Color Spaces and Perception

also today: pre-survey results, 2D project brainstorming

CS 4300/5310

Computer Graphics

ANNOUNCEMENTS

Deadlines

- Assignment 1: Today!
  - Art contest?

- 2D Project Proposal: January 22nd
  - Submit as a group on Blackboard

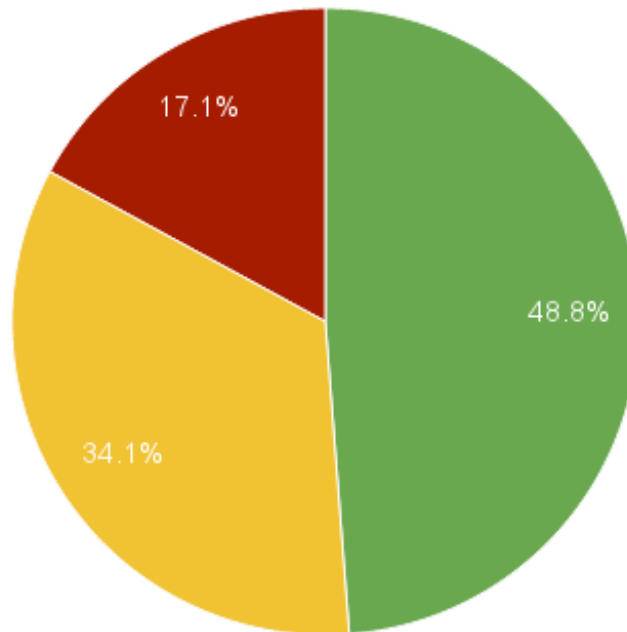- 2D Project main deadline: February 5th

pre-course survey results

WHO ARE YOU?

Required Course?

Course Requirement

- Yes, I am required to take computer graphics
- I am using computer graphics to fulfill a degree requirement, but graphics itself is not required
- No

48.8% — Yes, I am required to take computer graphics
34.1% — I am using computer graphics to fulfill a degree requirement, but graphics itself is not required
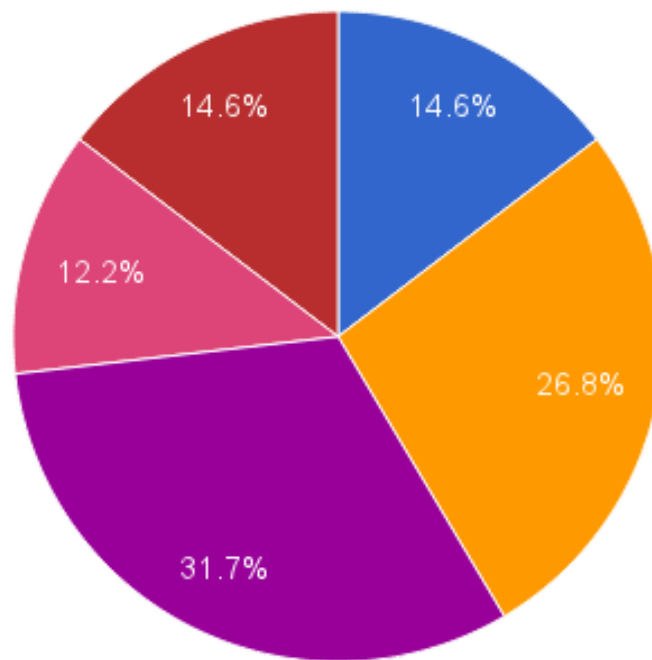17.1% — No

Java Experience

Java Familiarity
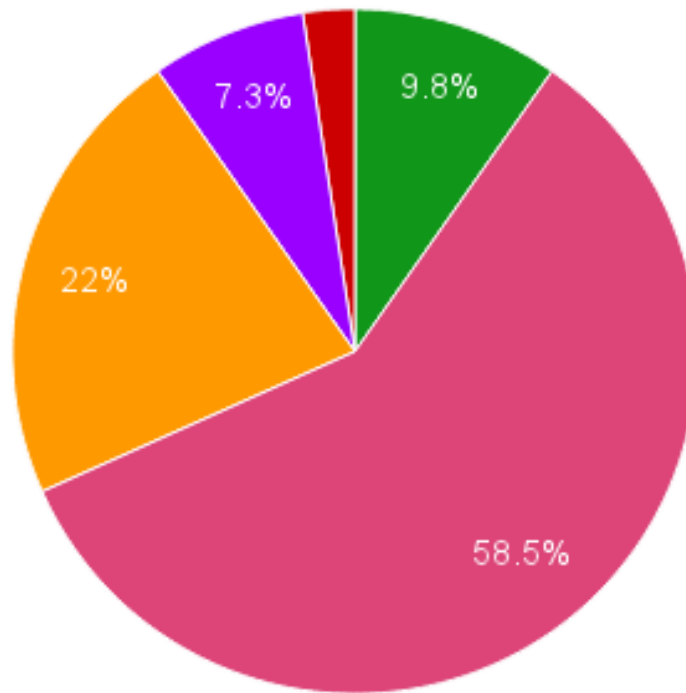
- **Expert:** I use this language all the time
- **Intermediate:** I have used it in several classes or for a couple of projects
- **Beginner:** I have written some simple programs in it, but nothing complex
- **Aware:** I have read some programs written in Java, but never written in it
- **None:** I have never been exposed to Java
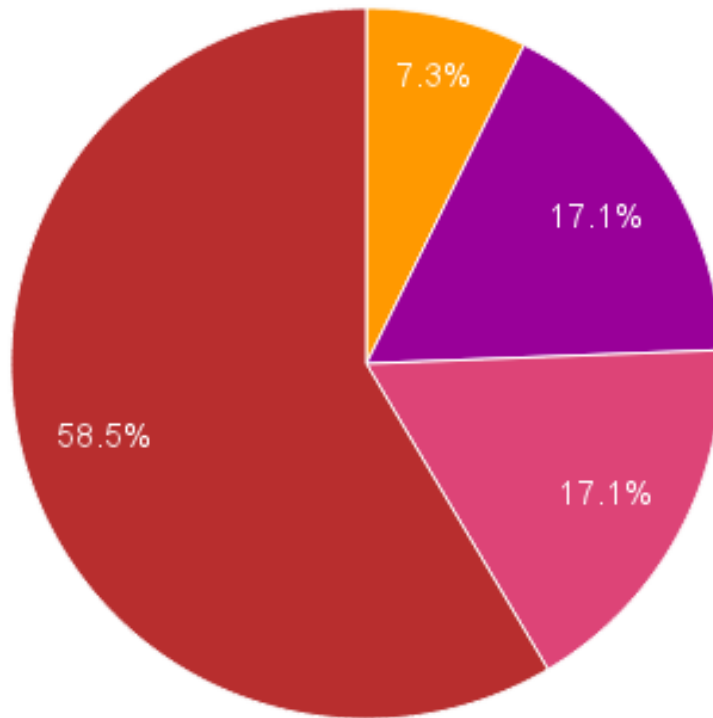
9.8% — 58.5% — 22% — 7.3%

