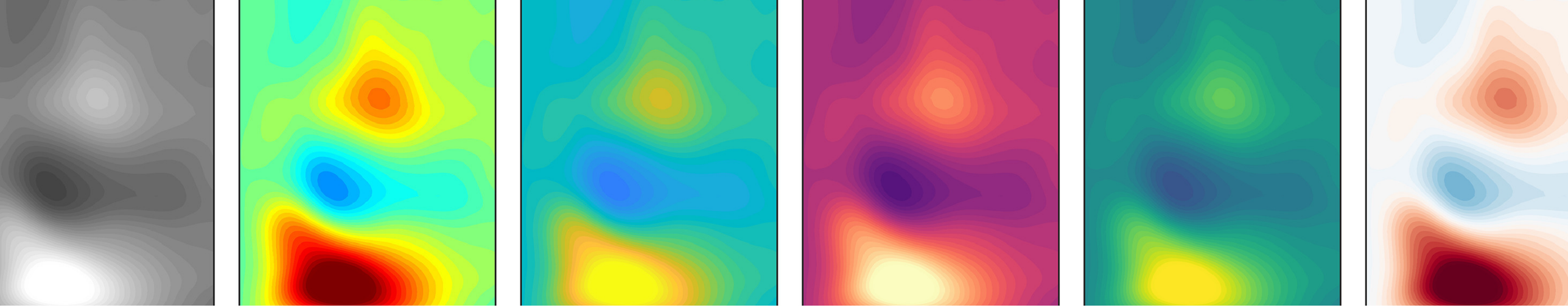


Color in Visualization

Laura Garrison, Associate Professor in Visualization

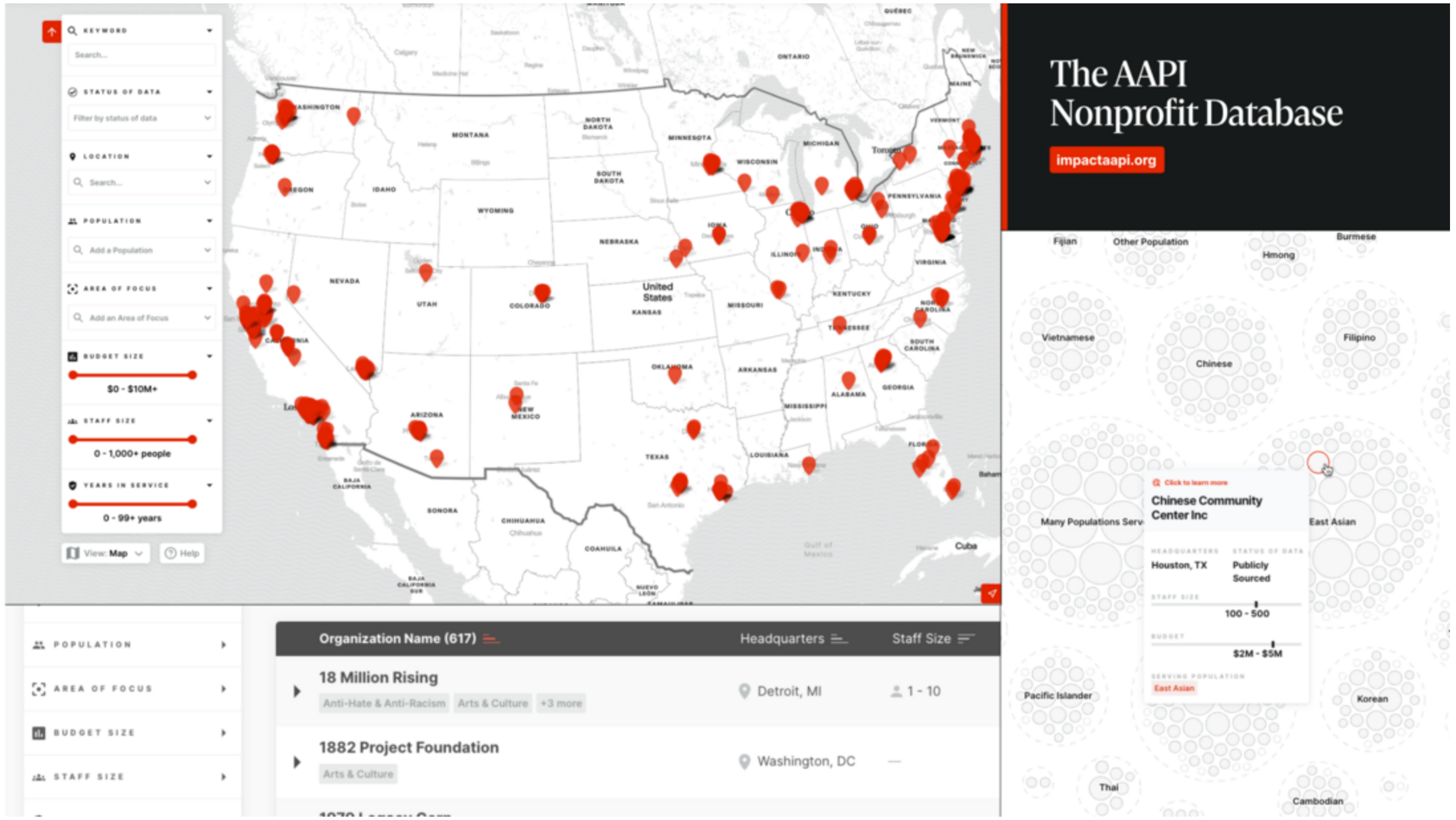
Dept of Informatics, UiB

laura.garrison@uib.no

Bjerknes Data Visualization Workshop, 4-6 Dec 2023

Why use color in visualization?

To label something



[The AAPI Nonprofit Database]

To measure something

The Blue Paradox

To represent something

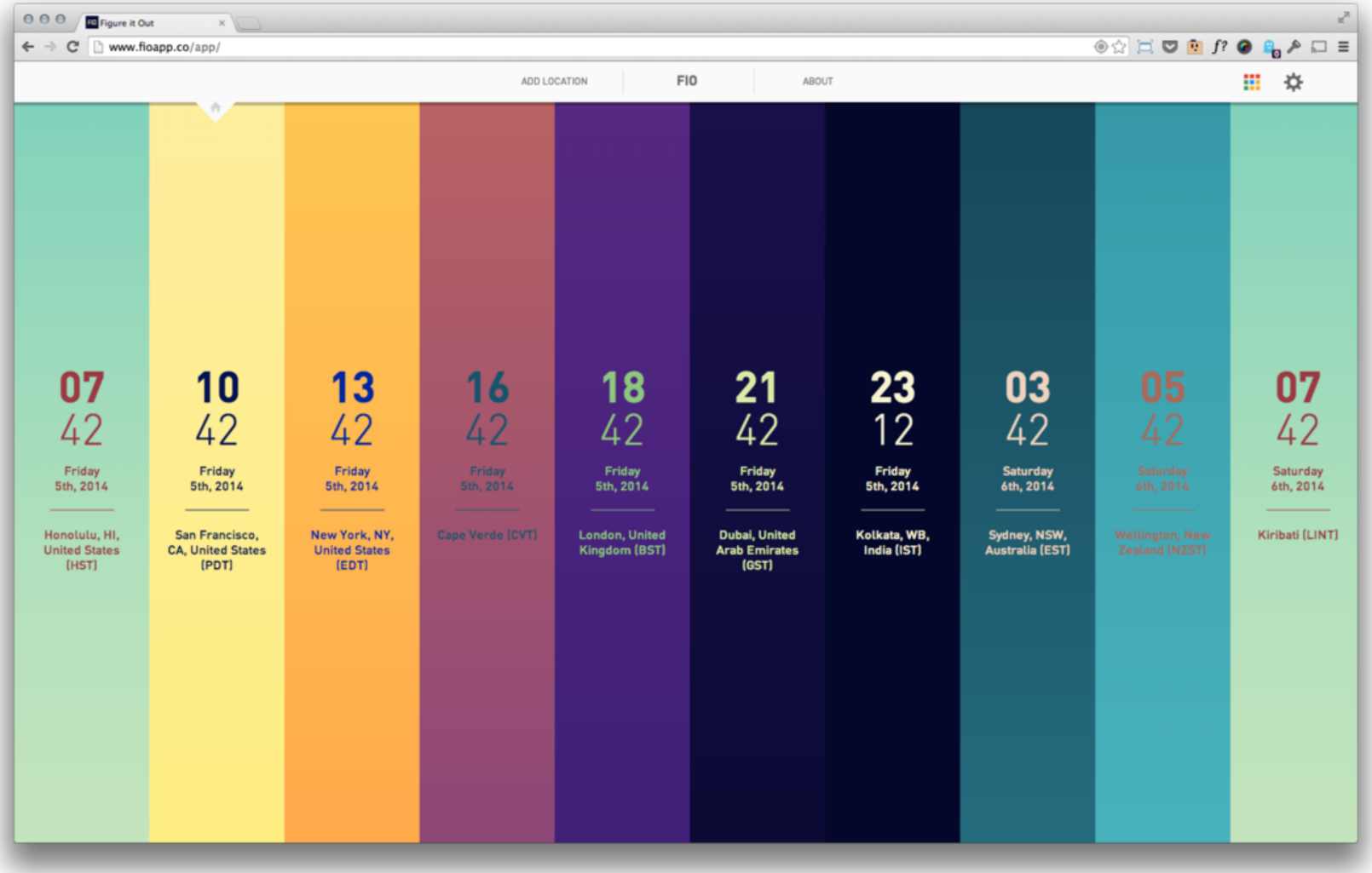
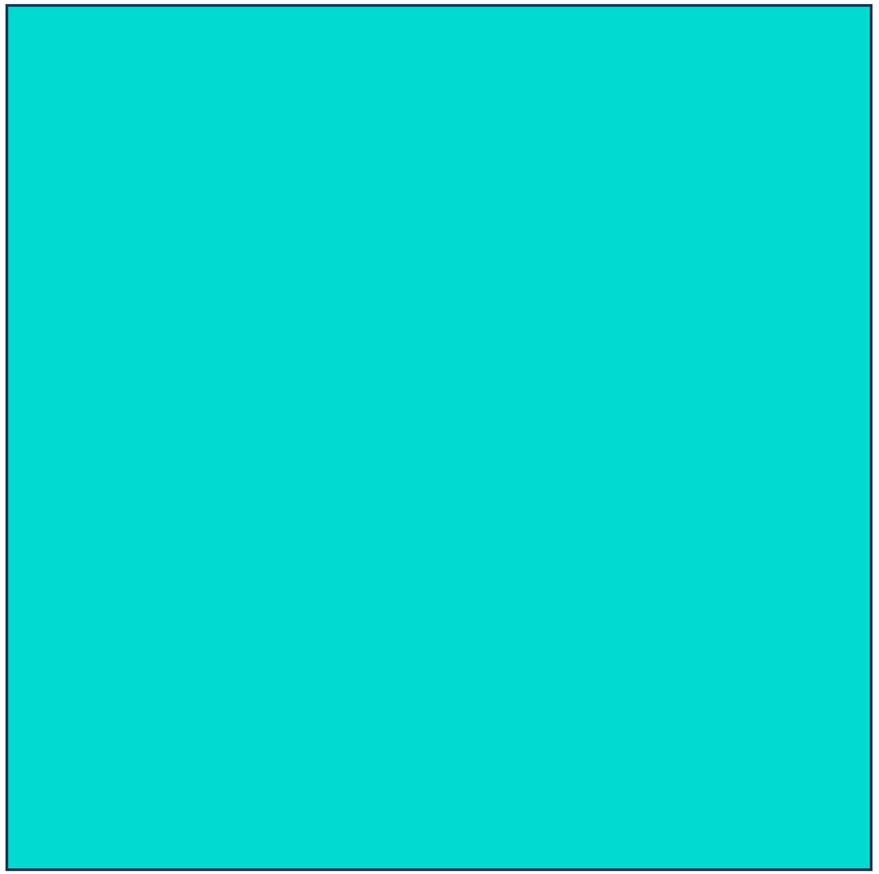


Figure it out

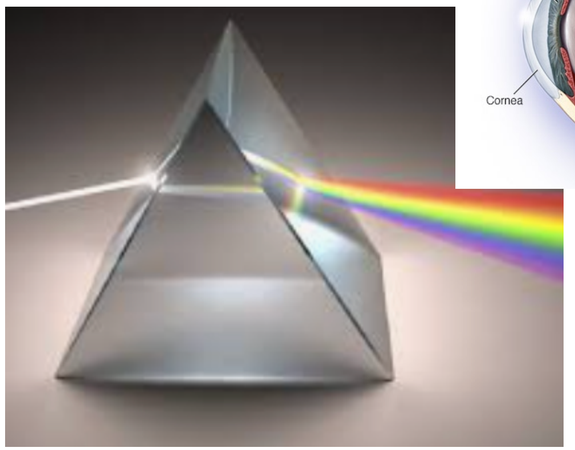
To decorate something

Vote.org 2022 impact report

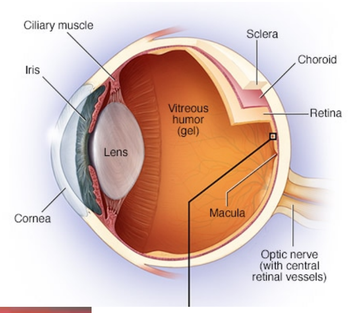
What color is this?

