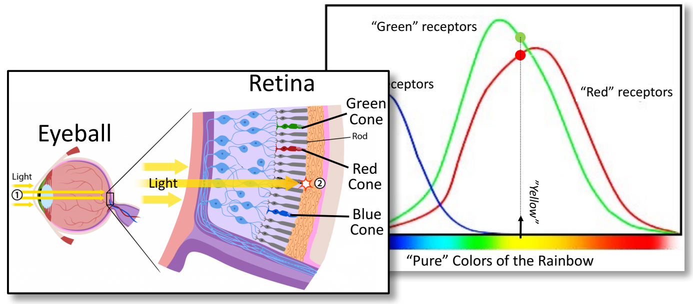
- Show printer cartridges & Ask the audience: What are these?
  – Ask audience member to read what colors are used?
  – Q: How does a printer use only three colors to reproduce every color we can see? Why these weird colors?
  – Today we'll be explaining why Red / Green / Blue are important colors to humans, and how printers use only three colors to print any color we can see.

Repeatedly reinforce the connection to printing, dyes and the human eye, throughout activity.

Discussion **Human Eye (5 min)**

Human Eye Discussion

- Refer to printouts & poster
  1) Human Eye
  2) Color Sensitivity Plot



1) The human eye has three types of "cone" color sensors: Red / Green / Blue
   - "Rods" detect only brightness (black/white)
2) They actually detect a range of colors, and the brain interprets the signals from each sensor
3) Eg. "Yellow" on the plot sends a lot of Red & less Green, which we then call "yellow".
4) **We can Trick the brain into seeing any color by exciting only Red / Green / Blue in the right ratio**

FUN FACTS: intersperse these during the rest of the activity

- Dogs have only yellow and blue cones, and thus have red-green color-blindness.
- Some women (2-3%) have a *fourth cone* with peak sensitivity between red and green, which allows them to differentiate colors much better, and even see colors that the rest of us don't have names for.
- There are other colors we can't see, such as ultraviolet (UV) and infrared (IR).
- Some birds and rodents can see UV light. That means they can see colors we can't see, just like we can see colors that dogs can't see!

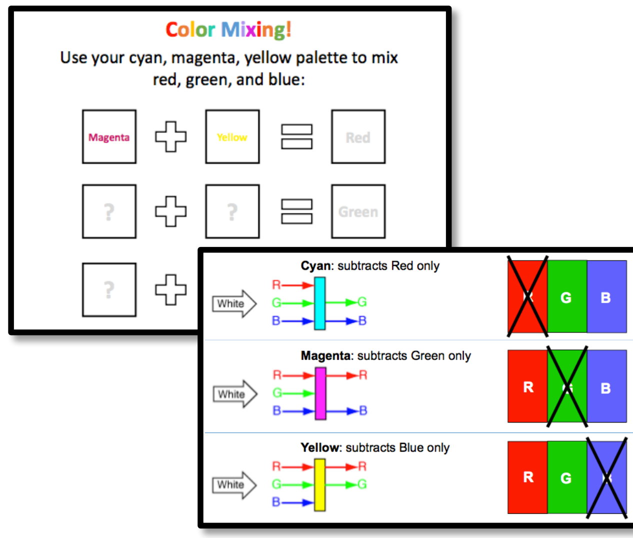
- There are also light-sensitive “Rod” cells in our eyes, which mostly help us to see things that aren’t related to color (light/dark, night-vision and motion).
- We have 6-7 million cones in one eye! They are mostly centered around the optic nerve (see eye diagram).
- We have mostly “red” cones (~64%), a fair number of “green” cones (~32%), and a few “blue” cones (~2%). The exact proportion varies from person to person.
- Blue cones are very light sensitive, partially to make up for the much larger number of red and green cones. But, it turns out that that this isn’t enough to overcome the relatively huge numbers of red and green cones. Since we can see blue just as well as red and green, our brain might be tricking us into thinking that there is more blue than what our eyes actually sense.
- Colors that aren’t in the rainbow as complex mixes of the various colors. “Brown” is actually dark orange along with other colors.
- Color blindness arises when one of these types of cones are not as active as they should be, whether that be due to the cells themselves or the brain being unable to fully receive that particular signal from the eye.
  The color sensitivity plot shows that Red and Green are so similar, that a small change can make them almost indistinguishable – this is why Red-Green color blindness is the most common.

