

Data Visualization & Design

Week 3

This week in **visualization**...

Five-day chance of tropical-storm-force wind

A horizontal color scale representing a gradient from light yellow on the left to dark purple on the right. Numerical markers are placed at 5, 50, 70, and 90%, with vertical tick marks extending downwards from each label.



Current extent of tropical-storm-force wind

- Major hurricane (>110 mph)
 - Hurricane (74-110 mph)
 - Tropical storm (39-73 mph)
 - Tropical depression (<39 mph)

Hurricane warning  watch 

All times are Eastern

States

Kansas City

ILLINOIS

OHIO

Pittsburgh

1

Show impact times



Bermuda

Sargasso Sea

Source

Source: National Weather Service. Note: impact lines represent the earliest reasonable arrival time of tropical-storm-force winds.

- Shows area with a **chance of tropical storm**, instead of area indicating likely path of storm center
- Area of **different storm probabilities**
- **Current extent** of storm
- Informative **key**

Five-day chance of tropical-storm-force winds

Informative key



Current extent of tropical-storm-force winds

- Major hurricane (>110 mph)
 - Hurricane (74-110 mph)
 - Tropical storm (39-73 mph)
 - Tropical depression (<39 mph)
- Hurricane warning — watch —

All times are Eastern

States

AHOMA

Dallas

Shreveport

Jackson

Louisiana

New Orleans

Houston

Christi

ILLINOIS

INDIANA

OHIO

Pittsburgh

N.J.

MD.

DEL.

W.V.A.

VIRGINIA

Norfolk

KENTUCKY

TENNESSEE

Raleigh

ARKANSAS

Montgomery

MISSISSIPPI

Atlanta

ALABAMA

GEORGIA

Tallahassee

FLORIDA

Tampa

Show impact times

+

-

Area with possible chance of storm

Area of different storm probabilities

Current extent of storm

Hurricane Florence
11 a.m. Wed.

Bermuda
Sargasso Sea

Source

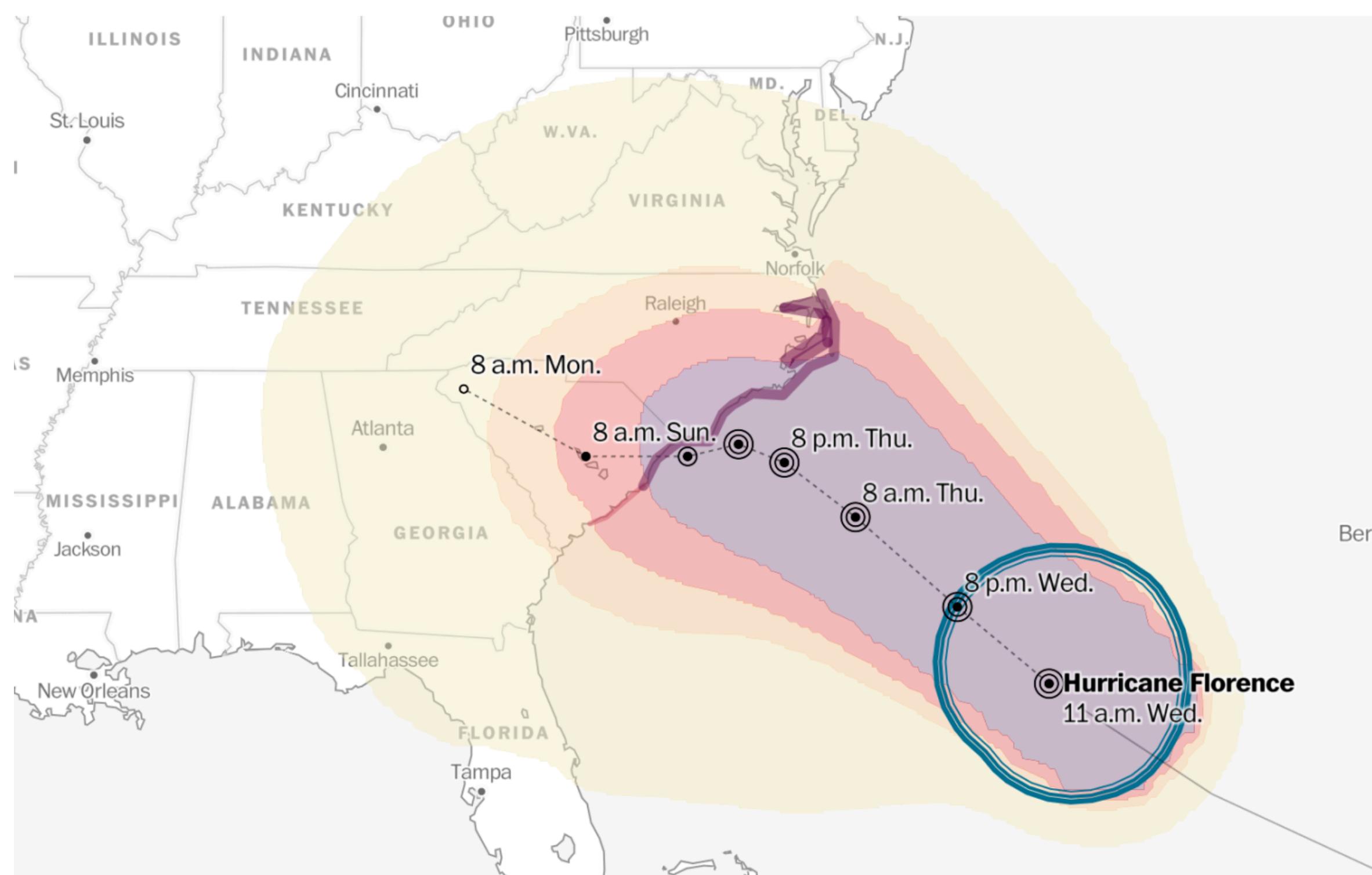
Source: National Weather Service. Note: impact lines represent the earliest reasonable arrival time of tropical-storm-force winds.

Five-day chance of tropical-storm-force winds

5 50 70 90%

Current extent of tropical-storm-force winds

- Major hurricane (>110 mph)
 - Hurricane (74-110 mph)
 - Tropical storm (39-73 mph)
 - Tropical depression (<39 mph)
- Hurricane warning — watch —



Service. Note: impact lines represent the earliest reasonable arrival time of tropical-storm-force winds.

The Washington Post

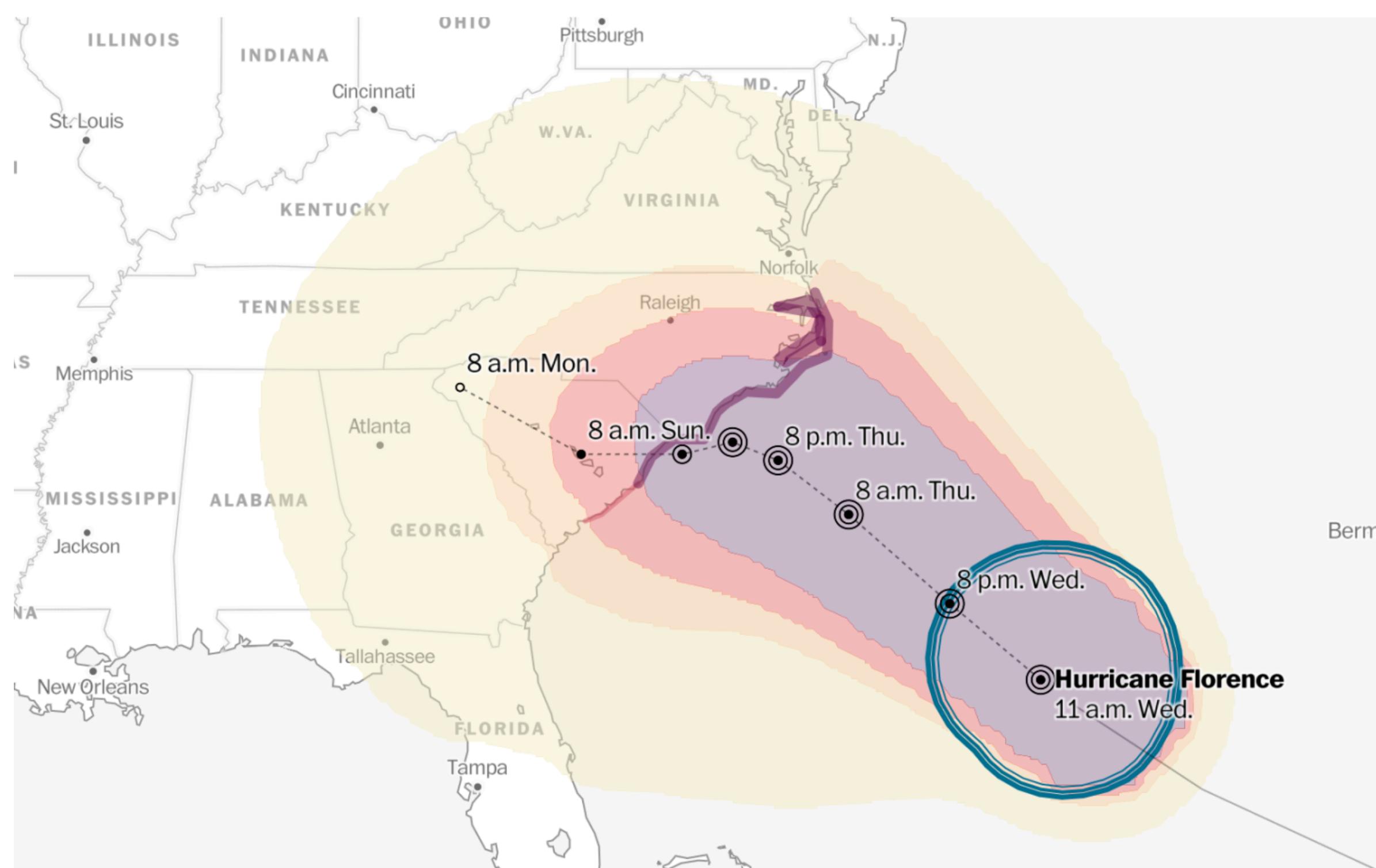


USA Today

Five-day chance of tropical-storm-force winds

5 50 70 90%

Current extent of tropical-storm-force winds

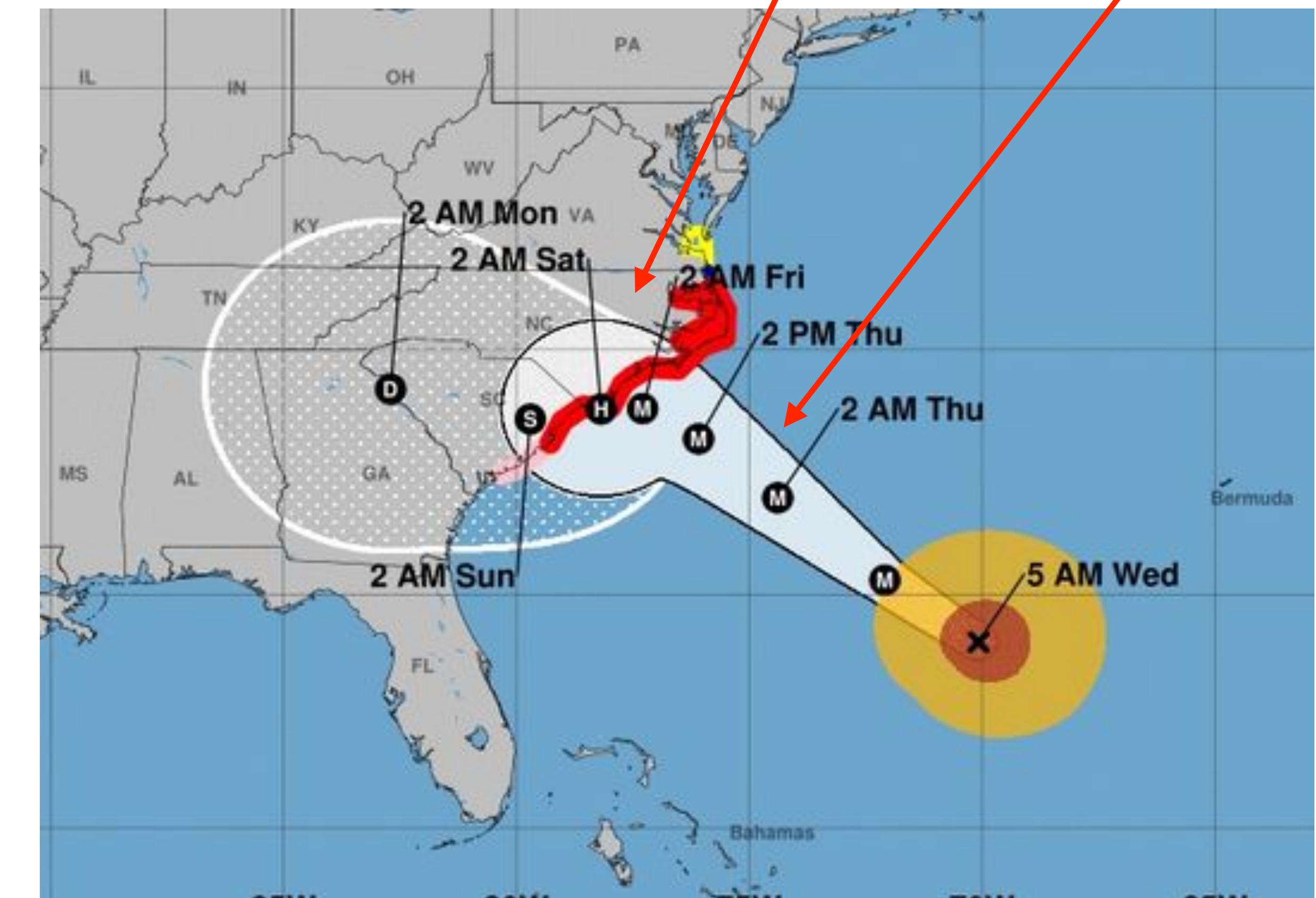


ervice. Note: impact lines represent the earliest reasonable arrival time of tropical-storm-force winds.

The Washington Post

No indication of adjacent affected regions

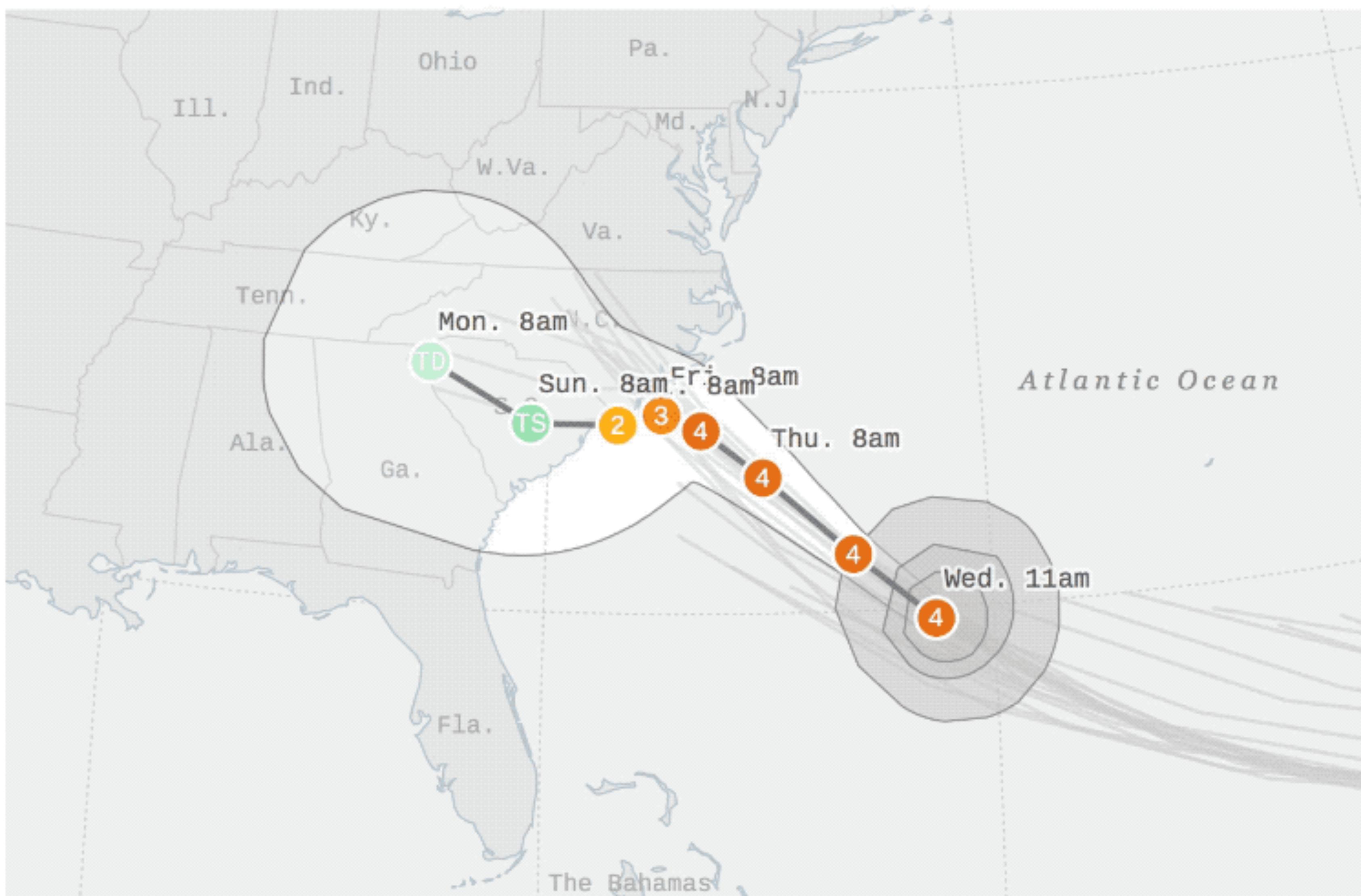
Arbitrary cone cutoff



USA Today

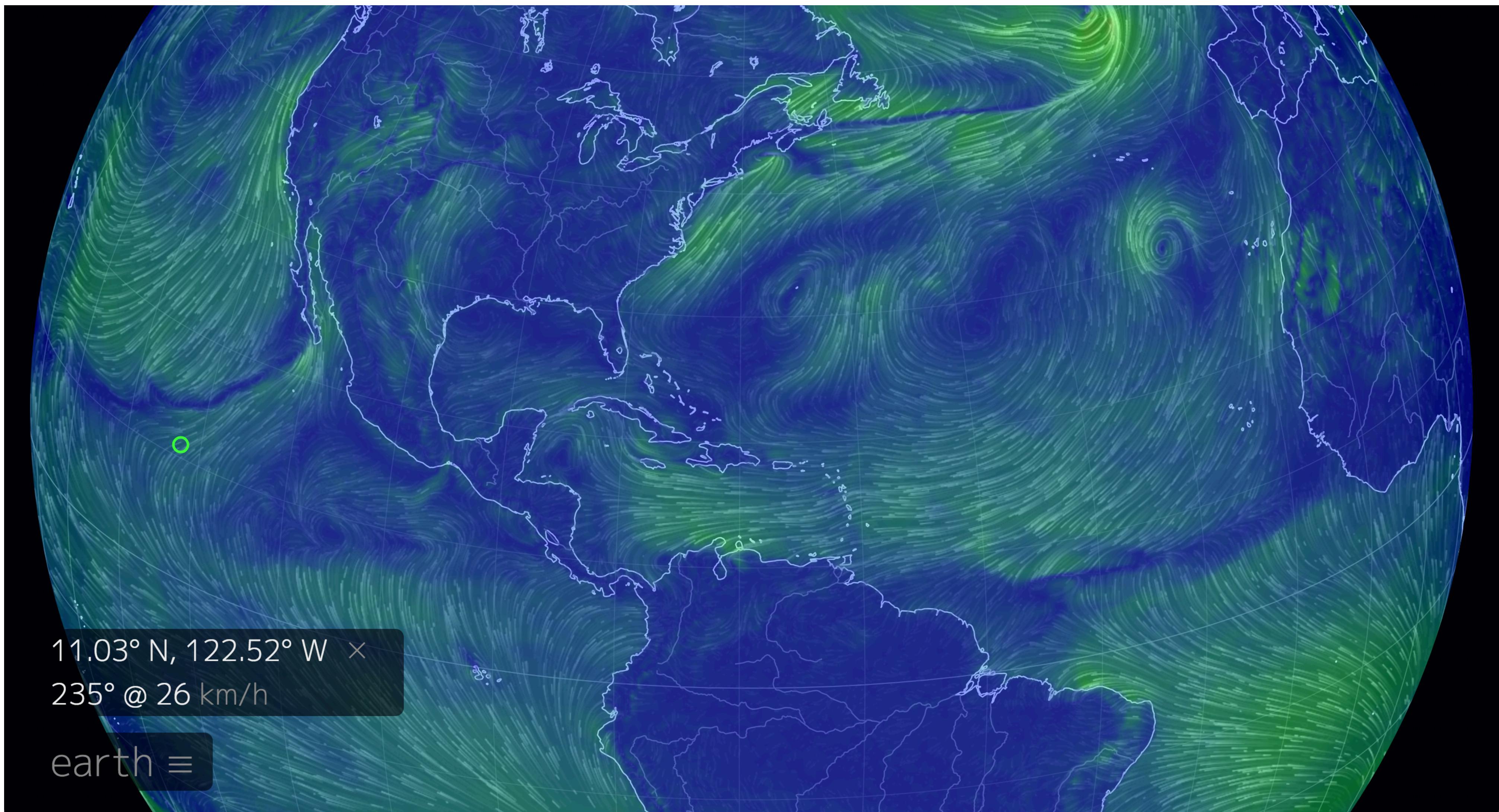
(No key)

Wed. Sep. 12, 11am



[Source: Axios](#)





[Source: Cameron Baccario](#)

