

Color in Visualization

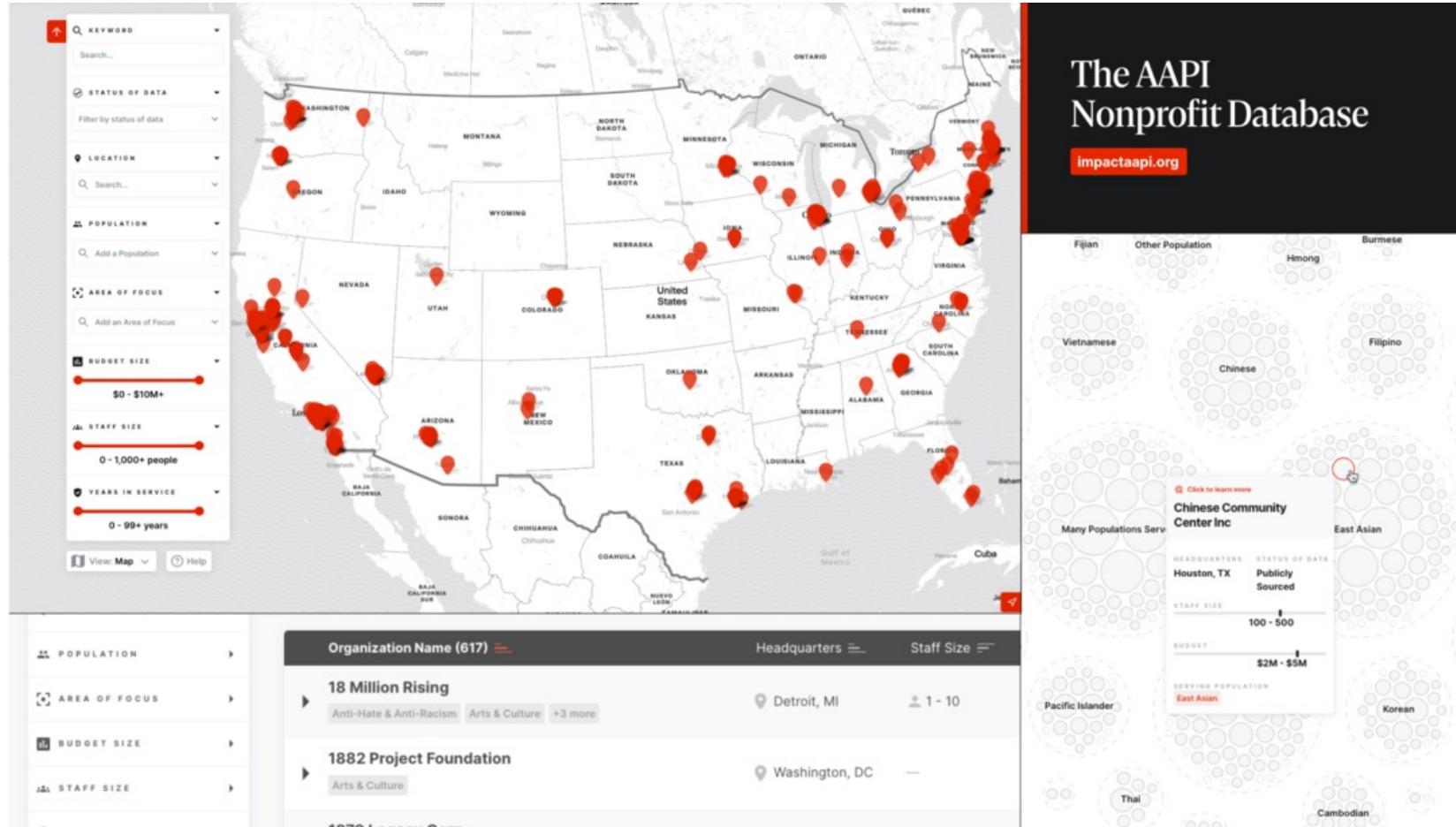
Laura Garrison, University of Bergen

laura.garrison@uib.no

ICTP Workshop 2023

Why use color in visualization?

To label something



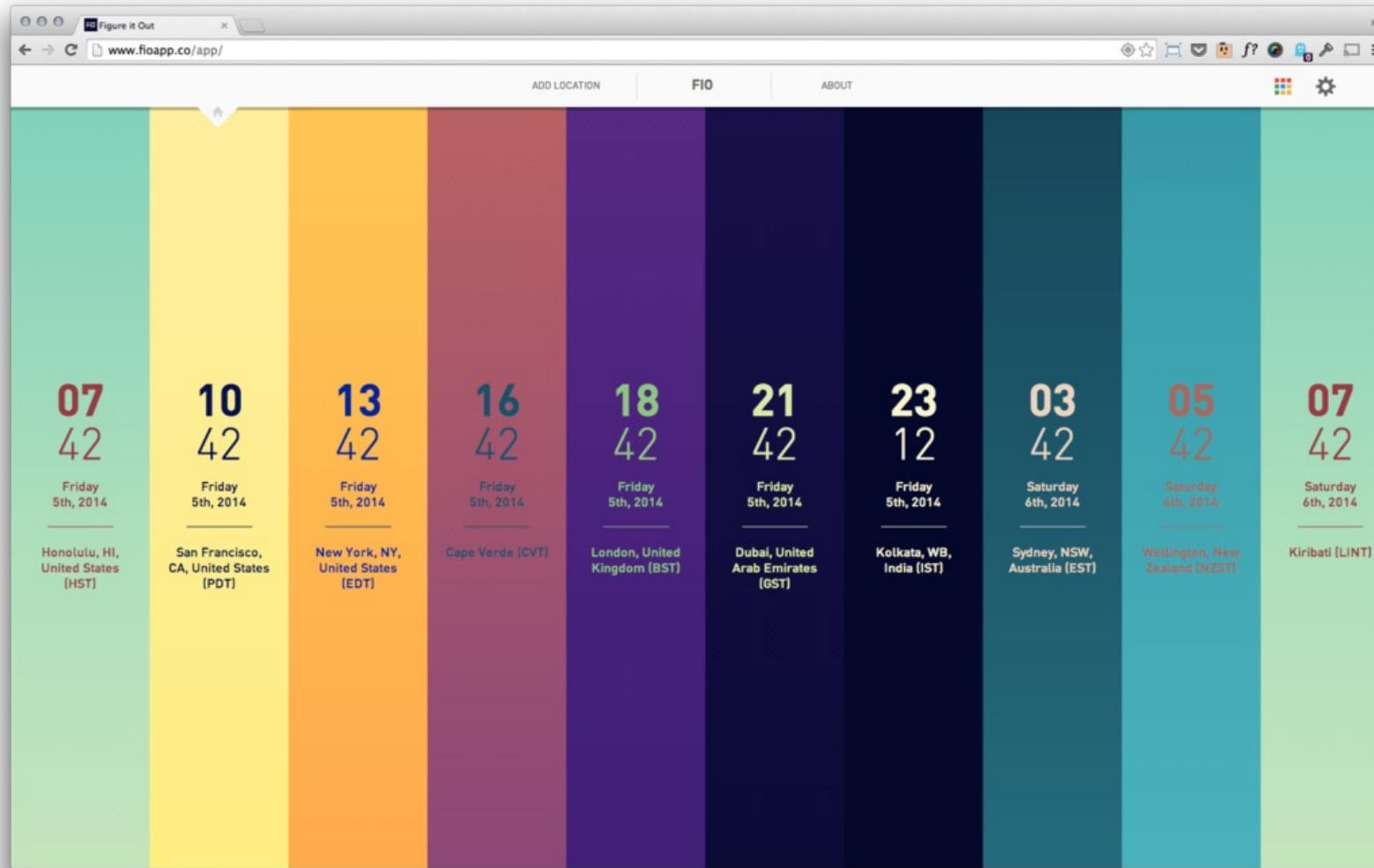
[The AAPI Nonprofit Database](#)

To measure something



The Blue Paradox

To represent something

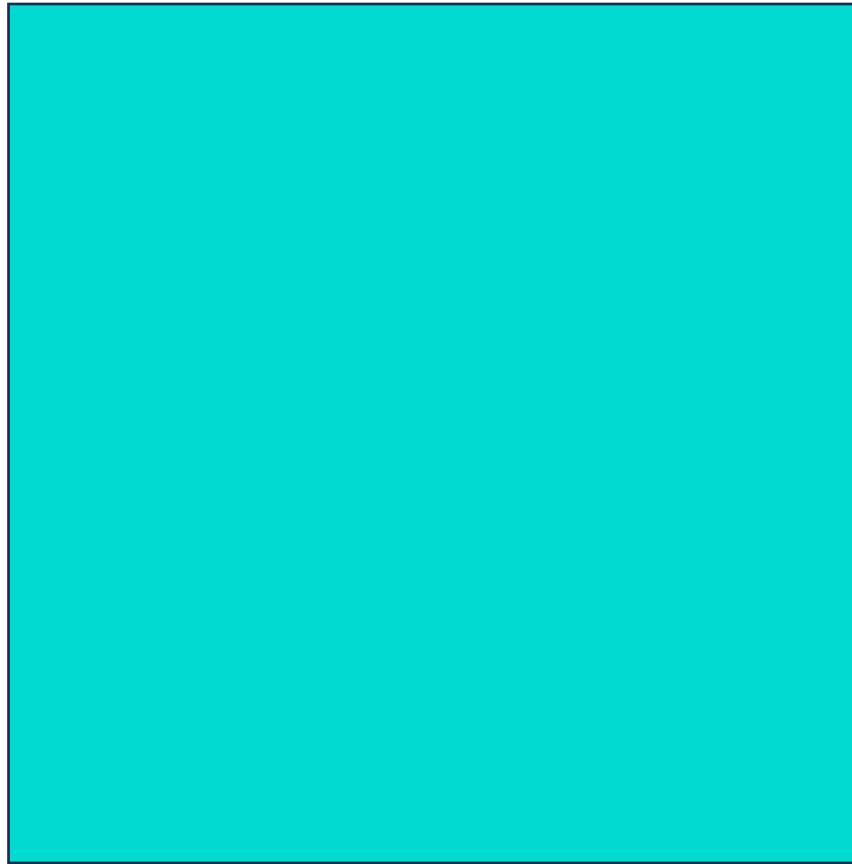


[Figure it out](#)

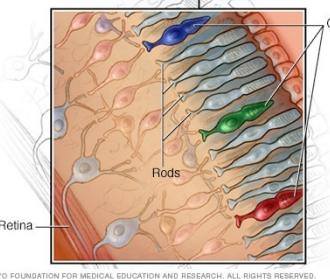
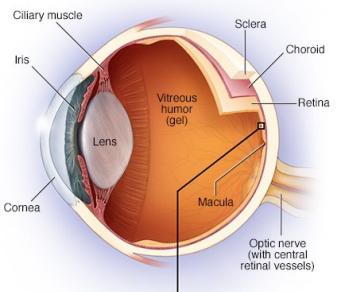
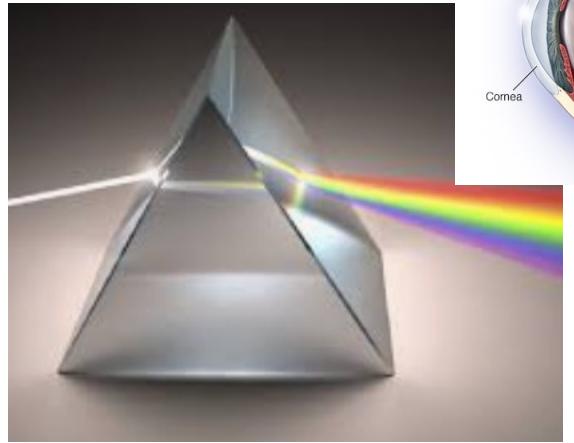
To decorate something



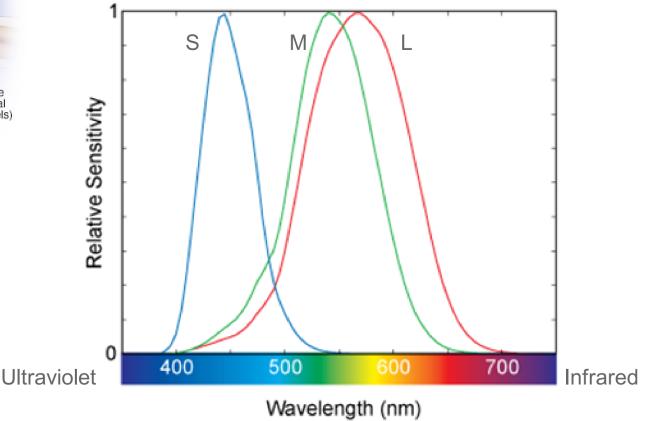
What color is this?



