

Lecture 6: Perception - Color

DS 4200
SPRING 2023

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NORTHEASTERN UNIVERSITY

Slides and inspiration from Cody Dunne, Dylan Cashman, Remco Chang, Lane Harrison, Connor Gramazio, Michelle Borkin, Krzysztof Gajos, Hanspeter Pfister, Miriah Meyer, Jonathan Schwabish, and David Sprague

Last Class

We:

- Reviewed marks and channels
- Reviewed decomposing graphics (ic-04)

Any Questions?

Today

- High-level overview of color
- Intro to JavaScript

Expressiveness + Effectiveness

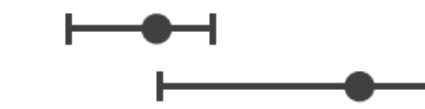
Channels: Expressiveness Types and Effectiveness Ranks

→ **Magnitude Channels: Ordered Attributes**

Position on common scale



Position on unaligned scale



Length (1D size)



Tilt/angle



Area (2D size)



Depth (3D position)



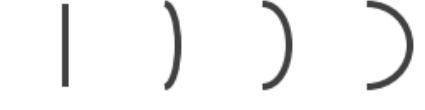
Color luminance



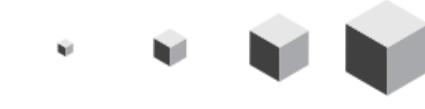
Color saturation



Curvature



Volume (3D size)



→ **Identity Channels: Categorical Attributes**

Spatial region



Color hue



Motion



Shape

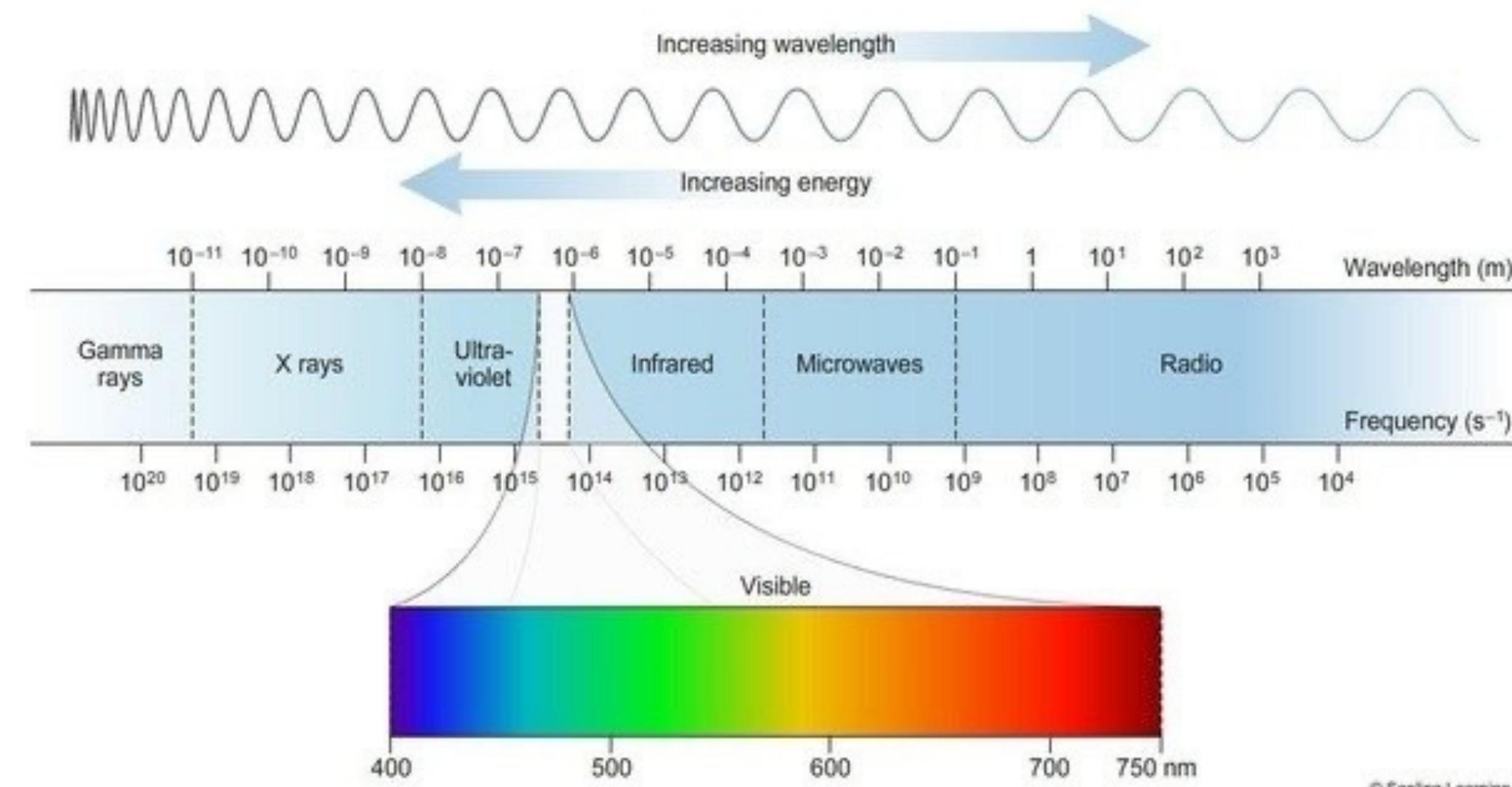


▲ Most
Effectiveness
Least ▼

COLOR PERCEPTION

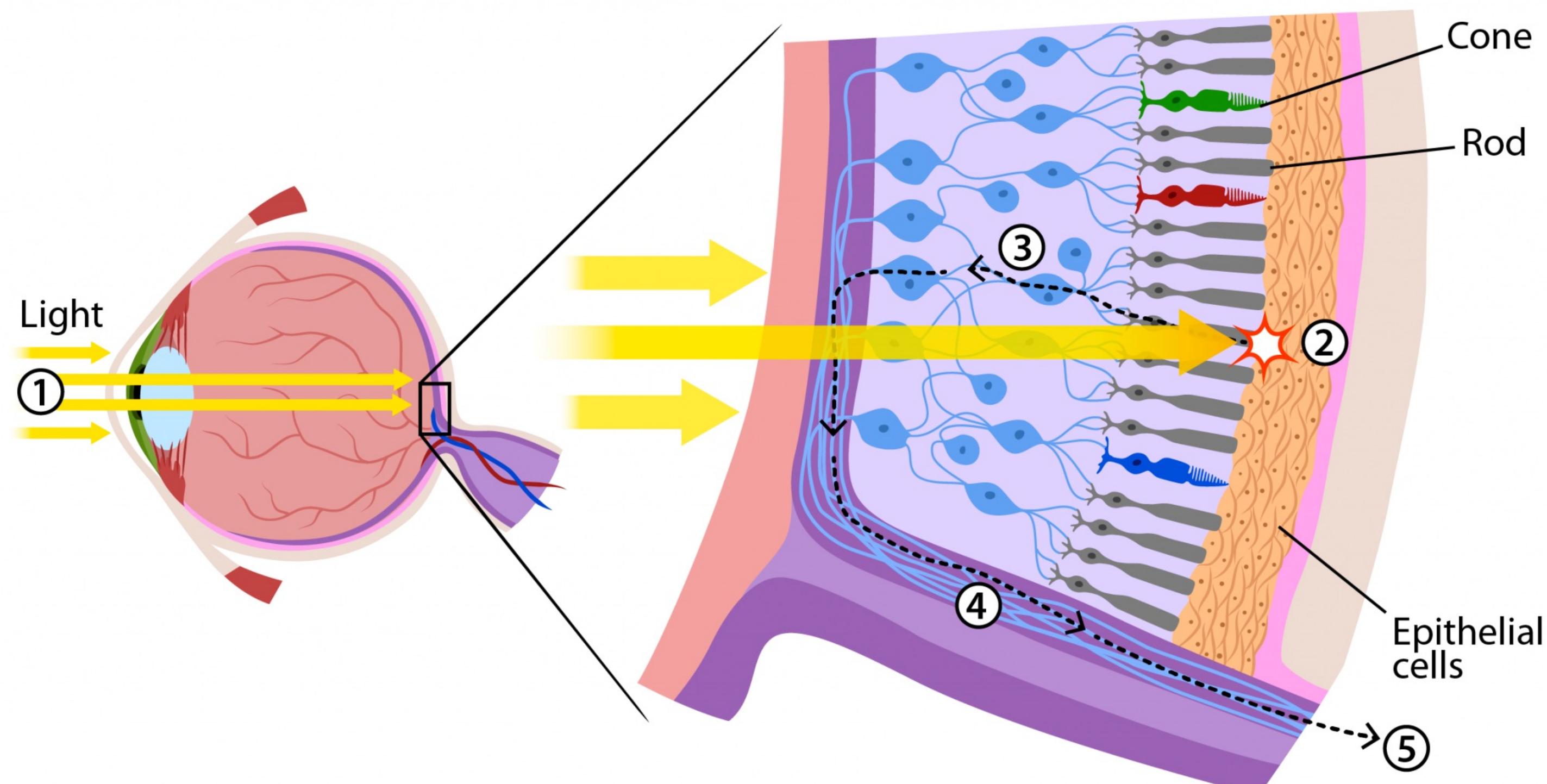
Color Perception

Color results from different wavelengths of light.