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

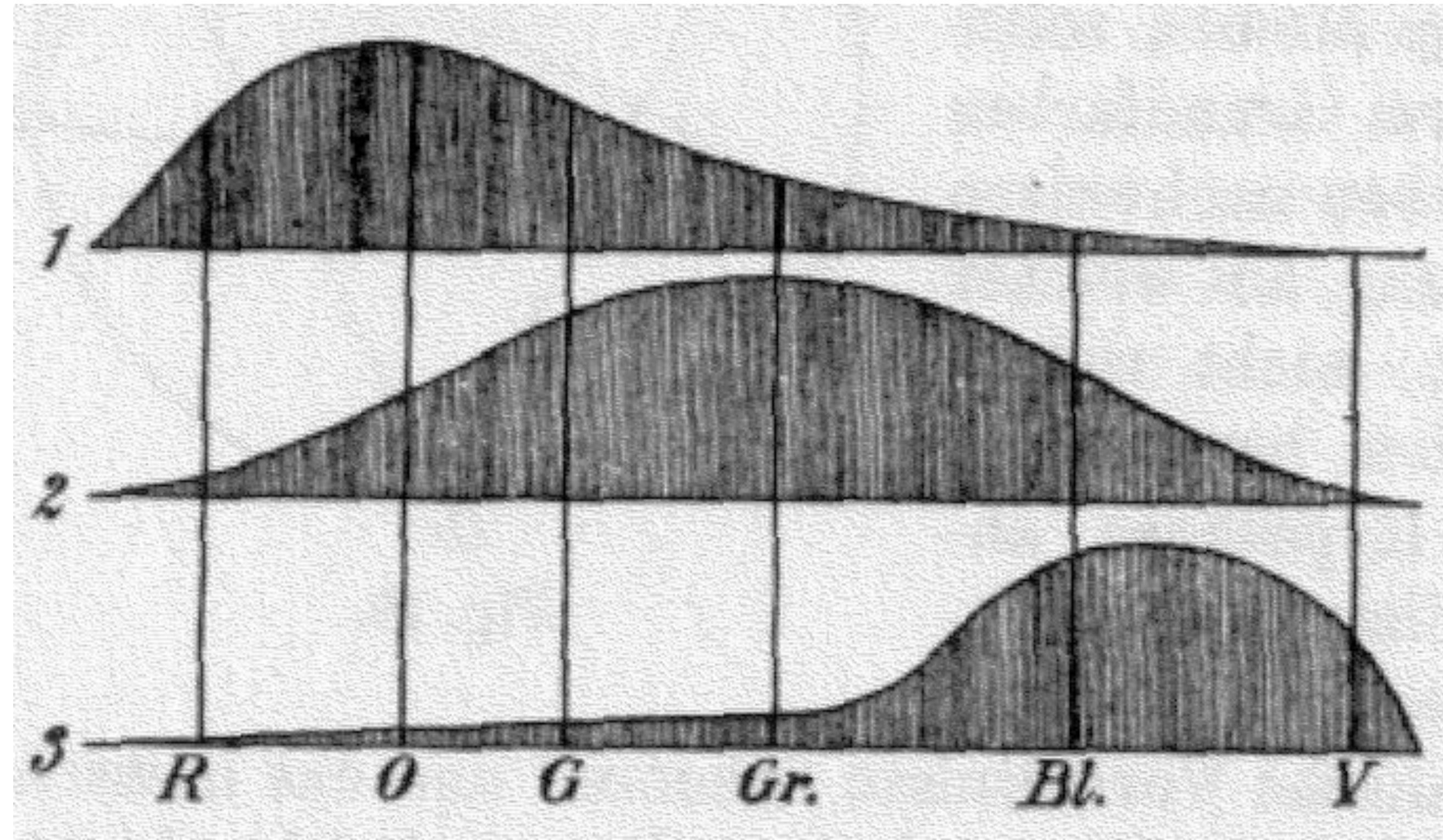
1. Color **Perception & Representation**
2. Applying Color
3. Practical Tips
4. Color **Exercise**
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Human Perception of Color

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

Concept — **Tristimulus theory**

- 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

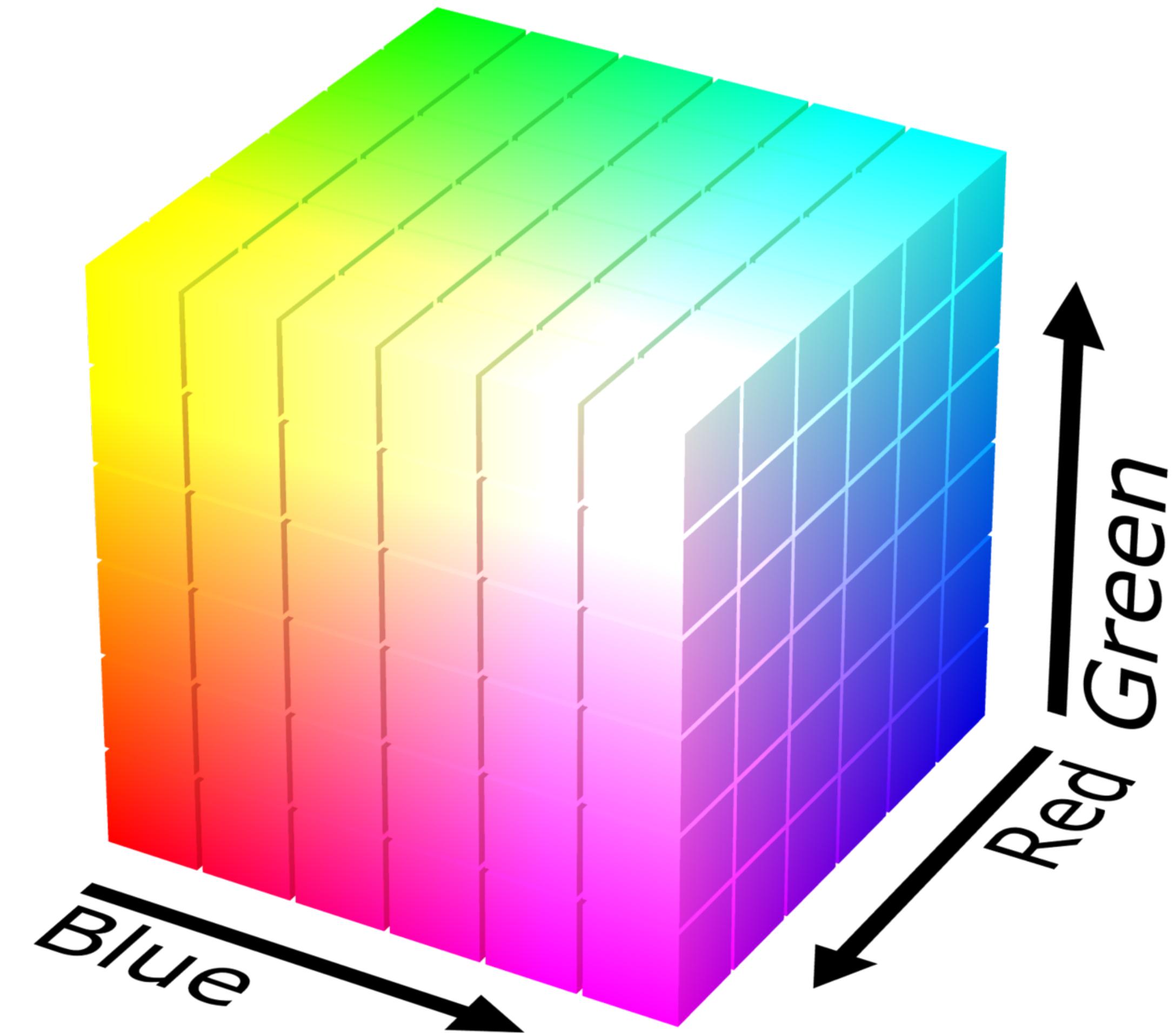


PANTONE®
18-0107
Kale



PANTONE®
19-4045
Lapis Blue

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

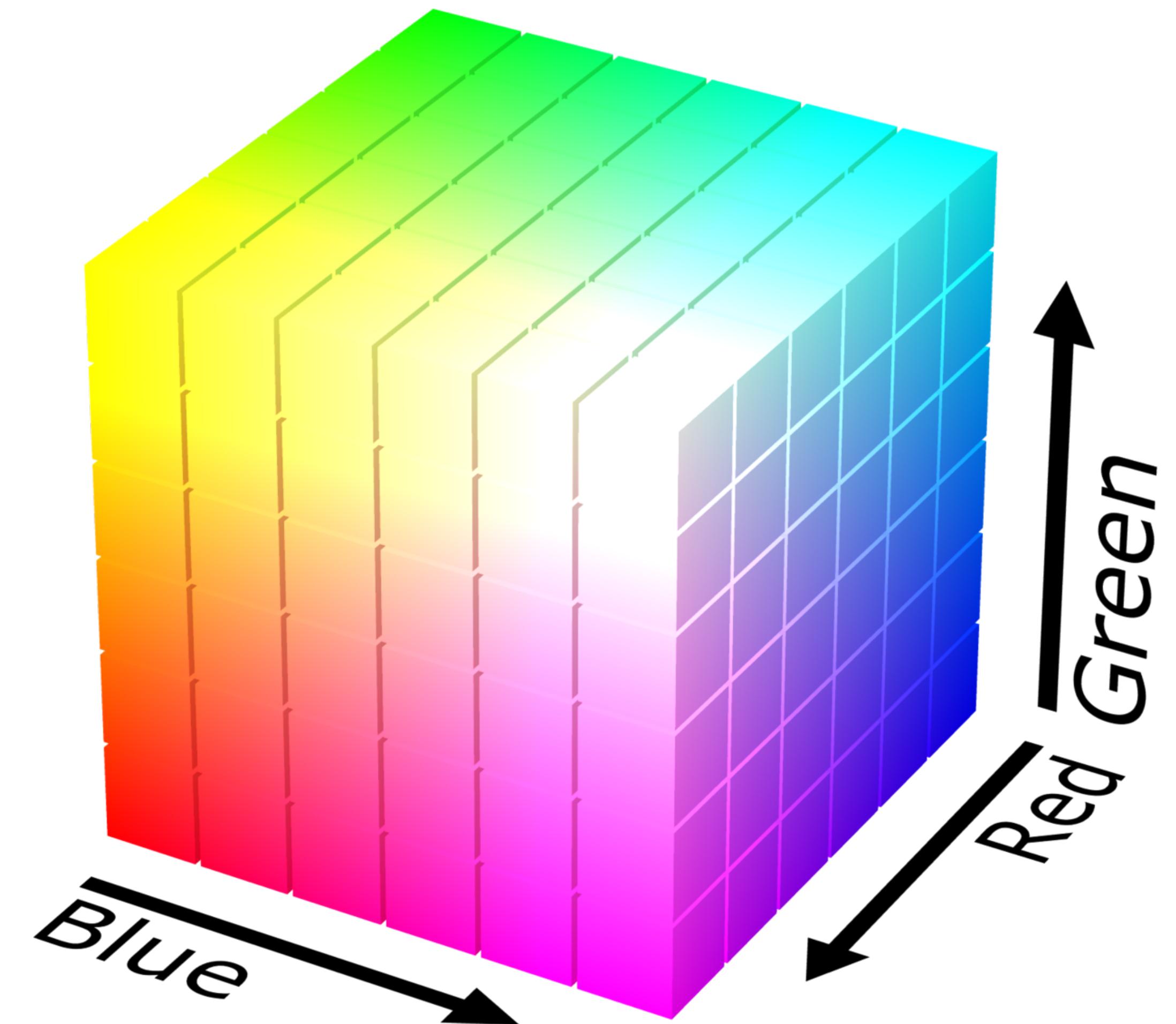


Common color spaces are widely implemented
in visualization software and design tools.

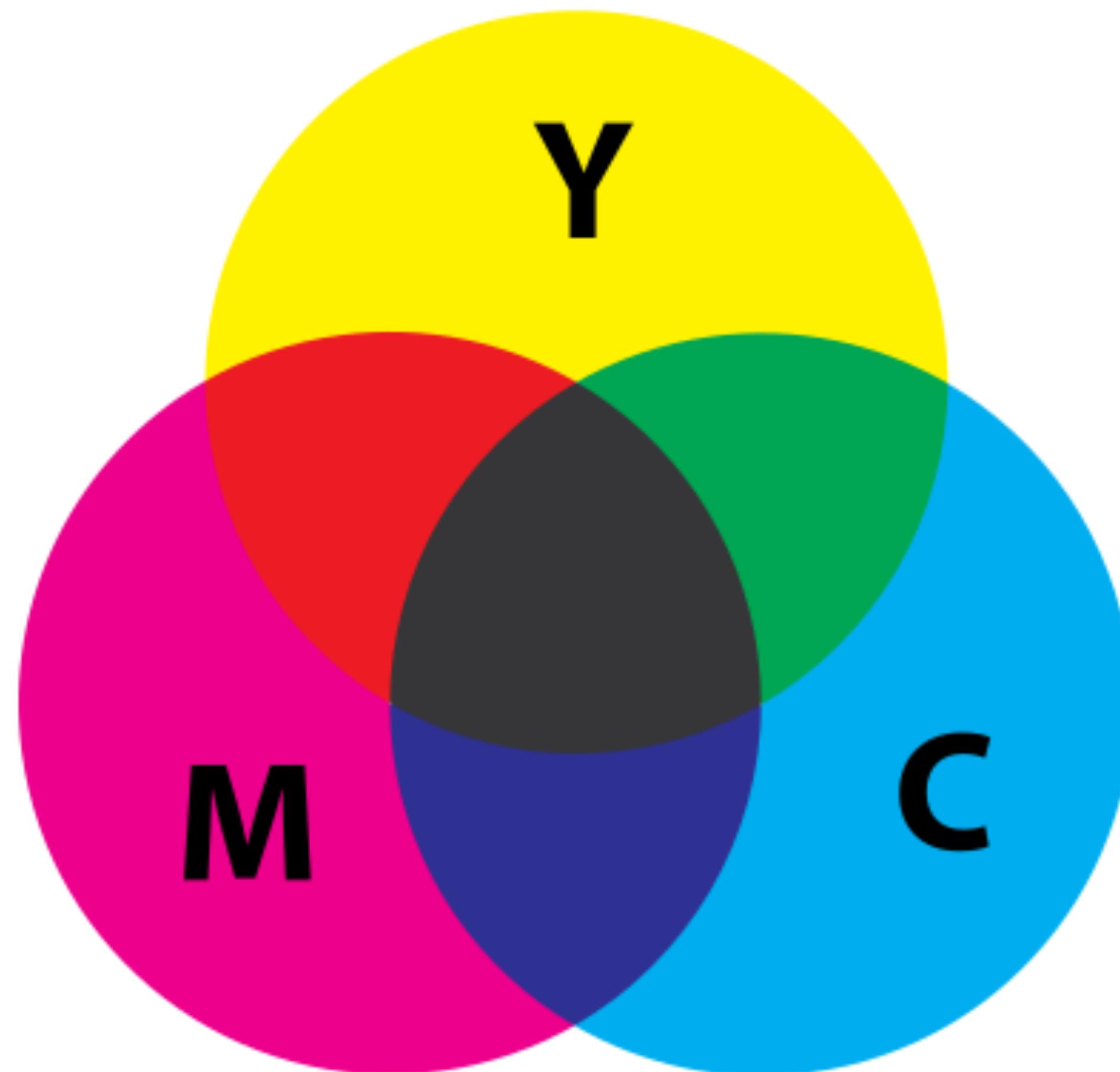
List of common color spaces

- **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)

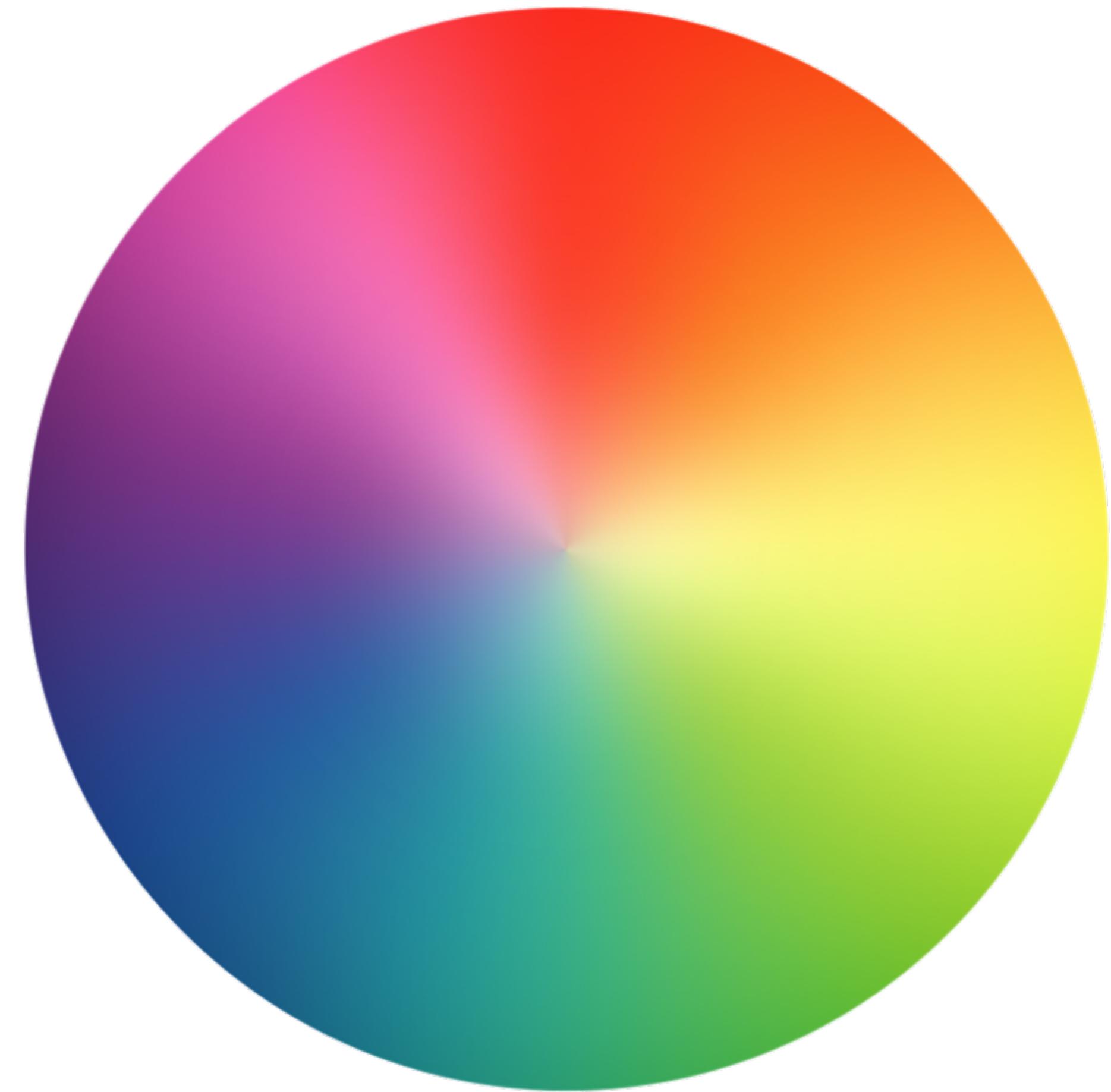
RGB (Red, Green, Blue)



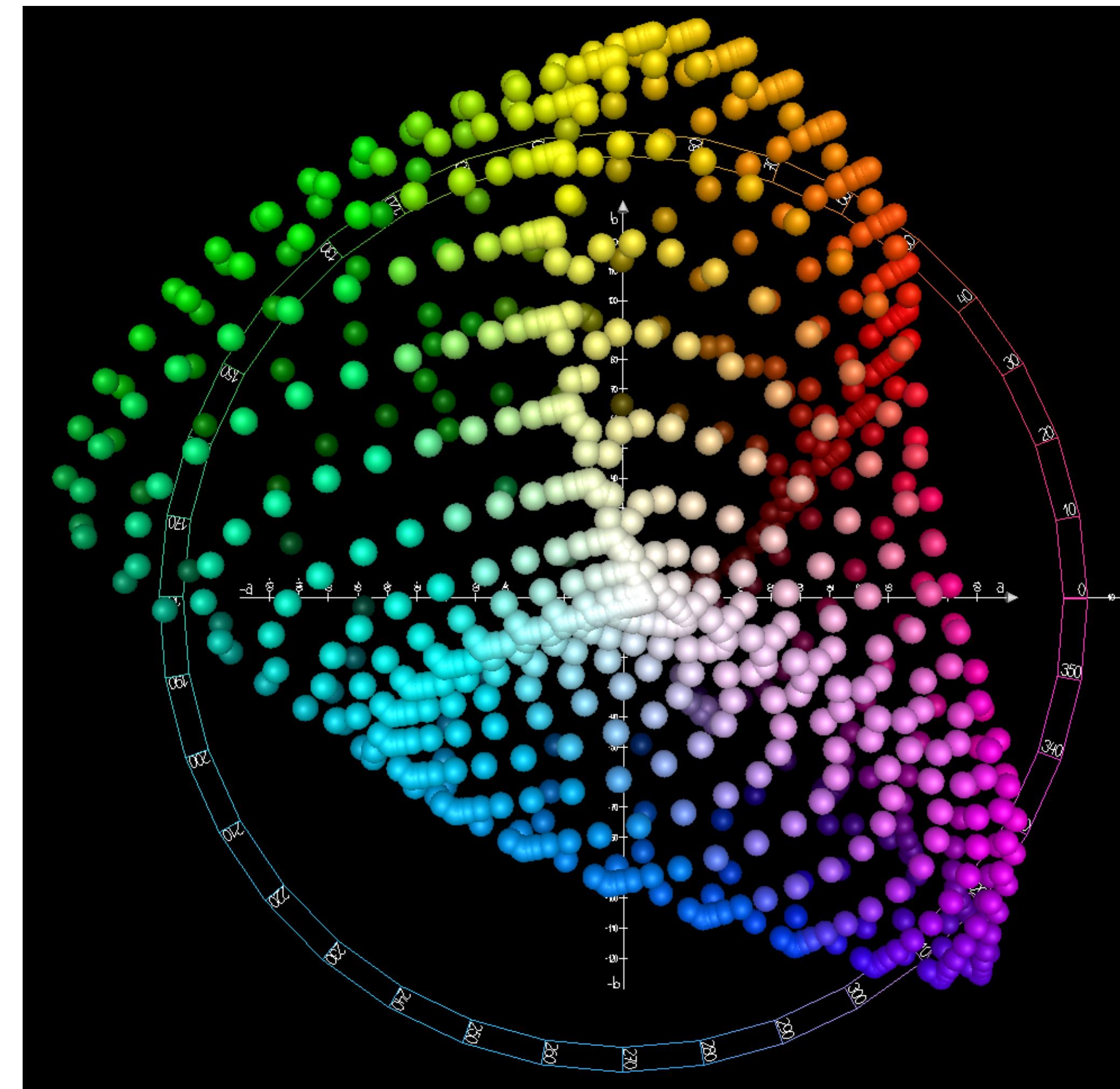
CMYK (Cyan, Magenta, Yellow, Black)



HSL (Hue, Saturation, Lightness/Luminance)