Seeing color



Three cones (S, M, L)



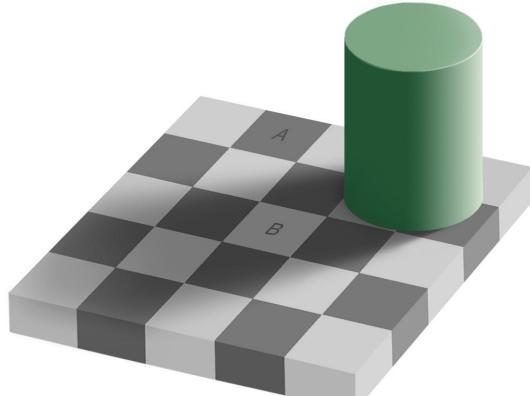
Light

Cone response

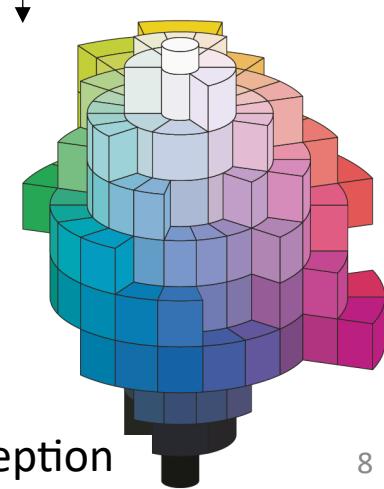
Opponent Signals

Teal!

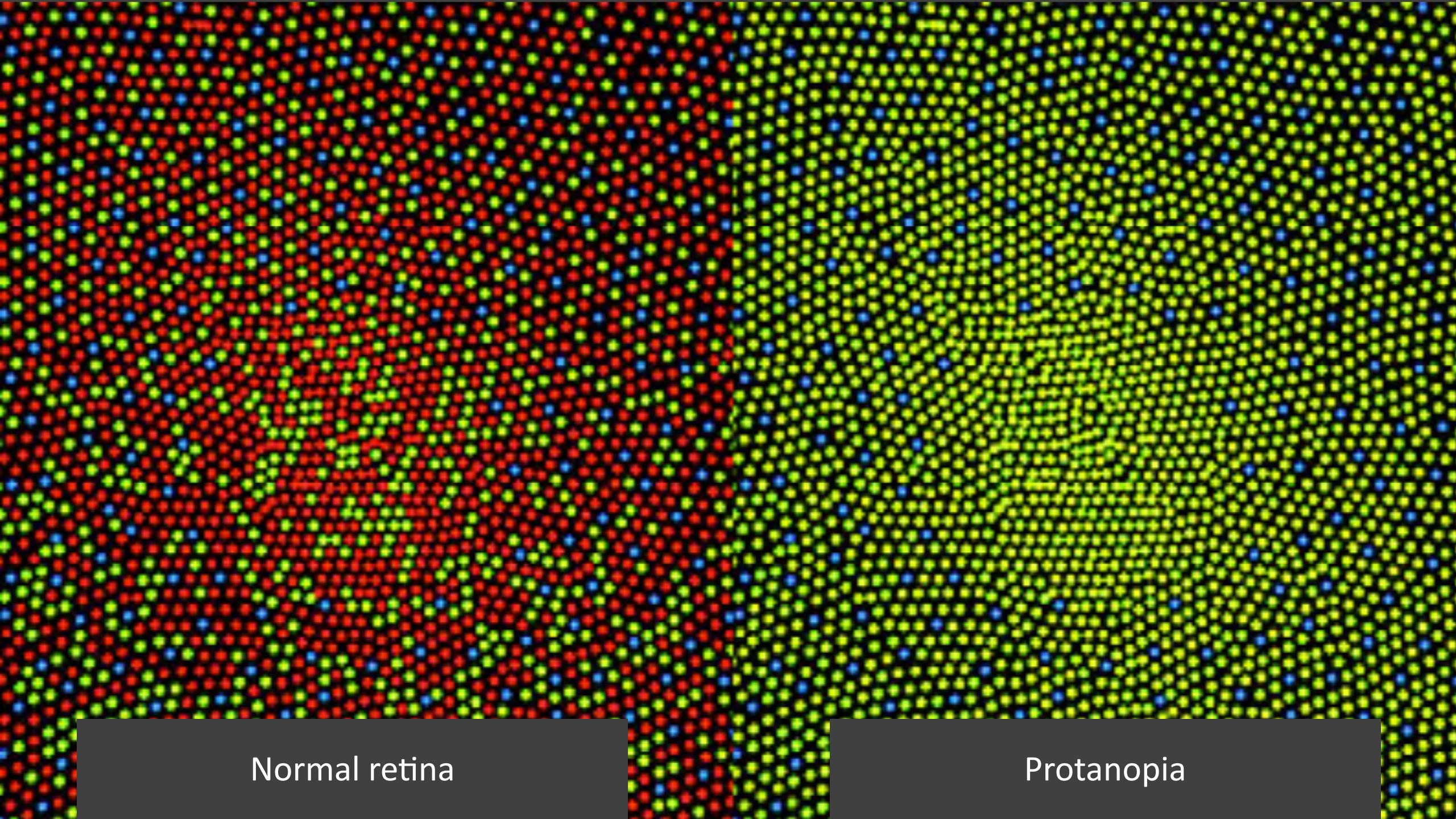
Color cognition



Color appearance

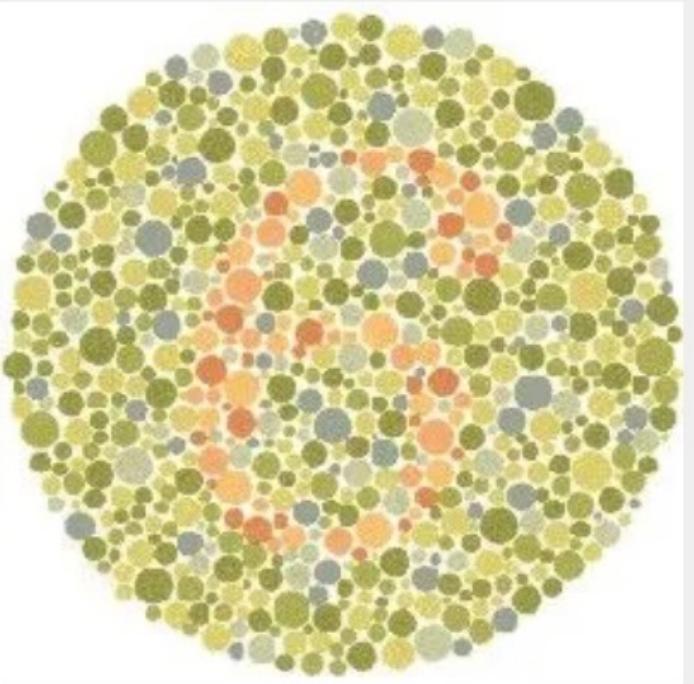


Color perception

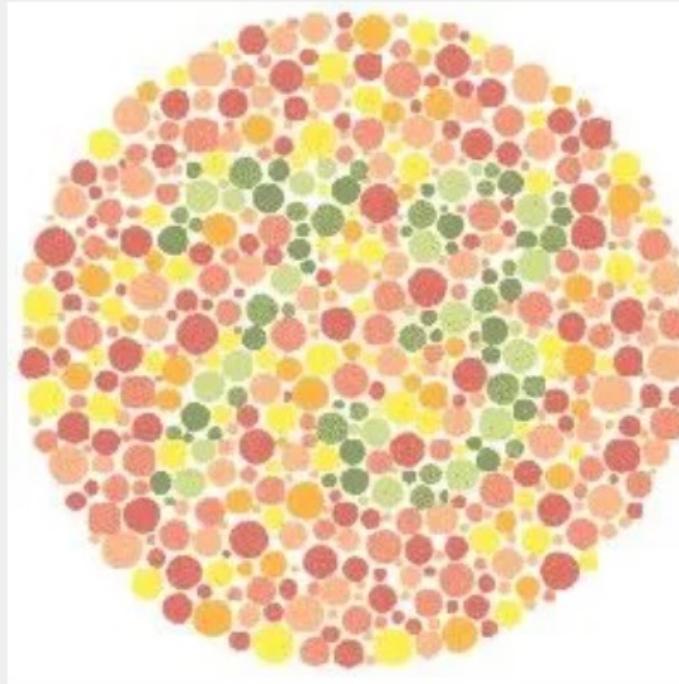


Normal retina

Protanopia



Enter The Number



Enter The Number

Color in Practice

Color systems

Reflective Materials, e.g. paper

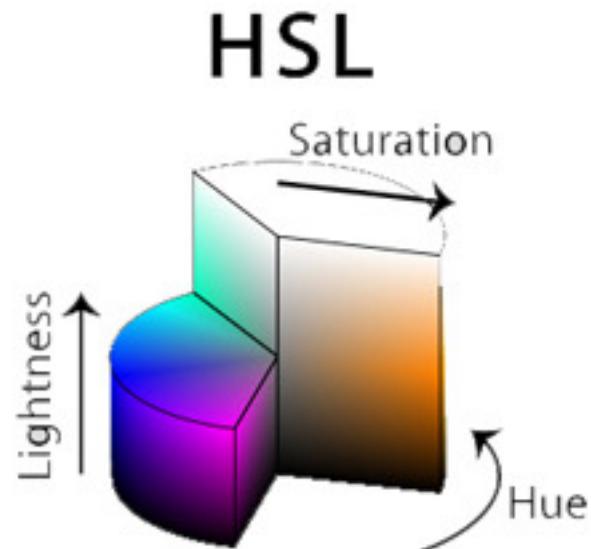


CMYK - Subtractive Color

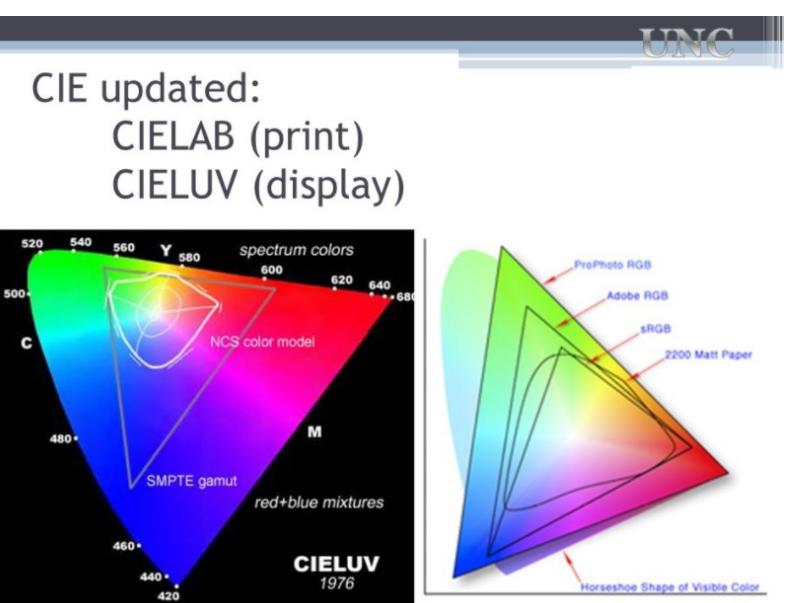
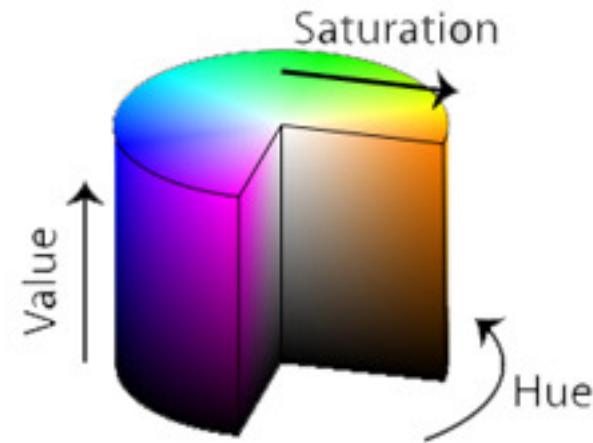


RGB - Additive Color

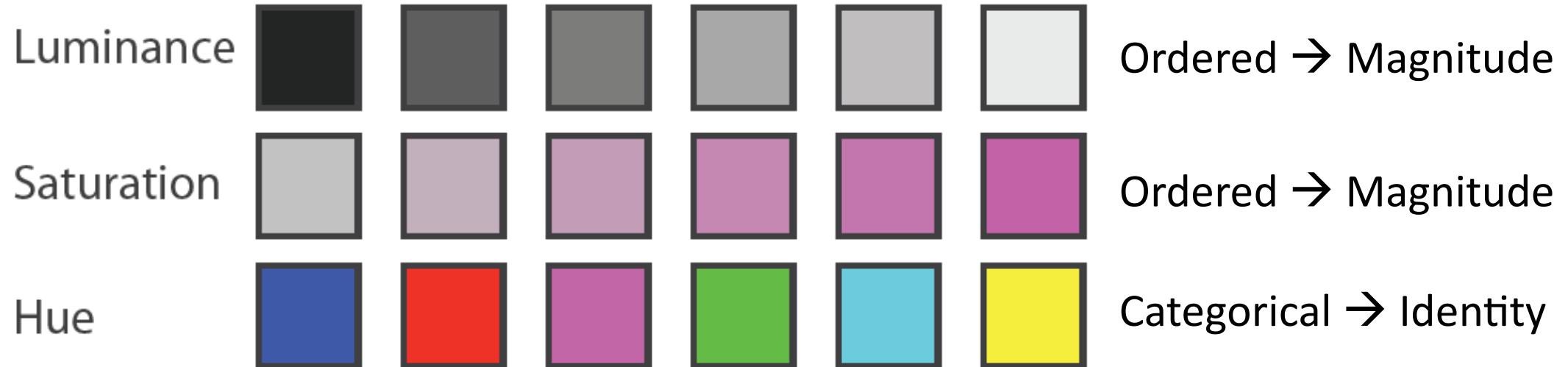
Emissive Materials, e.g., screens



HSV

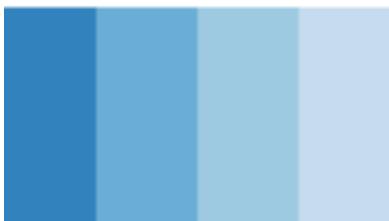


Three color channels



Categorical Encoding

- Ordered or unordered?
- Ordered => magnitude -> **S** or **L**
- Unordered => identity -> **H**
- Color separation with even spacing across color space