C++ Experience

C++ Familiarity

- Expert: I use this language all the time
- Intermediate: I have used it in several classes or for a couple of projects
- Beginner: I have written some simple programs in it, but nothing complex
- Aware: I have read some programs written in C++, but never written in it
- None: I have never been exposed to C++

OpenGL Experience

OpenGL Familiarity

- 7.3%
- 17.1%
- 58.5%
- 17.1%

Legend:
- Intermediate: I have used it in several classes or for a couple of projects
- Beginner: I have written some simple programs in it, but nothing complex
- Aware: I have read some programs that use OpenGL, but never written any
- None: I have never been exposed to OpenGL
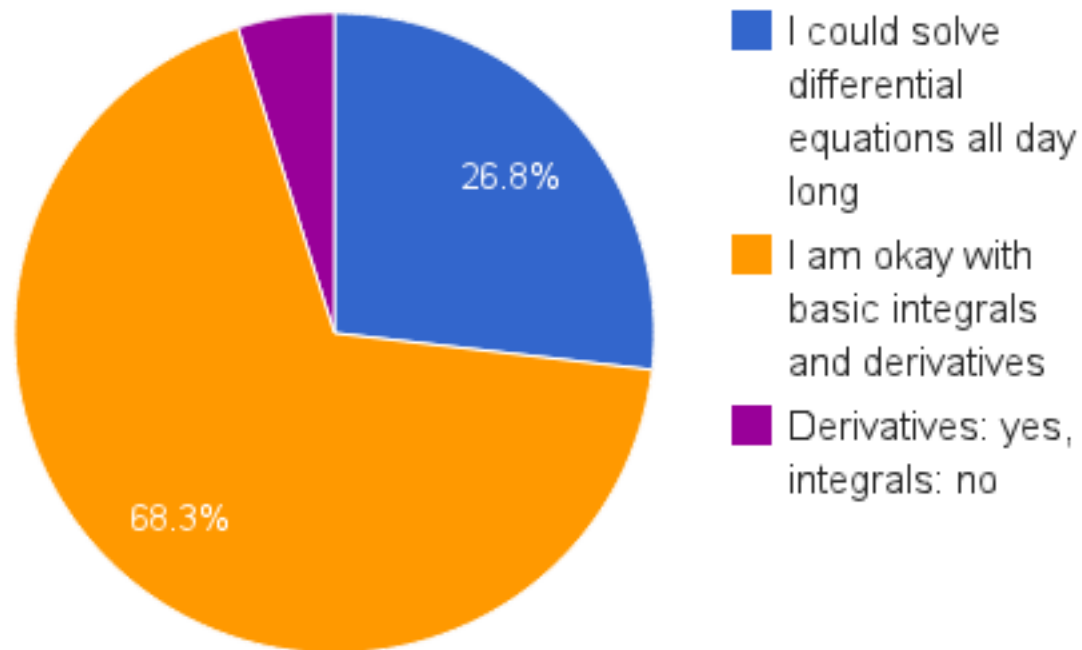
Linear Algebra

Linear Algebra Knowledge
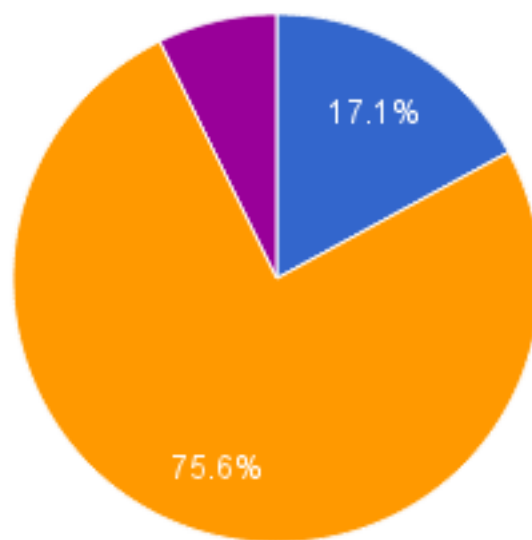
- I have completely mastered linear algebra
- I sort of remember matrix math
- I don't remember much at all

17.1%

75.6%

Calculus

WHAT IS COLOR?

Graphics Problems

- **Modeling**
  - 2D and 3D representation
  - Curved surfaces
  - Procedural techniques
- **Rendering**
  - Realism
  - Speed
  - Non-realism
- Animation
  - Illusion of life
  - Motion capture
  - Keyframing
  - Physical simulation

Graphics Problems

- **Modeling**
  - 2D and 3D representation
  - Curved surfaces
  - Procedural techniques
- Rendering
  - Realism
  - Speed
  - Non-realism
- Animation
  - Illusion of life
  - Motion capture
  - Keyframing
  - Physical simulation
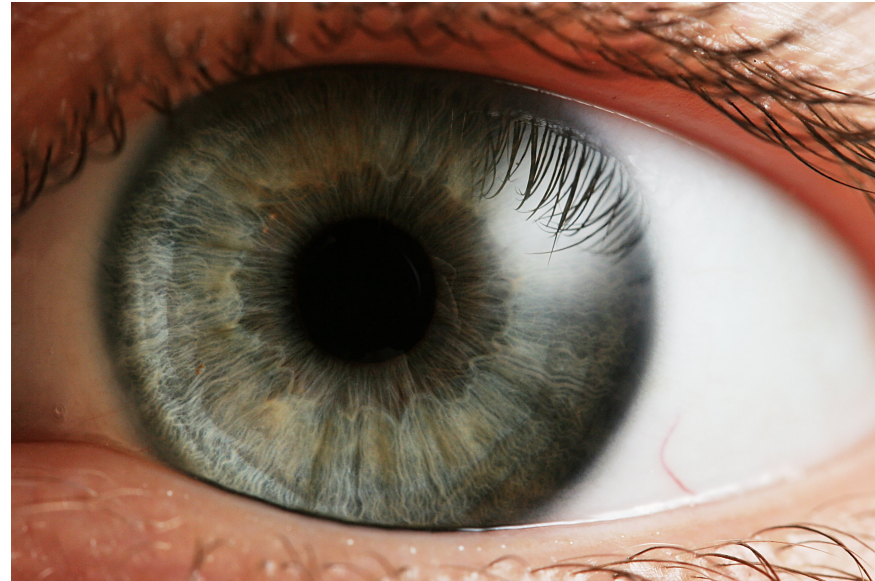
What is Color?

