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COLOR, POP-OUT, ILLUSIONS

GOALS FOR TODAY: LEARN HOW...

- ...to find visual idioms and ideas for inspiration.
- ...to effectively use color as a channel for visual encodings including different colormap types.
- ...we process color in the visual system.
- ...individual color differences (i.e., colorblindness) should be accommodated in visualizations.
- ...interactions can occur between colors and with lighting.
- ...illusions and tricks can affect perception.

VISUALIZATION IDEAS



Visualization Taxonomy

In order to address the variety of visualization types in the MassVis database, we created a taxonomy for static (i.e., non-interactive) visualizations. The taxonomy classifies static visualizations according to the underlying data structures, the visual encoding of the data, and the perceptual tasks enabled by these encodings. It contains twelve visualization categories and several popular subtypes for each category. In addition, we supply a set of properties that aid in the characterization of the visualizations. This taxonomy was created originally to classify the **2k dataset**, and we continue to use this terminology in our **papers**. For more information about the taxonomy, please read this document: **taxonomy details**

If you use this taxonomy, please cite this paper:  **Bibtex**

<http://massvis.mit.edu/>

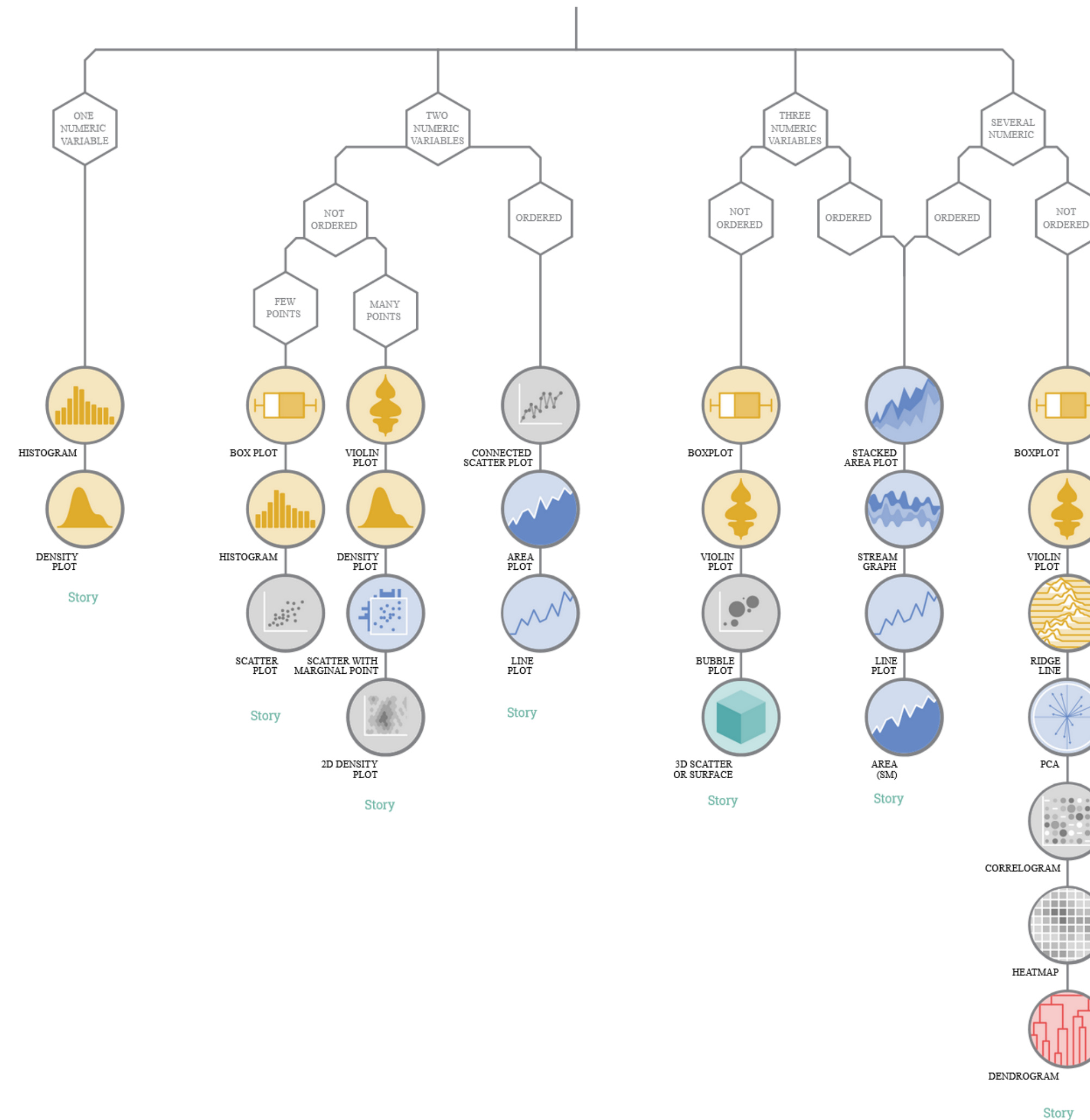
Borkin, M., Vo, A., Bylinskii, Z., Isola, P., Sunkavalli, S., Oliva, A., & Pfister, H., 2013, "[What Makes a Visualization Memorable?](#)", IEEE Transactions on Visualization and Computer Graphics (Proceedings of InfoVis 2013), 19, 12, 2306-2315.

More visualization “catalogs”

Data to Viz

<https://www.data-to-viz.com/>

What kind of data do you have? Pick the main type using the buttons below. Then let the decision tree guide you toward your graphic possibilities.



More visualization “catalogs”

DataVizProject

<http://datavizproject.com/>

The Data Visualization Catalogue

<http://www.datavizcatalogue.com/>



More visualization ideas

<https://matplotlib.org/gallery.html>

<https://github.com/d3/d3/wiki/Gallery>

<https://plot.ly/python/>

This screenshot shows the 'Gallery' page of the D3.js GitHub repository. The page features a 'Visual Index' grid with 16 categories of charts: Box Plots, Bubble Chart, Bullet Charts, Calendar View, Non-contiguous Cartogram, Chord Diagram, Dendrogram, Force-Directed Graph, Circle Packing, Population Pyramid 2000, Stacked Bars, Streamgraph, Sunburst, Node-Link Tree, Treemap, and Voronoi Diagram. On the right side, there is a 'Data-Driven Documents' section with links to Home, Gallery, Examples, Tutorials, and Plugins, and a 'Help' section with links to Stack Overflow, Slack, Google Group, and Gitter. An 'API Reference' link is also present.

This screenshot shows the Plotly Python Open Source Graphing Library website. The header includes the Python logo and the text 'Plotly Python Open Source Graphing Library'. Below this, a search bar is labeled 'Search Plotly's Python Docs'. The main content area is titled 'Plotly Fundamentals' and contains five interactive cards: 'Dash - Interactive Python Apps', 'Static Image Export', 'Updating Plotly Graphs', 'Jupyter Notebook Tutorial', and 'More Plotly Fundamentals'. Below this is a 'Basic Charts' section with four chart examples and a 'More Plotly Fundamentals' button.

This screenshot shows the Matplotlib website. The header features the 'matplotlib' logo. Below the logo, there is a section titled 'Lines, bars, and markers' which displays several chart examples with labels: 'barh_demo', 'fill_demo', 'fill_demo_features', 'line_demo_dash_control', 'line_styles_reference', 'linestyles', 'marker_fillstyle_reference', 'marker_reference', and 'filled markers'.

COLOR

Visual Perception and Cognition

Pre-Attentive Processing

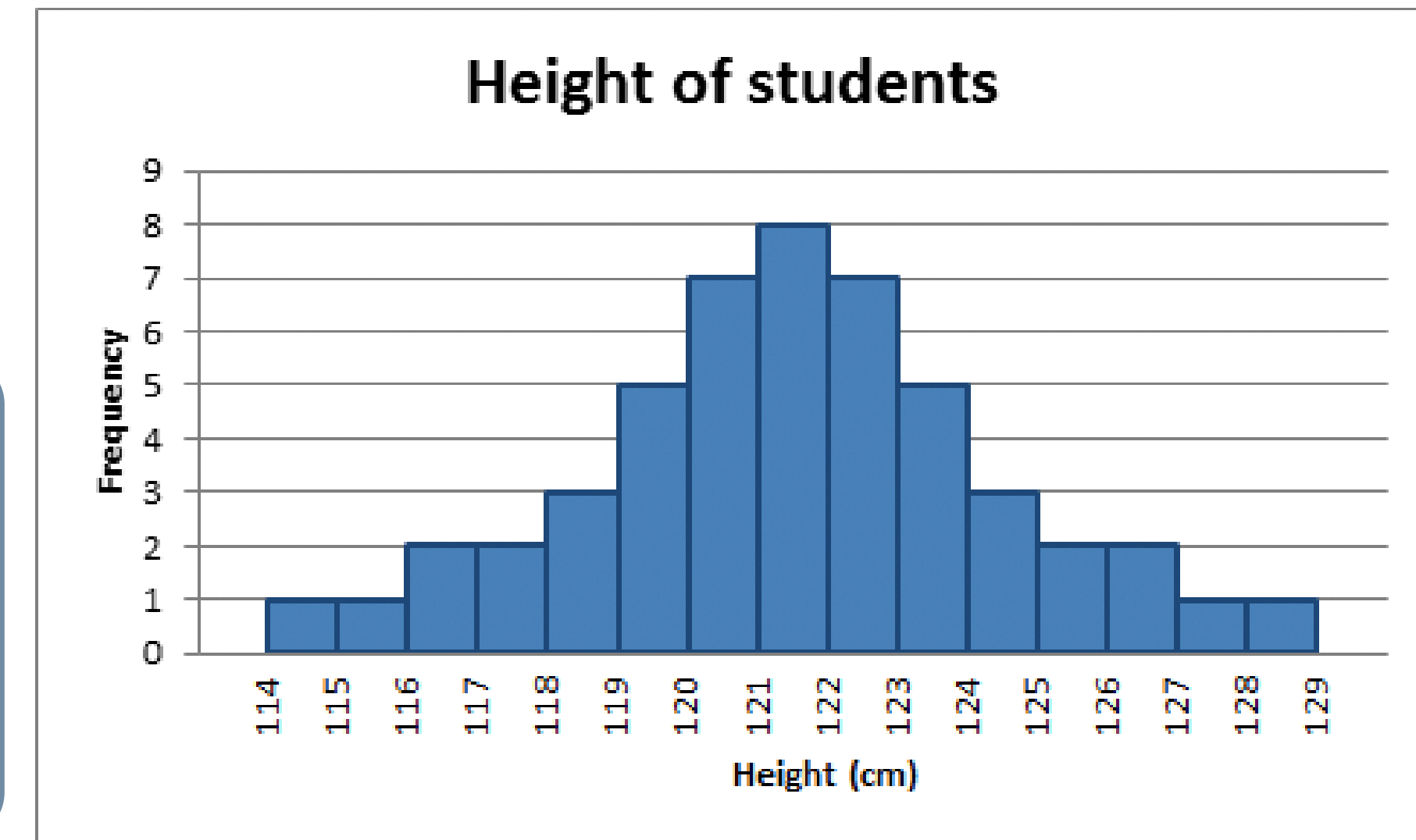
- Automatic
- Lasts < 1 second

Working Memory / Short-Term Memory

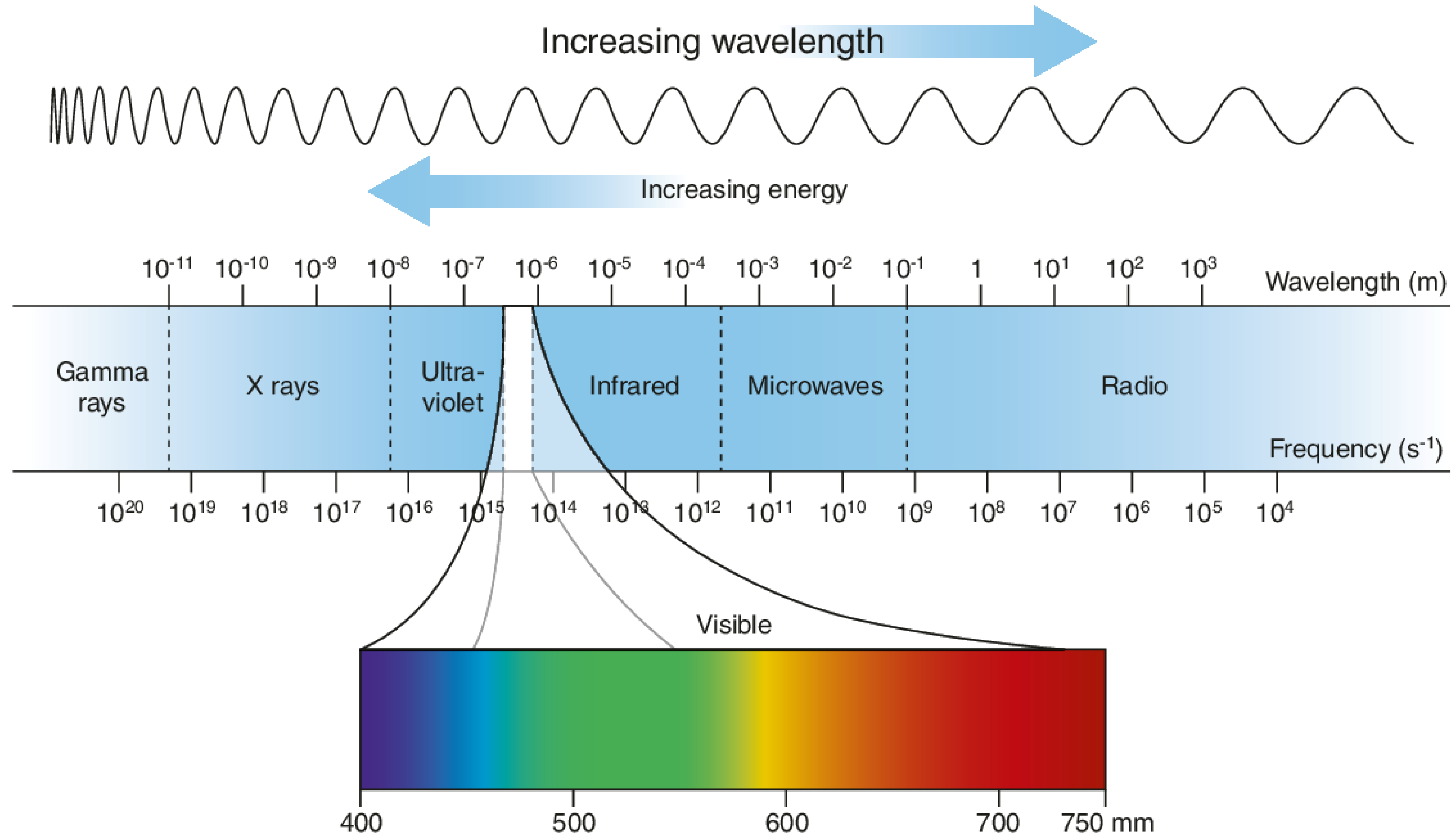
- Conscious
- Limited (information retained for seconds)

Long-Term Memory

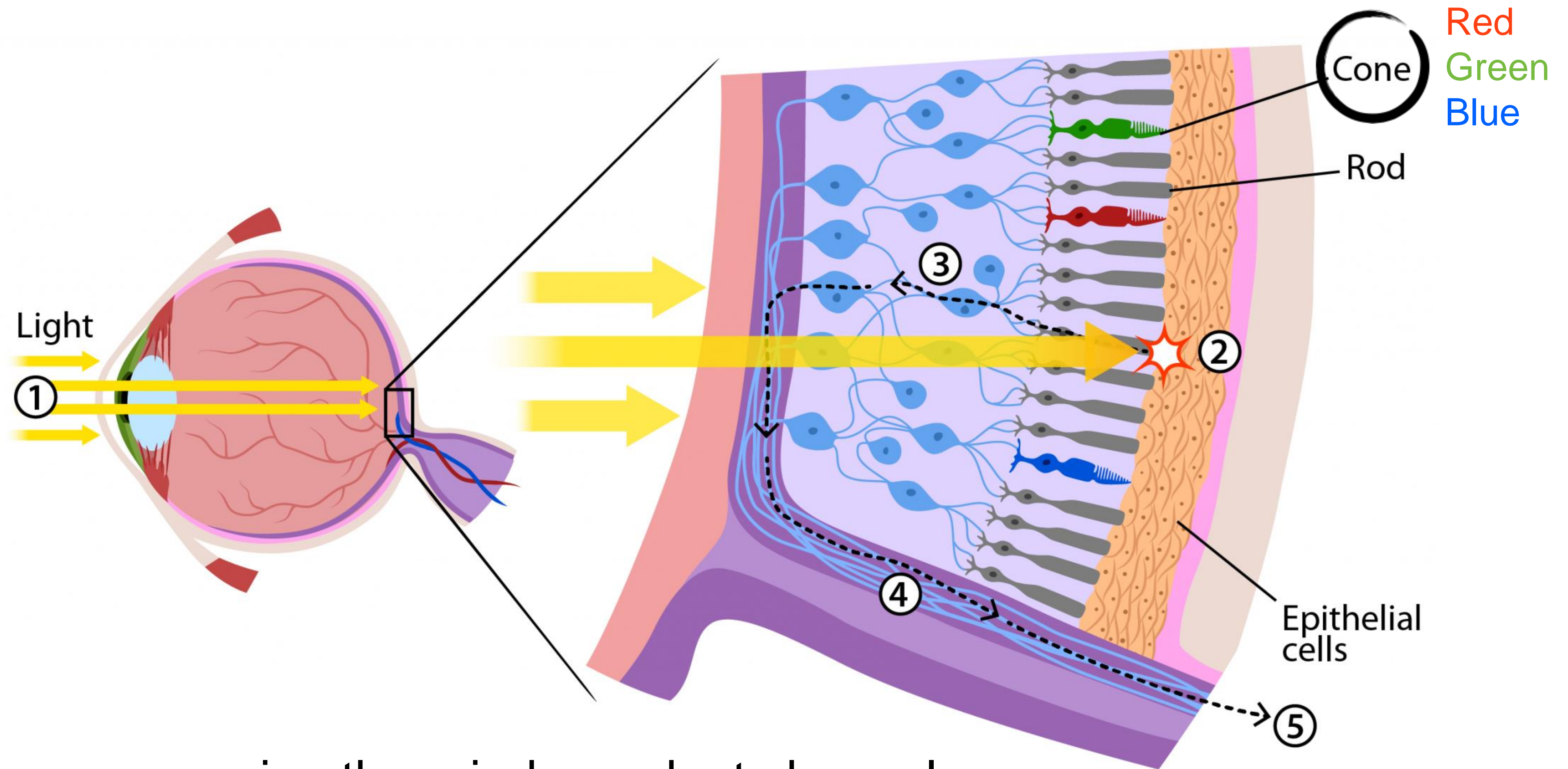
- Storage of repeated working memory tasks
- Can be consciously retrieved