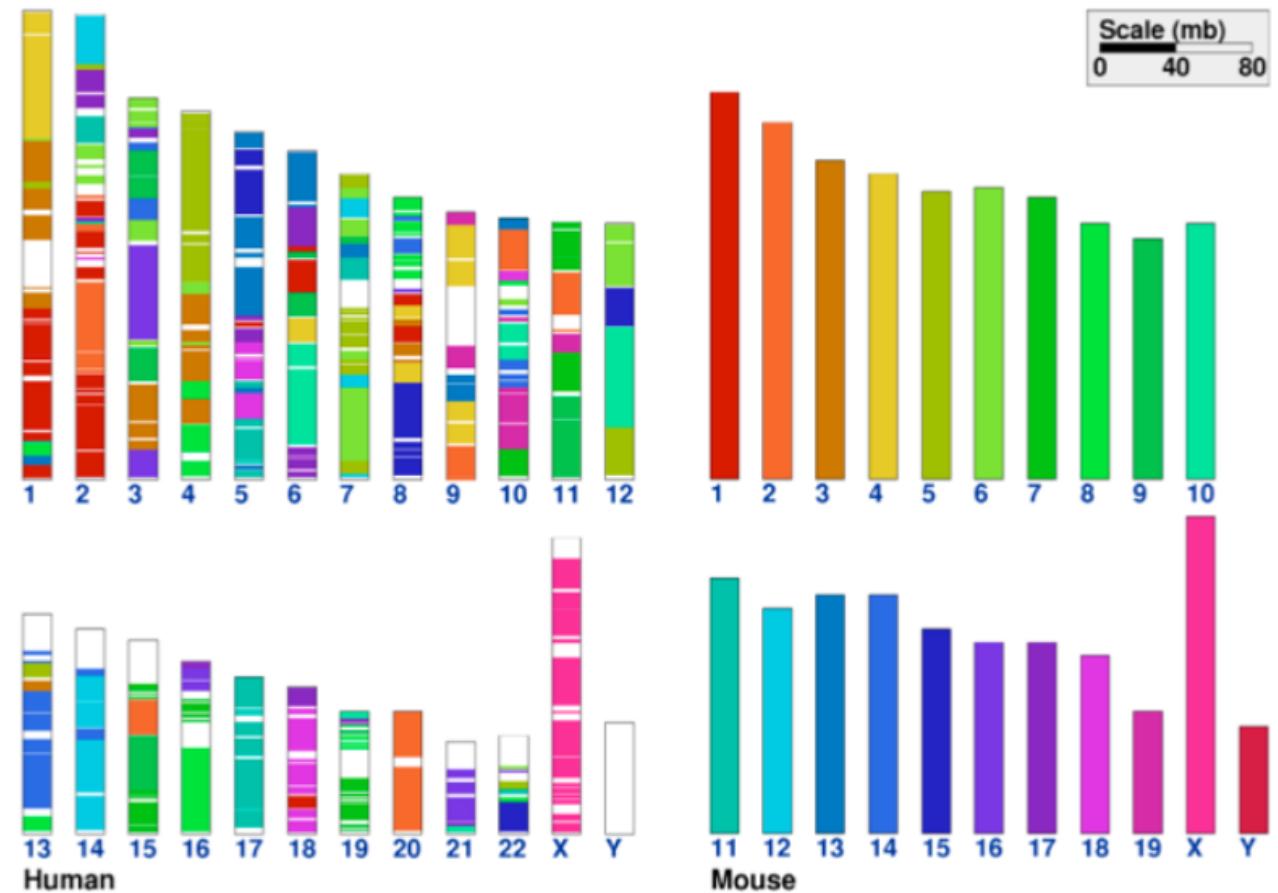


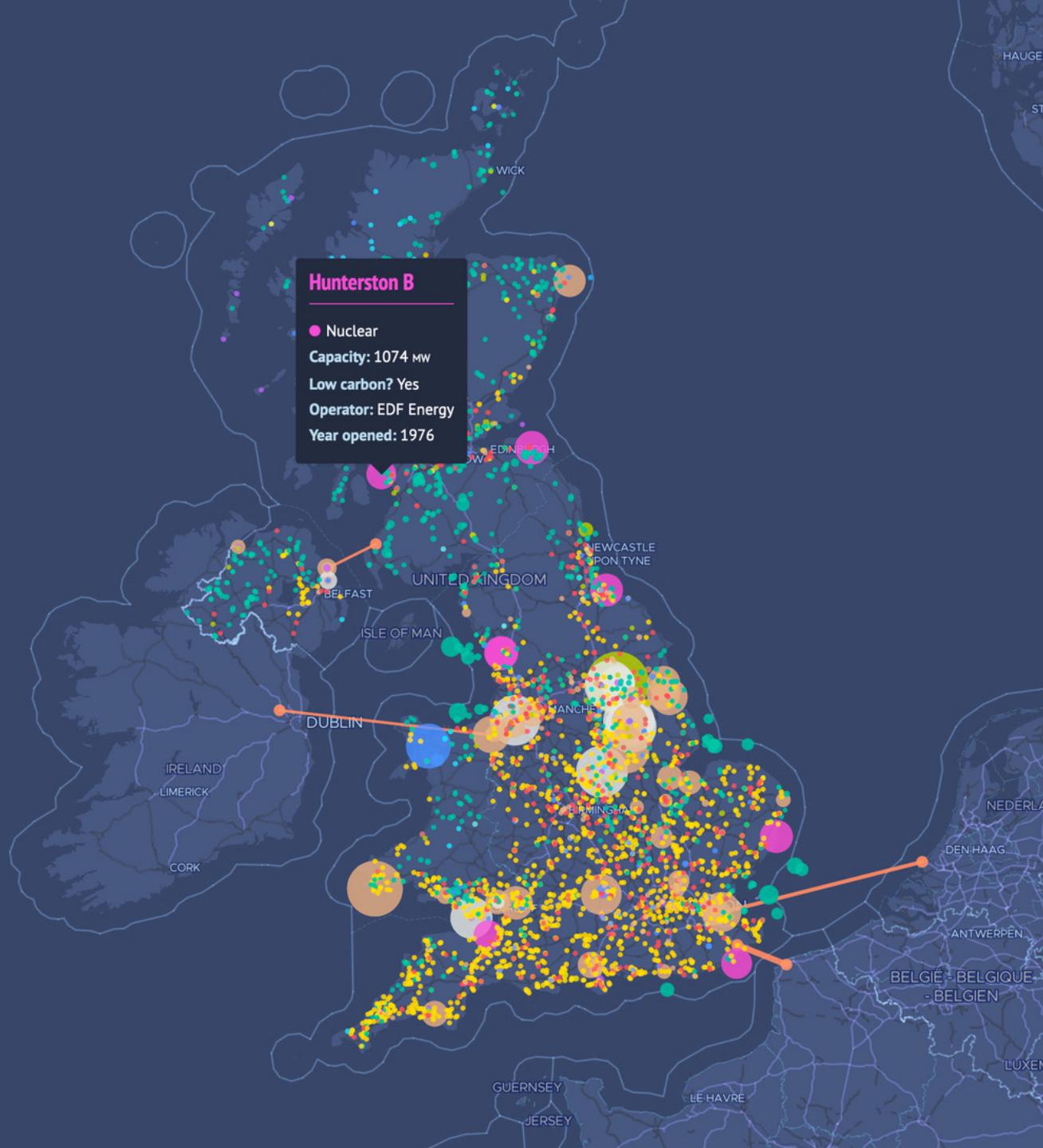
This is a discrete gradient – good for binned quant data, or ordered



How many colors?

- Limit to number of colors that are easily discriminable
- Ideally – 3-9 steps
 - Limit mappings to hold in memory (cognition)
 - Simultaneous contrast (perceptual overload)



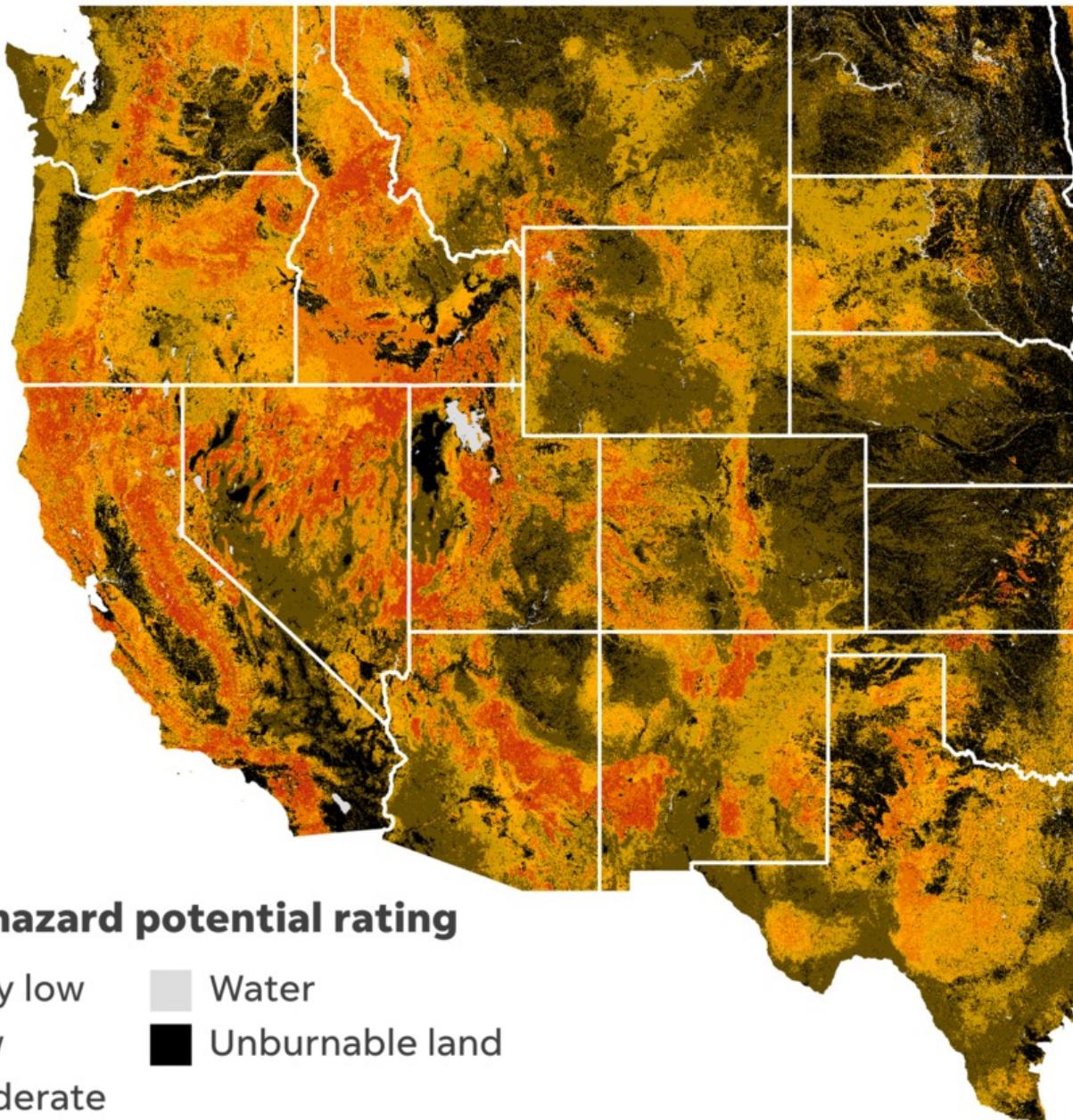


How The UK Transformed Its Electricity Supply In Just A Decade

by Carbon Brief

Information is Beautiful 2023
Award Short list

[link](#)



