

# Data Visualization & Design

**Week 3**

# Announcements

Online session: **2/19**

# Assignment #1

First draft: ~~2/4~~

Final: **2/9, 11:59PM**

1. Color **Perception & Representation**
2. **Applying** Color
3. Practical **Tips**
4. Color **Exercise**
5. Critique

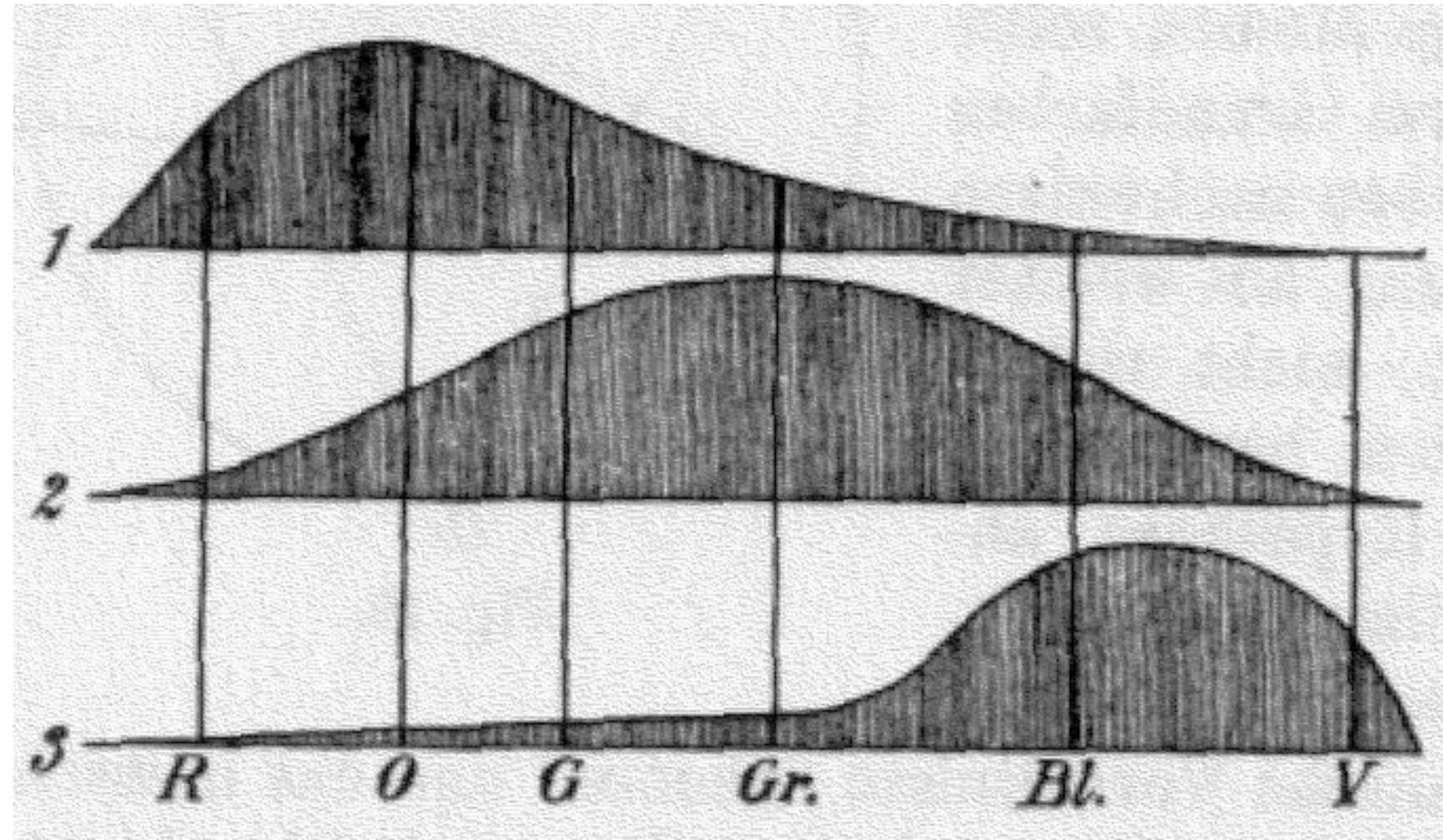
1. Color **Perception & Representation**
2. Applying Color
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# Human Perception of Color

When visualizing data, **color is a versatile tool** for encoding values and communicating difference.

- In 1801, scientist **Thomas Young** proposed that the retina of the human visual system contains three “kinds of fibers,” each sensitive to a different wavelength of light.
- This theory, referred to now as the **“trichromatic theory of color vision,”** informs the way computers display color images, and holds implications for human color perception.

Relative  
sensitivity



Wavelength

- Color is an inherently **three-dimensional space**
- There are exactly **three different types of color receptors** in the human eye
  - Sensitivity to **long wavelengths**
  - Sensitivity to **medium wavelengths**
  - Sensitivity to **short wavelengths**
- As such, any color can be uniquely represented using **three values**

# Representing Color **Digitally**

**Digital representations of color** tie together both human perception and the physical properties of light.

# Concept: **Color Space**

- A way of organizing colors that takes into account both **human perception** and **digital representation**
- Color spaces enable reproducible representations of color
- May be **arbitrary** (ex. Pantone) or **mathematical** (ex. RGB)

# Example: ***Arbitrary*** Color Space (Pantone system)



PANTONE®  
13-0755  
Primrose Yellow



PANTONE®  
13-1404  
Pale Dogwood



PANTONE®  
14-1315  
Hazelnut



PANTONE®  
14-4620  
Island Paradise



PANTONE®  
15-0343  
Greener



PANTONE®  
17-1462  
Flame



PANTONE®  
17-2034  
Pink Yarrow



PANTONE®  
17-4123  
Niagara

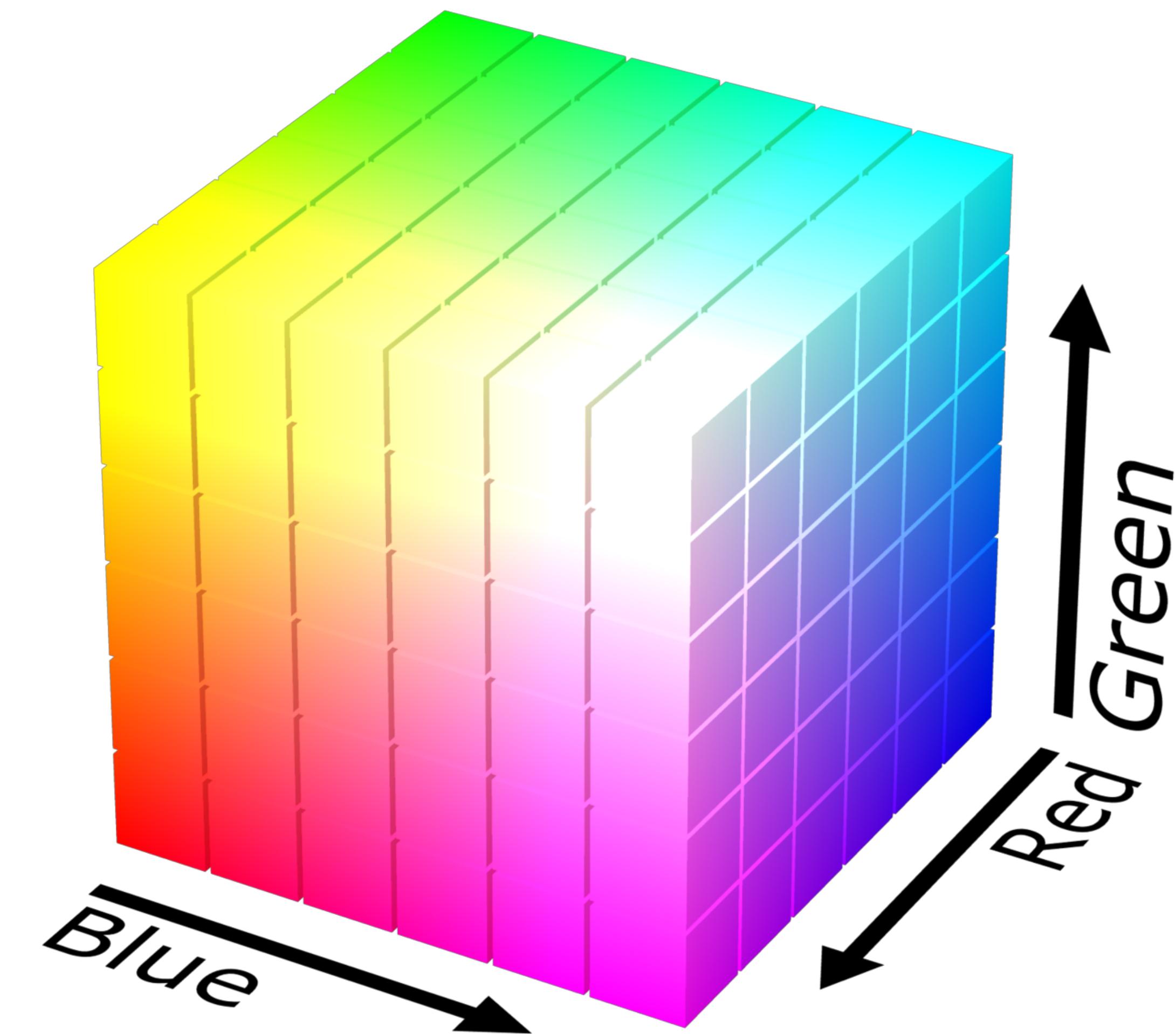


PANTONE®  
18-0107  
Kale



PANTONE®  
19-4045  
Lapis Blue

Example: ***Mathematical*** Color Space (RGB)

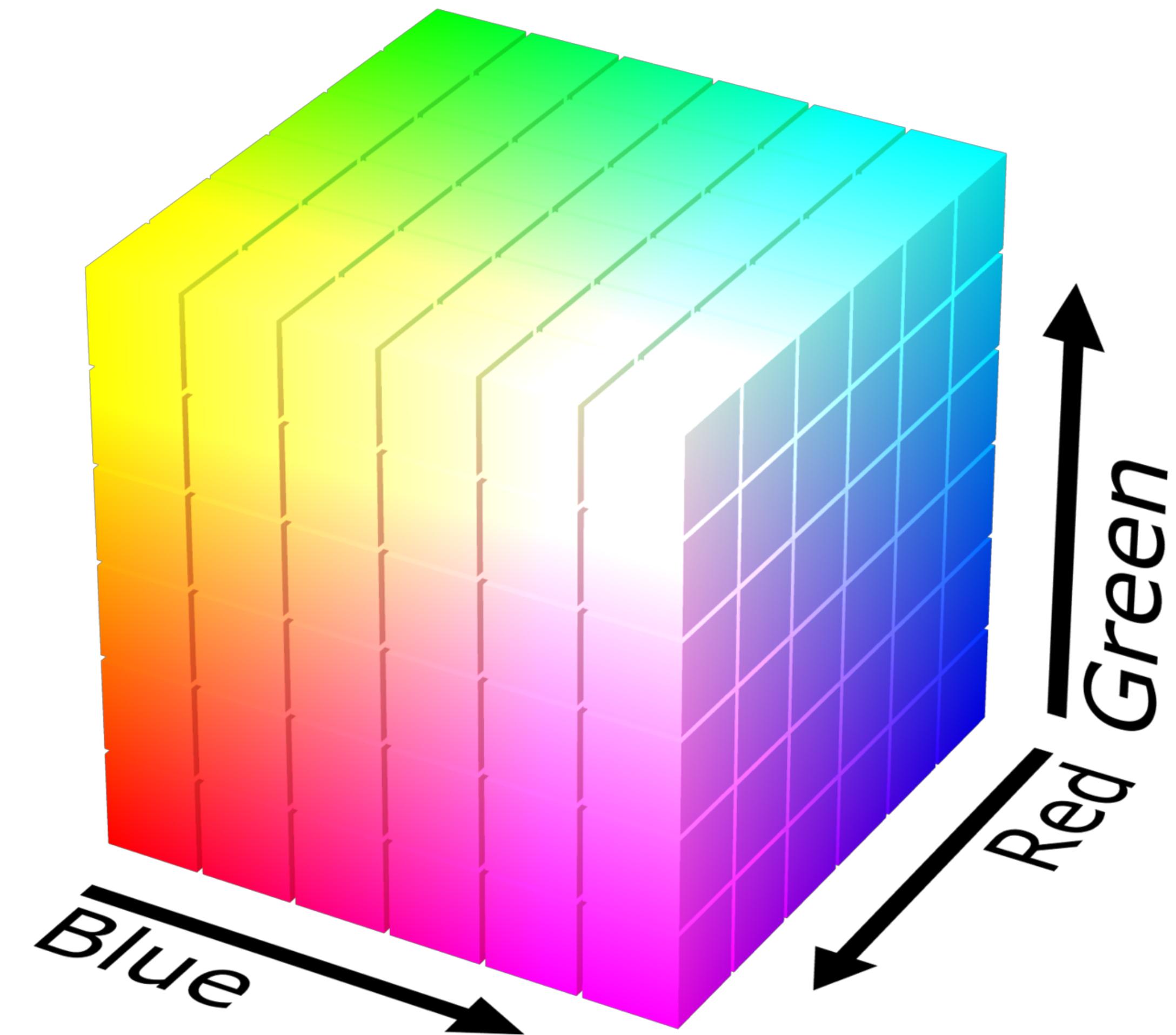


**Common color spaces** are widely implemented  
in visualization software and design tools.

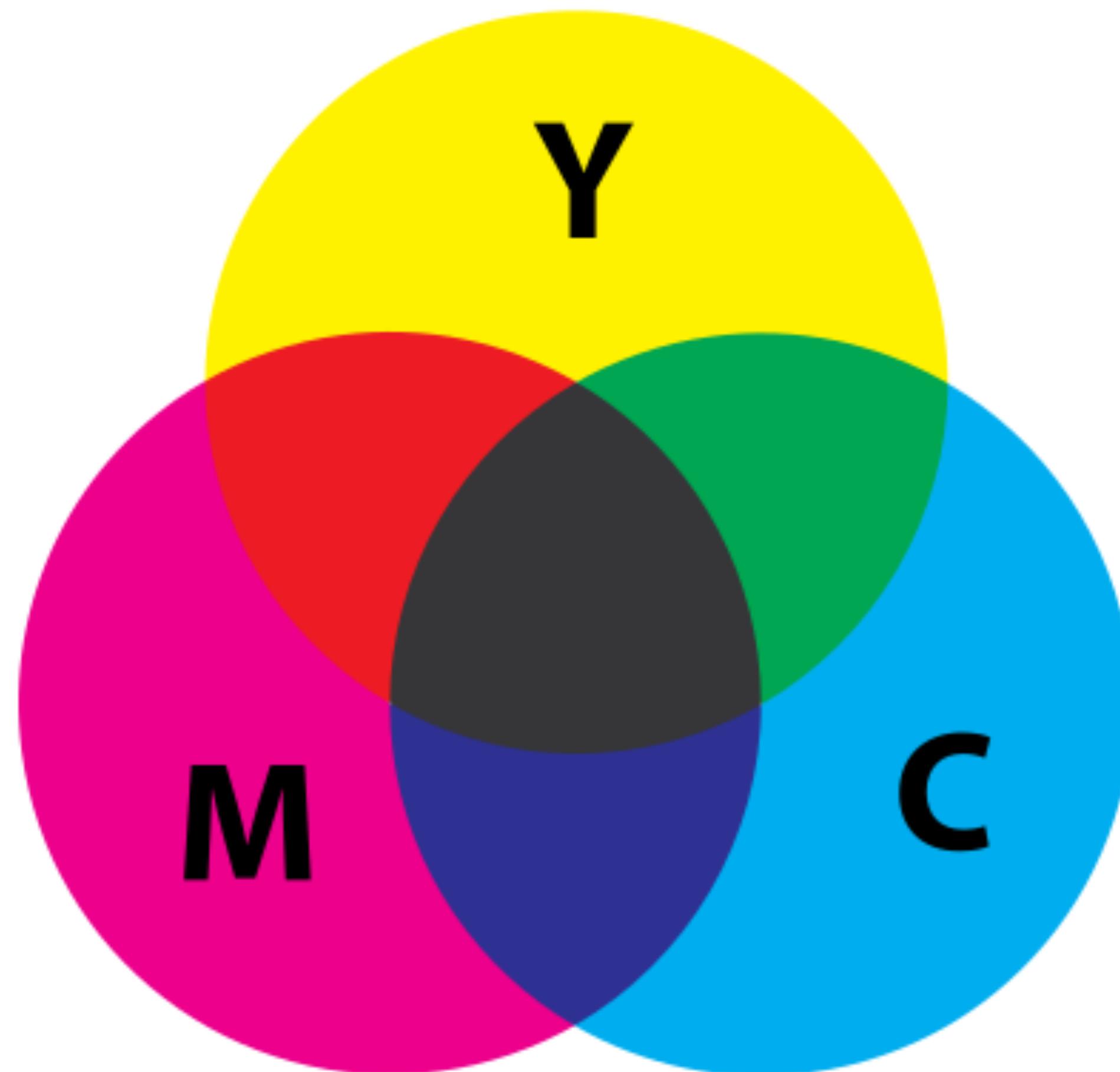
# List of common color spaces

- **RGB** (Red, Green, Blue)
- **CMYK** (Cyan, Magenta, Yellow, Black)
- **HSL** (Hue, Saturation, Lightness/Luminance)
- **CIELAB** (or L\*a\*b\*: Lightness, Green–Red and Blue–Yellow)

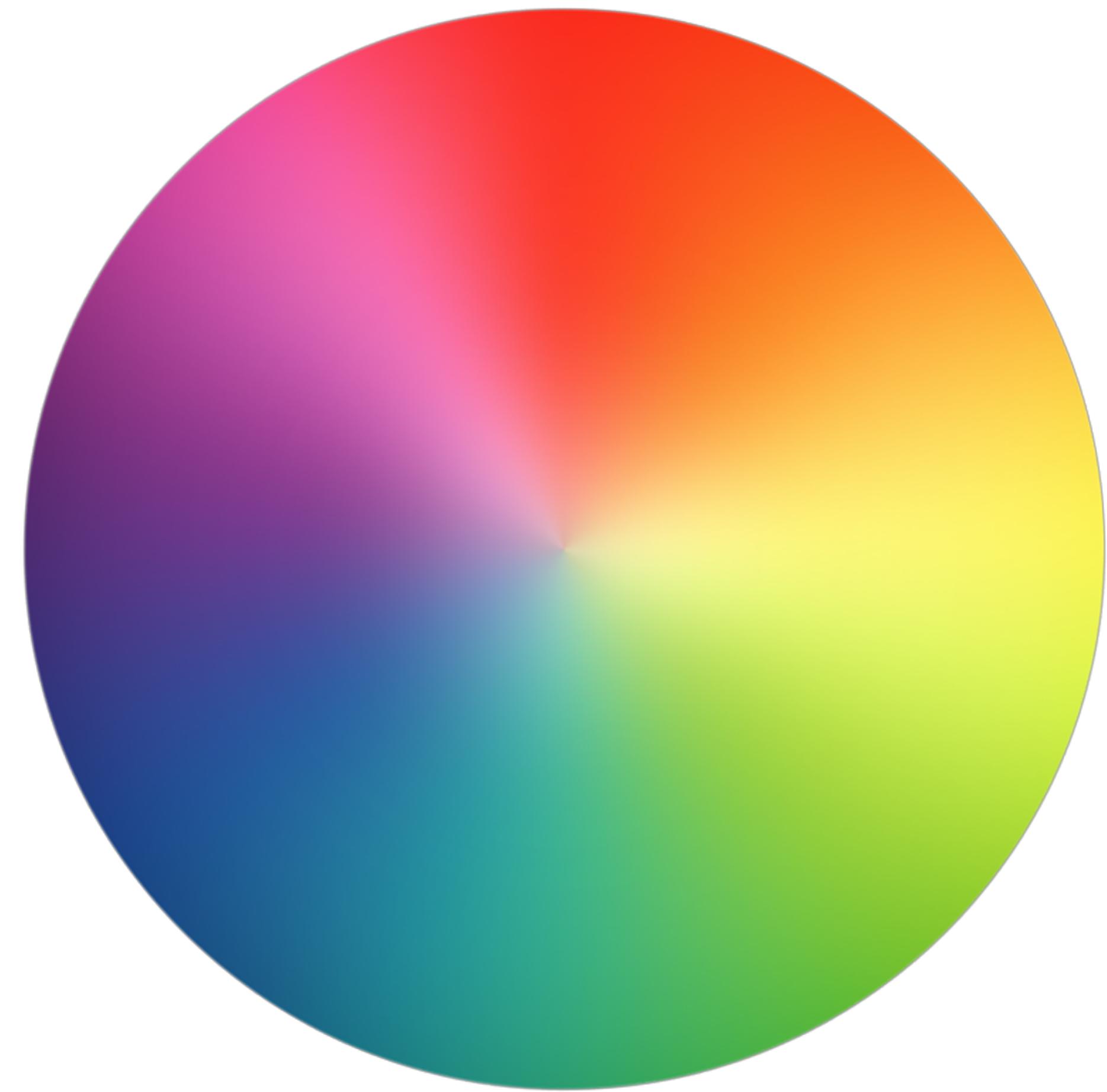
# **RGB** (Red, Green, Blue)