Color = Wavelength

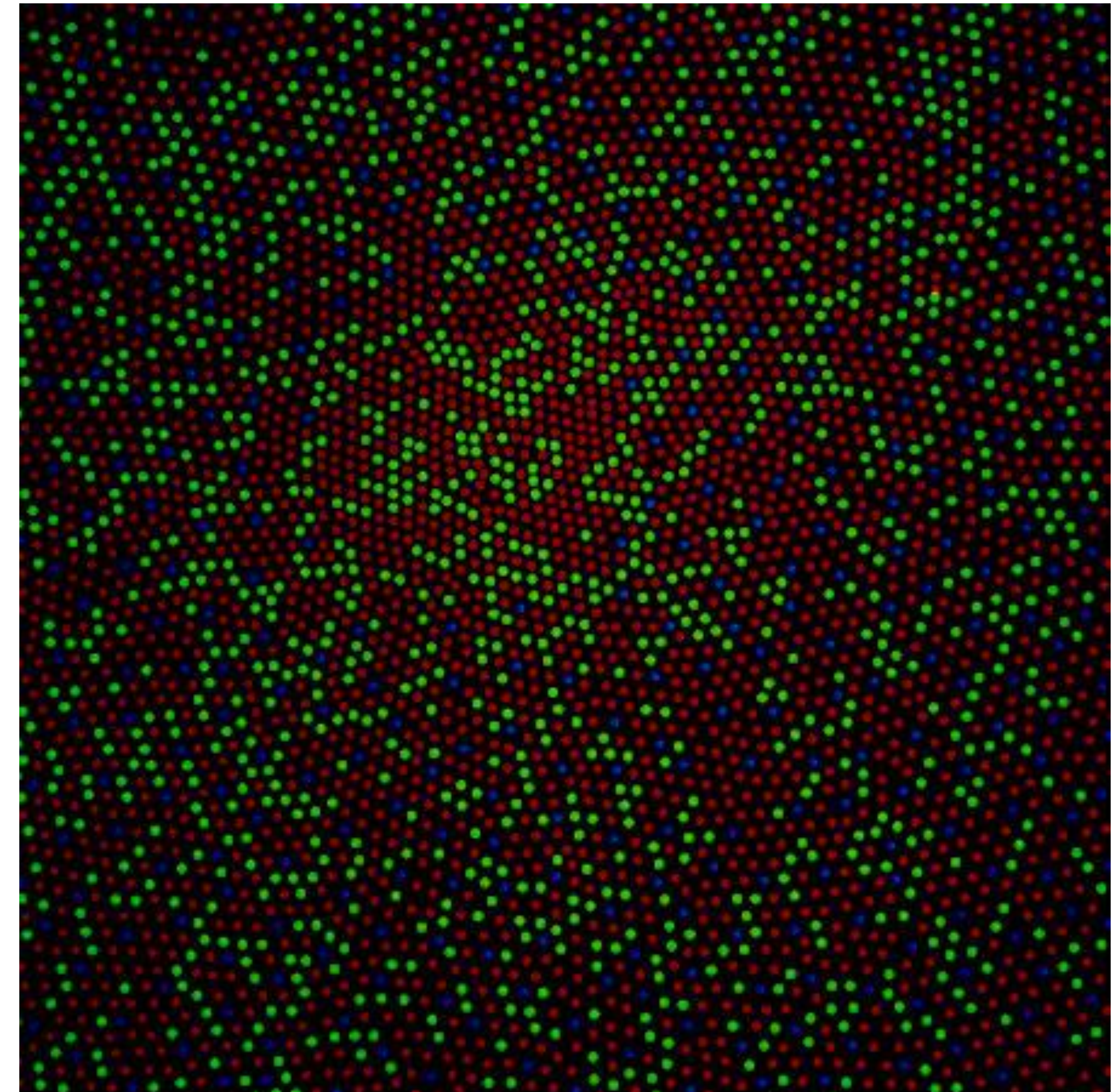
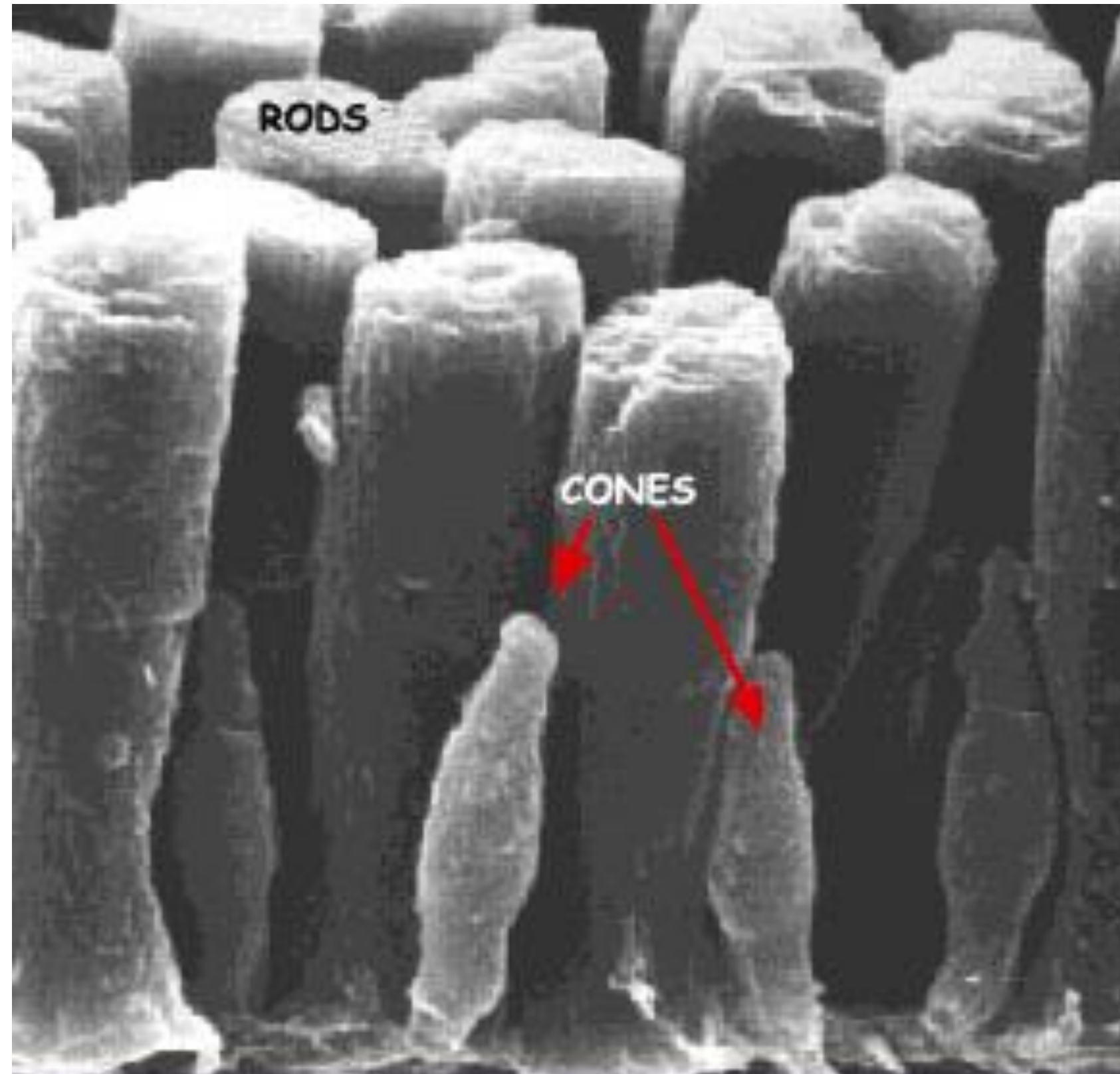


WAVELENGTH → SIGNALS

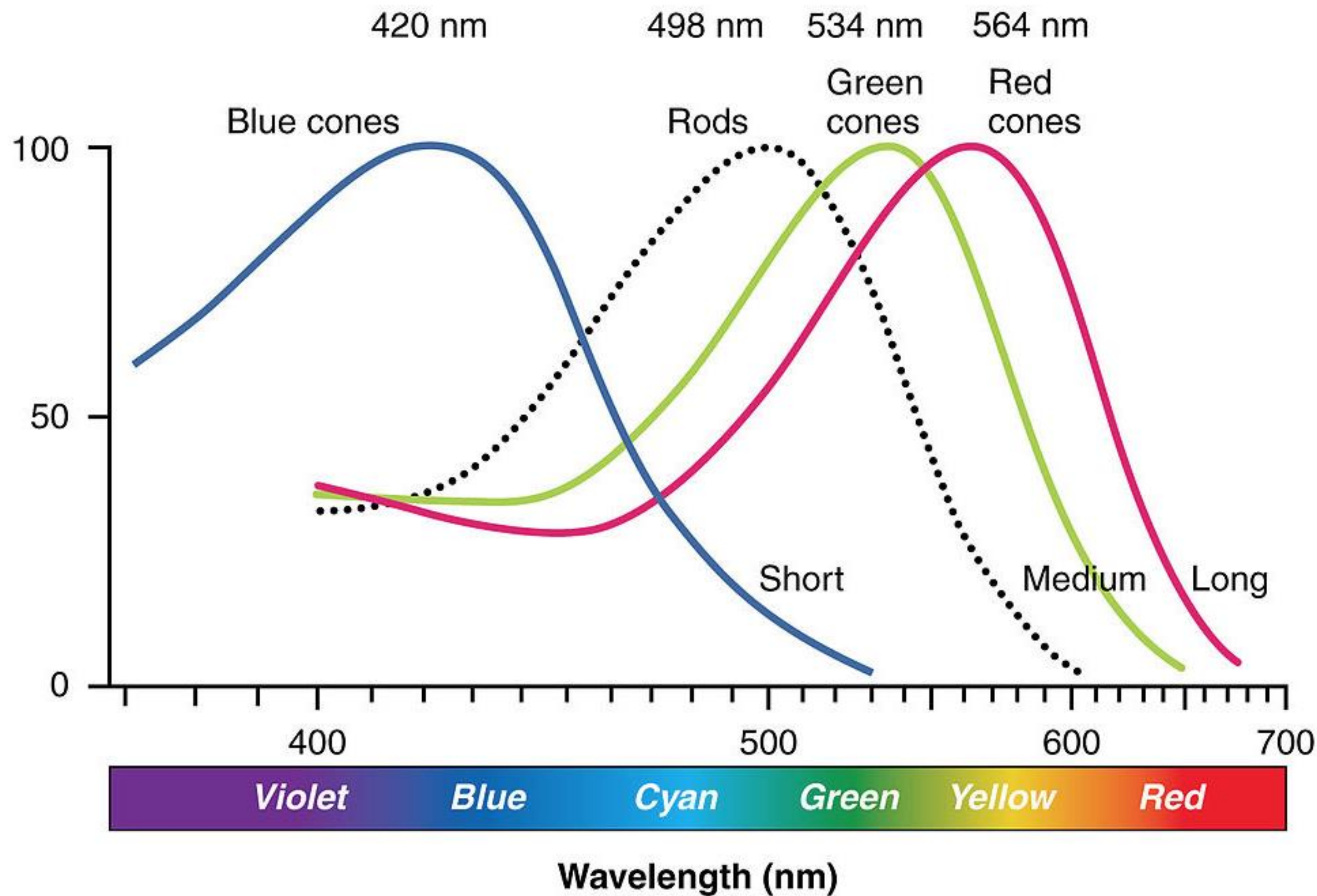


trichromacy = possessing three independent channels for conveying color information

RODS & CONES



VARIABLE ACTIVATION



This is why darkness (lightness) is an effective encoding channel!

Rods: 120 million

Cones: 5-6 million

This is why we are so sensitive to red!

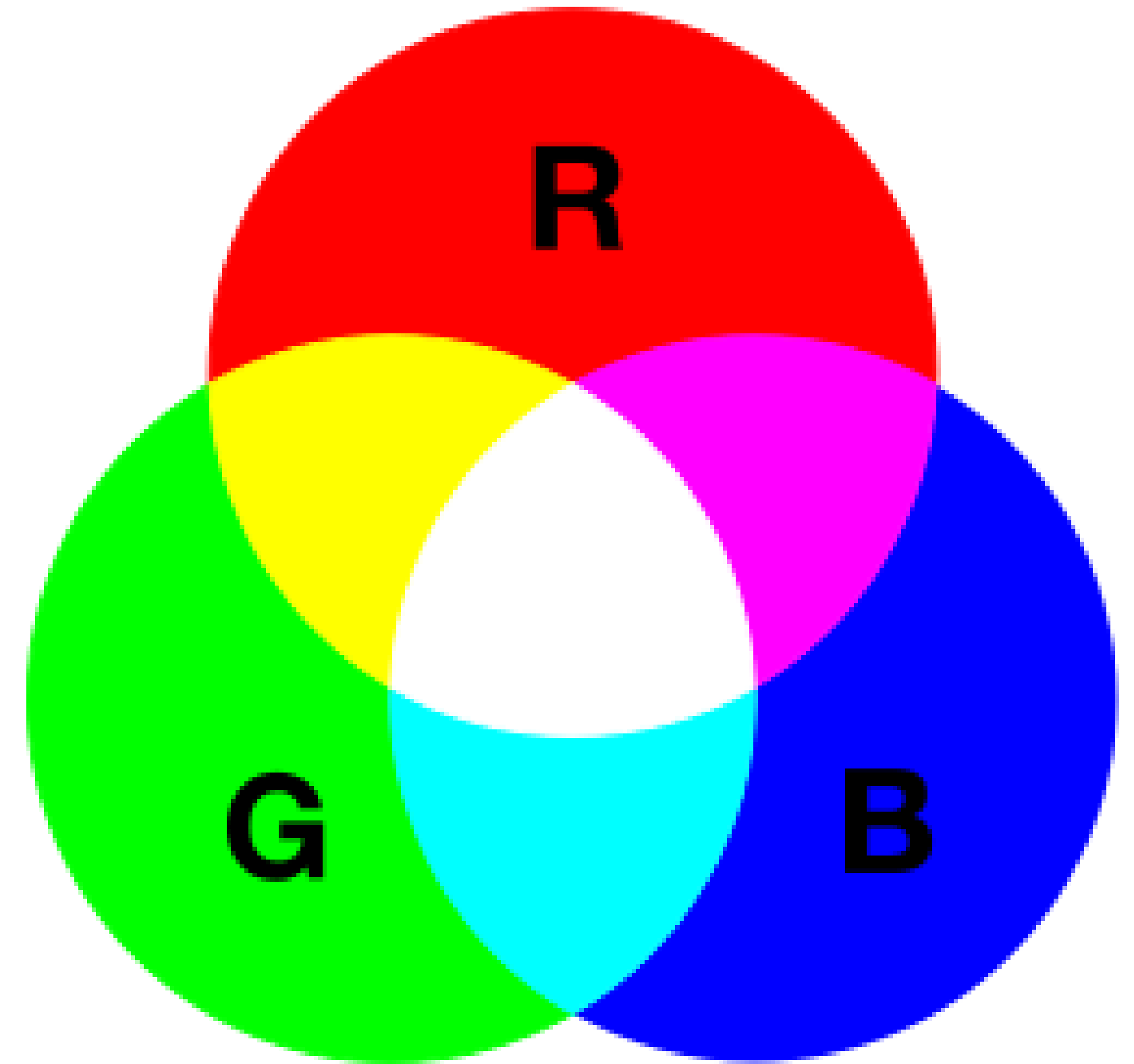
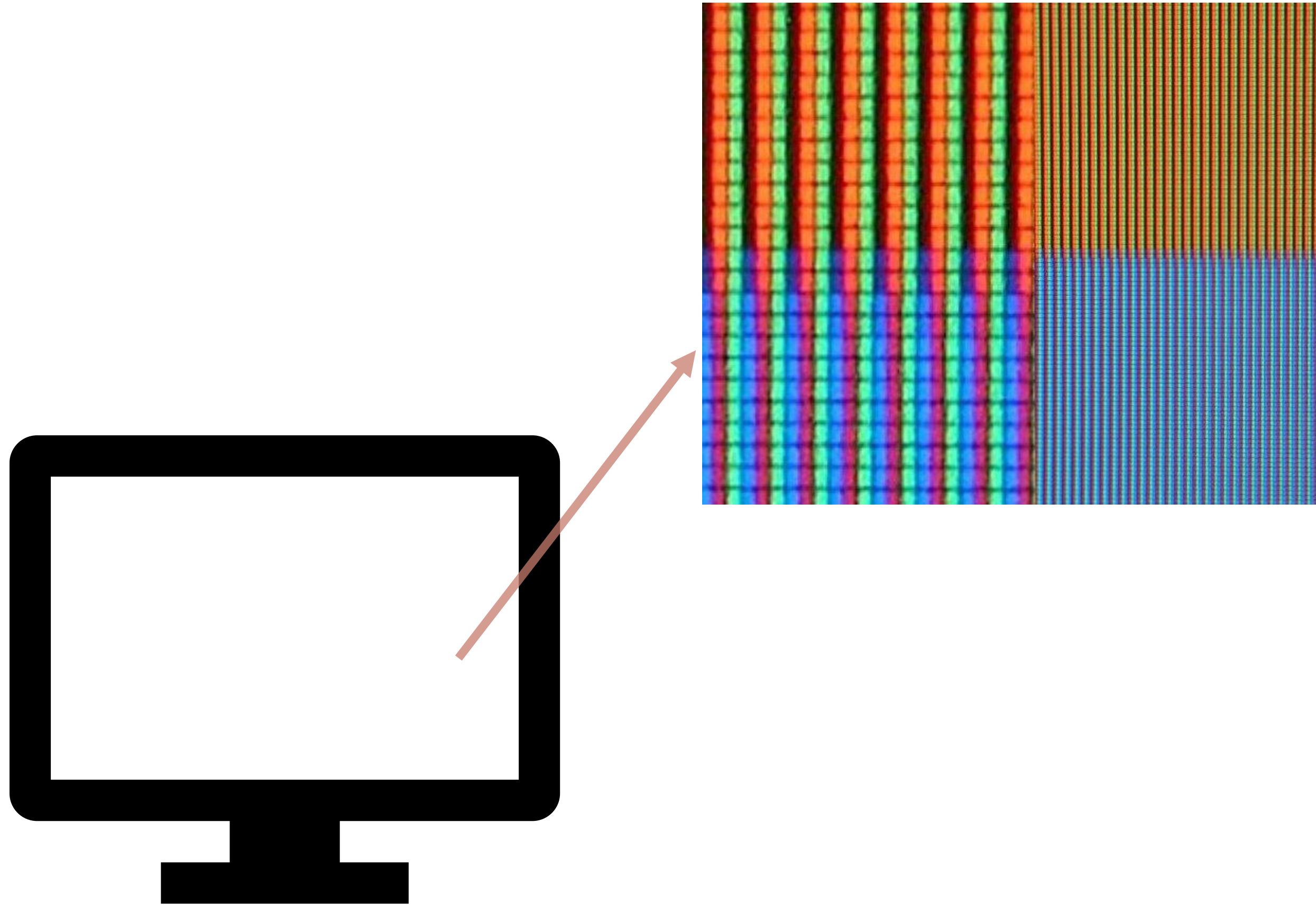
Cones:

64% red-sensitive

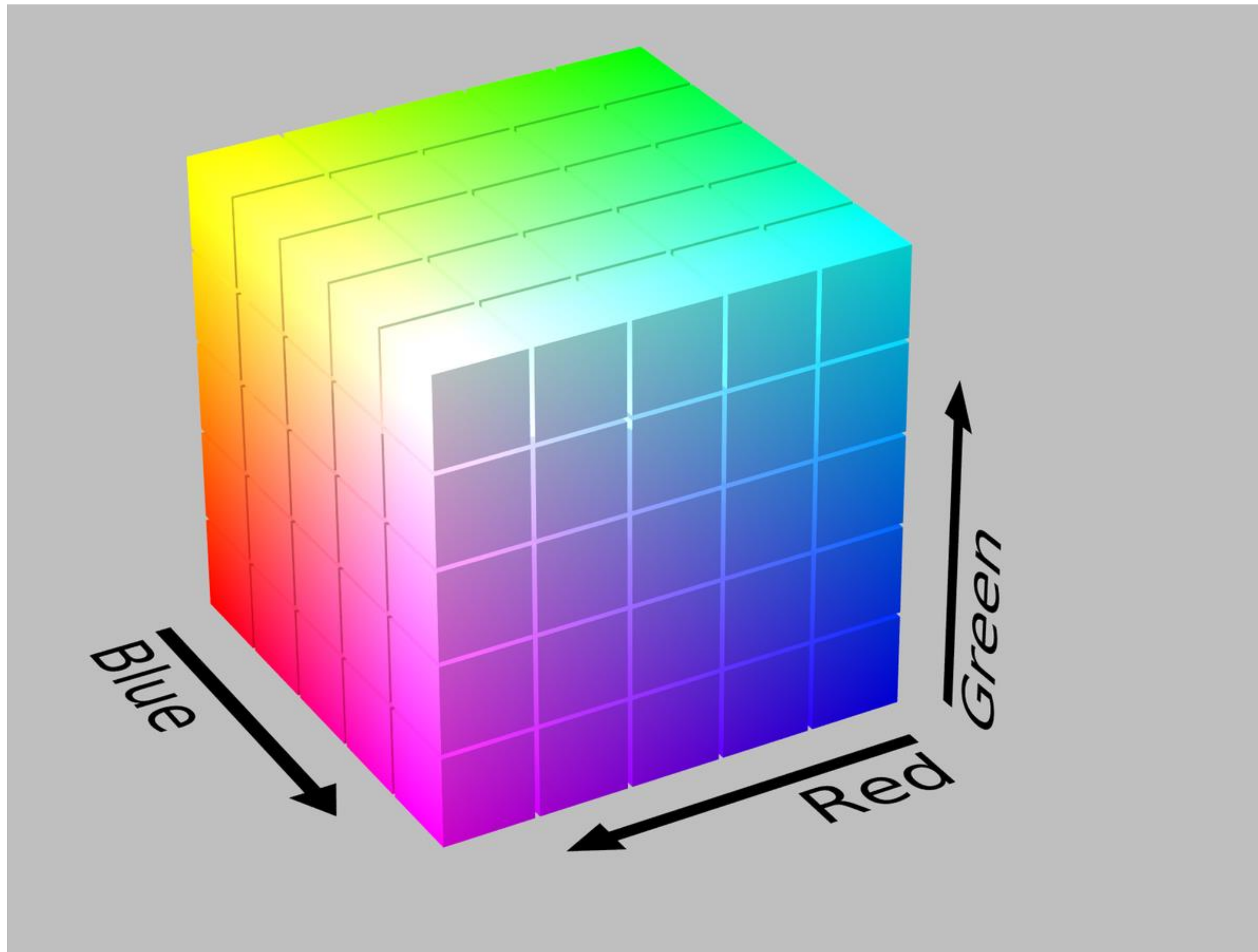
32% green-sensitive

2% blue-sensitive.

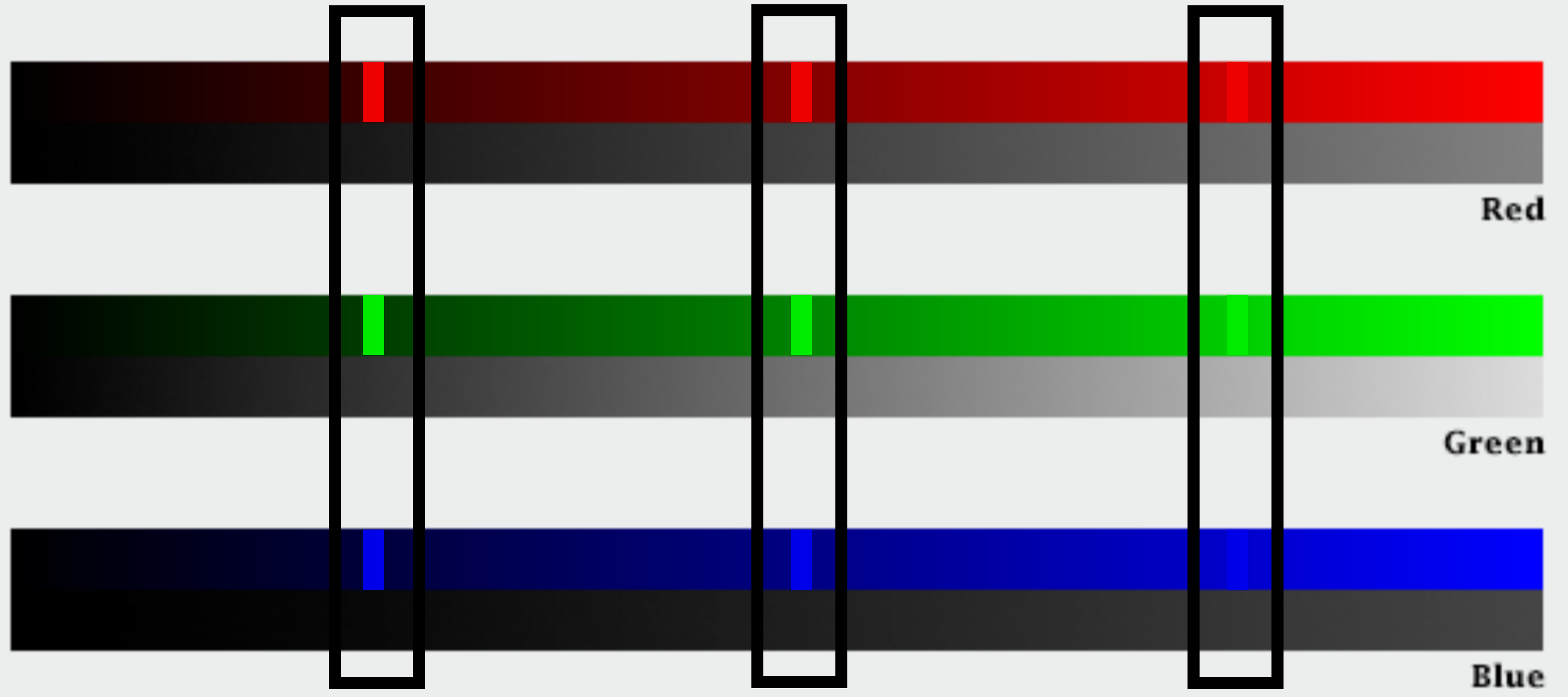
Modeling Color with RGB



Modeling Color with RGB

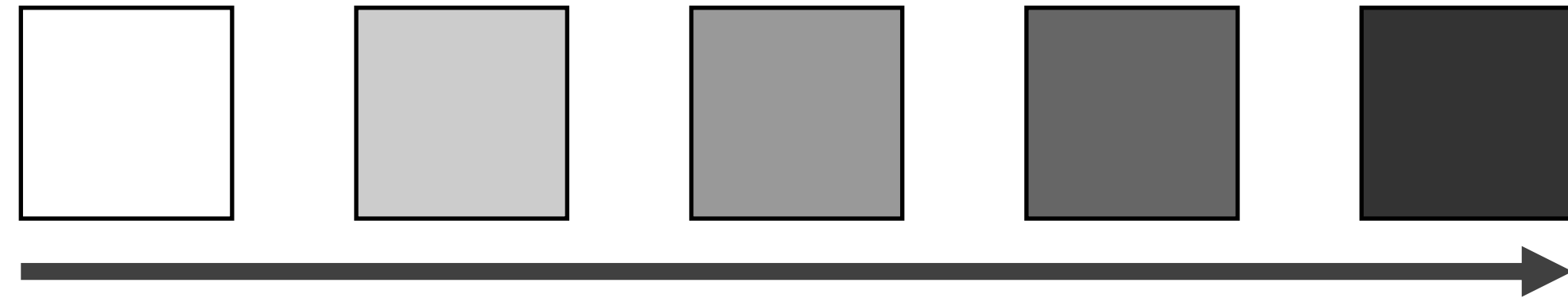


Modeling Color with RGB: Problematic

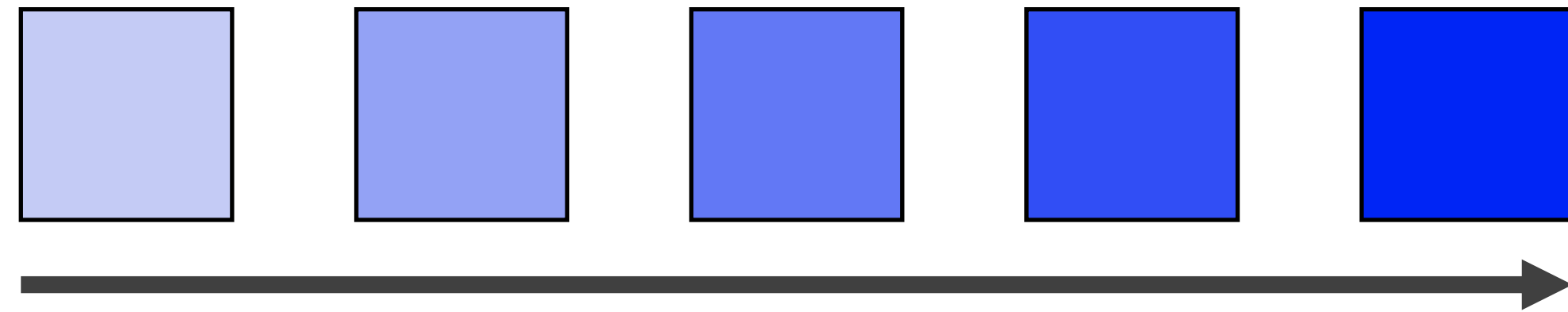


Color Vocabulary and Perceptual Ordering

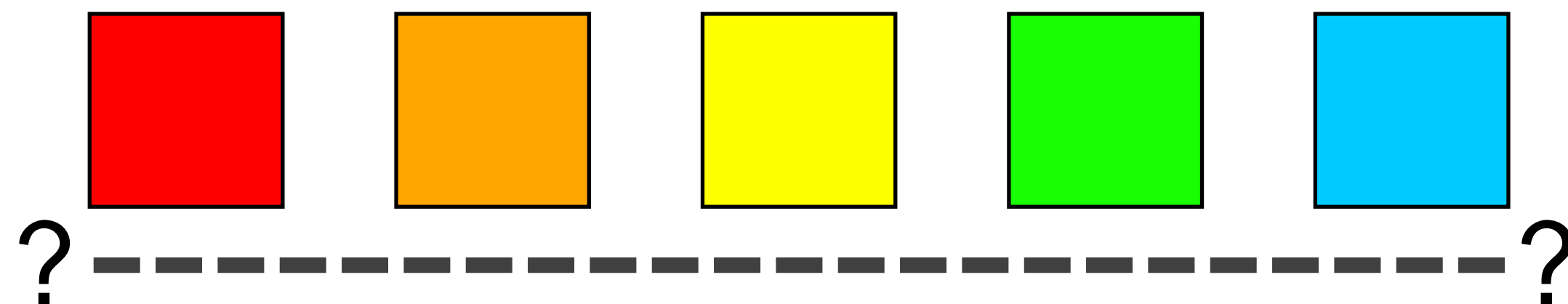
Darkness (Lightness)



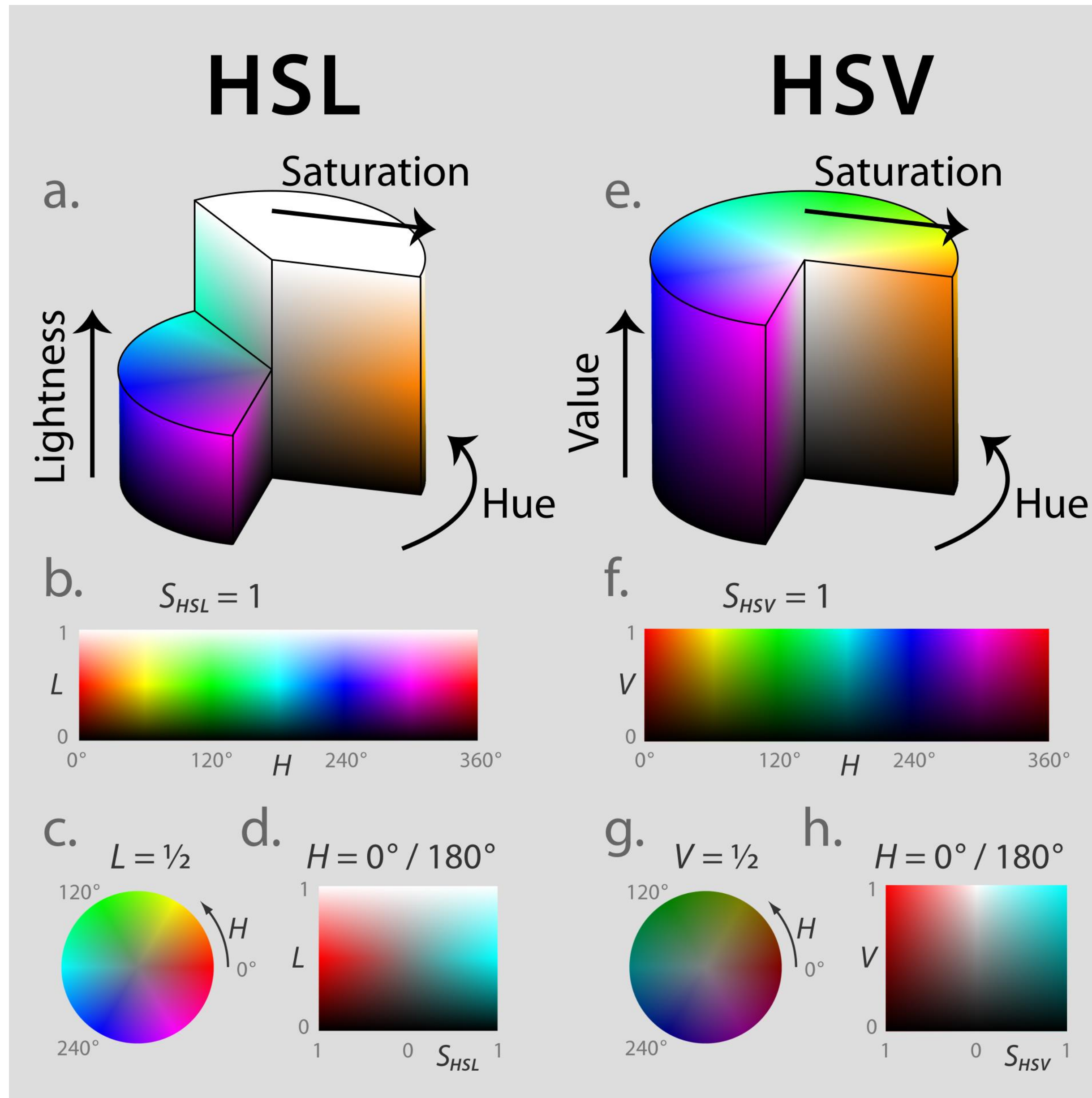
Saturation



Hue



Modeling Color with HSL or HSV

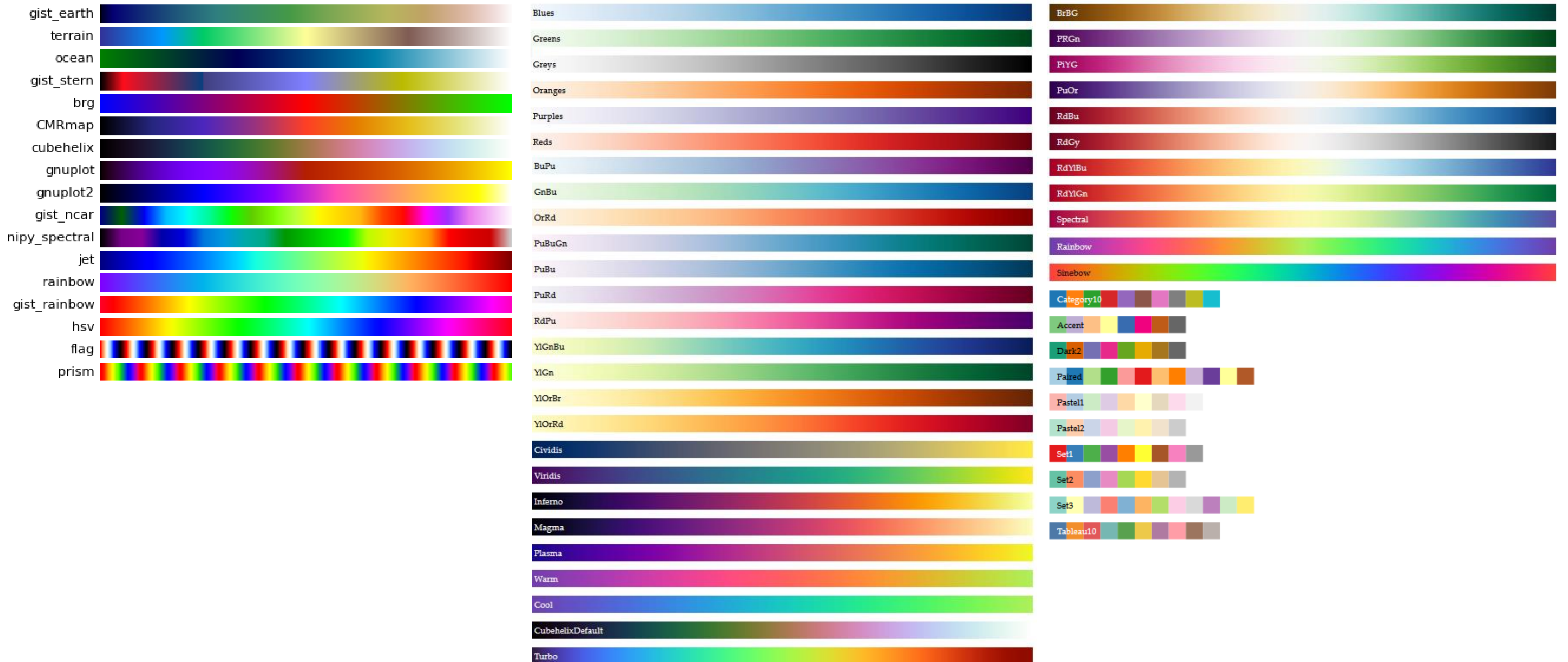


Still Imperfect

“...avoiding catastrophe becomes the first principle in bringing color to information: above all, do no harm.”
-Edward Tufte