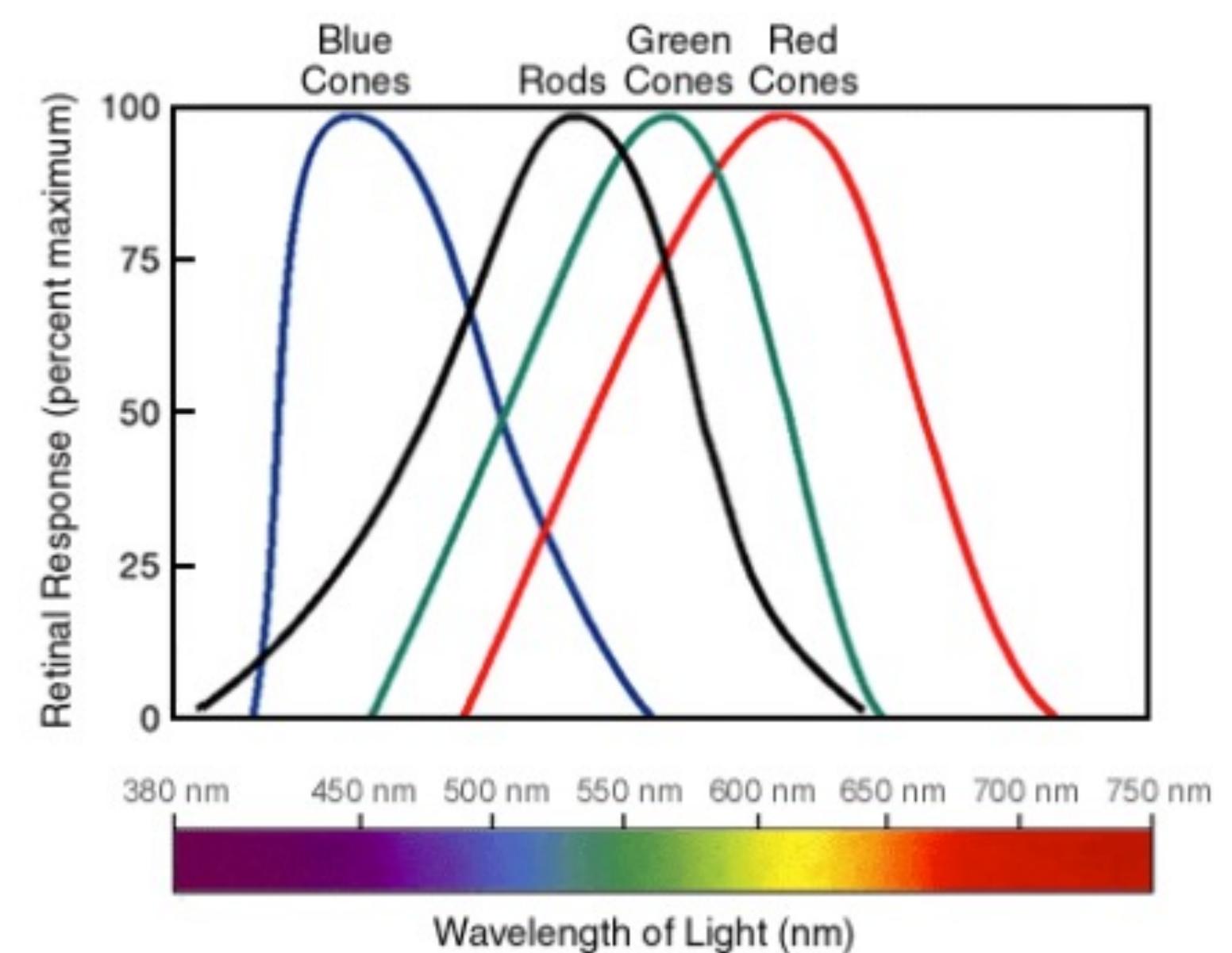
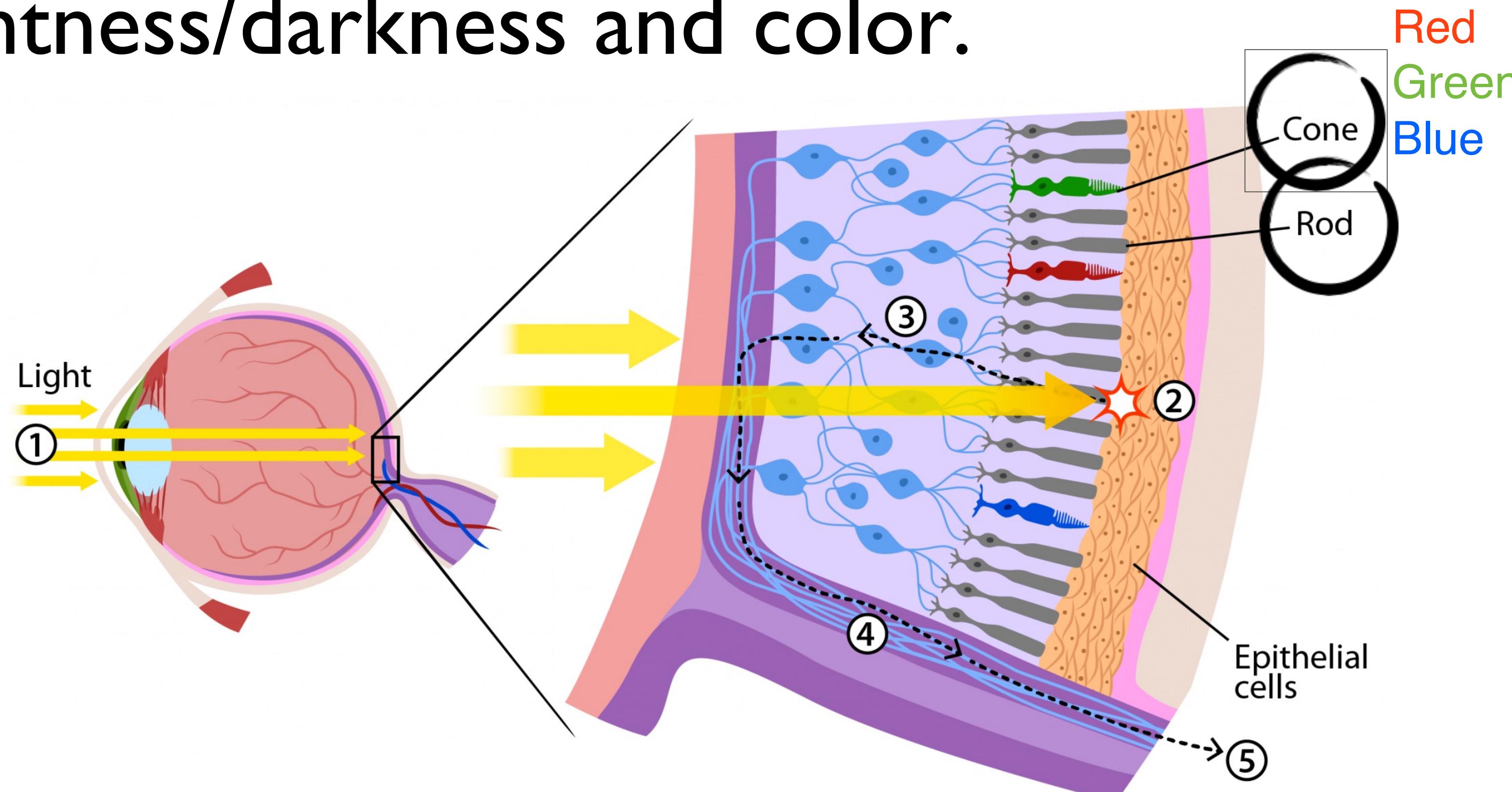
Color Perception

Your eye takes in light waves and translates them to lightness/darkness and color.

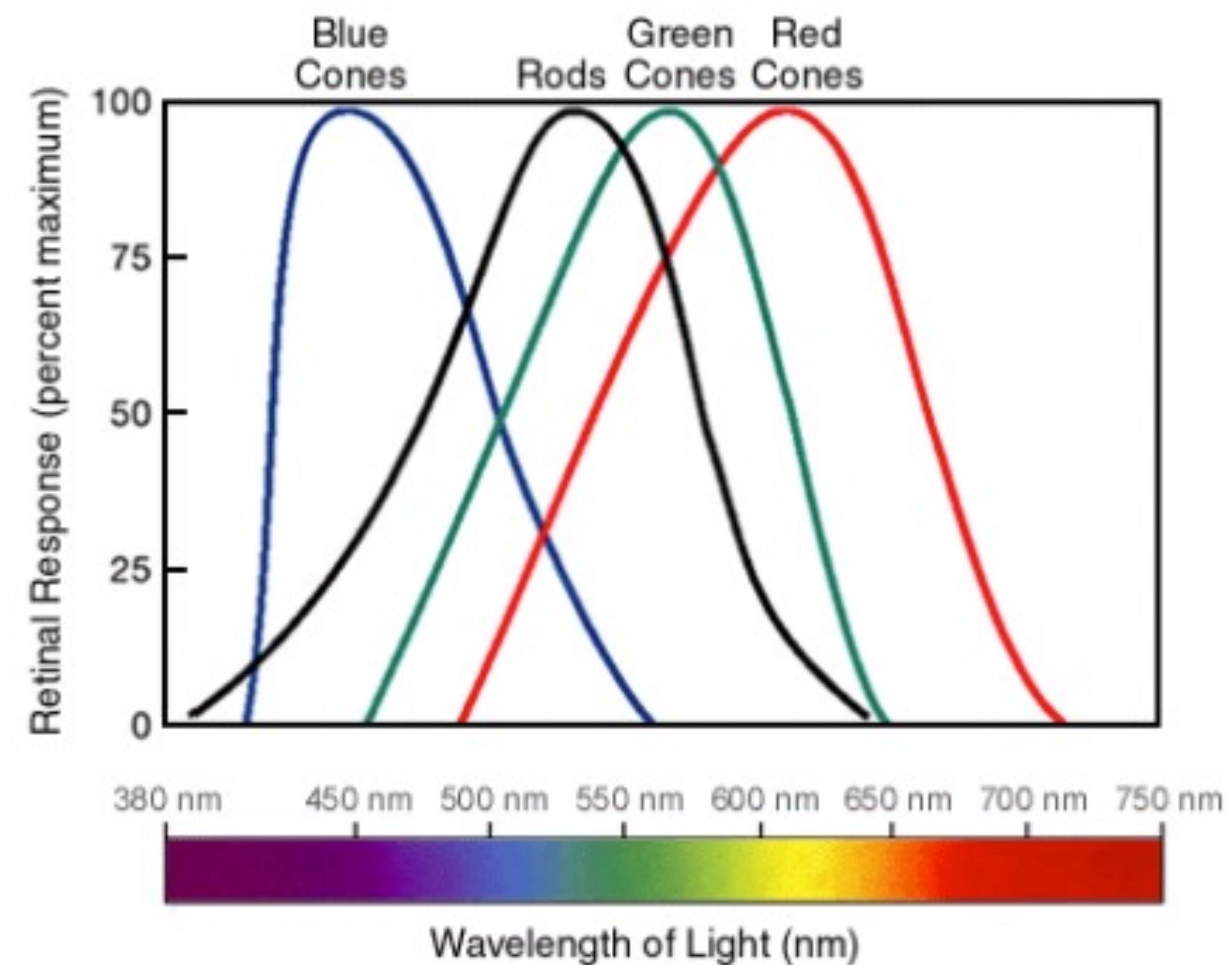


Color Perception

Your eye takes in light waves and translates them to lightness/darkness and color.