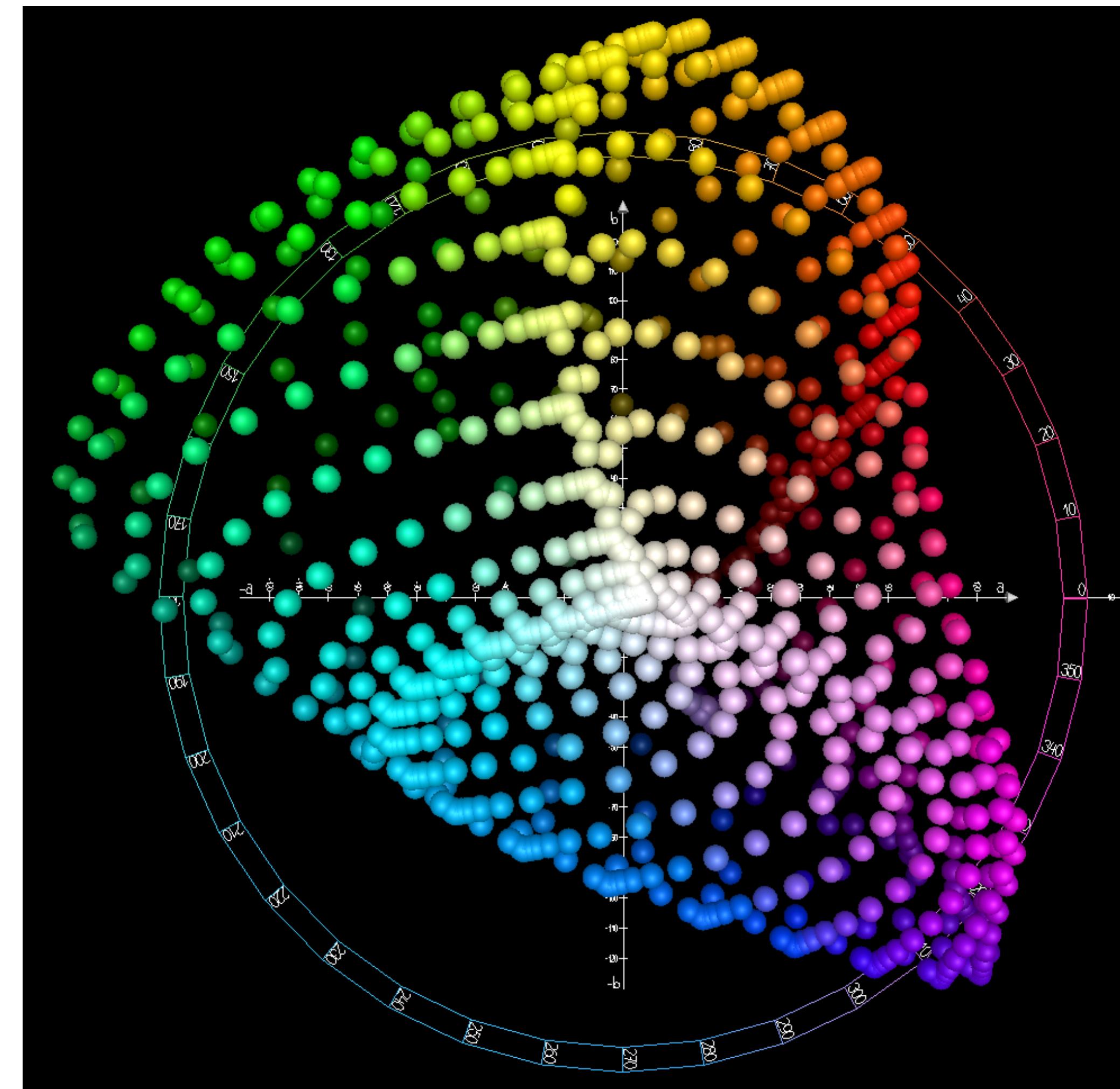
# **CMYK** (Cyan, Magenta, Yellow, Black)



# **HSL** (Hue, Saturation, Lightness/Luminance)



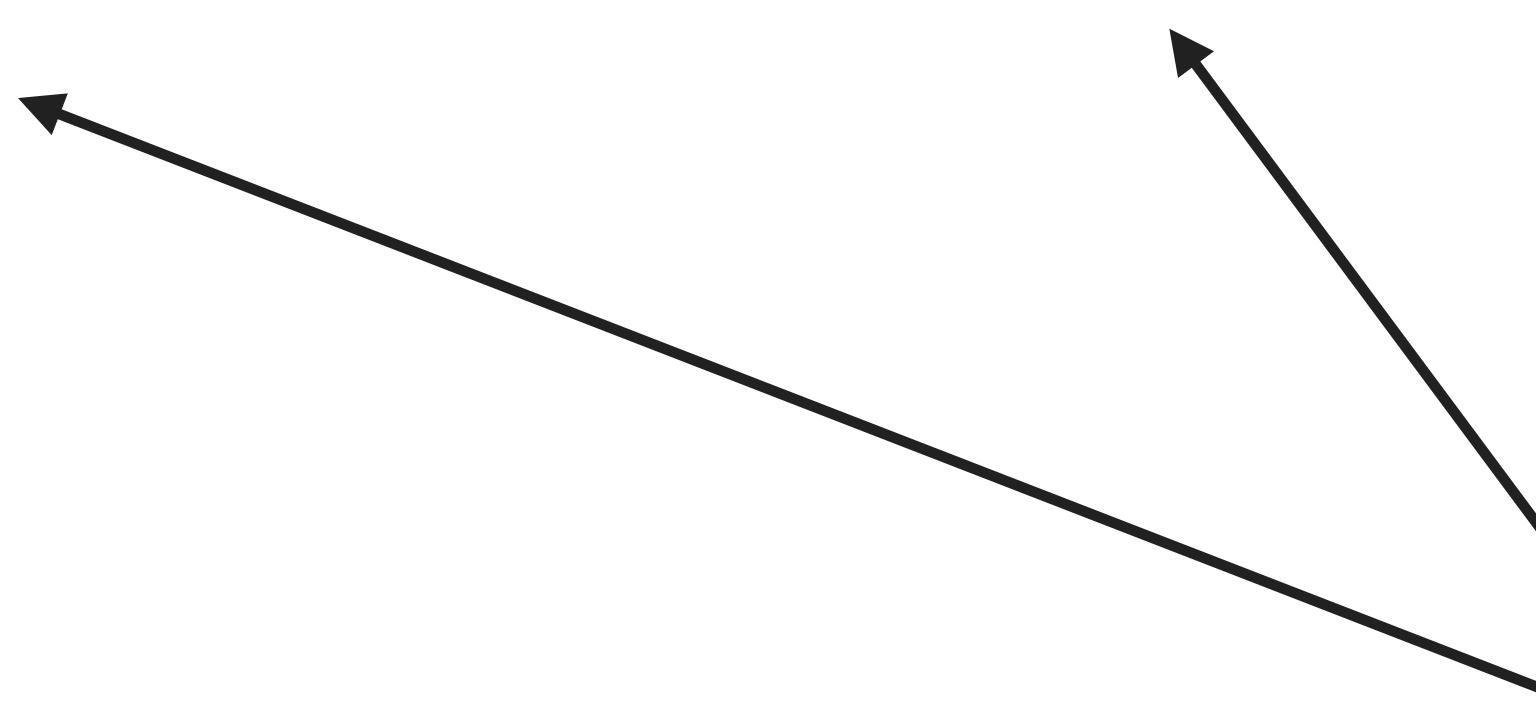
# CIELAB (or L<sup>\*</sup>a<sup>\*</sup>b<sup>\*</sup>: Lightness, Green–Red and Blue–Yellow)<sup>†</sup>



<sup>†</sup>International Commission on Illumination

# List of common color spaces

- **RGB** (Red, Green, Blue)
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- **HSL** (Hue, Saturation, Lightness/Luminance)
- **CIELAB** (or  $L^*a^*b^*$ )



Especially useful for data  
visualization

In certain color spaces, **color mixing** informs the combined behavior of different hues.

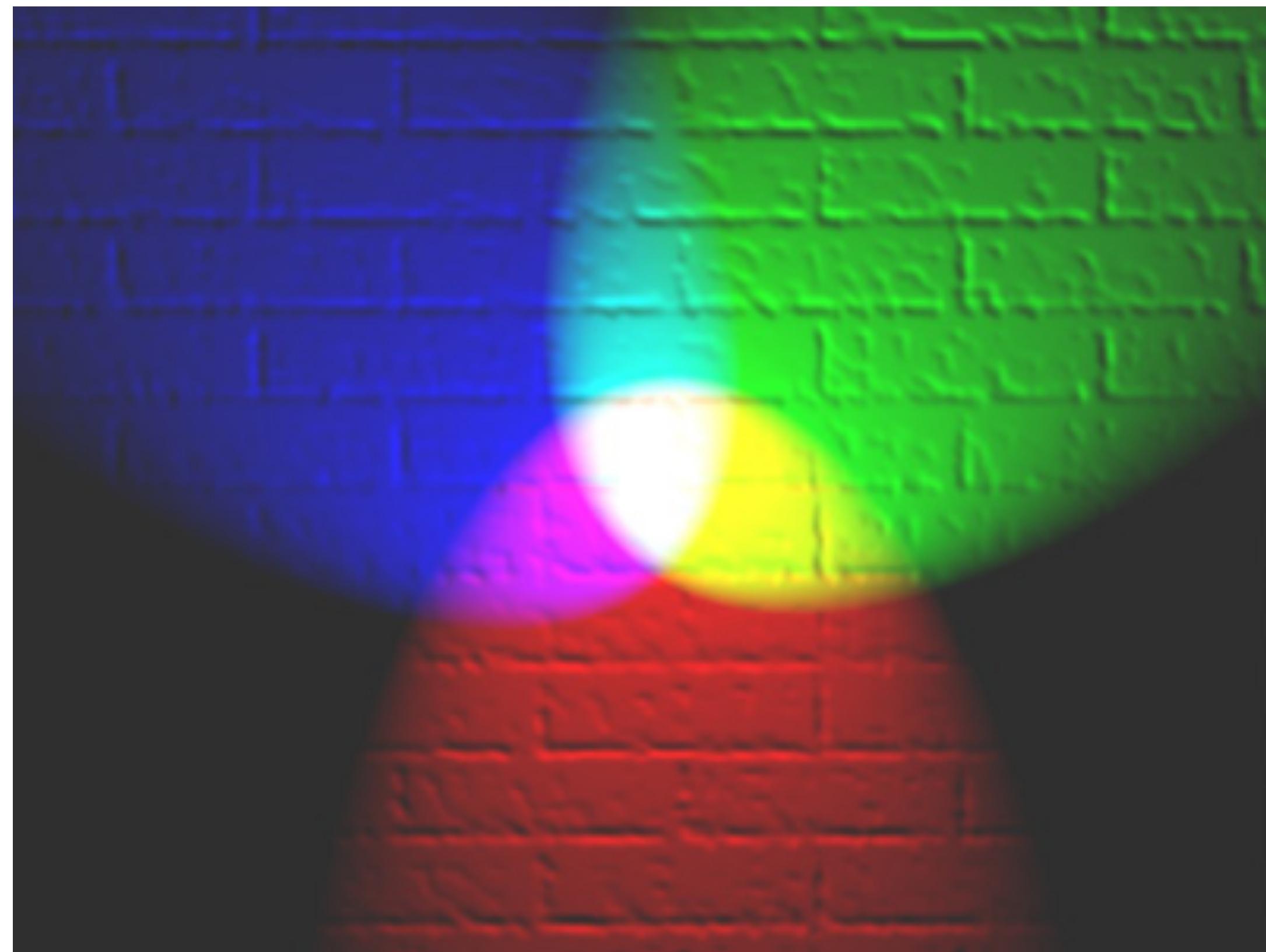
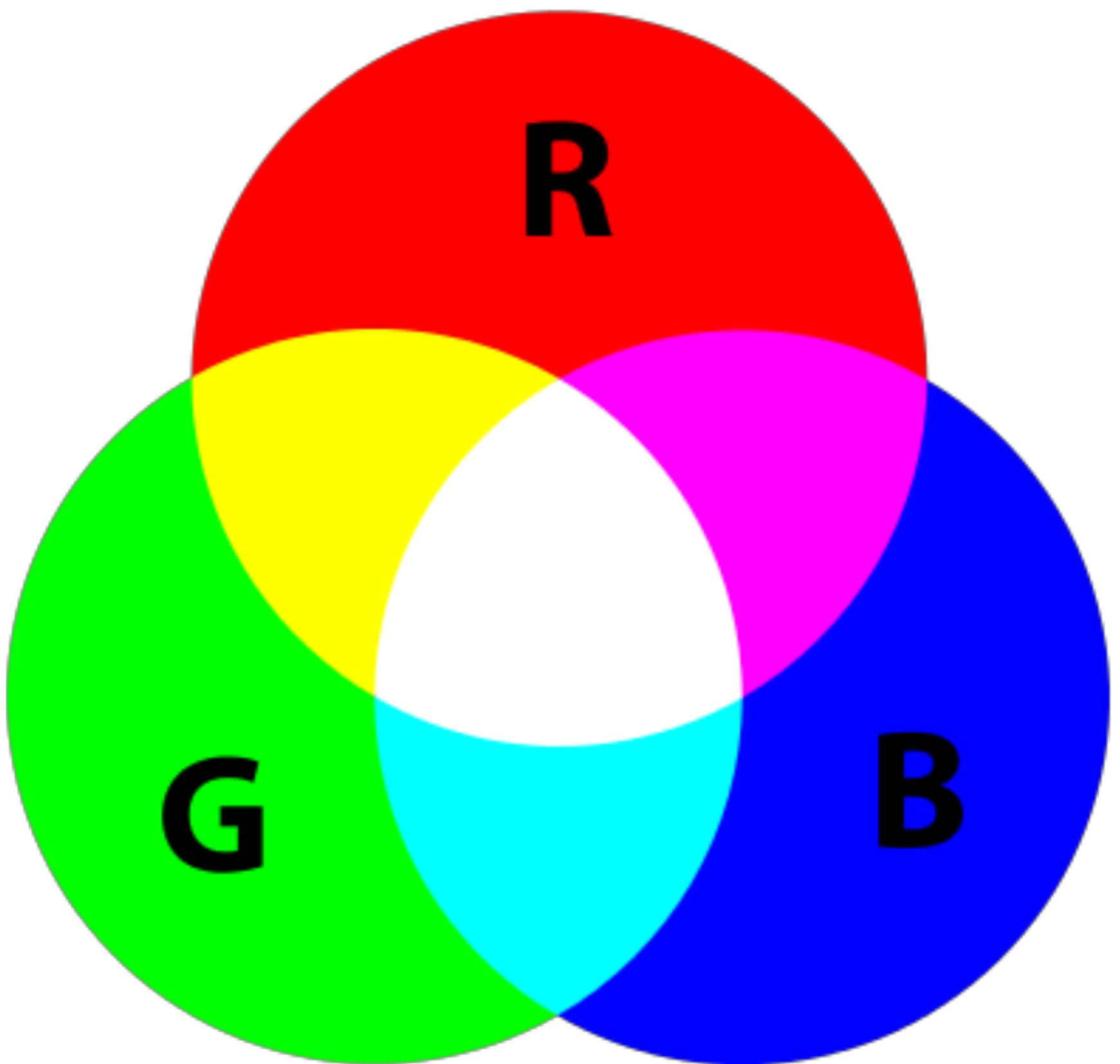
There are two types of color mixing:

1. **Additive**
2. **Subtractive**

# Color Mixing: **Additive**

- Additive color is created by **mixing different light colors**
- **RGB (most common)**: the three values in this space refer to the intensity output of the three light colors used in a monitor, television, or projector
  - **R** — Red
  - **G** — Green
  - **B** — Blue
- Does not correspond to the mixing of physical colors

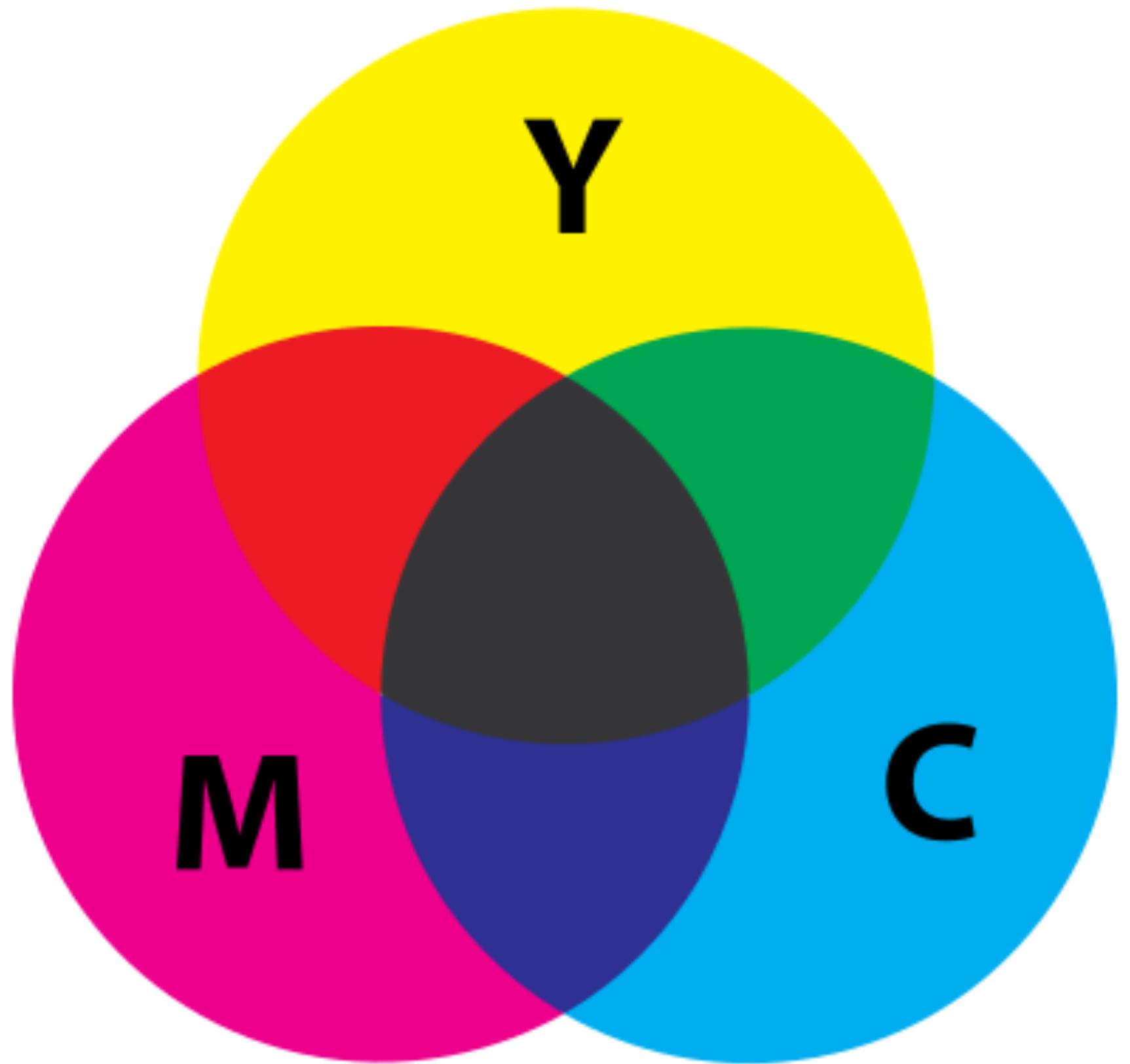
# Color Mixing: **Additive**



# Color Mixing: **Subtractive (*Absorbs Light*)**

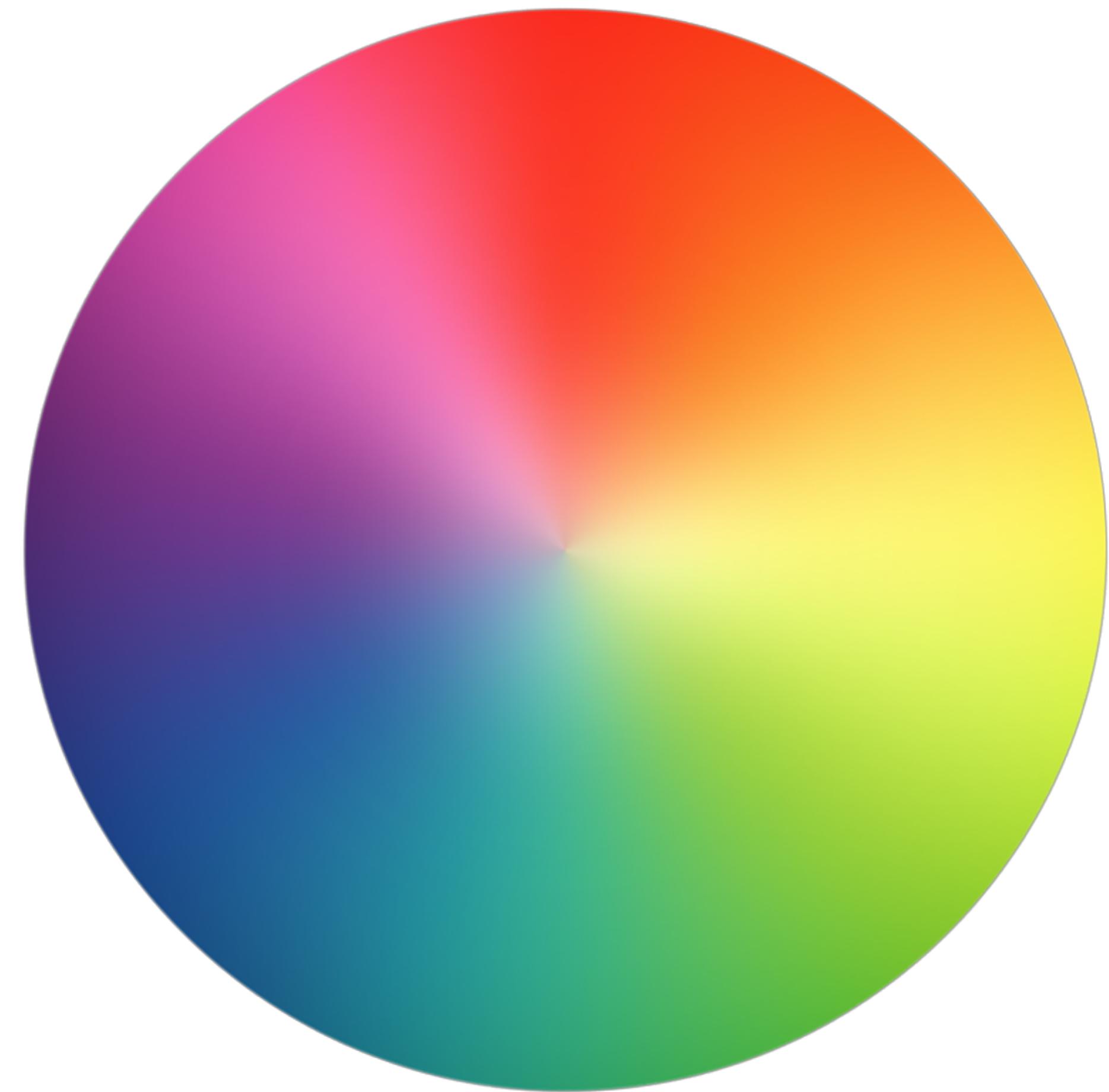
- Subtractive color is created by **mixing different ‘paint’ colors**
- **CMYK (widely used)**: the three primary hues in this space are:
  - **C** — Cyan
  - **M** — Magenta
  - **Y** — Yellow
- Does correspond to the mixing of physical colors
- Black can be approximated, but pure black is nearly impossible to achieve

# Color Mixing: **Subtractive (Absorbs Light)**



Some color spaces **do not rely on color mixing** to create additional hues.