- Visible light: the portion of the light spectrum we can see

- Color: corresponds to a wavelength of light
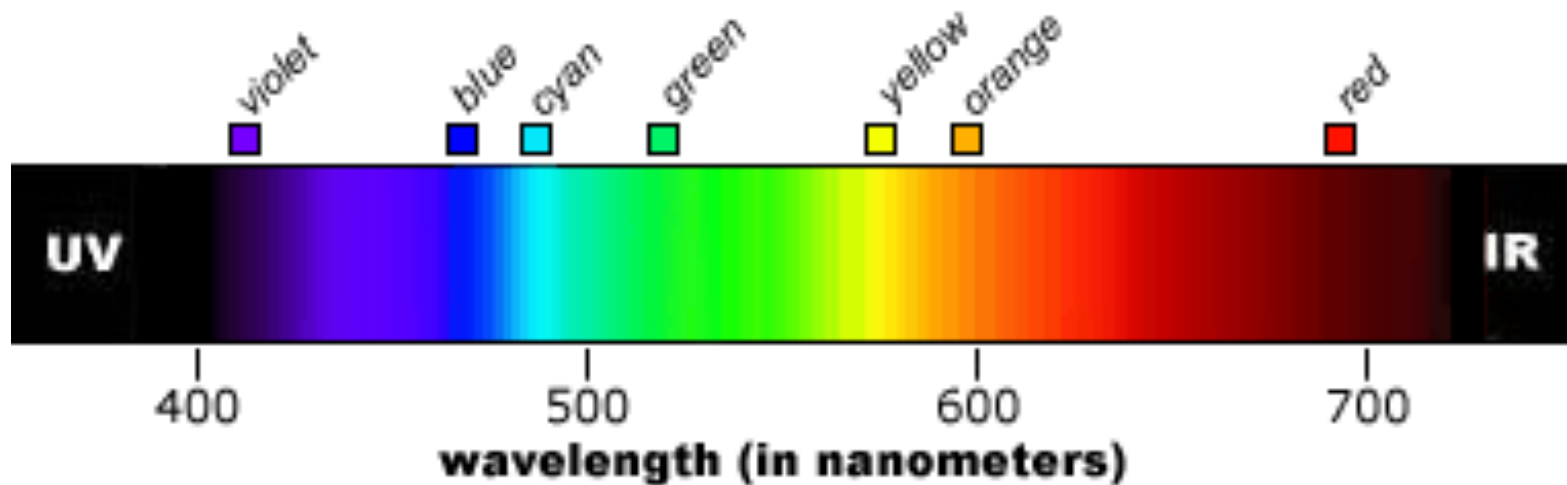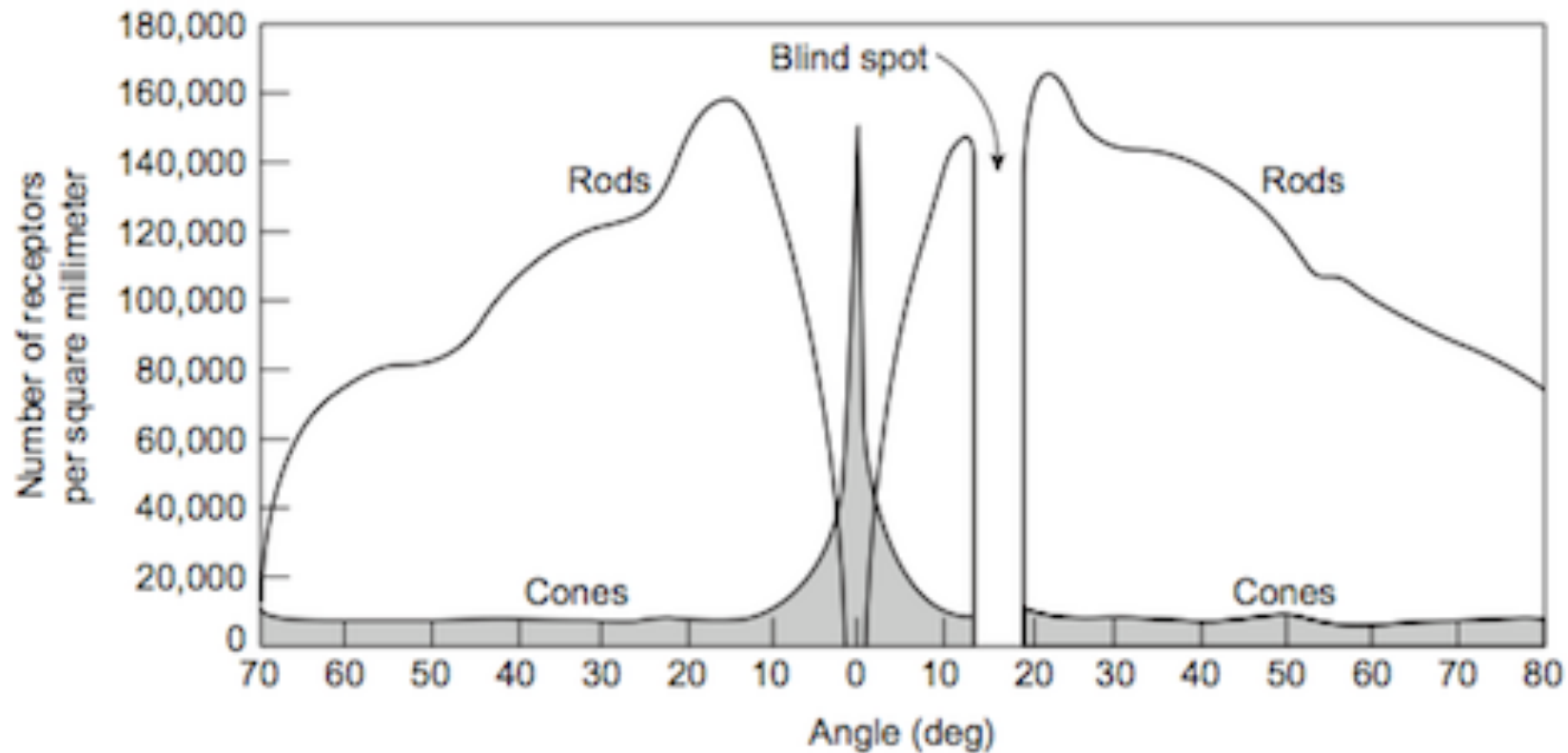
How do we perceive color?