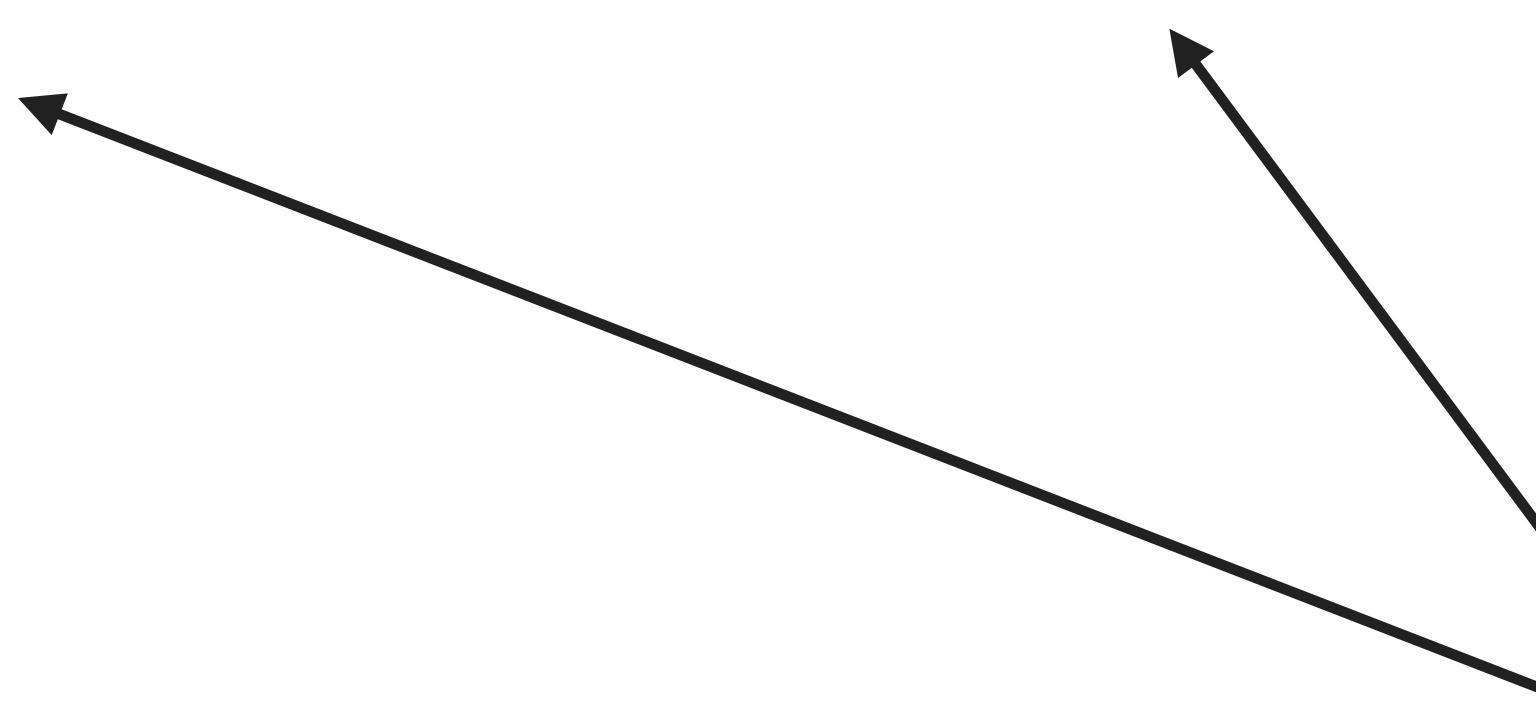
CIELAB (or L^{*}a^{*}b^{*}: Lightness, Green–Red and Blue–Yellow)[†]



[†]International Commission on Illumination

List of common color spaces

- **RGB** (Red, Green, Blue)
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- **CIELAB** (or L*a*b*)



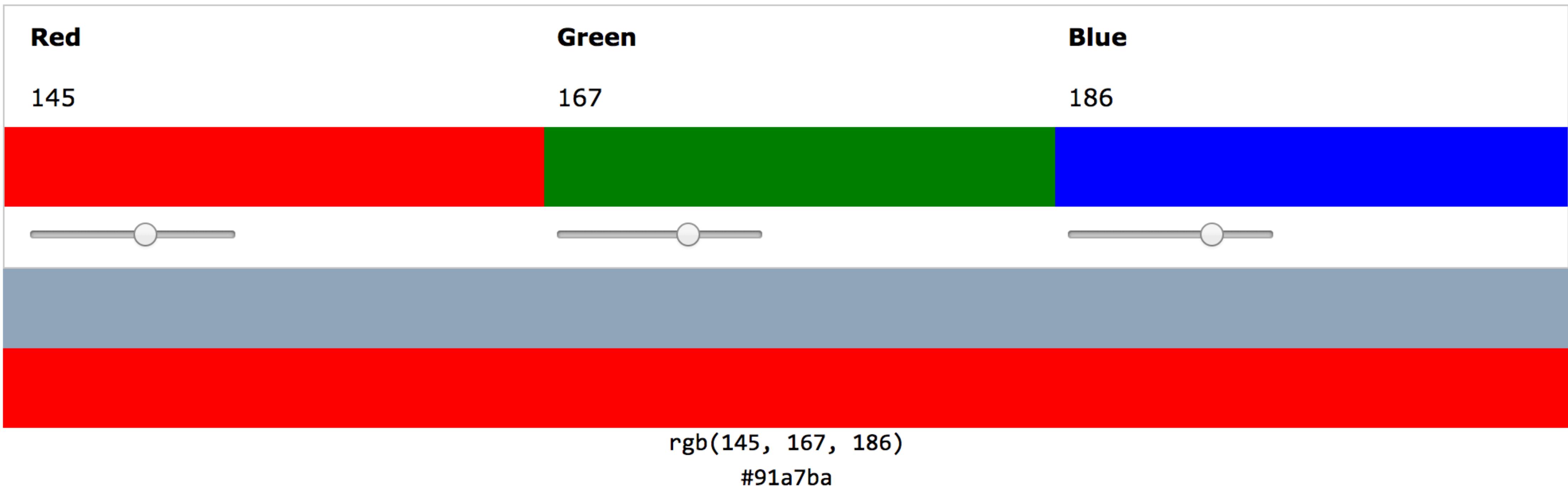
Especially useful for data visualization

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

Prepare your squares!

...and open [https://www.w3schools.com/
colors/colors_picker.asp](https://www.w3schools.com/colors/colors_picker.asp)

RGB (Red, Green, Blue)



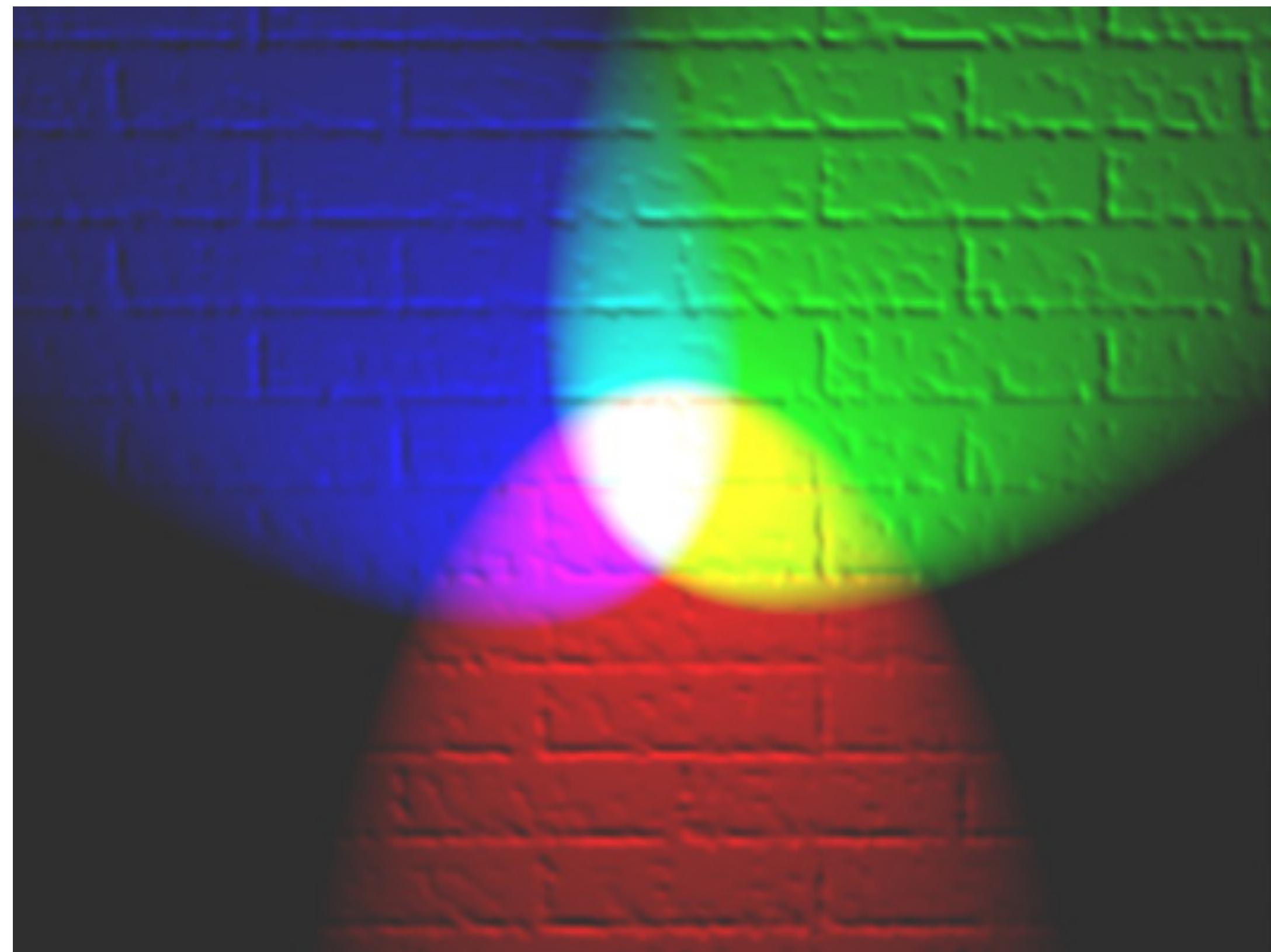
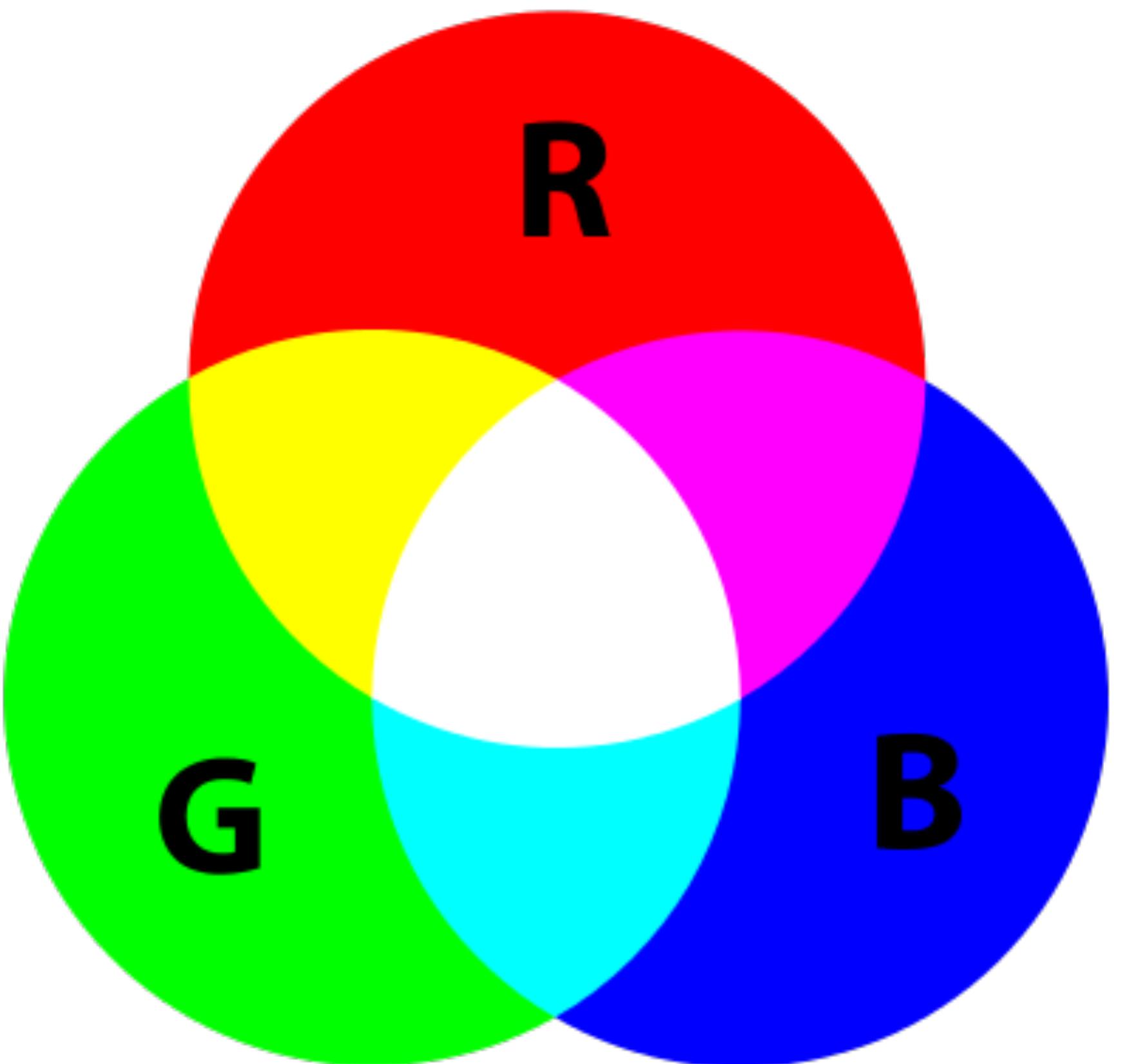
There are two types of color mixing:

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

Color Mixing: **Additive**

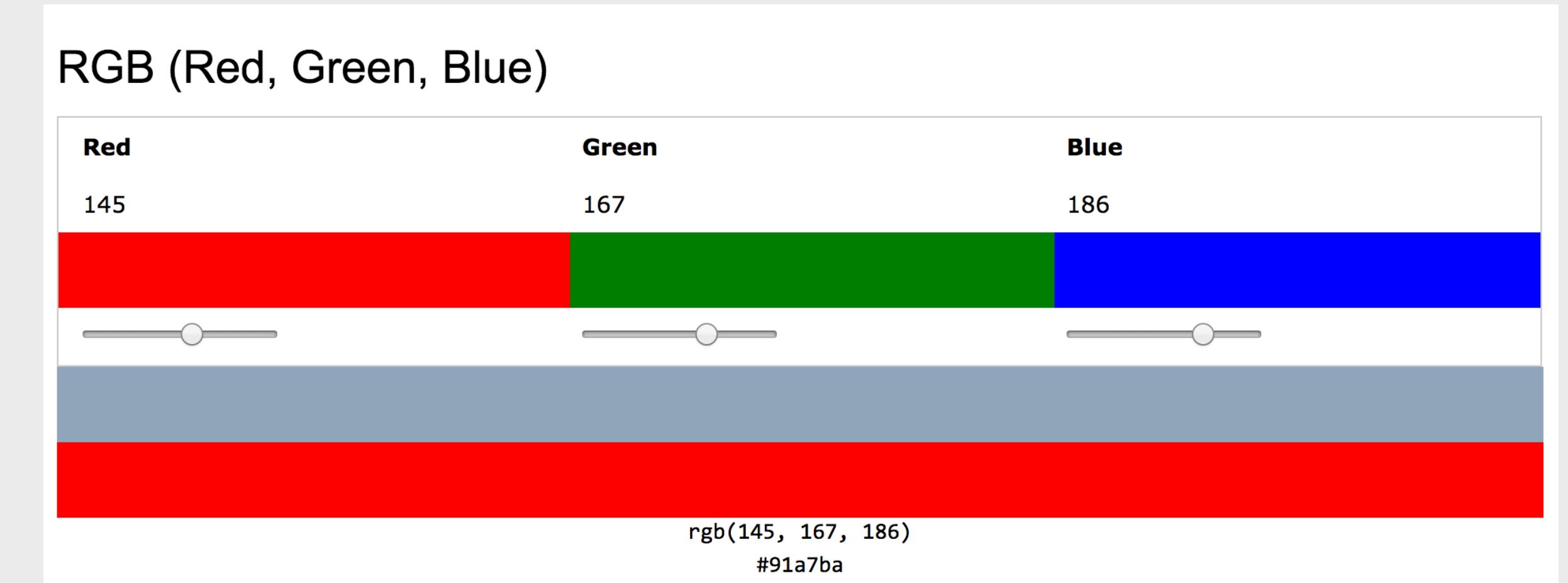
- Additive color is created by **mixing different light colors**
- **RGB (most common)**: the three values in this space refer to the intensity output of the three light colors used in a monitor, television, or projector
 - **R** — Red
 - **G** — Green
 - **B** — Blue
- Does not correspond to the mixing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

Color Mixing: **Additive**

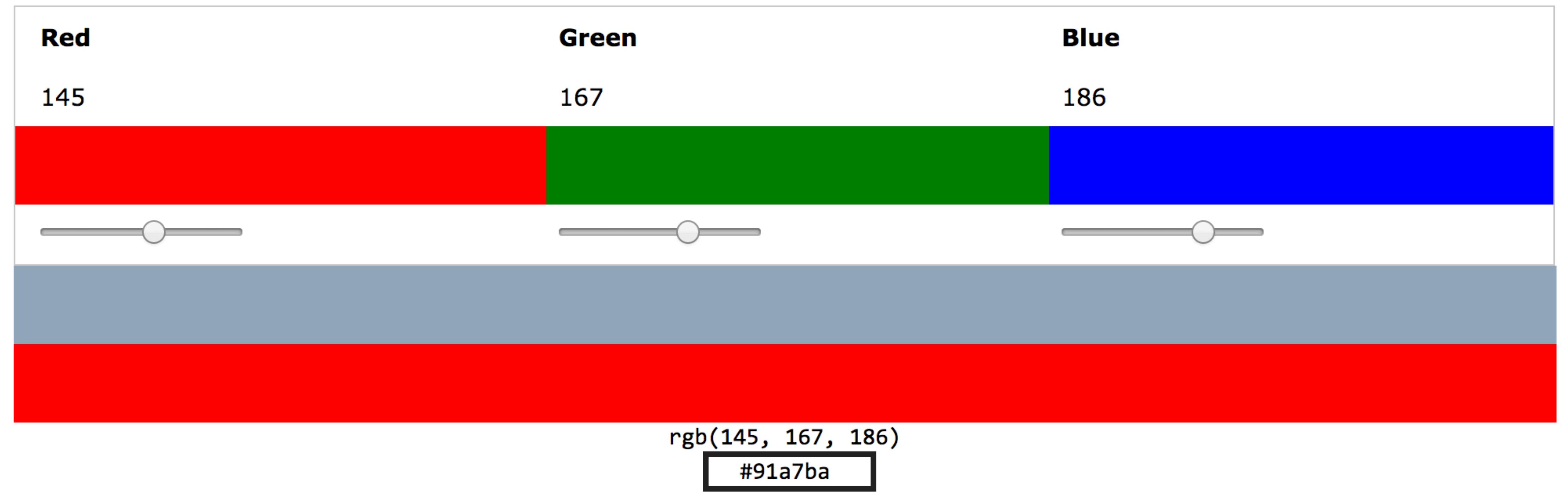


PAUSE:

- Go to w3schools
- Choose one colored square
- Use the RGB controls to create that color



RGB (Red, Green, Blue)



Hex Code

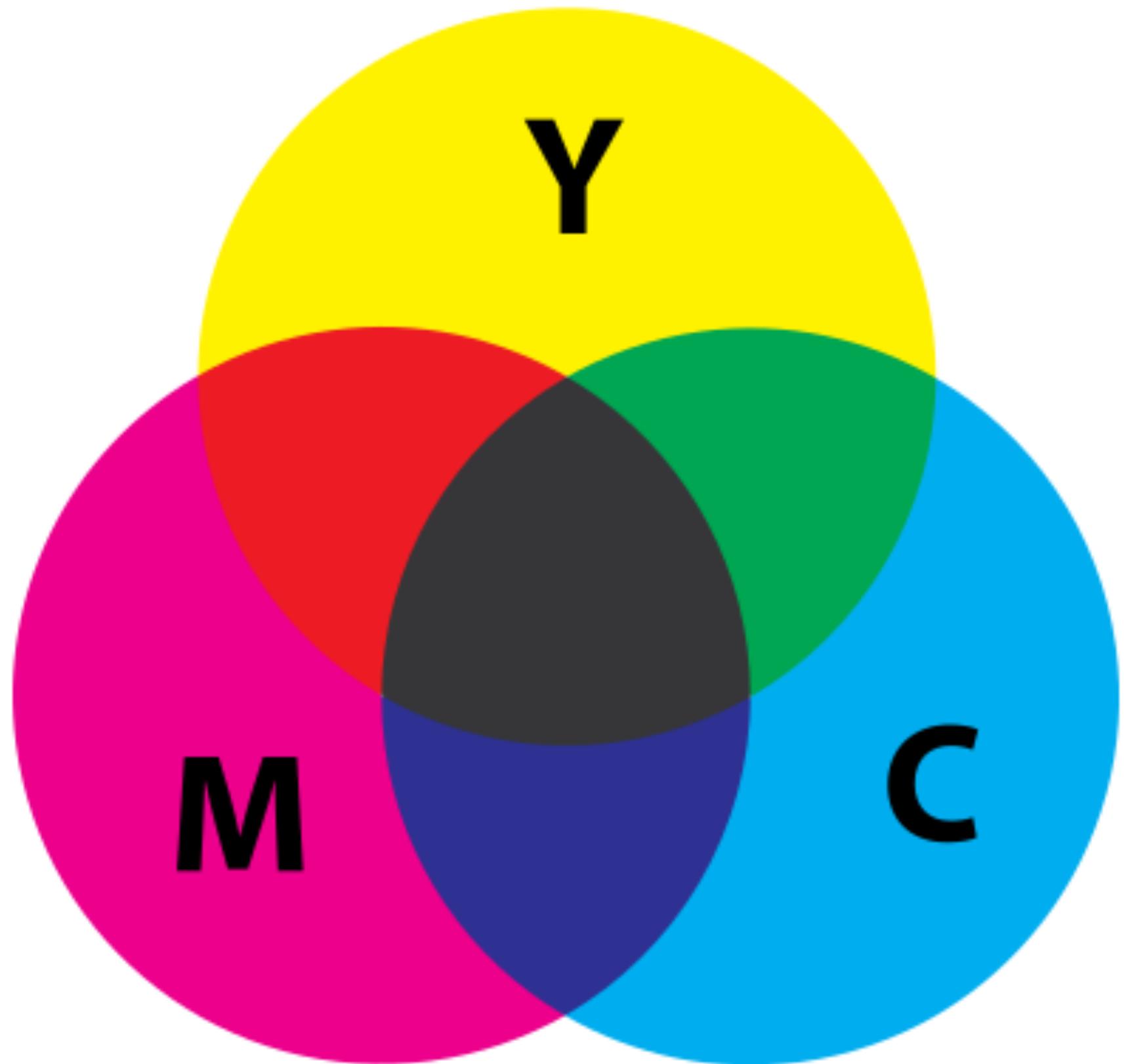
These values may be entered into different applications to **define a color exactly**.