# **HSL** (Hue, Saturation, Lightness/Luminance)





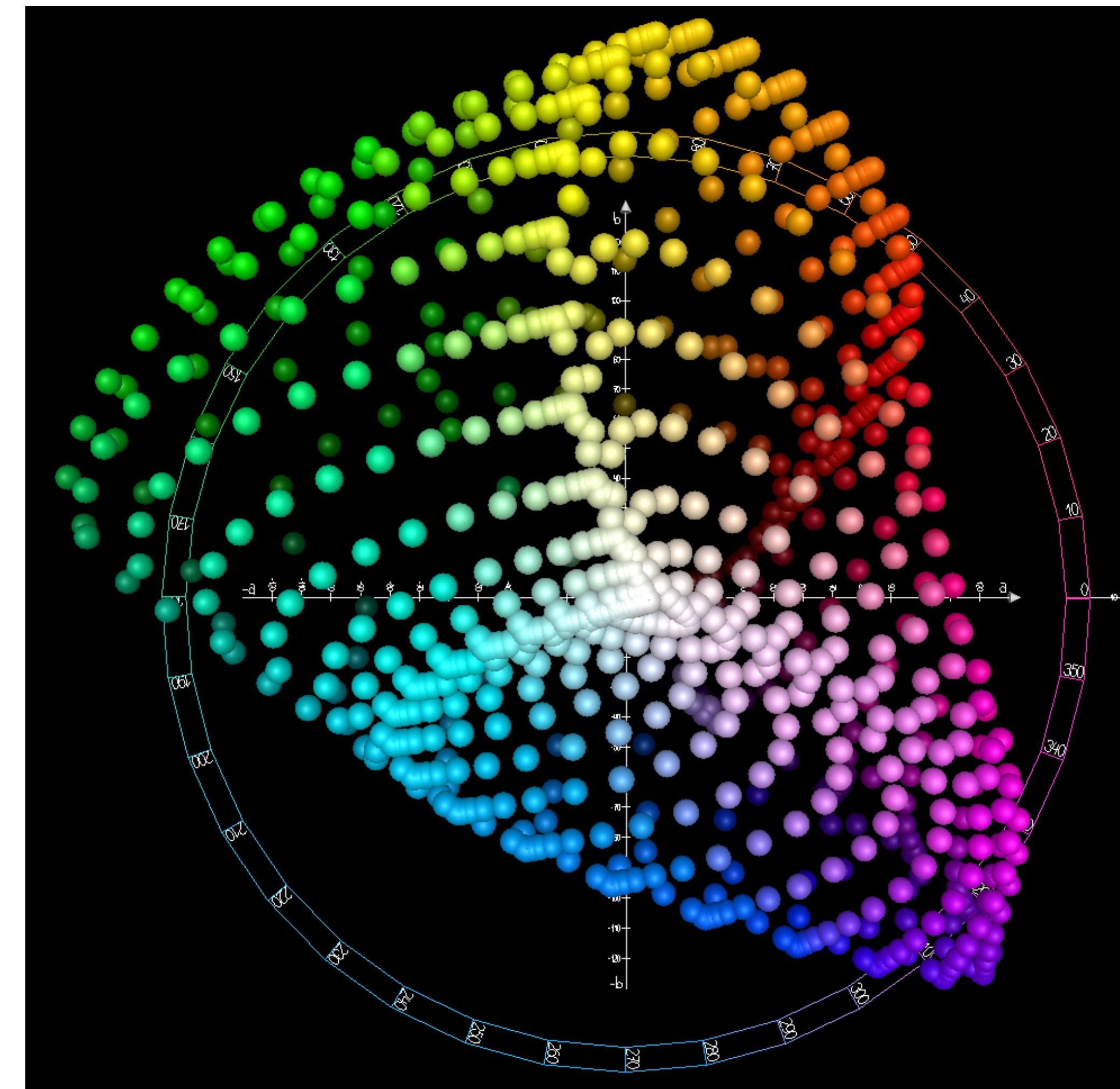
- **Hue** — The actual color
- Saturation
- Luminance



- Hue
- **Saturation** – The amount of grey in a color
- Luminance

- 
- Hue
  - Saturation
  - **Luminance** – The amount of white or black in a color

# CIELAB (or L<sup>\*</sup>a<sup>\*</sup>b<sup>\*</sup>: Lightness, Green–Red and Blue–Yellow)<sup>†</sup>



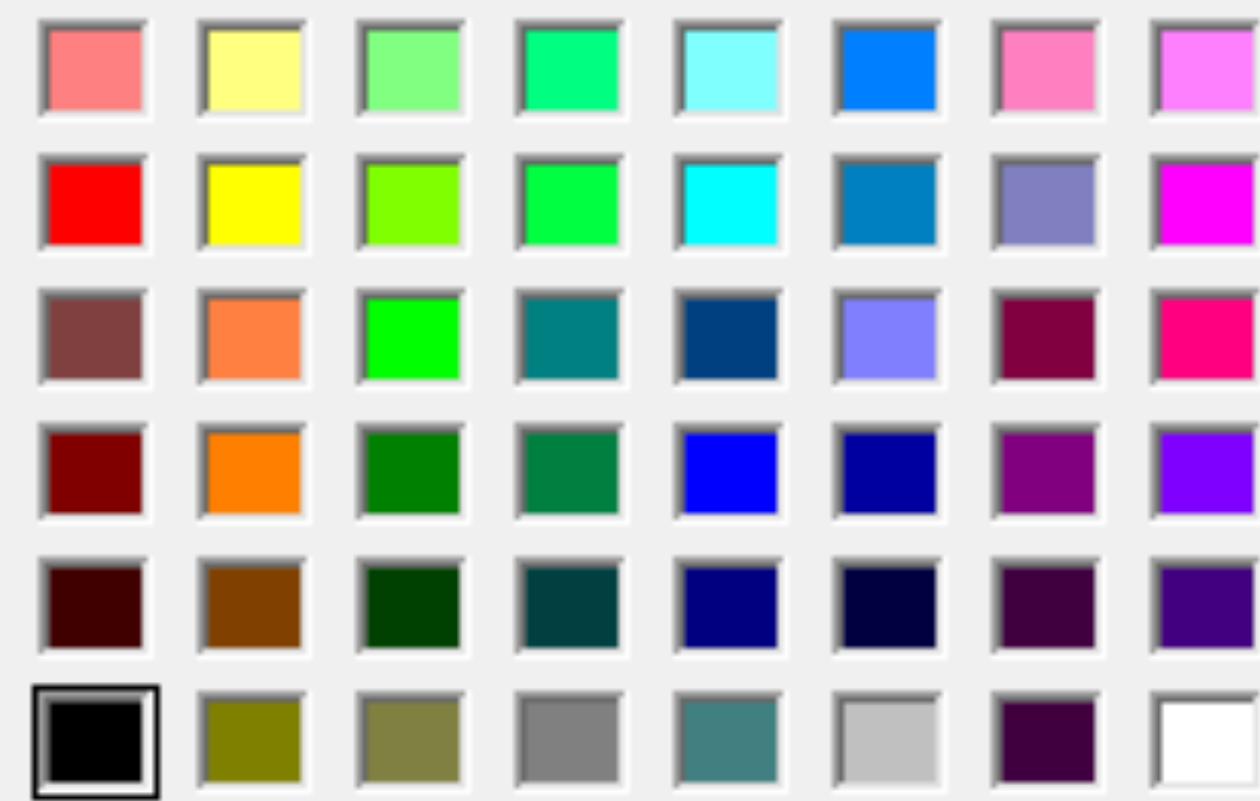
<sup>†</sup>International Commission on Illumination

- Concerned with being **perceptually uniform** to human color vision
- Numerical change = visually perceived change

**Typical color controls** surface RGB and HSL  
(and sometimes CMYK) to the user.

## Edit Colors

### Basic colors:



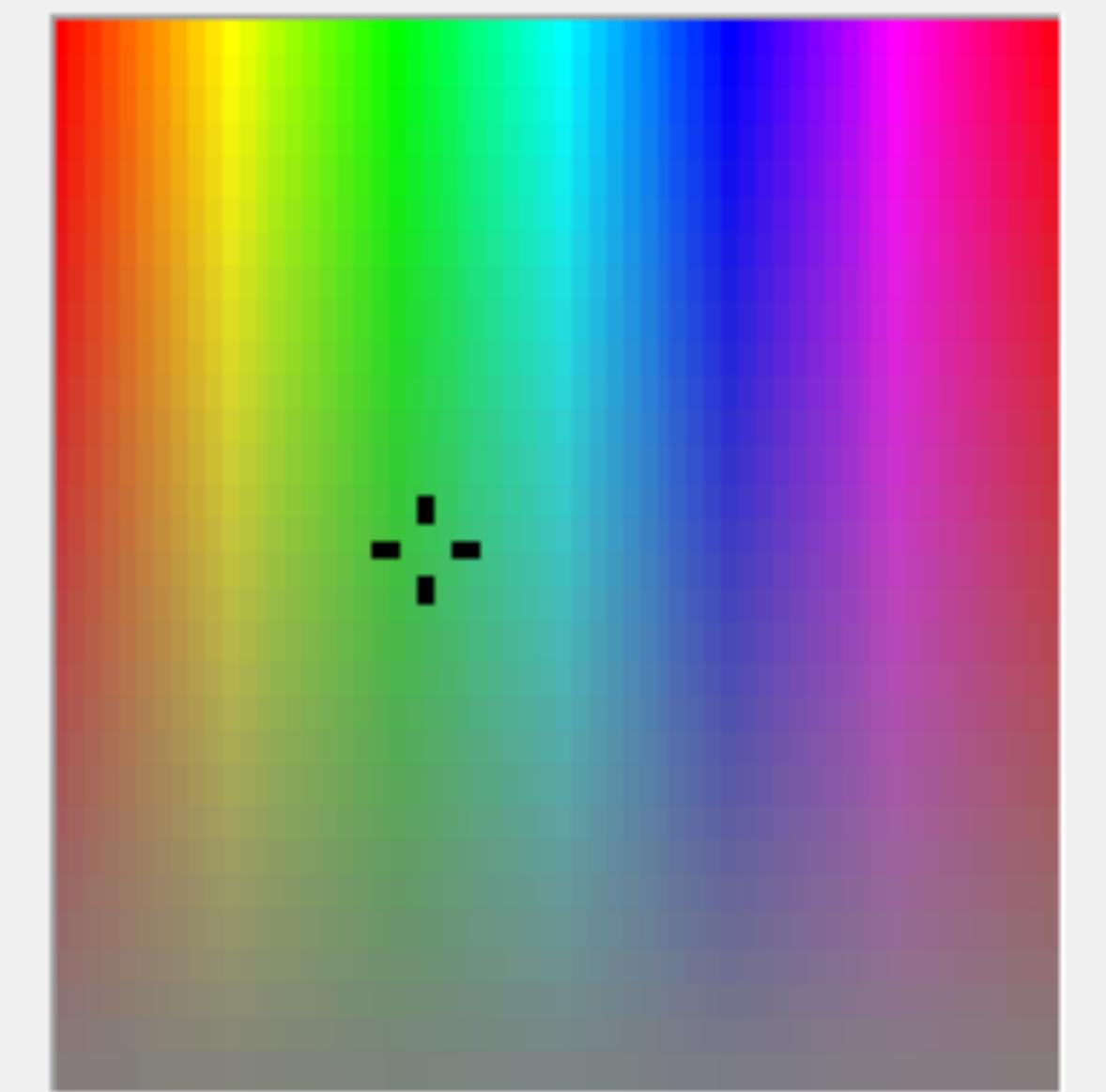
### Custom colors:



[Define Custom Colors >>](#)