Color Perception



This is why lightness/darkness is an effective encoding channel!

Rods: 120 million

Cones: 5-6 million

Cones:

64% red-sensitive

32% green-sensitive

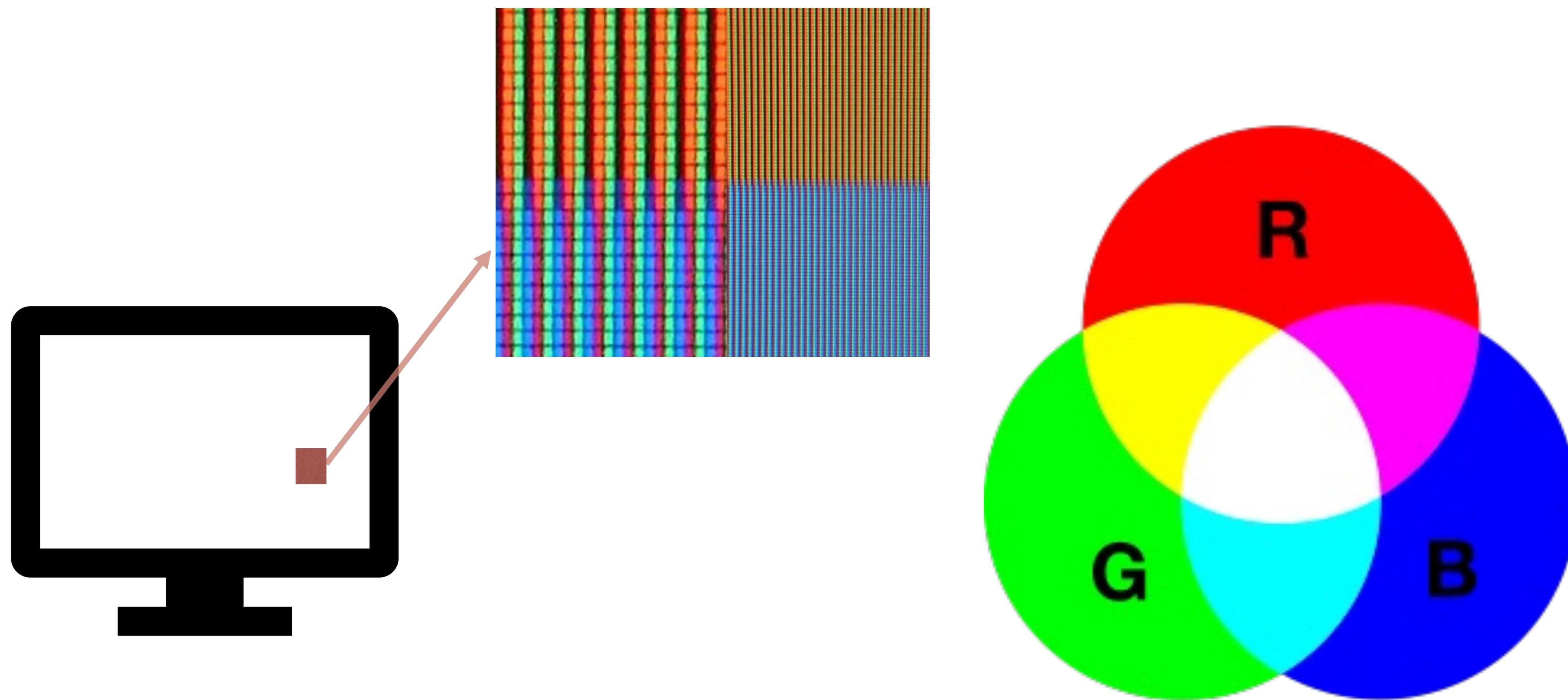
2% blue-sensitive.

This is why we are so sensitive to red!

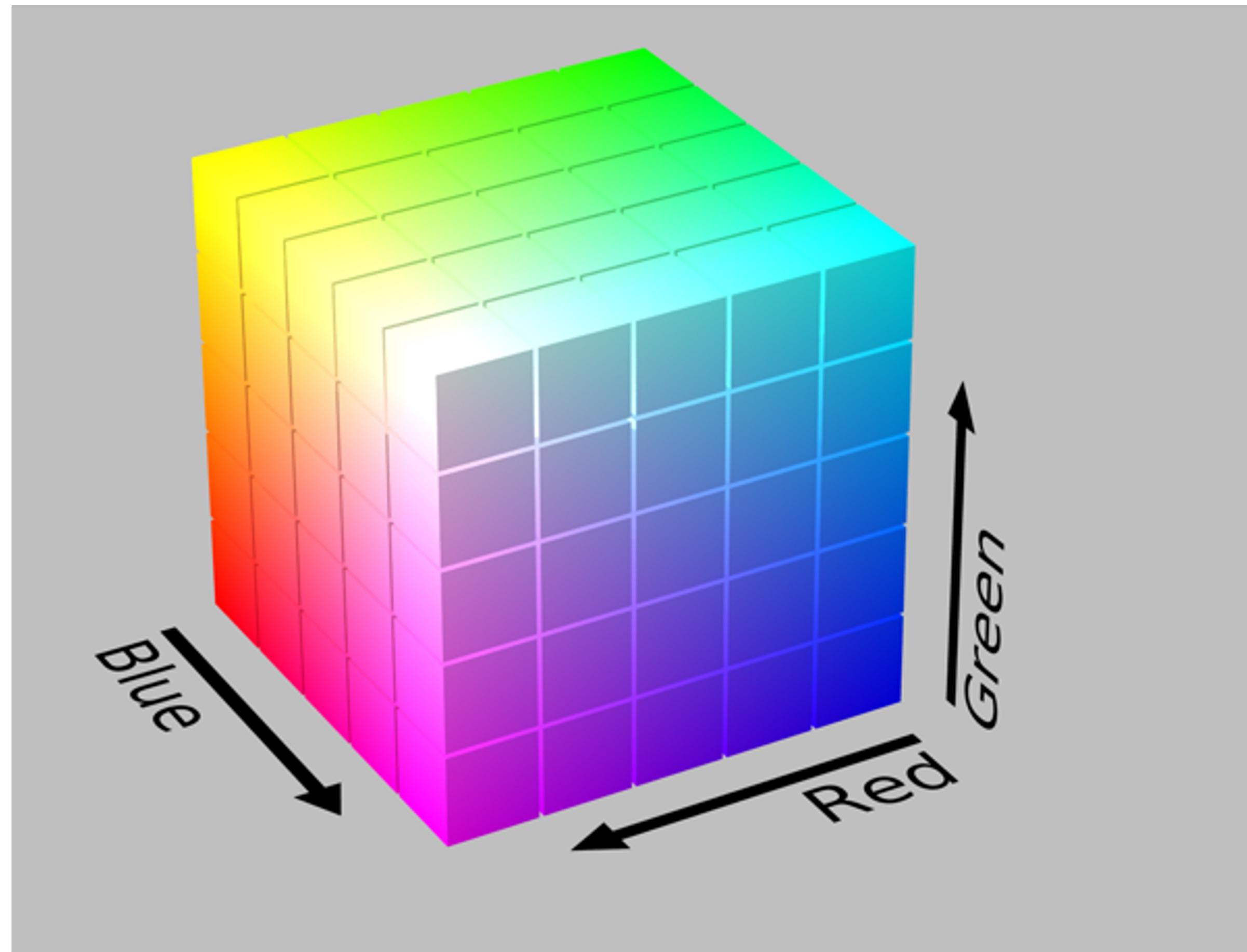
Color Models and Spaces

COLOR MODEL \ SPACE = Mathematical model
describing the way colors can be represented.

RGB (Red, Green, Blue)