- Rods: sensitive to low light

- Cones: sensitive to bright light
  - **S**hort wavelength
  - **M**edium wavelength
  - **L**ong wavelength
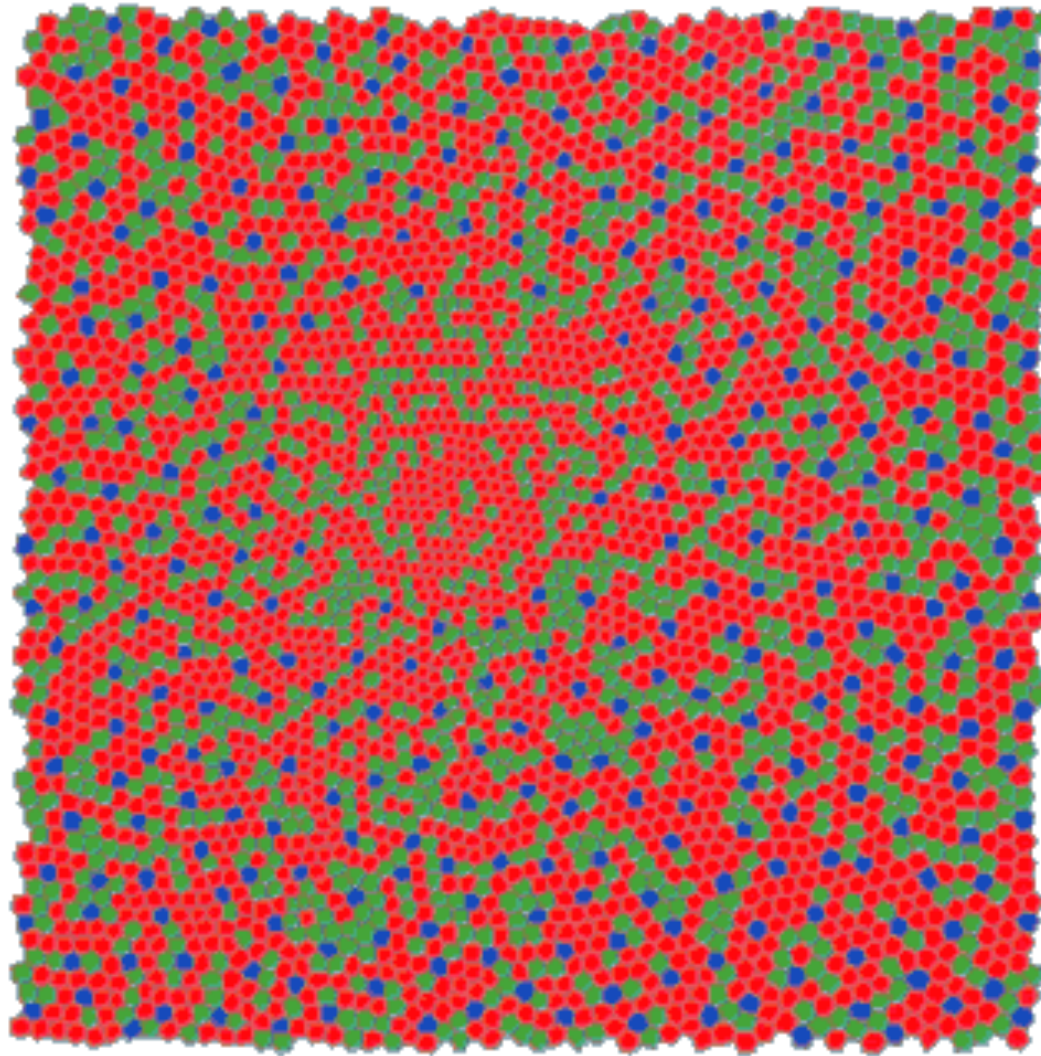
How do we perceive color?

- Hue: what color is it?

- Saturation: how close to grey is it?

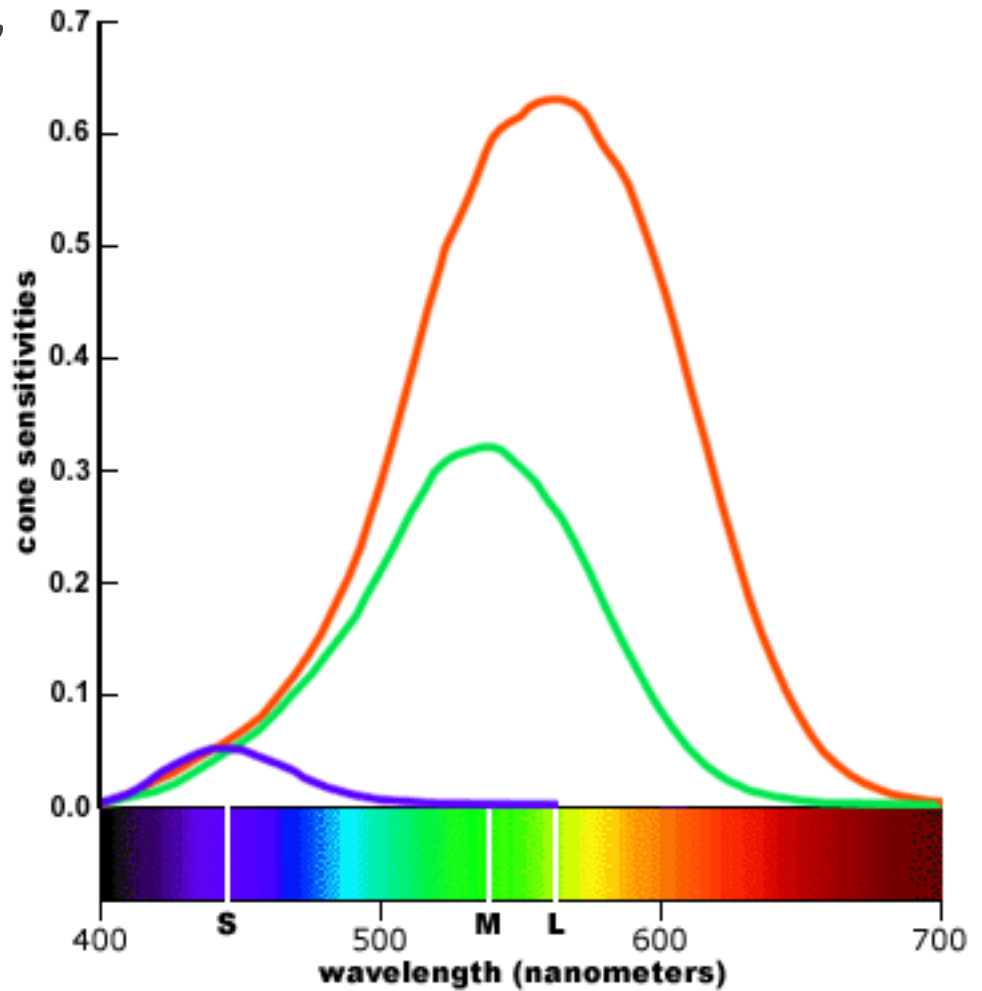- Lightness: how intense is the light?