OK

Cancel



Hue: 87

Red: 0

Sat: 122

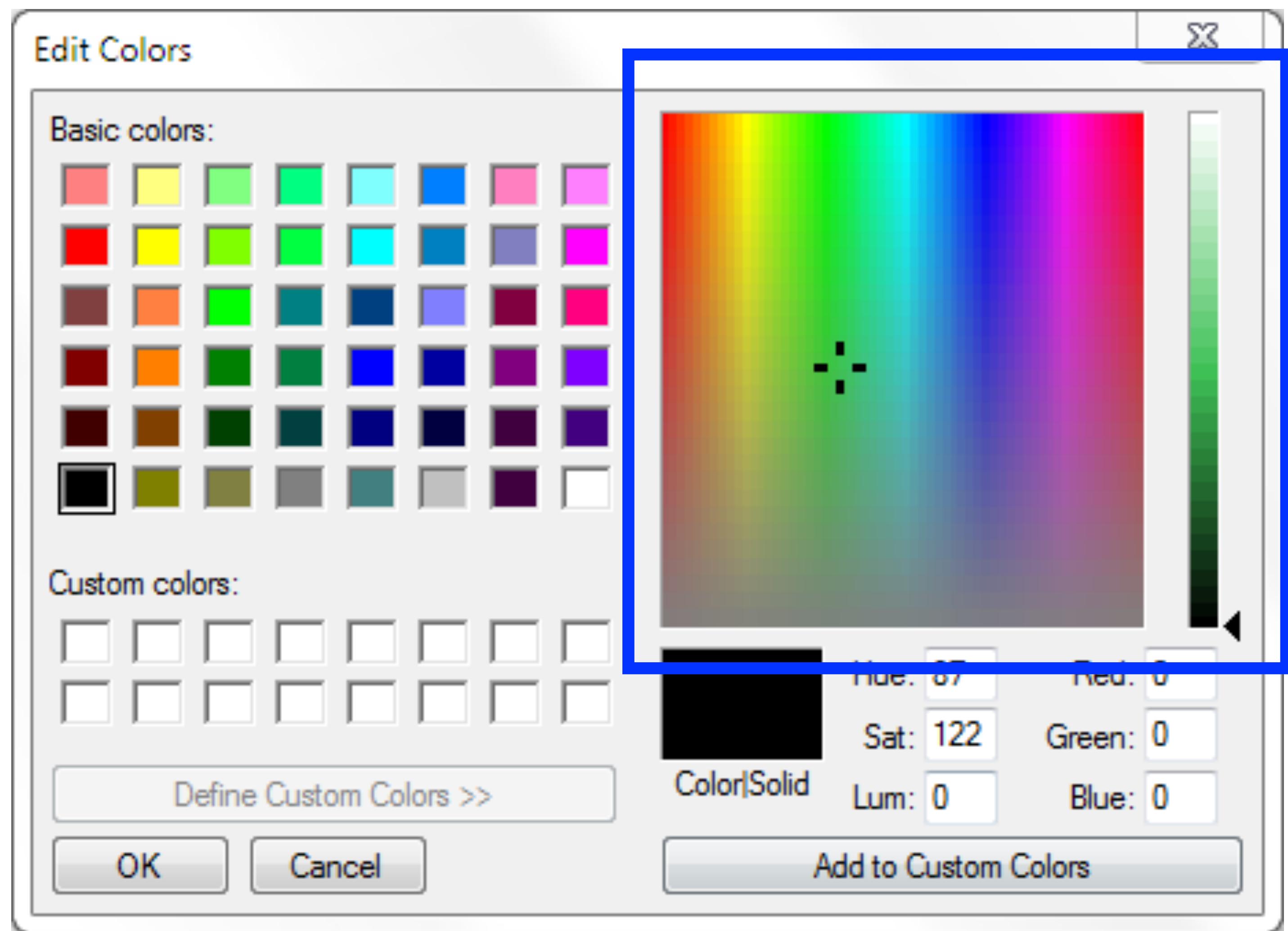
Green: 0

Lum: 0

Blue: 0

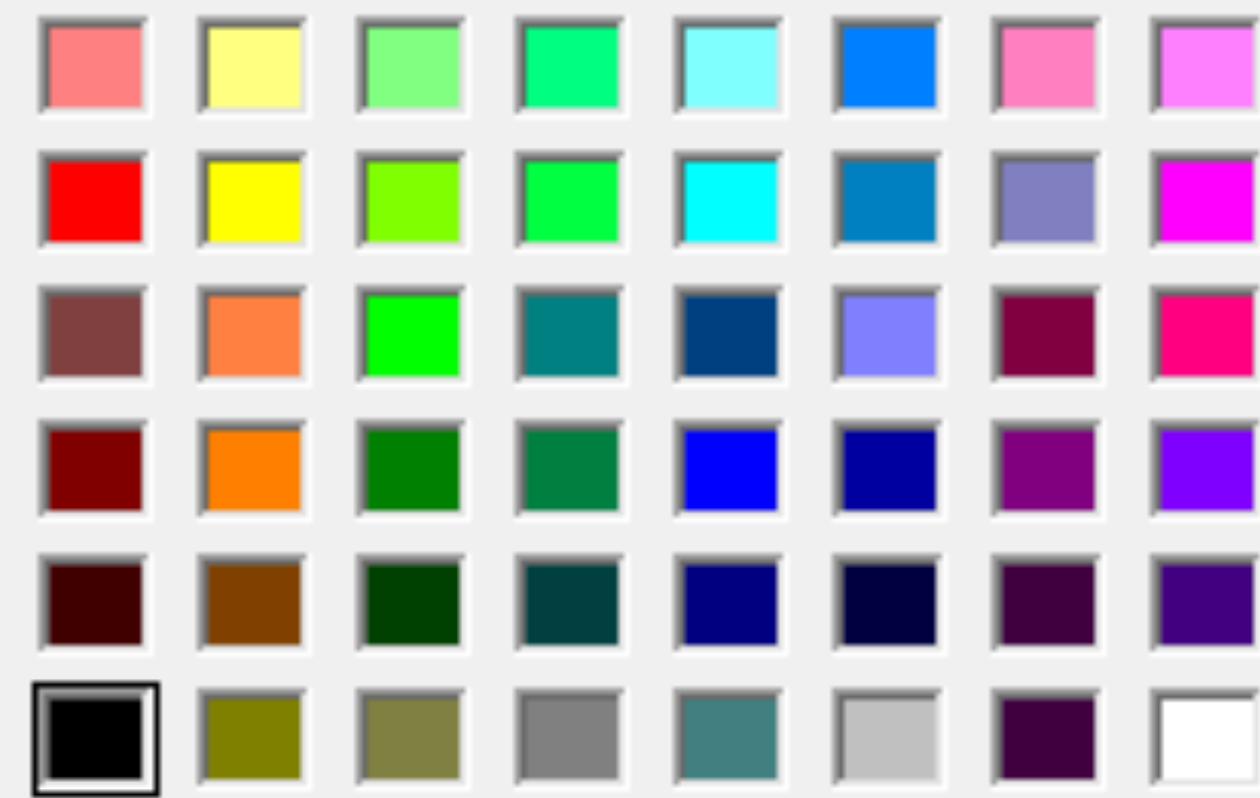
Color|Solid

Add to Custom Colors



## Edit Colors

### Basic colors:



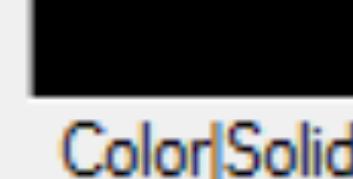
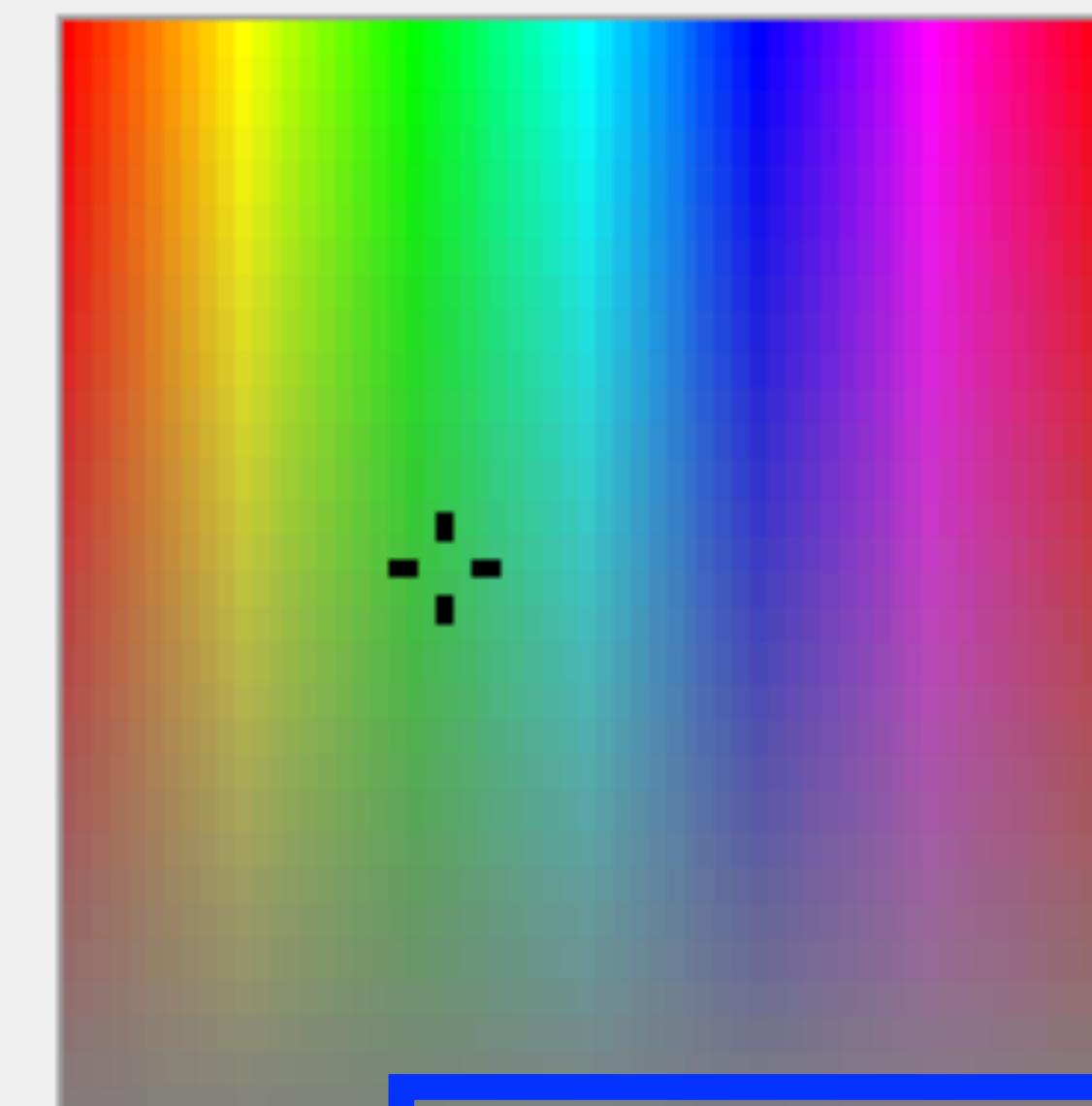
### Custom colors:



[Define Custom Colors >>](#)

OK

Cancel



Color|Solid

Hue: 87

Red: 0

Sat: 122

Green: 0

Lum: 0

Blue: 0

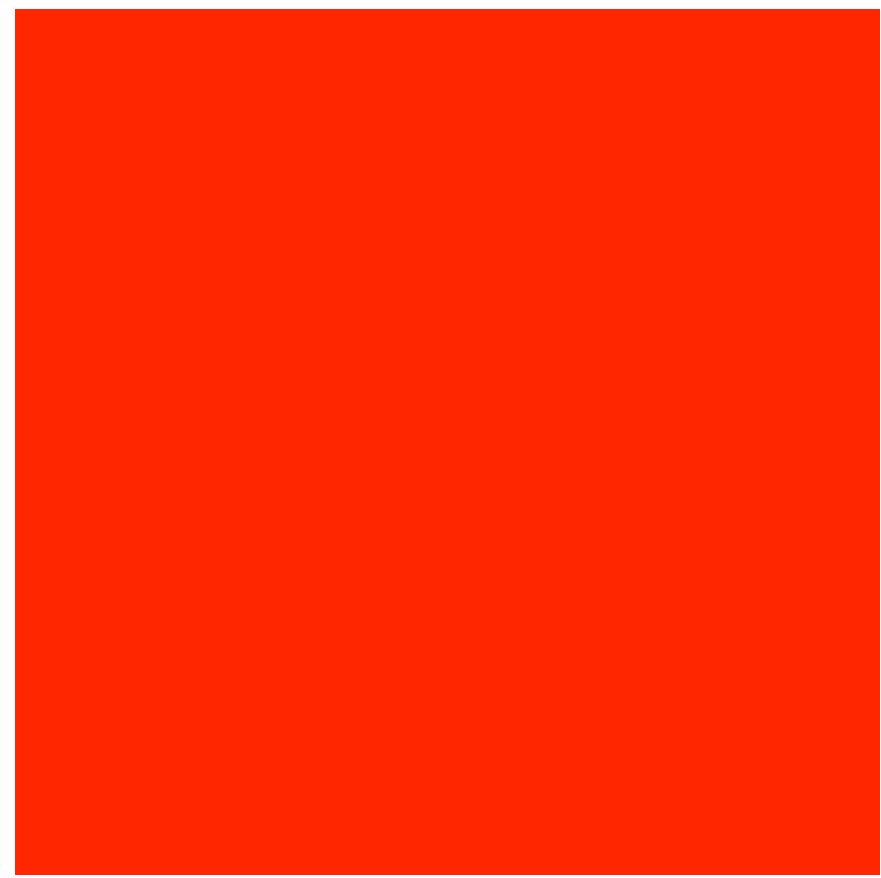
Add to Custom Colors

For the purposes of visualization, we are more concerned with **how color is perceived** than how it is formed...

...which means that **using tools that incorporate HSL** (or CIELAB!) will produce the most visually successful results.

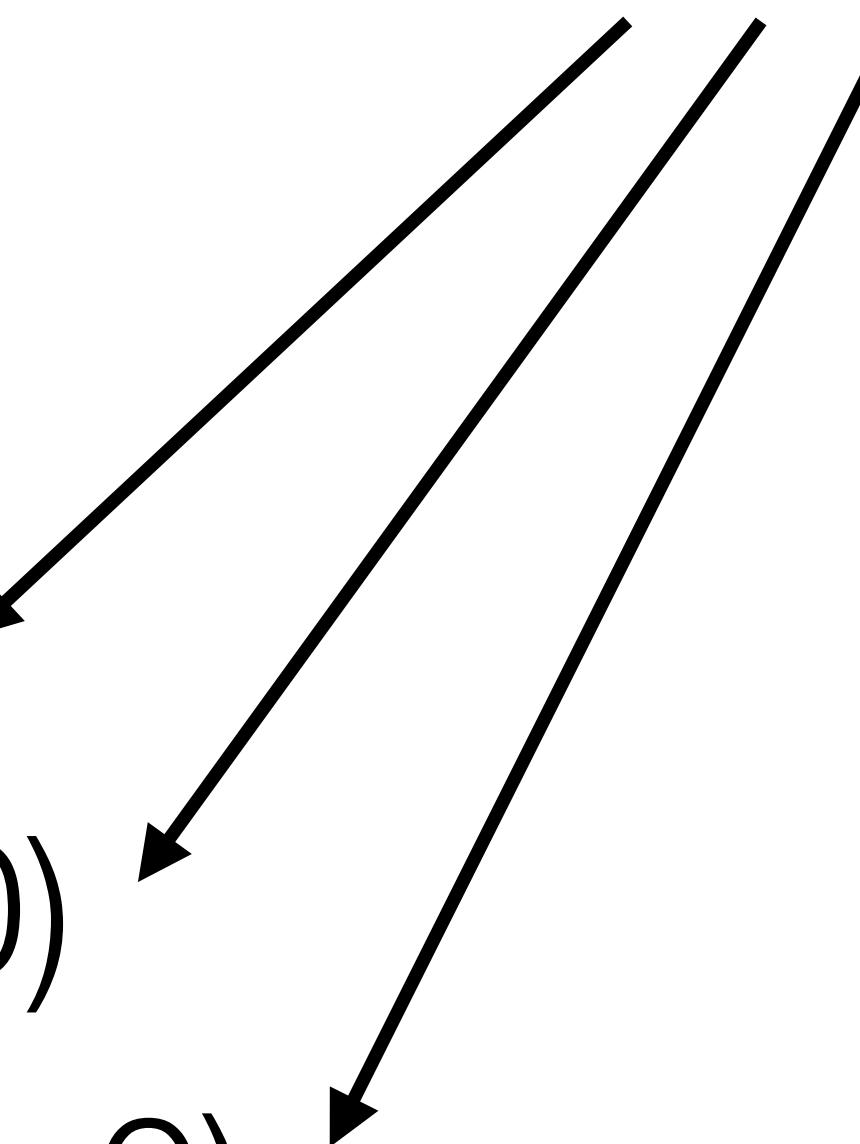
# Color **syntax**

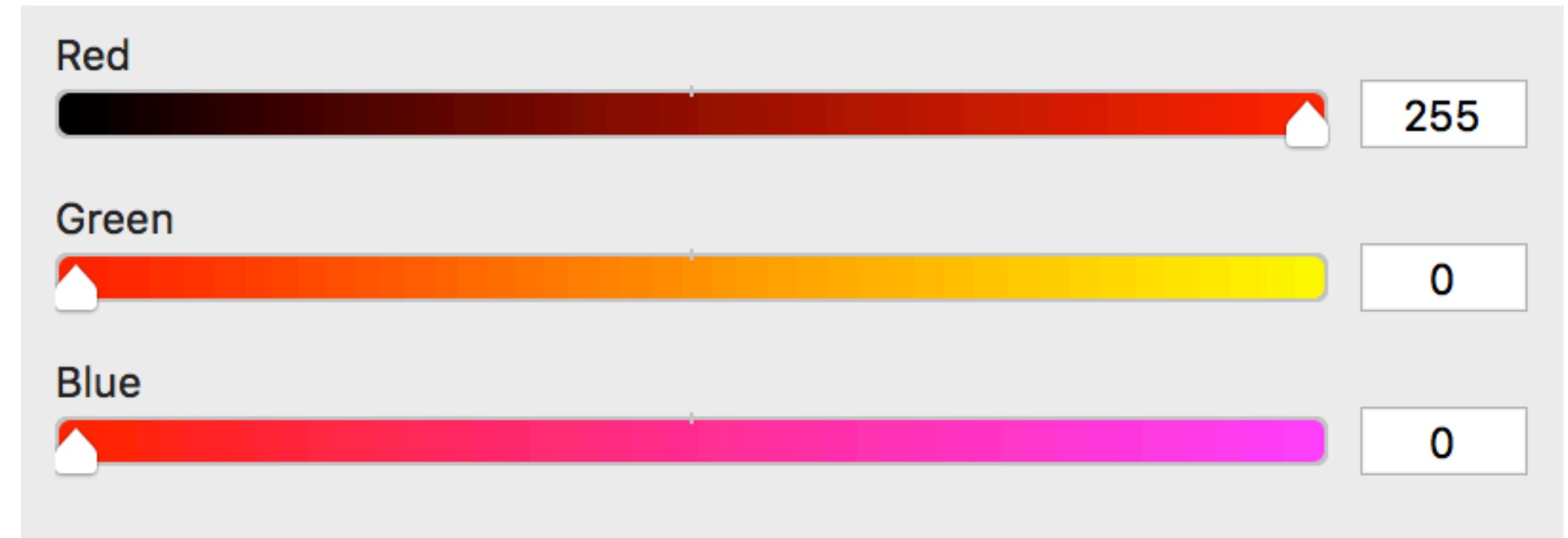
When working with color in a **digital context**, most color pickers allow you to specify values in RGB, CMYK, or HSL/HSB.



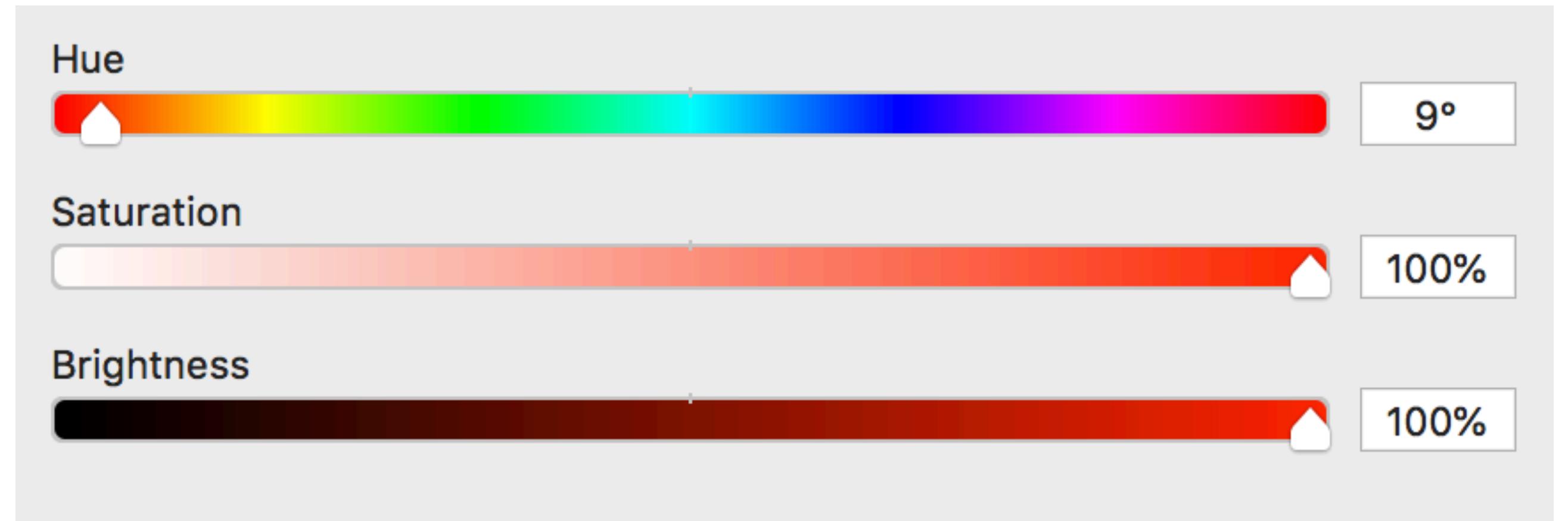
**This** color may be specified  
in any of **these** ways.

- RGB(255, 0, 0)
- HSL(9, 100, 100)
- CMYK(0, 80, 94, 0)

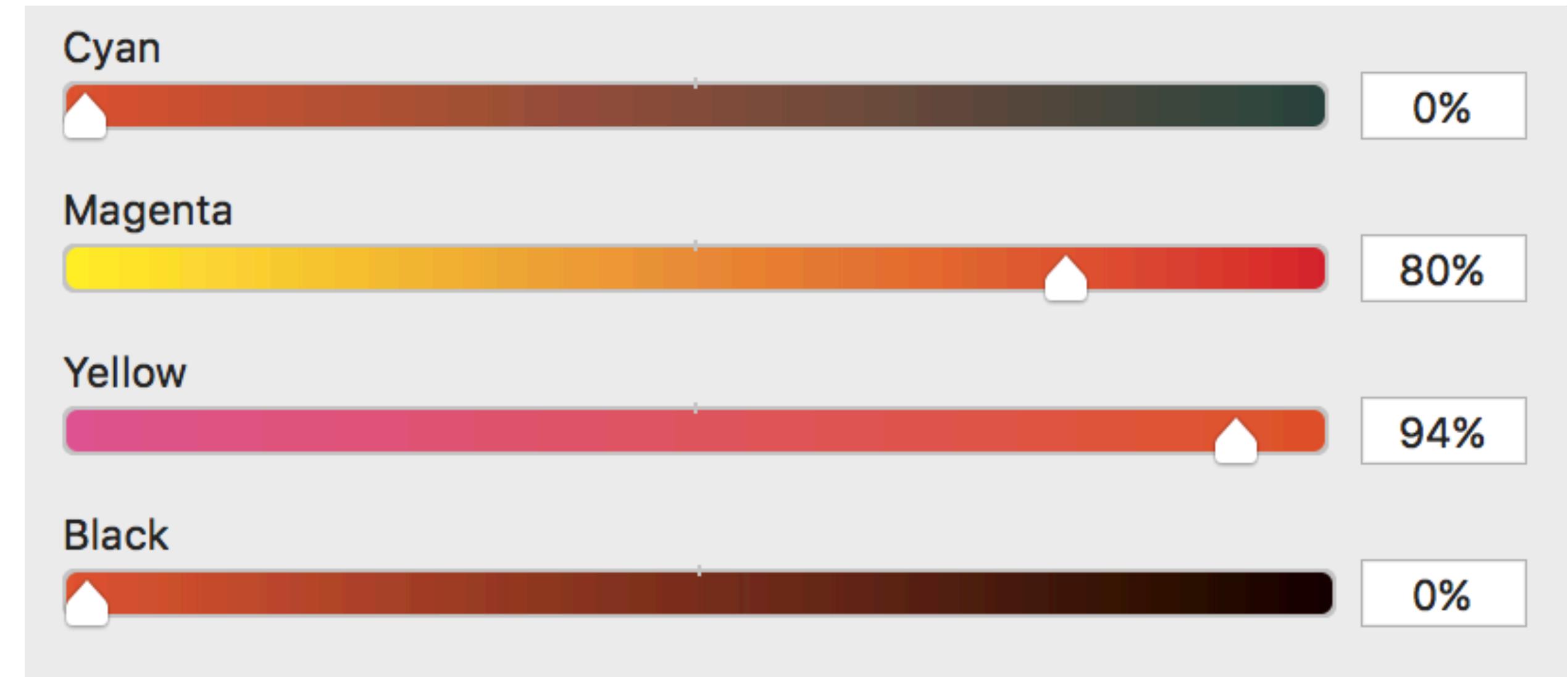




- **RGB(255, 0, 0)**
- HSL(9, 100, 100)
- CMYK(0, 80, 94, 0)



- RGB(255, 0, 0)
- **HSL(9, 100, 100)**
- CMYK(0, 80, 94, 0)



- RGB(255, 0, 0)
- HSL(9, 100, 100)
- **CMYK(0, 80, 94, 0)**

Color scheme **generators** allow you to input values as a hex code, or in RGB, CMYK, or HSL/HSB.