(ex. Powerpoint)

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



PAUSE:

Group and order your swatches by **Hue**.



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



PAUSE:

Group and order your swatches by **Saturation**.

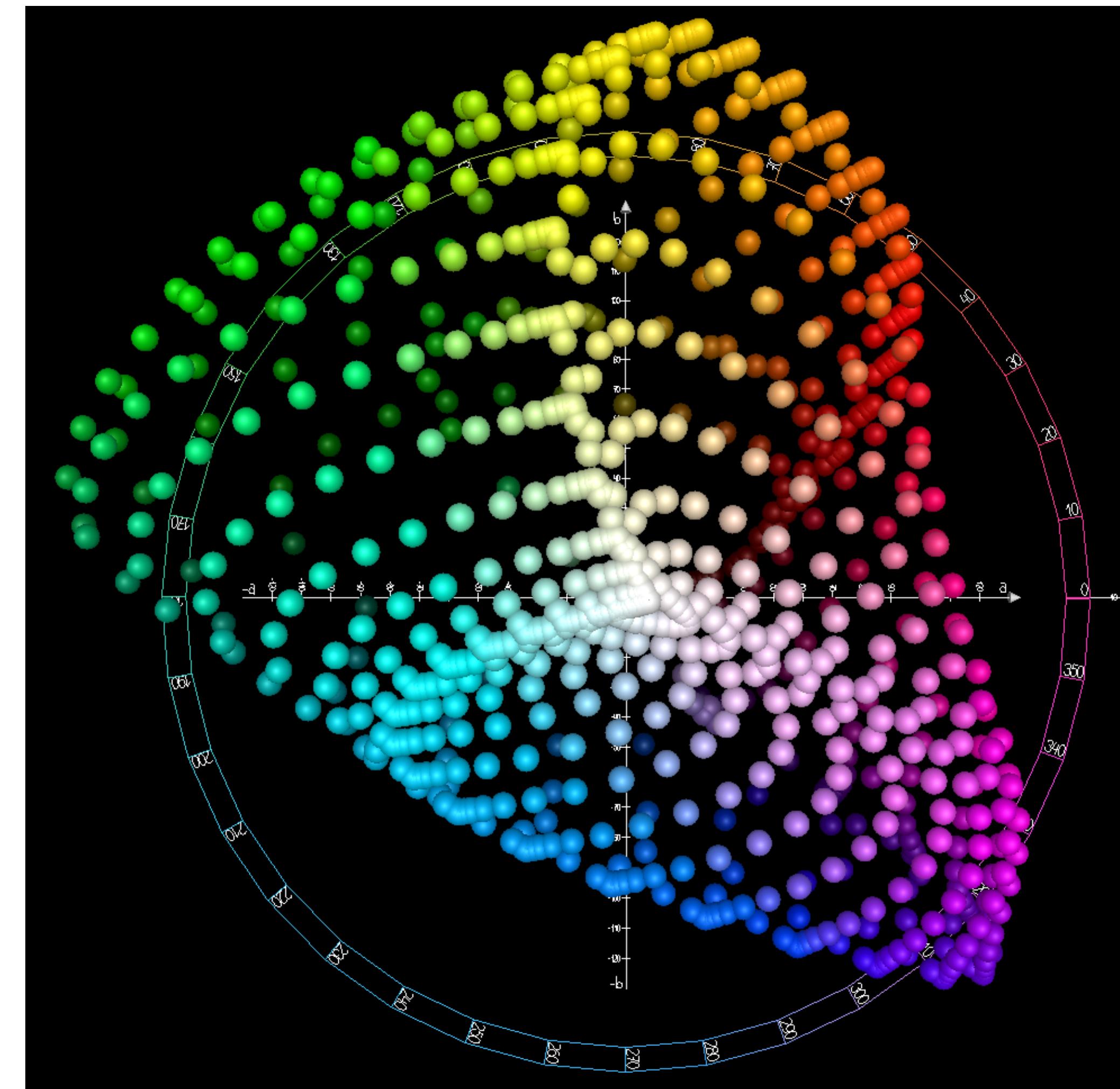
- 
- Hue
 - Saturation
 - **Luminance** – The amount of white or black in a color



PAUSE:

Group and order your swatches by **Luminance**.

CIELAB (or L^{*}a^{*}b^{*}: Lightness, Green–Red and Blue–Yellow)[†]



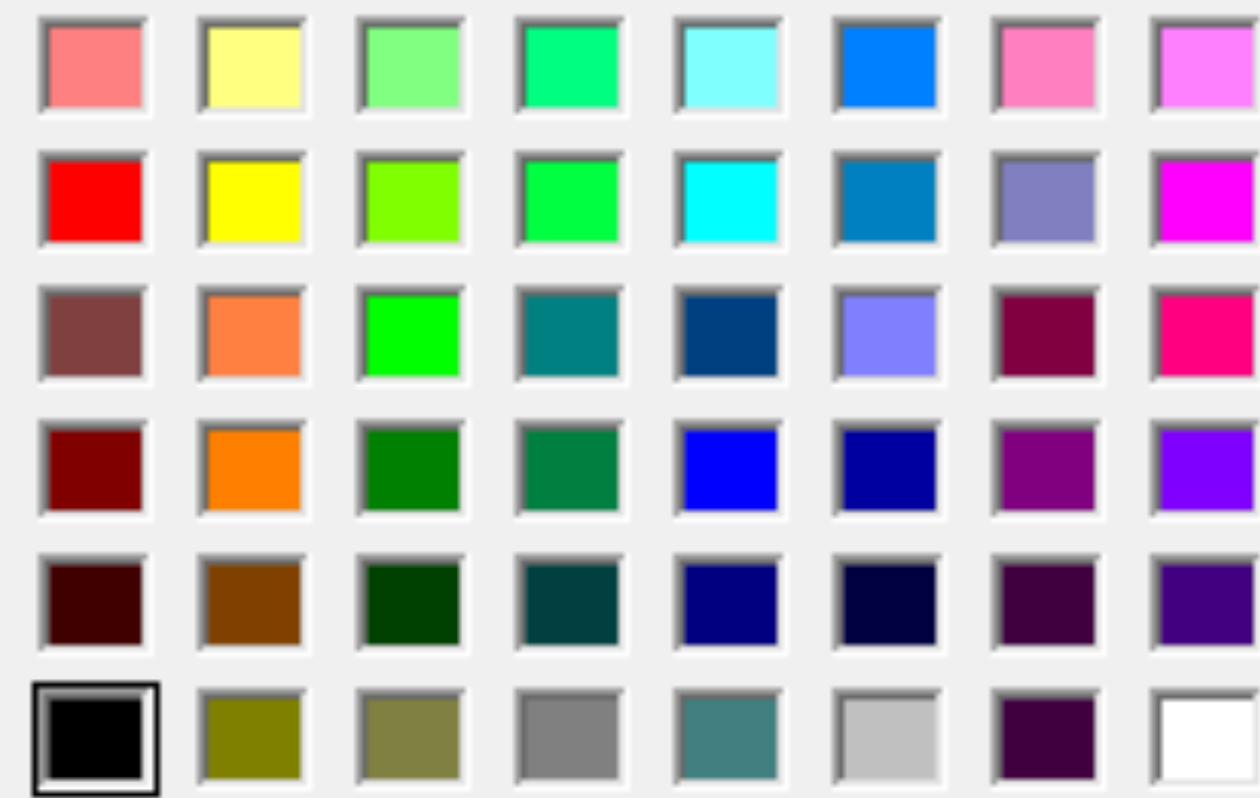
[†]International Commission on Illumination

- 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:



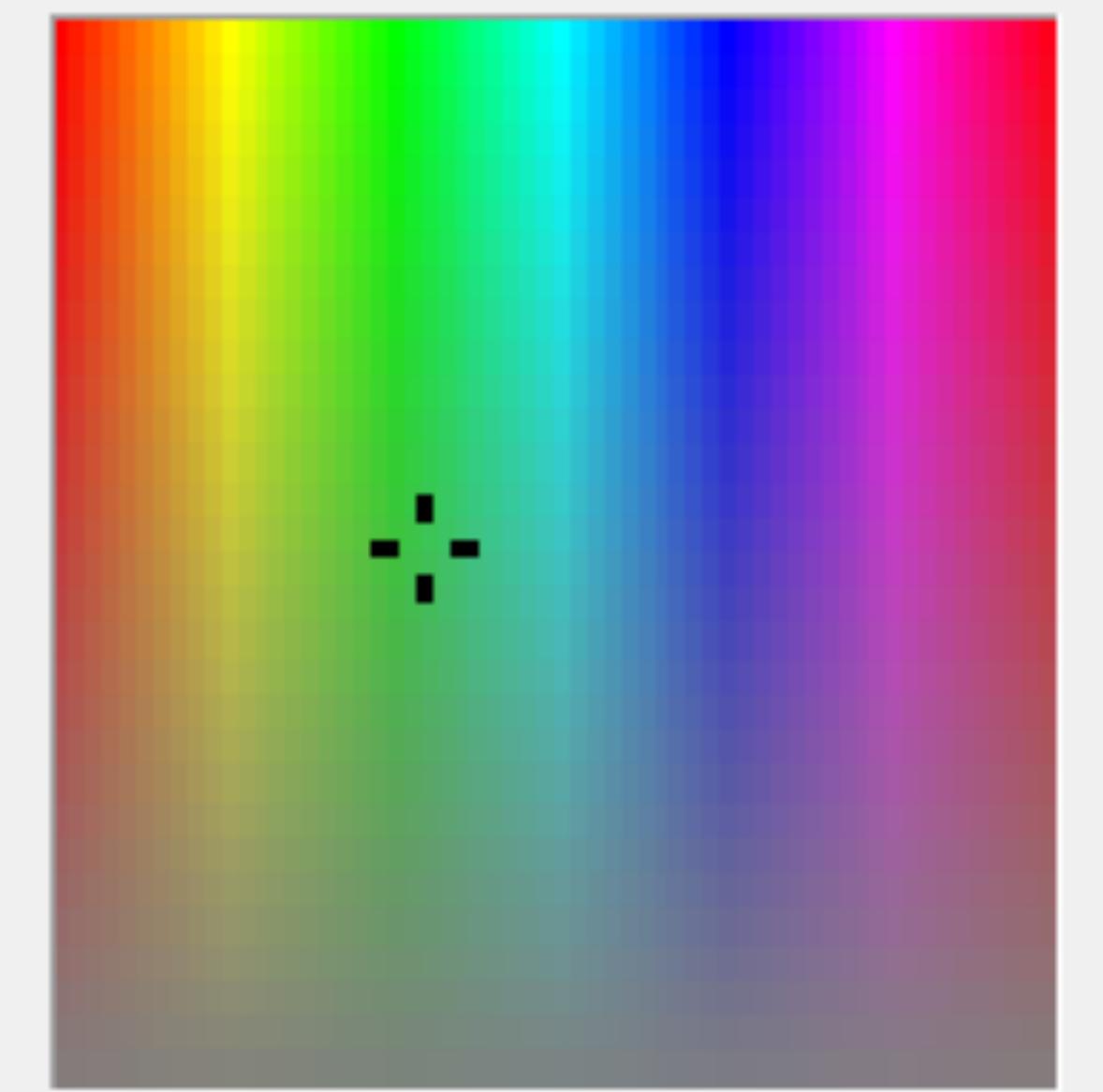
Custom colors:



[Define Custom Colors >>](#)

OK

Cancel



Hue: 87

Sat: 122

Color|Solid

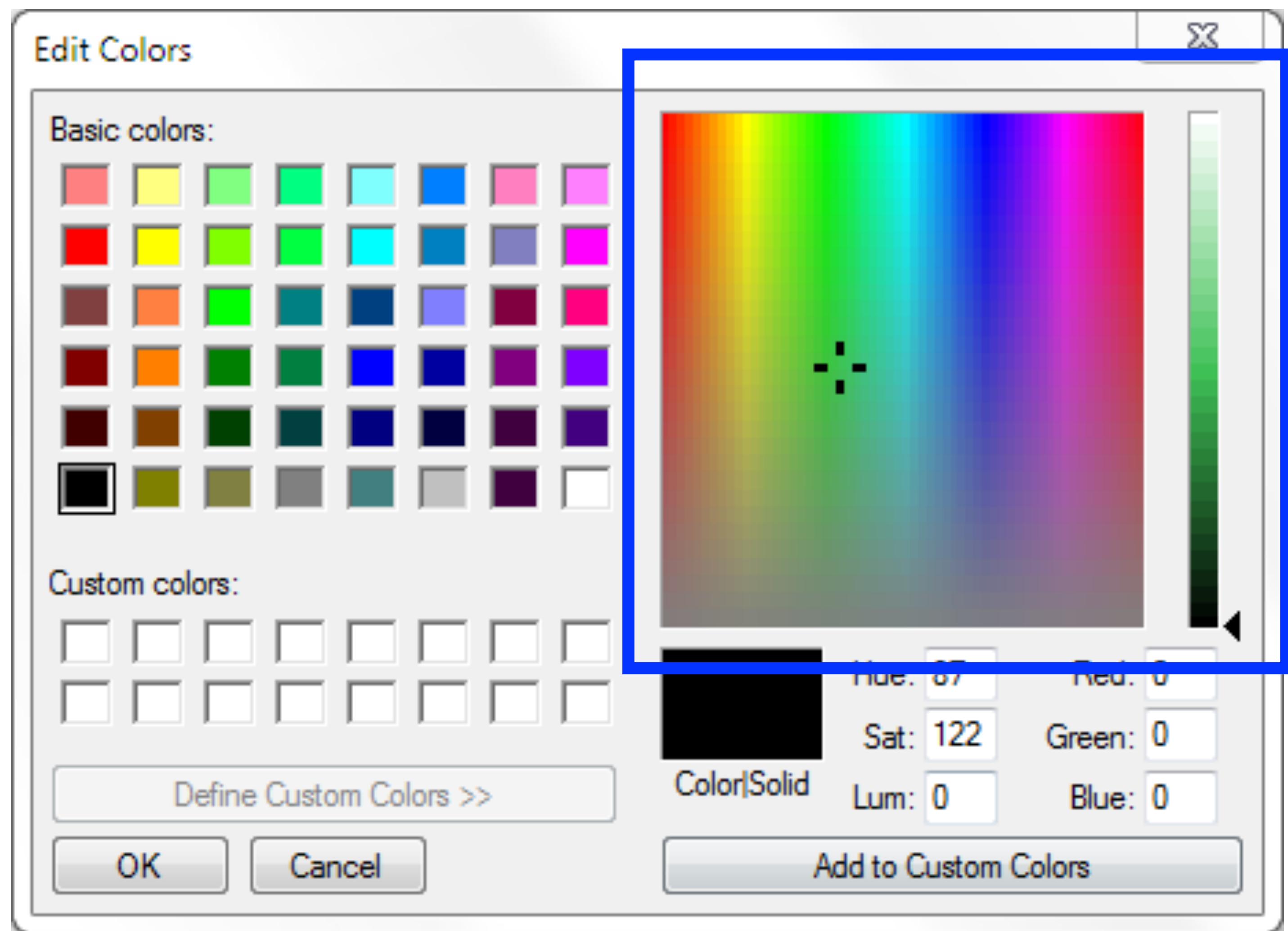
Red: 0

Green: 0

Lum: 0

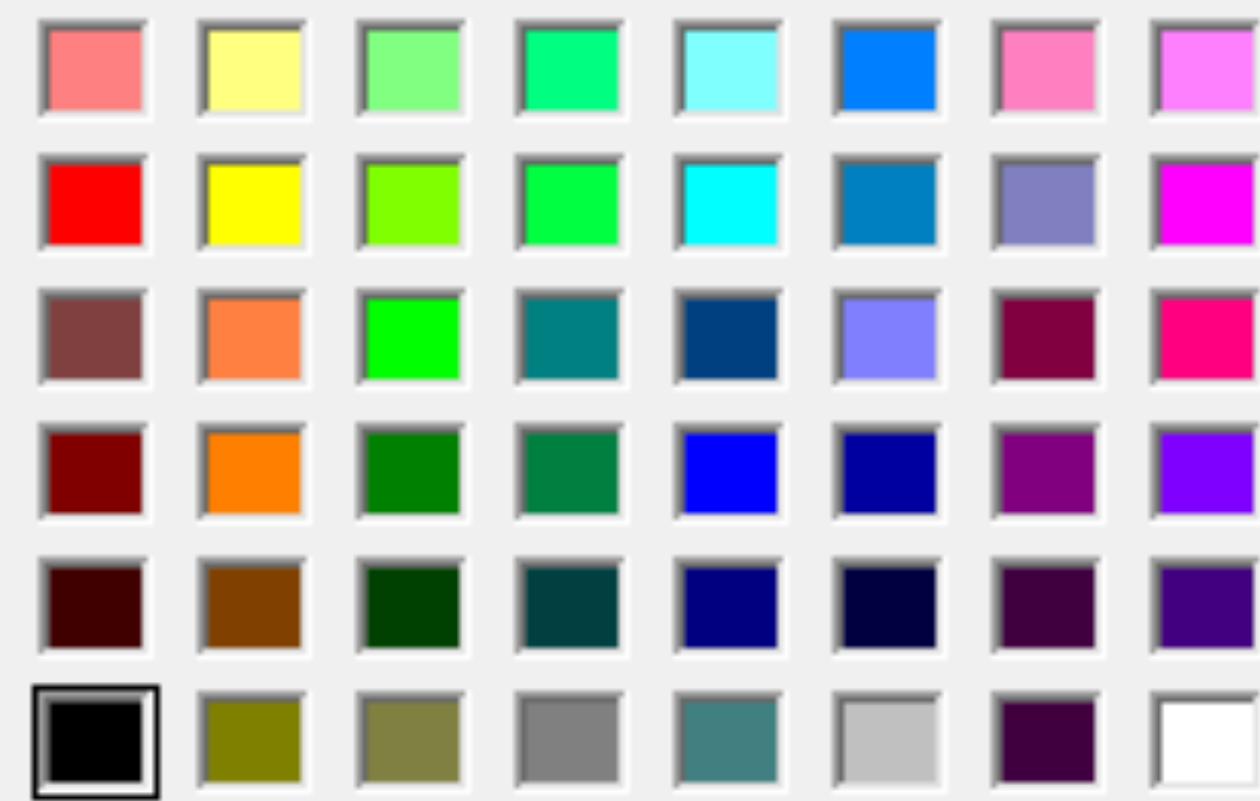
Blue: 0

Add to Custom Colors



Edit Colors

Basic colors:



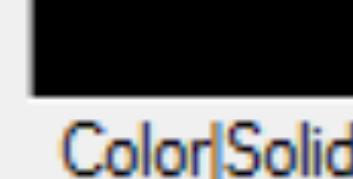
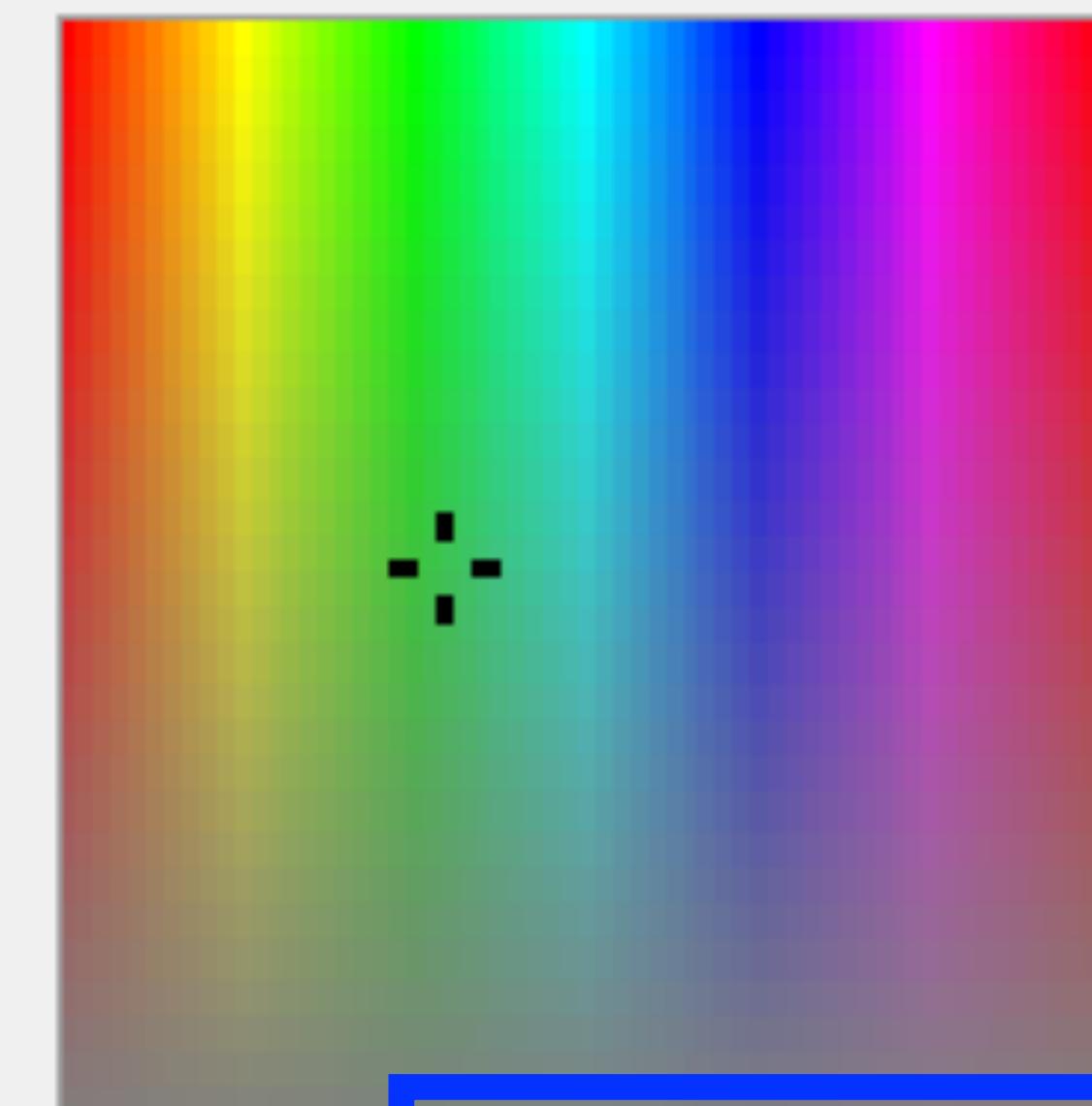
Custom colors:



[Define Custom Colors >>](#)

OK

Cancel



Color|Solid

Hue: 87

Red: 0

Sat: 122

Green: 0

Lum: 0

Blue: 0

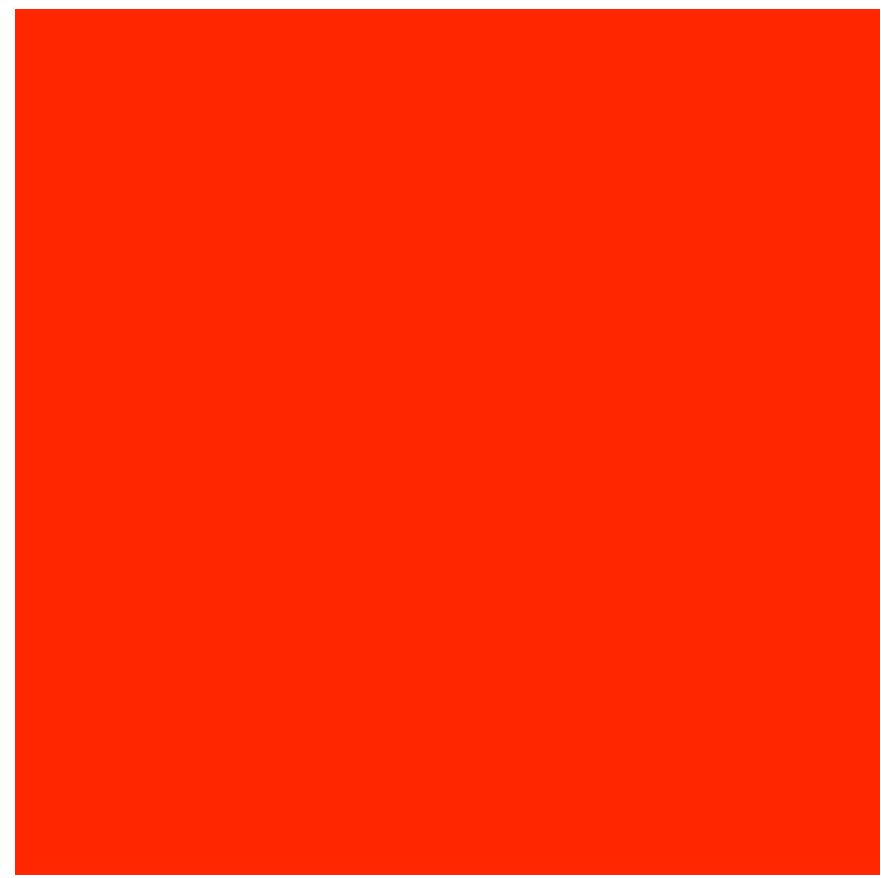
Add to Custom Colors

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.