Color Maps

Color Map = map between value (domain) and color (range)



Encode > Map

→ Color

→ Color Encoding

→ Hue



→ Saturation



→ Luminance



≈ Darkness
(Lightness)

→ Color Map

→ Categorical



→ Ordered

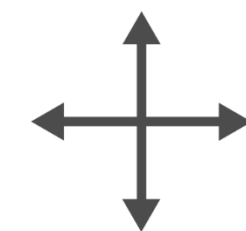
→ Sequential



→ Diverging



→ Bivariate



→ Size, Angle, Curvature, ...

→ Length



→ Angle



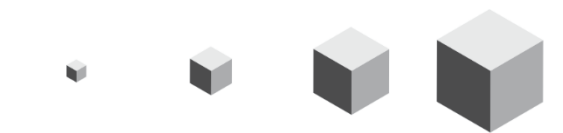
→ Area



→ Curvature



→ Volume



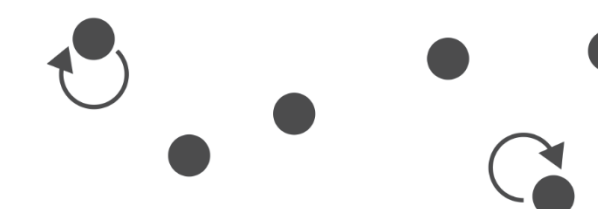
→ Shape



→ Motion

→ Motion

Direction, Rate,
Frequency, ...



Color Maps

THREE MAIN TYPES:

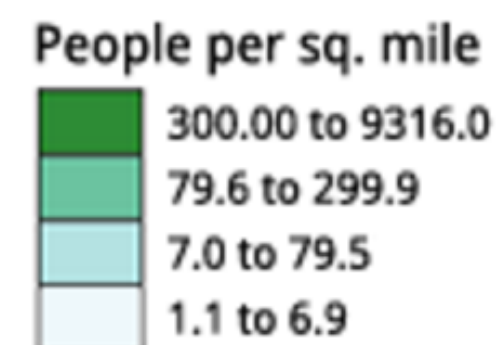
Categorical



Does not imply magnitude differences
(categorical/nominal data)

Distinct hues with similar emphasis

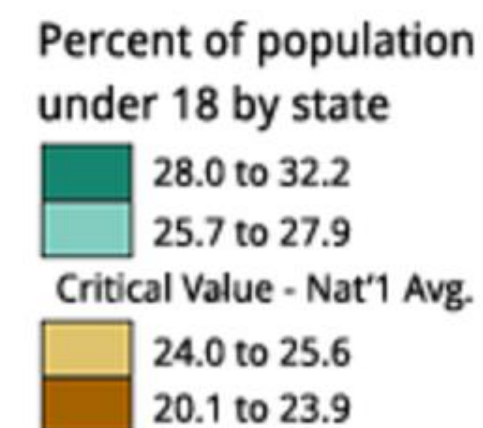
Sequential



Best for ordered data that progresses from low
to high (ordinal, quantitative data)

Darkness (lightness) channel effectively employed

Diverging



For data with a “diverging” (mid) point
(quantitative data)

Equal emphasis on mid-range critical values and
extremes at both ends of the data range

Color Maps

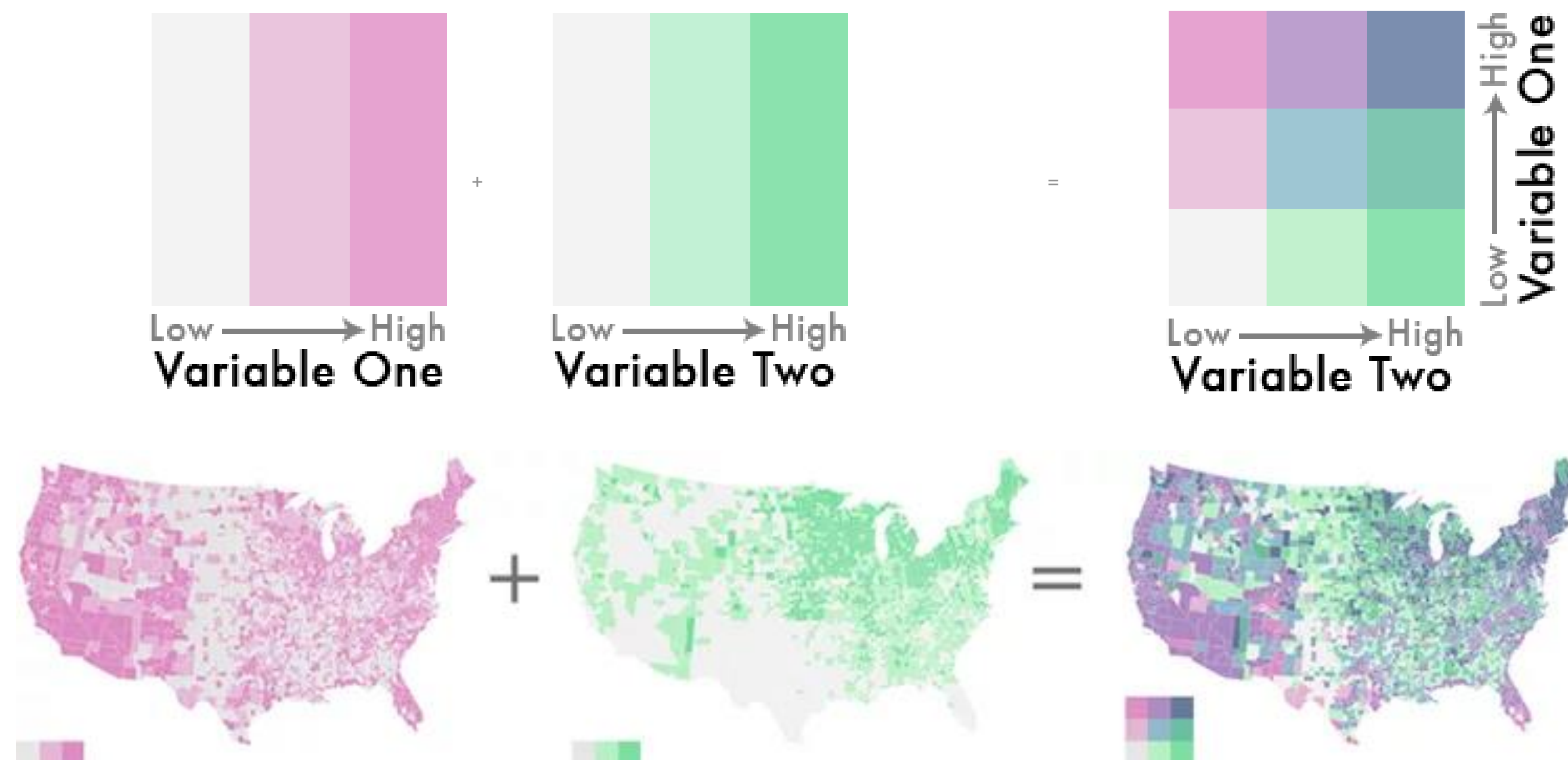
ALSO...

Bivariate

Displays two variables

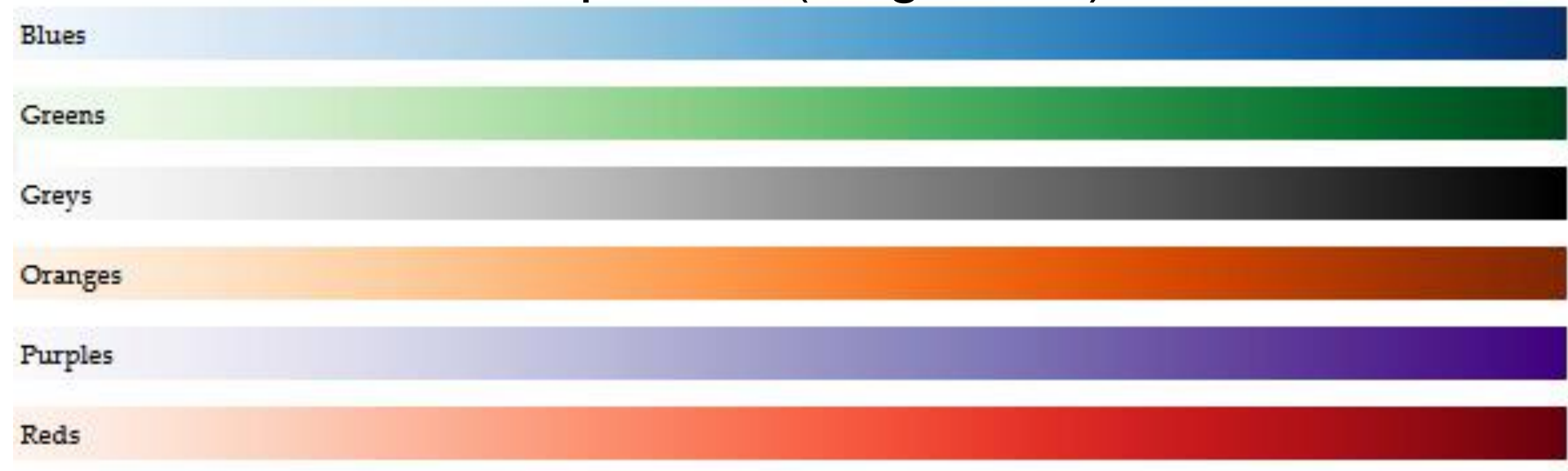
Combination of two sequential color schemes

These are very difficult to design effectively, make intelligible, and be color blind friendly.



Types of Color Maps

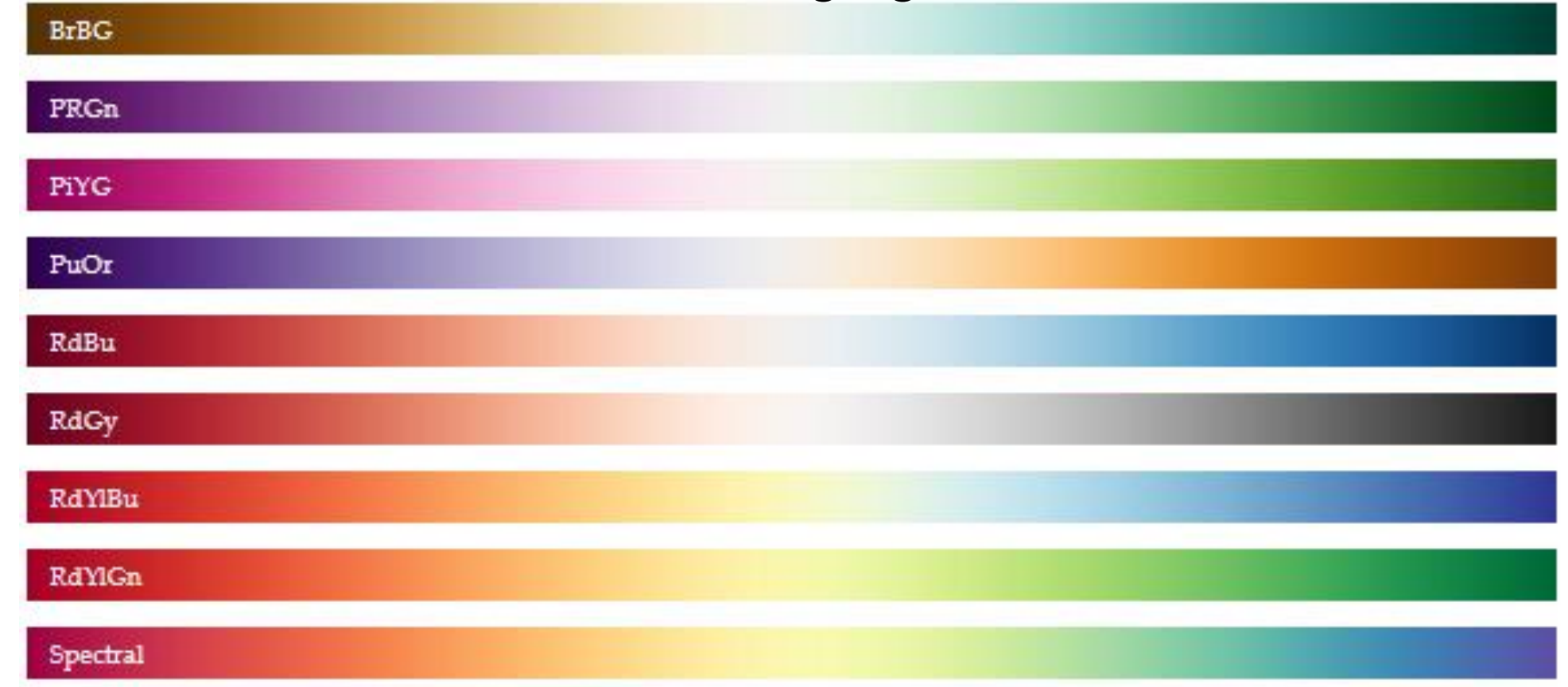
Sequential (single hue)



Sequential (multiple hue)