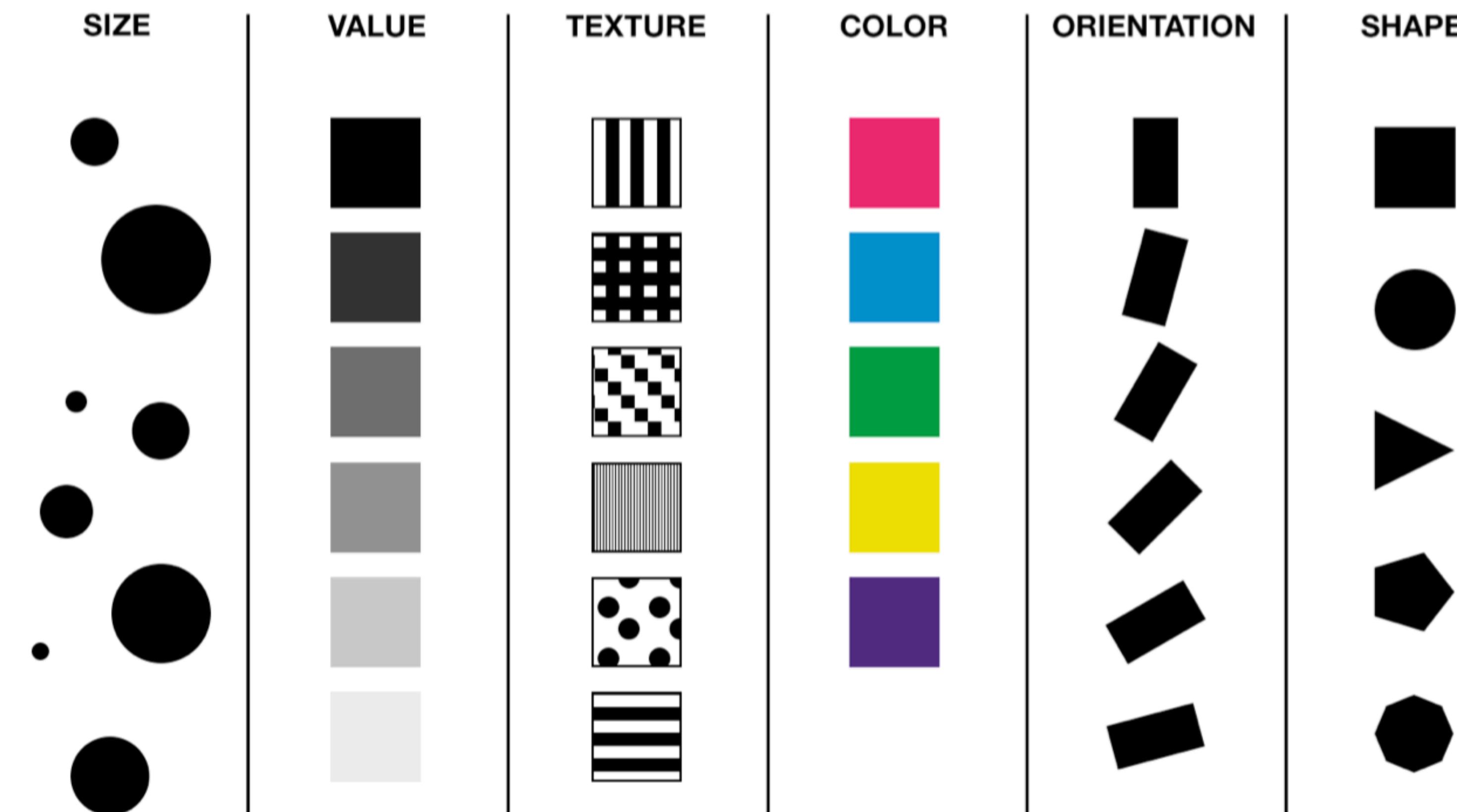
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Recap:

# Visual Variables (Channels)

**Jacques Bertin**

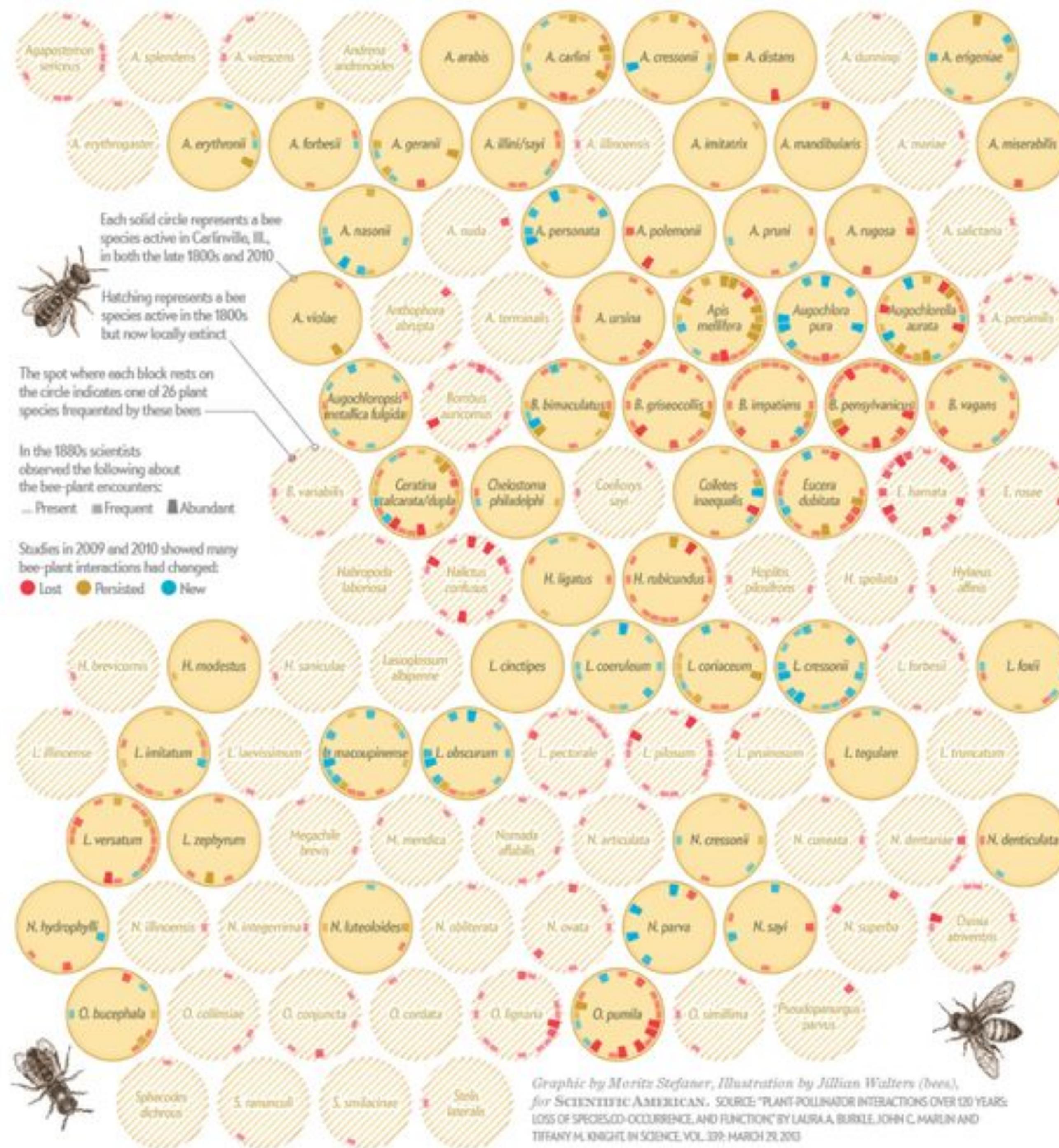
*The Semiology of Graphics (1967)*



The process of mapping data to visual variables is called **visual mapping**.

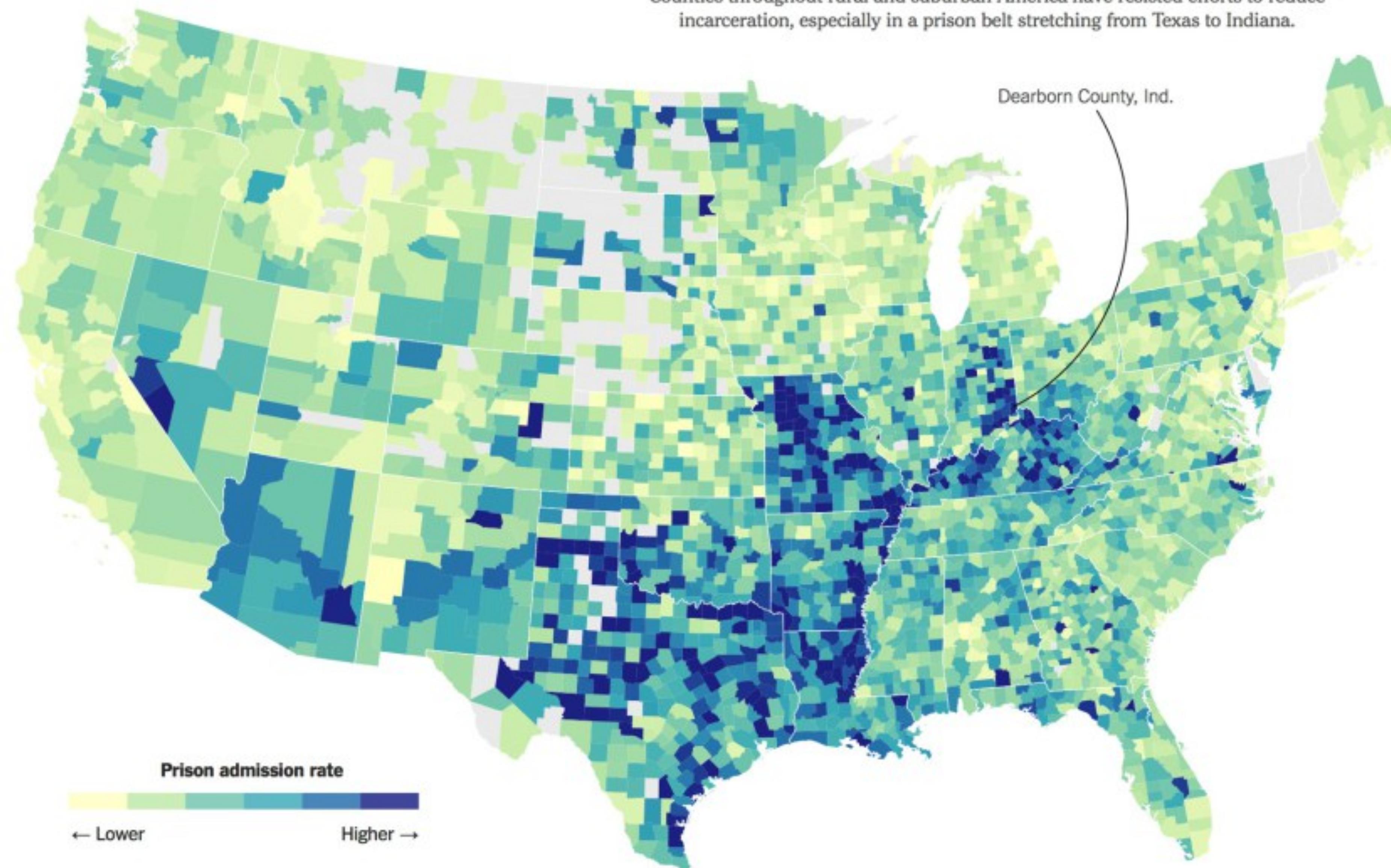
Selecting visual variables to represent different aspects of the same information can greatly influence the **perception and understanding** of the presented information.

**Color is an especially useful visual variable**, because it is flexible enough to represent both qualitative and quantitative data.



## Where Americans Are Sent to Prison Most

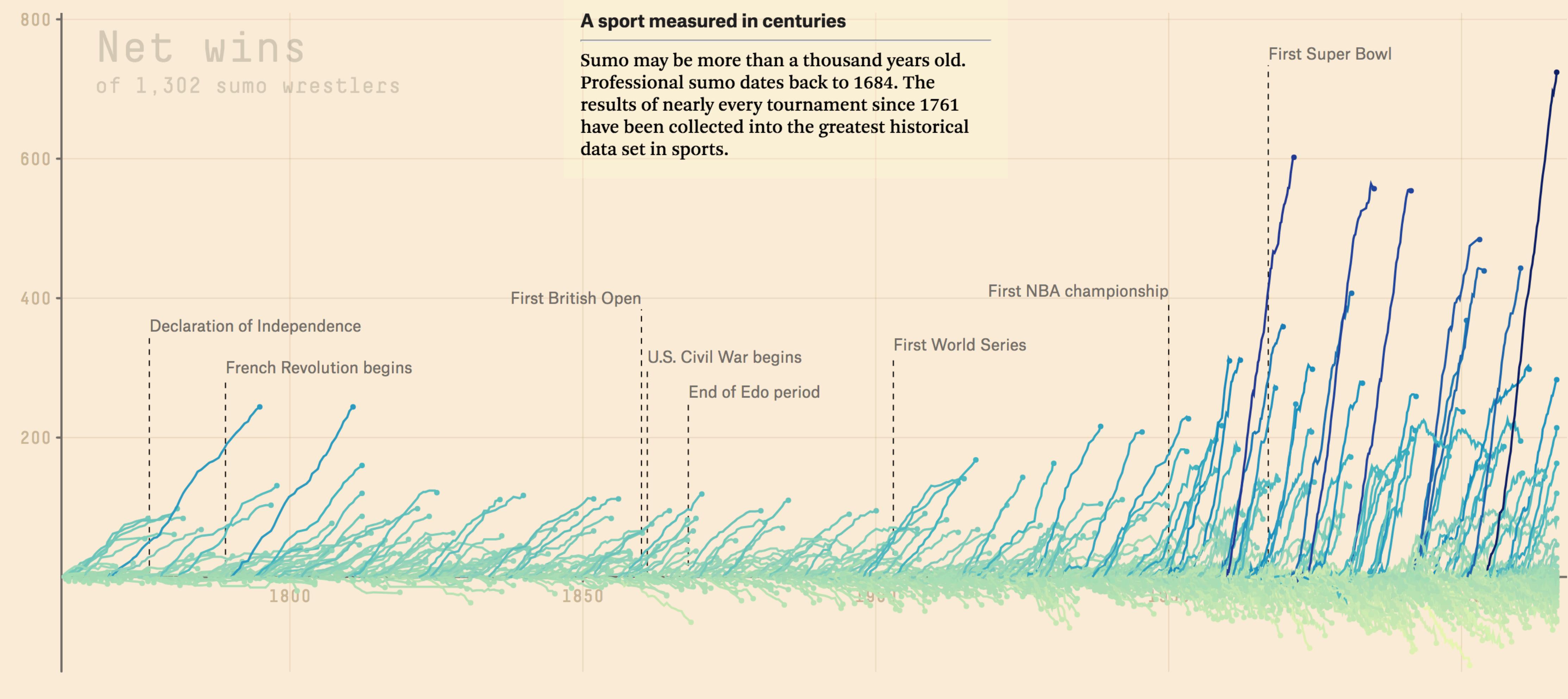
Counties throughout rural and suburban America have resisted efforts to reduce incarceration, especially in a prison belt stretching from Texas to Indiana.



# A History Of Sumo

By Matthew Conlen

◀ 1 / 6 ▶



Color is also **affective**. It can influence feelings or emotions in the viewer.

**power**  
**sophistication**  
**mystery**  
**death**

**hope**  
**simplicity**  
**cleanliness**  
**goodness**  
**purity**

**love**  
**passion**  
**romance**  
**danger**  
**energy**

**intelect**  
**friendliness**  
**warmth**  
**caution**  
**cowardice**

**peace**  
**sincerity**  
**confidence**  
**integrity**  
**tranquility**

**authority**  
**maturity**  
**security**  
**stability**

**life**  
**growth**  
**nature**  
**money**  
**freshness**

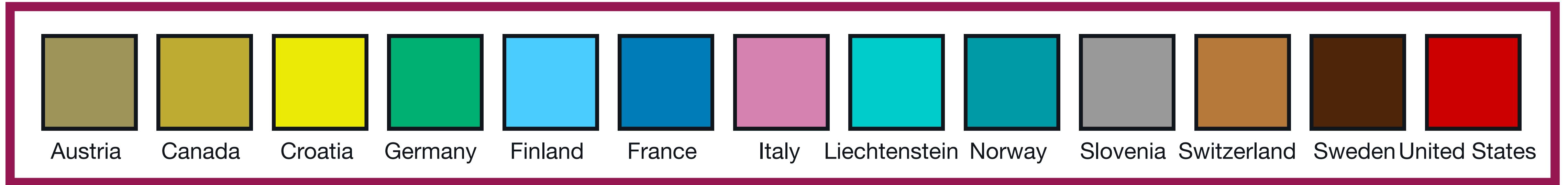
**innovation**  
**creativity**  
**thinking**  
**ideas**

**royalty**  
**luxury**  
**wisdom**  
**dignity**

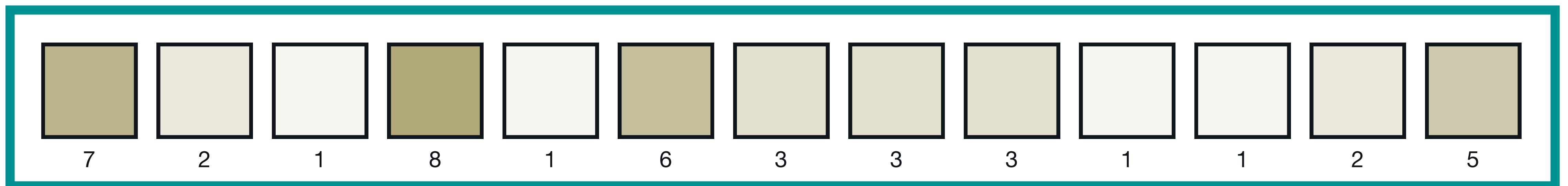
Despite the ubiquity of color association hypotheses, their claims are often contradictory (and, of course, **contextual**).

# Color and Data

**Not all channels work for all types of data.** Think about what best corresponds to what you're working with.



***Qualitative data (nominal)***



***Qualitative data (ratio)***

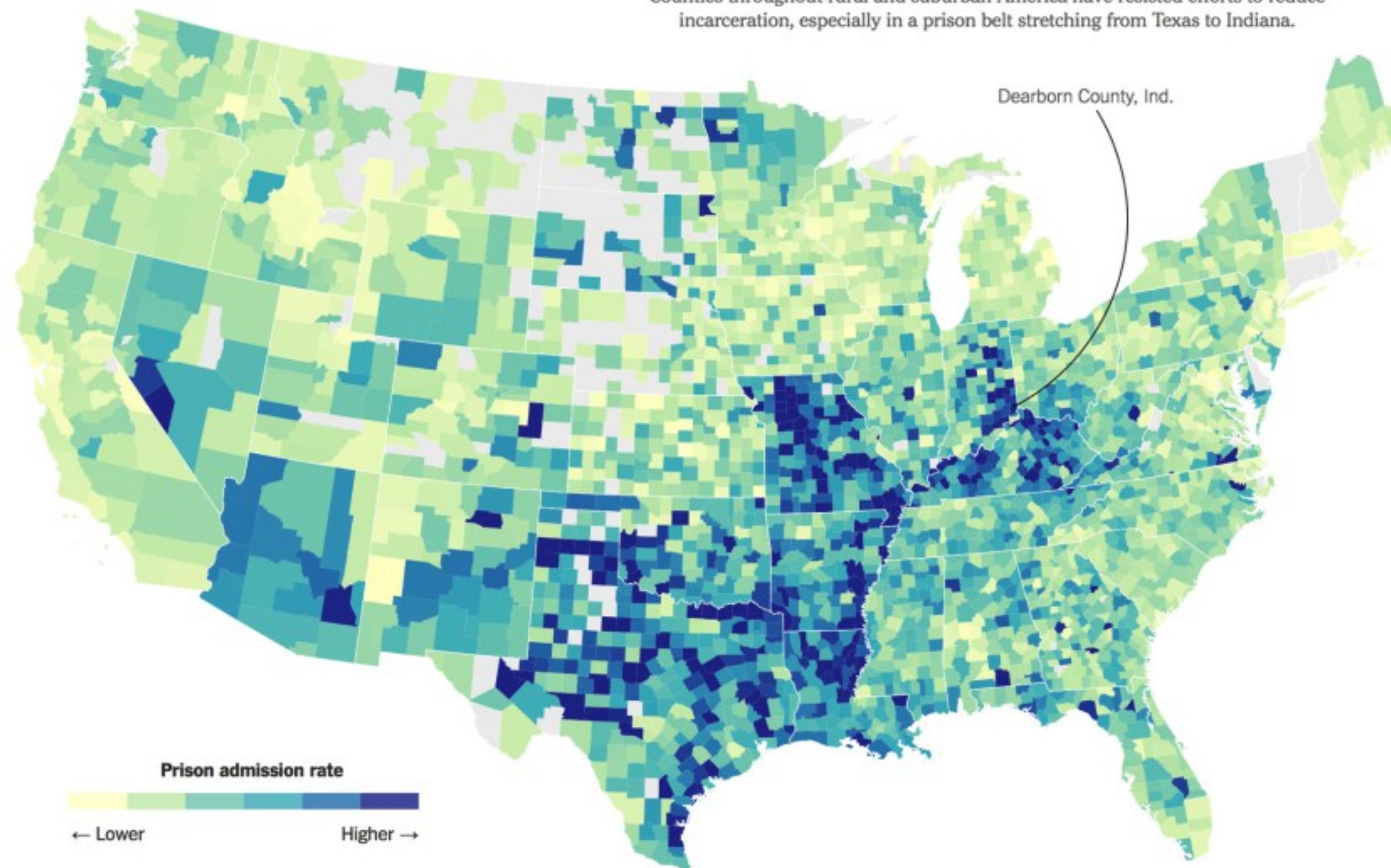
Working with color becomes challenging when trying to create **scales that appear to have even increments** (*perceptual uniformity*).