Wildfire hazard potential rating

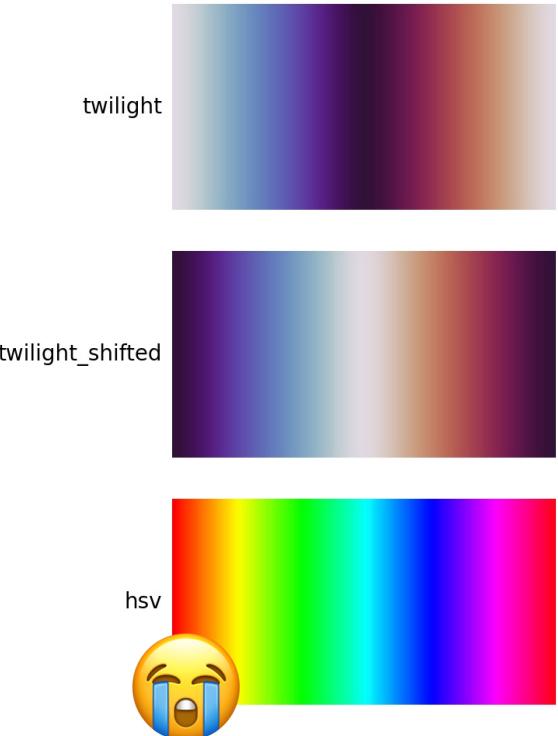
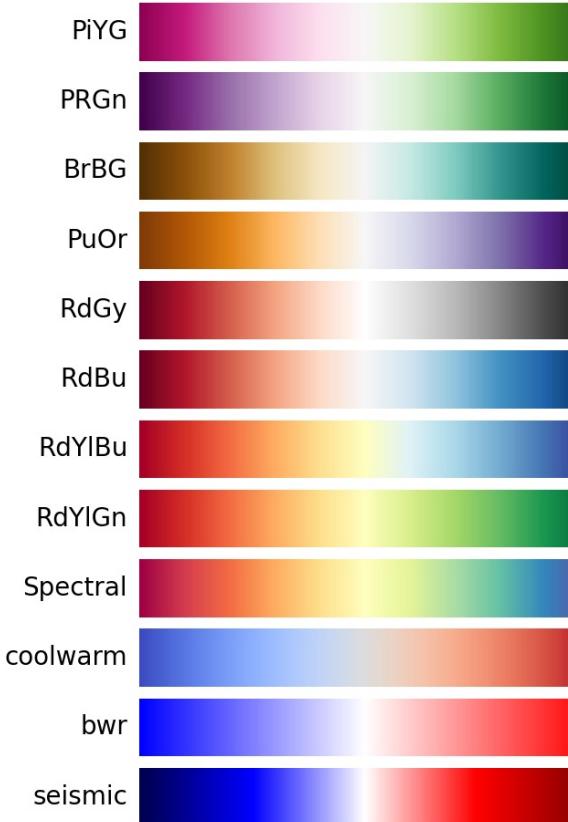
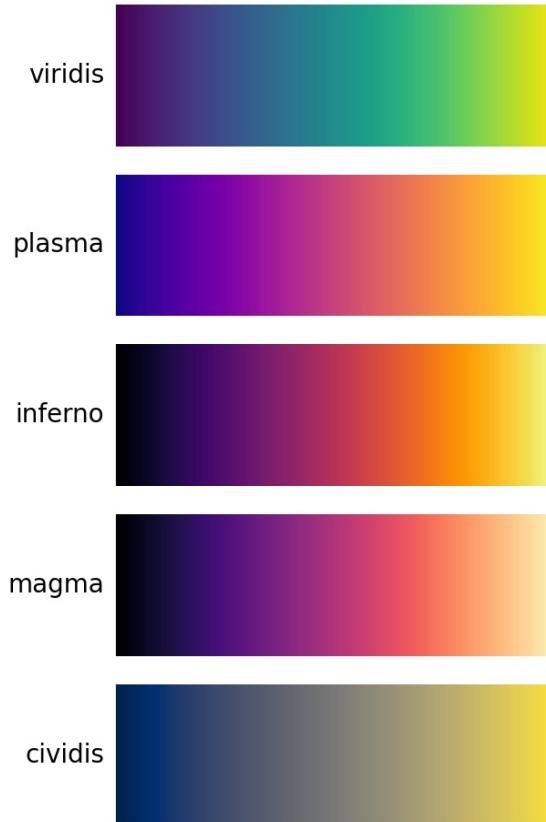
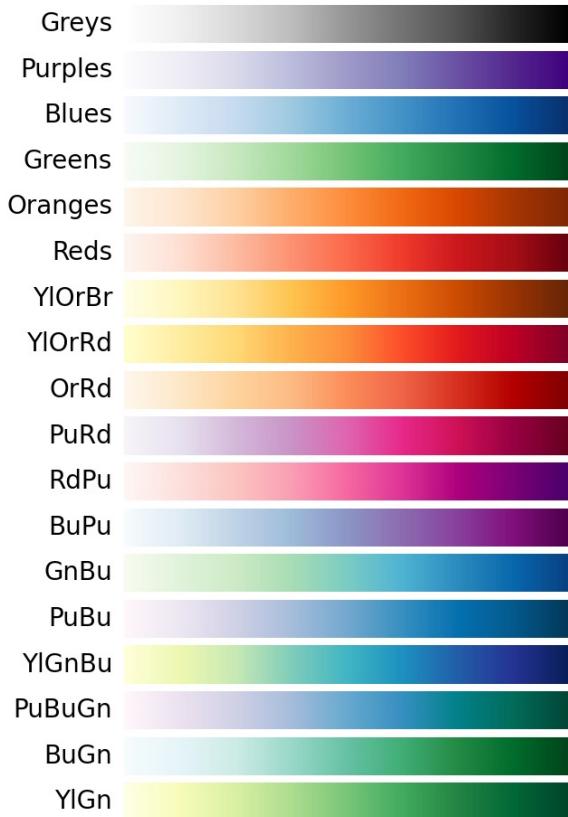
	1 - Very low
	Water
	Unburnable land
	2 - Low
	3 - Moderate
	4 - High
	5 - Very high

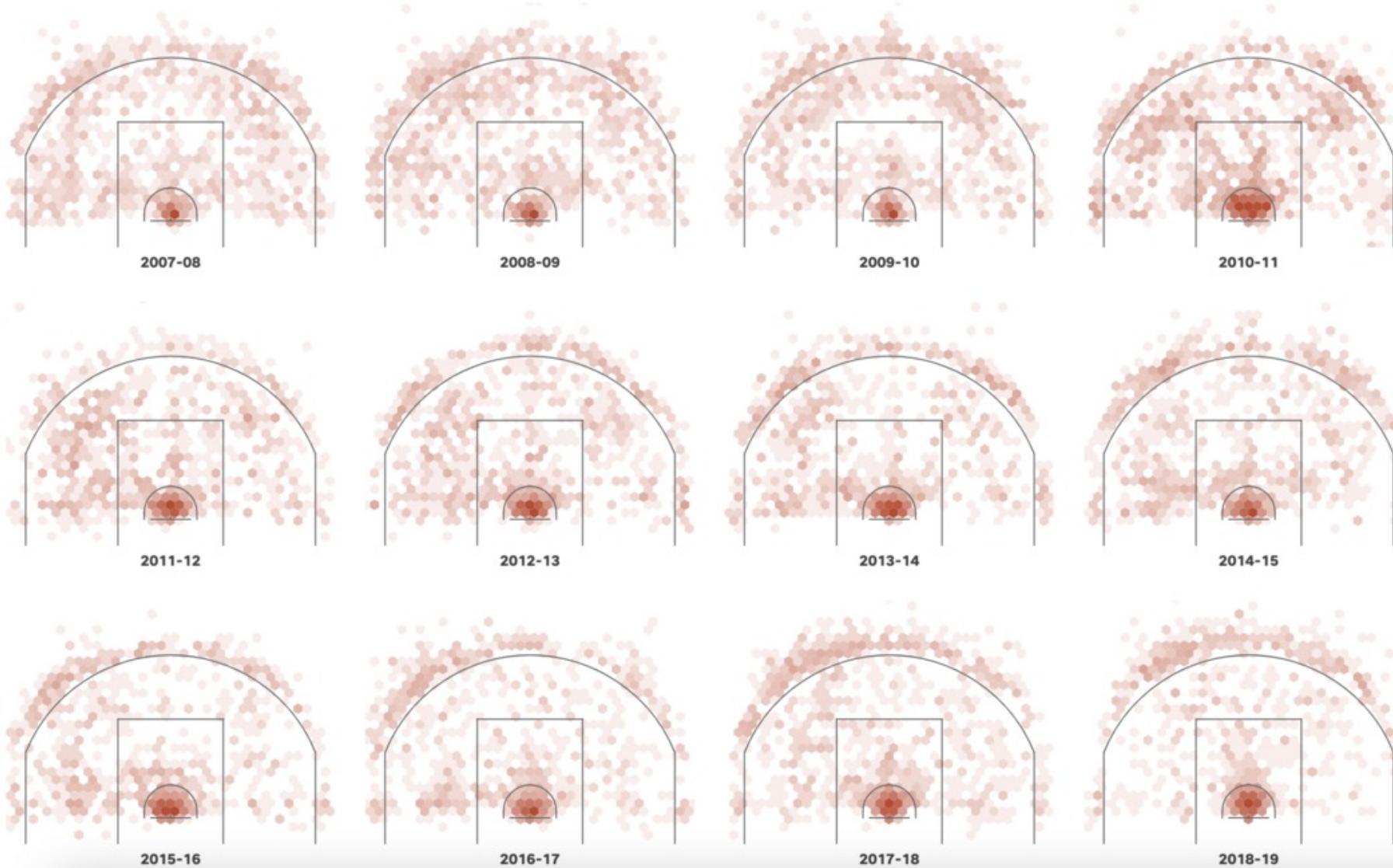
Ahead Of The Fire
By USA today

[link](#)

Quantitative Encoding

- Gradients
- Sequential, diverging, cyclic



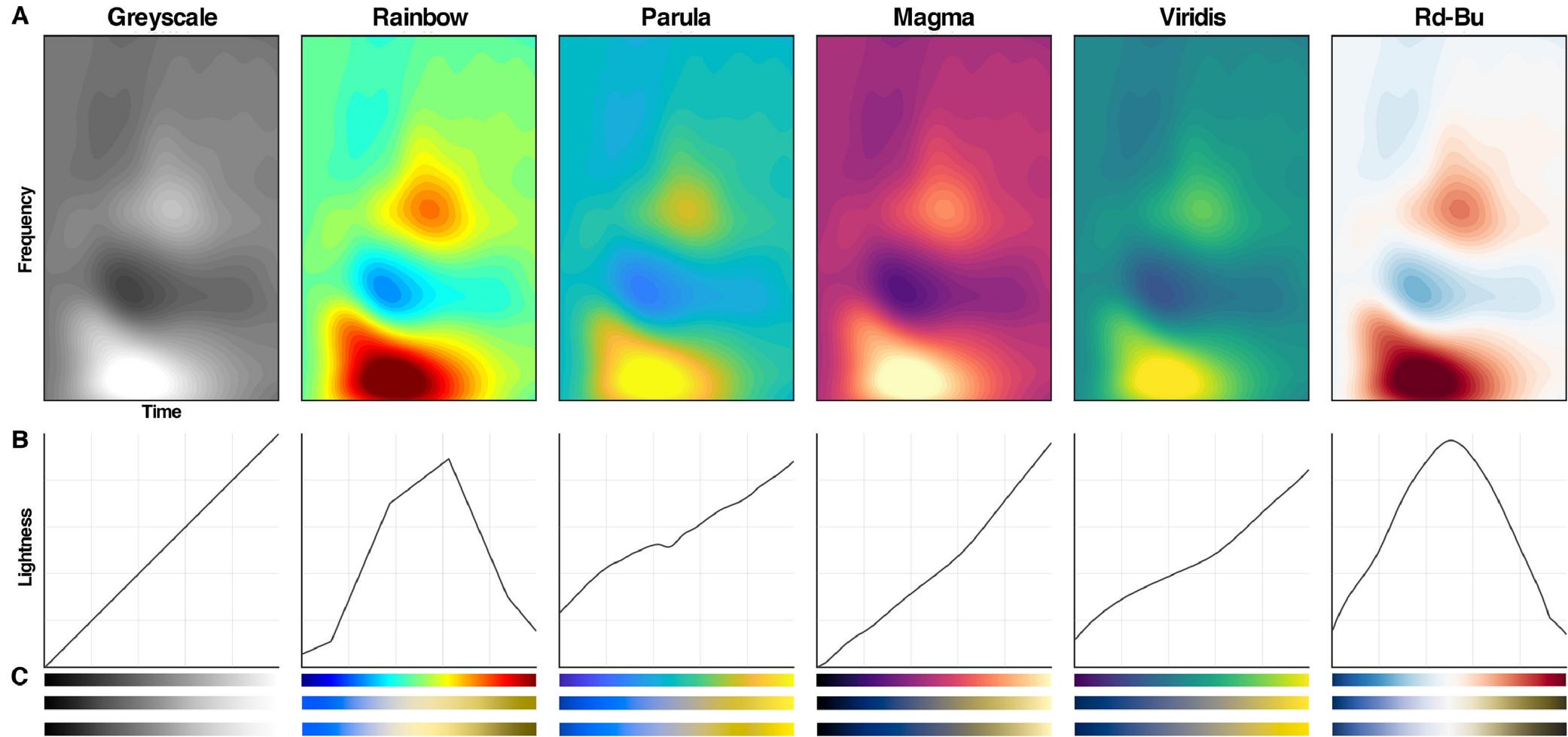


LeBron James has captured the scoring title. We visualized every shot.
by USA Today