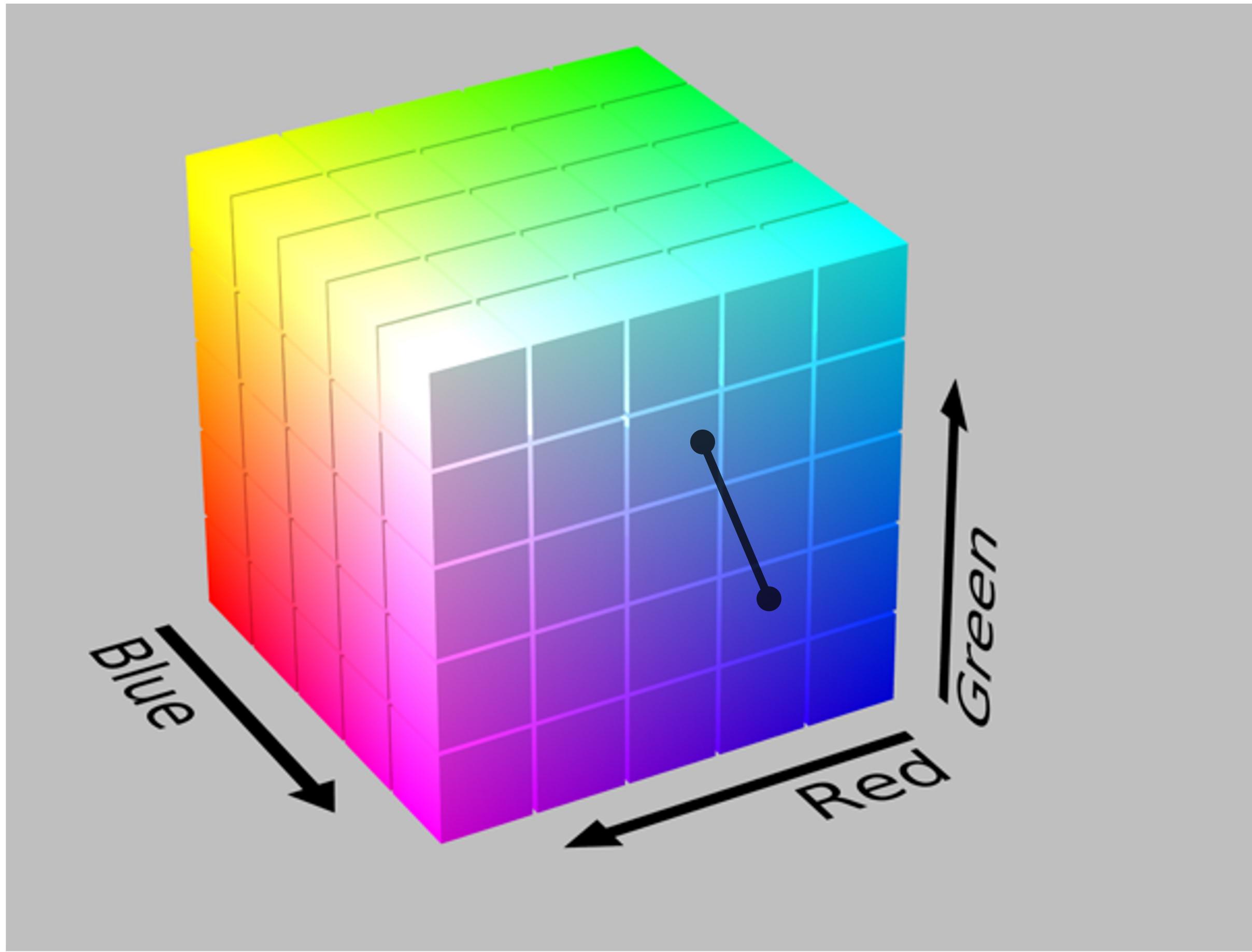


RGB



Colors exist in a cube space
and are mixtures of Red,
Green, and Blue

RGB



Issues

- Distance between colors nowhere near how we perceive differences

A: (5, 7, 15)

rgb(0, 128, 0)

rgb(128, 0, 0)



B: (15, 17, 25)

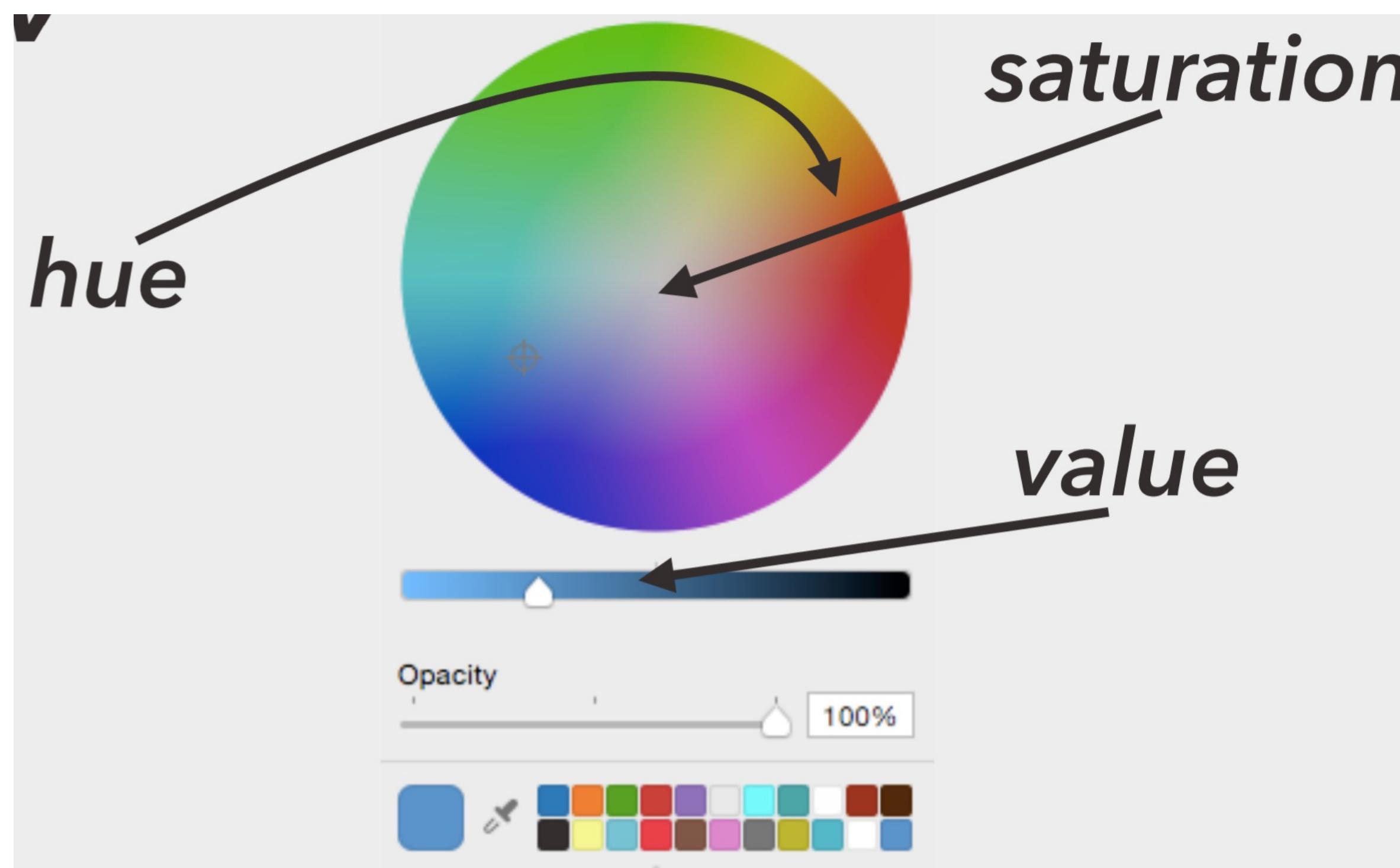
rgb(10, 138, 10)



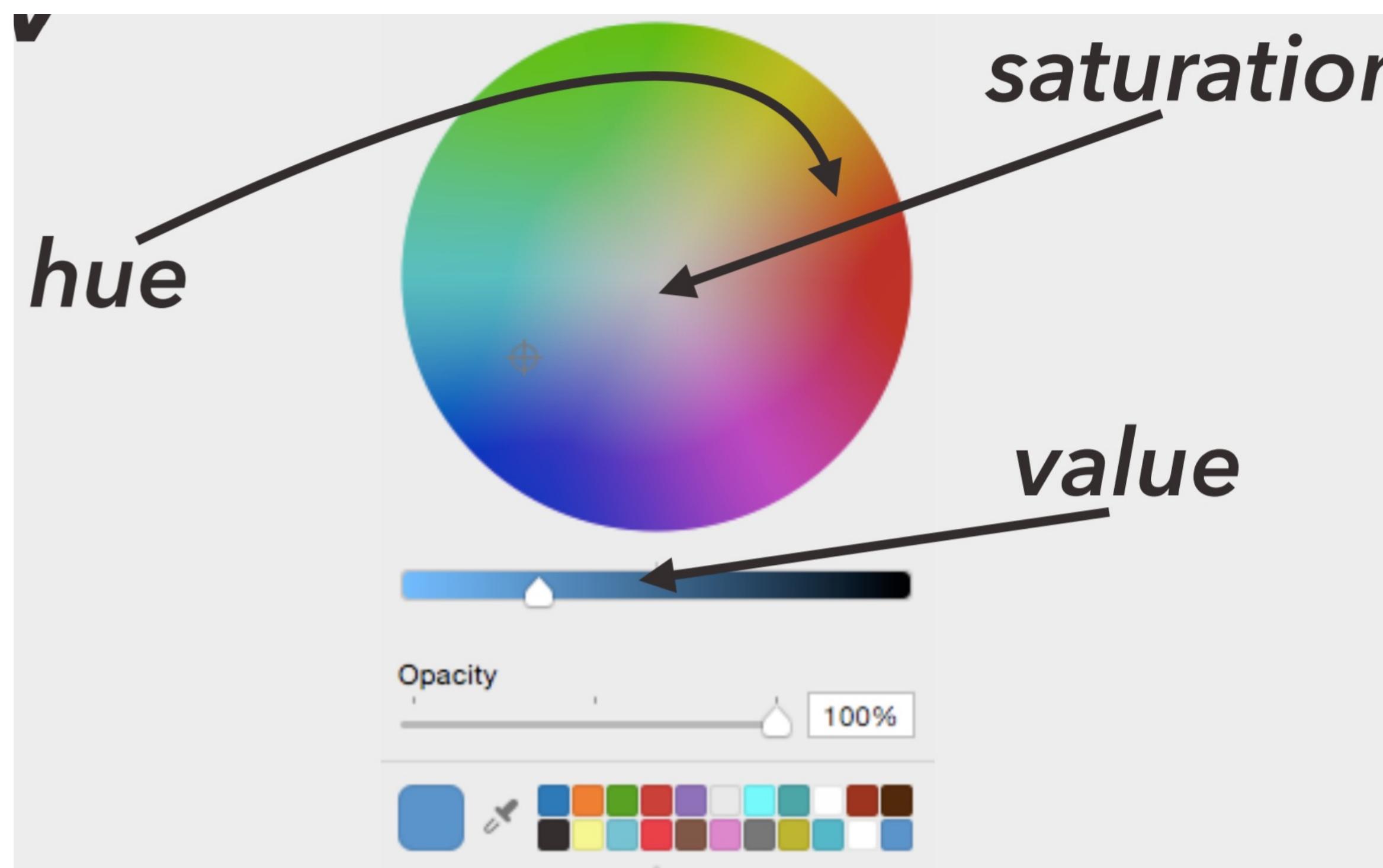
rgb(138, 10, 10)



HSV/L (Hue-Saturation-Value/Lightness)



HSV/L (Hue-Saturation-Value/Lightness)