Cone/Rod Density

Cone Distribution

Cone mosaic

Color Sensitivity

- Cone color sensitivity, weighted by proportion of L, M, and S cones in retina
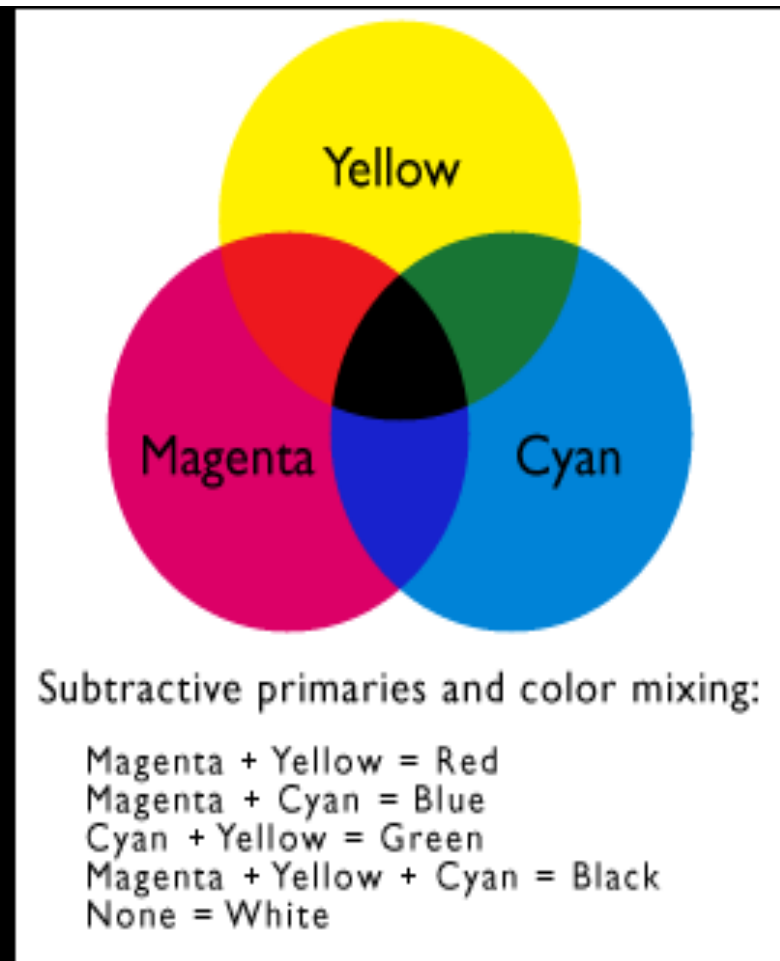
- What color are we most sensitive to?

Metamerism

- Two different light functions evaluate to the same tristimulus values

Additive vs. Subtractive Color

Additive primaries and color mixing:

Red + Green = Yellow
Red + Blue = Magenta
Green + Blue = Cyan
Red + Blue + Green = White
None = Black

Subtractive primaries and color mixing:

Magenta + Yellow = Red
Magenta + Cyan = Blue
Cyan + Yellow = Green
Magenta + Yellow + Cyan = Black
None = White
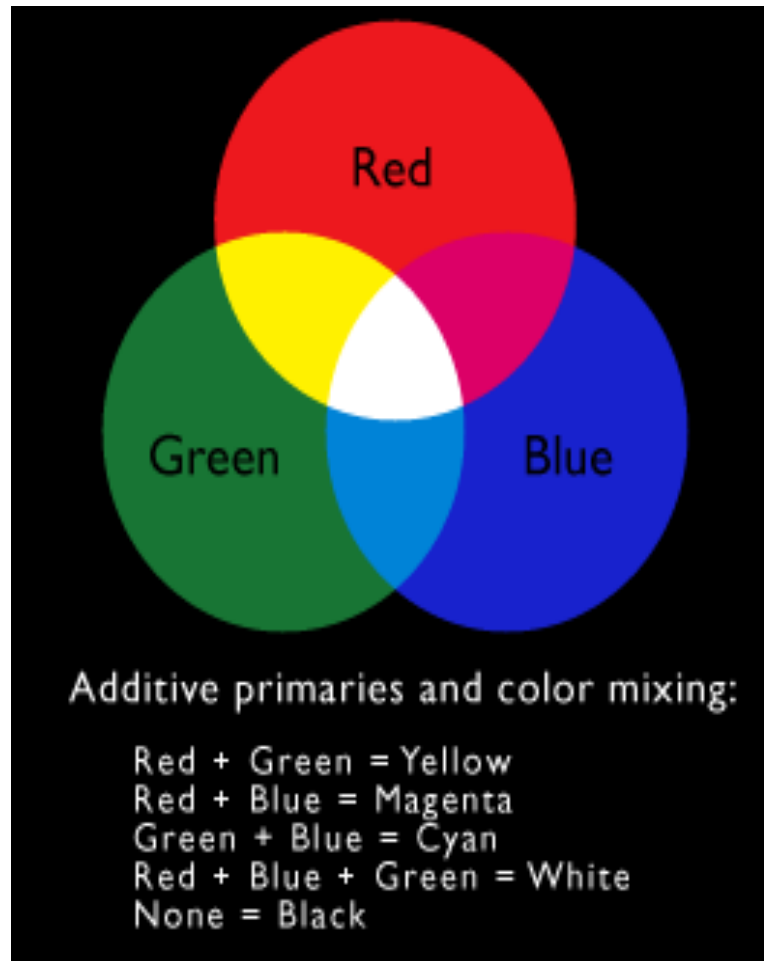
Grassman's Laws

- Trichromaticity: any color can be expressed as a function of three component colors