Source: hyperphysics.phy-astr.gsu.edu

Hands-On **Color Mixing (10 min tot.)**

Subtractive Color Mixing

- 3 squeeze bottles (1 ea. cyan, yellow, magenta)
- Paintbrushes (6 per student)
- Water trough for discarded brushes
- Water cups (1-2)
- Plates/Tray for mixing (1 per student)
- Color mixing worksheet (1 ea. per student)



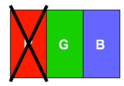
Intro: (2min)

- Printers use so-called CMYK color mixing.
  - Show them a couple of empty printer cartridges.
  - What do the different letters stand for?
  - Answer: Cyan, Magenta, Yellow, Black
- CMYK inks are used for *subtractive* color mixing. **CMY each "absorb" one color that our eye can see.**
  - "**Absorb**": like a rag absorbs water, these dyes absorb exactly One color.
- Remind them that white is made up of all the colors.
  - The printer paper or t-shirt fabric we use must be white so it reflects back all of the colors. We can then start subtracting from white.
    - Black changes only the brightness
  - **Cyan** subtracts only **red**.
  - **Magenta** subtracts only **green**.
  - **Yellow** subtracts only **blue**.
- Now we can control Red/Green/Blue, and trick our brain into seeing any color we want.

WARNING/Instructions to students

1. Be careful not to stain your clothes! These paints should wash out in water.
2. Squirt colors onto tray and mix with brushes
3. Use a fresh brush each time, to prevent mixing old colors.
4. Brushes must go into water trough after use.

Activity: (8 min)

1) Lead class in filling out the first row of RGB color math
    a. Combine two 

diagrams to leave only Red unabsorbed.
    b. *Answer*: Magenta + a little Yellow = Red

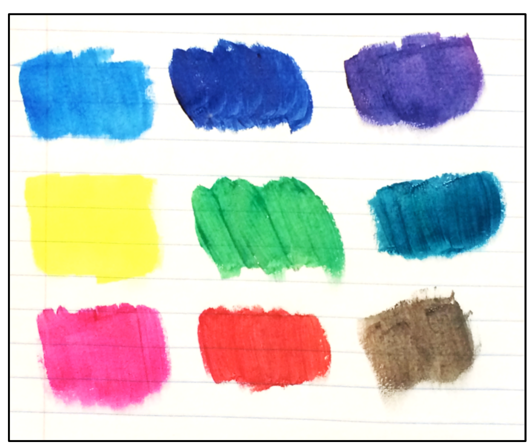
2) Reiterate subtractive color mixing, i.e.
    a. magenta subtracts green and
    b. yellow subtracts blue, therefore
    c. magenta + yellow leaves only red

3) Have students fill in the remaining rows on their own (front and back) using their color math logic
    a. <u>Note</u>: When mixing blue, we want Dark Blue – Cyan is **not** the blue we are looking for.

- For students who finish quickly, hand out color math part 2 (more challenging combos)
- ~~Optional: Block Printing with colors. (Not deployed yet)~~

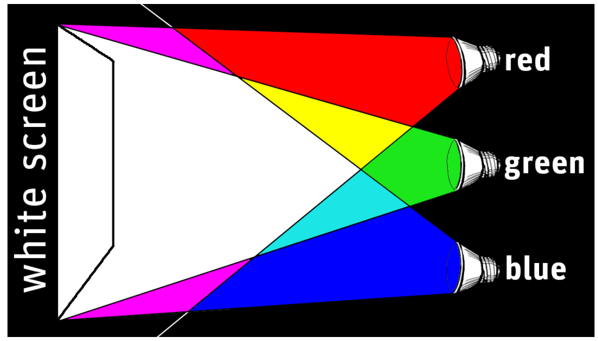
<u>Tips:</u>

- Encourage them to experiment with color ratios to get desired results
- Pick up a clean brush for each new color mix to avoid getting muddy colors



Hands-On

Color Shadows (5 mins)



Materials:

- Red, green, and blue flashlights
- White sheet taped up somewhere
- Duct tape to secure flashlights & sheet

Procedure:

1. Turn off the lights (make the room as dark as possible)

2. Shine the flashlights at the screen (sheet) such that the spot is as white as possible (you can adjust the spot size of the lights by sliding the sleeve)

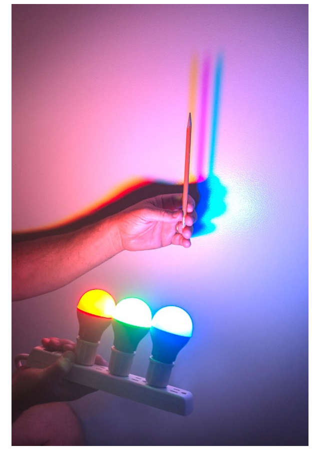
3. **Ask:** What color should I Block to get:
    a. Cyan ⇒ Block Red (B + G only)
    b. Magenta ⇒ Block Green (R + B only)
    c. Yellow ⇒ Block Blue (R + G only)

4. Have students take turns standing in front of screen or holding objects.
    a. Make observations of shadow colors
    b. Will see C, M, Y colored shadows

5. Play with the distance between the object and screen and observe the results

6. Try combinations of just two colors (RG, GB, and RB), then just one at a time

Questions to ask the students:



1. What colors are the shadows? (CMY)
2. What happens if we use only two colors? What color is the shadow?
3. How is this different/similar to subtractive mixing?
4. What happens when an object blocks all three lights?
5. How does this relate to what we learned about rods and cones?