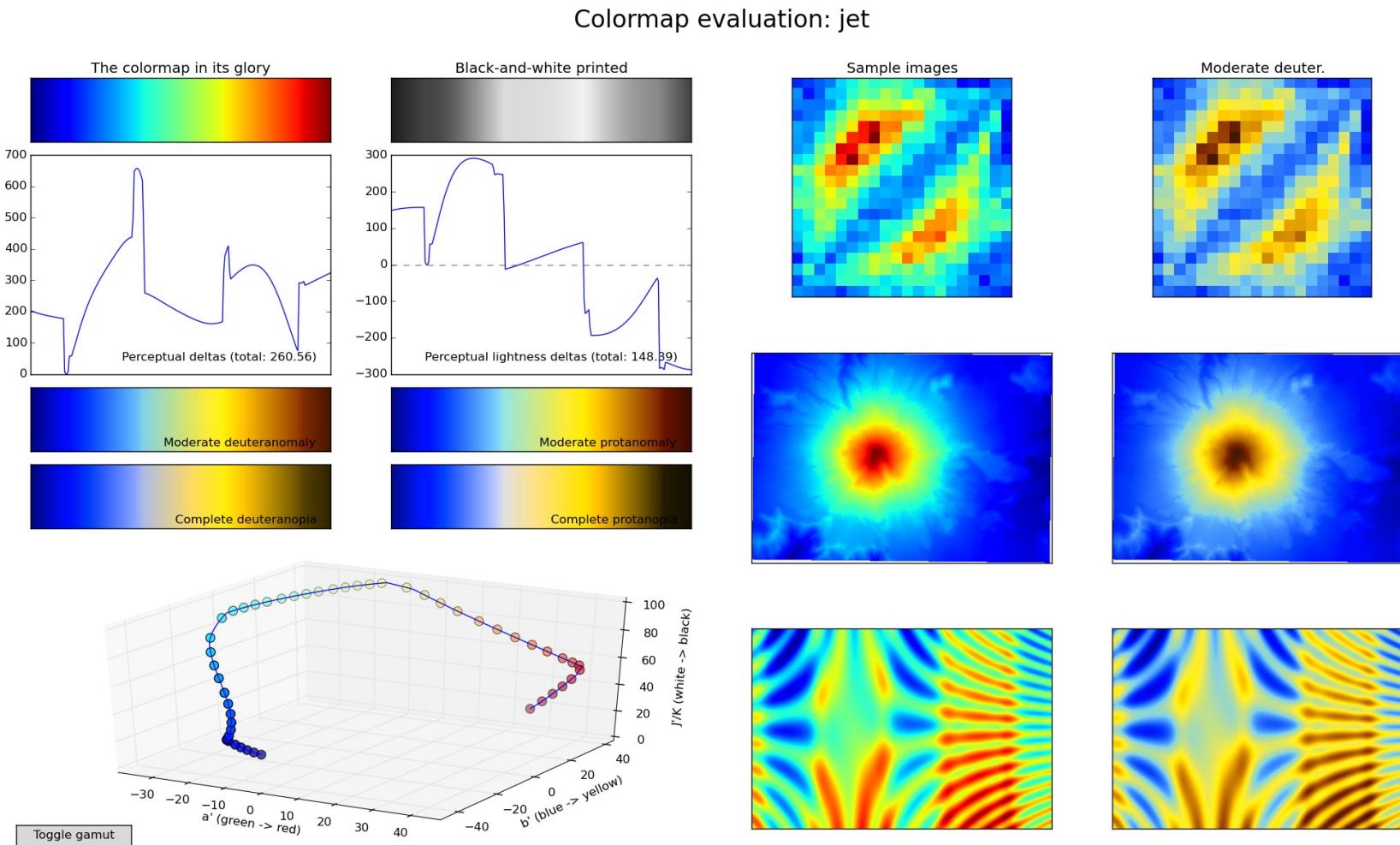
[link](#)

What makes a color map good?

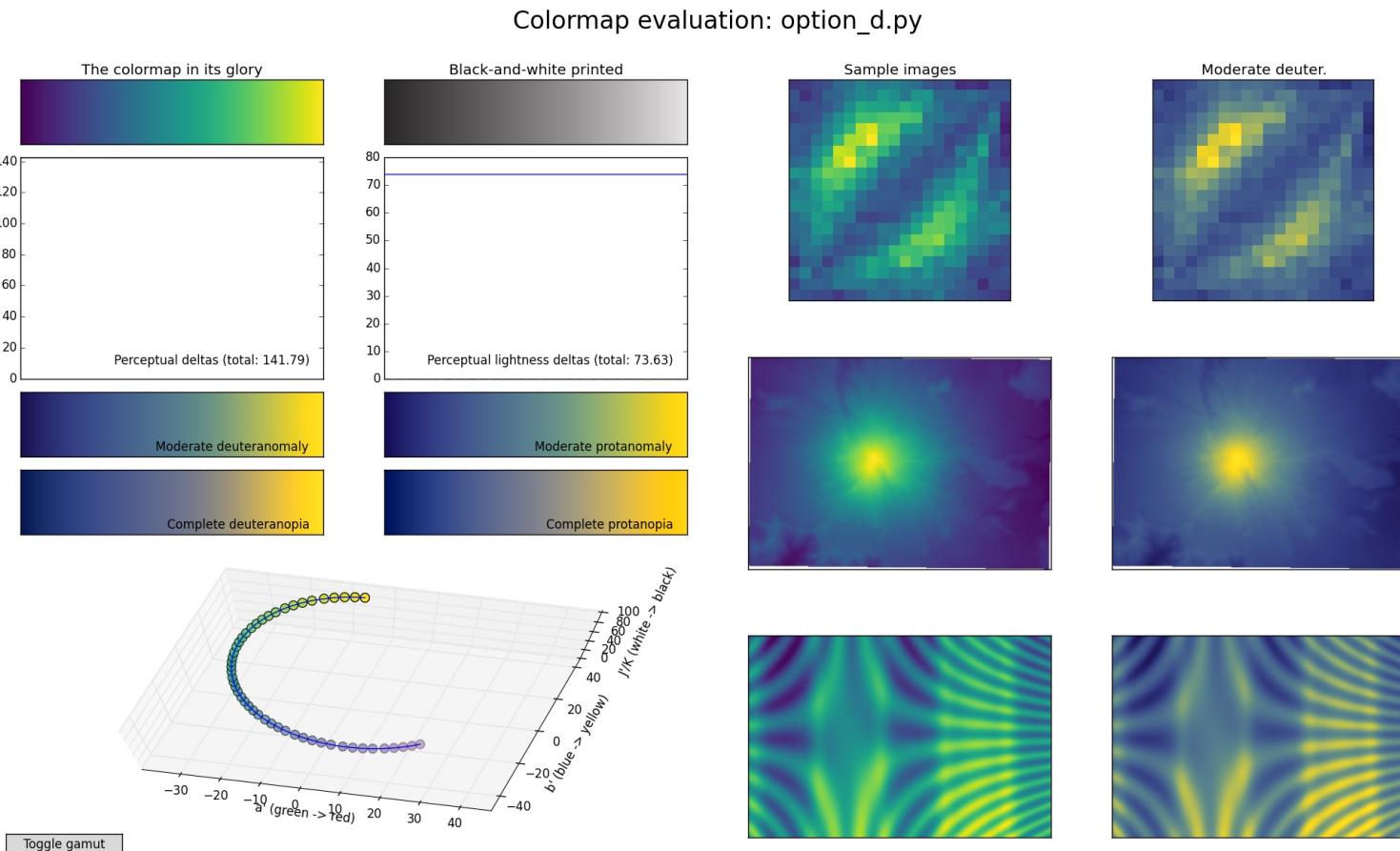
Perceptual uniformity- luminance



Perceptual uniformity – jet (rainbow map)

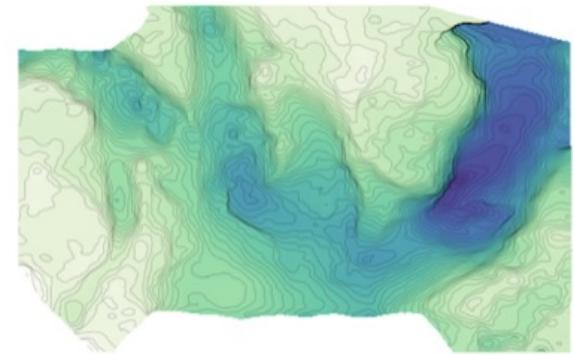
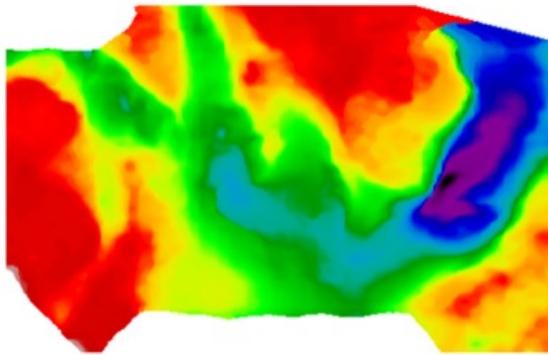


Perceptual uniformity – viridis map

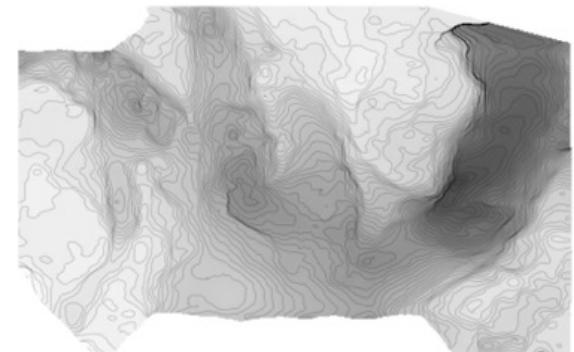
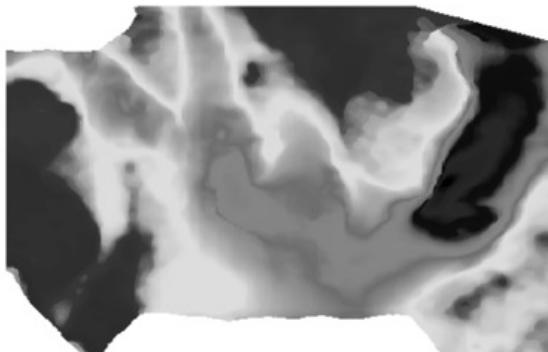
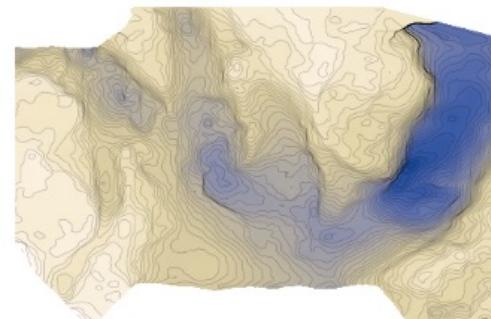
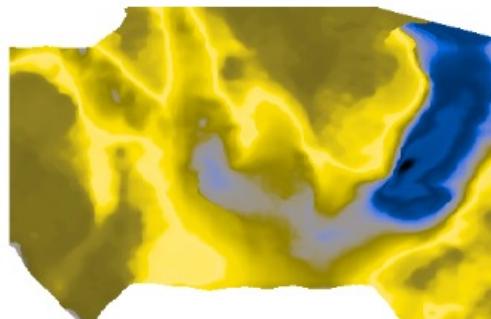


Semantics

Nova Scotia sea floor
depth



Let's check that it is indeed colourblind-safe and grey-safe:

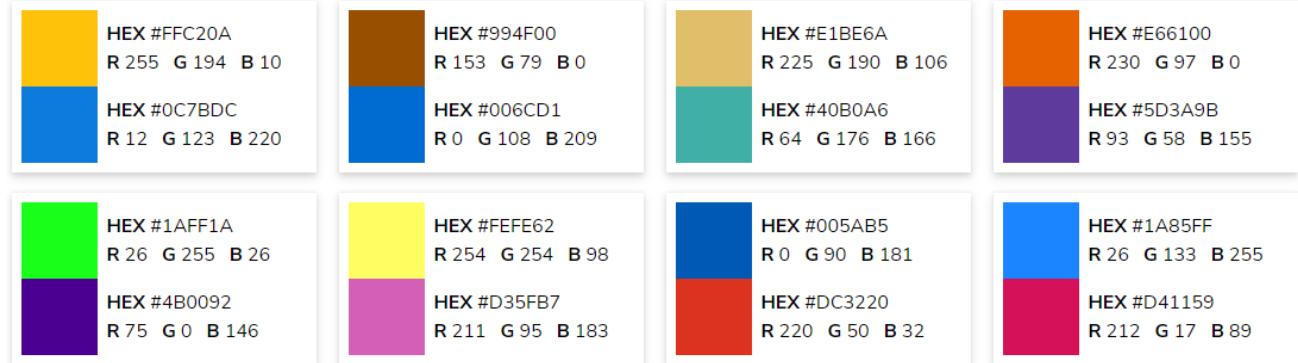


Is this a
pit? What?