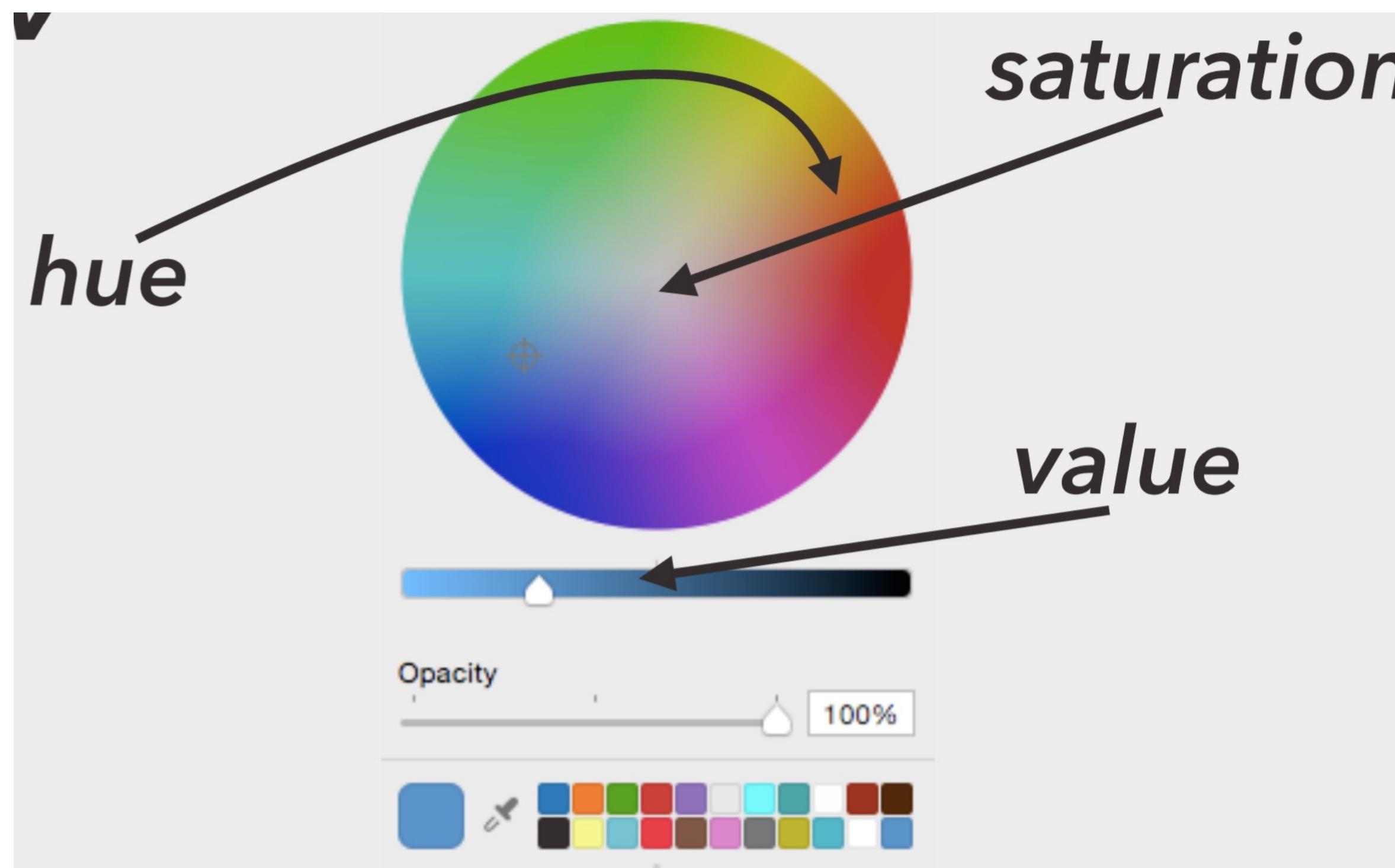


HUE = Pure colors (not mixed with white or black)

SATURATION = Amount of white mixed with pure color

VALUE/LIGHTNESS = Amount of black mixed with pure color

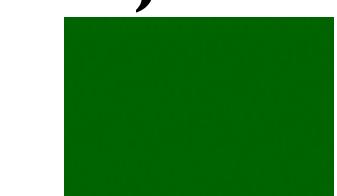
HSV/L (Hue-Saturation-Value/Lightness)



Distance between colors is closer, but not identical to how we perceive differences

A: (5, 7, 15)

`hsv(120, 100, 50)`



B: (15, 17, 25)

`hsv(130, 110, 60)`



`hsv(0, 100, 50)`



`hsv(10, 110, 60)`



Colormaps

Colormaps

Help us choose the correct colors to represent different attribute types

Categorical



Sequential



Divergent



Categorical

- Different color = different category
- Protip: choose colors that are perceptually distant
- Protip: choose colors that are roughly the same saturation and value



Sequential

- Saturation indicates difference in the amount of the phenomenon
- Protip: people interpret darker as meaning more



Divergent

- Two colors used to indicate extremes of a range
- Protip: neutral color in the middle
- Protip: differentiate between “average” or midpoint and “no data”



Expressiveness + Effectiveness

④ Magnitude Channels: Ordered Attributes

→ Ordered

→ *Ordinal*



→ *Quantitative*



④ Identity Channels: Categorical Attributes

→ Categorical



Divergent



Sequential



Categorical



Picking a Colormap

<http://colorbrewer2.org/>

Number of data classes: 6 how to use | updates | downloads | credits

Nature of your data: sequential diverging qualitative

Pick a color scheme:

Only show: colorblind safe print friendly photocopy safe

Context: roads cities borders

Background: solid color terrain color transparency

EXPORT

COLORBREWER 2.0
color advice for cartography

Colorgorical Source

Generate

Number of colors: 5

Score importance: Perceptual Distance, Name Difference, Pair Preference, Name Uniqueness

Select hue filters: 90°, 180°, 270°

Results: Color space, Hex, RGB, Lab, LCH, Array format, No quote, Charts, Clear all

Color palette: ["rgb(57,146,131)", "rgb(148,210,207)", "rgb(25,79,70)", "rgb(57,238,192)"]

Instructions

To generate a palette with n colors, just enter the number of colors you want and click Generate. Bigger palettes will take longer than smaller palettes to make. Results will automatically appear when ready.

For greater detail, please consult our [paper](#) or the [source code](#).

Score Importance

Perceptual Distance: Increasing Perceptual Distance favors palette colors that are more easily discriminable to the human eye. To accurately model human color acuity, this is performed using CIEDE2000 in CIE Lab color space.

Name Difference: Increasing Name Difference favors palette colors that share few common names.

About

Colorgorical was built by Connor Gramazio with advisement from David Laidlaw and Karen Schloss.

Documentation

If you'd like to read more about how Colorgorical works, please read our paper [here](#). If you're curious about the implementation, please see the Colorgorical GitHub repository located [here](#).

If you use Colorgorical, please use the following citation:

```
@article{gramazio-2017-ccd,
  author={Gramazio, Connor C. and Laidlaw, David H. and Schloss, Karen},
  journal={IEEE Transactions on Visualization and Computer Graphics},
  title={Colorgorical: creating discriminable and preferable color palettes}
```

<http://vrl.cs.brown.edu/color>

Color Considerations

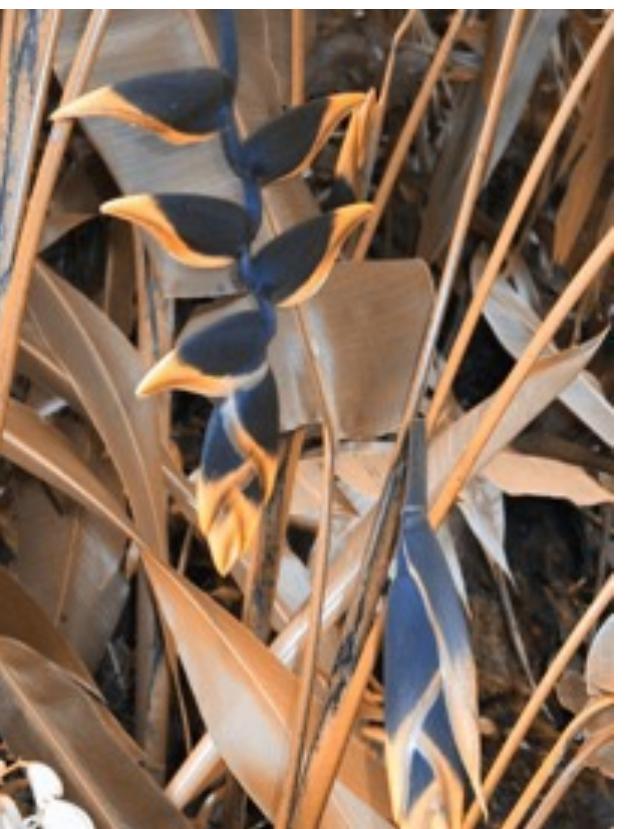
Colors - Beware

- When possible, use semantically meaningful colors
(ex. red=hot, blue=cold)
- Be aware of cultural differences
(ex. red in Chinese Culture vs Red in US culture)



Colors - Beware

- Use colorblind safe pallets.