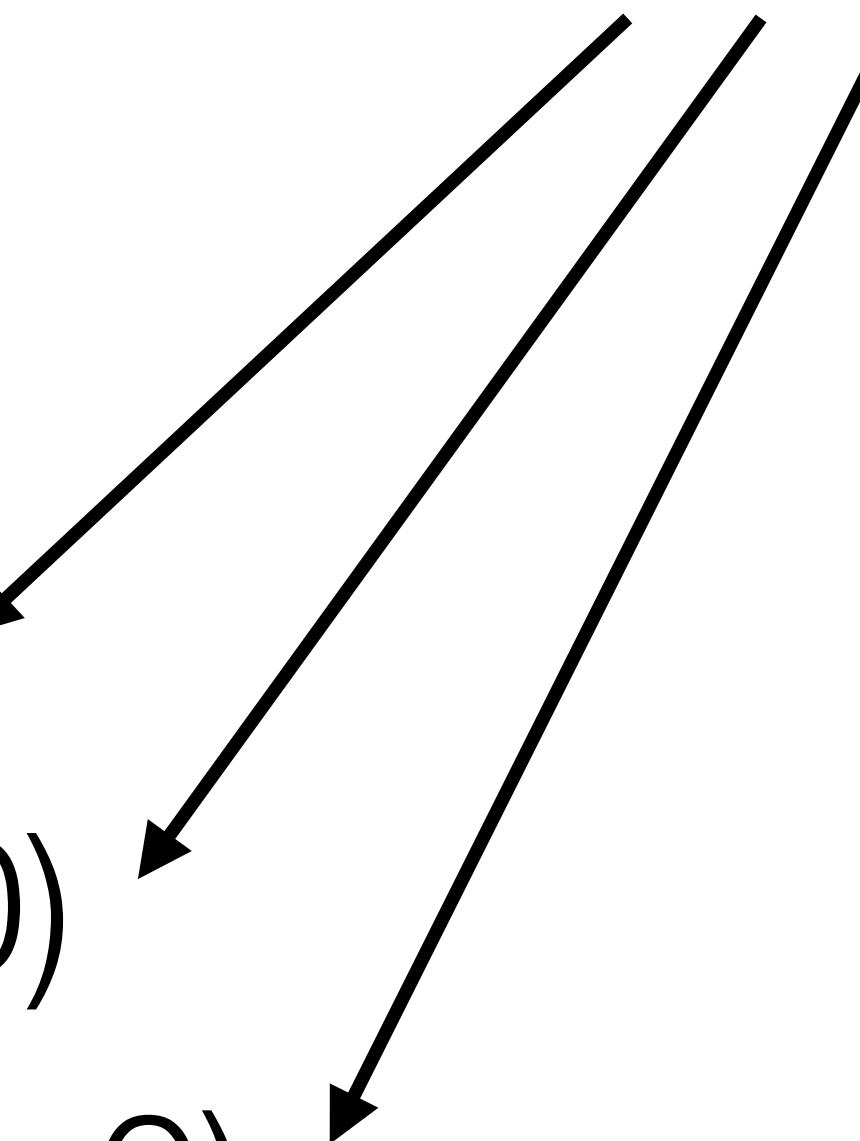
Color **syntax**

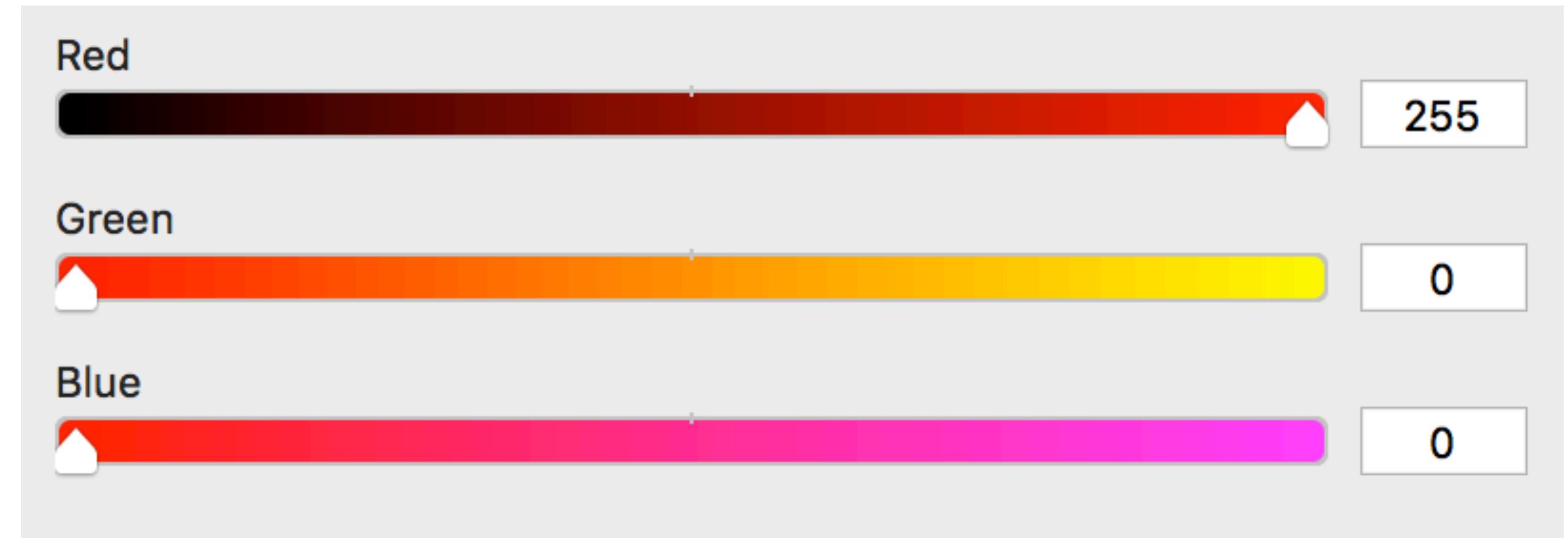
When working with color in a **digital context**, most color pickers allow you to specify values in RGB, CMYK, or HSL/HSB.



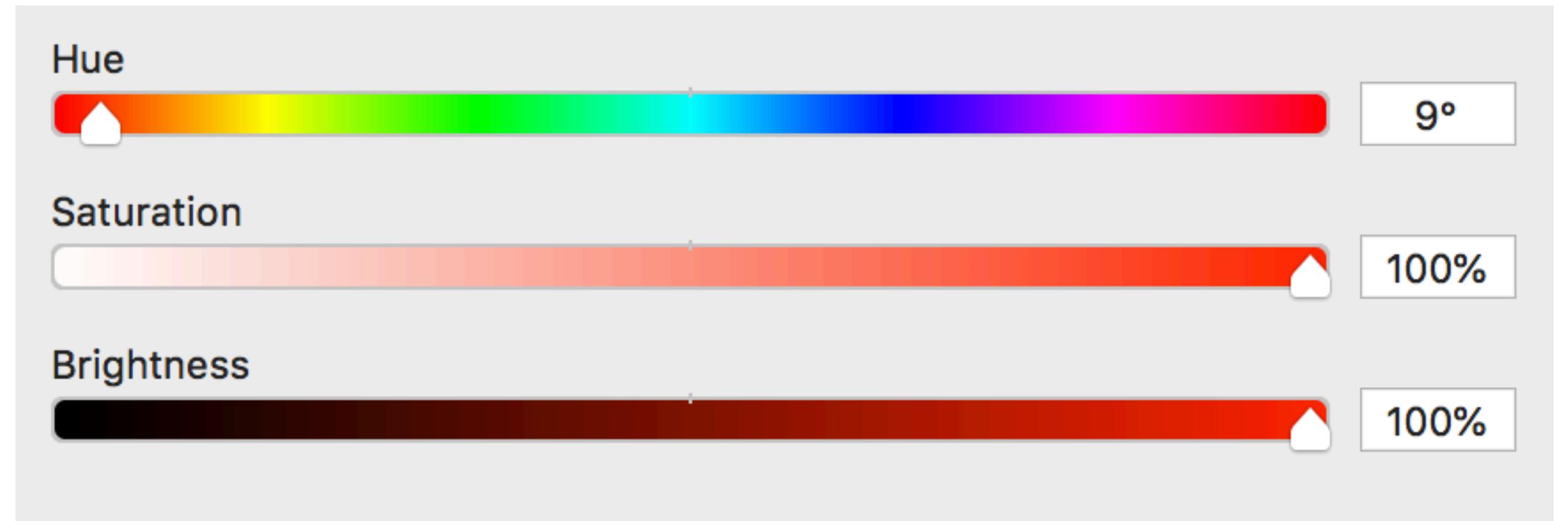
This color may be specified
in any of **these** ways.

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

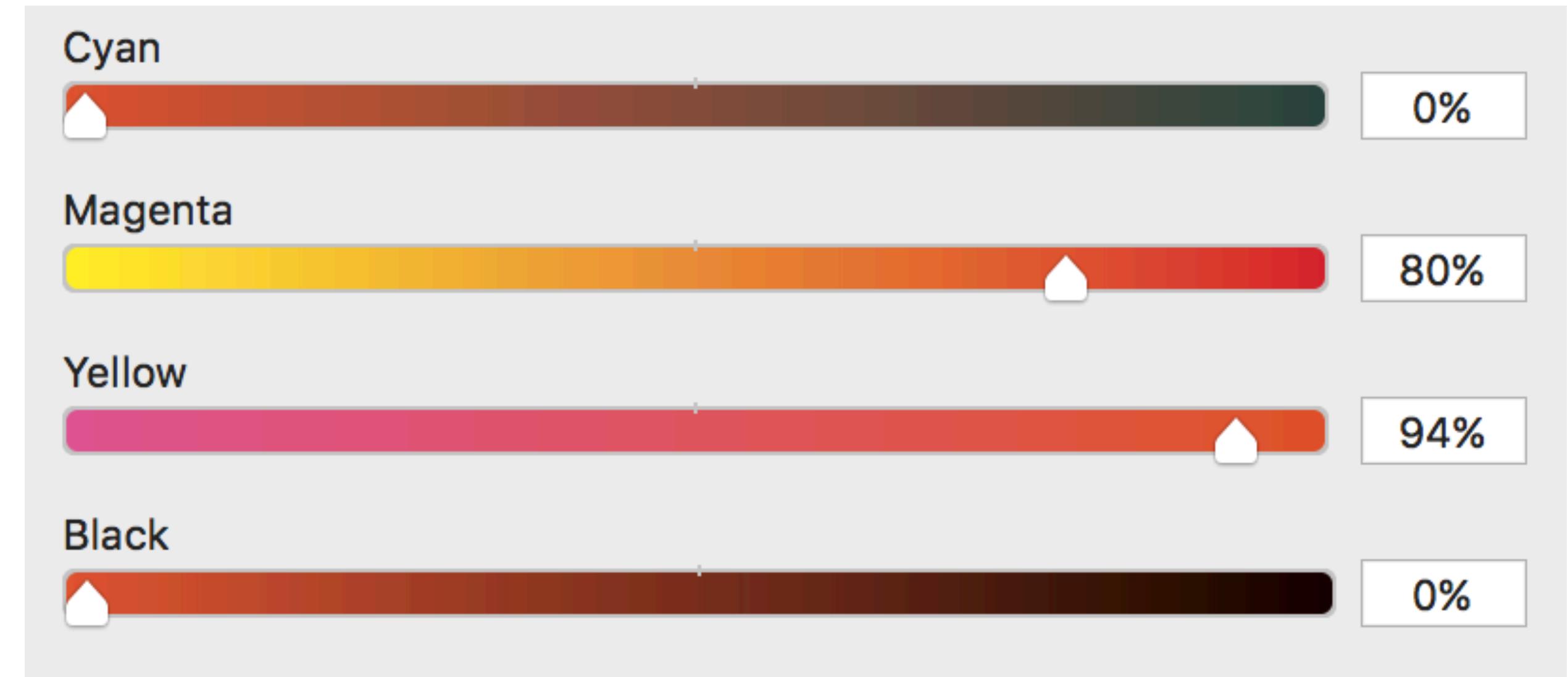
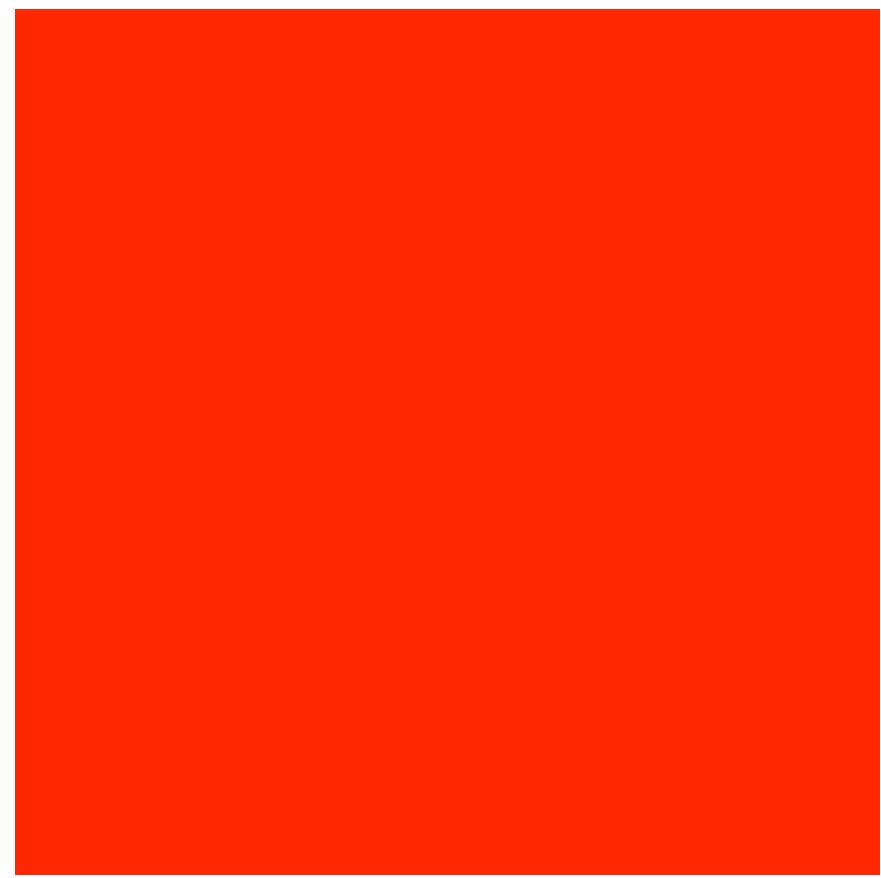




- **RGB(255, 0, 0)**
- HSL(9, 100, 100)
- CMYK(0, 80, 94, 0)



- 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.

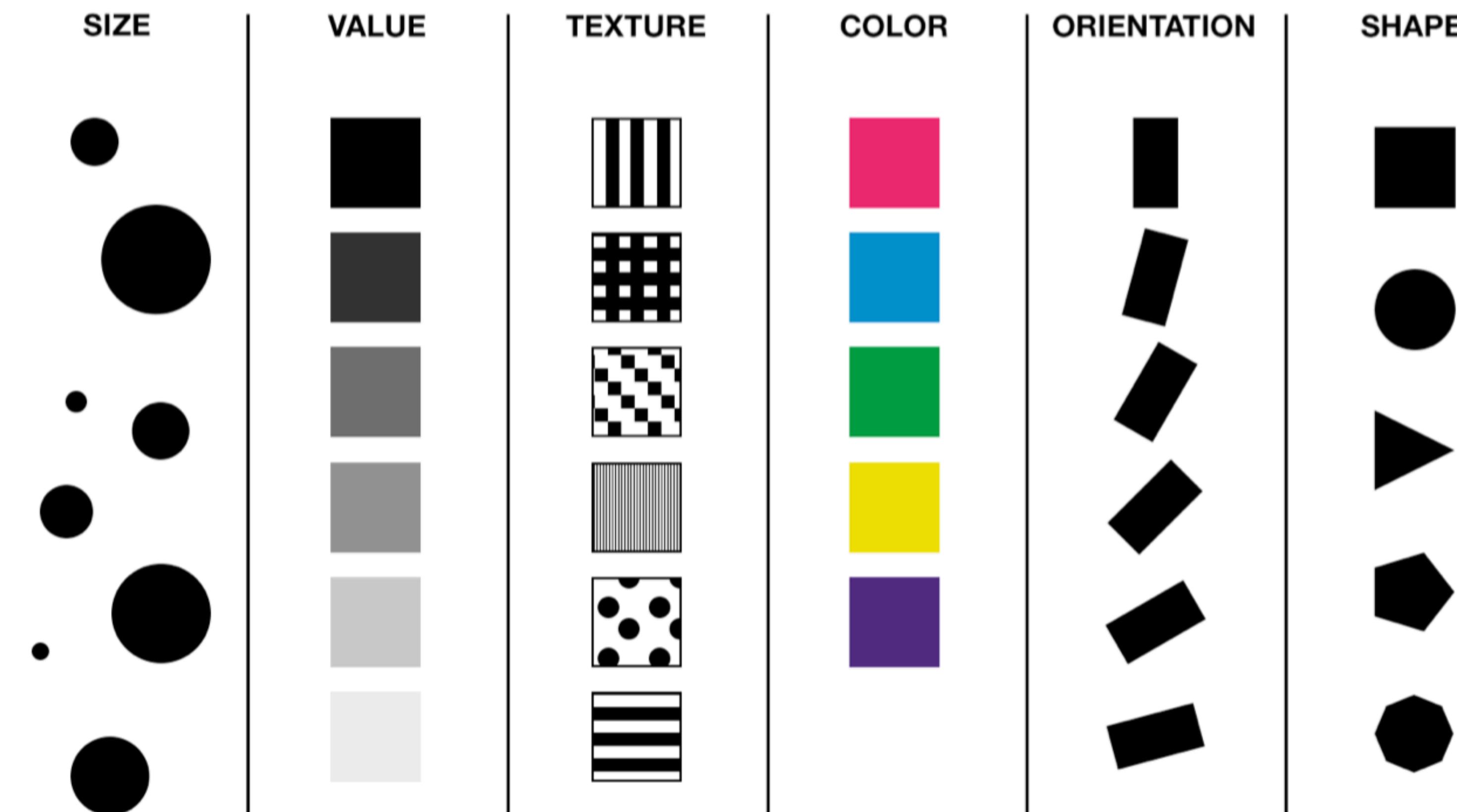
1. Color **Perception & Representation**
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Recap:

Visual Variables (Channels)

Jacques Bertin

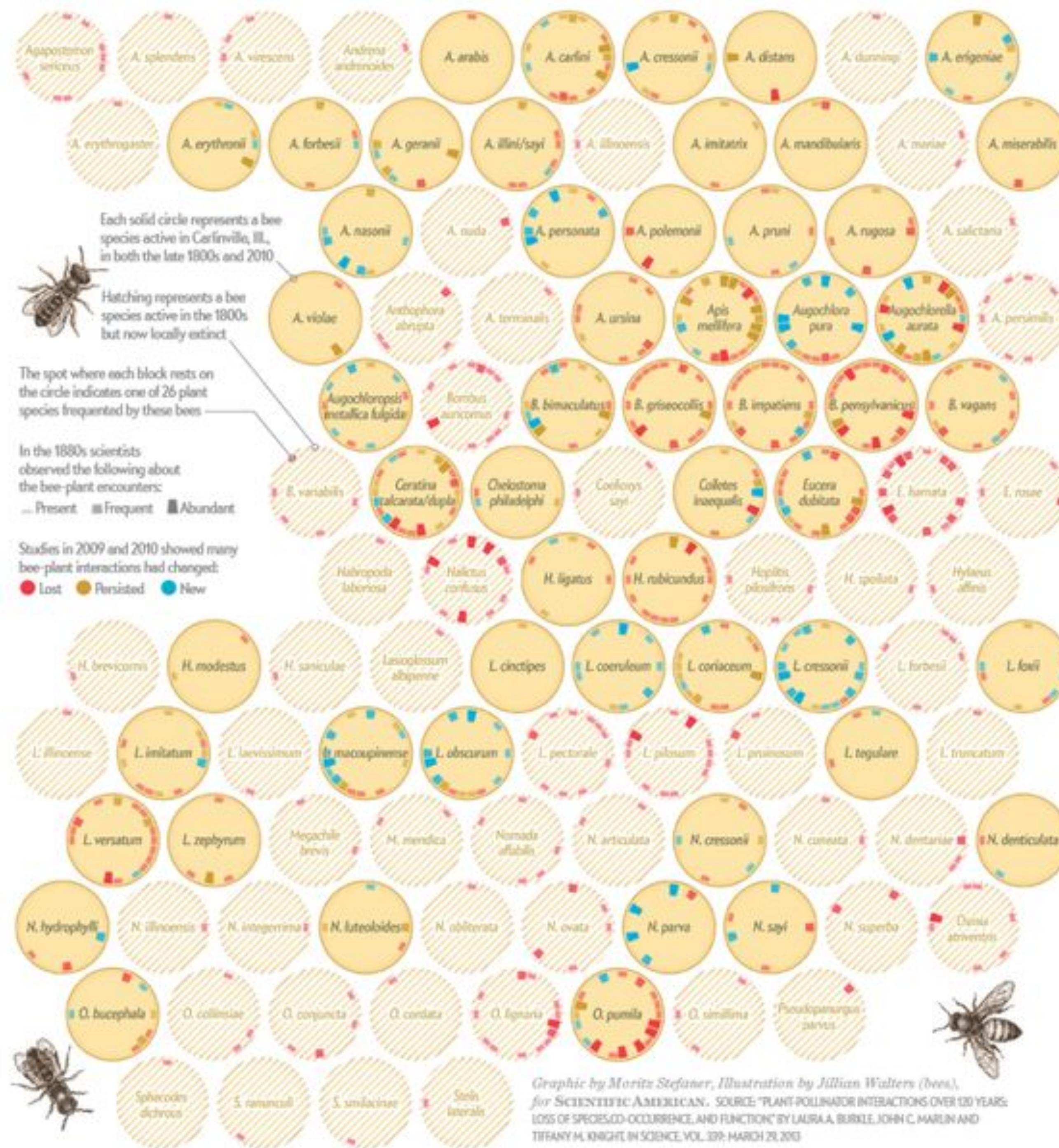
The Semiology of Graphics (1967)