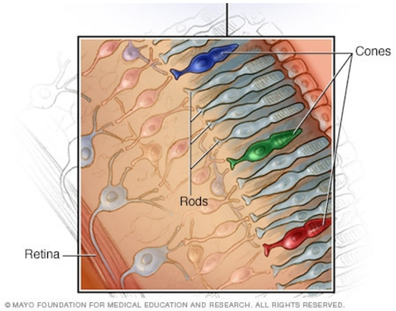


Seeing color

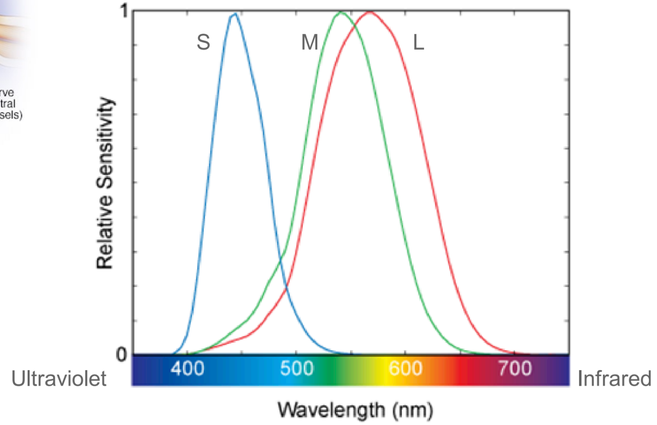


Light

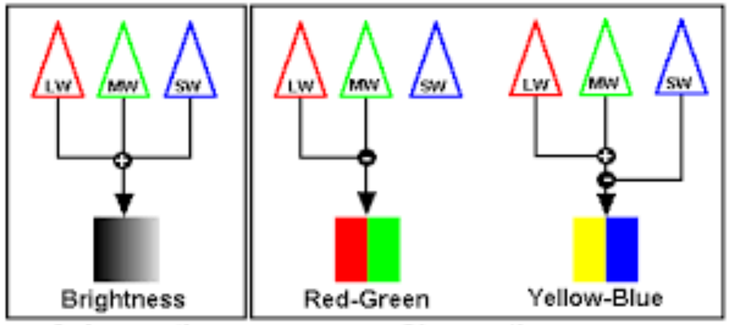




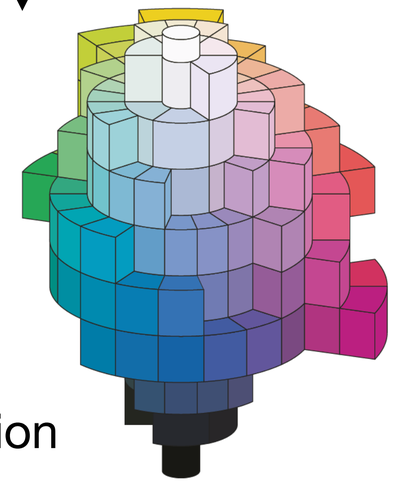
Three cones (S, M, L)



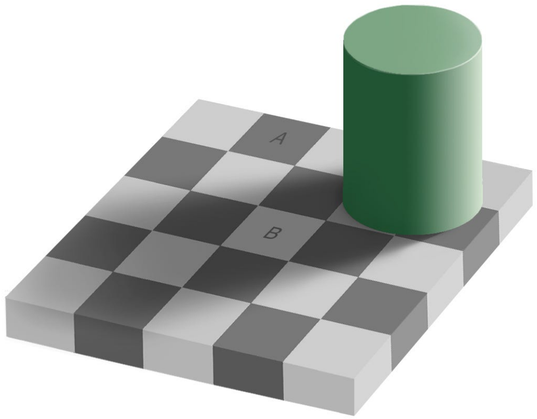
Cone response



Opponent Signals



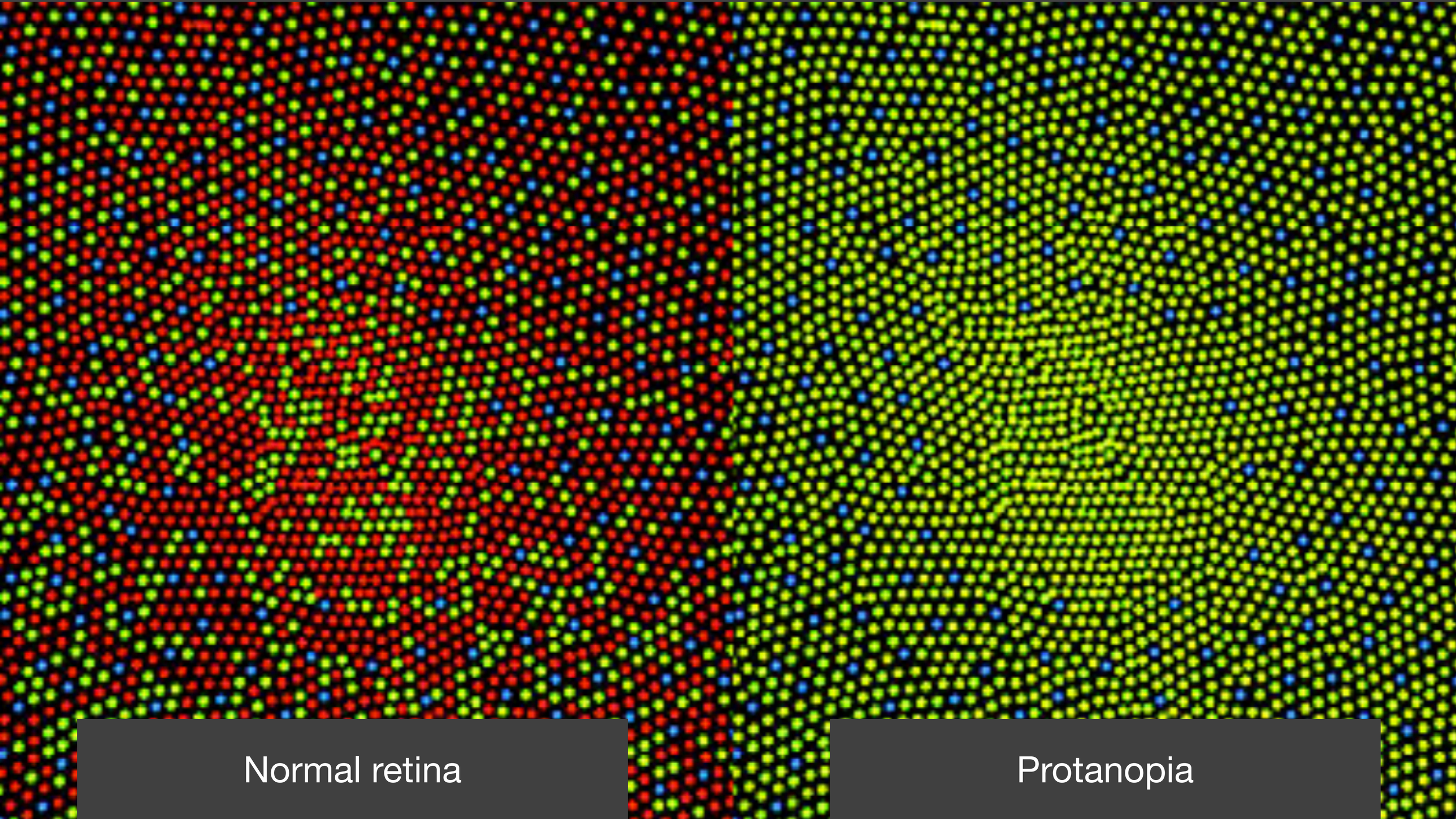
Color perception

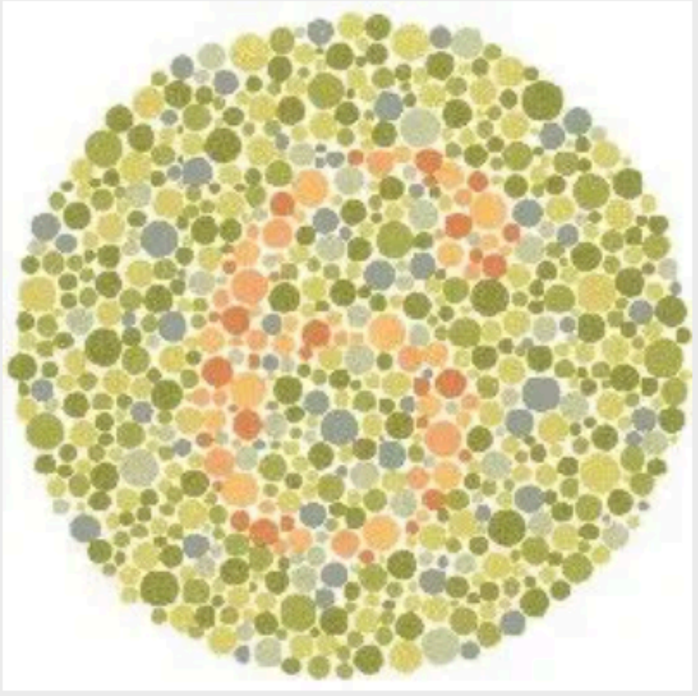


Color appearance

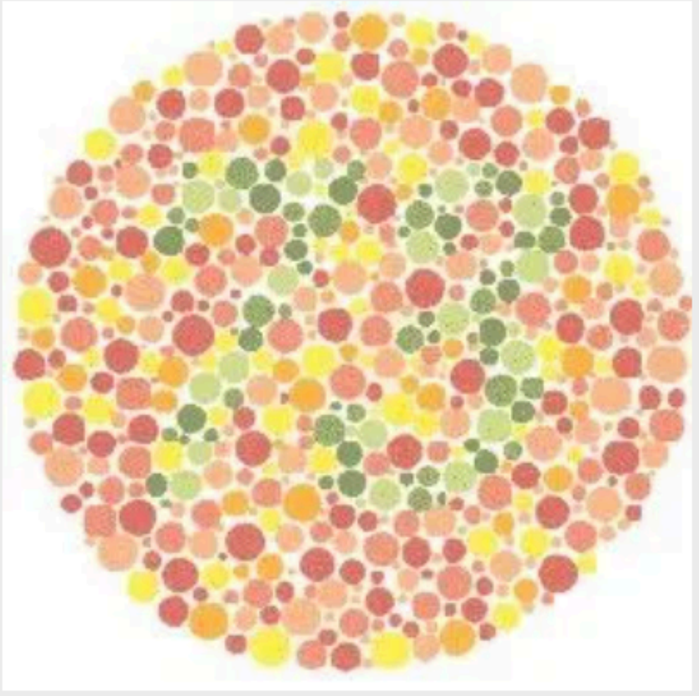
Teal!