Colors - Beware

- Saturation can cause illusions

**HIGH
SATURATION**
→ Participants
reported more
red than green

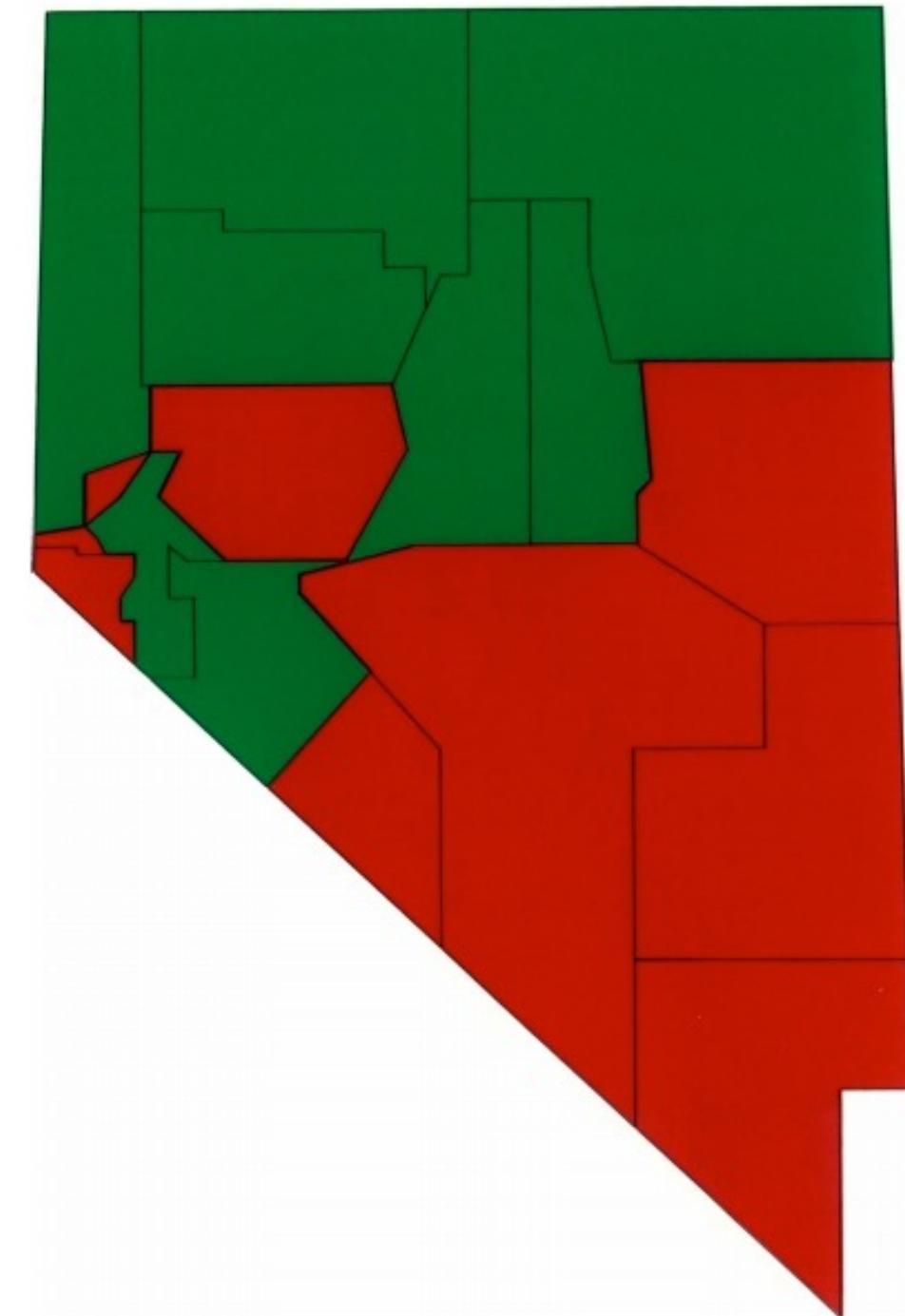


Figure 1. Stimulus From the High-Saturation Group

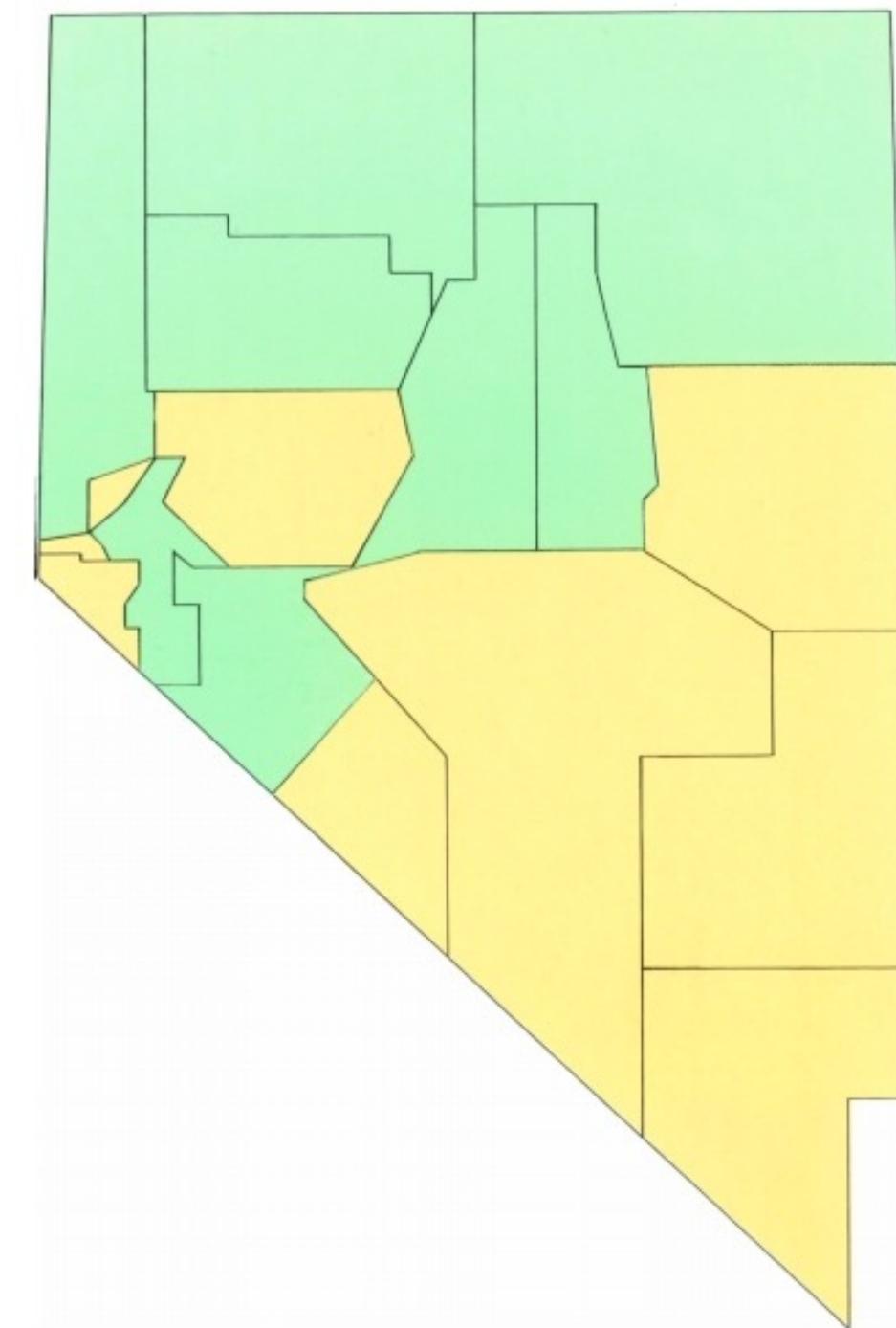


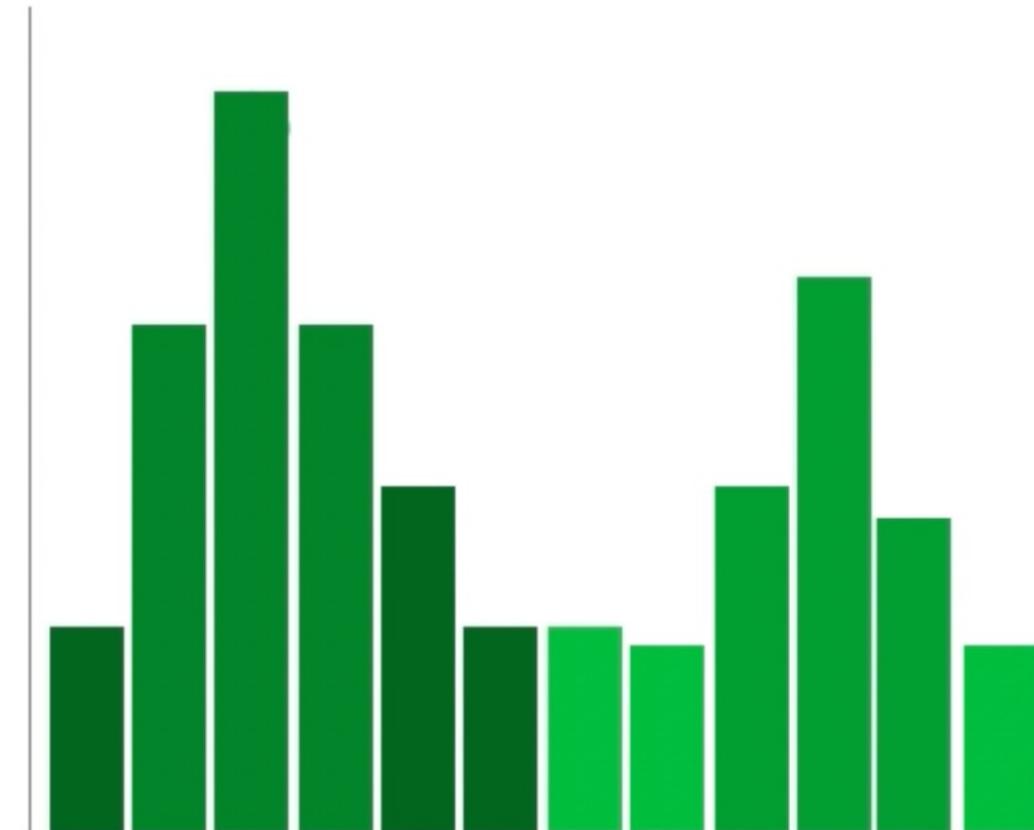
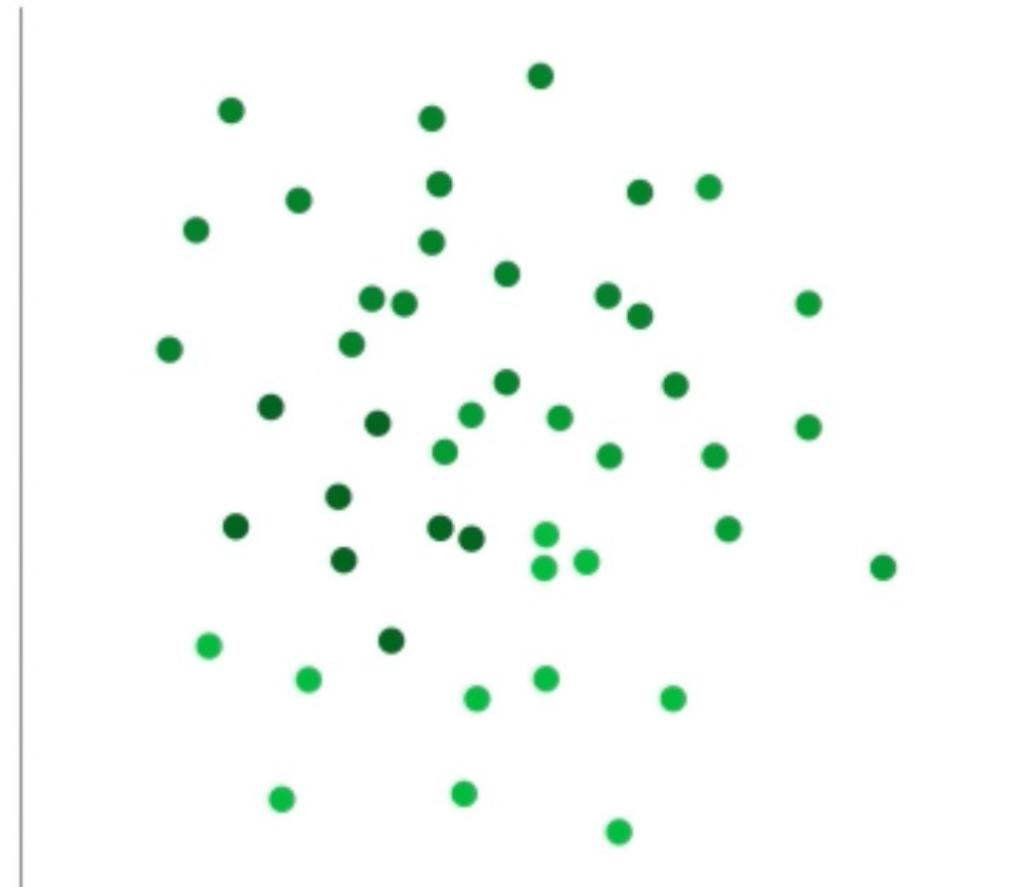
Figure 2. Stimulus From the Low-Saturation Group