Explanation

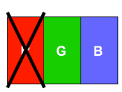
– In the case of color shadows, we are observing **additive** color mixing (light mixing instead of pigment mixing).
– When we aim all three RGB bulbs at the screen, we see white because all three types of cones (R+G+B) are activated, resulting in white.
– The reason we see CMY colored shadows, is due to combinations of the three RGB light colors overlapping,
    - i.e. red and green mix additively to make yellow.
– The perception of the color yellow is created in our brain by the red and green cones activated **separately**, instead of by one pure color (as in a rainbow).
– Notice that the additive primaries, RGB, mix to create the subtractive primaries, CMY.
– Recall that, for inks, yellow ink subtracts blue because yellow absorbs only blue. This passes only red and green, which for lights will additively mix to make yellow.

Wrap-Up

Last 30 seconds

- By controlling only R+G+B, we can trick the brain into perceiving every color
- We see white when all three types of cones (R+G+B) are activated
- The perception of the color yellow is created in our brain by the red and green cones activated **separately**, instead of by one pure color.

Troubleshooting / Extra Notes

- **Paints**
  - Use 

    part of worksheet to help students figure out which color will bleed through when two paints are mixed.
  - It's all about getting the **ratio** correct. Start with a squirt of one color, and then start *gradually* adding another, small bits at a time.

- **Colored Shadows**
  - Block two flashlights and observe the resulting colors as you add one at a time.
  - Note that these are the exact same "color maths" done with the CMY inks.

Classroom Preparation on FUSE day

1. Tables
   a. Laminated pictures (eyeball, spectrum)
   b. Old Printer cartridges showing CMY colors
   c. Water container for used paint brushes
   d. Fresh trays/plates for mixing
   e. Fresh Color Mixing worksheets
   f. Squeeze bottles of CMYK paints diluted to
      i. ~0.5-inch of paint and fill water to ~2-in.
2. Rainbow Demo (**test before activity**)
   a. Fill container almost to top with water
   b. Place compact mirror with Non-Magnifying mirror at top, open to ~135° (obtuse angle)
   c. Ensure rainbow can reflect onto a White wall/surface before activity
   d. Set Mag-Lite to tightest focus (just barely twisted enough to turn on)
   e. Play with mirror angle and flashlight angle until get good rainbow on the wall.
3. Printer somewhere where audience can look closely, opened to show CMYK cartridges
4. Paints
   Place supplies at tables:
   a. 3 squeeze bottled: Cyan/Magenta/Yellow/Black
   b. 3 sets of 6 paint brushes
   c. water trough with ~1/2 – 1 inch water
   d. fresh plates/trays for mixing
   e. Color Mixing Worksheets (yellow + magenta = …)
   f. Human Eye + RGB Math handout
5. Color Shadows

a. Tape up Bed sheet somewhere with ~6-10 feet of space in front of sheet, enough space for people to stand in front and play
b. Set up R/G/B flashlights, adjust focus to large-spot, aimed so they overlap
    i. Tape down to table if needed, with button accessible

<u>Transition between groups:</u>

1. Sticker on student's pass cards upon entering class
2. New clean paintbrushes (leave used ones in water)
3. New Color Math Worksheets
4. New Clean Mixing Trays

Supplies Used

Rainbow Demo:
- Clear Plastic Tupperware: 6 x 4 x 2”: $2
- Foldable Compact makeup mirror, with mirror on both sides: $3
- Mini-Maglite LED Flashlight 200 lumens: $15

Color Mixing:
- Color Mixing Paints: Speedball Acrylic Screen Printing Ink Starter Kit ($17)
    - Will be diluted – one set supplies 15-20 activities
- Watercolor Paint Brushes: $10 for 150
    - Use ~6-7 per family
- Plastic water trough: $15 for 5
    - For keeping used brushes wet until can be cleaned
- Condiment Squeeze Bottles: $15 for 4
    - Paints will be diluted into these: ~1 Tablespoon paint per ~1/2 Cup water
- Plastic mixing trays: $2 ea.
    - For mixing paints in

Colored Shadows
- White Bed Sheet: Kmart $5
    - To provide white surface in classroom, in case wall/board not available
- Duct Tape to tape up sheet
- Red, Green Blue zoomable flashlights: $13 ea., so $40 total
    - CrazyFire Zoomable Blue/Red/Green Light LED Flashlight Lantern Torch
    - Zoom for controlling intensity via focus

Other Supplies
- Printer Cartridges: Dumpster dive in UCSB Electronics Waste.
- AA batteries – the Maglite flashlights need to be very bright
- AAA batteries – lots (the colored flashlights may run out!)
- Posters printed of Eyeball / Cone Sensitivity
- Posters printed of 4-color CMYK
- Posters printed of Color-Math