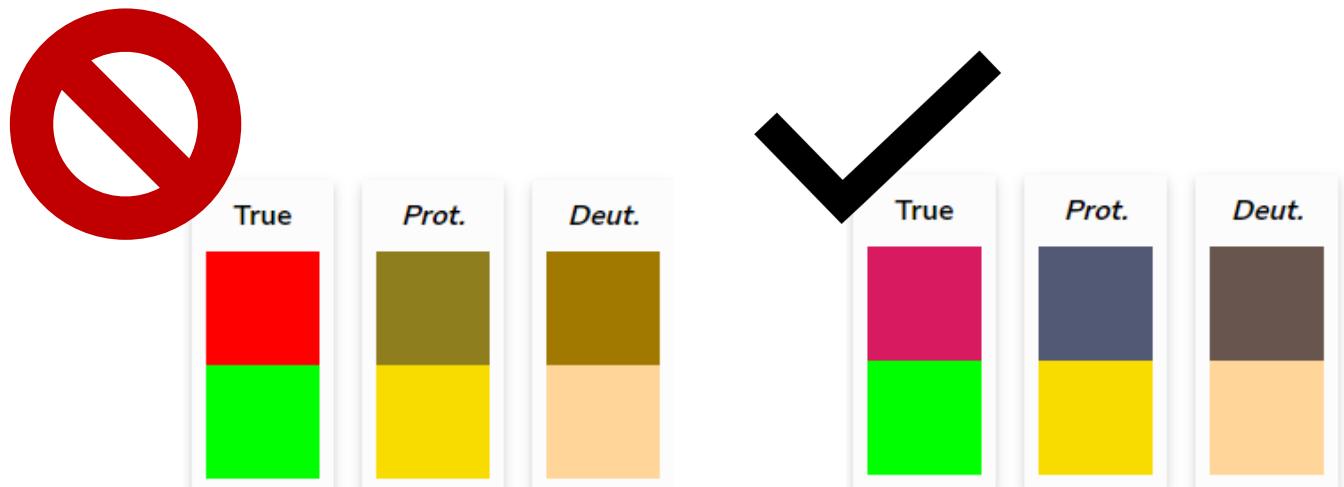


Accessible Colors

- Working color combinations (for colorblindness)



- Color combinations to avoid, e.g.:
 - Red-green
 - Purple-blue



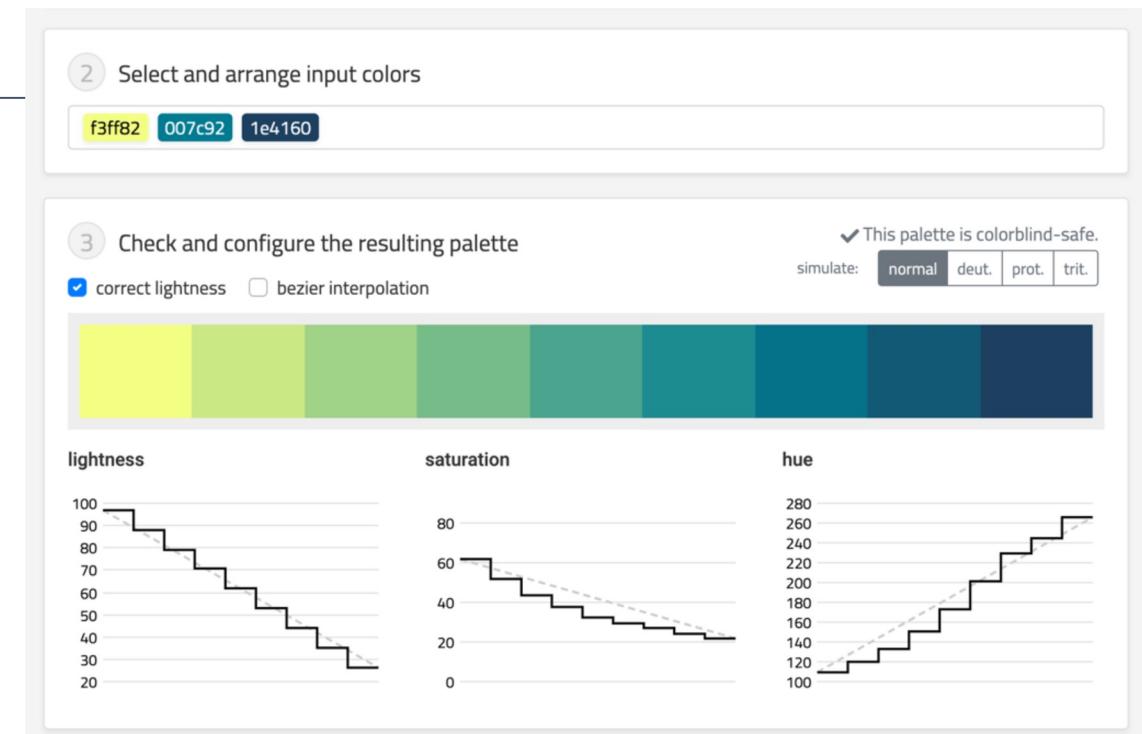
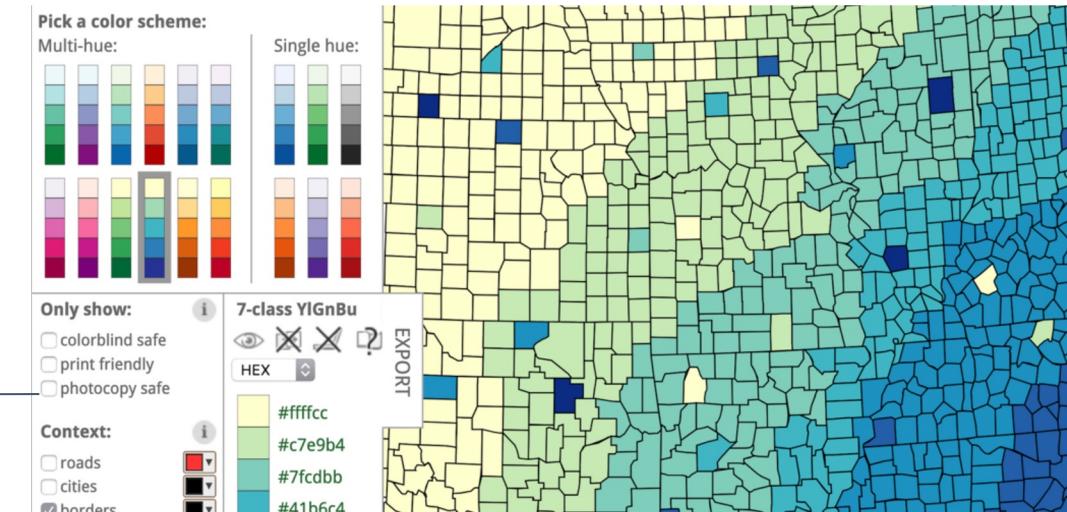
🛠 Color tools

- Colorbrewer (classic)

[https://colorbrewer2.org/#type=sequential
&scheme=BuGn&n=3](https://colorbrewer2.org/#type=sequential&scheme=BuGn&n=3)

- Make your own color palette:

<https://www.vis4.net/palettes/#/9|s|00429d,96ffea,ffffe0|ffffe0,ff005e,93003a|1|1>





Sequential Color Scheme Generator

<http://eyetracking.upol.cz/color/>

The screenshot shows the Sequential Color Scheme Generator 1.0 interface. At the top right is a color wheel with the title "SEQUENTIAL COLOR SCHEME GENERATOR 1.0". Below the title is a descriptive text block. To the left of the text is a color gradient bar with a circular origin point. To the right of the text are two color selection panels: "Select the color # 1" and "Select the color # 2". Each panel includes a color preview, color sliders for H, S, B, R, G, and B, and a hex color code field. Below these panels are sections for "Set the number of color scheme classes" (with a dropdown set to 6) and "Set the color distance steps between classes" (with five input fields: ΔE₀₀ A-B: 4, ΔE₀₀ B-C: 8, ΔE₀₀ C-D: 10, ΔE₀₀ D-E: 8, ΔE₀₀ E-F: 4). A "Compute" button is located at the bottom of this section.

This tool was designed to create **sequential color schemes** for choropleth maps. You can manipulate **colors**, **number of classes** of your scheme and visual difference between them by applying **color distance** steps defined by [CIEDE2000 method](#). To get some more detailed instructions hover with your mouse over ⓘ or ⓘ.

We believe it will be helpful to design better and more readable maps. Though the Sequential Color Scheme generator 1.0 seems to be a primitive tool, there is quiet lot of knowledge and research behind it, check out our papers (references below) and see ;-)

Enjoy!

Select the color # 1
gives the origin of the color scheme ⓘ

H: 103 %
S: 71 %
B: 82 %
R: 103
G: 211
B: 61
#: 67D33D

Select the color # 2
gives the direction of color scheme ⓘ

H: 0 %
S: 0 %
B: 100 %
R: 255
G: 255
B: 255
#: FFFFFF

Switch colors

Set the number of color scheme classes

n = 6 ⓘ

Set the color distance steps between classes ⓘ

ΔE ₀₀ A-B	4
ΔE ₀₀ B-C	8
ΔE ₀₀ C-D	10
ΔE ₀₀ D-E	8
ΔE ₀₀ E-F	4

Compute

🛠 Color tools

Colorgorical

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

Colorgorical

Generate

Number of colors: 6

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

Select hue filters: 90°, 180°, 270°

Drag wheel, or add angle: # to # +

Select lightness range: 25 to 85

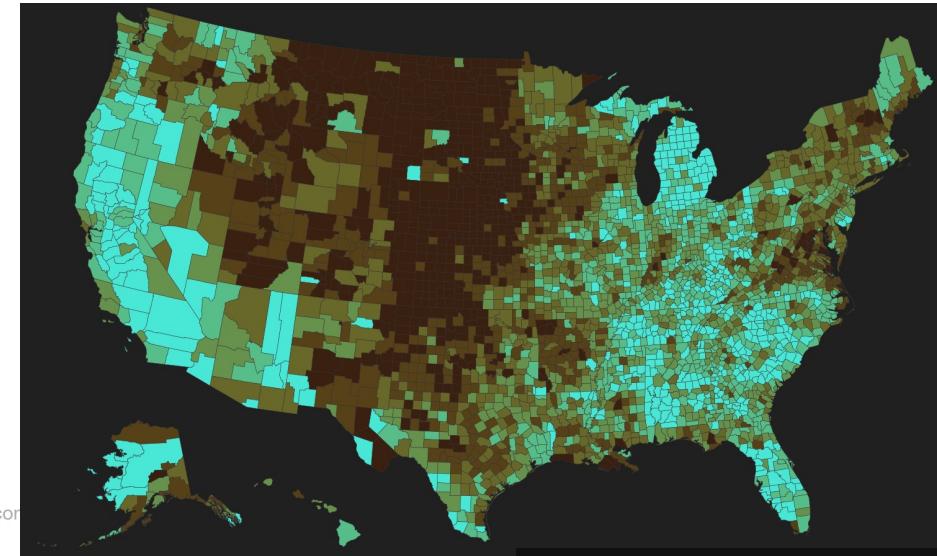
Results: Color space, Hex, RGB, Lab, LCH, Array format, " ", No quote, Charts

["rgb(180,221,212)", "rgb(21,78,86)", "rgb(117,237,133)", "rgb(165,15,169)"]

🛠 Color tools

Colorpicker for Data

<http://tristen.ca/hcl-picker/>

A screenshot of the "Colorpicker for data" interface. It includes a color wheel with three points highlighted: one at the top left (H-L), one at the bottom center (C-L), and one at the bottom right (H-C). To the right of the color wheel is a vertical color bar labeled "U.S Unemployment 2008" with a gradient from dark brown to light cyan, with "Low" at the bottom and "High" at the top. Below the color wheel is a "Copy" button and zoom controls (+/-). At the bottom, it says "Chroma 1".

Color	Hex Code
#3A2010	#3A2010
#564019	#564019
#66682A	#66682A
#67924E	#67924E
#59BE89	#59BE89
#49E7D6	#49E7D6

🛠️ Color tools

Check if your colors actually work (accessibility)

Lots of other online tools available to check this

VIZ PALETTE

By: Elijah Meeks & Susie Lu

PICK

#1DABE6, #1C366A, #C3CED0, #E43034, #FC4E51, #AF060F

Add Replace

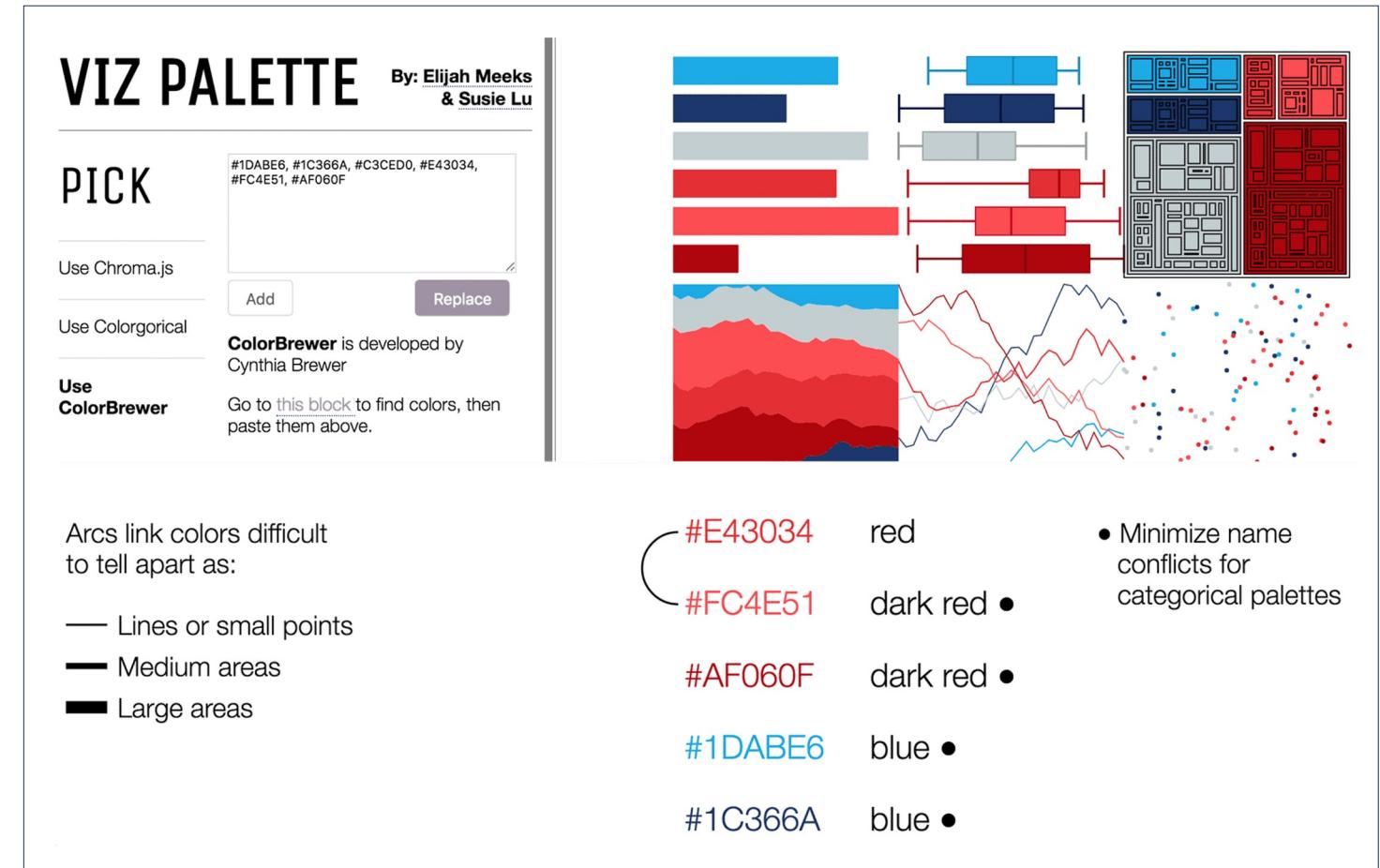
Use Chroma.js

Use Colgorical

Use ColorBrewer

ColorBrewer is developed by Cynthia Brewer

Go to [this block](#) to find colors, then paste them above.