**LOW
SATURATION**
→ Participants
reported equal
proportions
(which is correct)

Colors - Beware

- Mark type and size effects how we perceive color

How MANY CATEGORIES?



Colors - Beware



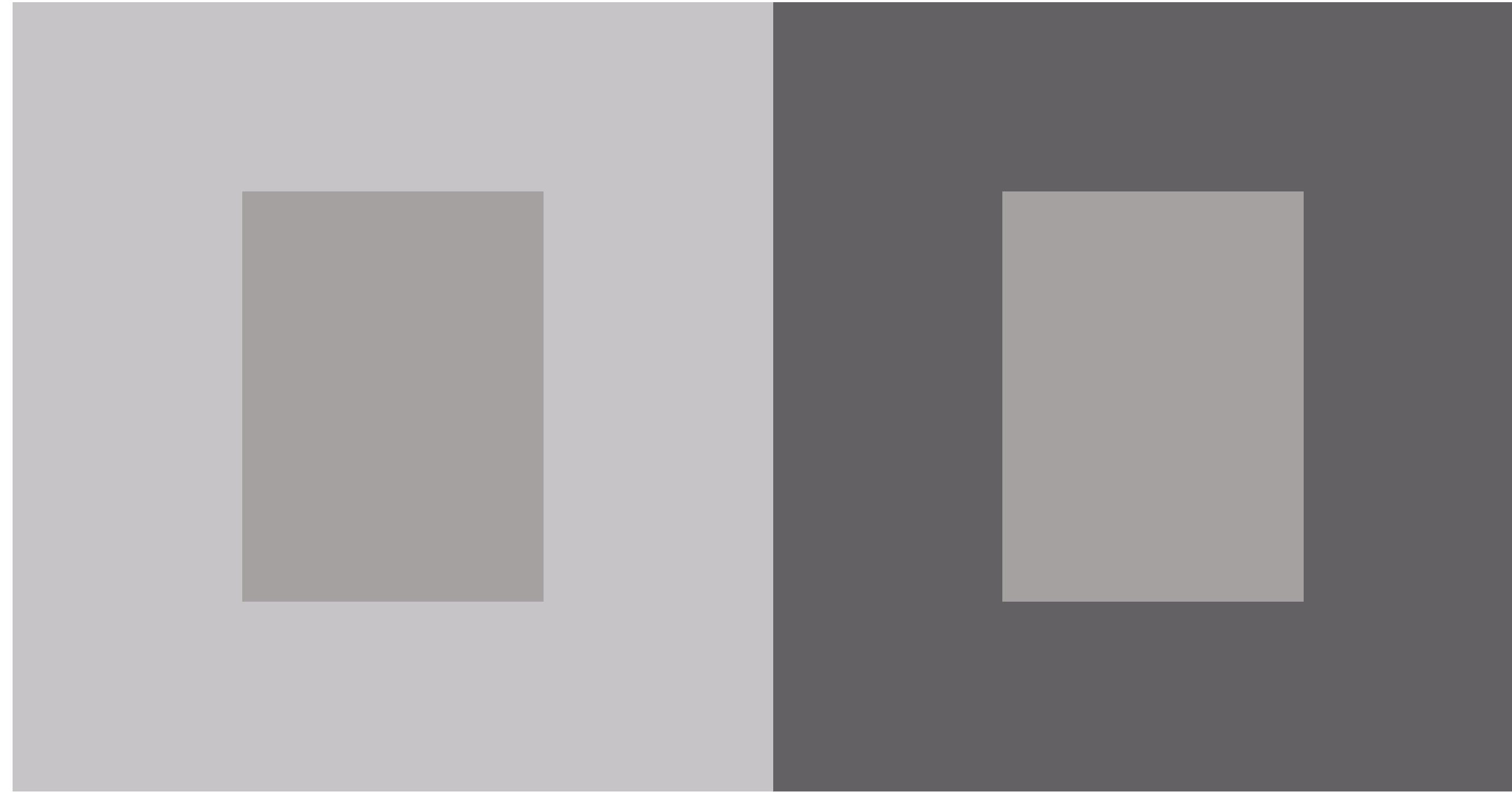
Is the smaller rectangle a solid color or gradient?

Colors - Beware

- **SIMULTANEOUS CONTRAST** – using a gradient as a background can distort how we see the foreground
 - Avoid using gradients as backgrounds



Colors - Beware



Are the smaller rectangles the same color or different colors?

Colors - Beware

- **SIMULTANEOUS CONTRAST** – solid backgrounds can distort how we see foreground shapes

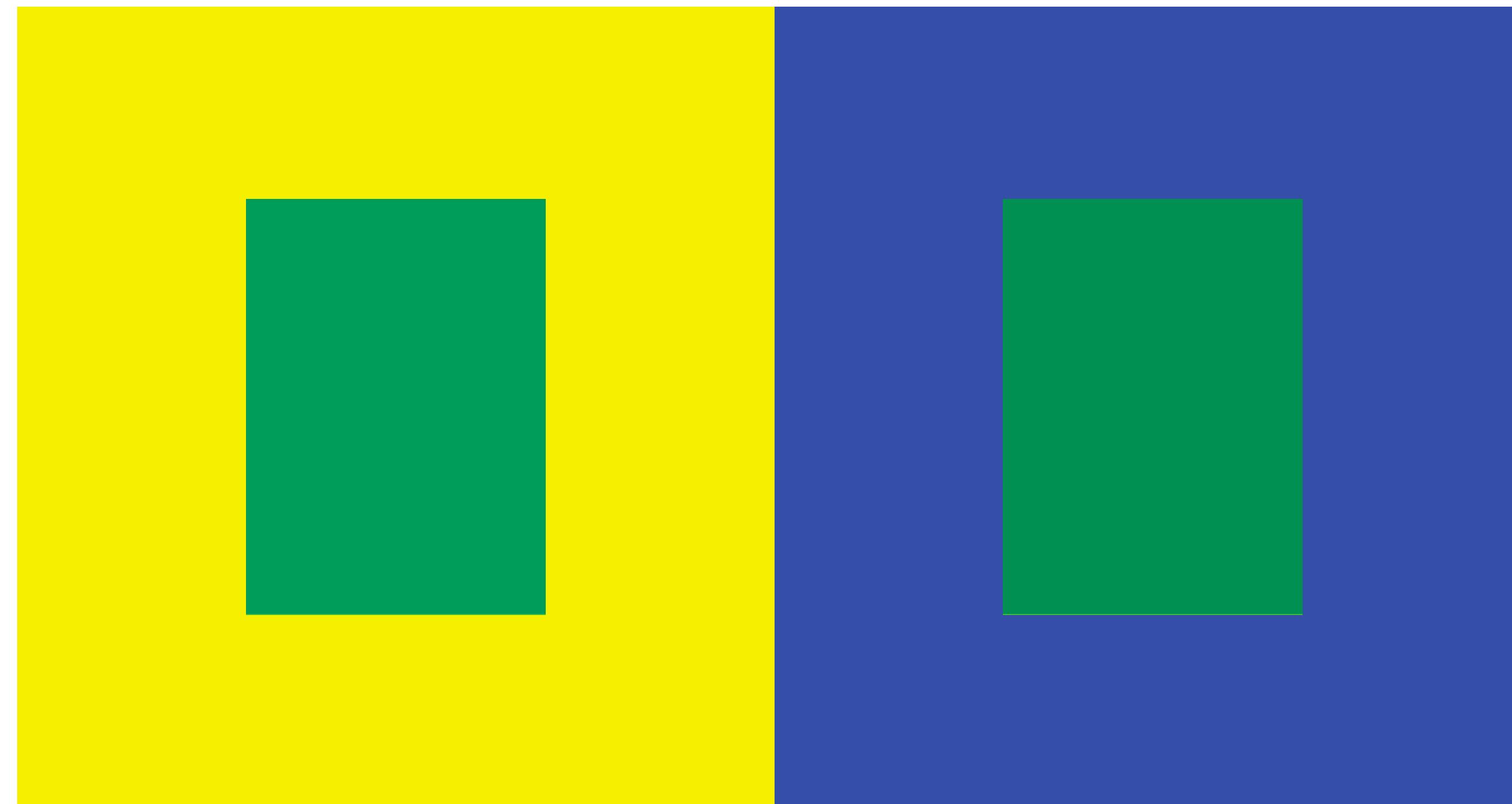


Colors - Beware

- **SIMULTANEOUS CONTRAST** – solid backgrounds can distort how we see foreground shapes