Diverging



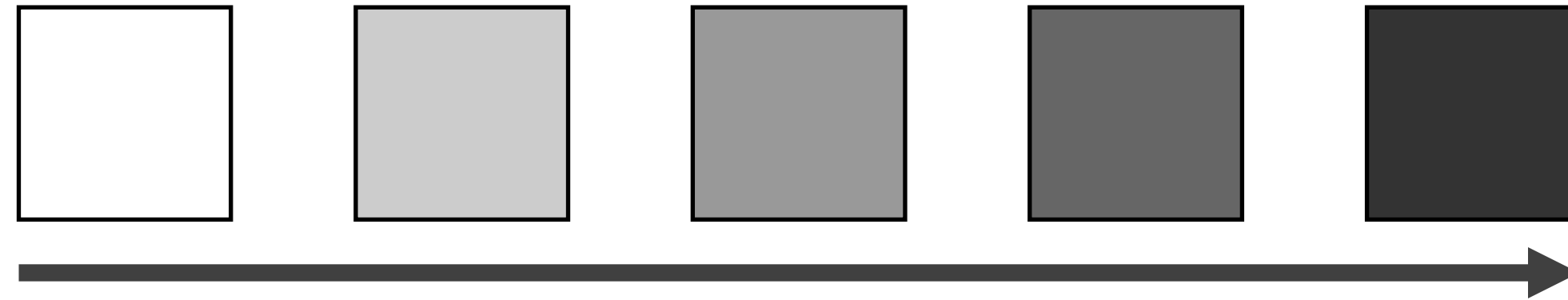
Categorical



Cyclical



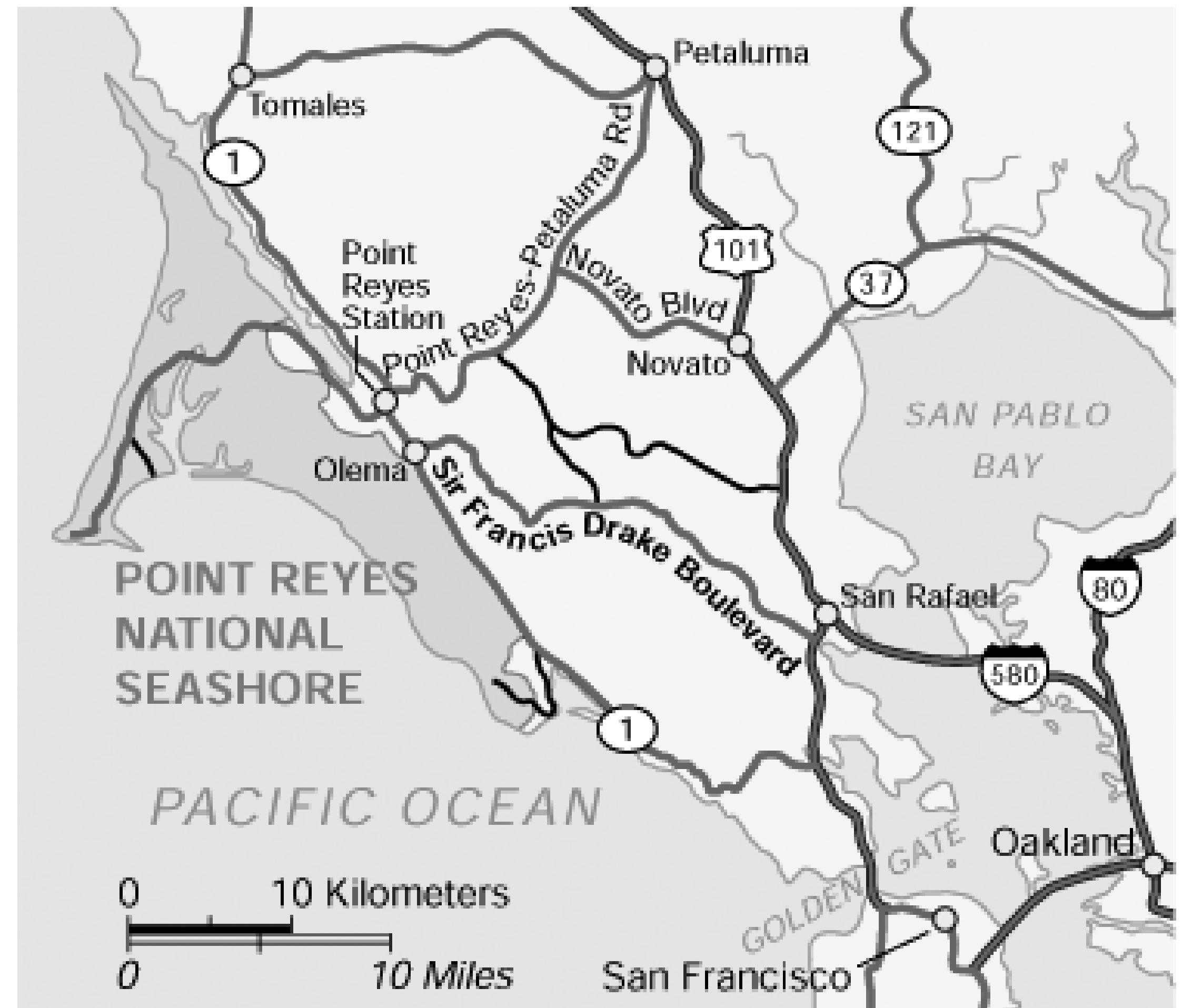
Darkness (Lightness) Channel



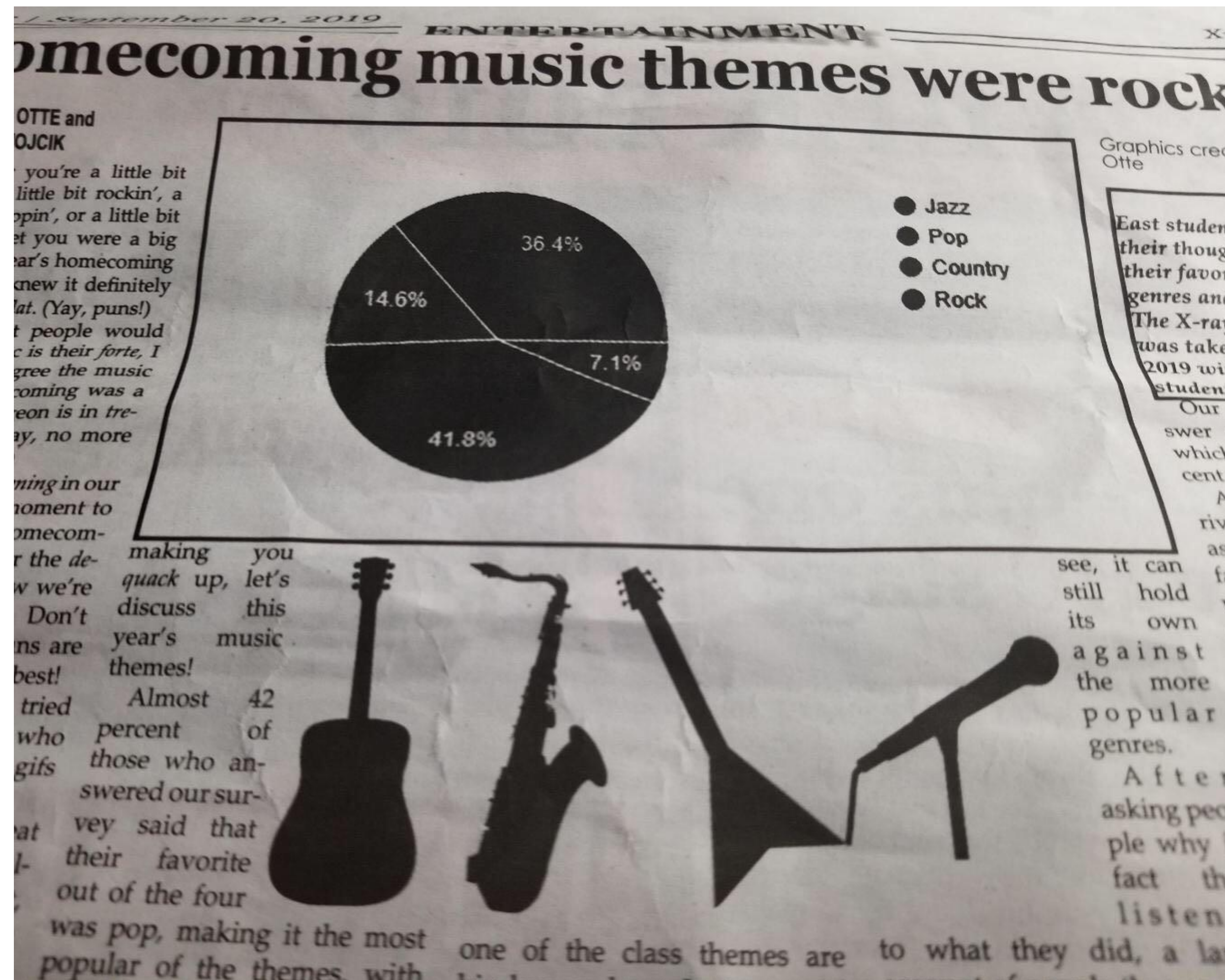
- No edges without darkness difference
- No shading without darkness variation
- Has higher spatial sensitivity than color channels
- Contrast defines legibility, attention, layering
- Controlling darkness is primary rule of design

“Get it right in black and white.”

-Maureen Stone



Understanding your medium matters



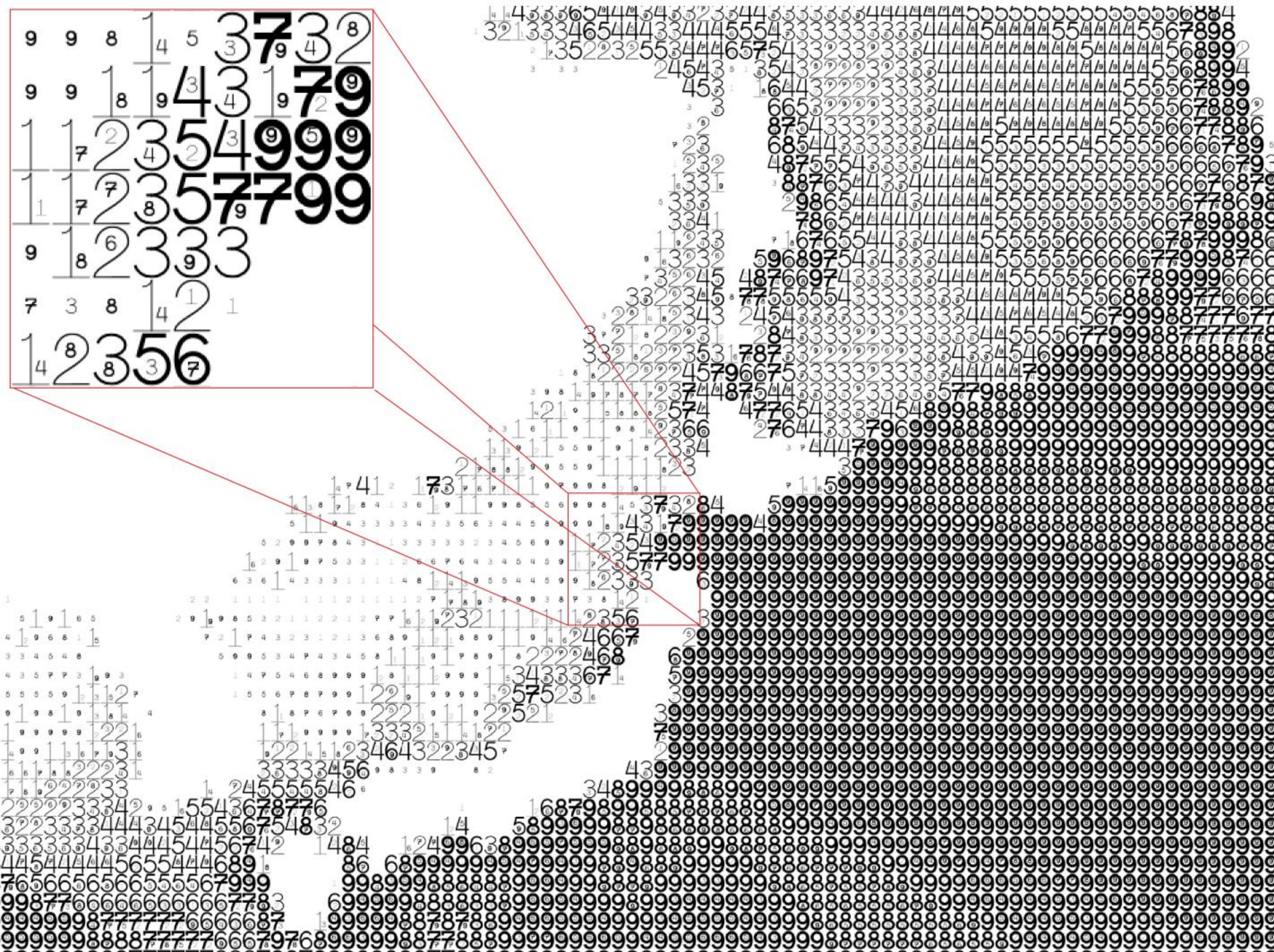
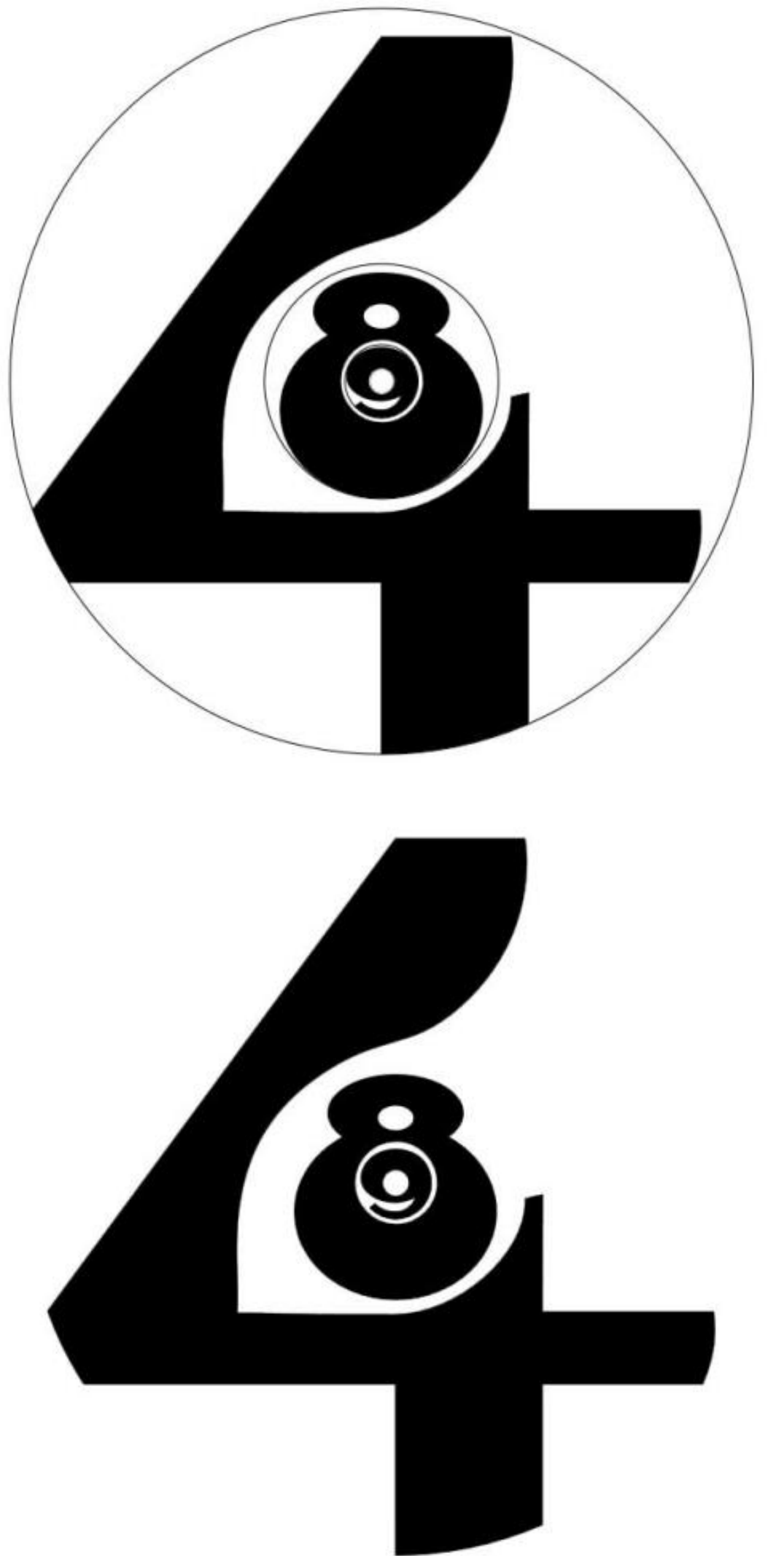
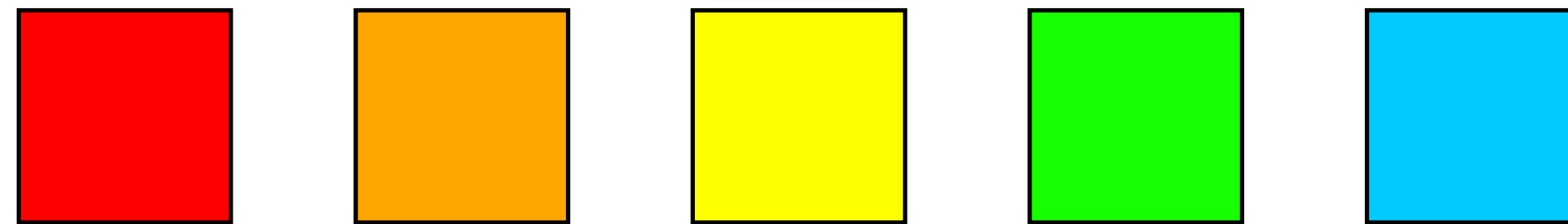


Figure 8: Maximum wave amplitudes for the Japan 2011 tsunami. Amplitudes were clipped at 99cm. Data adapted from NOAA; <http://www.noaa.gov/>.

FatFonts



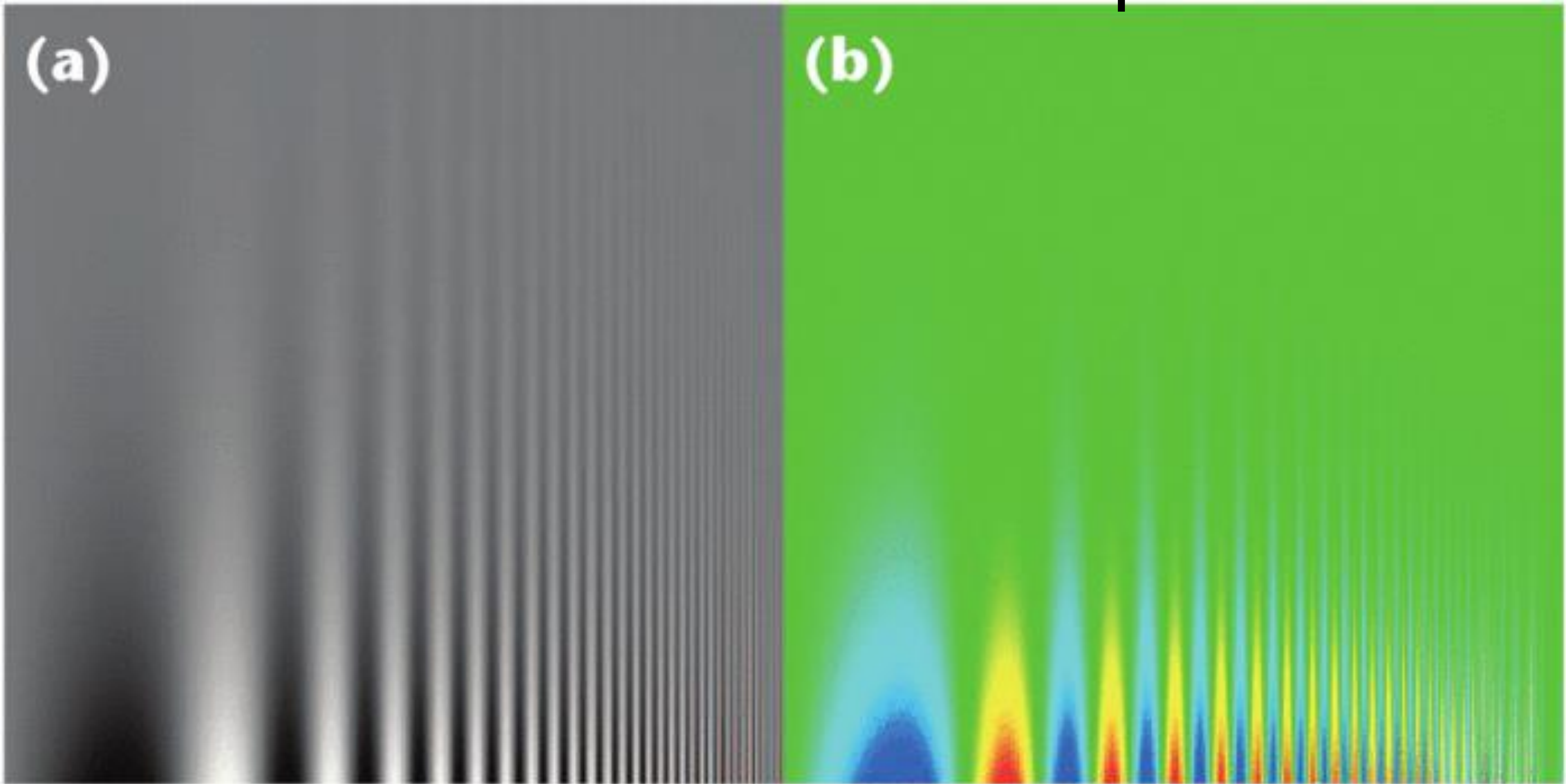
Rainbow Color Map (Hue)