# Why bother with perceptual uniformity?

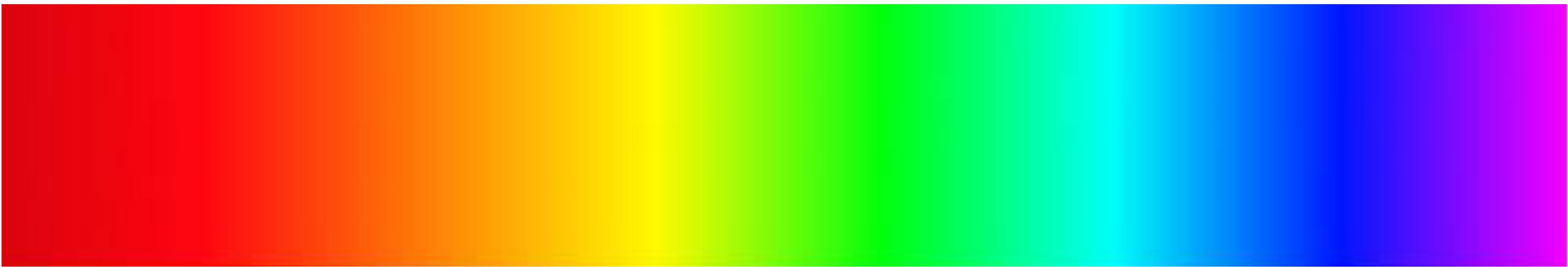
- Faithful representation of data
- Easy to compare and compute values

## Where Americans Are Sent to Prison Most

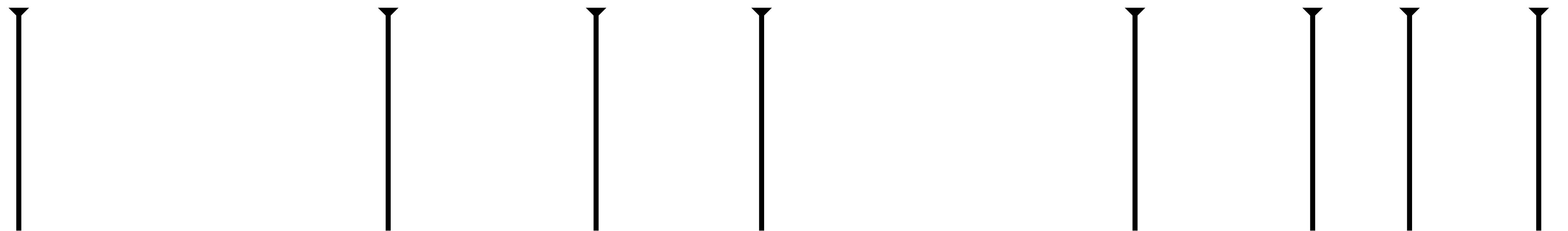
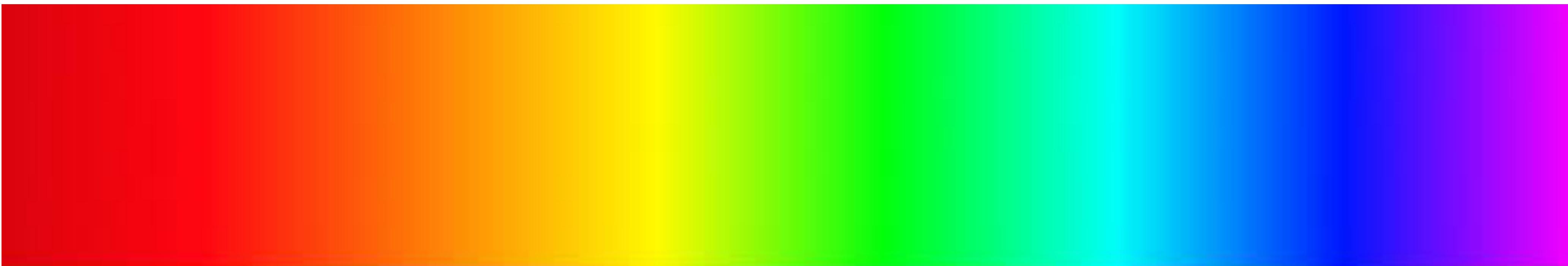
Counties throughout rural and suburban America have resisted efforts to reduce incarceration, especially in a prison belt stretching from Texas to Indiana.



Why not use a rainbow?

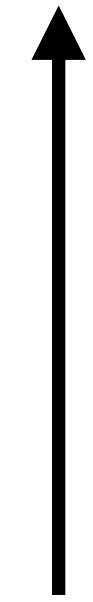
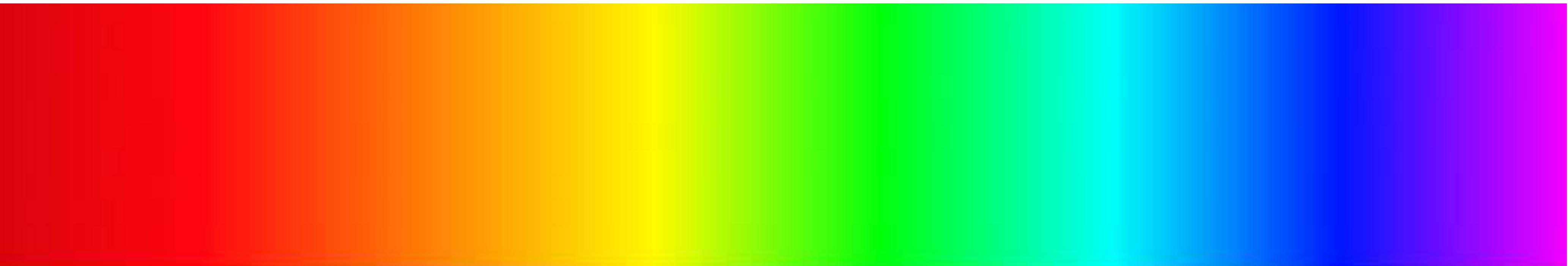


Why not use a rainbow?



Weirdly spaced differences

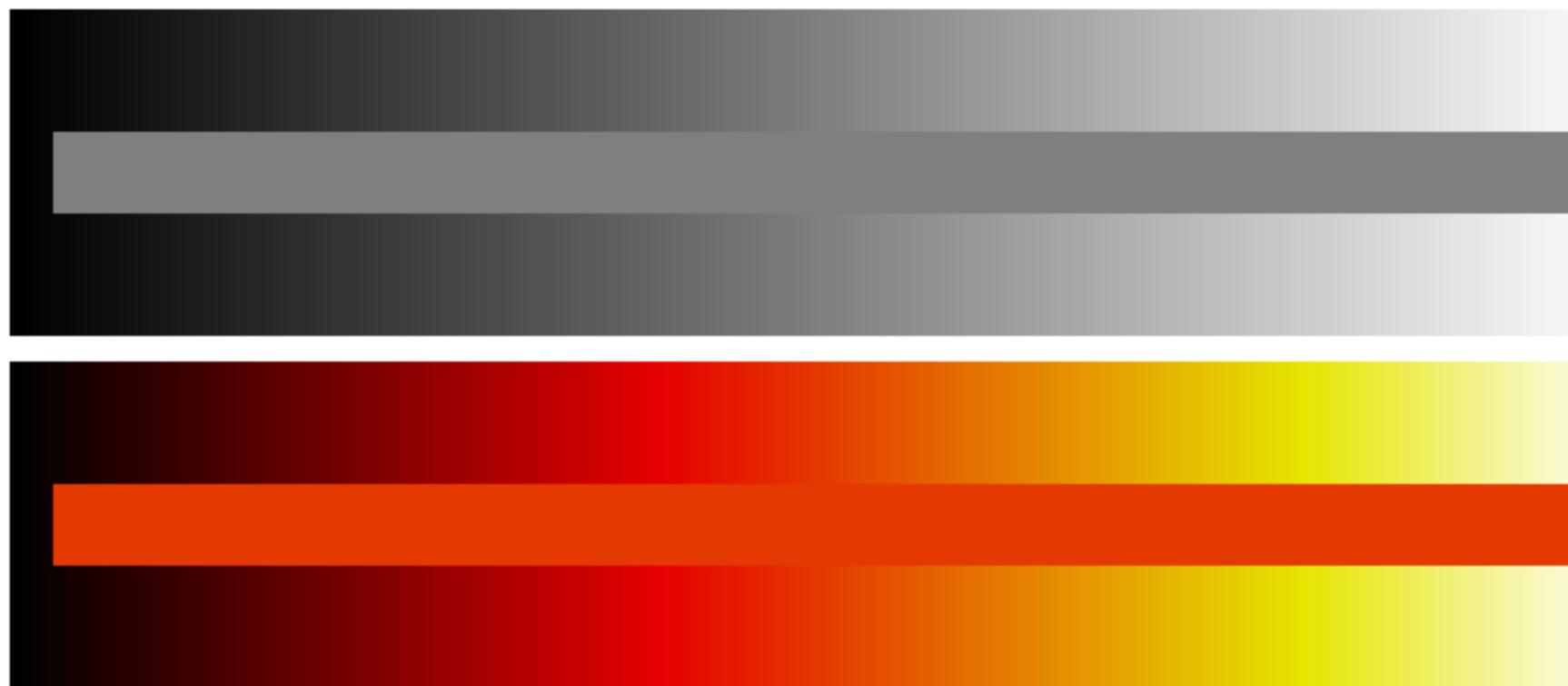
Why not use a rainbow?



*Mach color bands*

Even though rainbow scales are the default in many visualization applications, they produce undesirable **perceptual effects that distort the underlying data.**

Why not use a **grayscale** (luminance only)?



Pixel appearance is affected  
by surrounding pixels



Detail lost



Why not use an **isoluminant map** (chromatic shifts)?

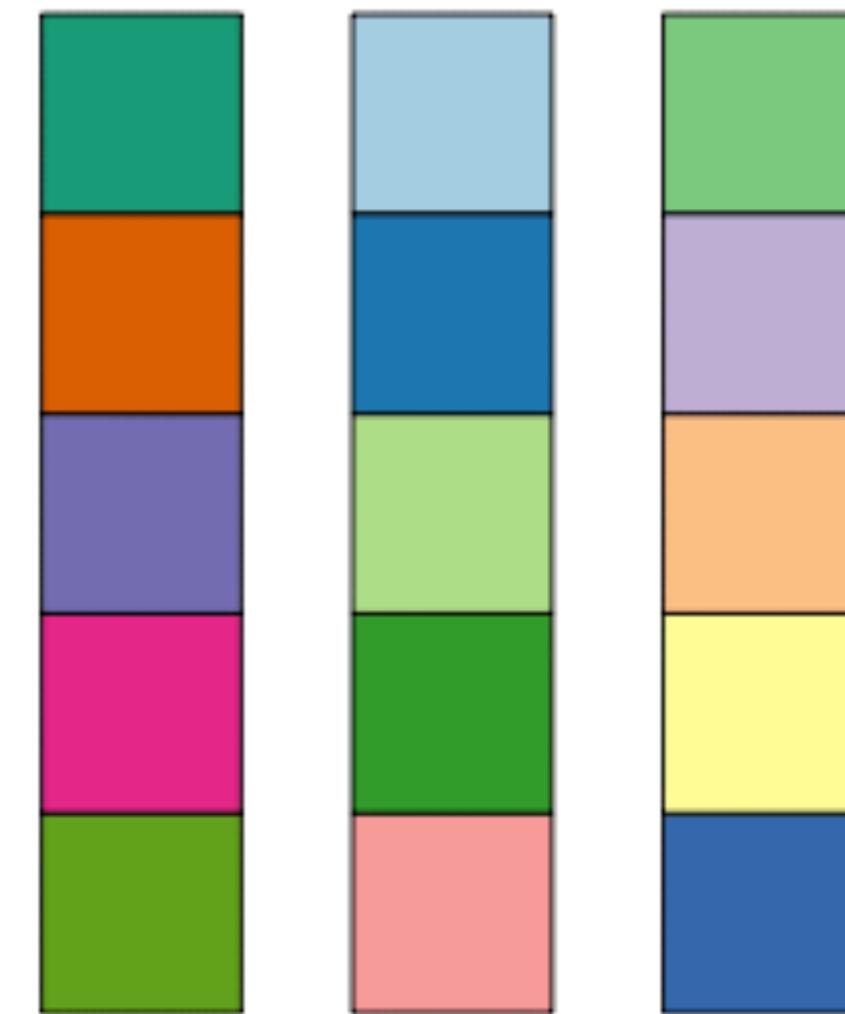


- Humans are more sensitive to changes in luminance
- Limits the number of colors represented, which can lead to lower-fidelity graphics

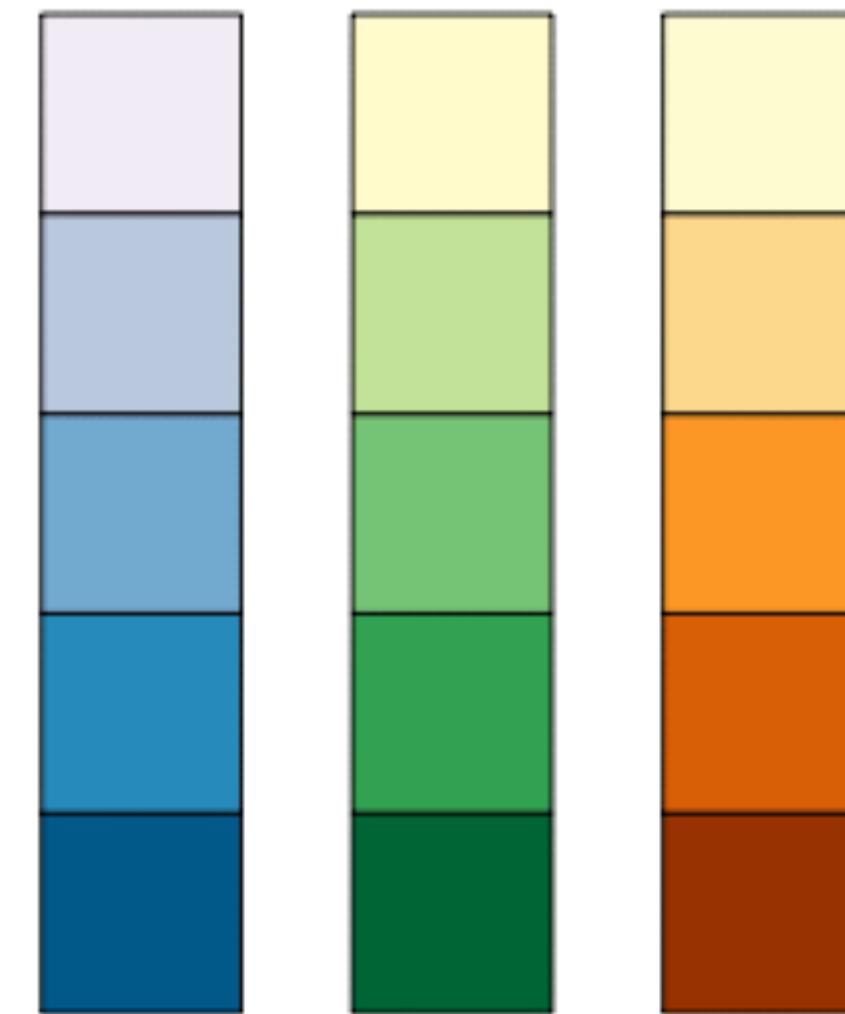
The right color scale **controls changes in hue** with shifts in saturation and luminance.