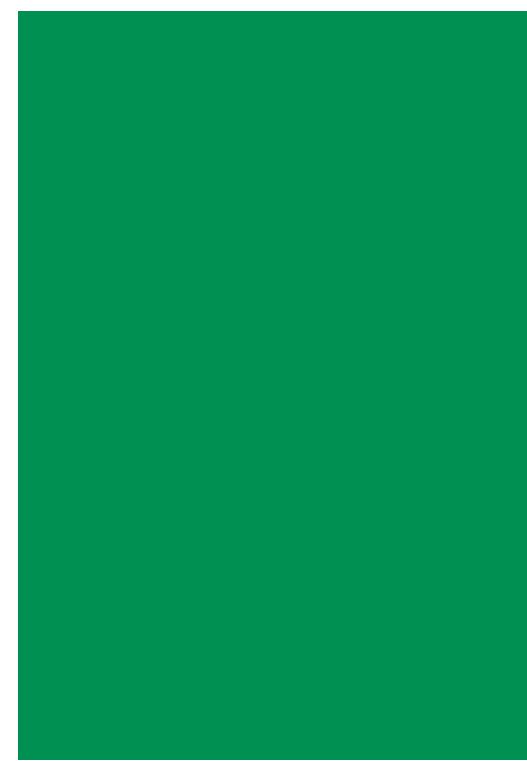


Colors - Beware



Are the smaller rectangles the same color or different colors?

Colors - Beware

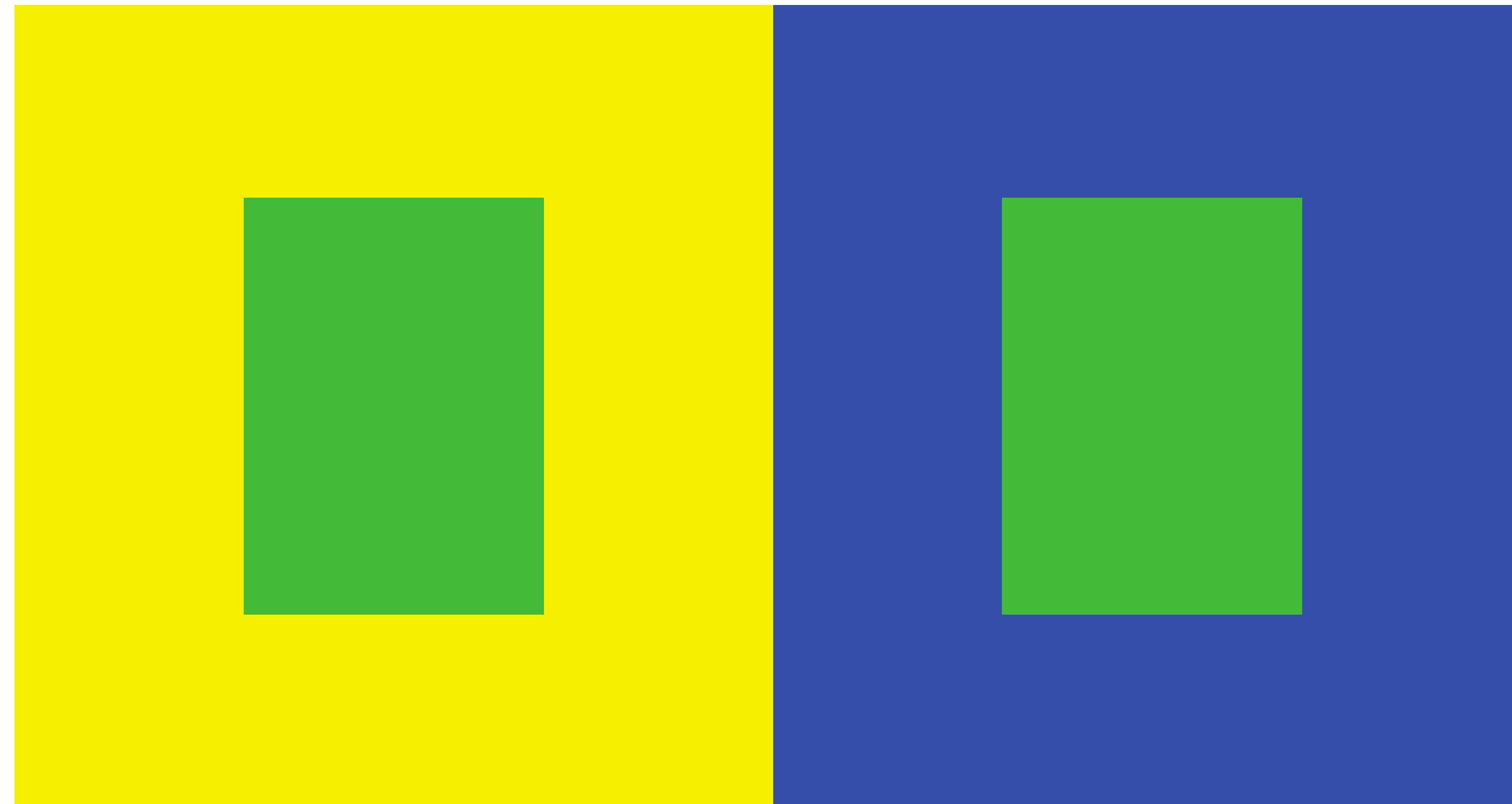


#009C59

#009051

Different!

Colors - Beware



Are the smaller rectangles the same color or different colors?

Colors - Beware

- **SIMULTANEOUS CONTRAST** – solid backgrounds can distort how we see foreground shapes



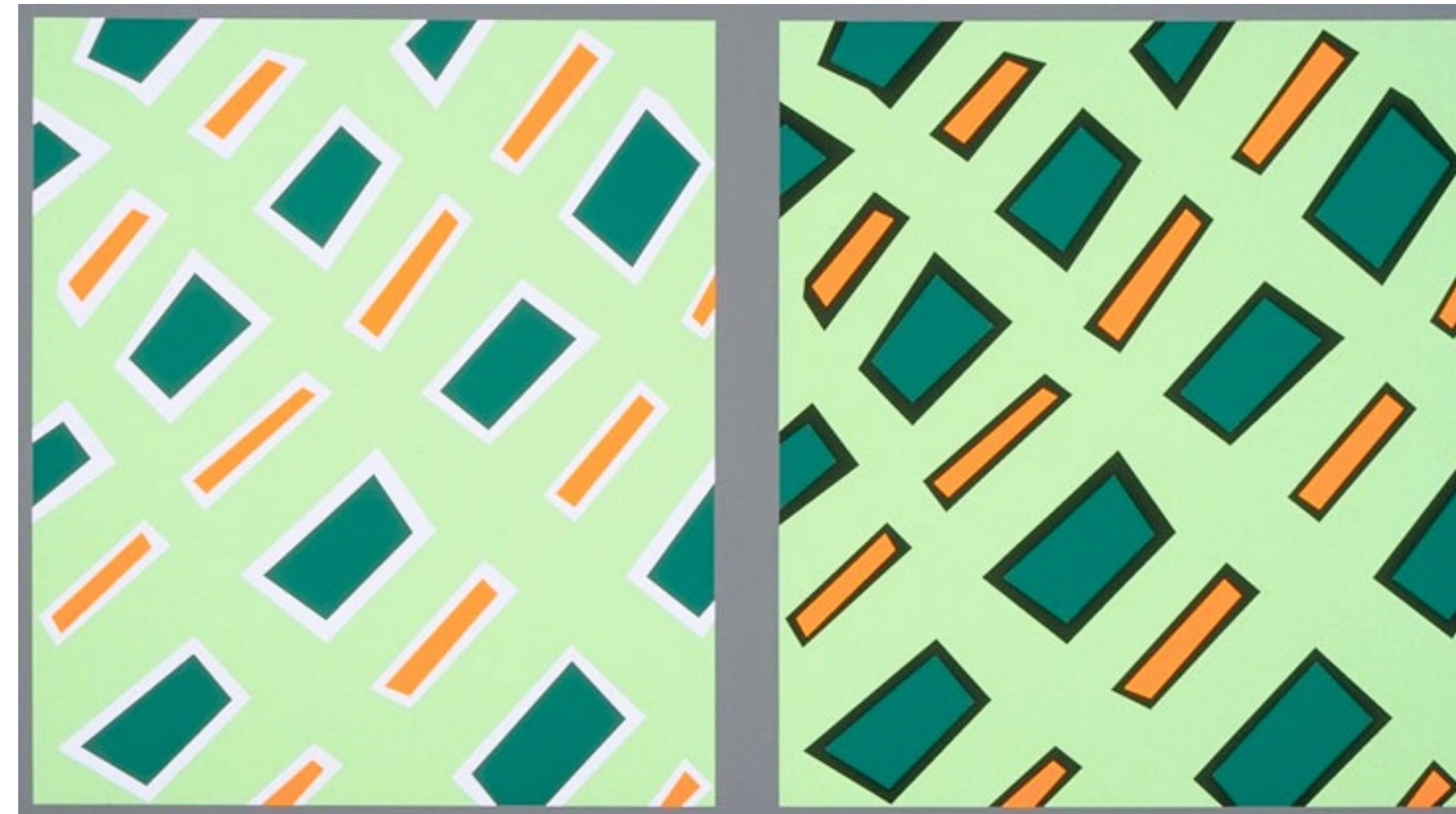
Colors - Beware

- **SIMULTANEOUS CONTRAST** – solid backgrounds can distort how we see foreground shapes



Colors - Beware

- **VON BEZOLD SPREADING EFFECT** – borders can change the appearance of shape's colors



Let's take a break! Stretch, go
for a walk, be social ☺
Be back here in 10 mins.

JAVASCRIPT

IC-05: JAVASCRIPT PT. I

Summary

Today we:

- Reviewed color at a high-level
- Practiced JavaScript (ic-05)

pm-01 is DUE before next class.

ic-05 is DUE today.