Color cognition


Normal retina
Protanopia



Enter The Number



Enter The Number

Color in Practice

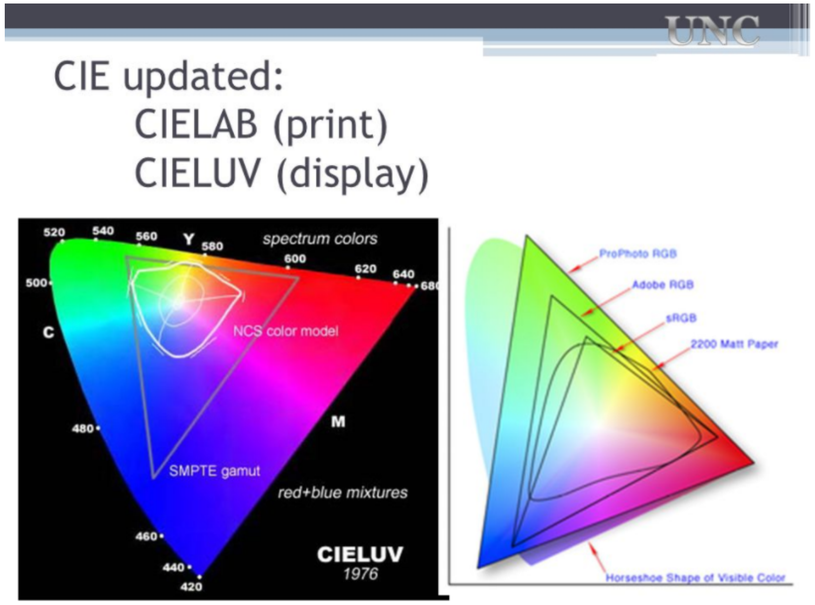
Color systems

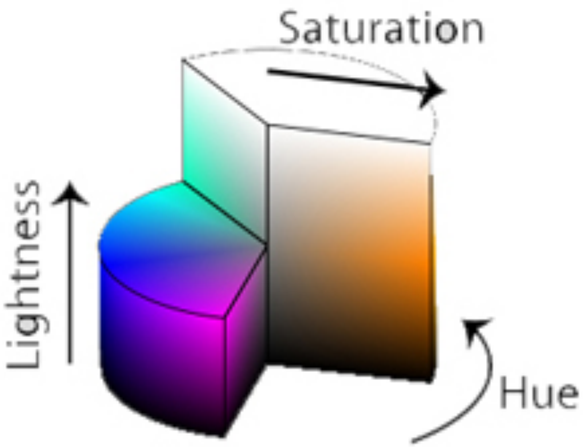
Reflective Materials, e.g. paper

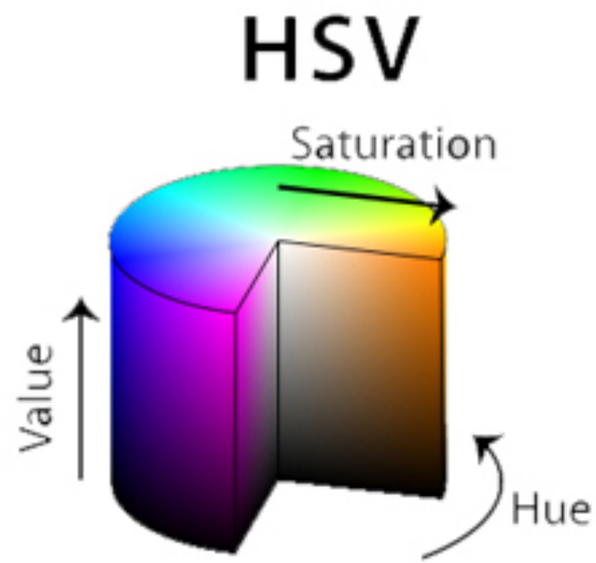
CMYK - Subtractive Color

RGB - Additive Color

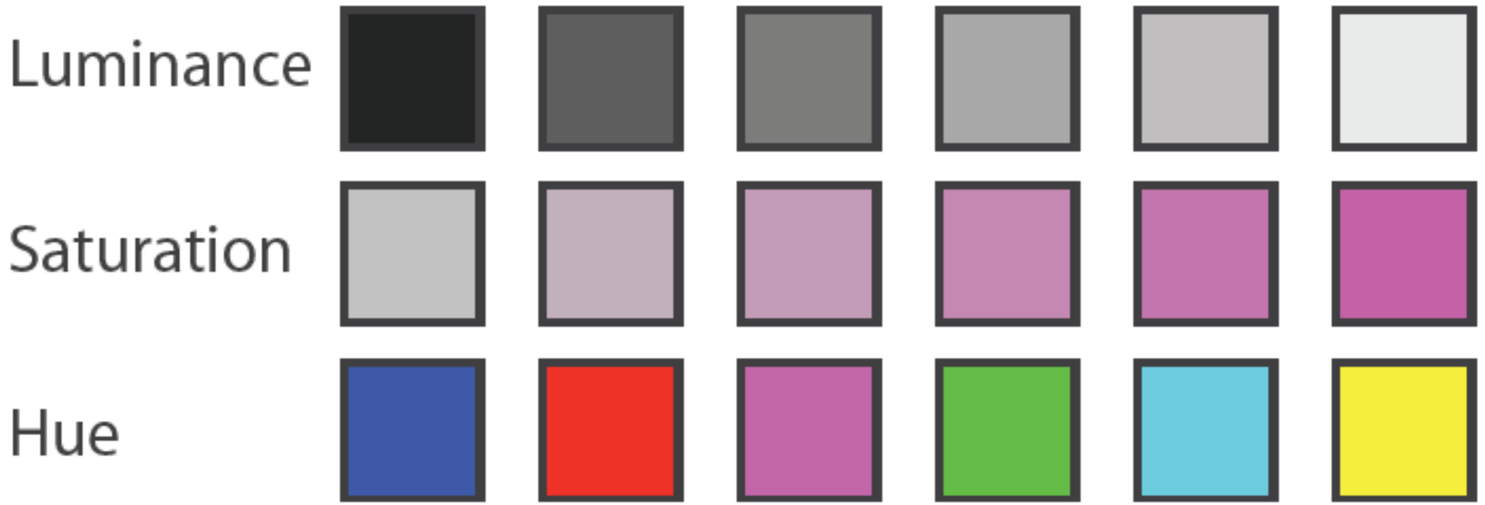
Emissive Materials, e.g., screens







Three color channels



Ordered → Magnitude

Ordered → Magnitude

Categorical → Identity

Categorical Encoding

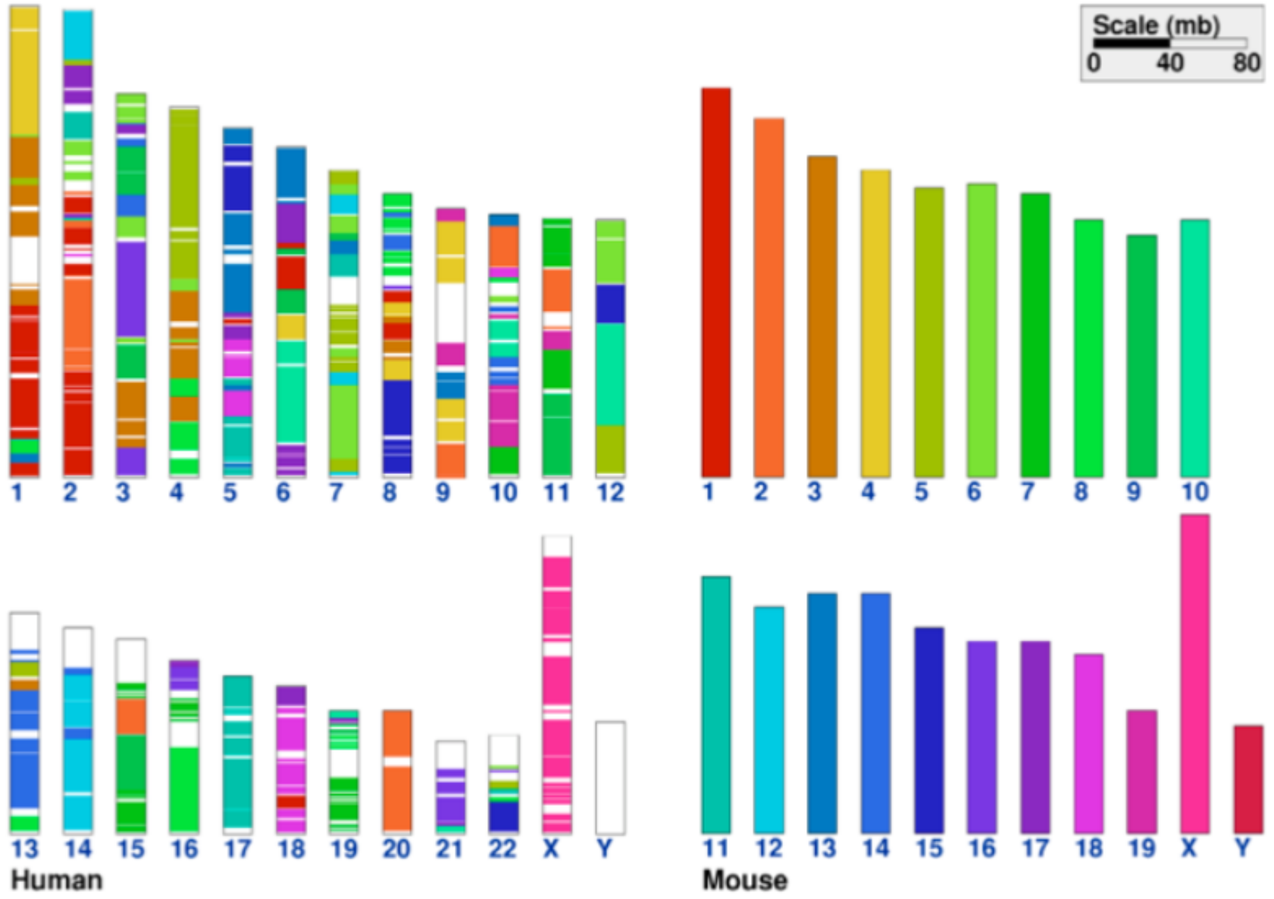
- Ordered or unordered?
- Ordered => magnitude -> **S** or **L**
- Unordered => identity -> **H**
- Color separation with even spacing across color space

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

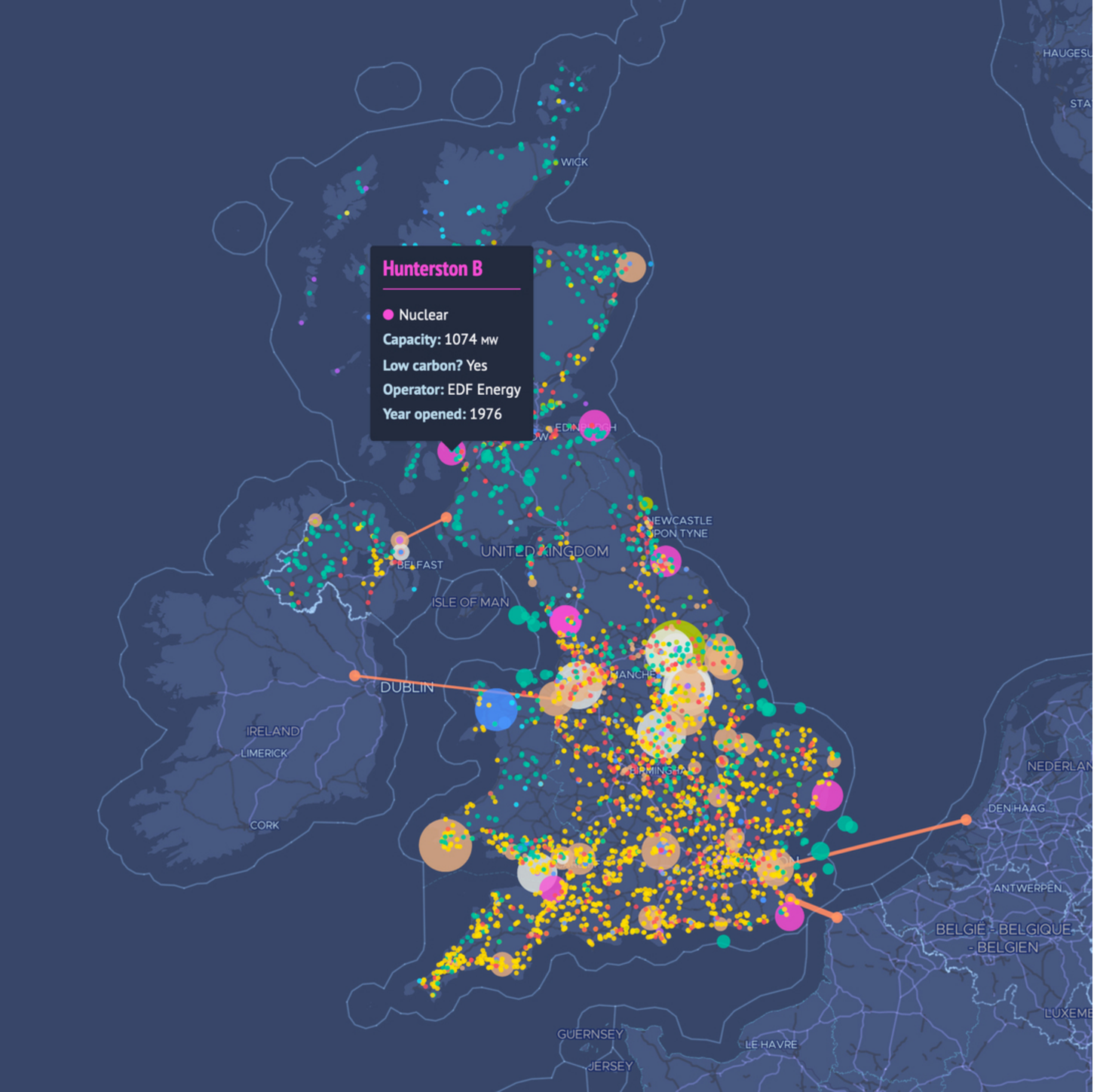
https://matplotlib.org/stable/users/explain/colors/colormaps.html#colormaps

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)



[Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Sinha and Meller. BMC Bioinformatics, 8:82, 2007.]