Many researchers have worked on this problem,  
including **Cynthia Brewer...**

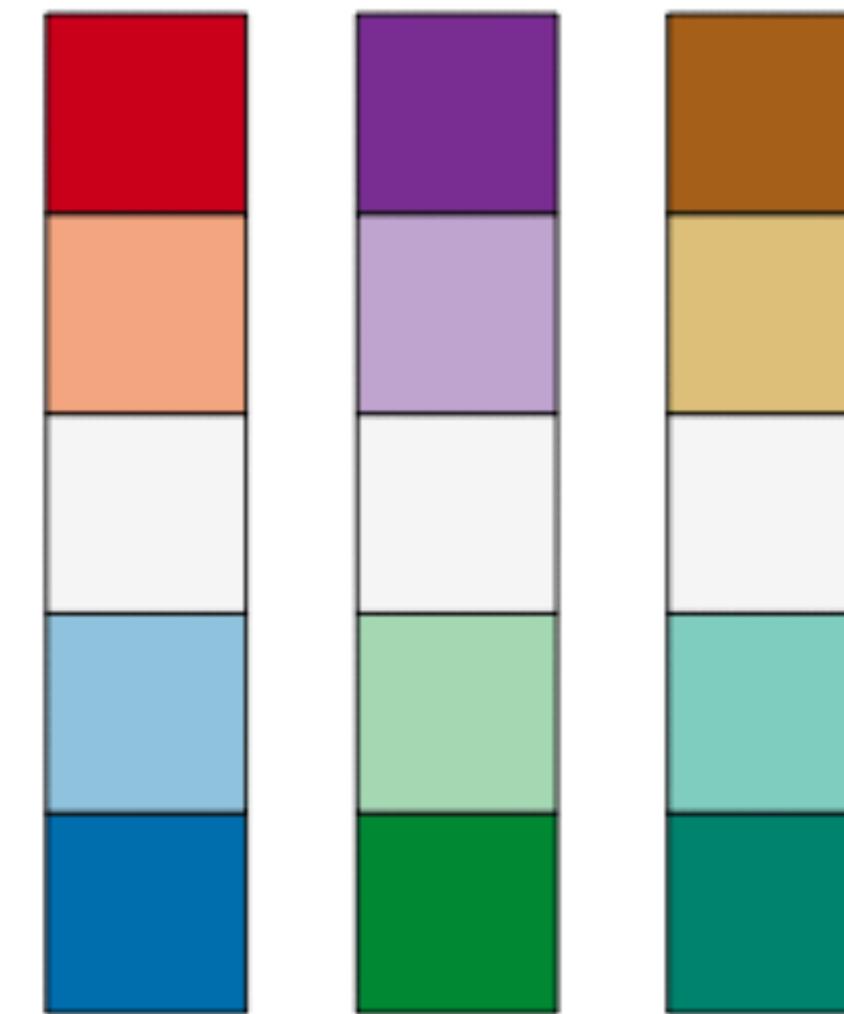
# Cynthia Brewer — Color Scales



**Qualitative**

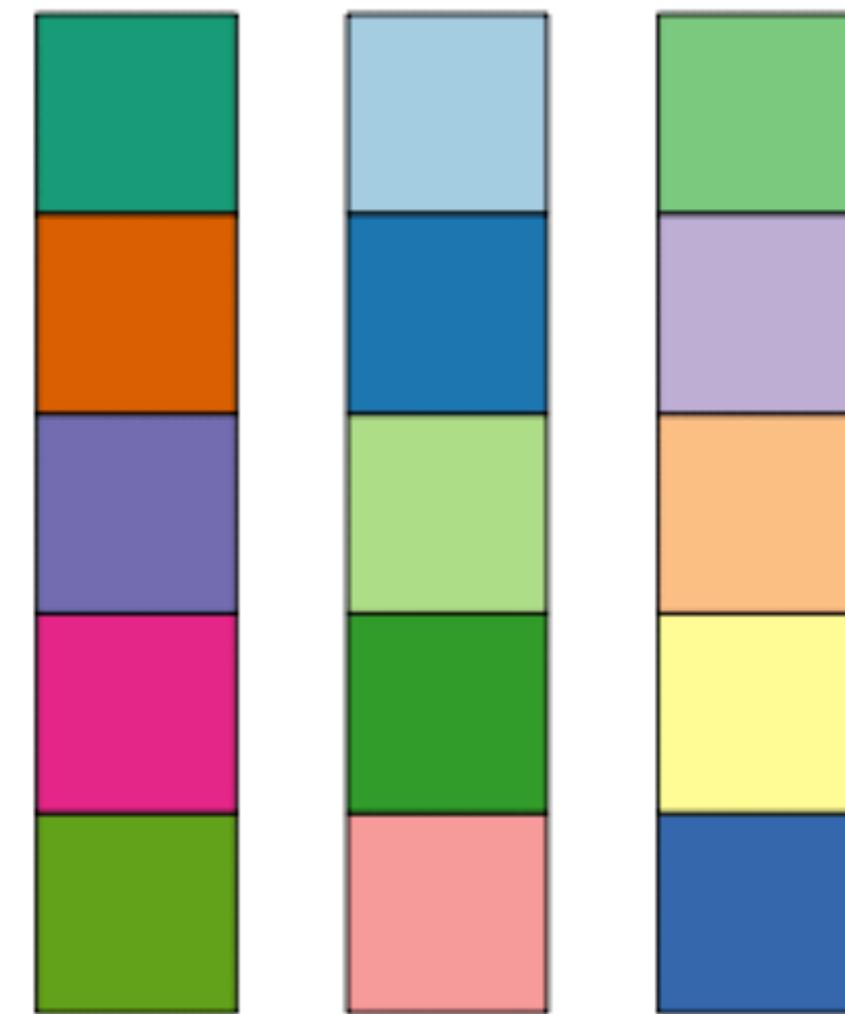


**Sequential**

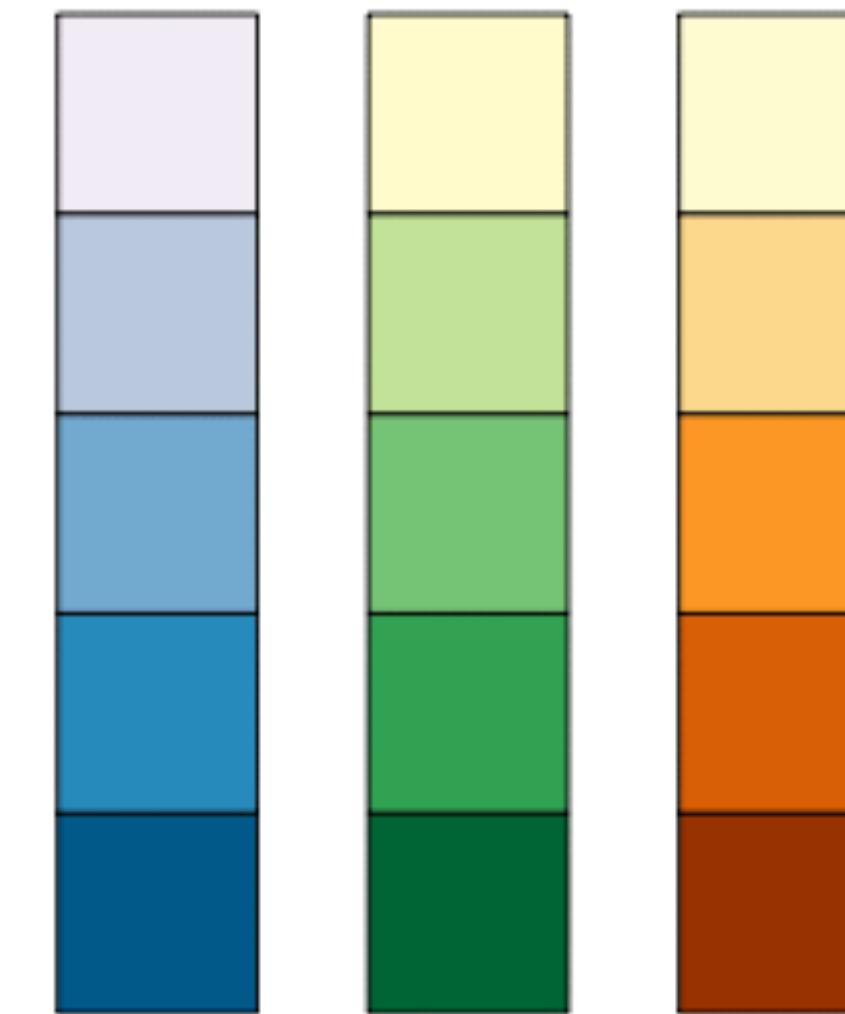


**Diverging**

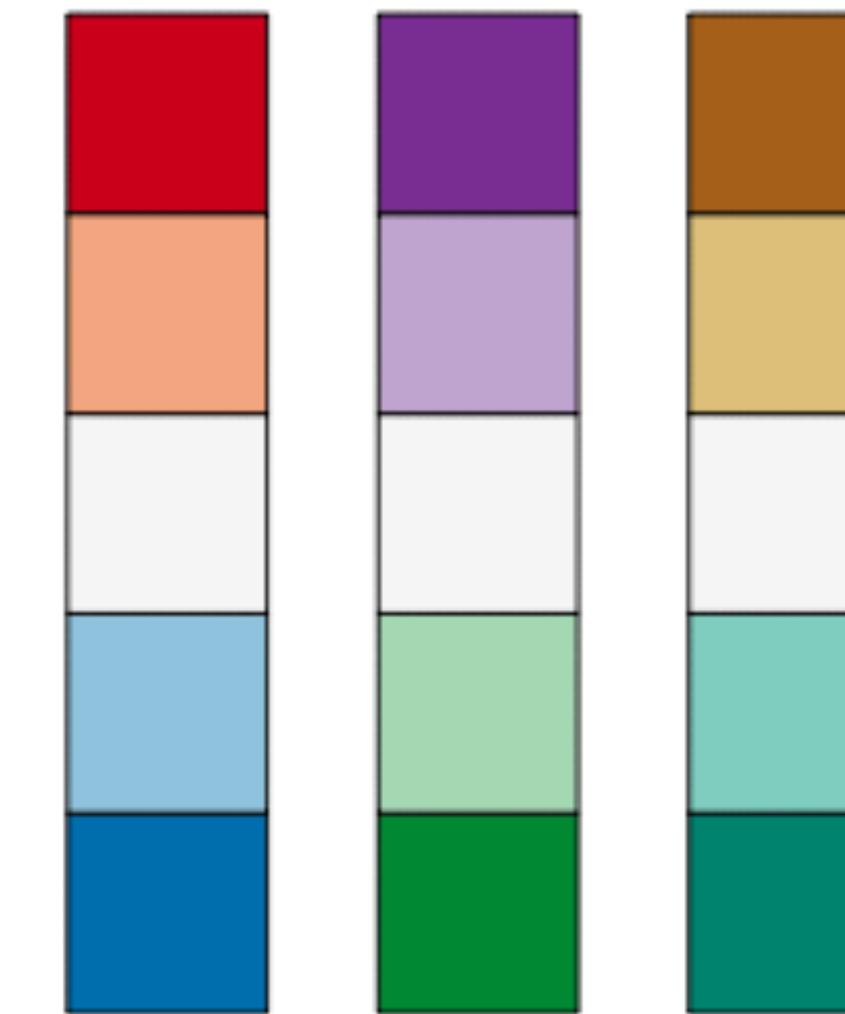
# Cynthia Brewer — Color Scales



**Qualitative**  
(Nominal)



**Sequential**  
(Ordinal, interval, ratio)



**Diverging**  
(Ordinal, interval, ratio)

...who make their work **easily accessible to all.**

- <http://colorbrewer2.org/>
- <https://gka.github.io/palettes/>

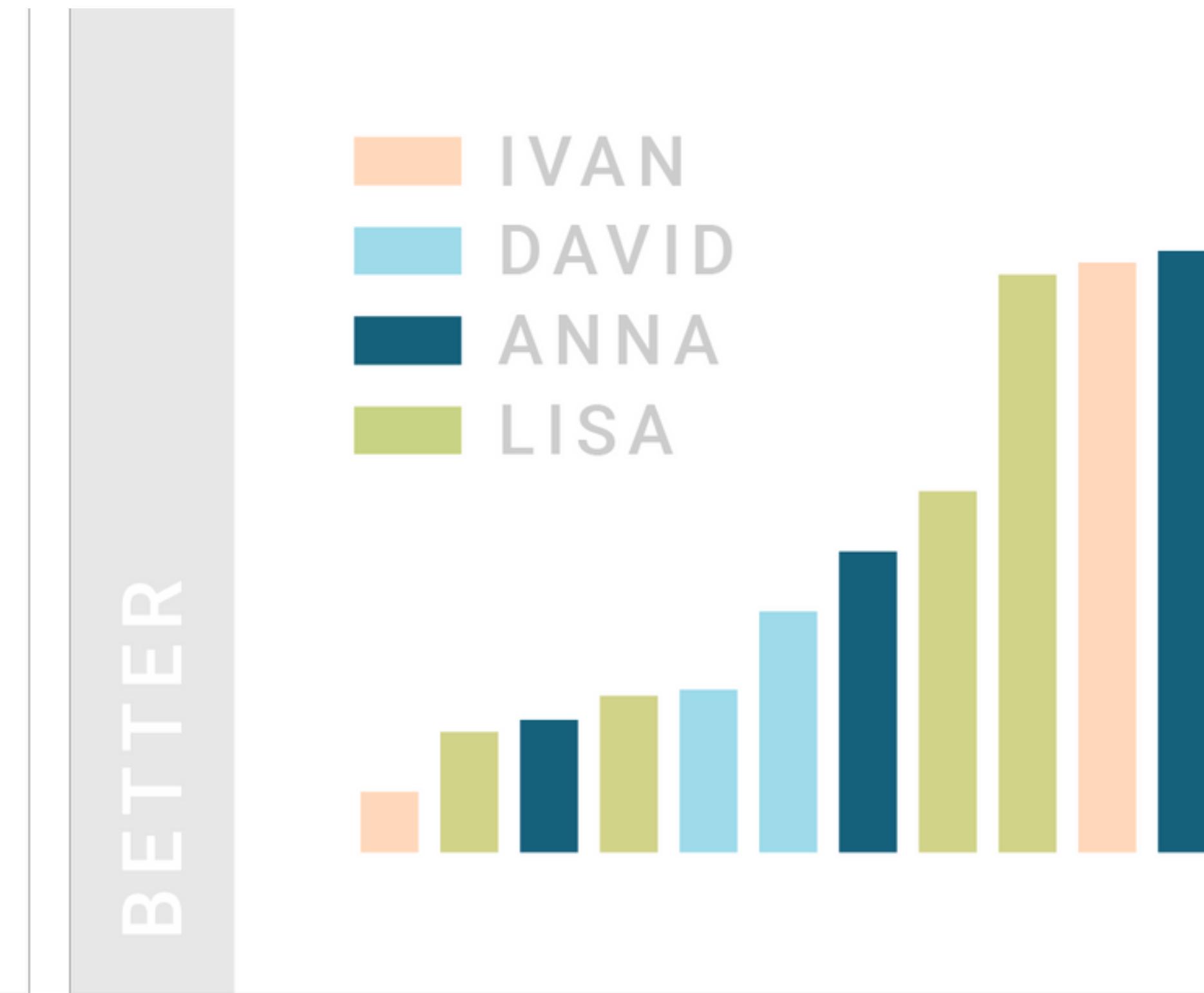
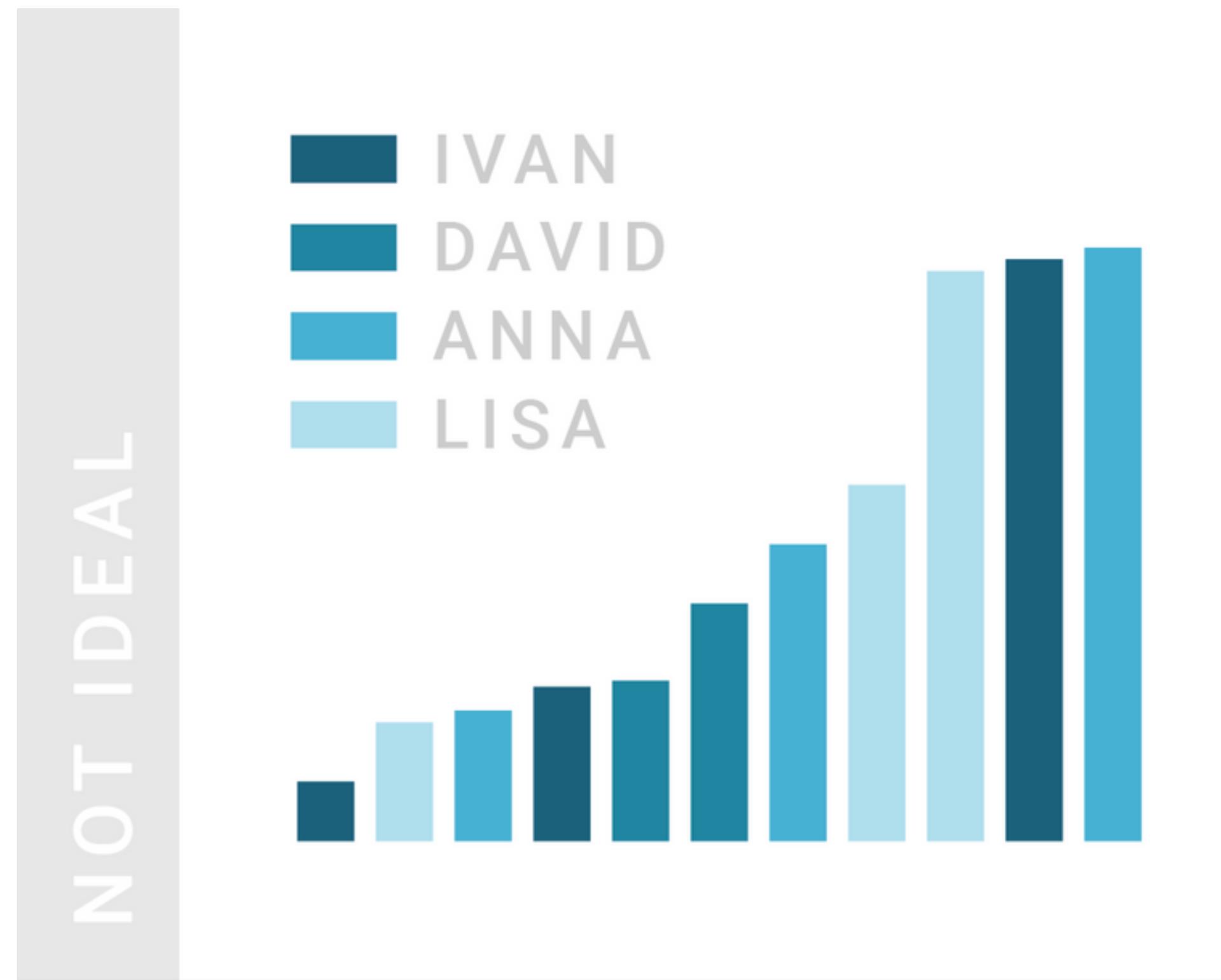
**Use your intuition.** Some combinations of variables are more readable than others.

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**Lisa Charlotte Rost** for ***Datawrapper*** put  
together a handy guide for using color in visualization.

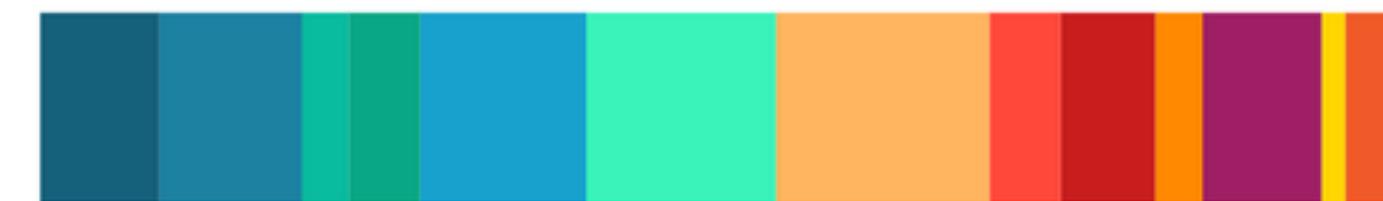
→ <https://blog.datawrapper.de/colors/>

Don't use a **gradient color palette** for categories and the other way around.



If you need more than **seven colors** in a chart, consider using another chart type or to group categories together.

NOT IDEAL

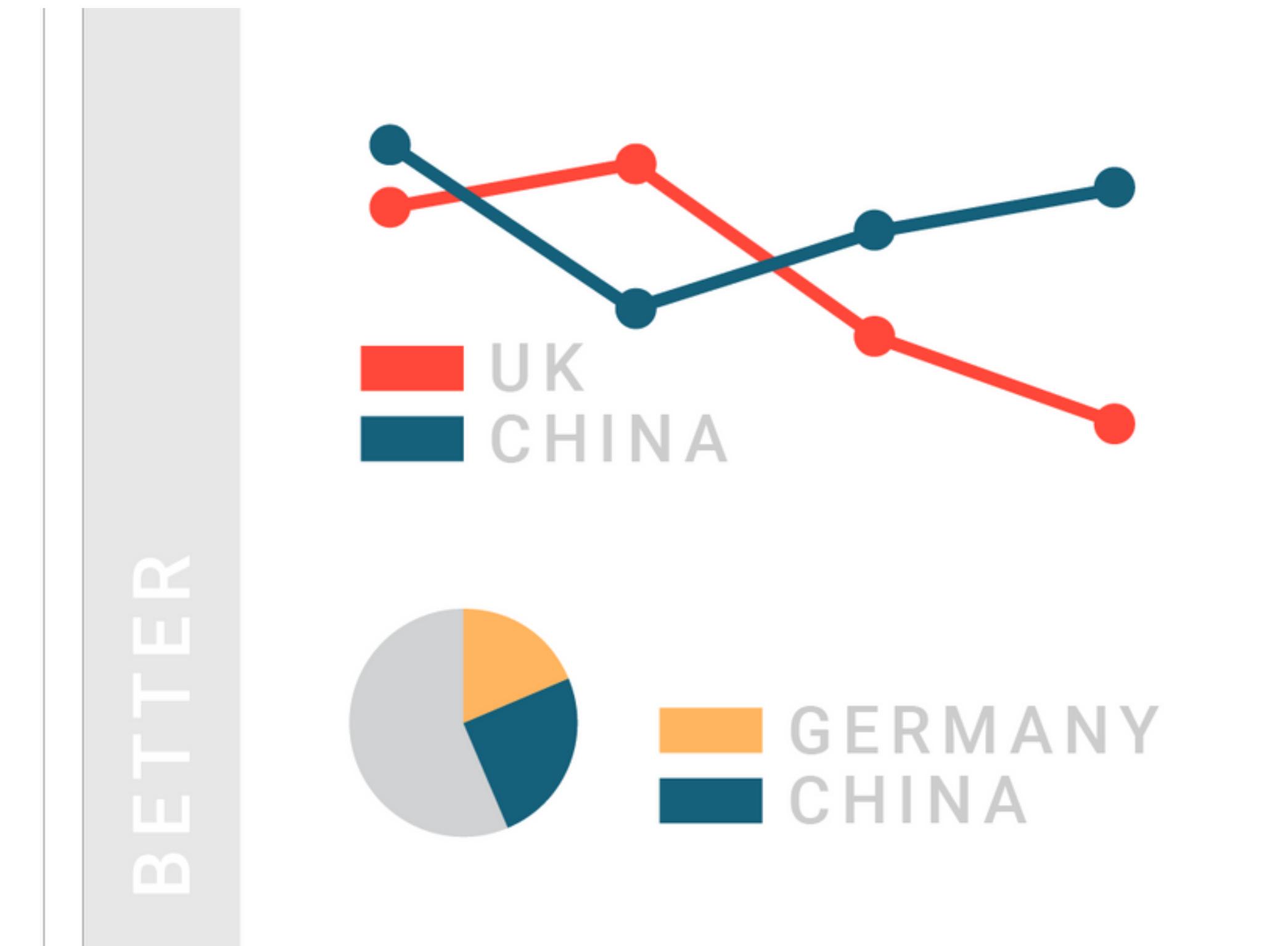
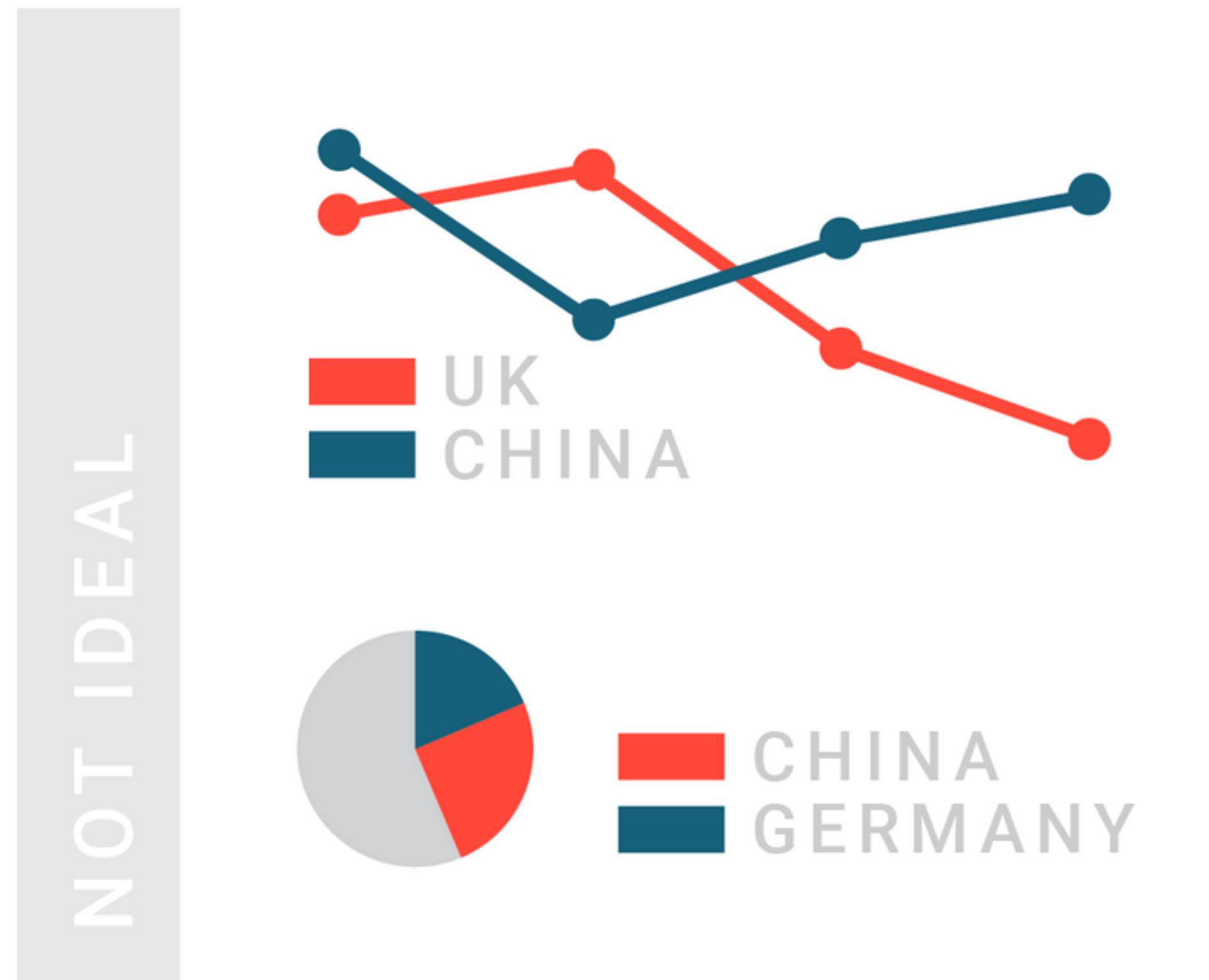


[Dark Teal]	A	[Light Teal]	B	[Cyan]	C
[Green]	D	[Blue]	E	[Light Green]	F
[Orange]	G	[Red]	H	[Maroon]	I
[Yellow]	J	[Purple]	K	[Yellow]	L
[Red]	M				

BETTER



Consider using the **same color** for the **same variables**.