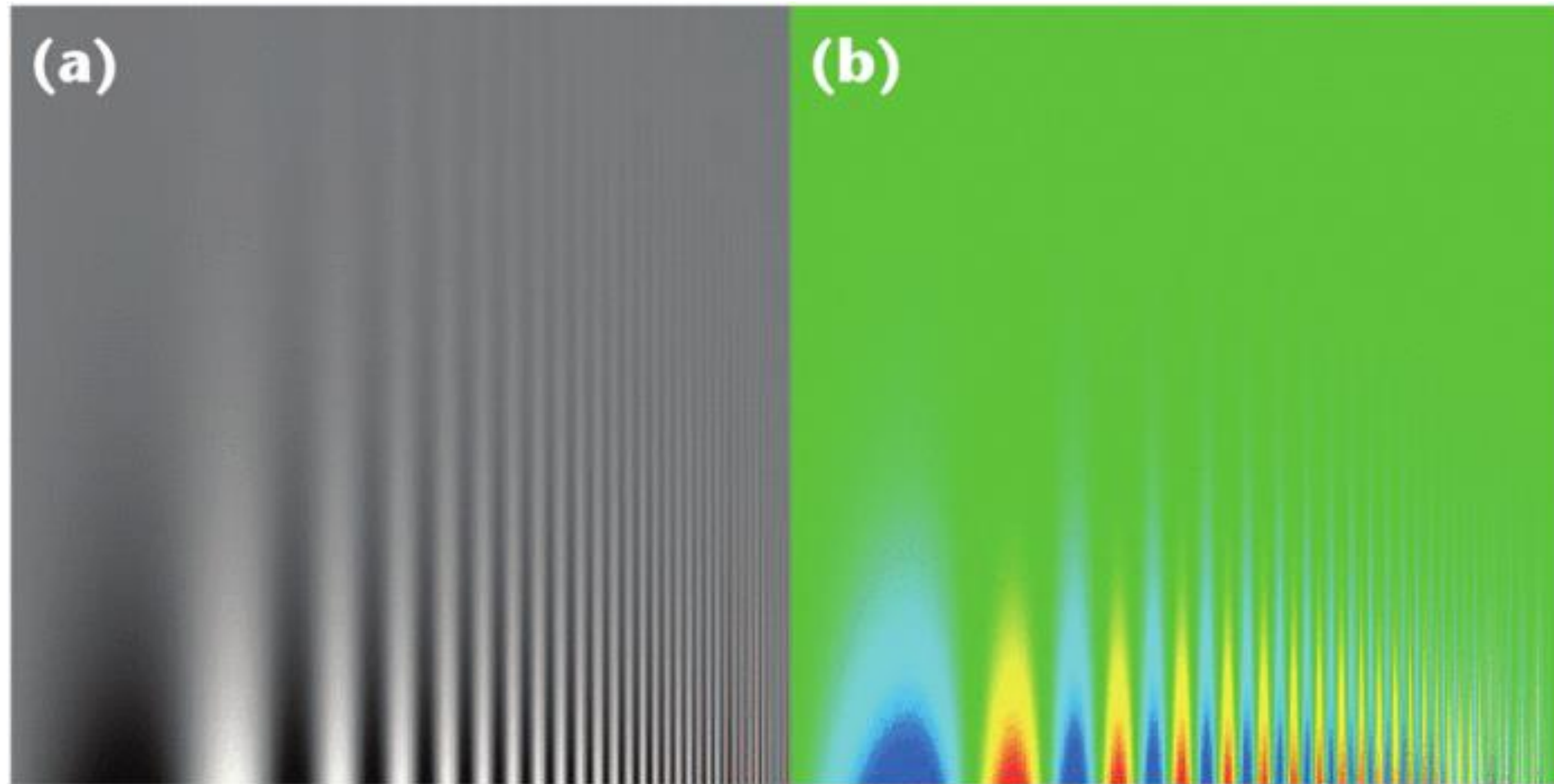
Rainbow Color Map

(a)

(b)



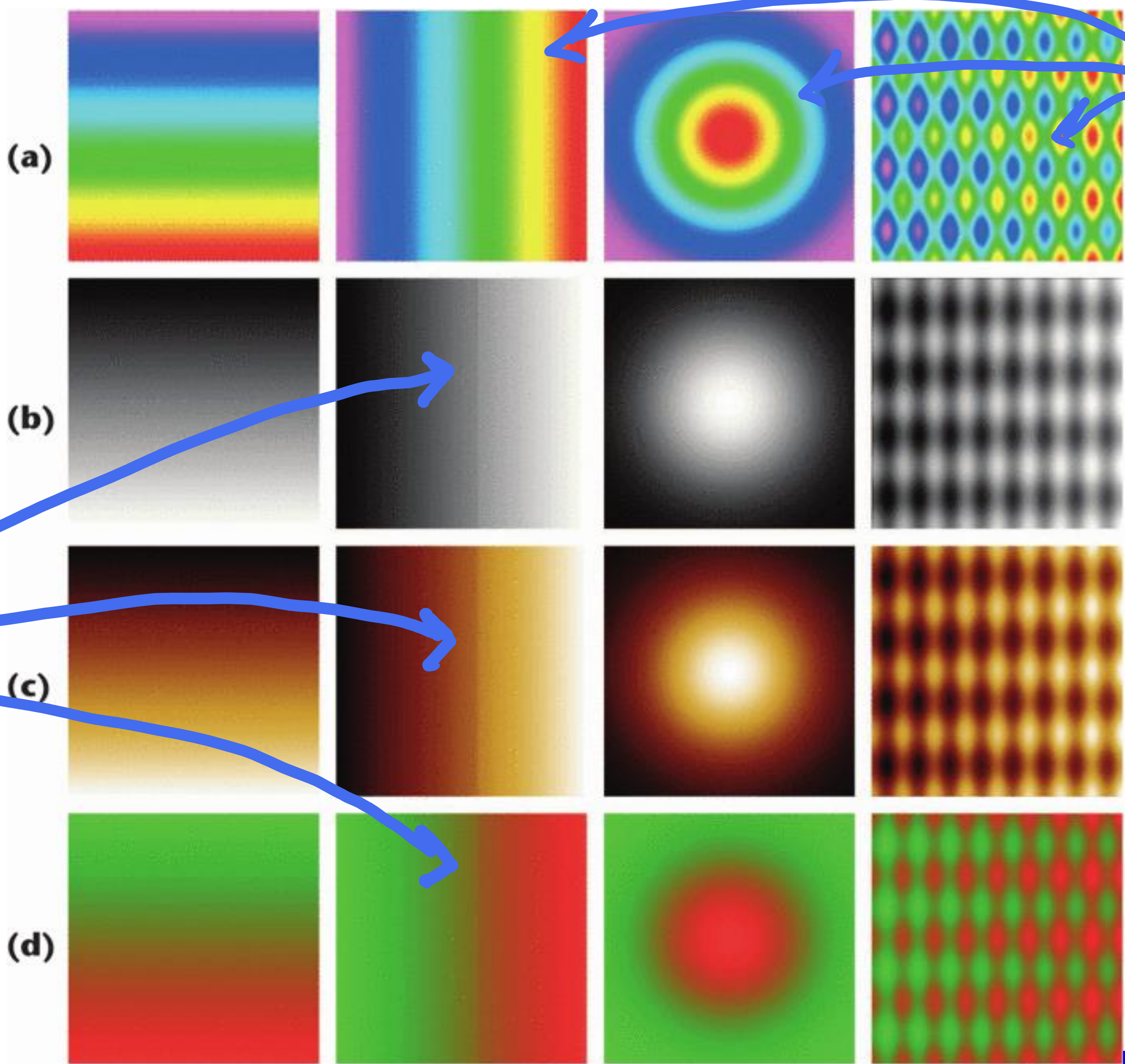
Rainbow Color Map



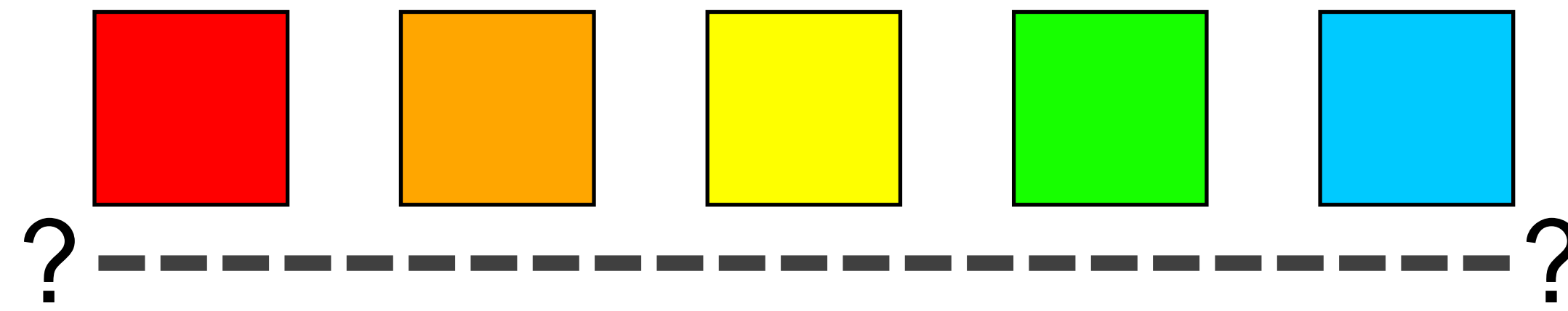
- No darkness variation (obscures details)
- Viewers perceive sharp transitions in color as sharp transitions in the data, even when this is not the case (misleading)

Real!

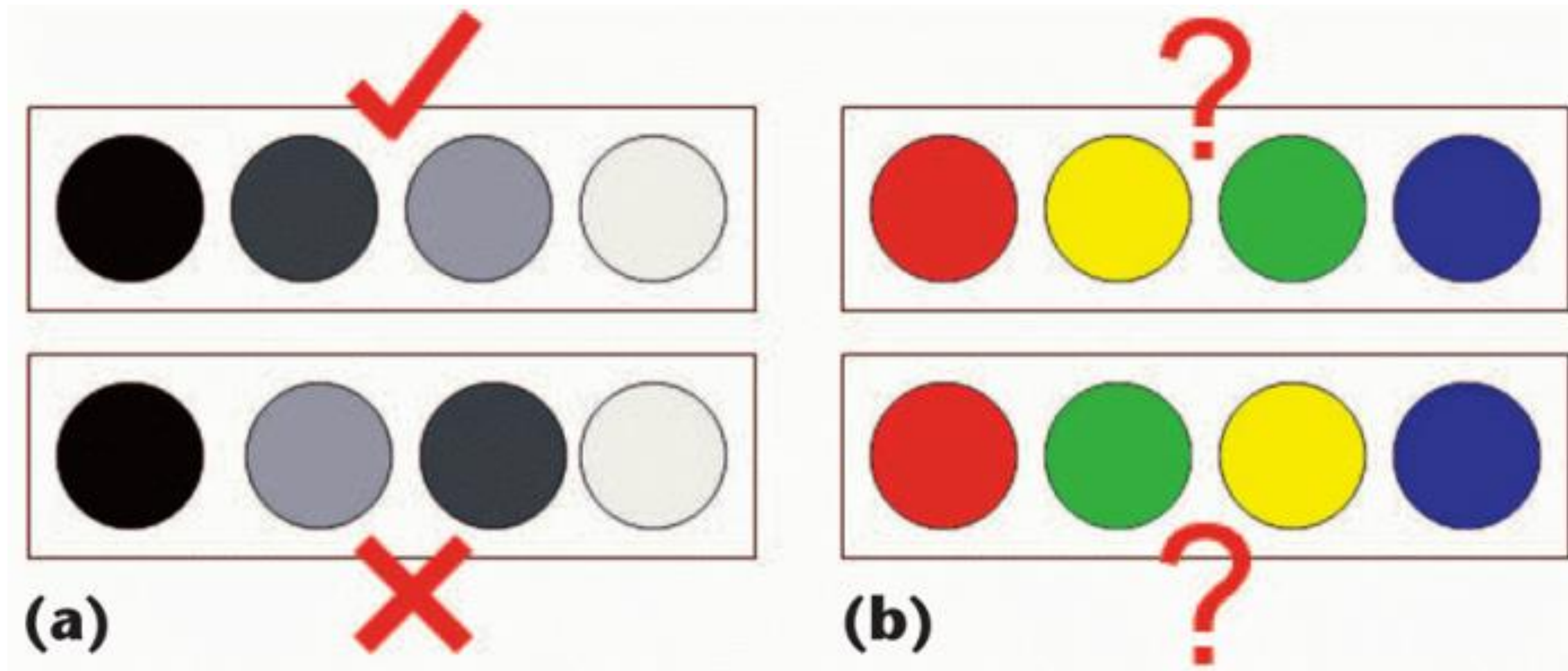
False



Rainbow Color Map (Hue)



No perceptual ordering (confusing)

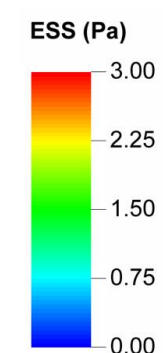
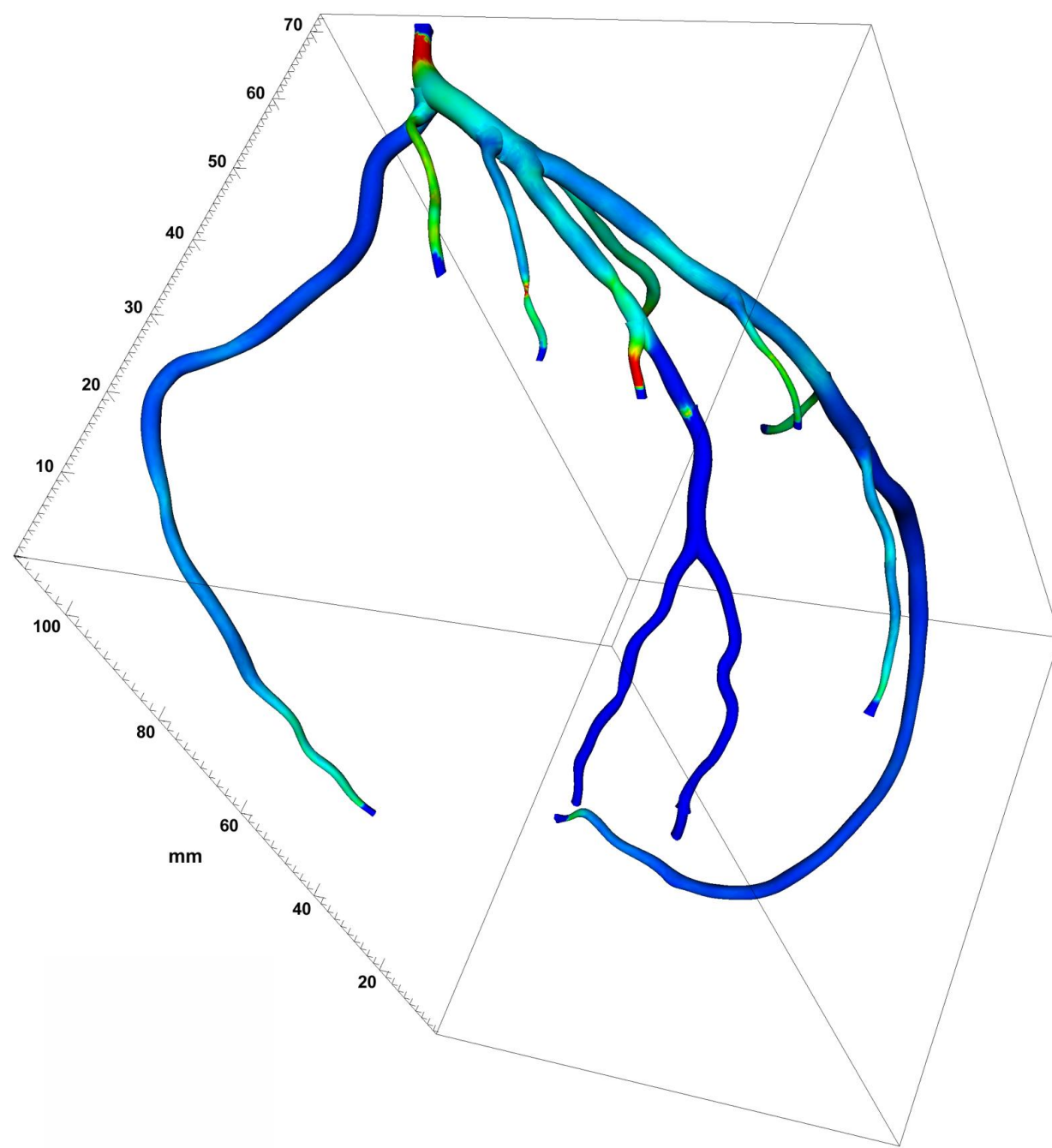


Rainbow Color Map

Rainbow:

3D: 39%

2D: 62%

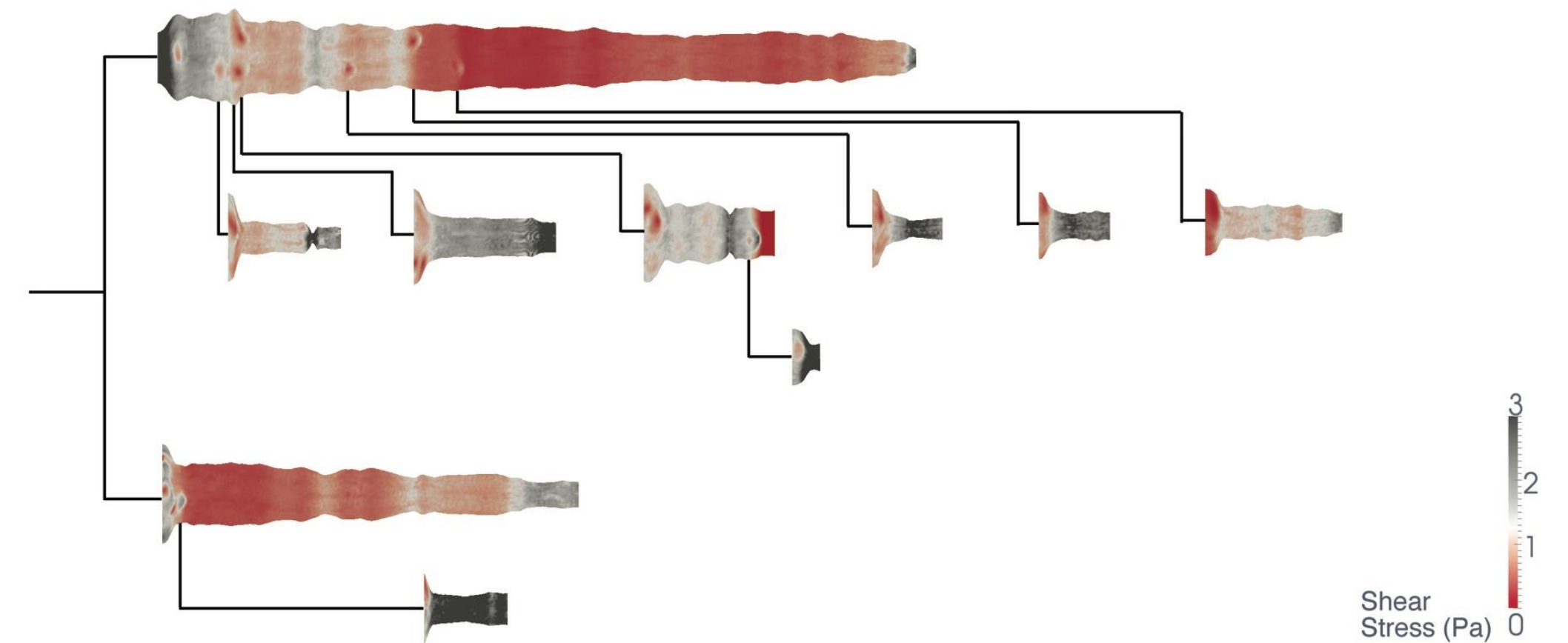


How many diseased regions found?