How The UK Transformed Its Electricity Supply In Just A Decade

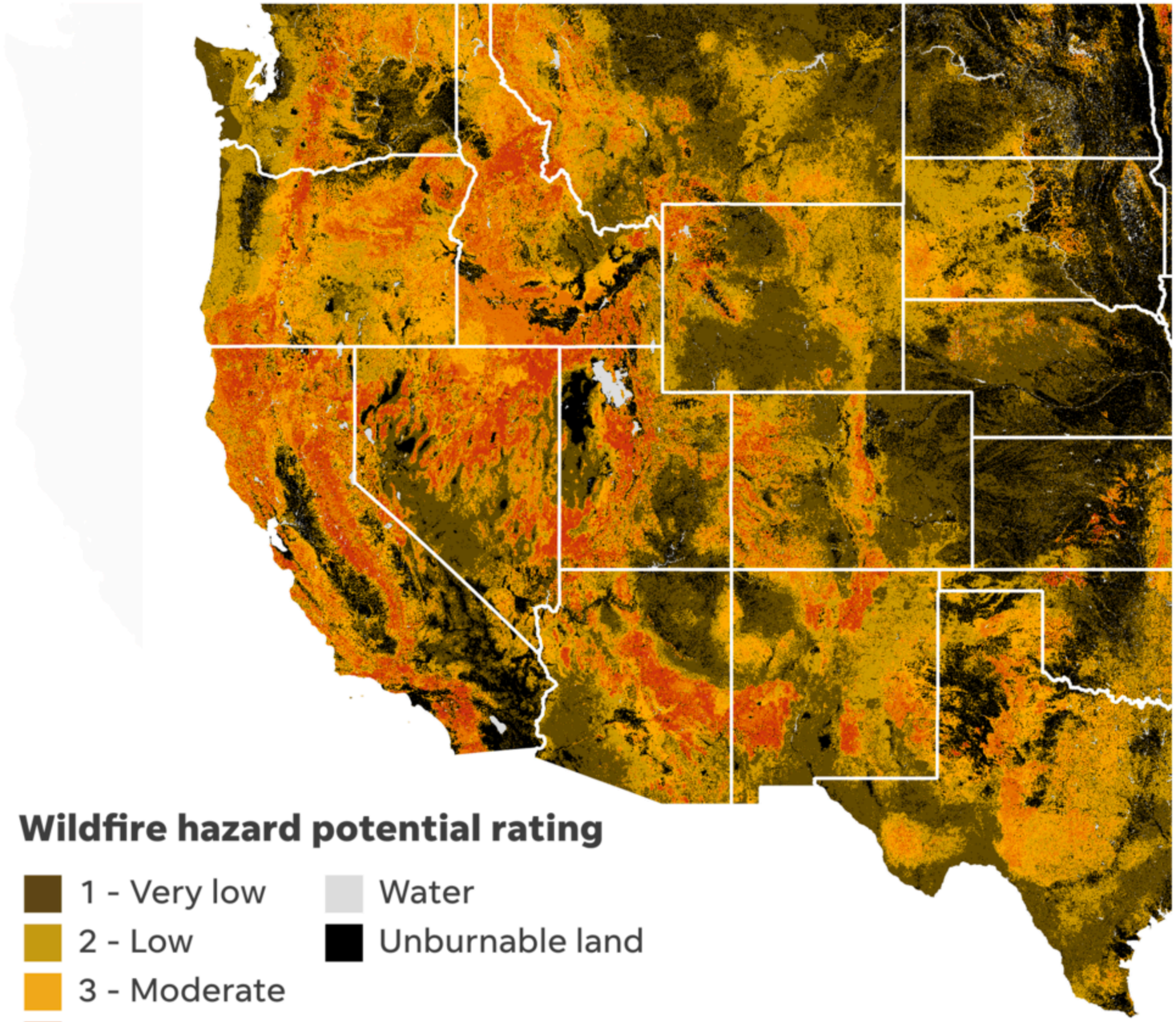
by Carbon Brief

Information is Beautiful
2023
Award Short list

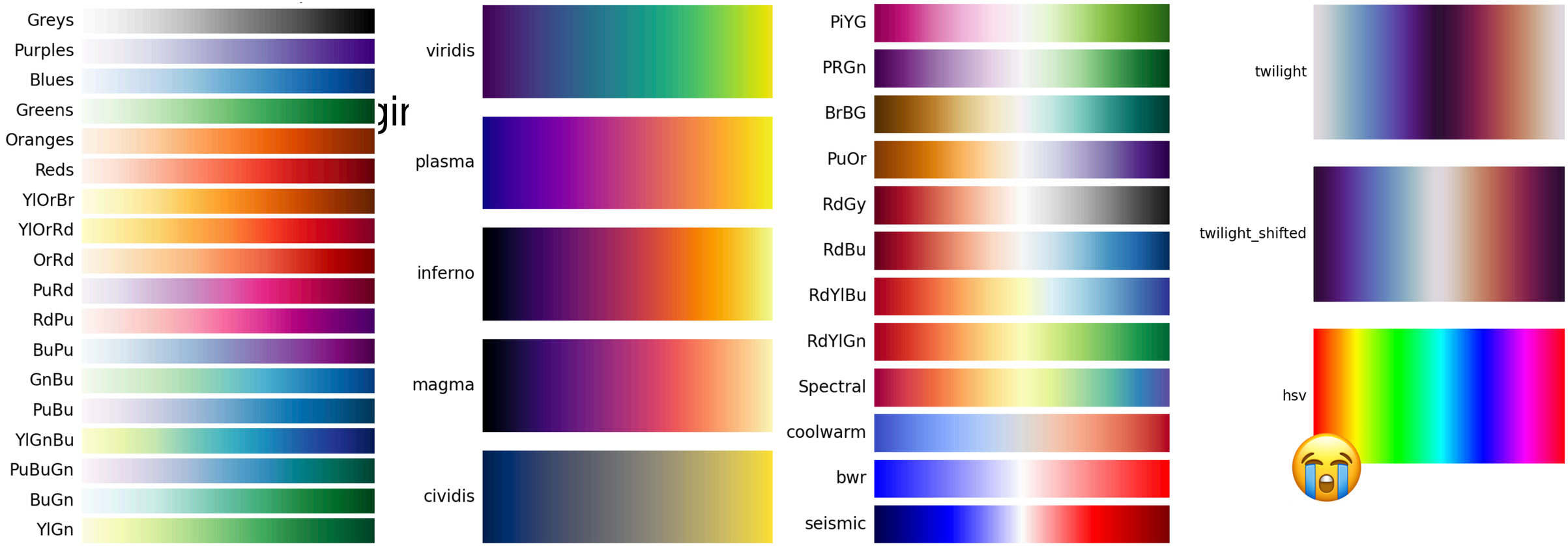
link

Ahead Of The Fire
By USA today

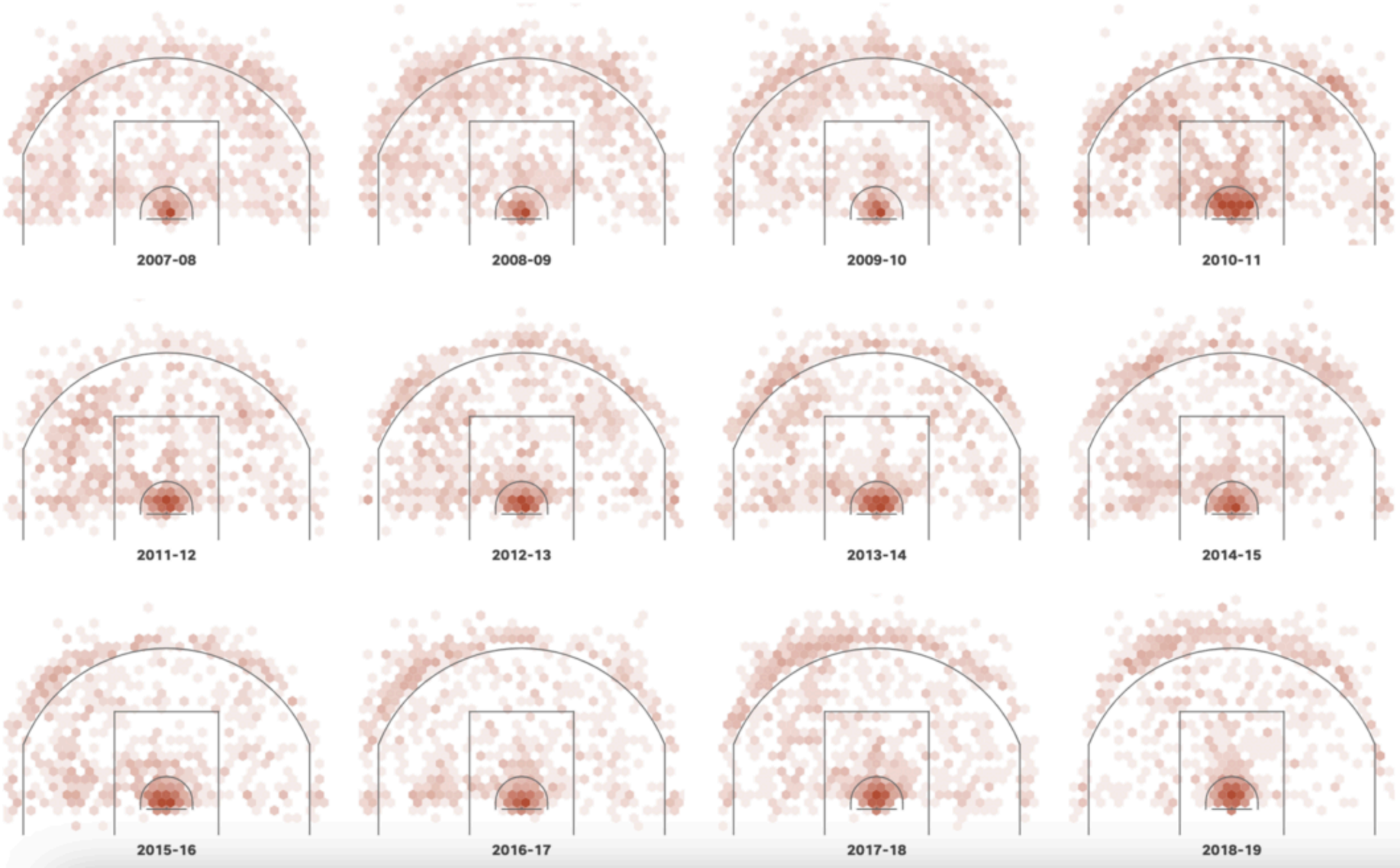
link



Quantitative Encoding



https://matplotlib.org/stable/users/explain/colors/colormaps.html#colormaps

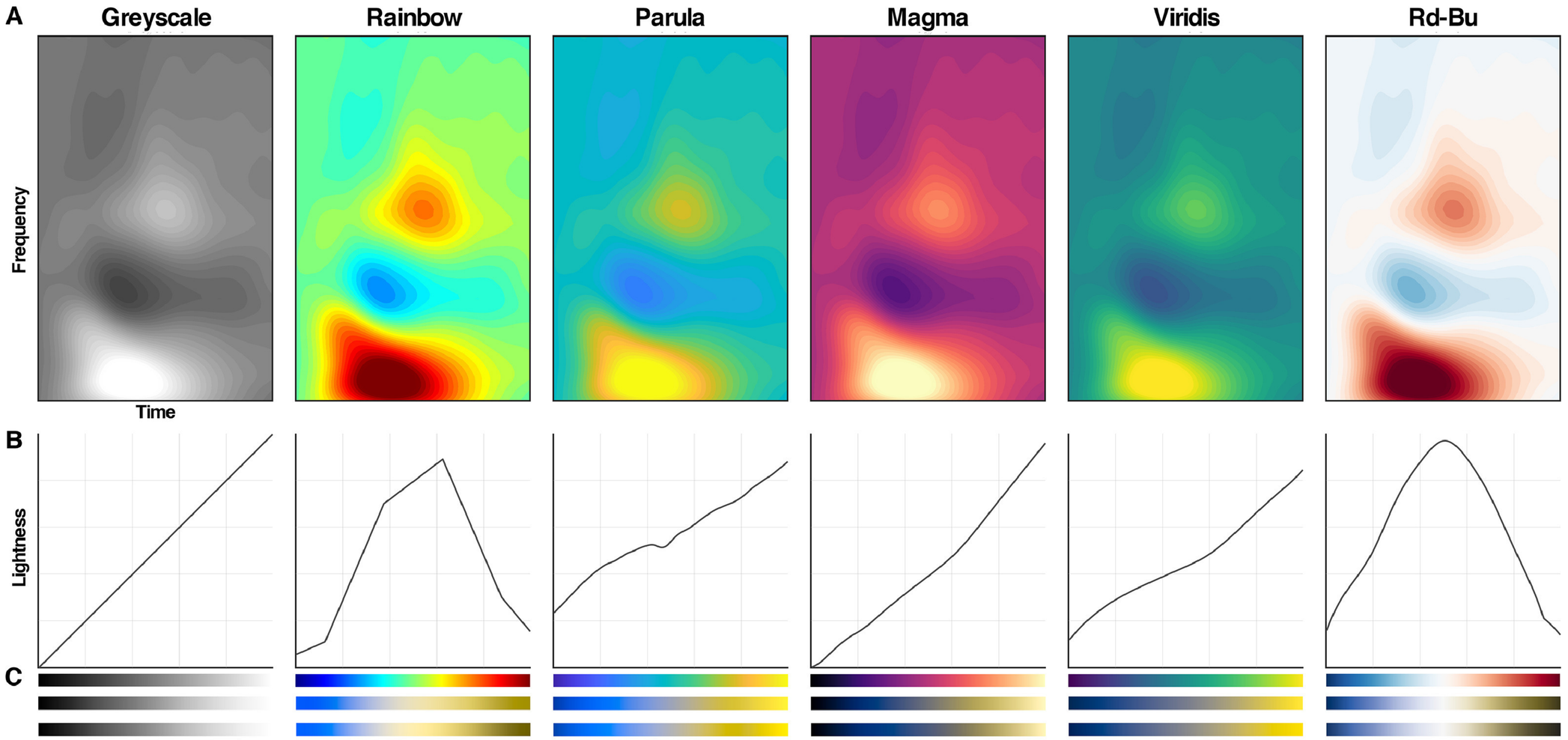


LeBron James has captured the scoring title. We visualized every shot.
by USA Today

link

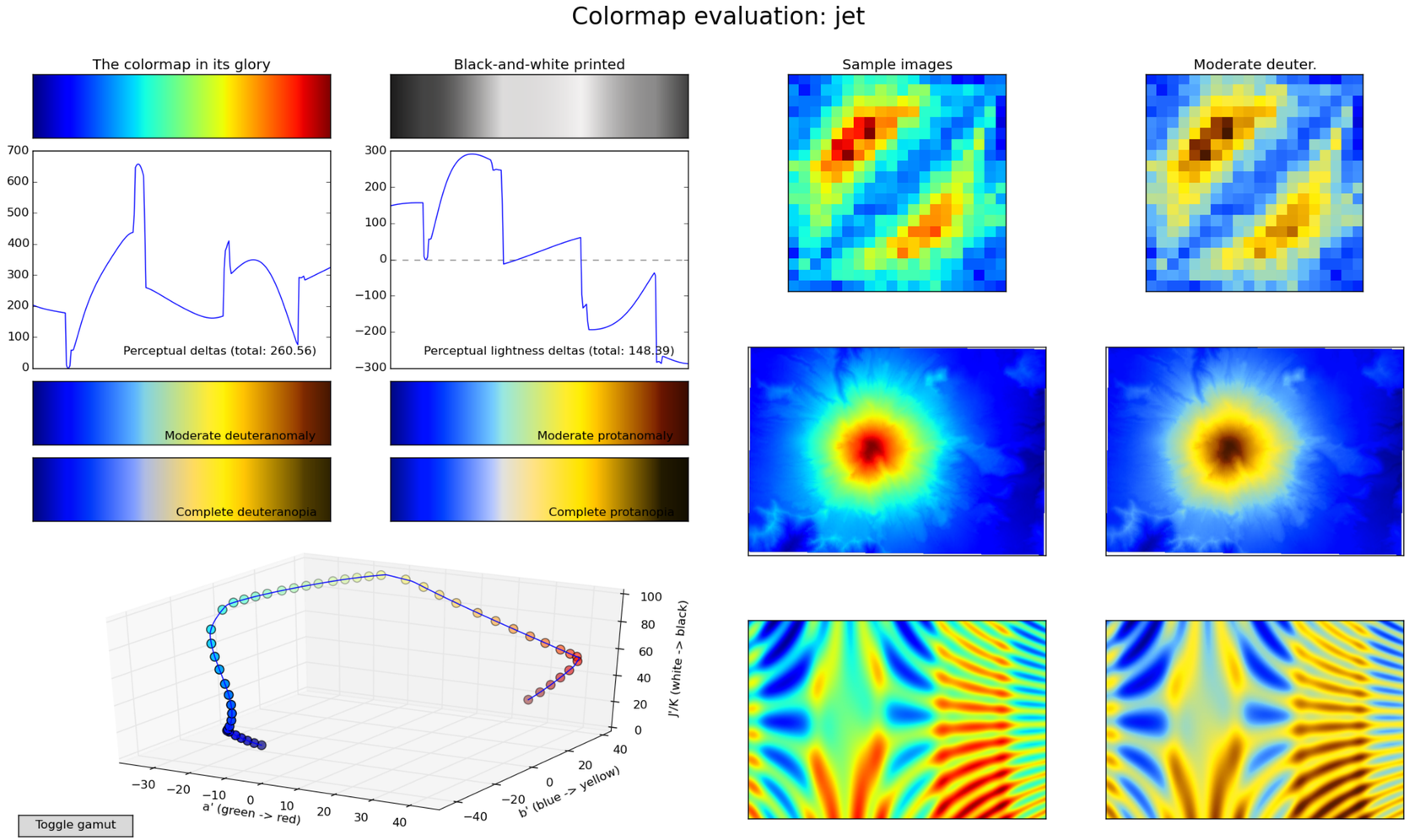
What makes a color map good?