Arcs link colors difficult to tell apart as:

- Lines or small points
- Medium areas
- Large areas

Color Hex	Color Name	Notes
#E43034	red	•
#FC4E51	dark red	•
#AF060F	dark red	•
#1DABE6	blue	•
#1C366A	blue	•

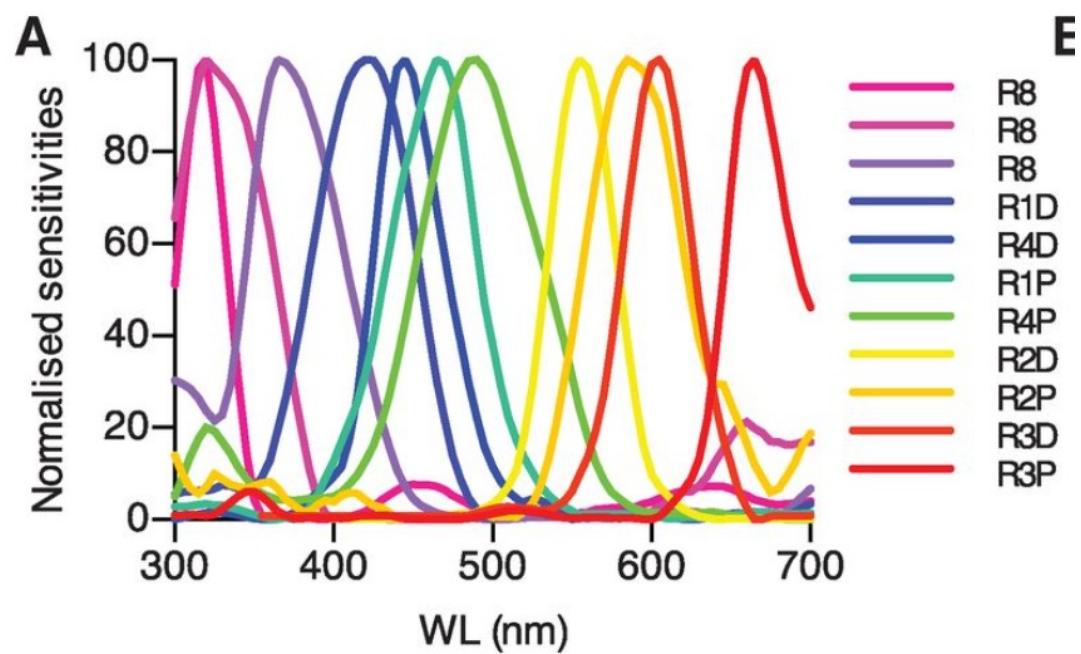
- Minimize name conflicts for categorical palettes

<https://projects.susielu.com/vizpalette>

Make good [color] choices

- Perceptually distinguishable colors
- Value distance matches perceptual distance
- Colors and concepts properly align
- Aesthetically pleasing, intriguing
- Respect color vision deficiencies
- Should survive printing to black & white
- Don't overwhelm people's capability!

We have 3 cones...the
mantis shrimp has 16(!!!)



<https://www.science.org/doi/10.1126/science.1245824>

The mantis shrimp is the harbinger of
blood-soaked rainbows.



It is bright.

It is dark.



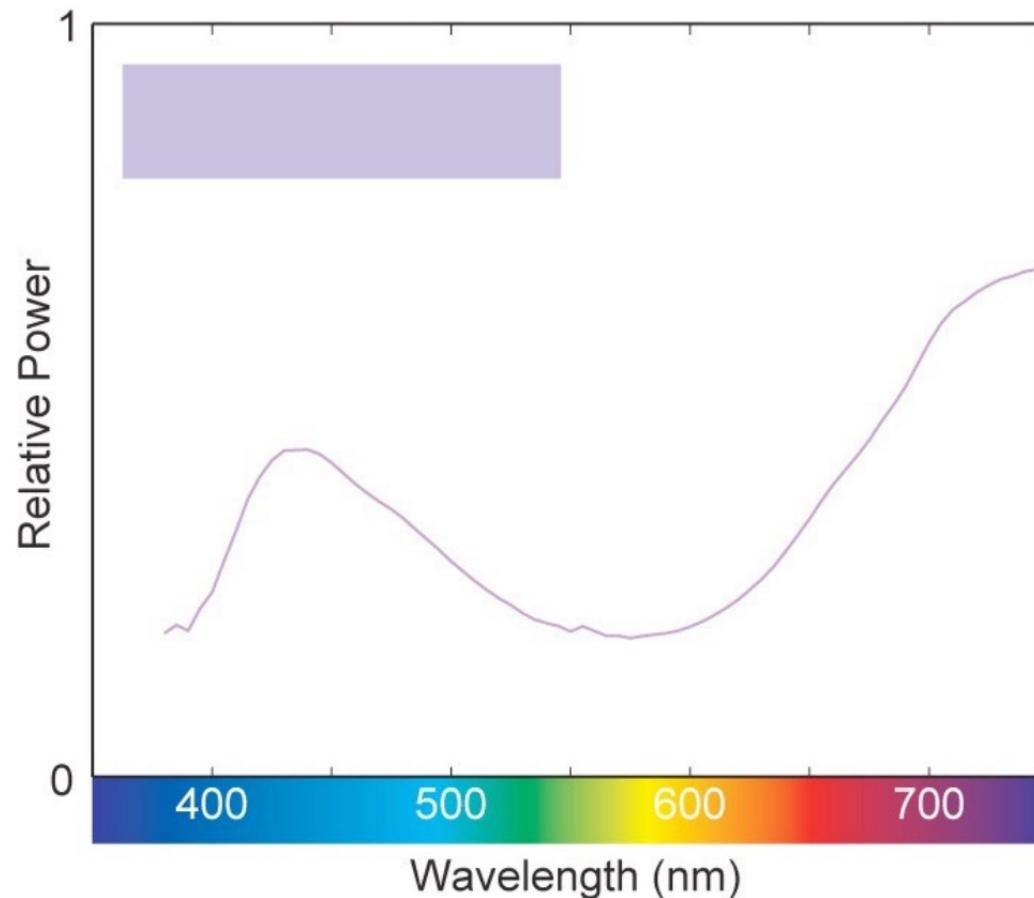
And it is beautiful.

https://theoatmeal.com/comics/mantis_shrimp

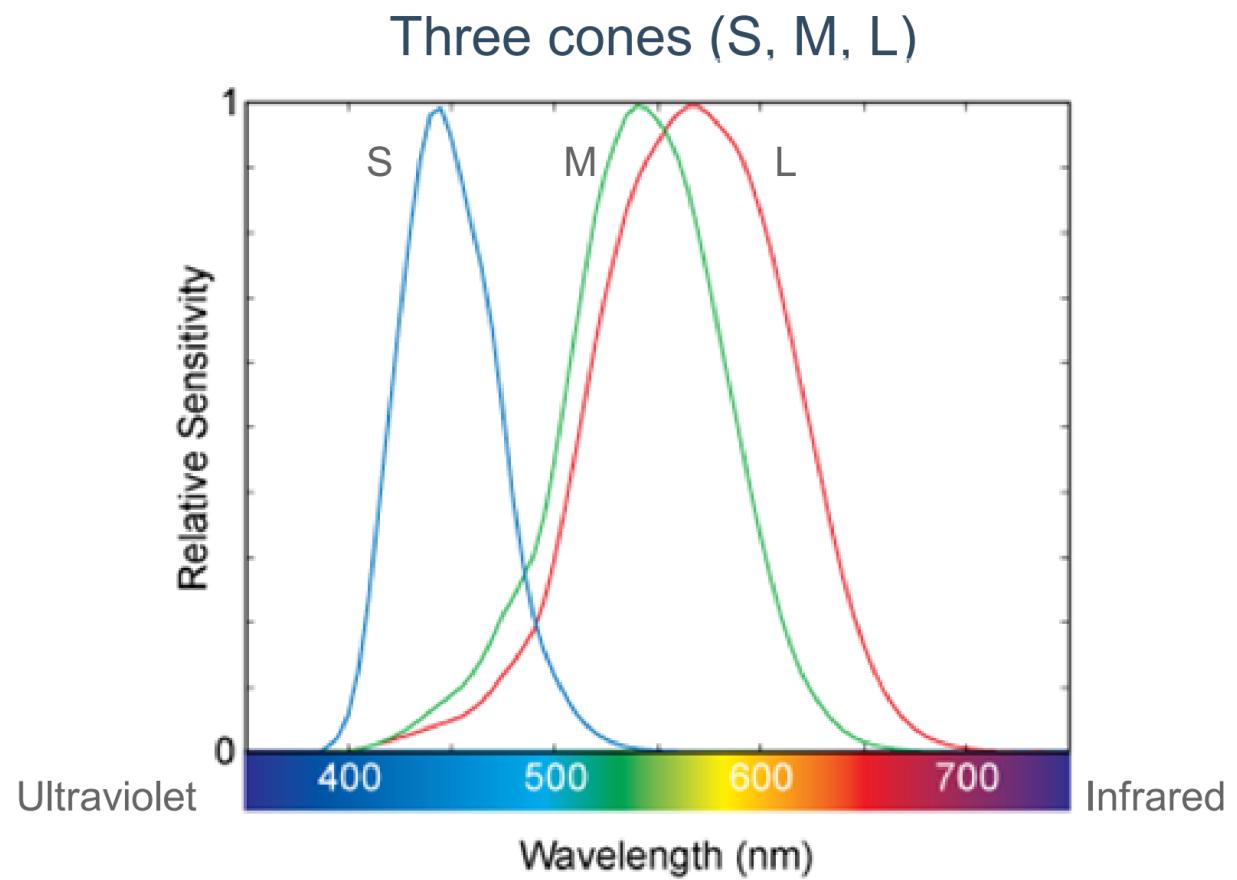
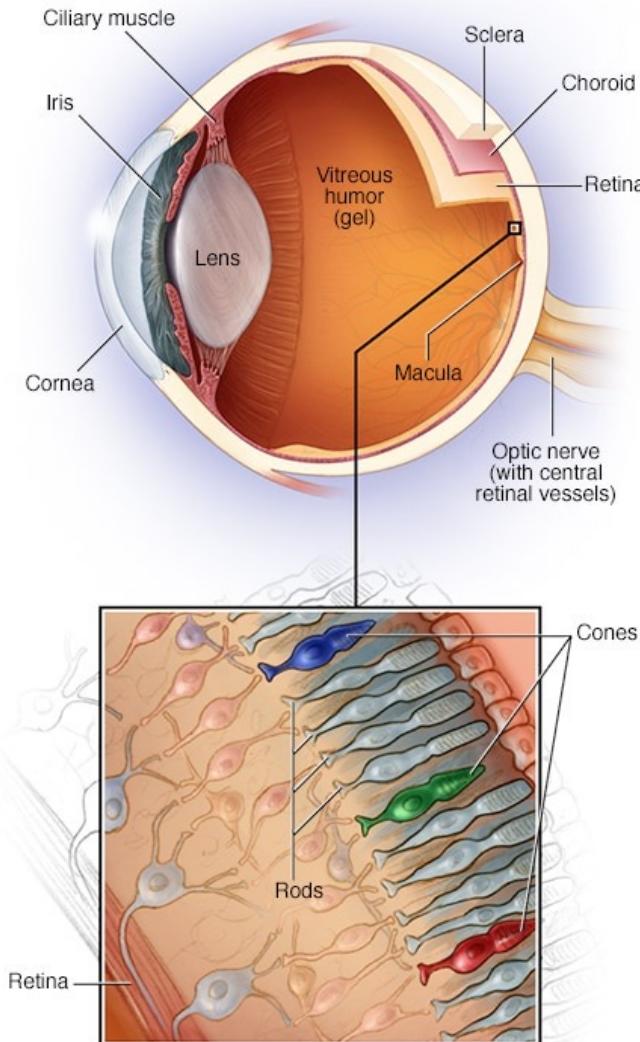
More (serious) color resources