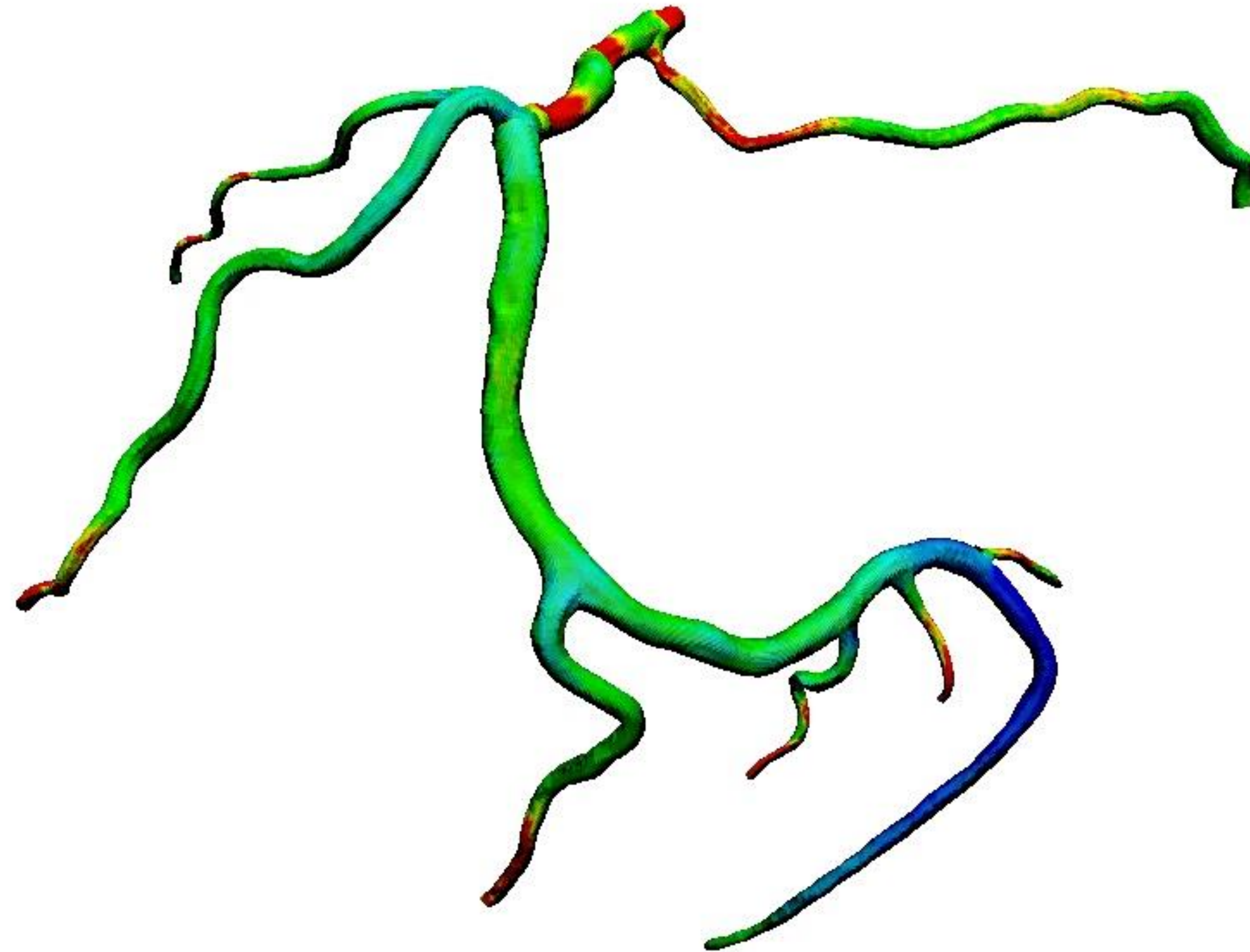
Diverging:

3D: 71% (Δ +31%)

2D: 91% (Δ +29%)

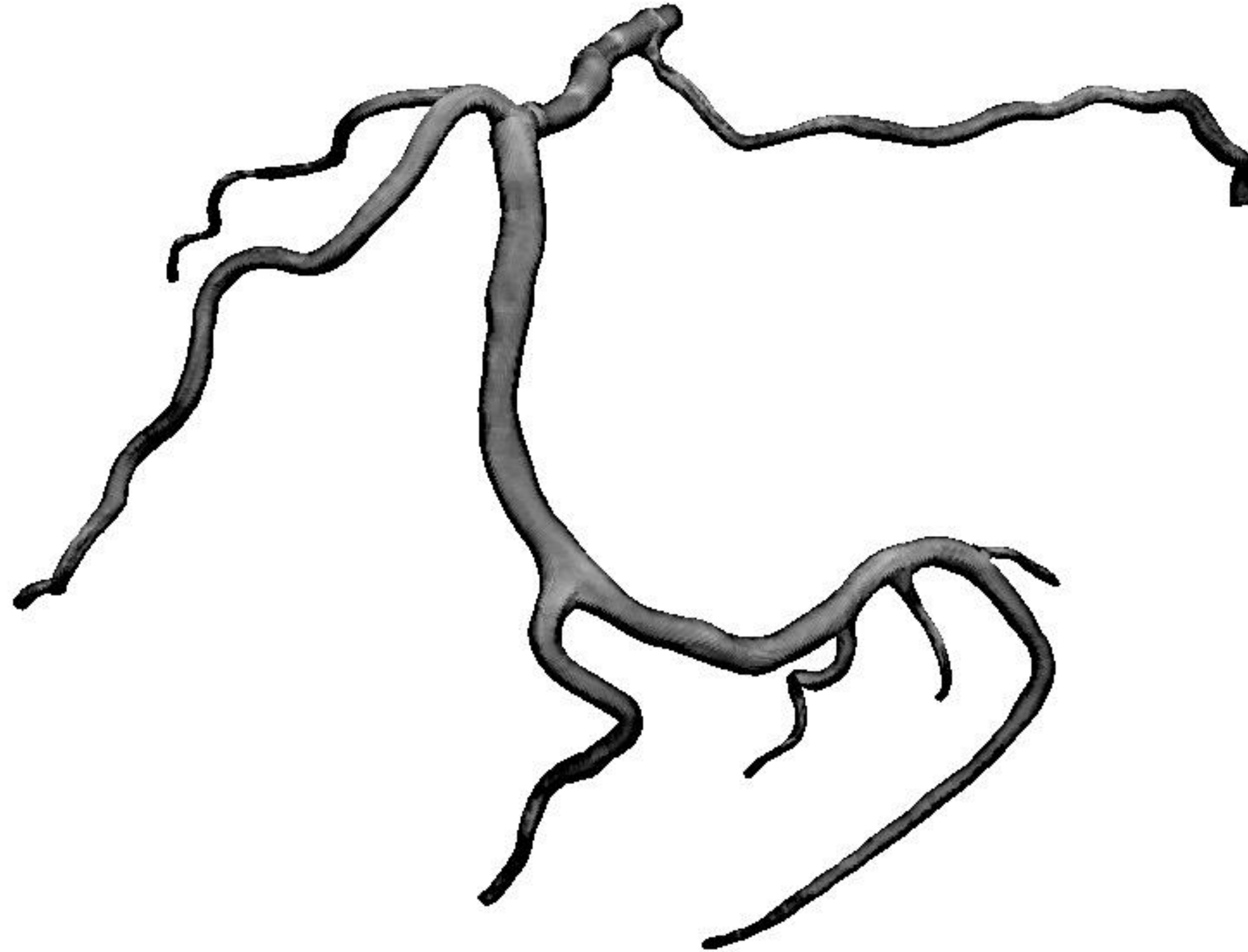


“Get it right in black and white.”

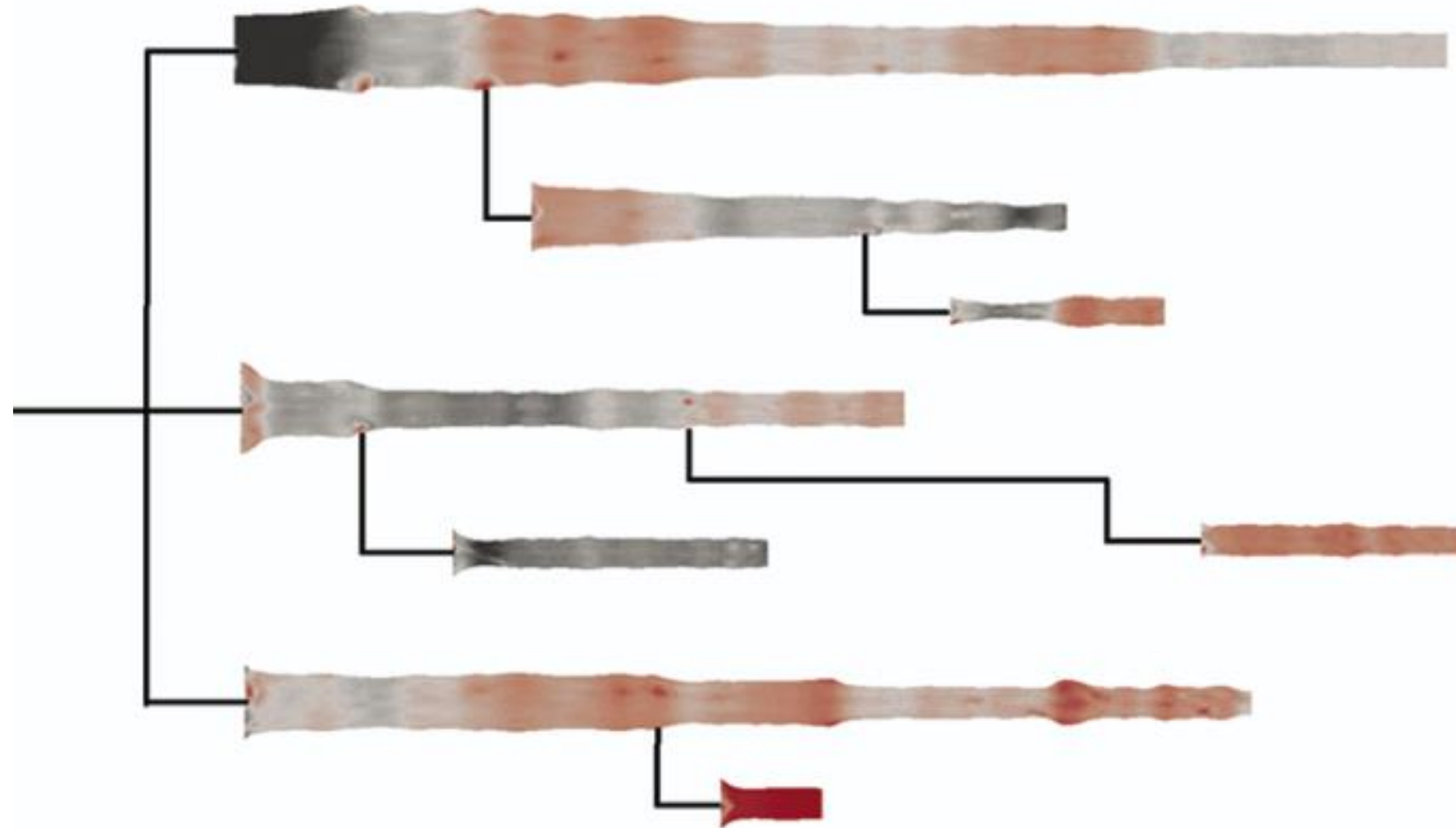


39% Diseased Regions Found

“Get it right in black and white.”

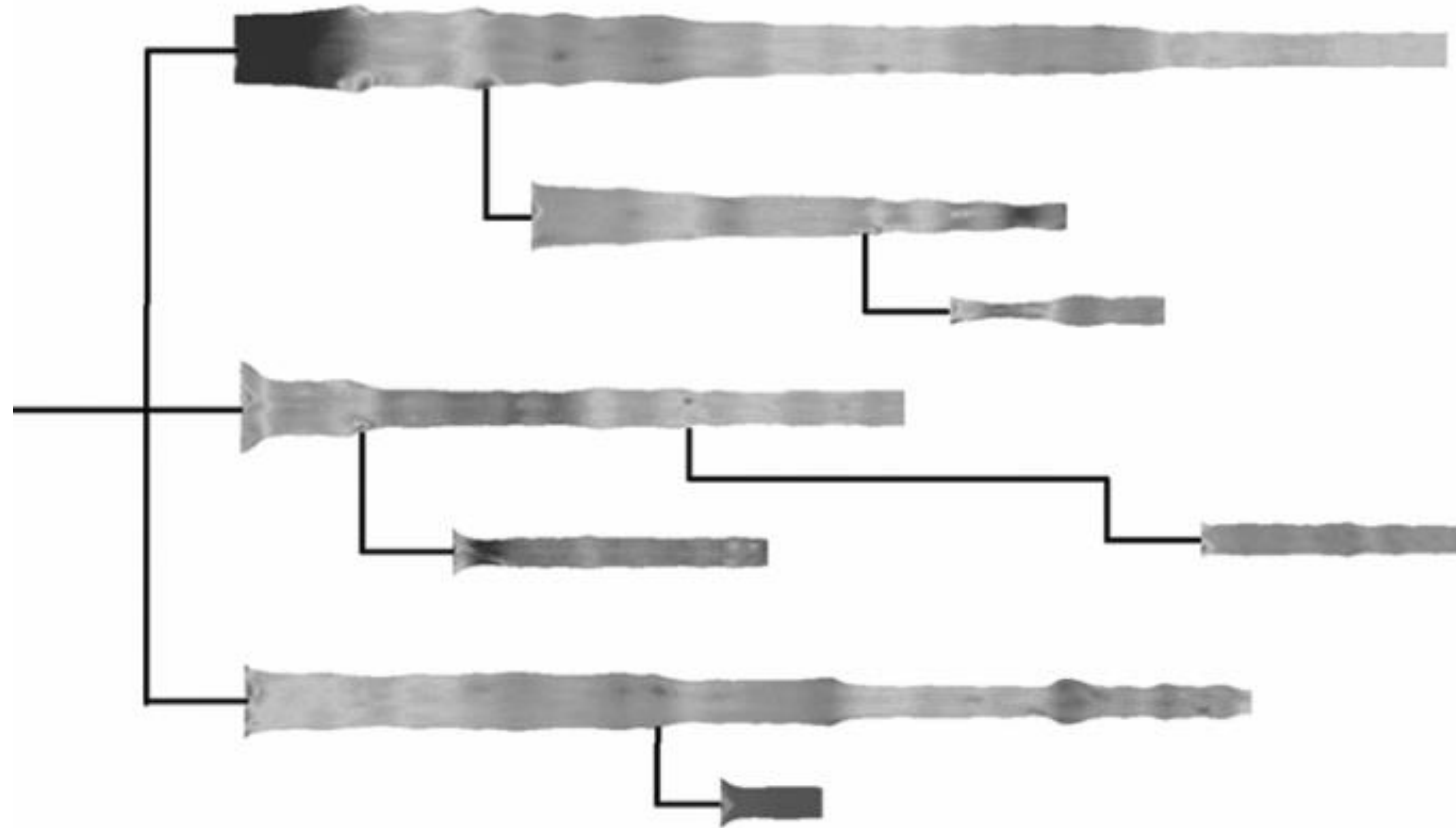


“Get it right in black and white.”



91% Diseased Regions Found

“Get it right in black and white.”



“Get it right in black and white.”

How Much Warmer Was Your City in 2016?