Perceptual uniformity - luminance



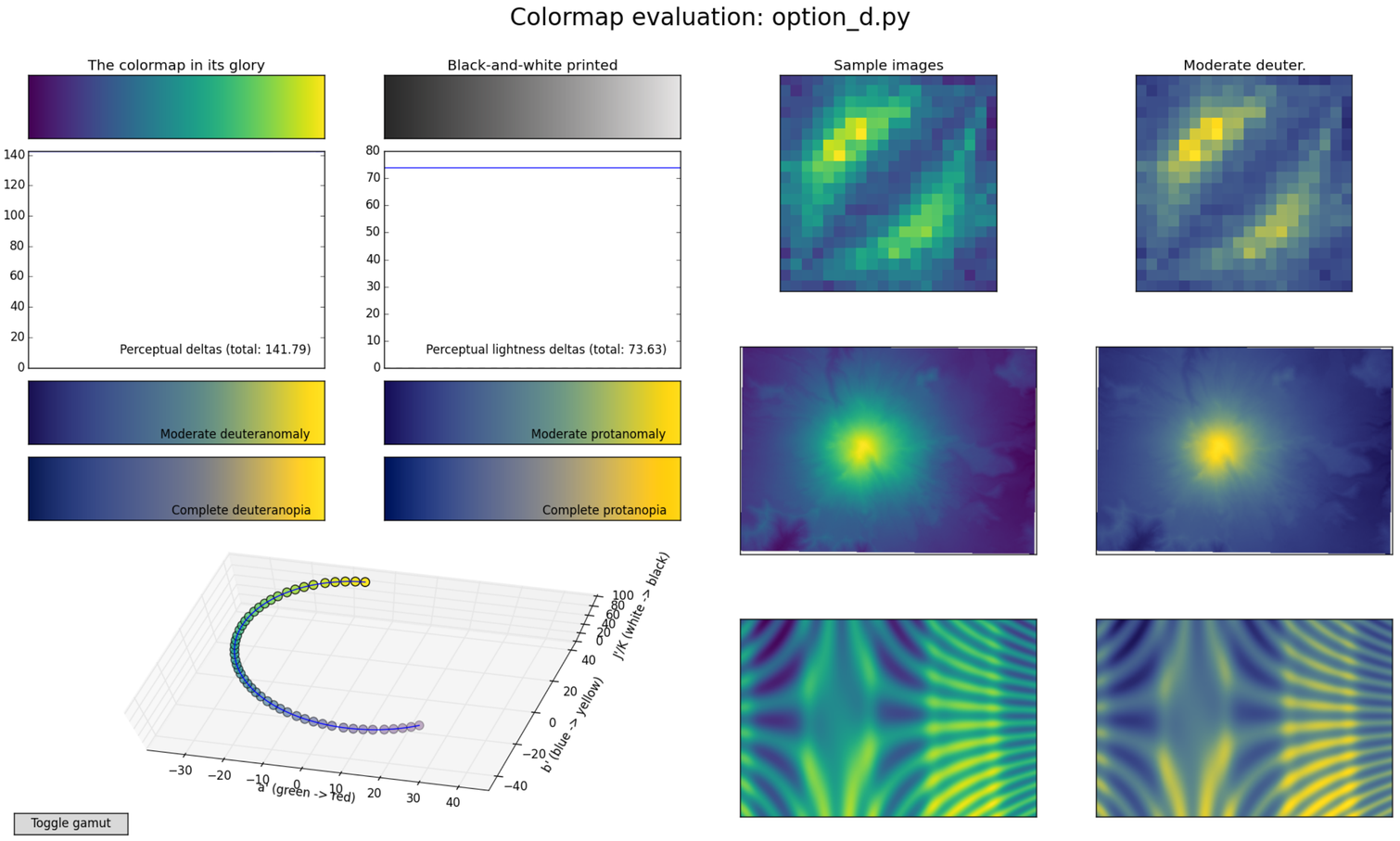
Over the rainbow: Guidelines for meaningful use of colour maps in neurophysiology, Cooper et al. 2021

Perceptual uniformity – jet (rainbow map)



https://bids.github.io/colormap/, https://gramaz.io/d3-cam02/#ciecam02

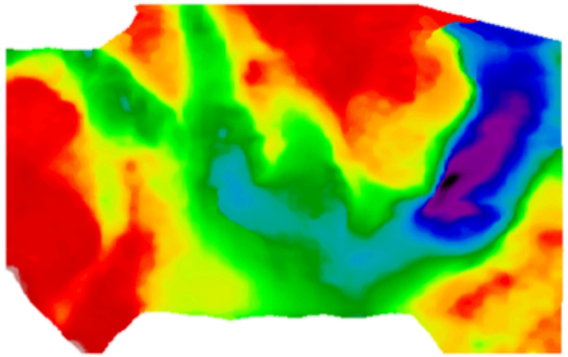
Perceptual uniformity – viridis map

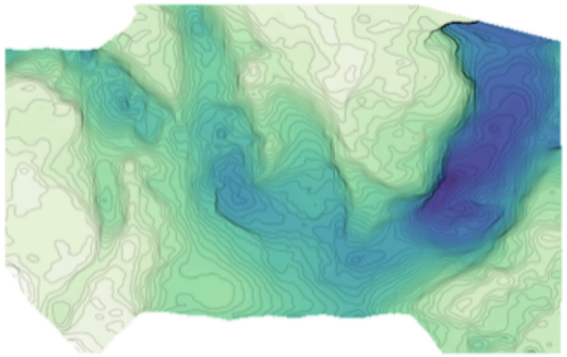


https://bids.github.io/colormap/

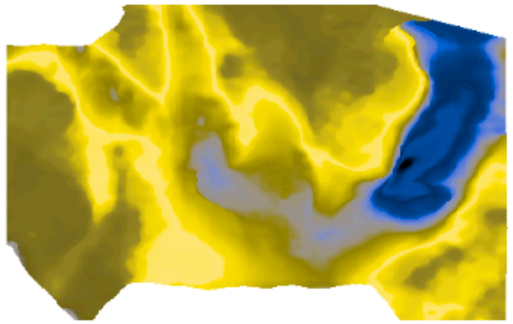
Semantics

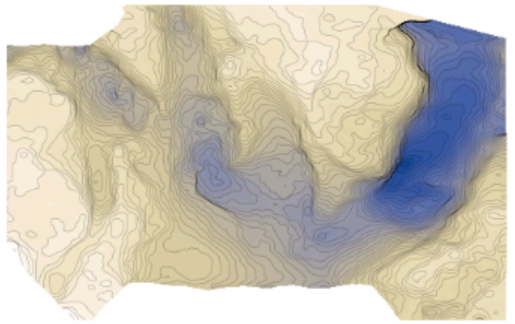
Nova Scotia sea floor depth



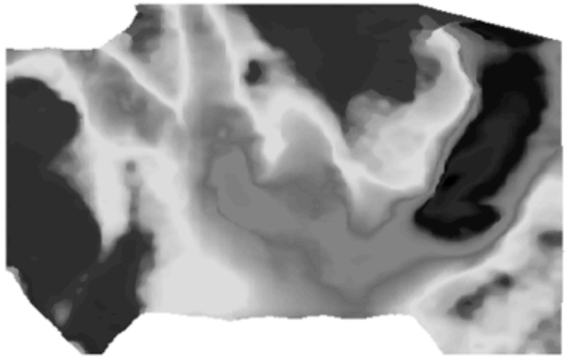


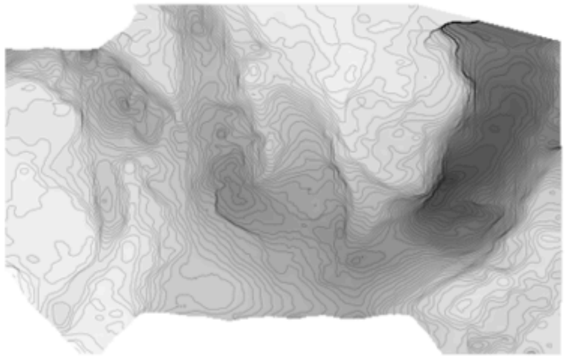
Let's check that it is indeed colourblind-safe and grey-safe:





Is this a pit? What?

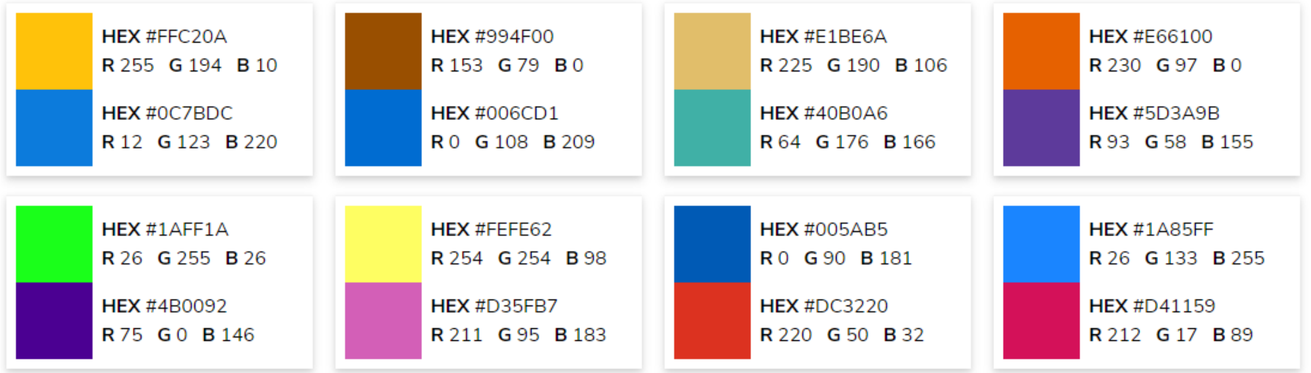




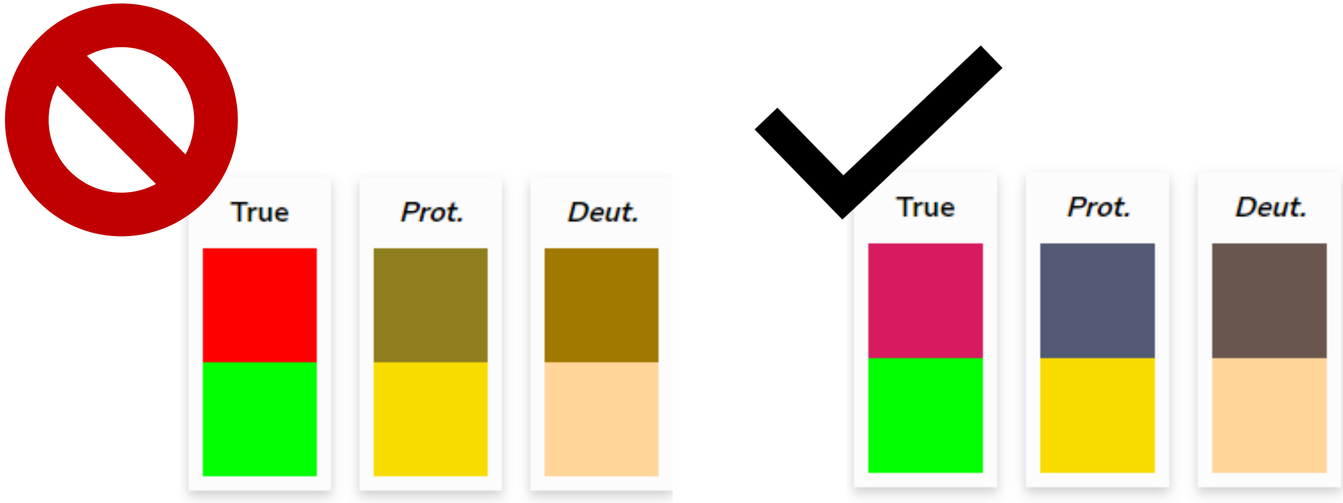
https://agilescientific.com/blog/2017/12/14/no-more-rainbows

Accessible Colors

- Working color combinations (for colorblindness)



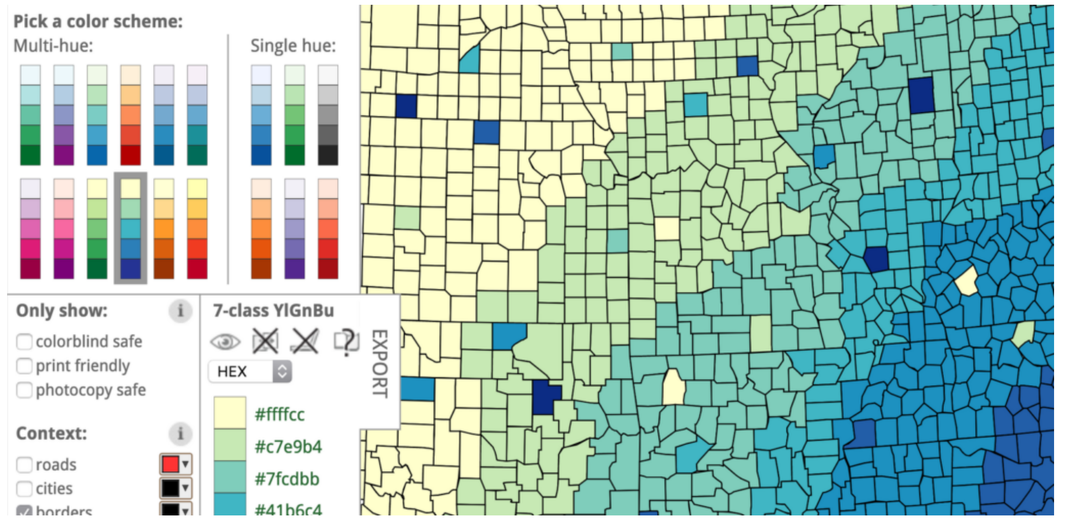
- Color combinations to avoid, e.g.:
  - Red-green
  - Purple-blue

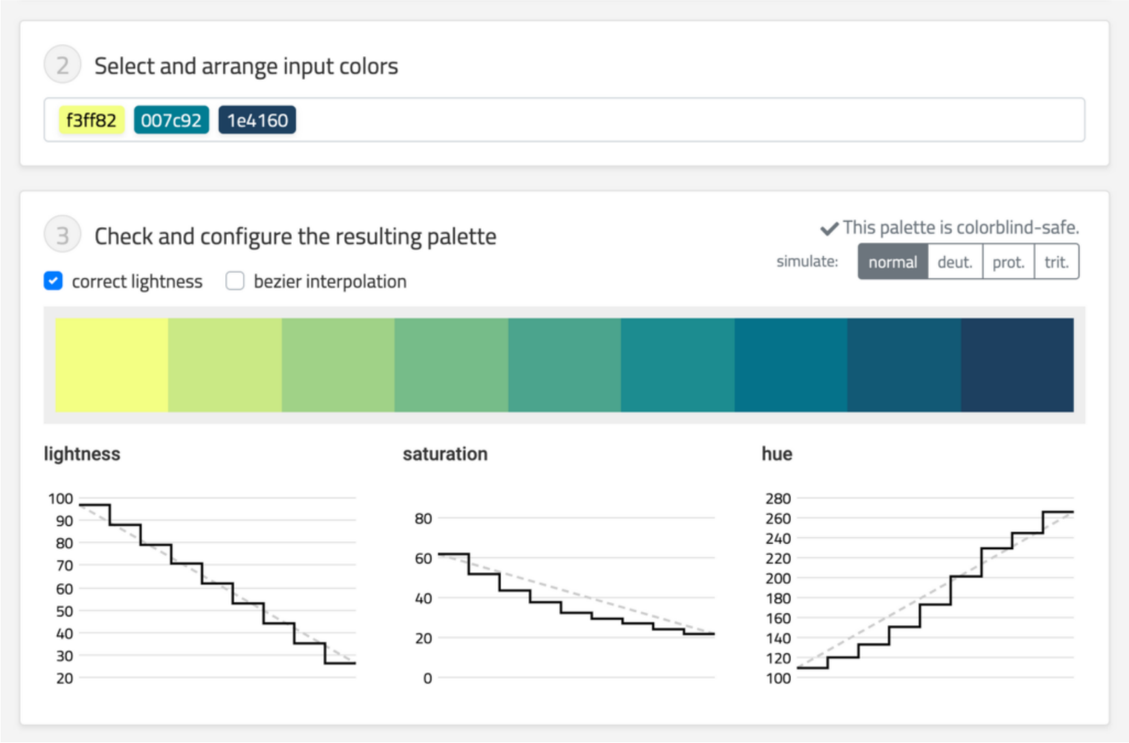


⚒️ Color tools

- Colorbrewer (classic) https://colorbrewer2.org/#type=sequential&scheme=BuGn&n=3