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

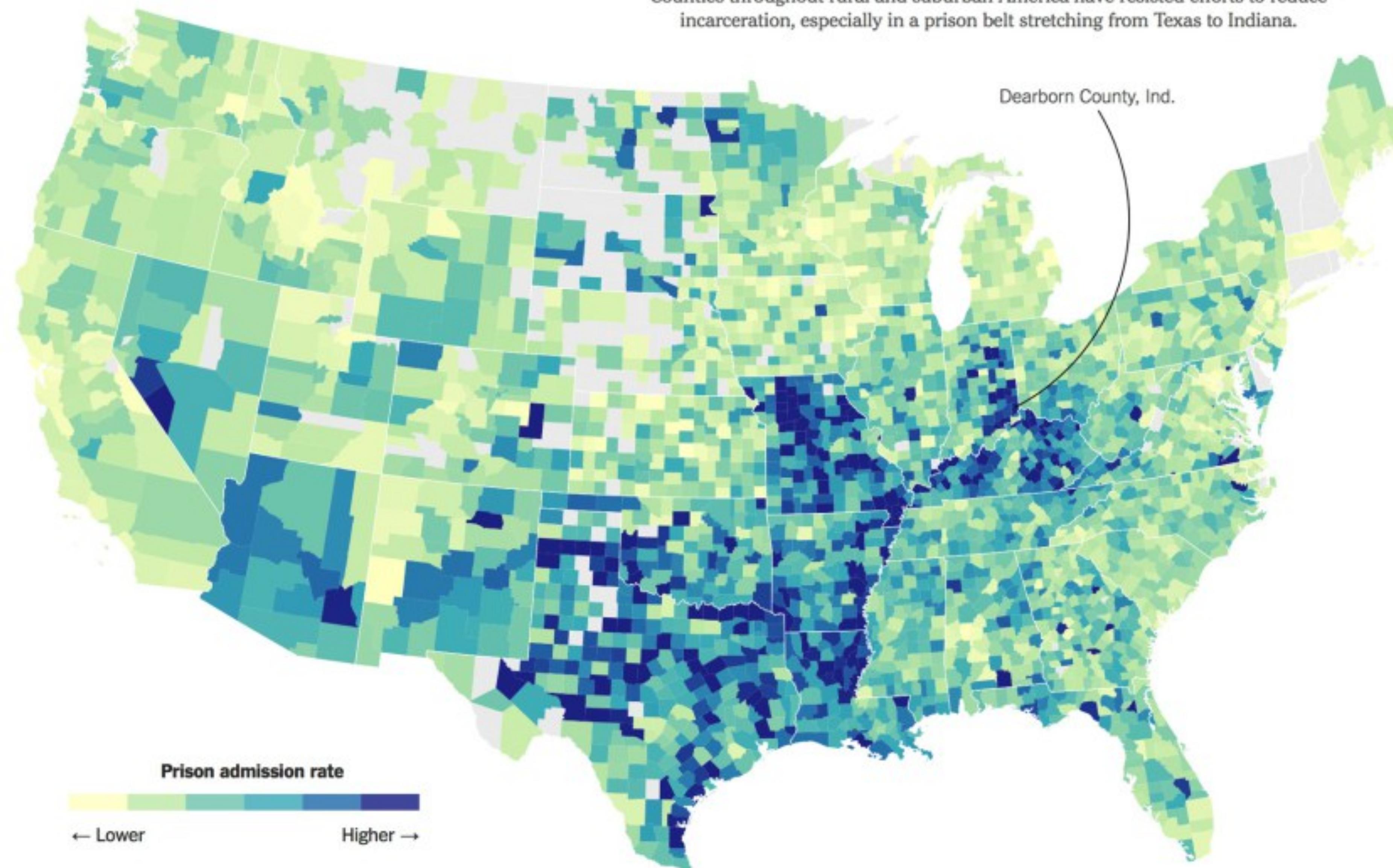
Selecting visual variables to represent different aspects of the same information can greatly influence the **perception and understanding** of the presented information.

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

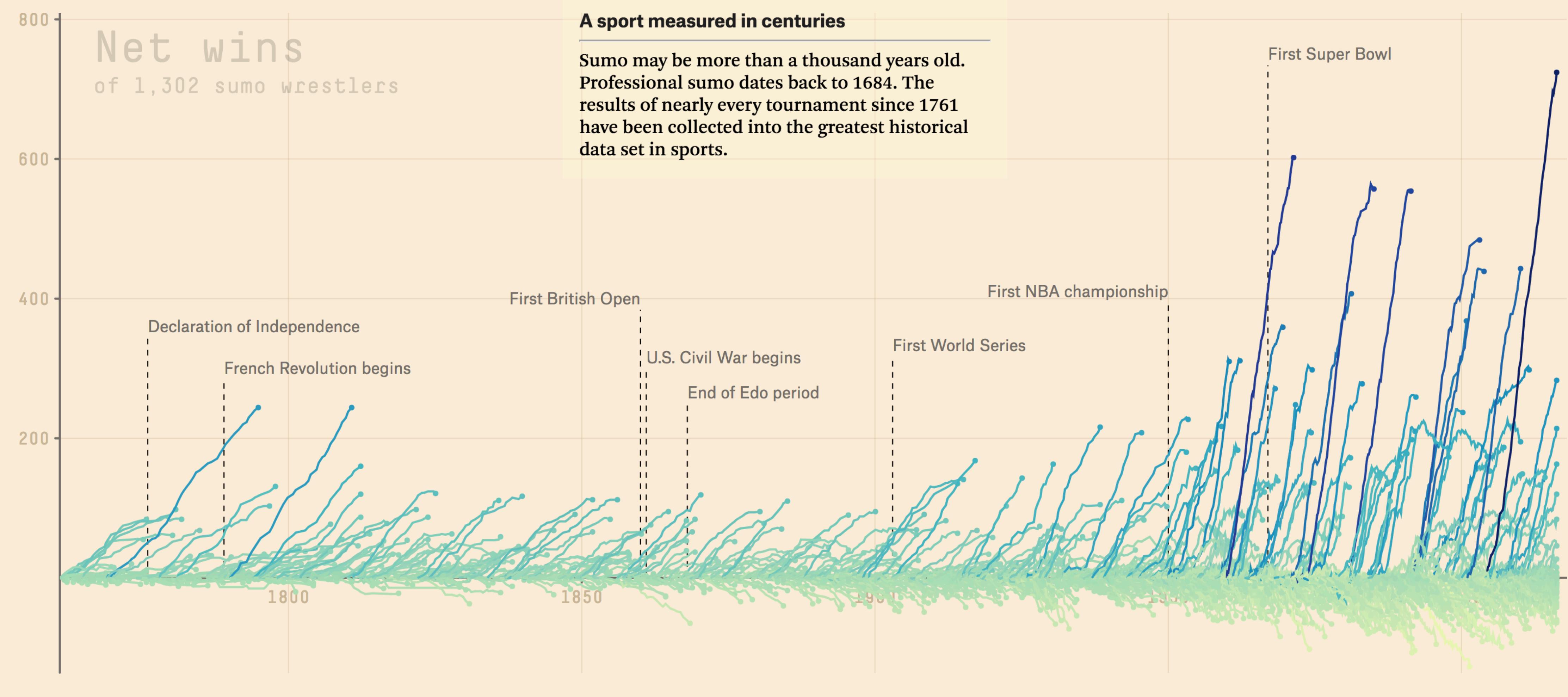
Counties throughout rural and suburban America have resisted efforts to reduce incarceration, especially in a prison belt stretching from Texas to Indiana.



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

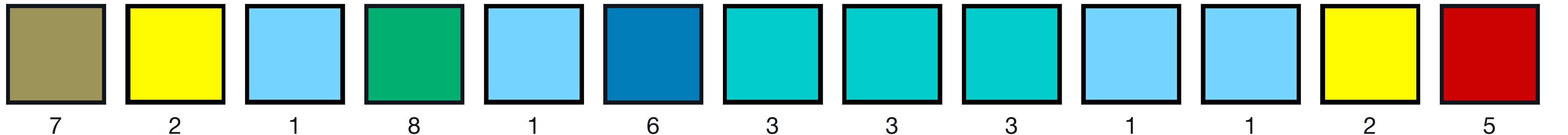
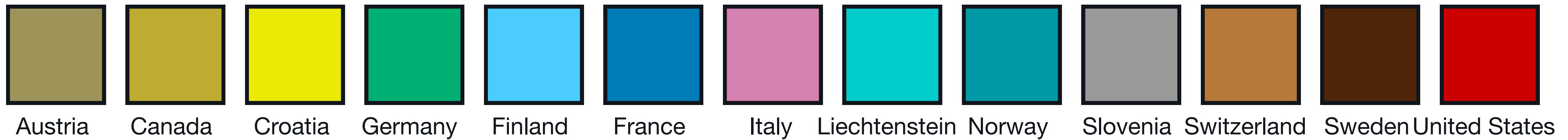
- Nominal
- Ordinal

Quantitative

- Interval
- Ratio

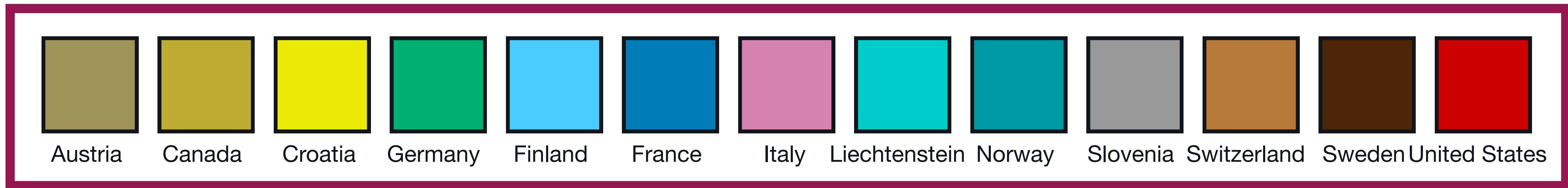
Which is more effective?

Channel: Color

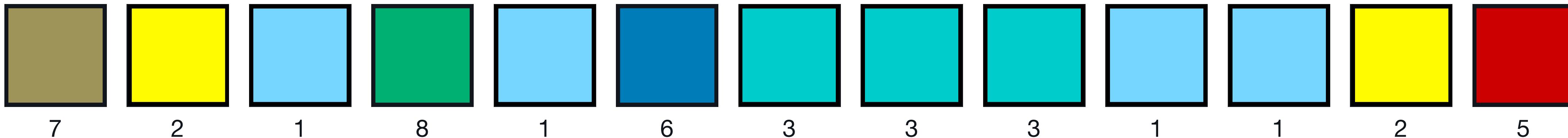


Which is more effective?

Channel: Color

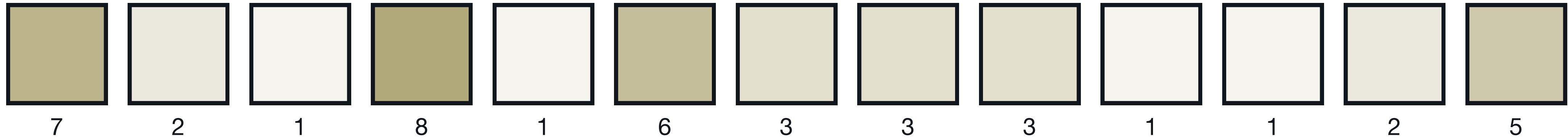
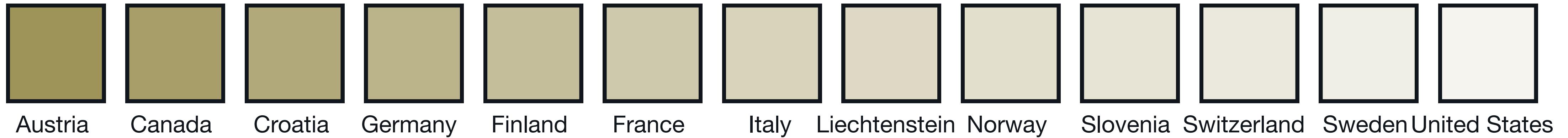


Qualitative data (nominal)



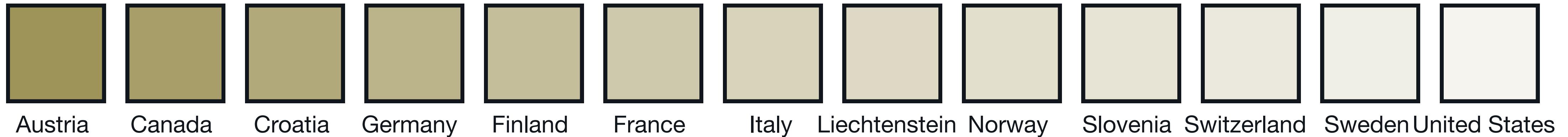
Which is more effective?

Channel: Value (Luminance, Saturation)

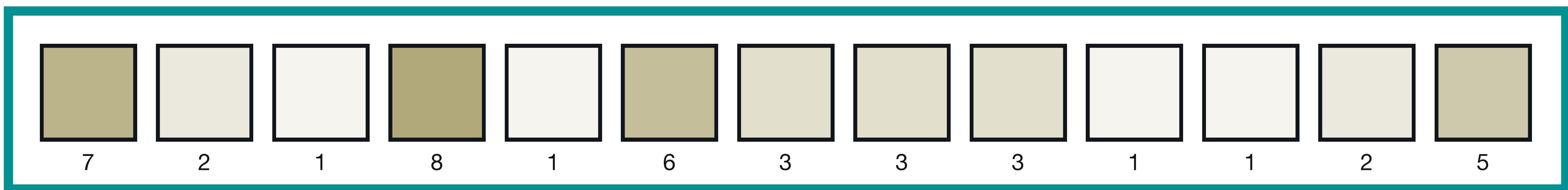


Which is more effective?

Channel: **Value (Luminance, Saturation)**



Qualitative data (ratio)



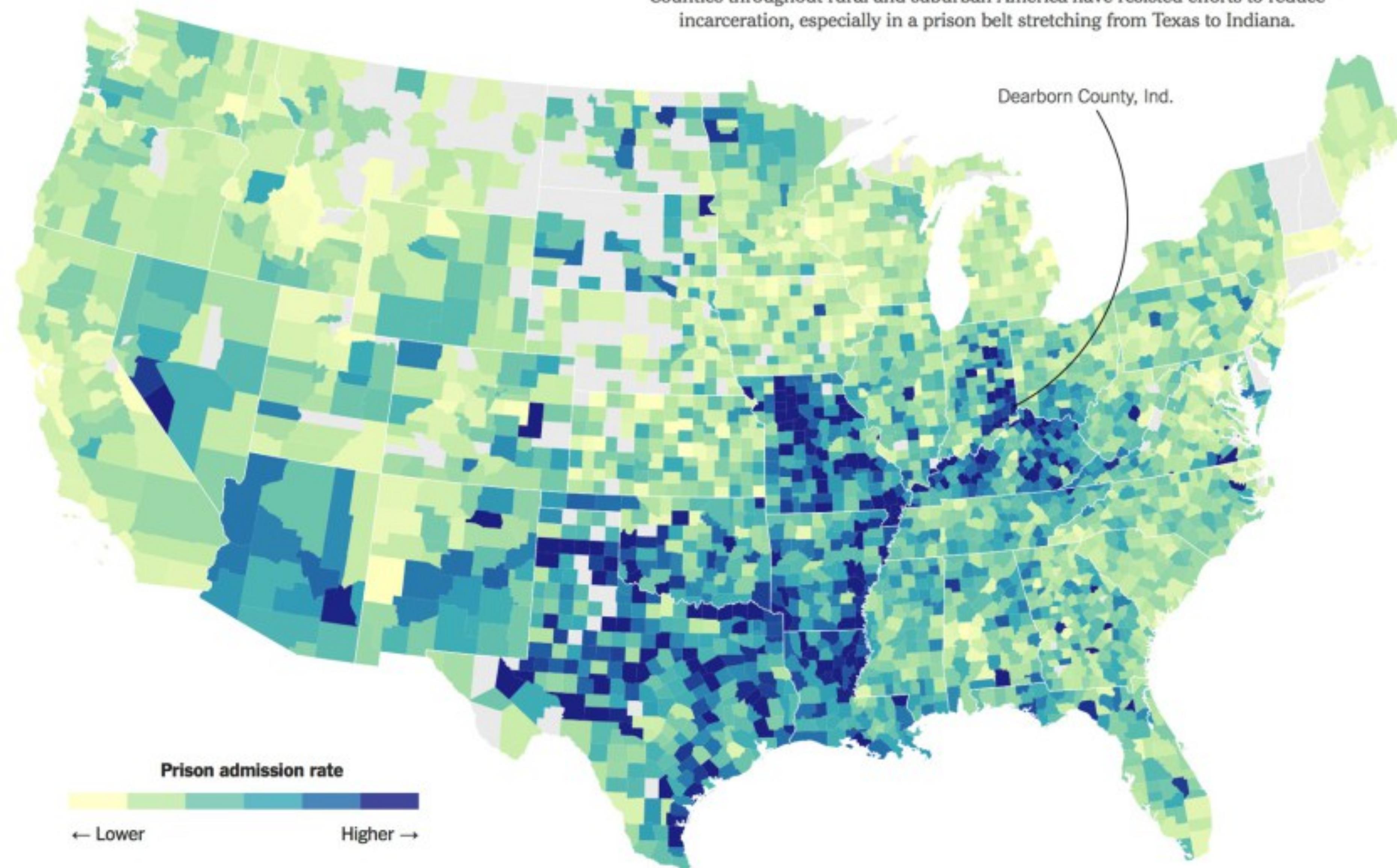
Working with color becomes challenging when trying to create **scales that appear to have even increments** (*perceptual uniformity*).

Why bother with perceptual uniformity?

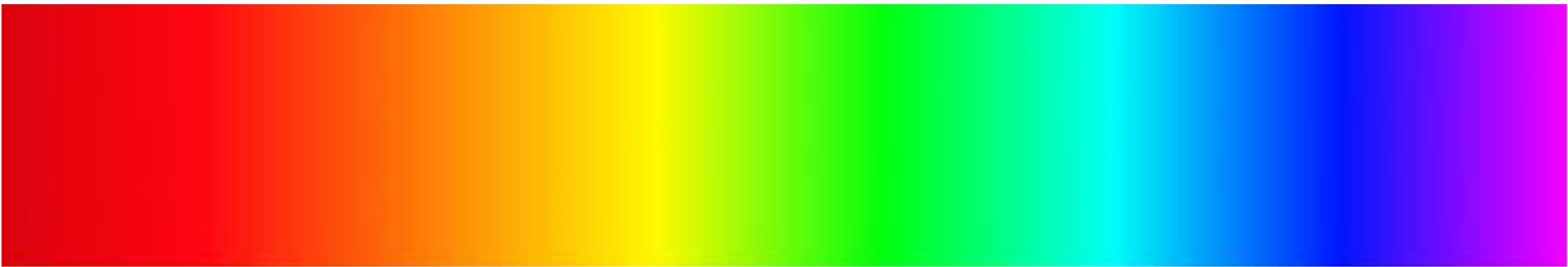
- Faithful representation of data
- Easy to compare and compute values

Where Americans Are Sent to Prison Most

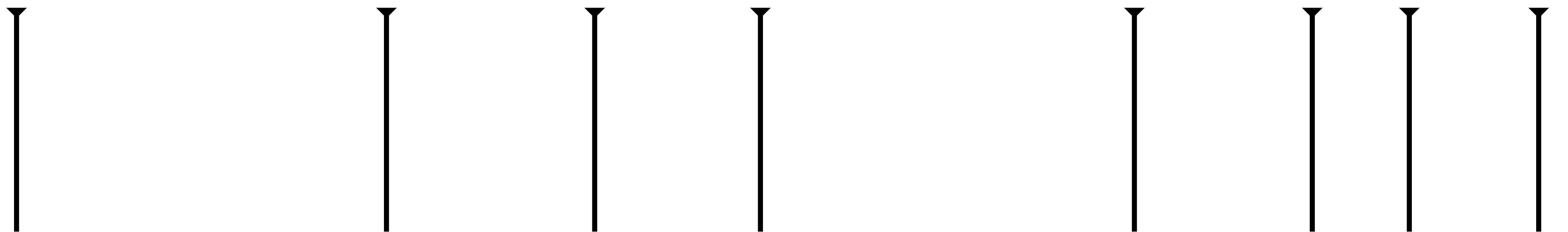
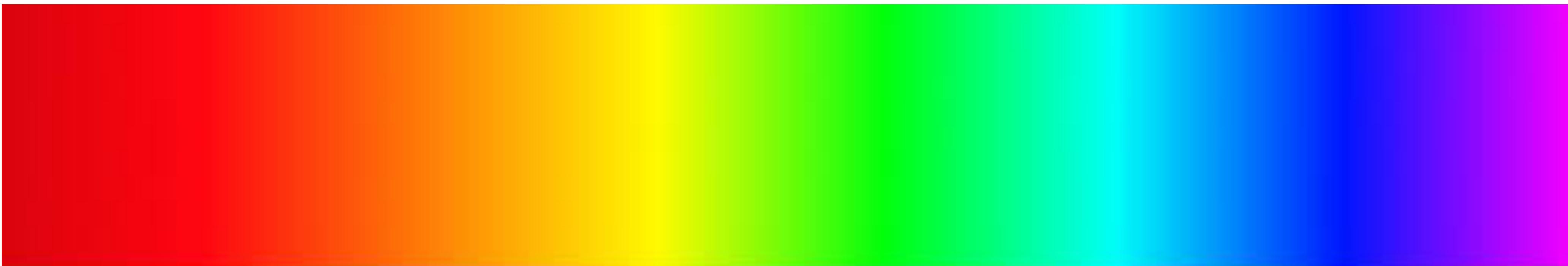
Counties throughout rural and suburban America have resisted efforts to reduce incarceration, especially in a prison belt stretching from Texas to Indiana.