- Grassman's Laws: color as **linear** combination
  - Scaling a color and scaling its primaries by the same amount preserves the match
    - 2C = 2R + 2G + 2B
  - Adding two colors is the same as adding its primaries
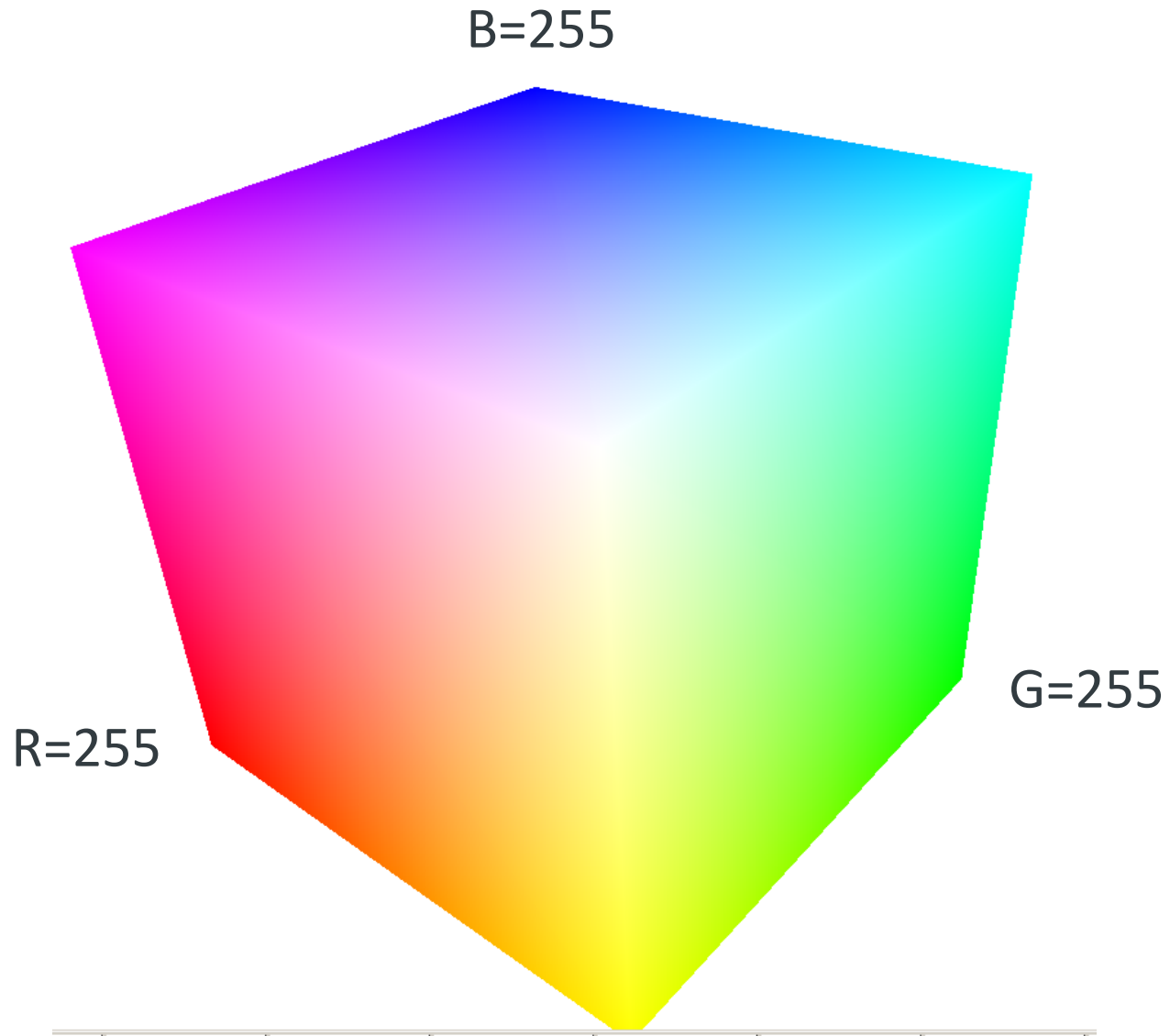   - C1 + C2 = (R1 + R2) + (G1 + G2) + (B1 + B2)

COLOR SPACES

Color Spaces as Spaces

- Gamut
  - Colors that can be represented by a color representation
  - Colors that can be seen on certain devices

- Representations of color form "spaces" of color
  - Distance between colors?
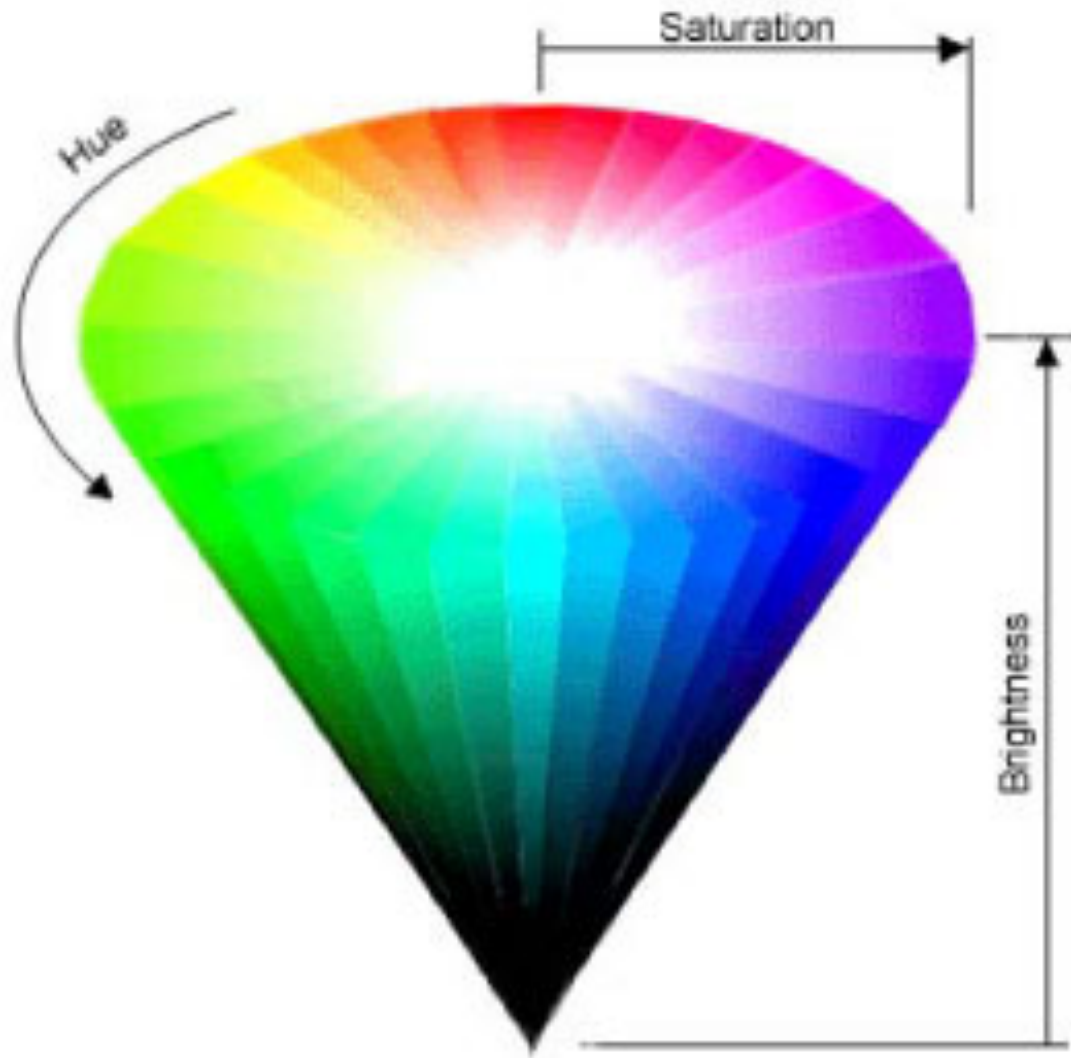 - Averaging colors?