- Make your own color palette: https://www.vis4.net/palettes/#/9|s|00429d,96ffea,ffffe0|ffffe0,ff005e,93003a|1|1

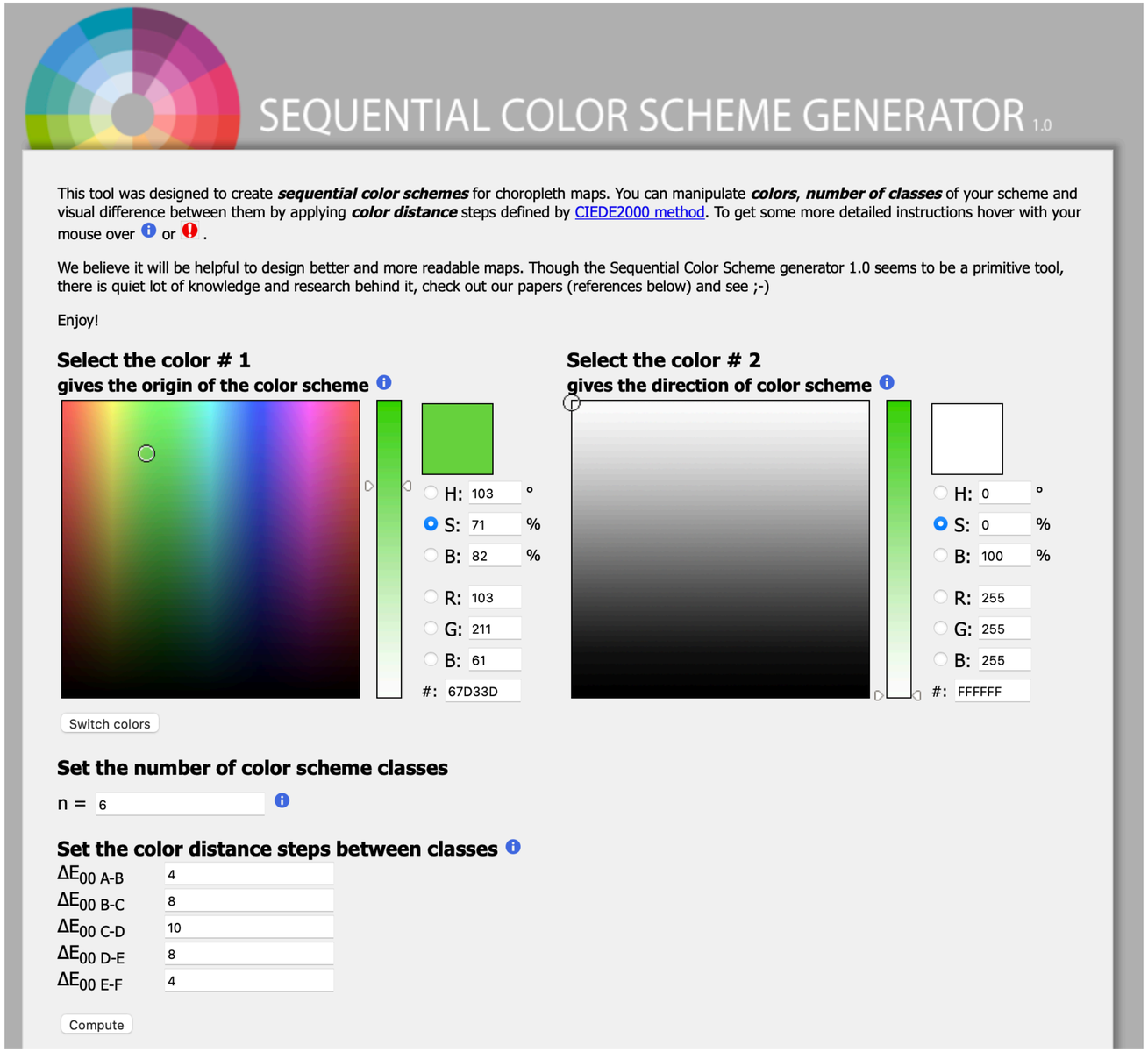




⚒ Color tools

Sequential Color Scheme Generator

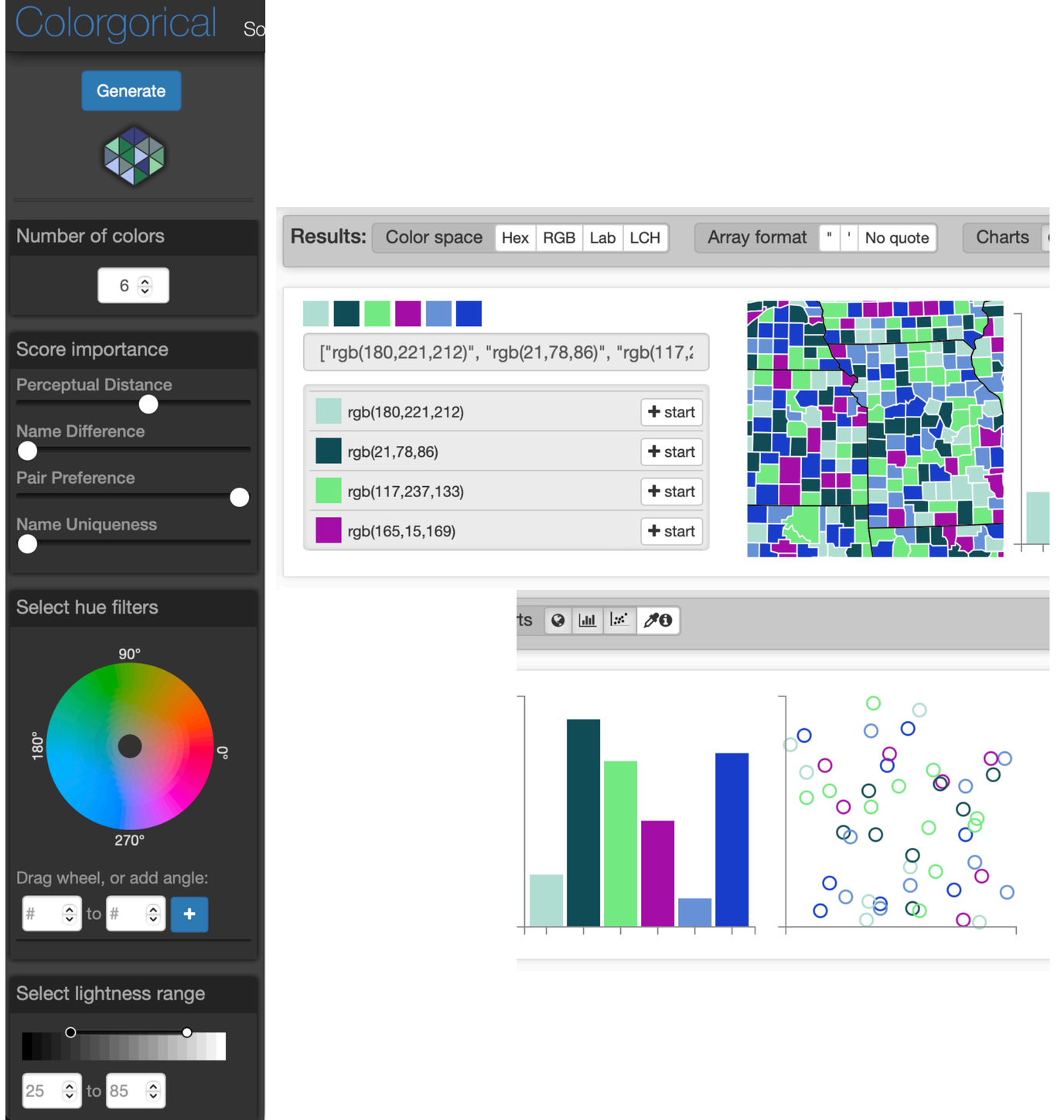
http://eyetracking.upol.cz/color/



⚒ Color tools

Colorgorical

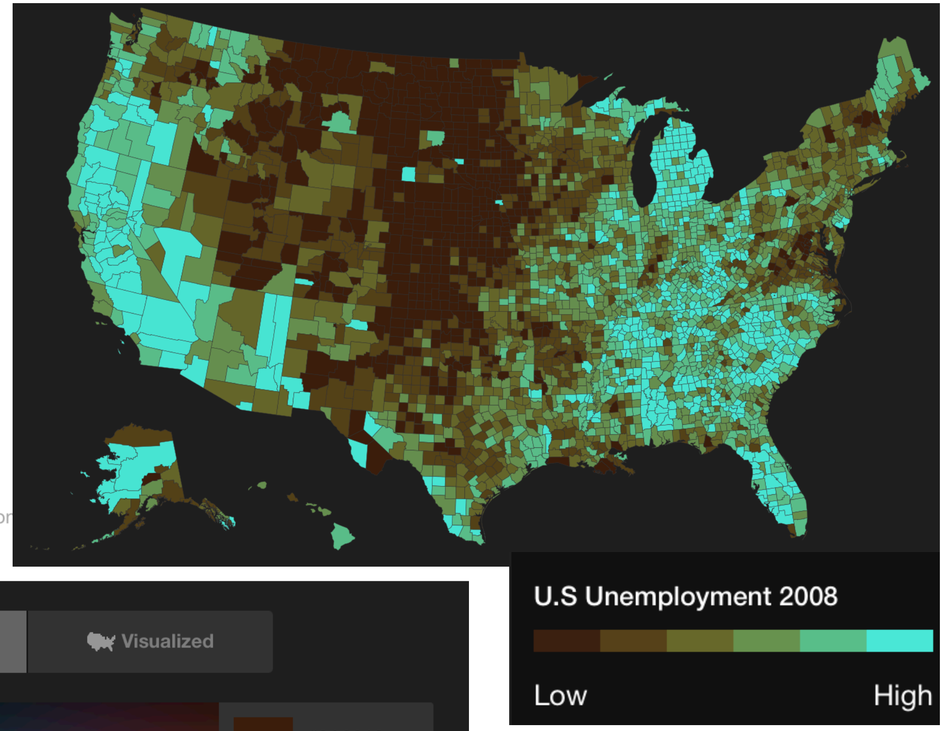
http://vrl.cs.brown.edu/color

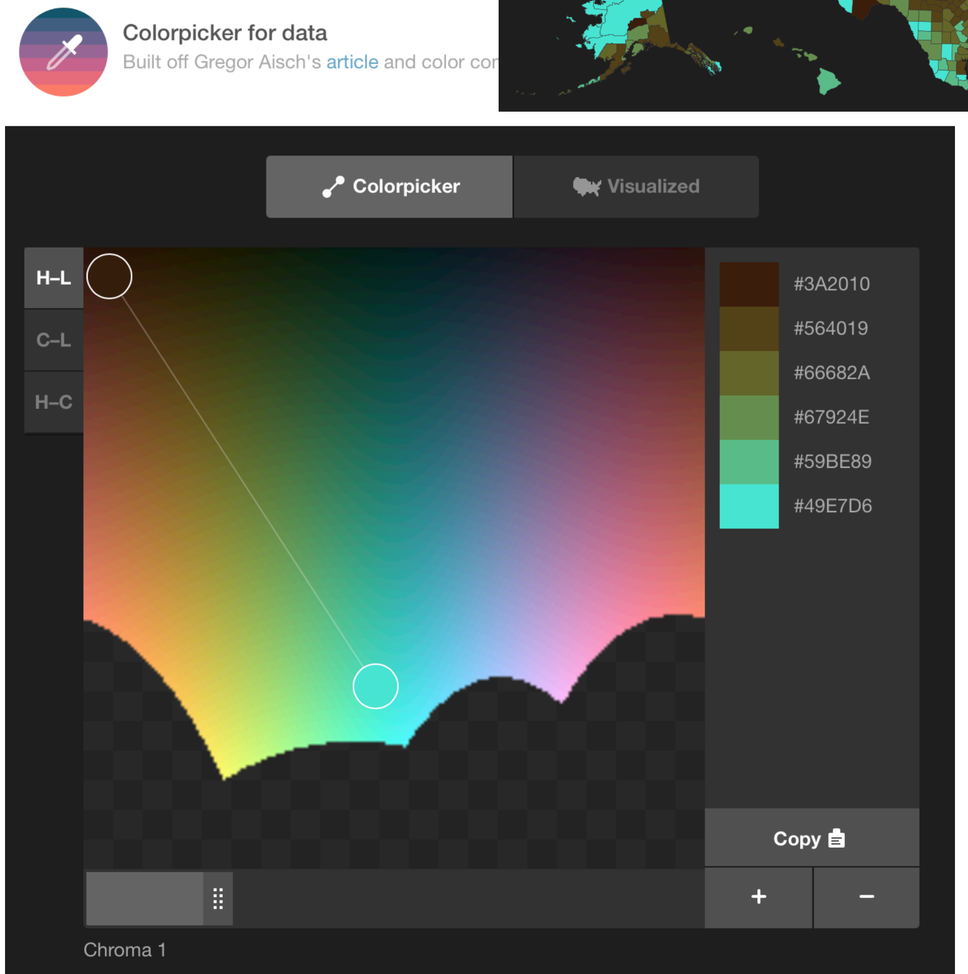


⚒ Color tools

Colorpicker for Data

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

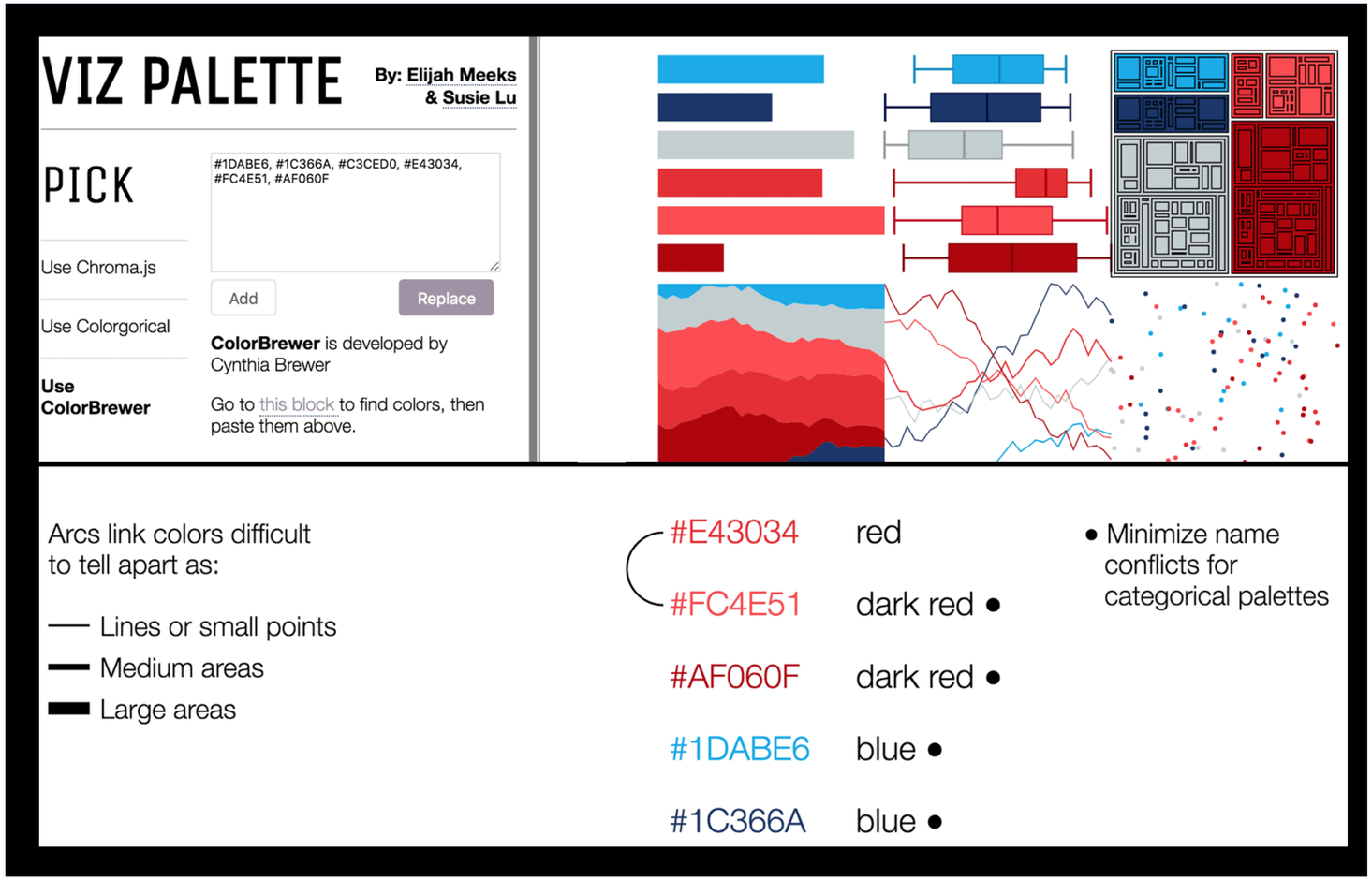




⚒ Color tools

Check if your colors actually work (accessibility)

Lots of other online tools available to check this

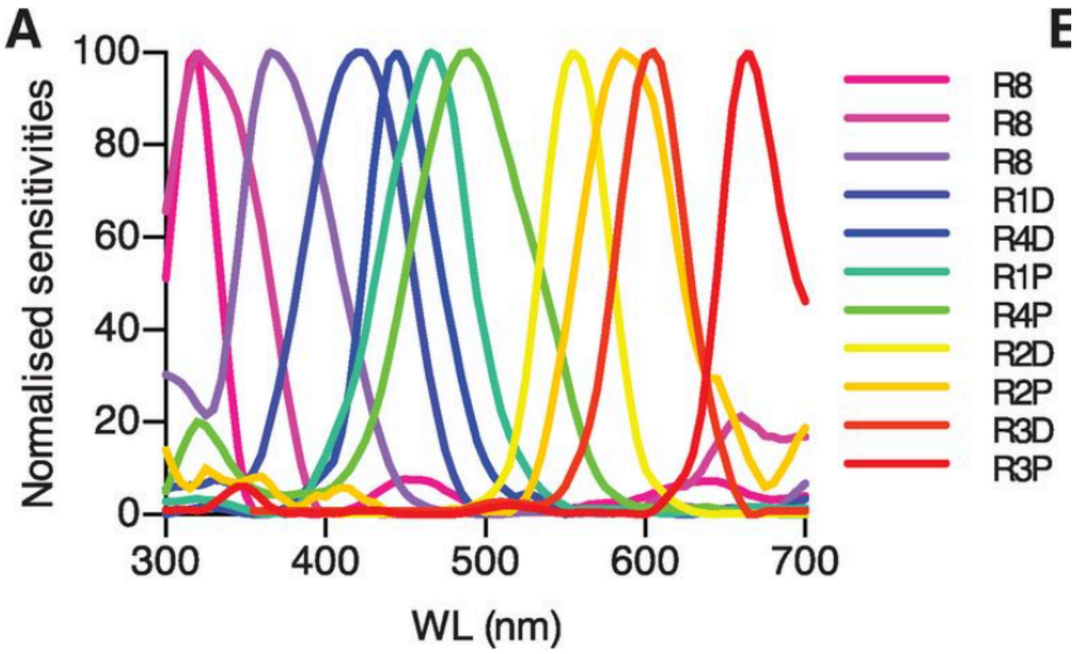


https://projects.susielu.com/vizpalette

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

https://theoatmeal.com/comics/mantis_shrimp