- [Mpl colormaps](#)
- [Color Use Guidelines for Data Representation. Cynthia Brewer. Proc. Section on Statistical Graphics, American Statistical Association, pp. 55-60, 1999. Color Scheme Explorer.](#)
- [How to pick more beautiful colors for your data visualizations. Lisa Charlotte Rost.](#)
- [Somewhere Over the Rainbow: An Empirical Assessment of Quantitative Colormaps. Yang Liu, Jeffrey Heer. ACM CHI 2018.](#)
- Matplotlib color scales [Matplotlib color maps](#)
- [Colorgorical: Creating Discriminable and Preferable Color Palettes for Information Visualization. Connor Gramazio, David Laidlaw & Karen Schloss. IEEE Transactions on Visualization and Computer Graphics. 2017.](#)

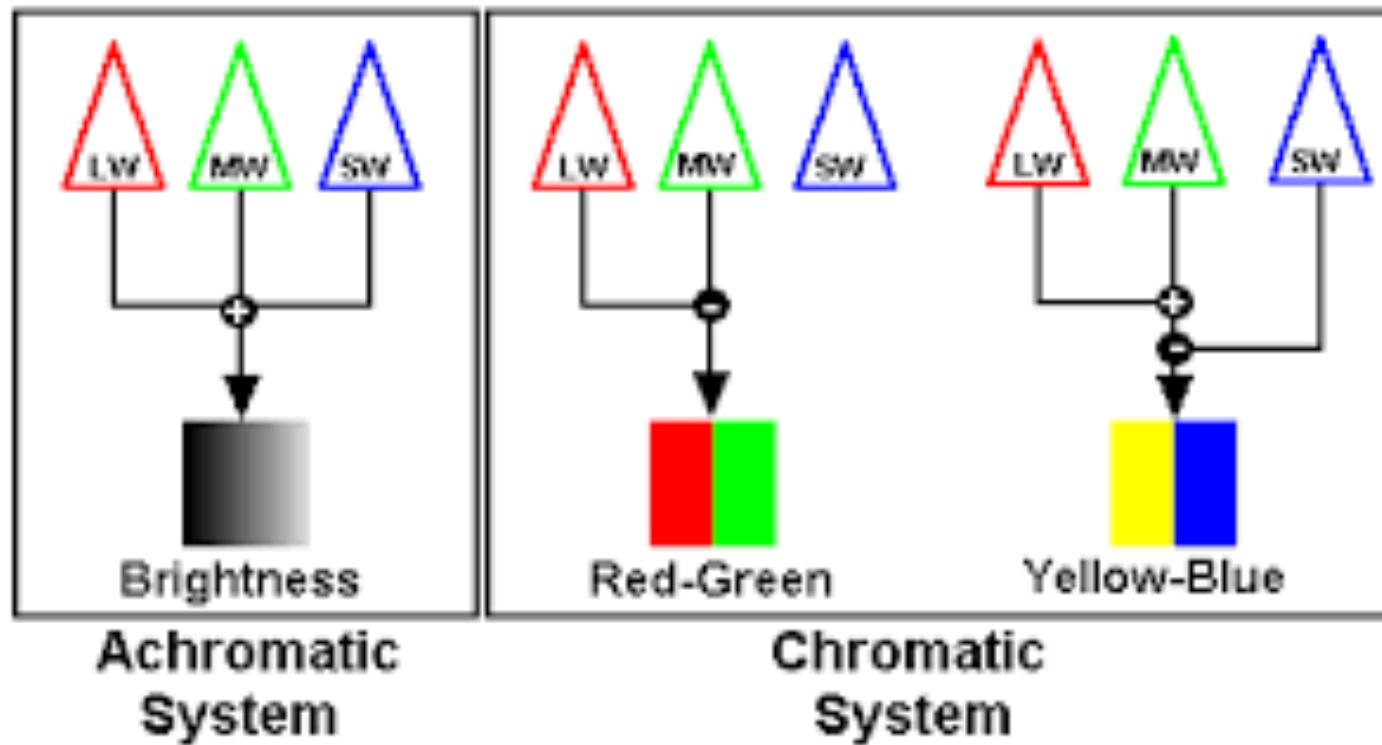
Light (e.g. Purple light)



Cone response

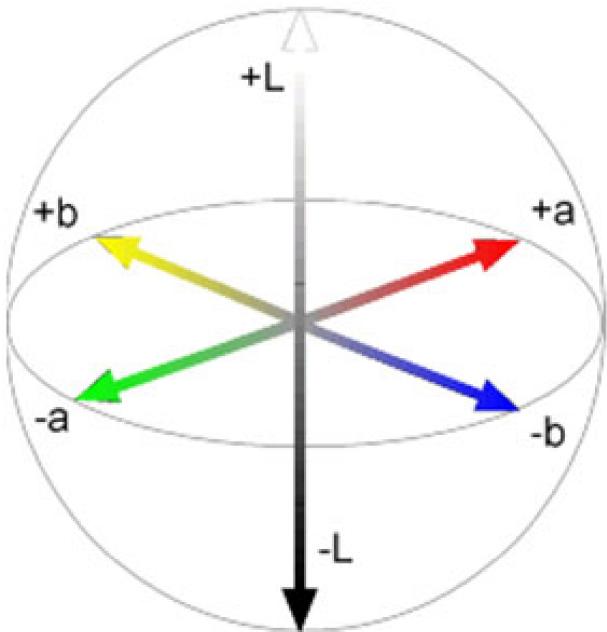


Opponent Processing



Color perception

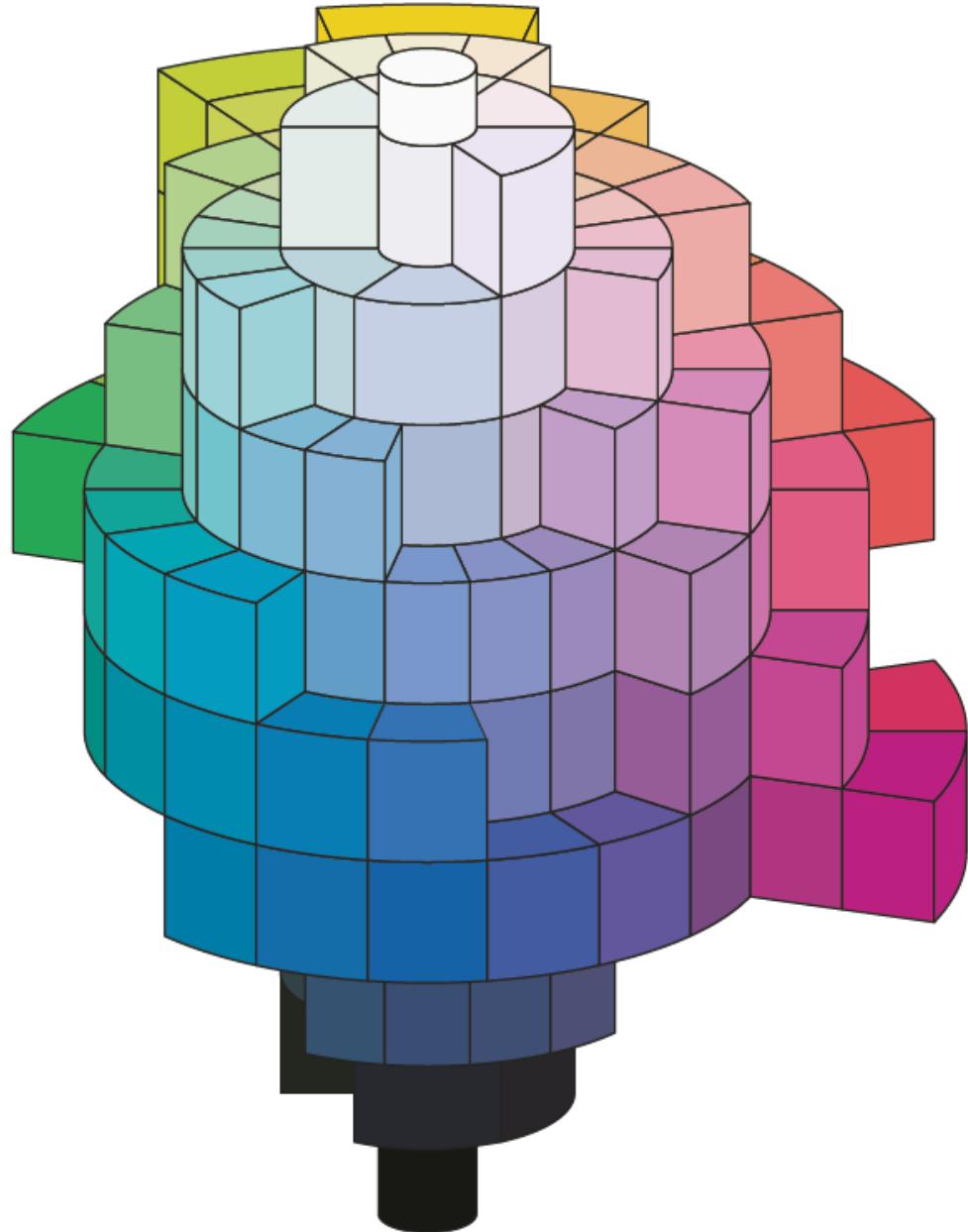
CIELAB



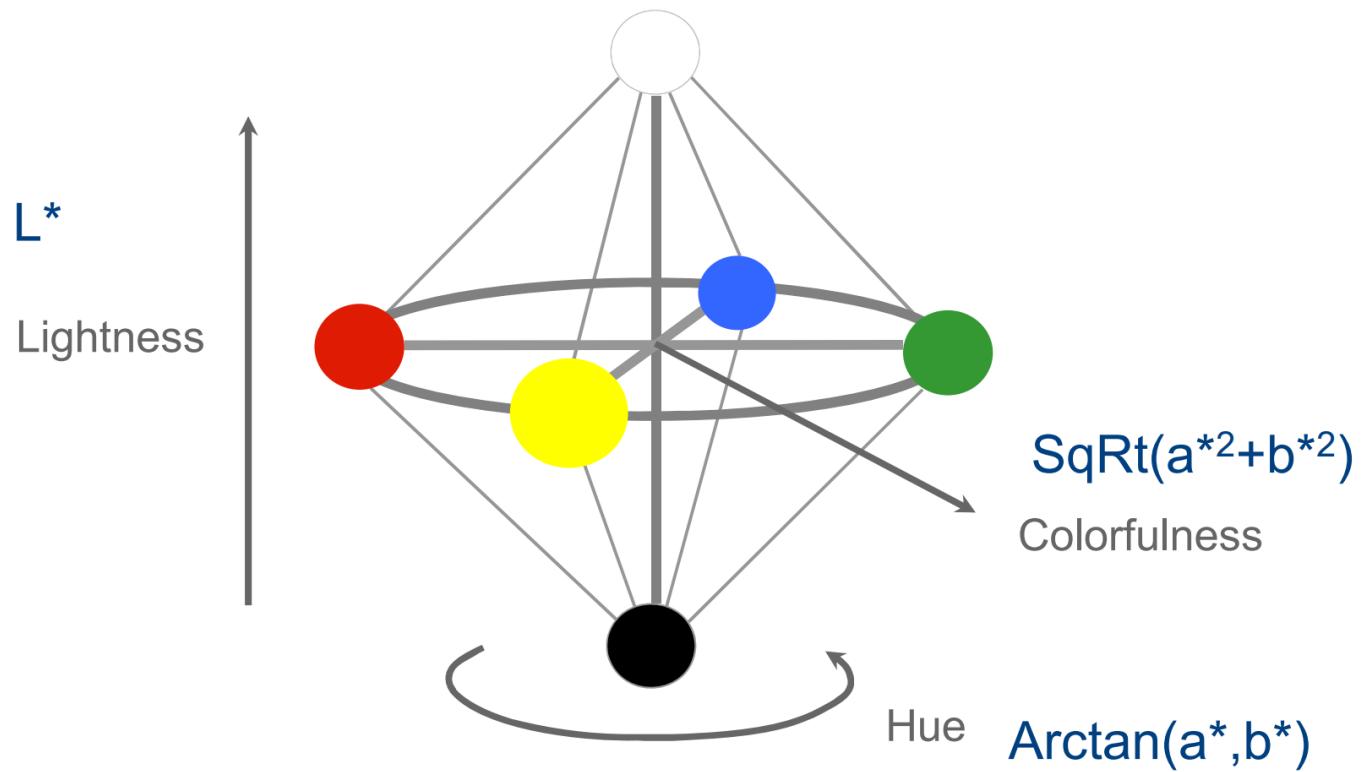
Computed from XYZ

- Calibrated RGB
- Reference white
- L^* , a^* , b^*

“Perceptually uniform”



CIELAB is a perceptual color space



Color appearance

- Eg how we perceive colors
 - Cornsweet illusion