Color Spaces: RGB

Color Spaces: HSV

- Hue:
  - 0 – 360 degrees

- Saturation:
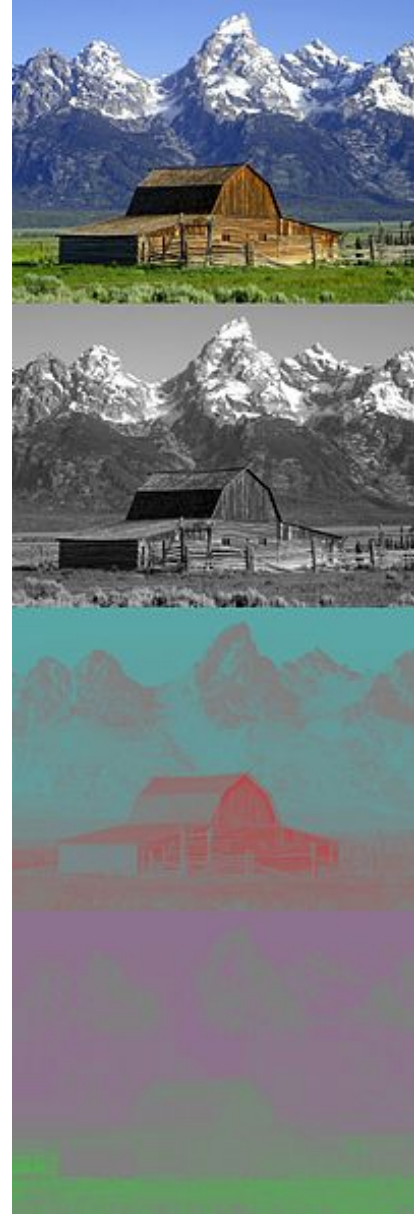 - 0 – 100 (radius)

- Value:
  - 0 – 100 (height)

Color Spaces: YIQ

- Y = luminance
  - luminance = ?*r + ?*g + ?*b

- I, Q hold all color information

- NTSC TV standard
  - Take away I, Q and you have B&W TV!

Color Spaces: YIQ

- Y = luminance
  - luminance = **0.299***r + ?*g + ?*b

- I, Q hold all color information

- NTSC TV standard
  - Take away I, Q and you have B&W TV!

Color Spaces: YIQ

- Y = luminance
  - luminance = **0.299***r + **0.587***g + **0.114***b

- I, Q hold all color information

- NTSC TV standard
  - Take away I, Q and you have B&W TV!
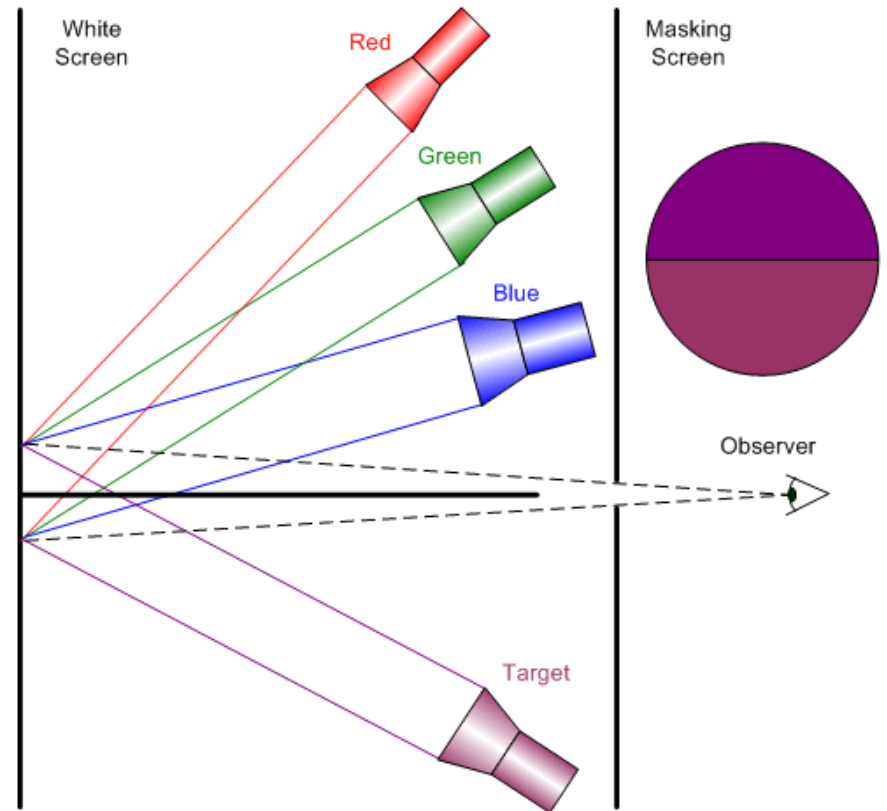
Color Spaces: CMY

- Cyan, Magenta, Yellow

  - Complements of: red, green, and blue

  - Subtractive color space, origin is white

  - Useful for printing on white paper

- What about K?