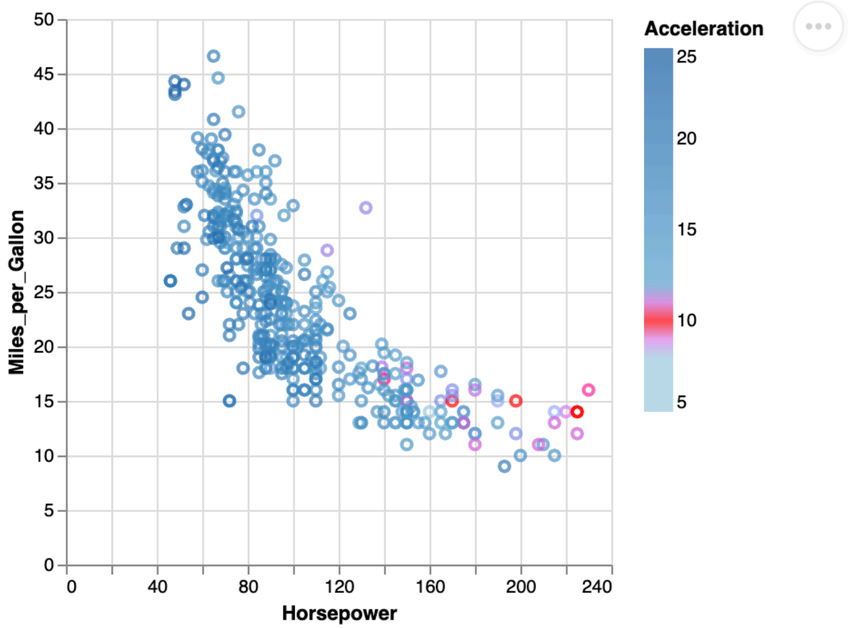
More (serious) color resources

- 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.

Your turn!

- Explore some of these color tools that we have discussed
- Bring one of your custom color maps into an Altair visualization from this morning (or the cartopy/xarray snippet)

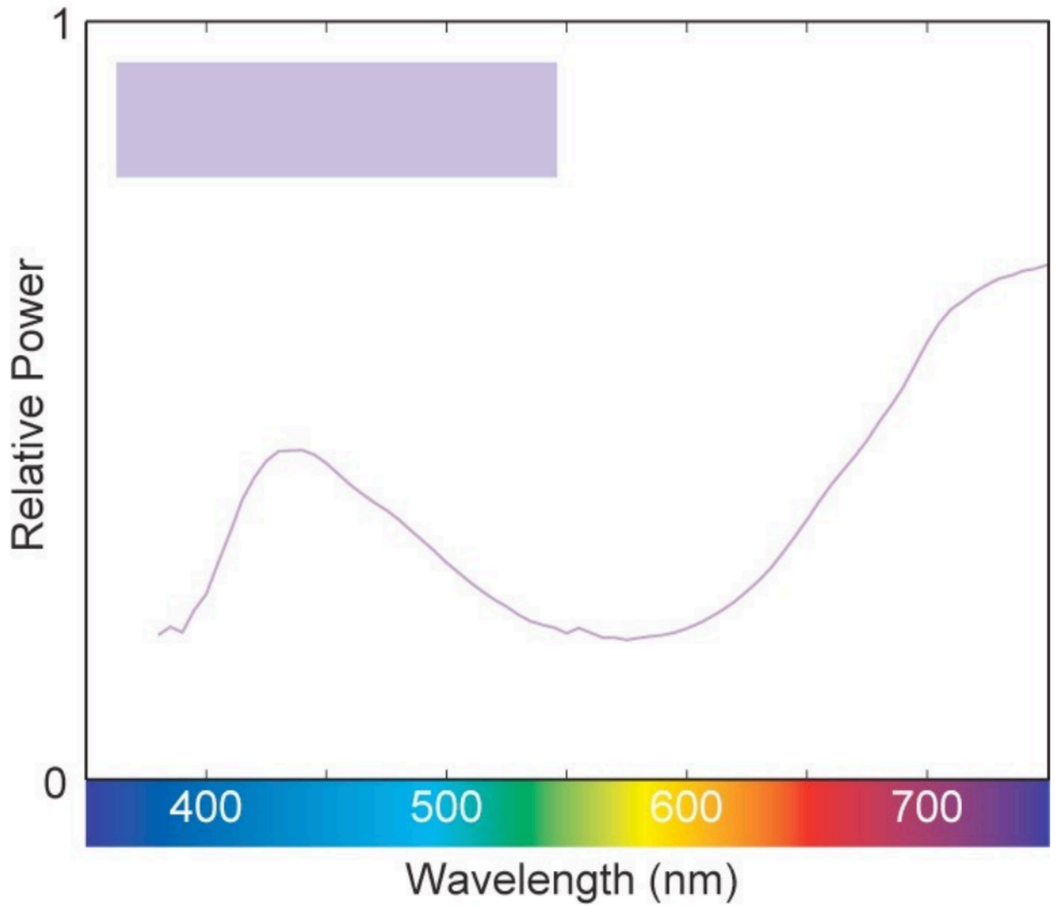
```
domain = [5, 8, 10, 12, 25]
range_ = ['#9cc8e2', '#9cc8e2', 'red', '#5ba3cf', '#125ca4']

alt.Chart(cars).mark_point().encode(
    x='Horsepower',
    y='Miles_per_Gallon',
    color=alt.Color('Acceleration').scale(domain=domain, range=range_)
)
```



From Vega-Altair documentation:
https://altair-viz.github.io/user_guide/customization.html#color-domain-and-range

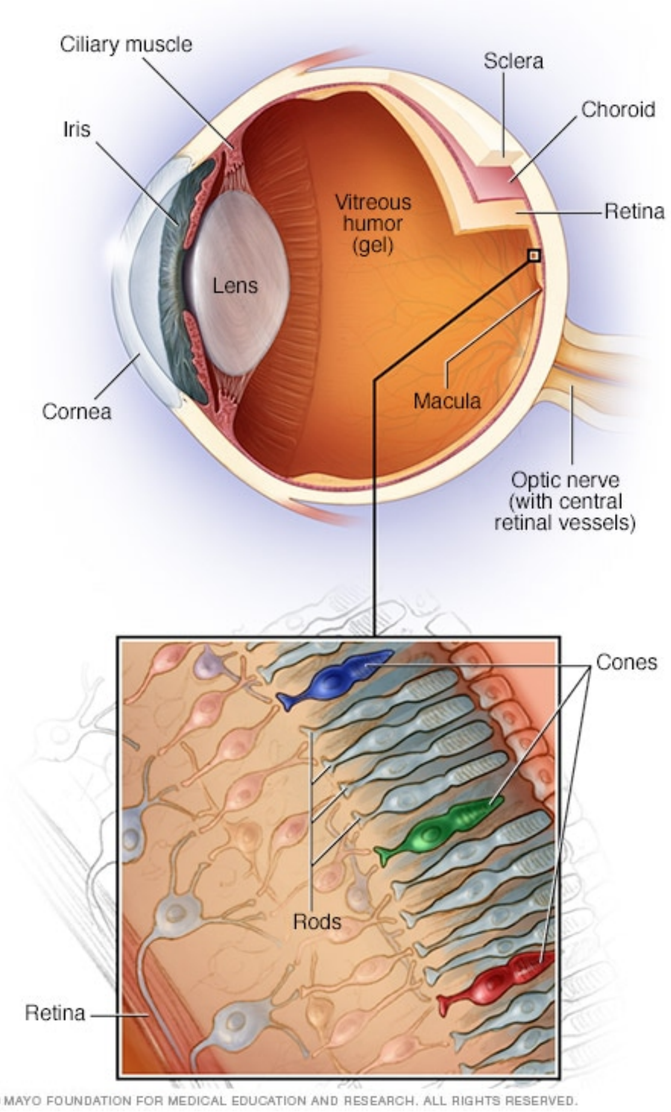
Continuous scale with red used to highlight a specific narrow range of values