Make sure to **explain to readers** what your colors encode.

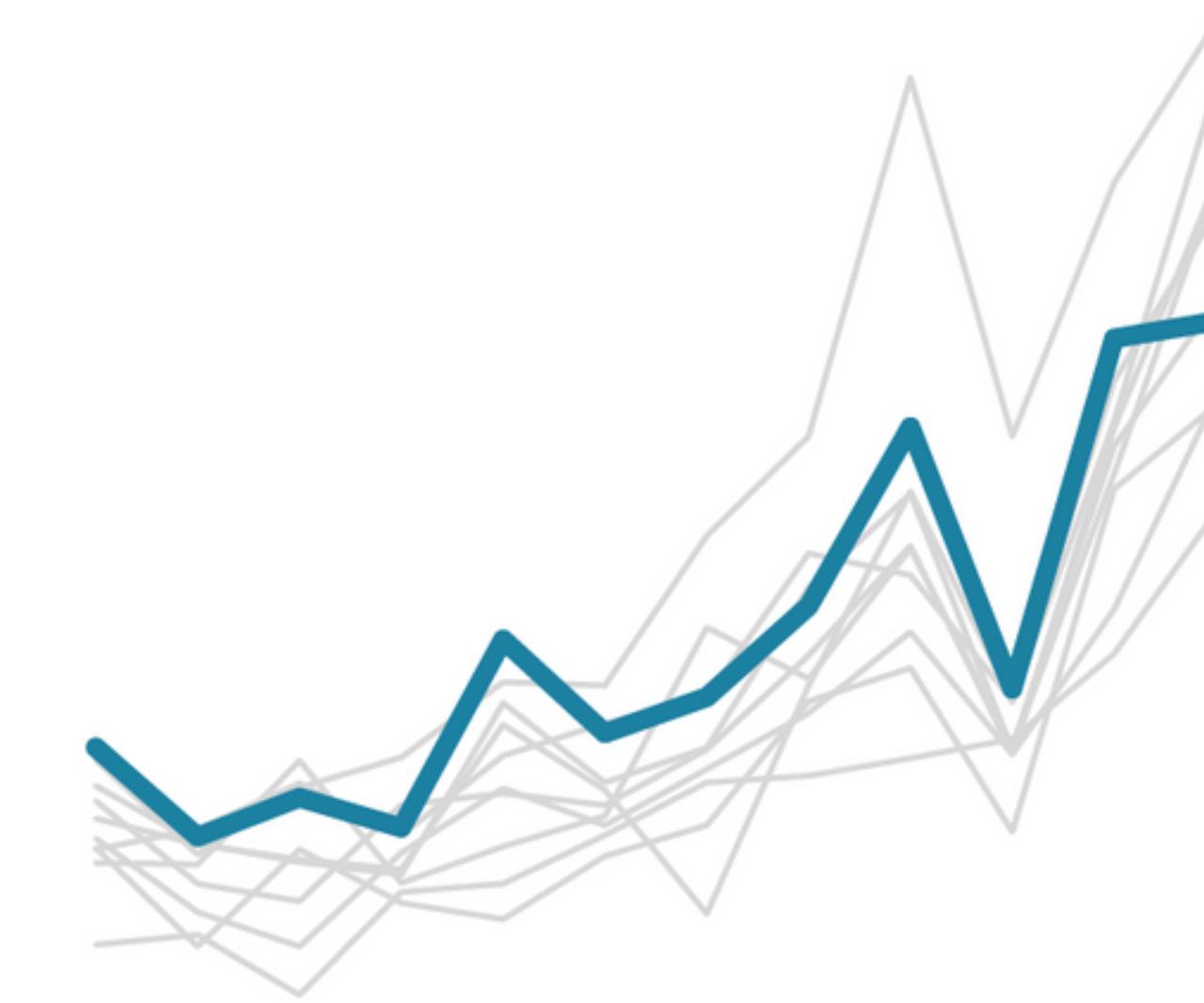


Consider the color grey as the **most important color** in visualization.

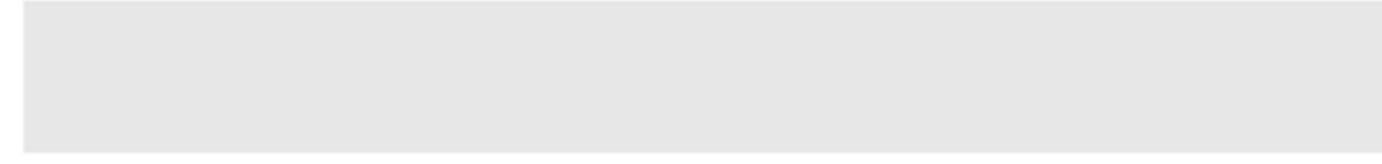
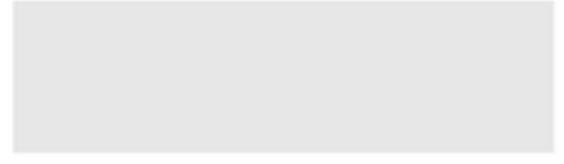
NOT IDEAL



BETTER



# Make sure your **contrasts** are high enough.

CONTRAST	CONTRAST RATIOS			
	1.0	1.1	1.5	2.5
				
	Choose if you dislike readers.	That's bad.	Not ideal.	That's bad.
	Ok in 1% of the cases.	That's bad.	That's bad.	Horrible.
	Can be a good choice.	Ok.	Not ideal.	My eyes!
	Safe choice.	Great.	Ok.	That's bad.
				Not ideal.

1. Color **Perception & Representation**
2. **Applying** Color
3. Practical **Tips**
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Prepare your squares!

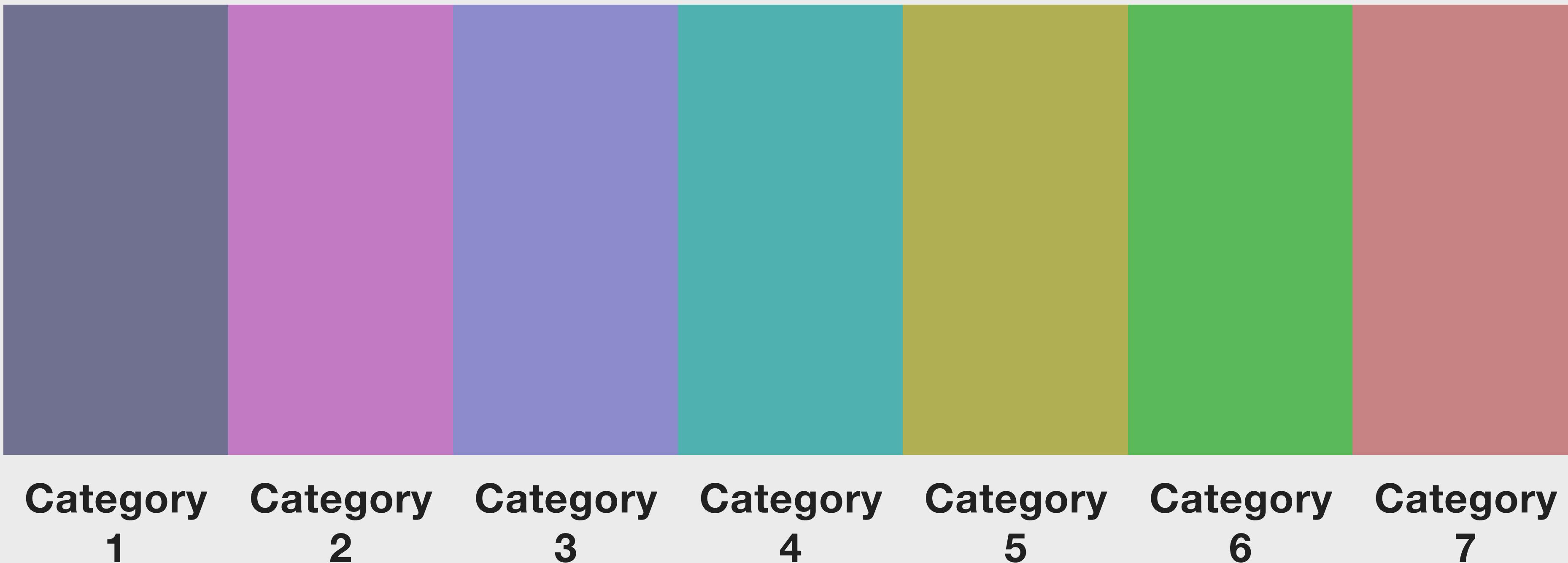
## *Challenge 1/5*

Generate a **seven-hue** color scale for **nominal data**.

## *Challenge 1/5*

Generate a **seven-hue** color scale for **nominal data**.



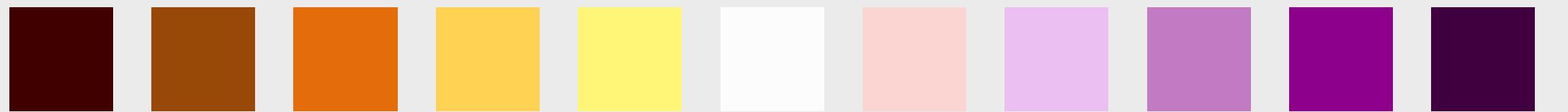


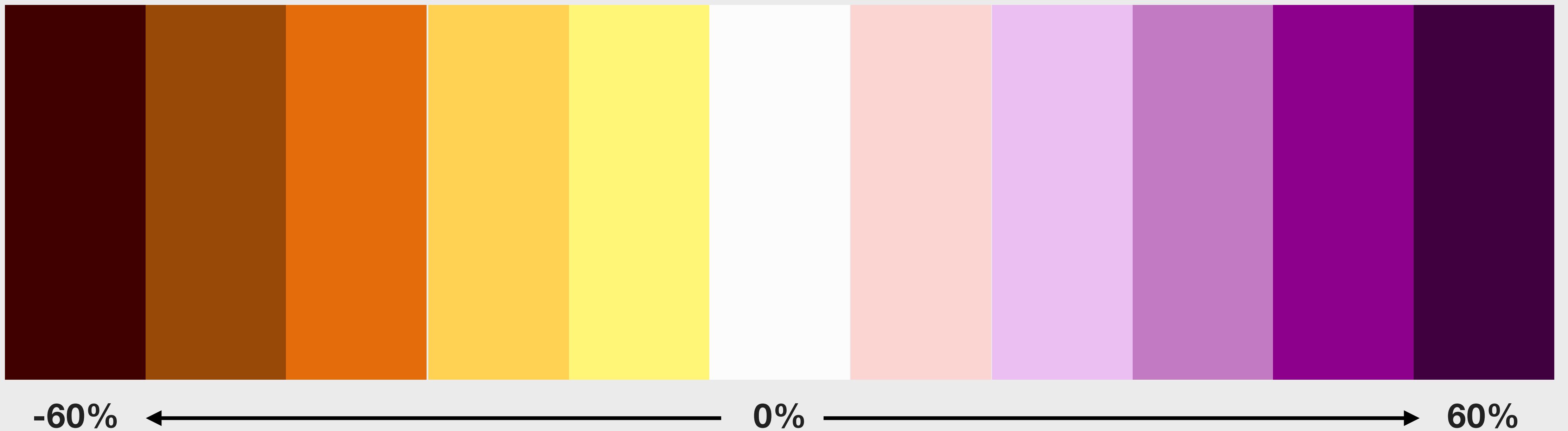
## *Challenge 2/5*

Generate a **diverging color scale** for **ratio data**.

## *Challenge 2/5*

Generate a **diverging color scale** for **ratio data**.





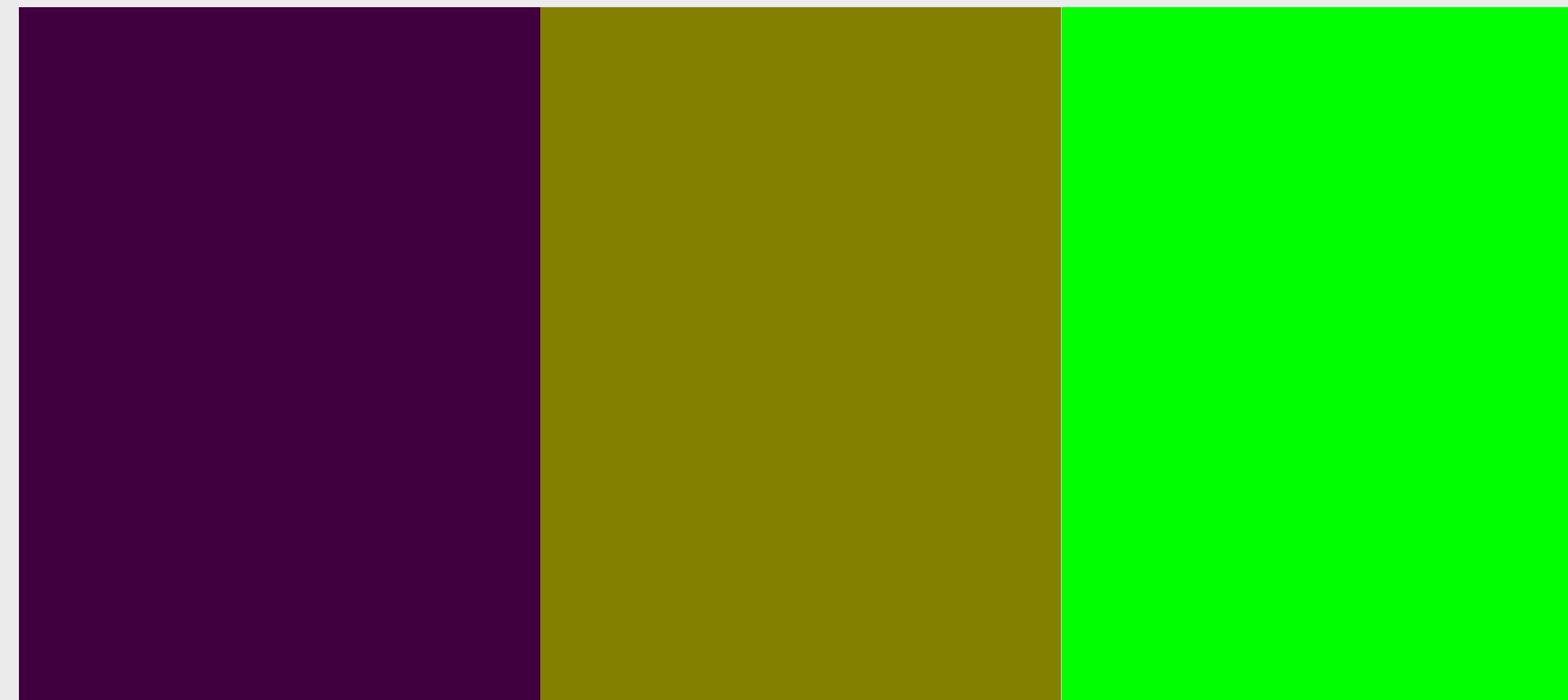
## *Challenge 3/5*

Generate a **three-hue** scale with **two neutral colors** and a **highlight color**.

## *Challenge 3/5*

Generate a **three-hue** scale with **two neutral colors** and a **highlight color**.





**Neutral #1**

**Neutral #2**

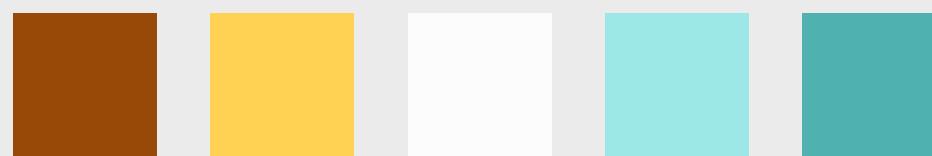
**Highlight**

## *Challenge 4/5*

Generate a **five-hue** scale for **ordinal data**.

## *Challenge 4/5*

Generate a **five-hue** scale for **ordinal data**.





**Hate**

**Dislike**

**Neither like  
nor dislike**

**Like**

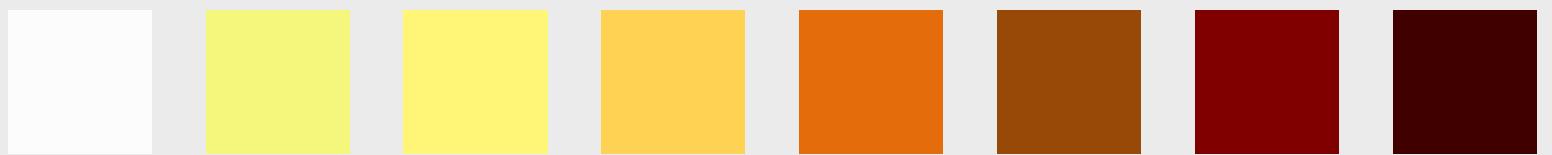
**Love**

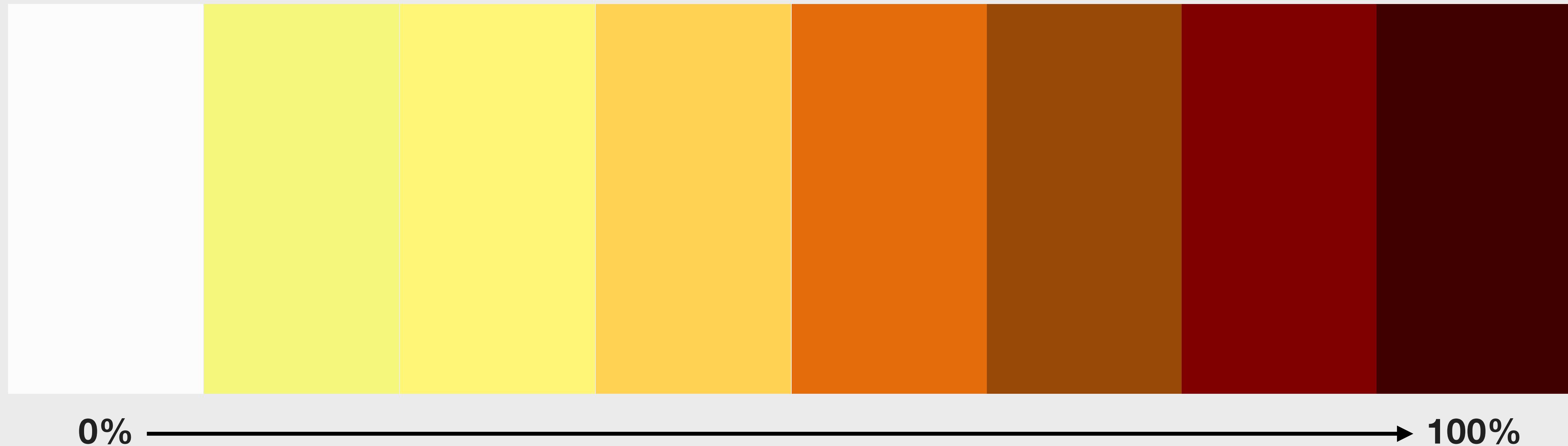
## *Challenge 5/5*

Generate a **single-ramp continuous** scale for  
**ratio data**.

## *Challenge 5/5*

Generate a **single-ramp continuous** scale for  
**ratio data**.





1. Color **Perception & Representation**
2. **Applying** Color
3. Practical **Tips**
4. Color **Exercise**
5. Critique

1. How do you **interpret** this graphic? What message does it convey?
2. How does the graphic use **space, shape, color, and size** to convey this message?
3. What is the **structure** of this graphic?

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