Why not use a rainbow?

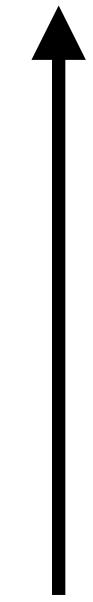
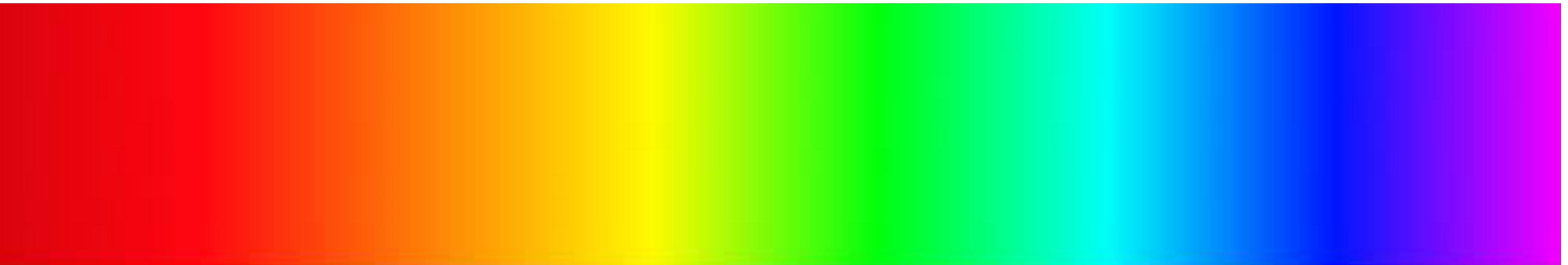


Why not use a rainbow?



Weirdly spaced differences

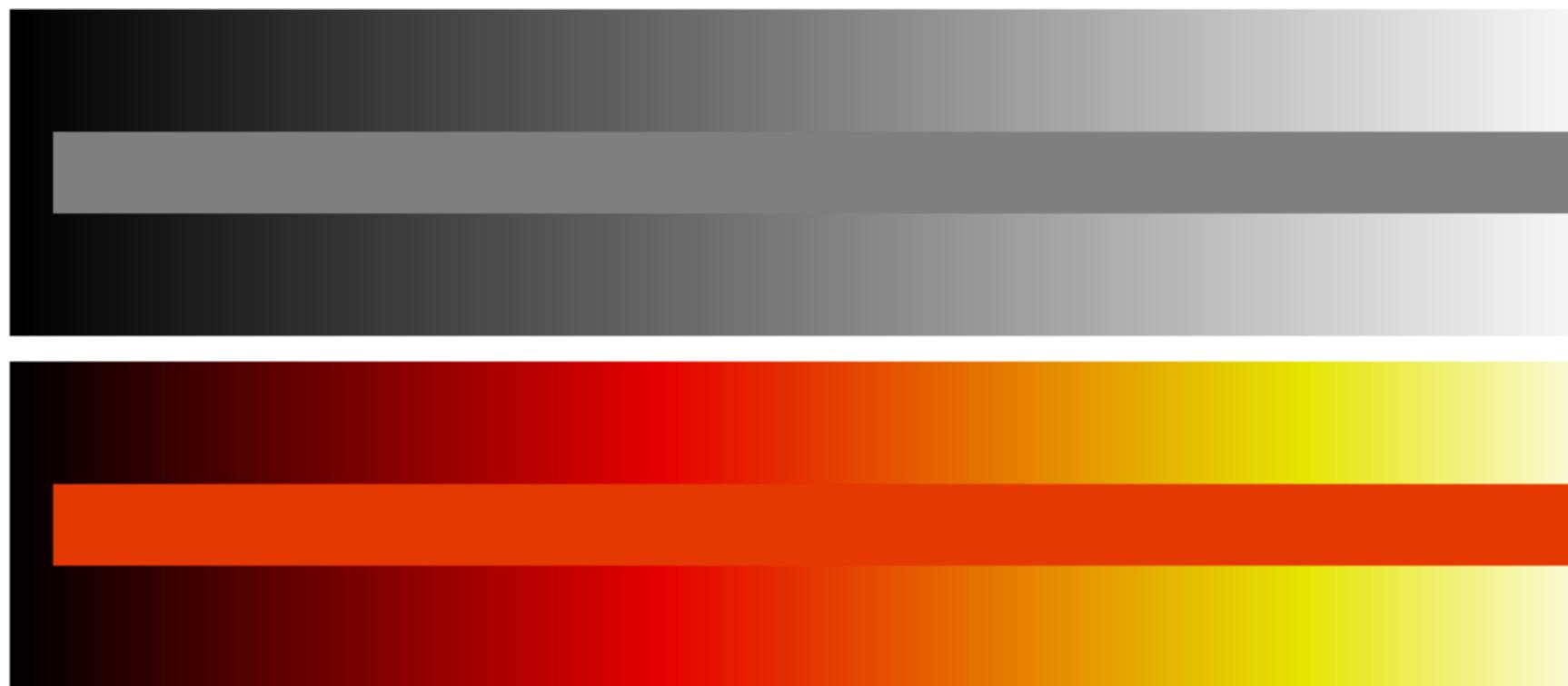
Why not use a rainbow?



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)?

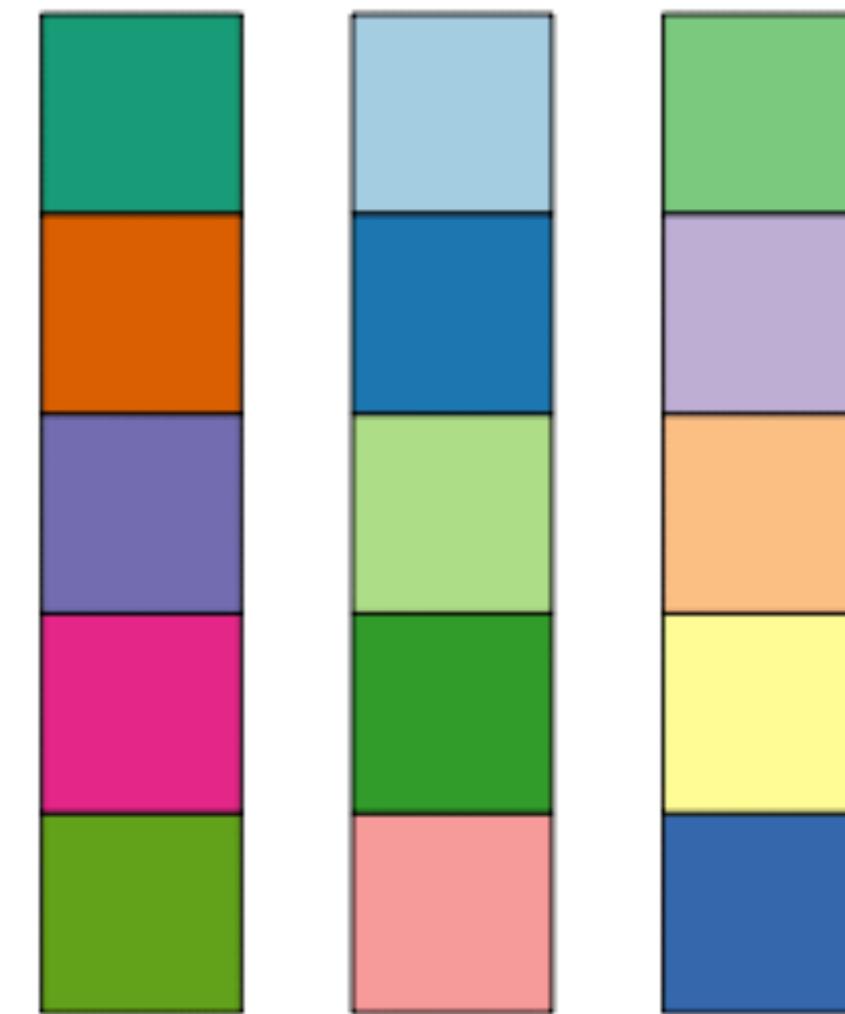


- Humans are more sensitive to changes in luminance
- Limits the number of colors represented, which can lead to lower-fidelity graphics

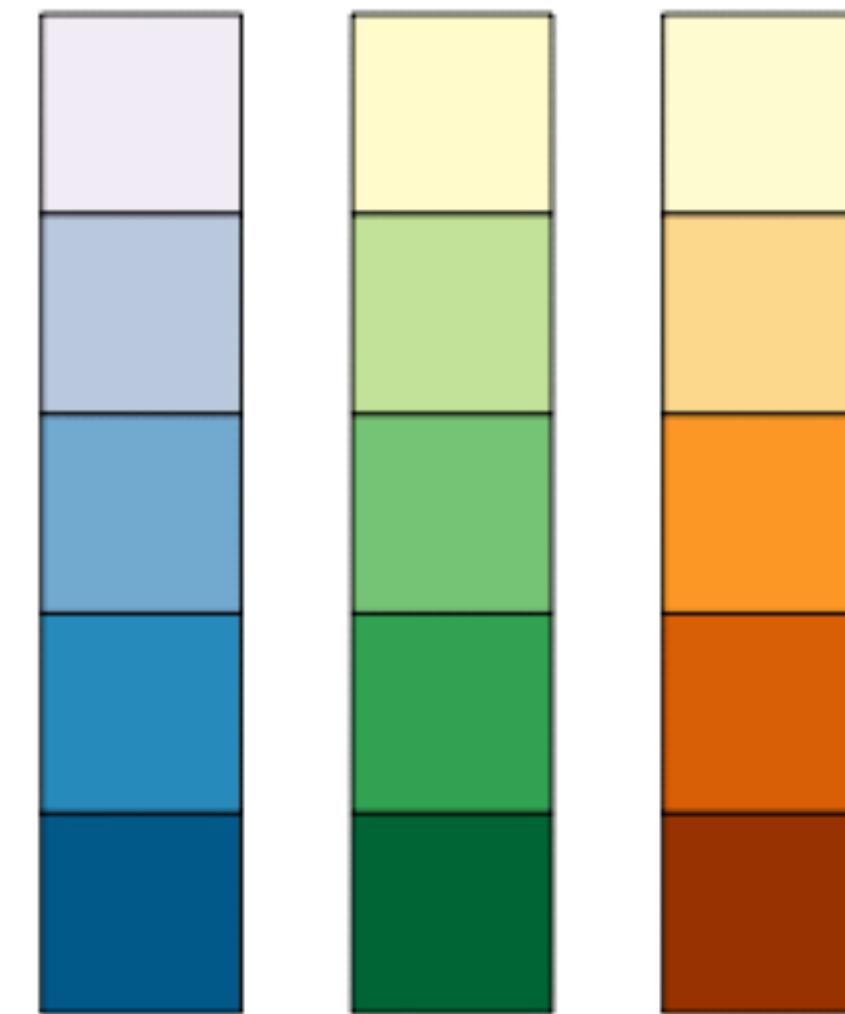
The right color scale **controls changes in hue** with shifts in saturation and luminance.

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

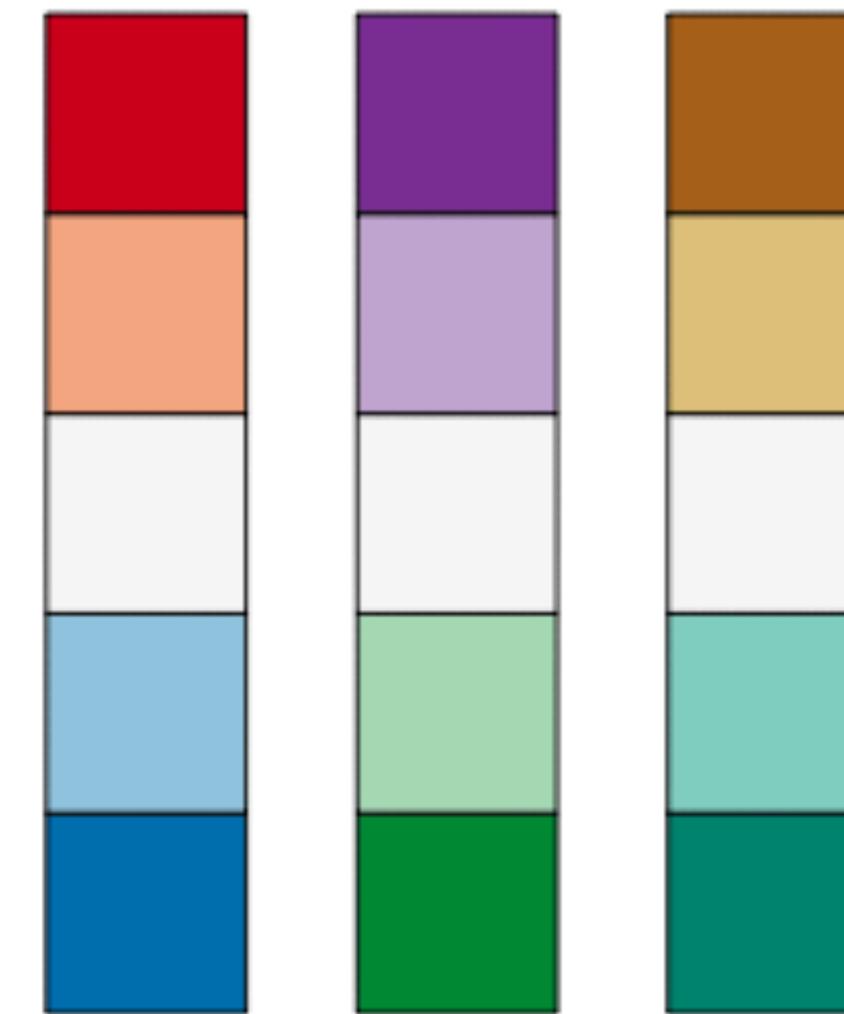
Cynthia Brewer — Color Scales



Qualitative

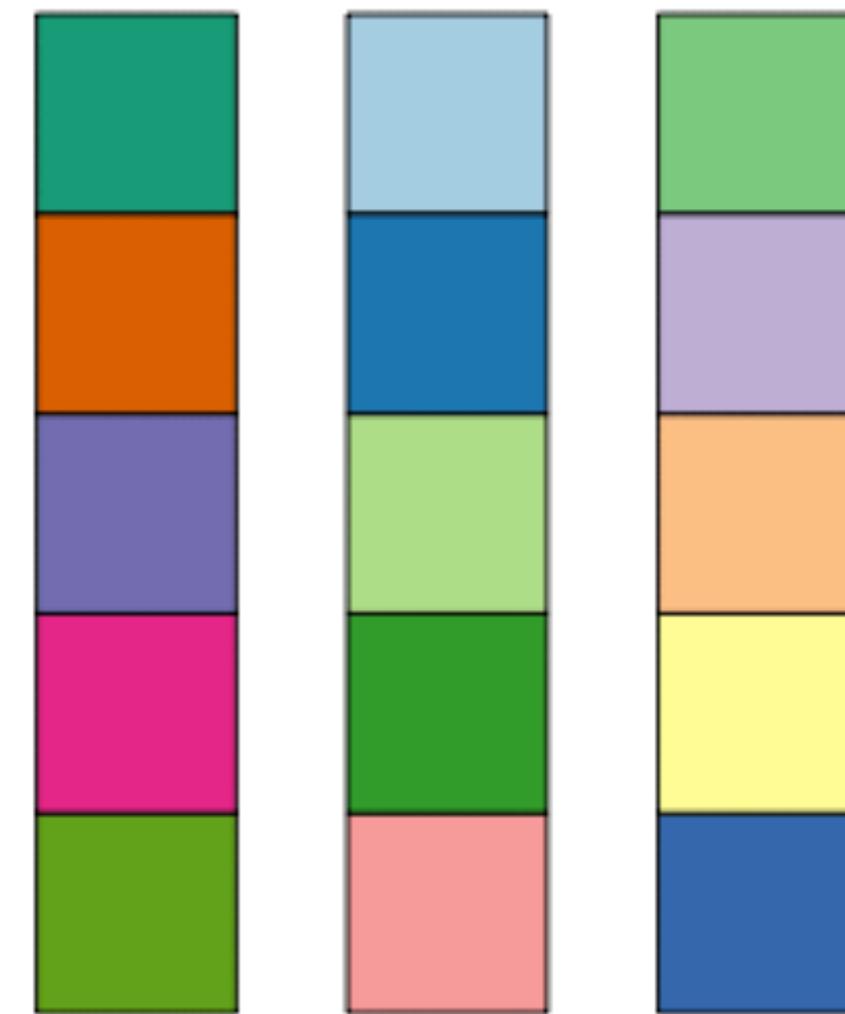


Sequential

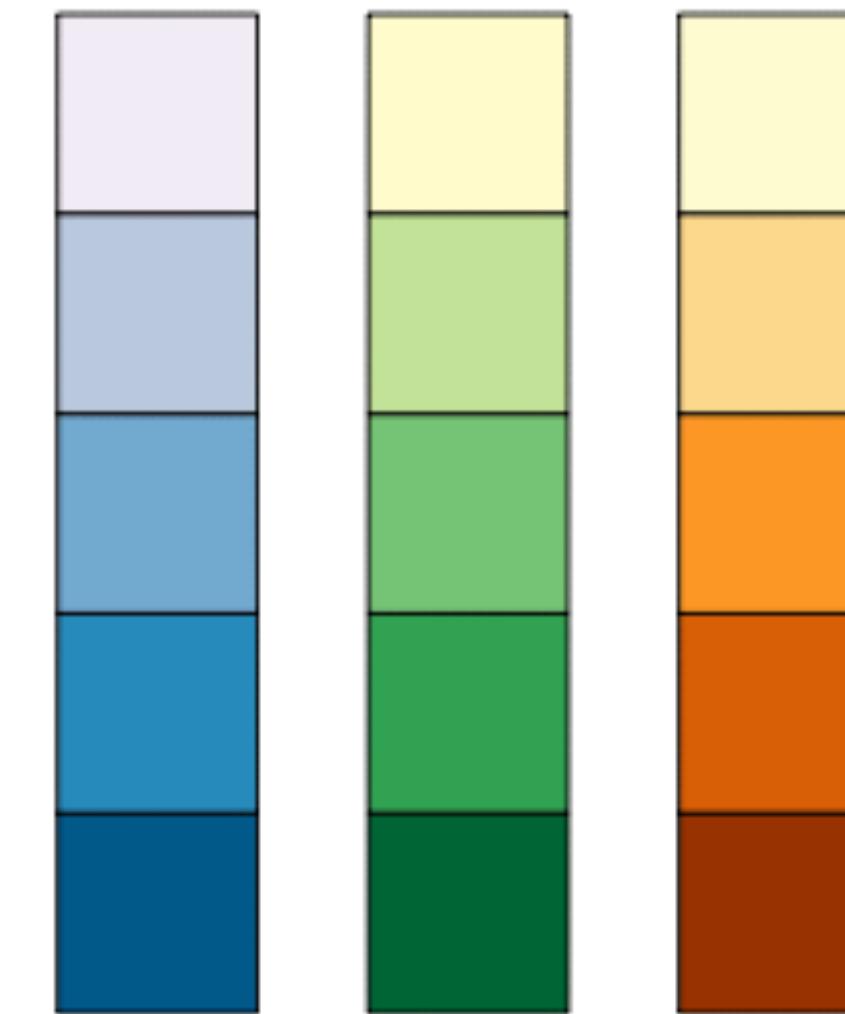


Diverging

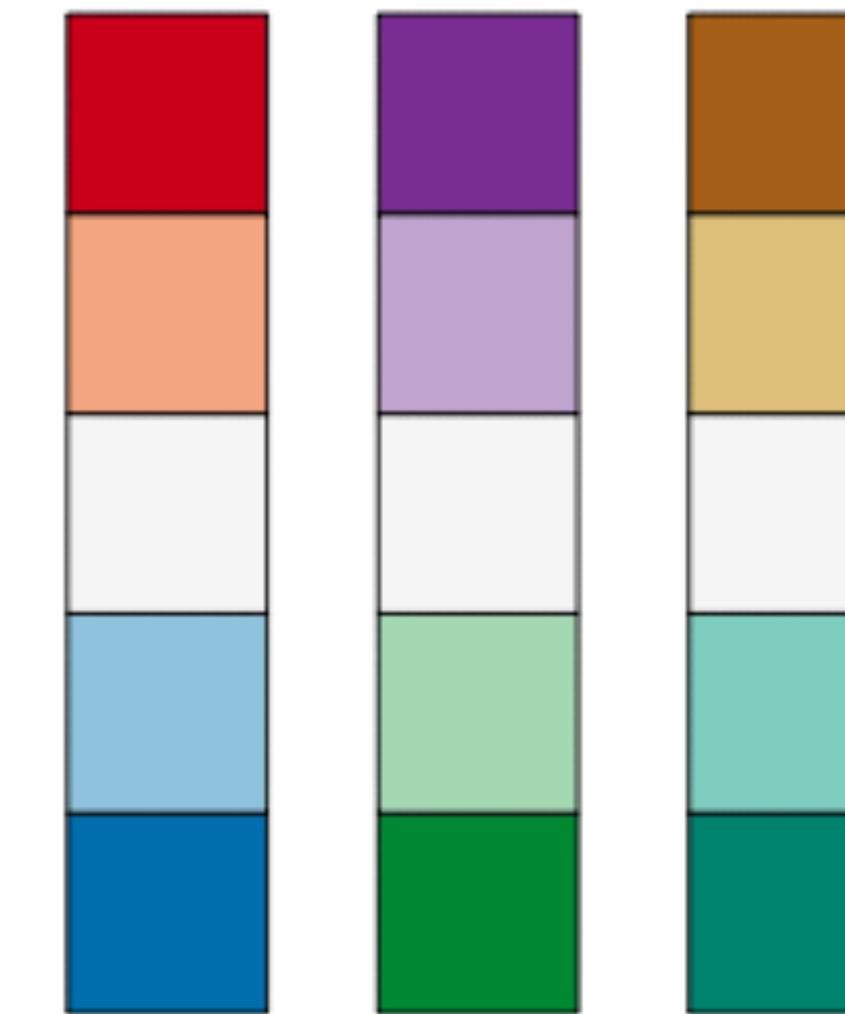
Cynthia Brewer — Color Scales



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.

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

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.