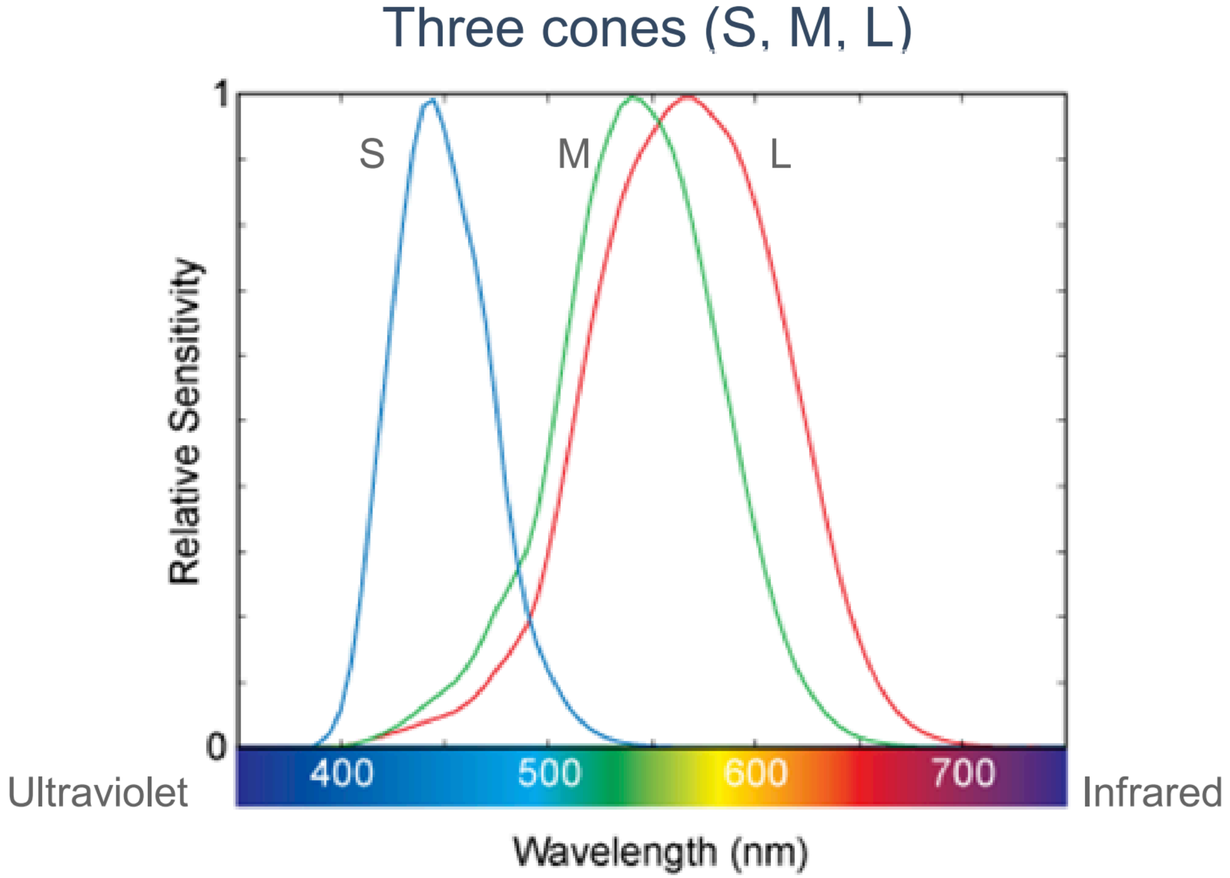
Light (e.g. Purple light)



A Field Guide to Digital Color, M. Stone

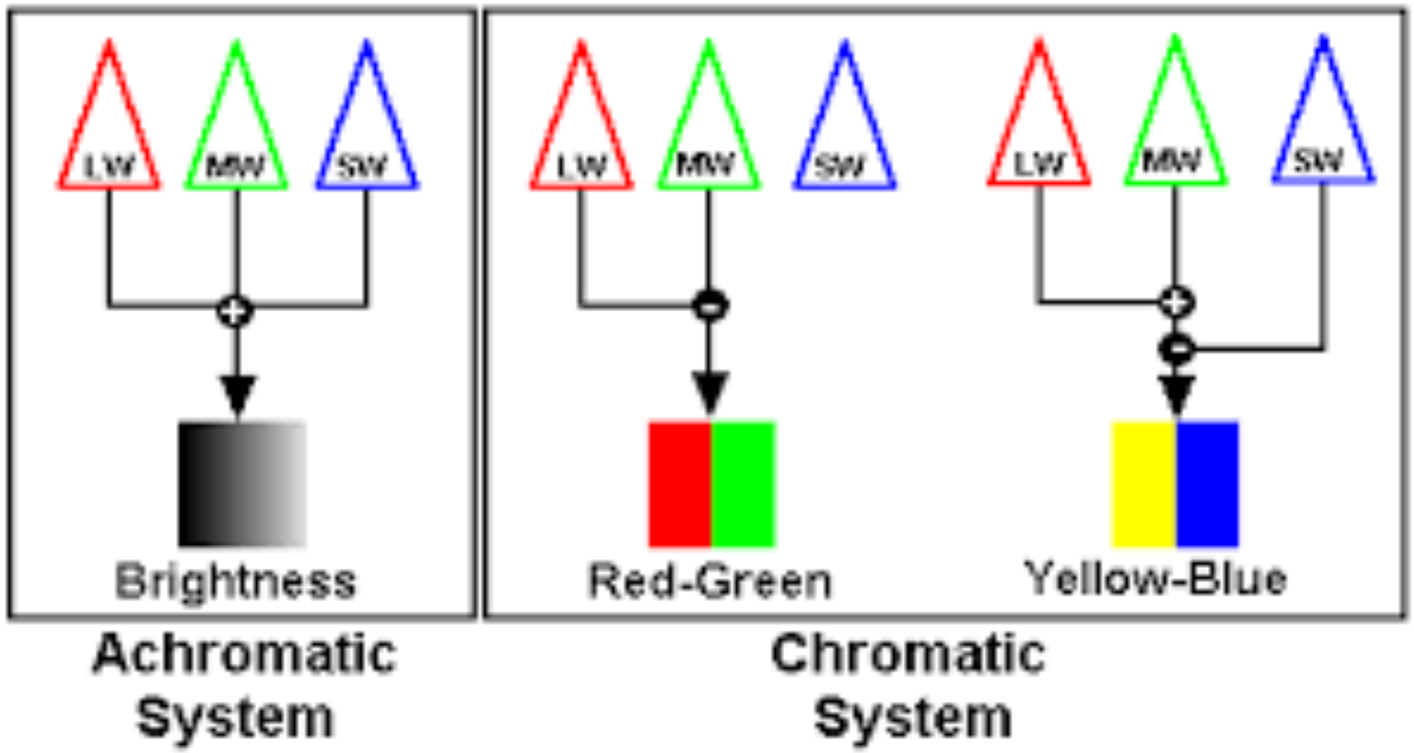
Cone response





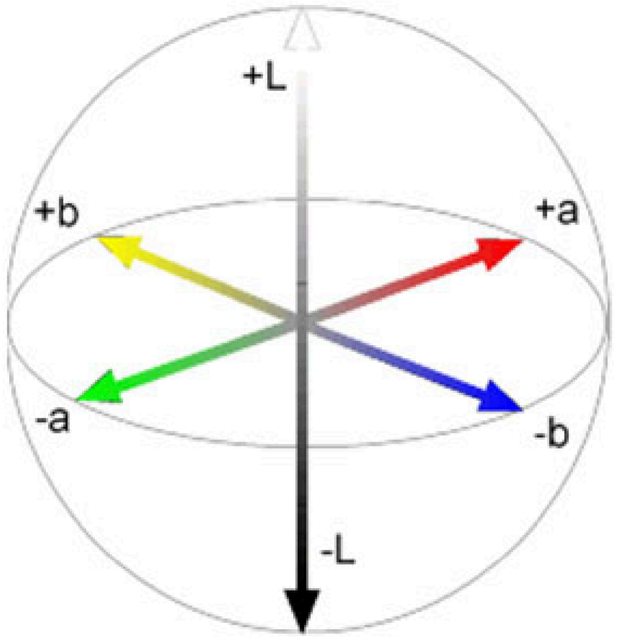
Eye anatomy, Cone response, A Field Guide to Digital Color, M. Stone

Opponent Processing



https://biology.stackexchange.com/questions/26216/advantage-of-opponent-color

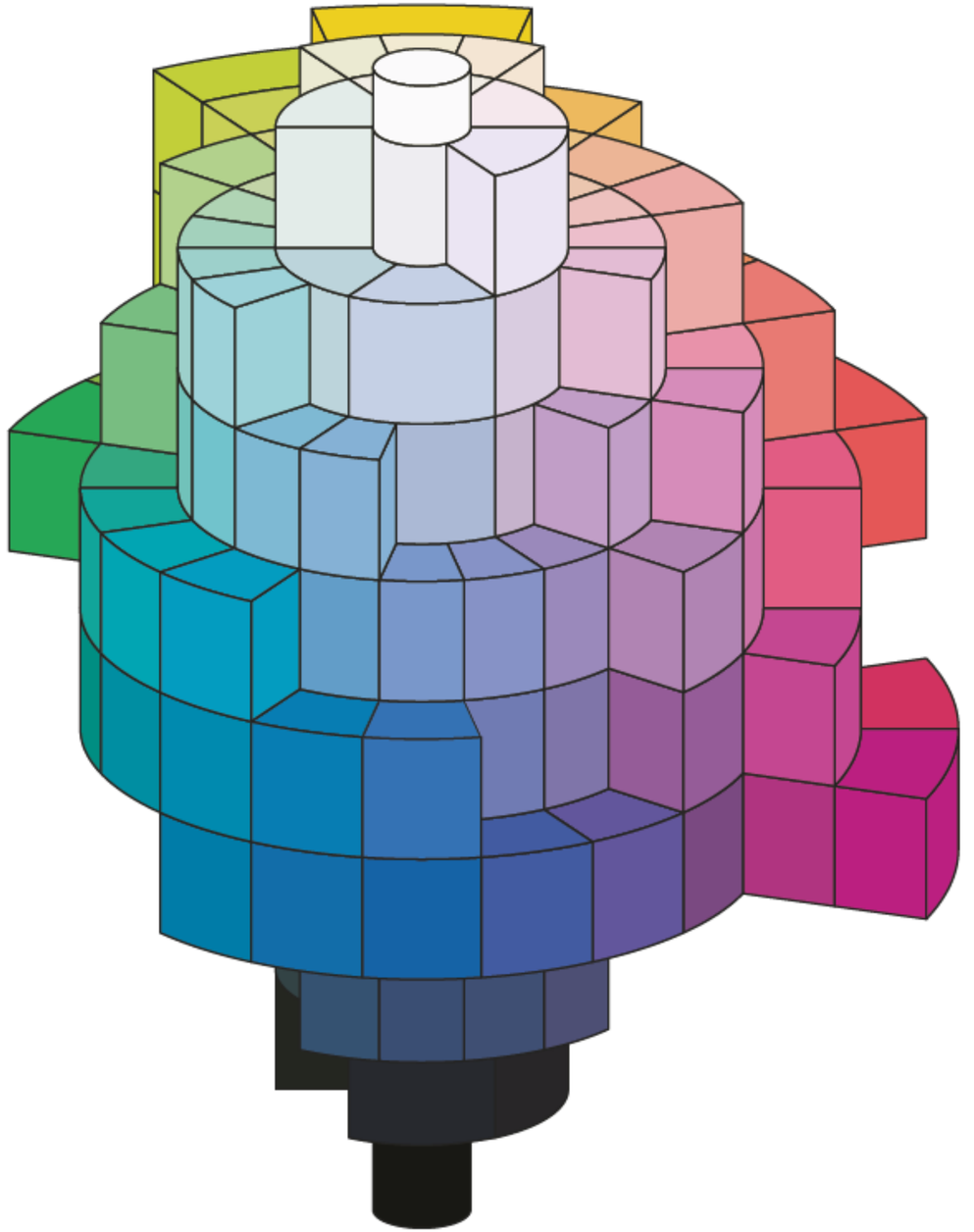
CIELAB



Computed from XYZ

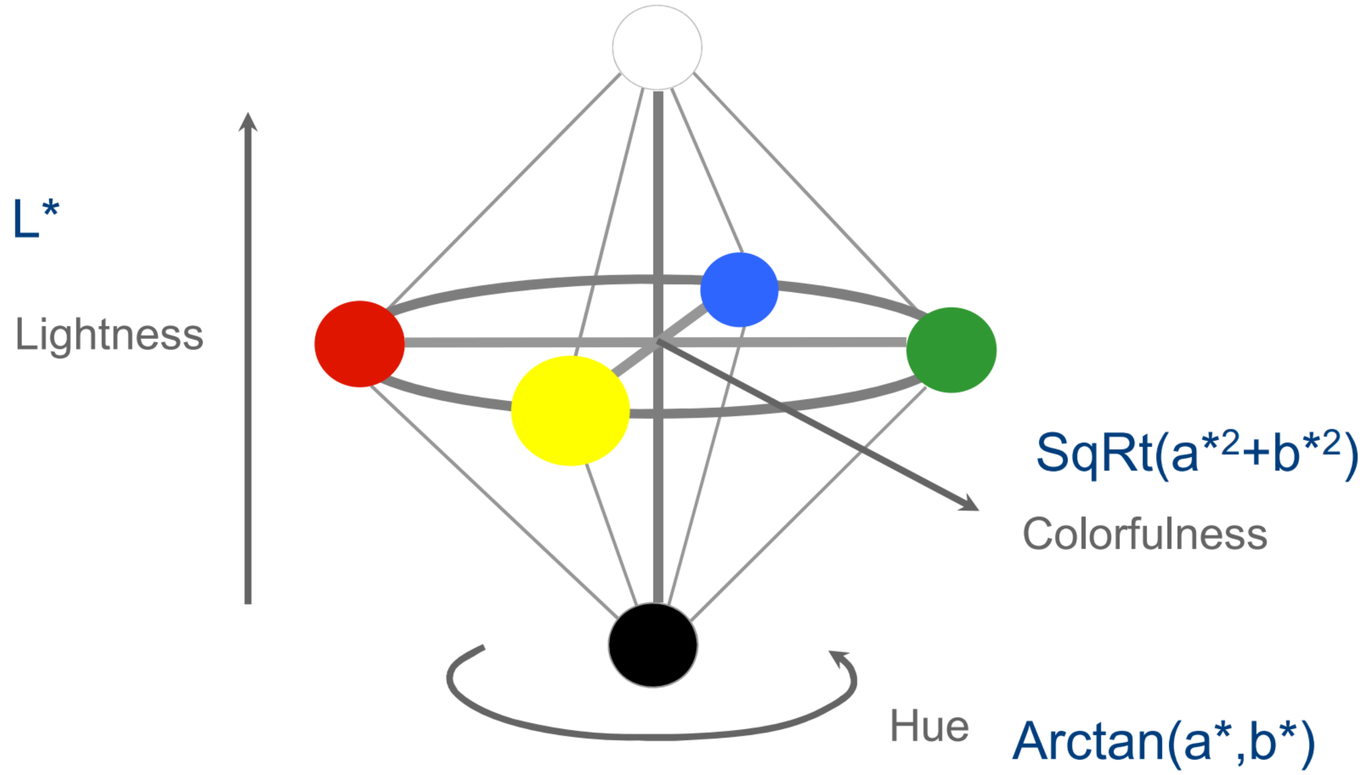
- Calibrated RGB
- Reference white
- L*, a*,b*

“Perceptually uniform”



https://courses.cs.washington.edu/courses/cse442/18au/lectures/CSE442-Color.pdf

CIELAB is a perceptual color space



https://courses.cs.washington.edu/courses/cse442/18au/lectures/CSE442-Color.pdf

Color appearance

- Eg how we perceive colors
  - Cornsweet illusion