  - Fourth component added by printers
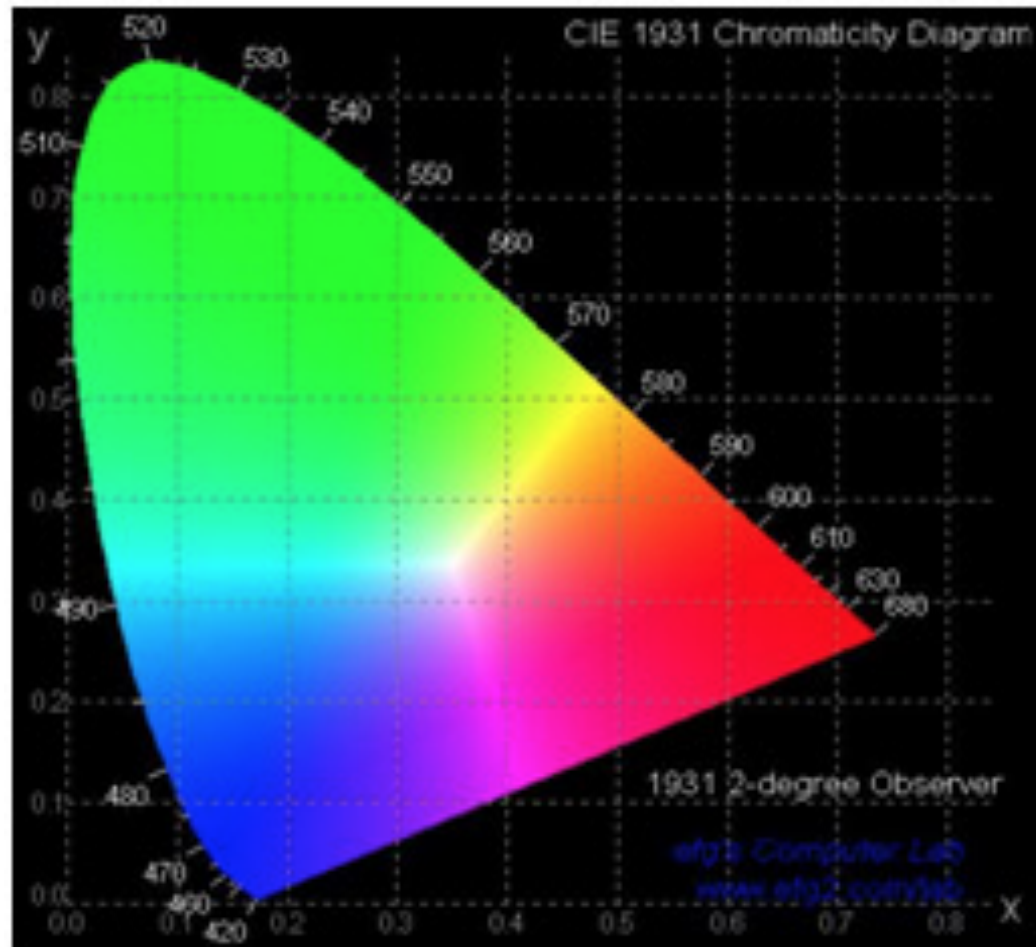

M=255   C=255

Y=255
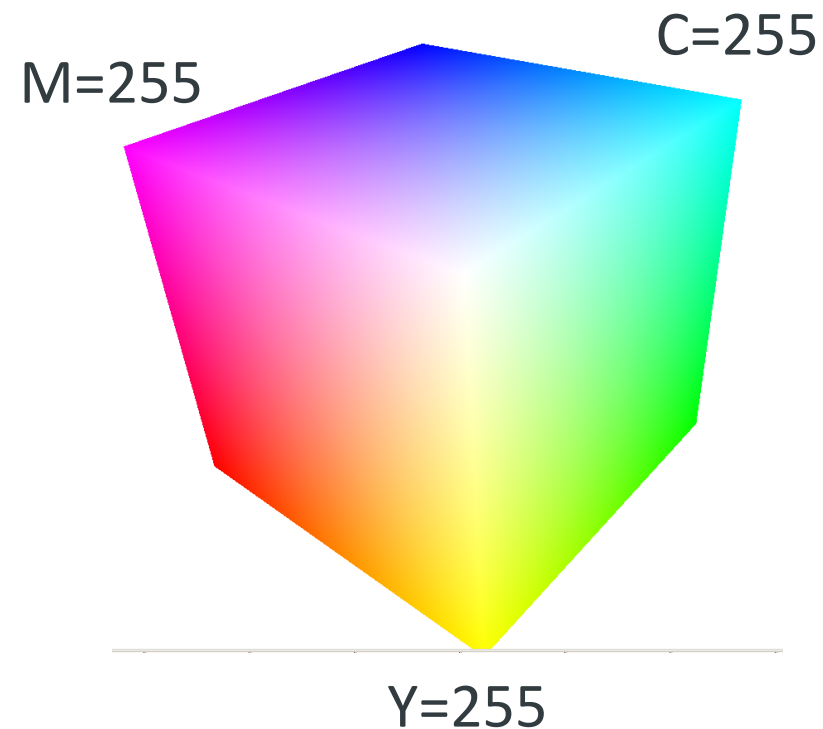
Standard Observers

- Each human perceives color differently
  - Why?

- Perform color matching experiments, average results to find the **standard observer**

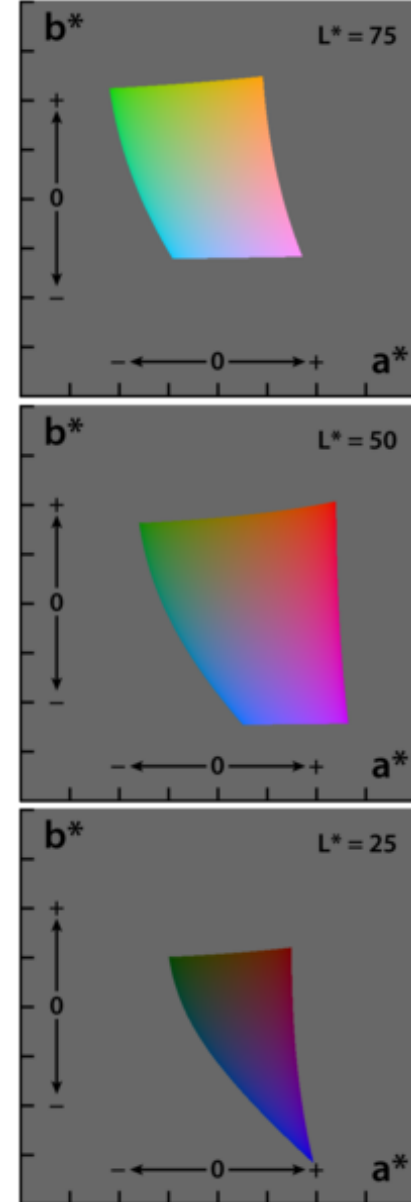# Color Spaces: XYZ

- X, Y, Z correspond to human tristimulus values

- Based on "average" human

- Lots of green

Color Spaces: Lab

- Good analog to human perception

- L is adjusted to be equivalent to human perception of brightness

- A and B experimentally determined to keep perceptually similar colors close together

requirements, initial ideas, early feedback

2D PROJECT BRAINSTORMING

2D Project Proposal: Grading Criteria

- 75%: Clarity of written text and adherence to project requirements

- 15%: Inclusion of relevant figures, diagrams, mockups, story boards…

- 5%: Schedule providing work breakdown and team member responsibilities

2D Project Execution: Grading Criteria

- 70%: adherence to scope-modified project proposal

- 20%: code style, legibility, and comments

- 10%: user manual

- Modifiers:

  - Project difficulty

  - Team member peer evaluations

2D Project Presentation: Grading Criteria

- 50% clarity of presentation
- 30% inclusion of visuals
- 20% adherence to time limit

- In-class demos following lightning presentations, time permitting

Goals

- Build an interactive 2D graphics program
- Implement 2D transformations
  - Translation (i.e. movement)
  - Scaling
  - Rotation
- Implement 2D picking (i.e. selecting/ manipulating drawn objects on screen)
- Writing about software features
  - Planning your project
  - User manual

Example Ideas

- Simple 2D game
  - Hundreds, Robot Unicorn Attack, One Button Bob
  - Interactive art?
- (Abstract?) painting
  - Brush styles: circles, squares, lines
  - "Paint" over existing photo, image manipulation
- Diagramming software
  - Click and drag to create elements, connectors attach to anchor points

Group Formation Recommendations

- Goals

- Desired development environment

- Level of experience
  - Grad students and undergrad students?

Brainstorming Exercise

- Break into large groups based on general area you're interested in
  - Not sure? Pick one for now, float to another later…
- 5-10 minutes: write down ideas individually
- Share project ideas with group
  - Everyone must share something
  - All ideas are good ideas
- Form smaller subgroups to refine ideas