NOT IDEAL



BETTER

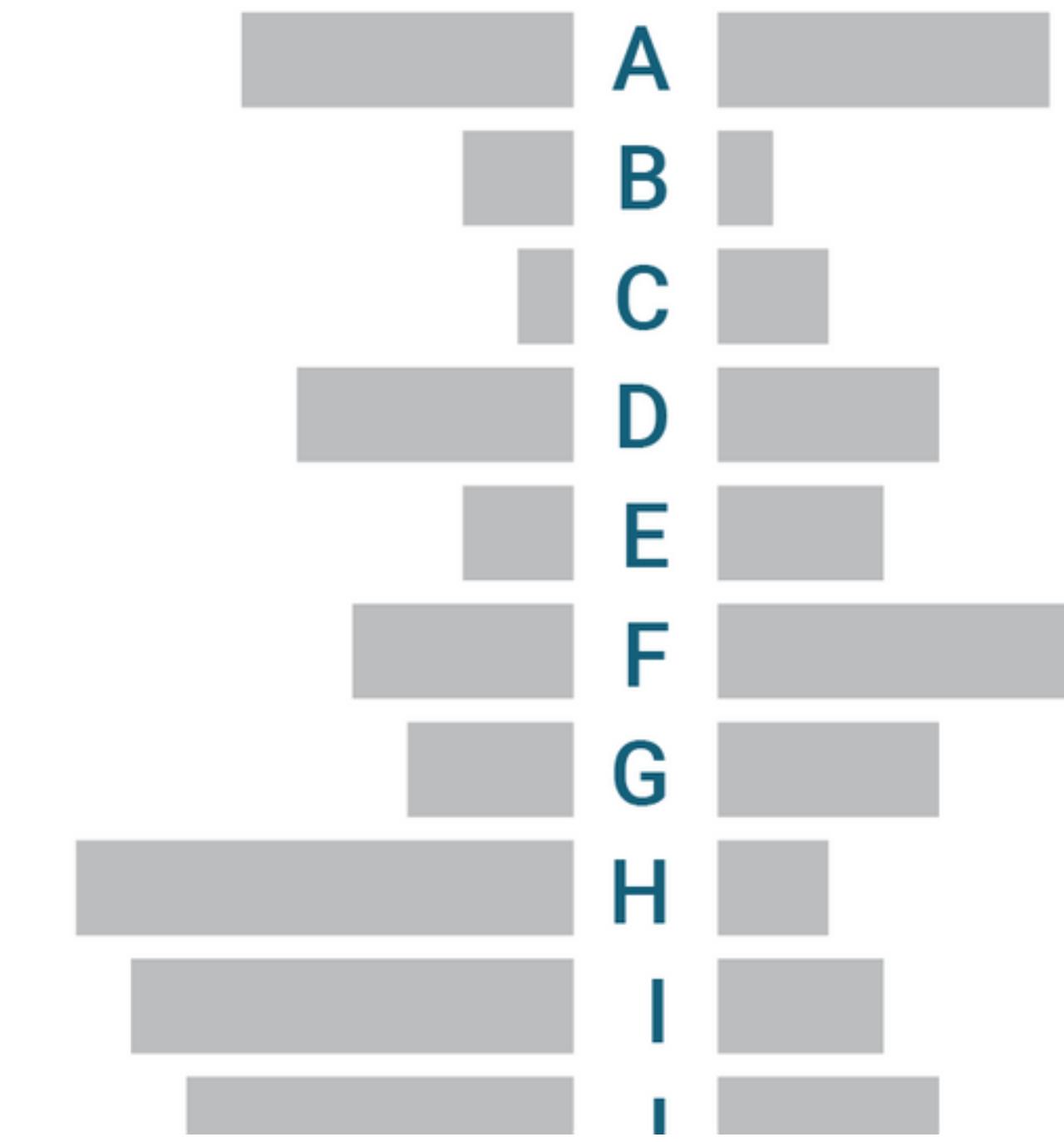


If you need more than **seven colors** in a chart, consider using another chart type or to group categories together.

NOT IDEAL



BETTER



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

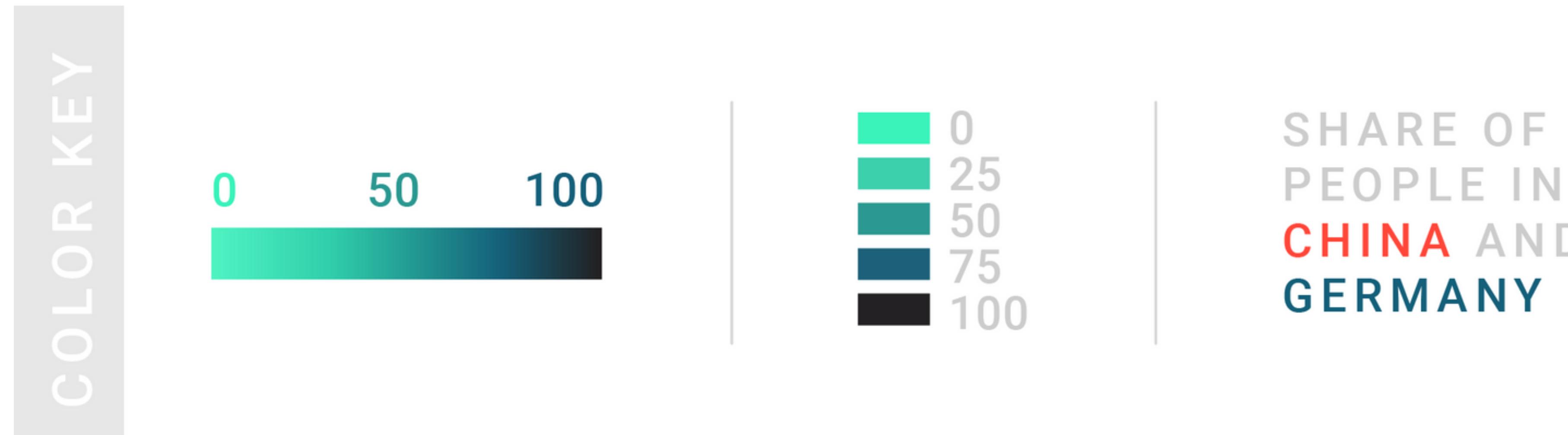
NOT IDEAL



BETTER



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

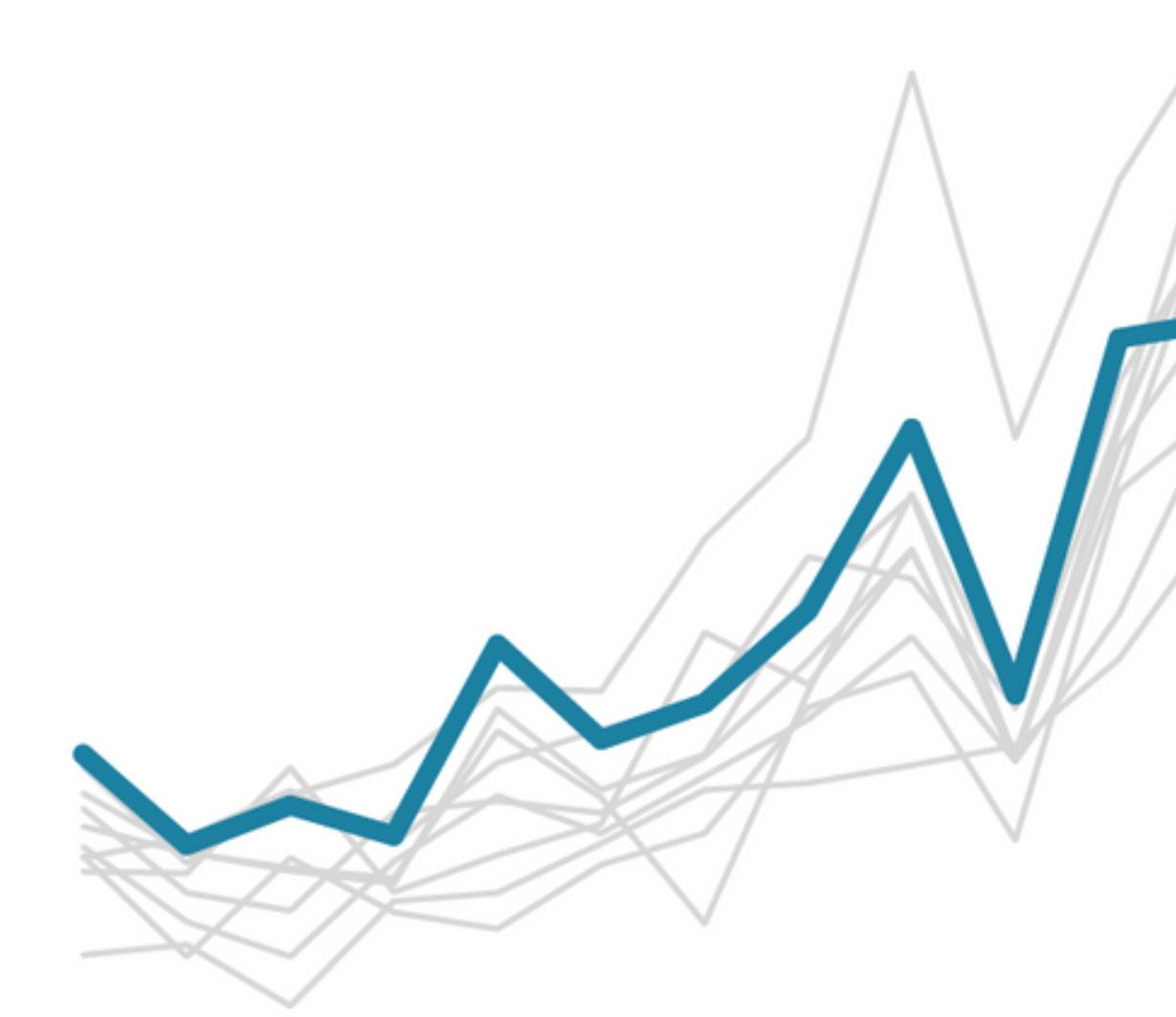


Consider the color grey as the **most important color** in visualization.

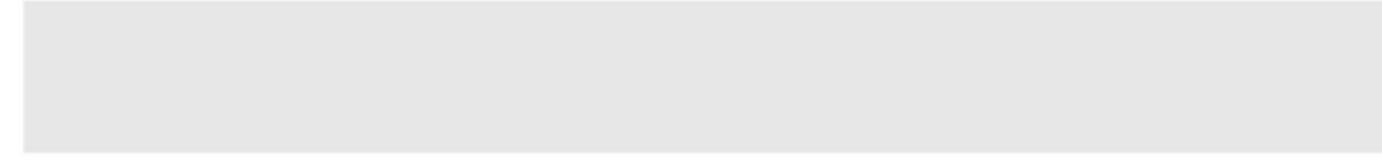
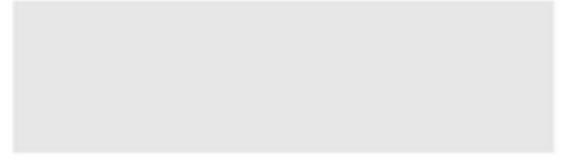
NOT IDEAL



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**
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4. Color **Exercise**
5. Critique

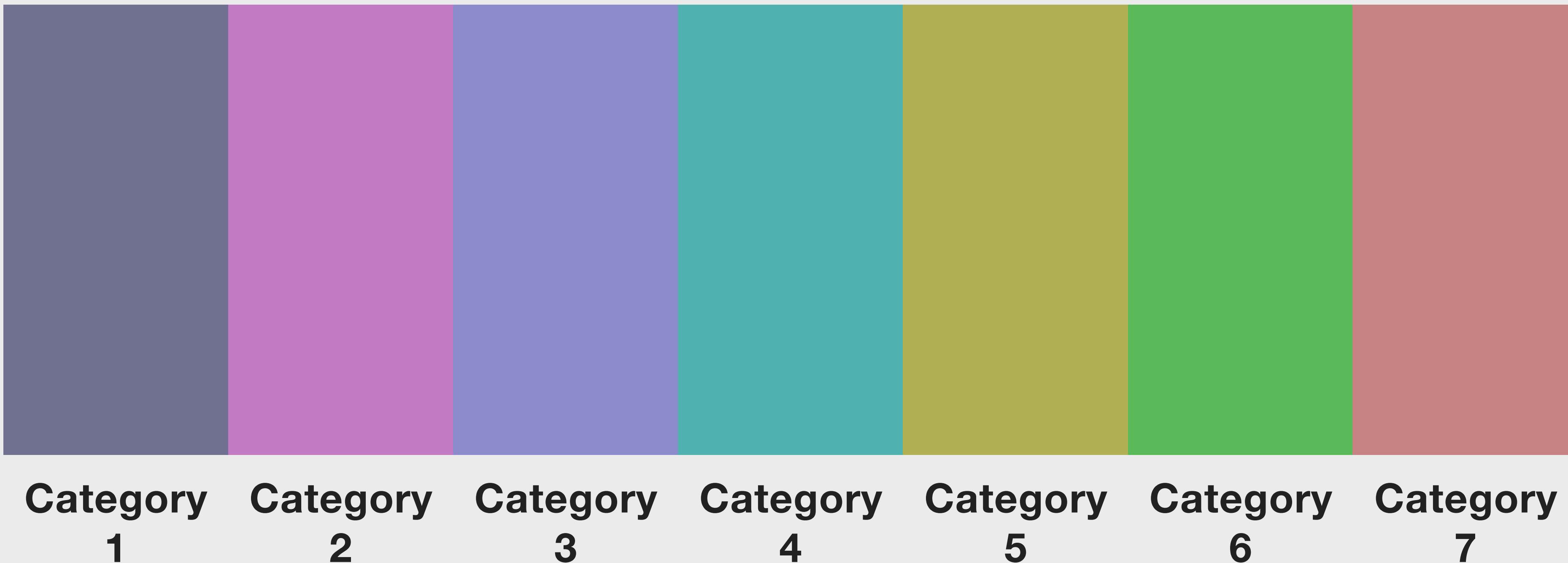
Challenge 1/5

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

Challenge 1/5

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



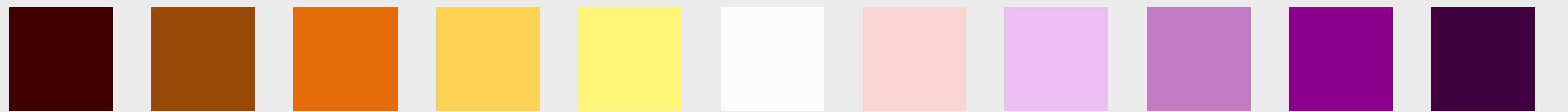


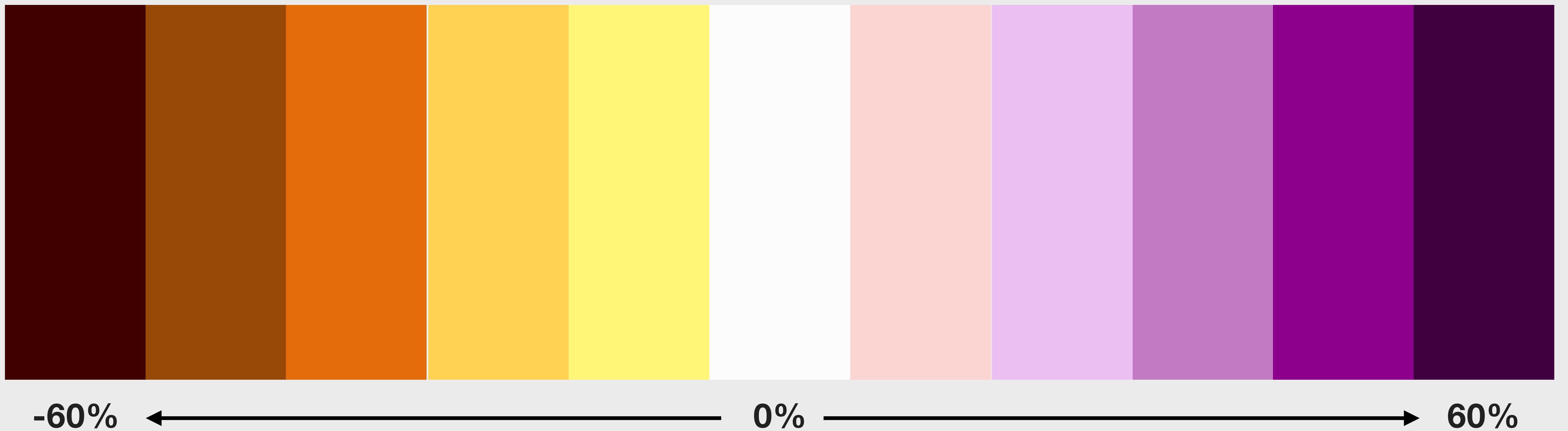
Challenge 2/5

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

Challenge 2/5

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





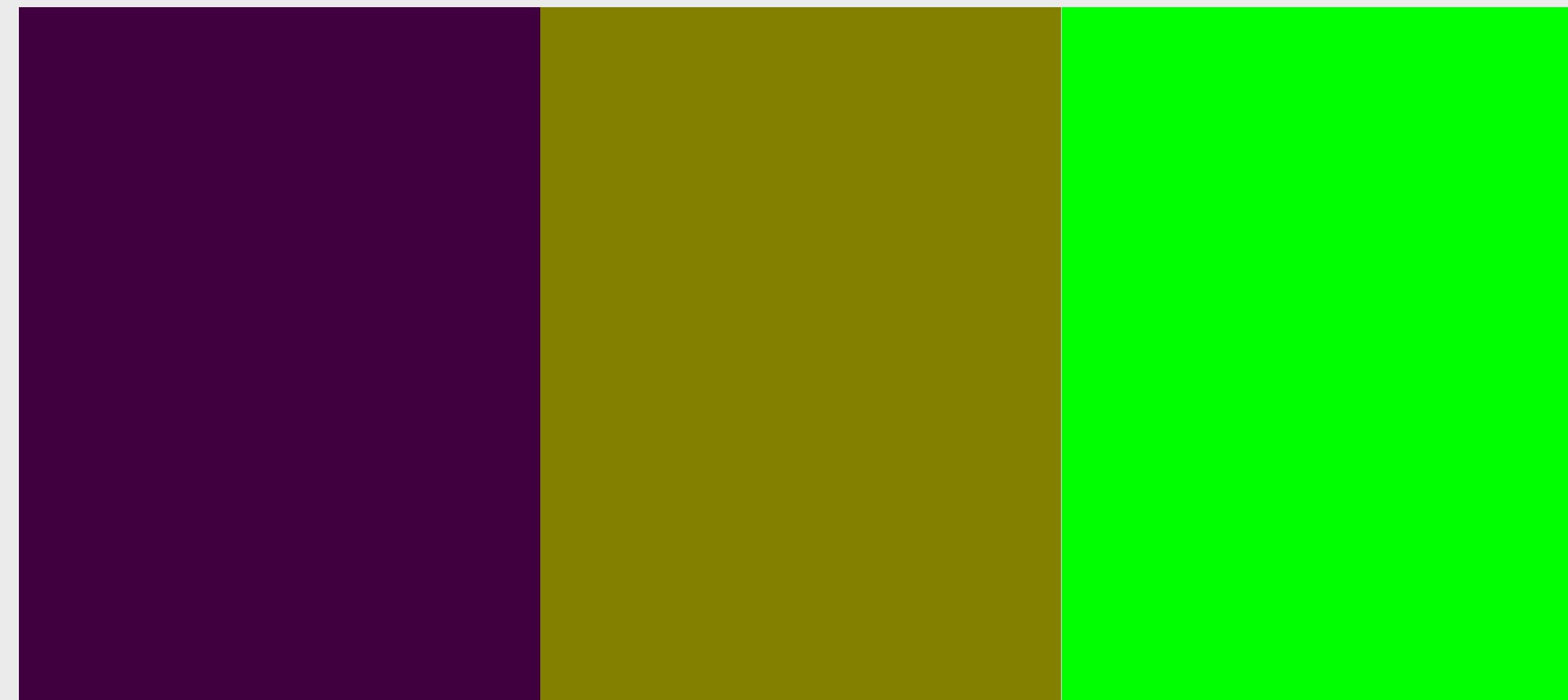
Challenge 3/5

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

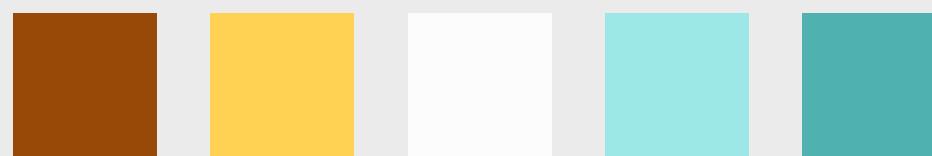
Highlight

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

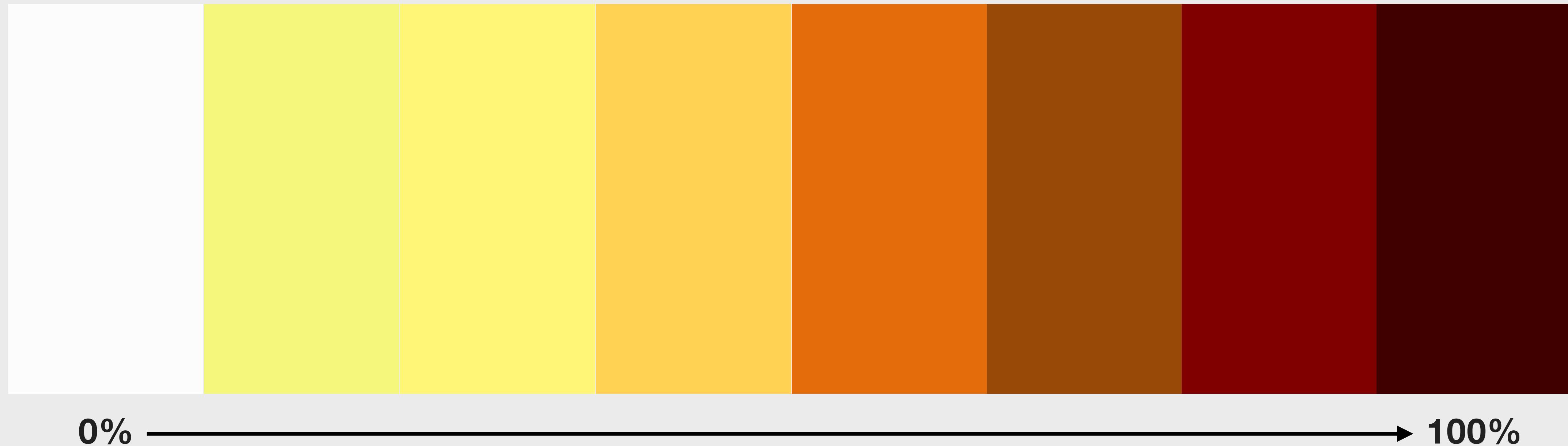
Challenge 5/5

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?

-