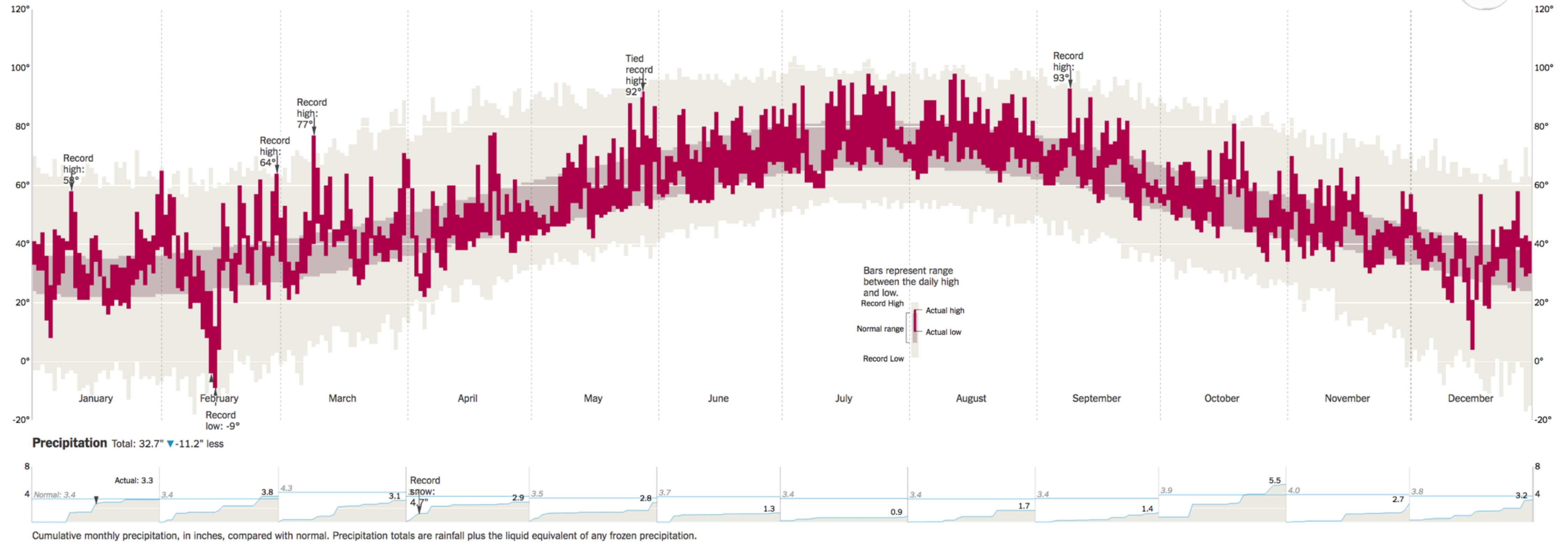
By K.K. REBECCA LAI JAN. 18, 2017

Last year is the hottest year on record for the third consecutive year. In a database of more than 5,000 cities provided by AccuWeather, about 90 percent recorded annual mean temperatures higher than normal. Enter your city below to see how much warmer (or cooler) it was.

◀ Boston, Mass. ▶

Temperature Average: 53.4° ▲ 1.9° above normal

°F °C



“Get it right in black and white.”

How Much Warmer Was Your City in 2016?

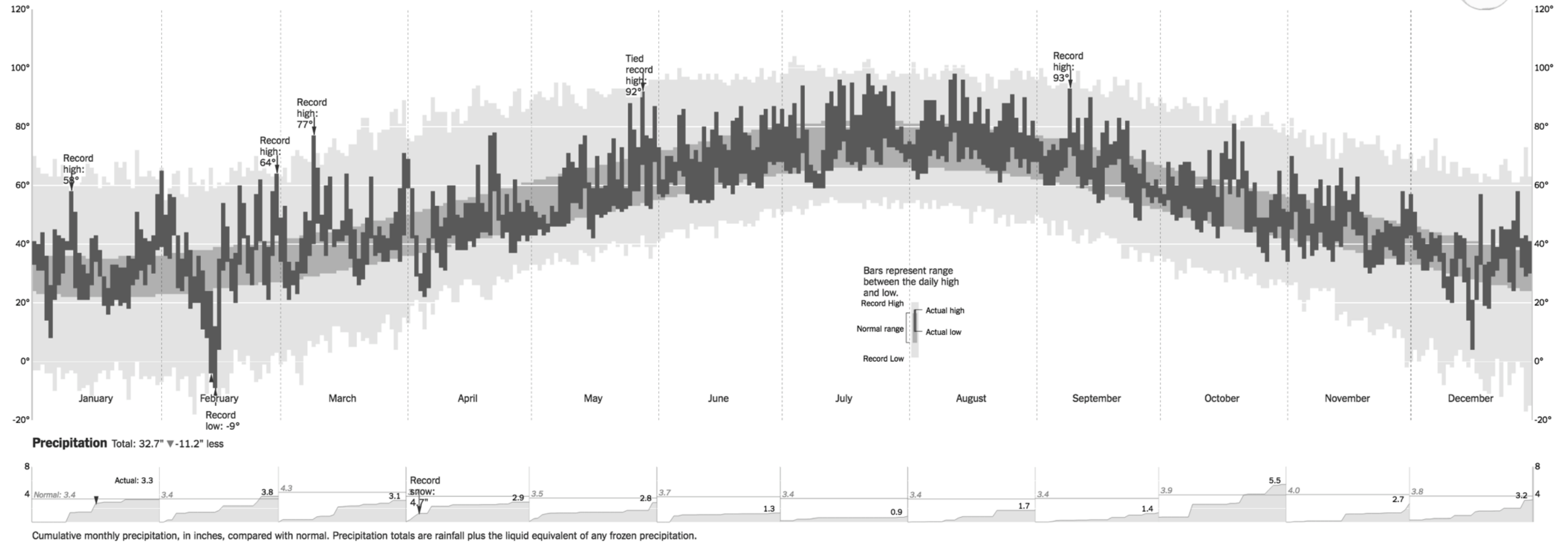
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Temperature Average: 53.4° ▲ 1.9° above normal

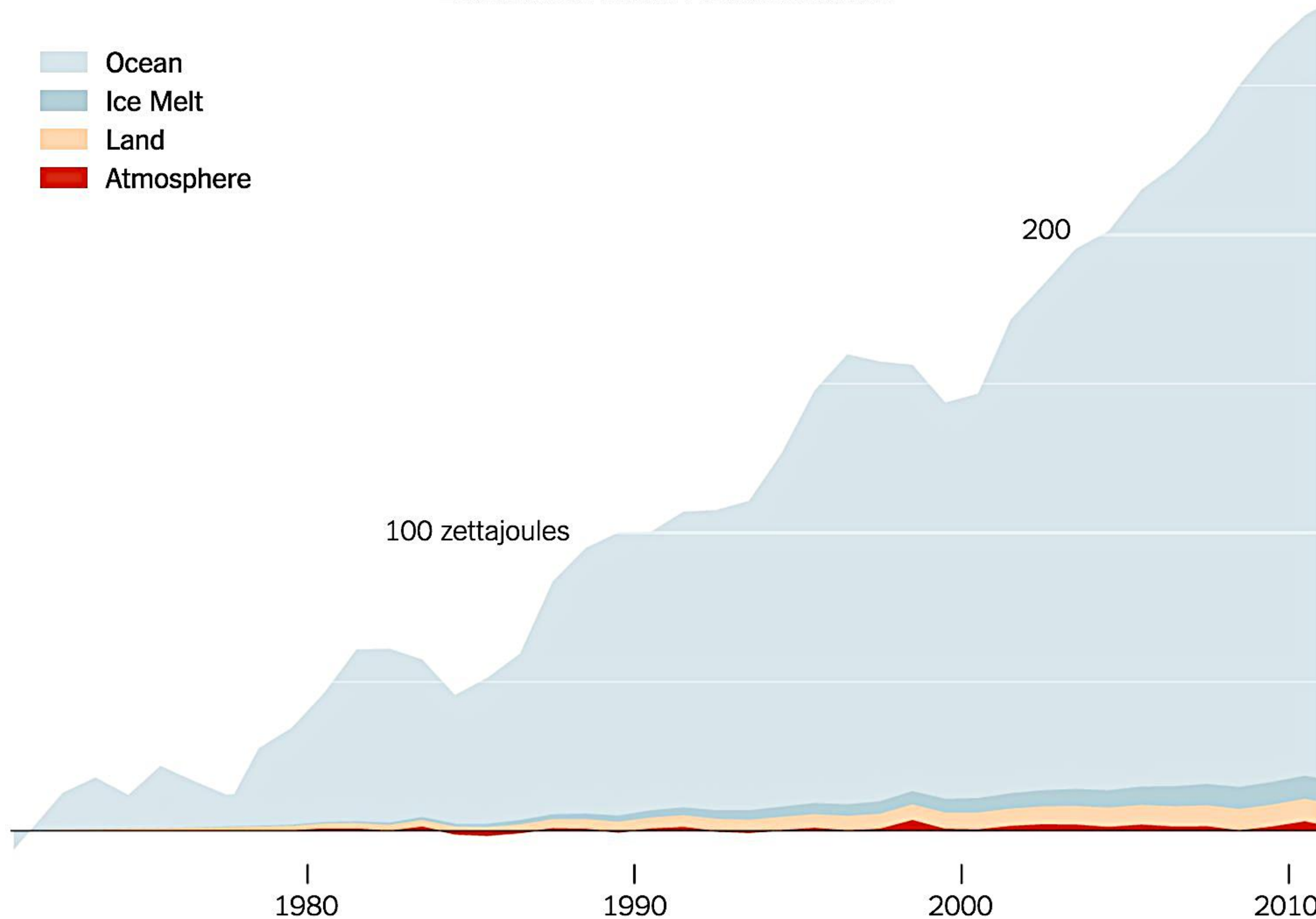
°F °C



“Get it right in black and white.”

Estimated Heat Accumulation

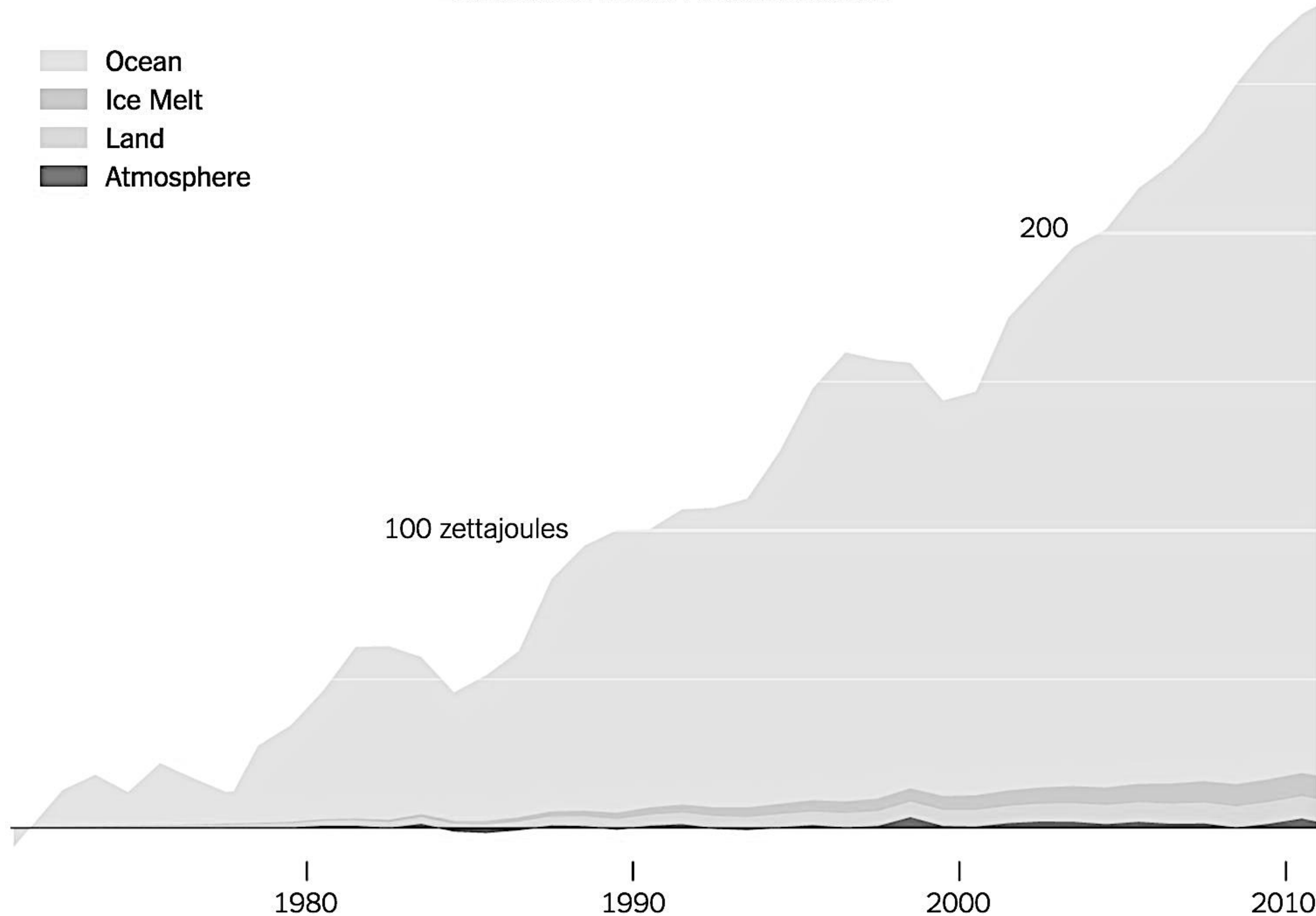
- Ocean
- Ice Melt
- Land
- Atmosphere



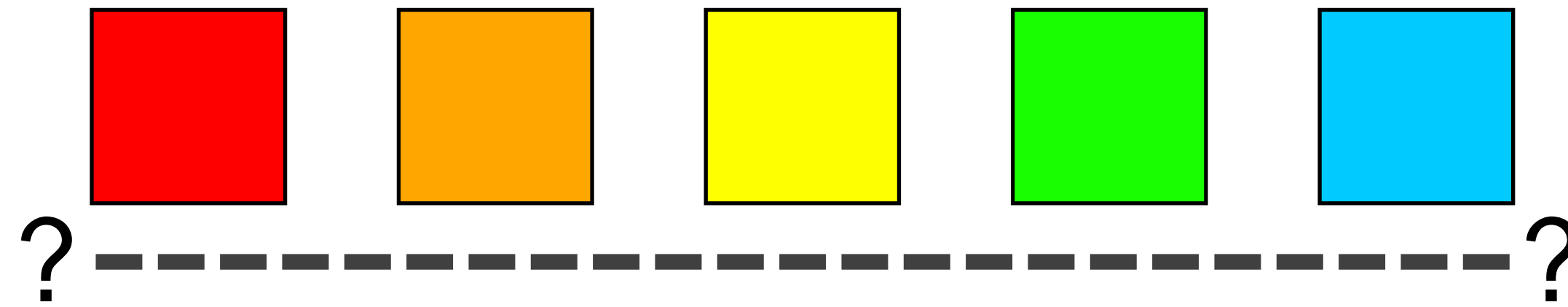
“Get it right in black and white.”

Estimated Heat Accumulation

- Ocean
- Ice Melt
- Land
- Atmosphere



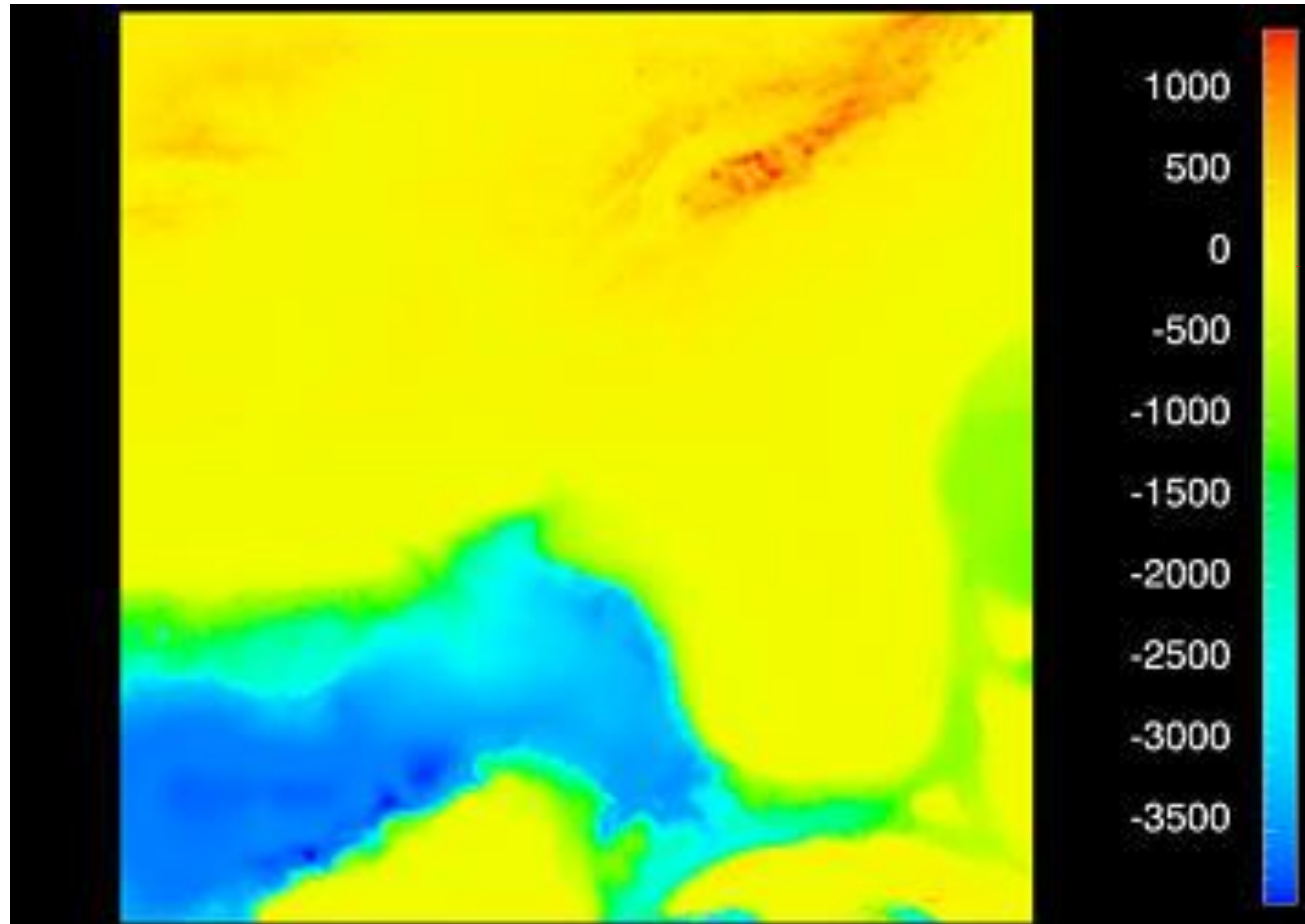
Rainbow Color Map (Hue)



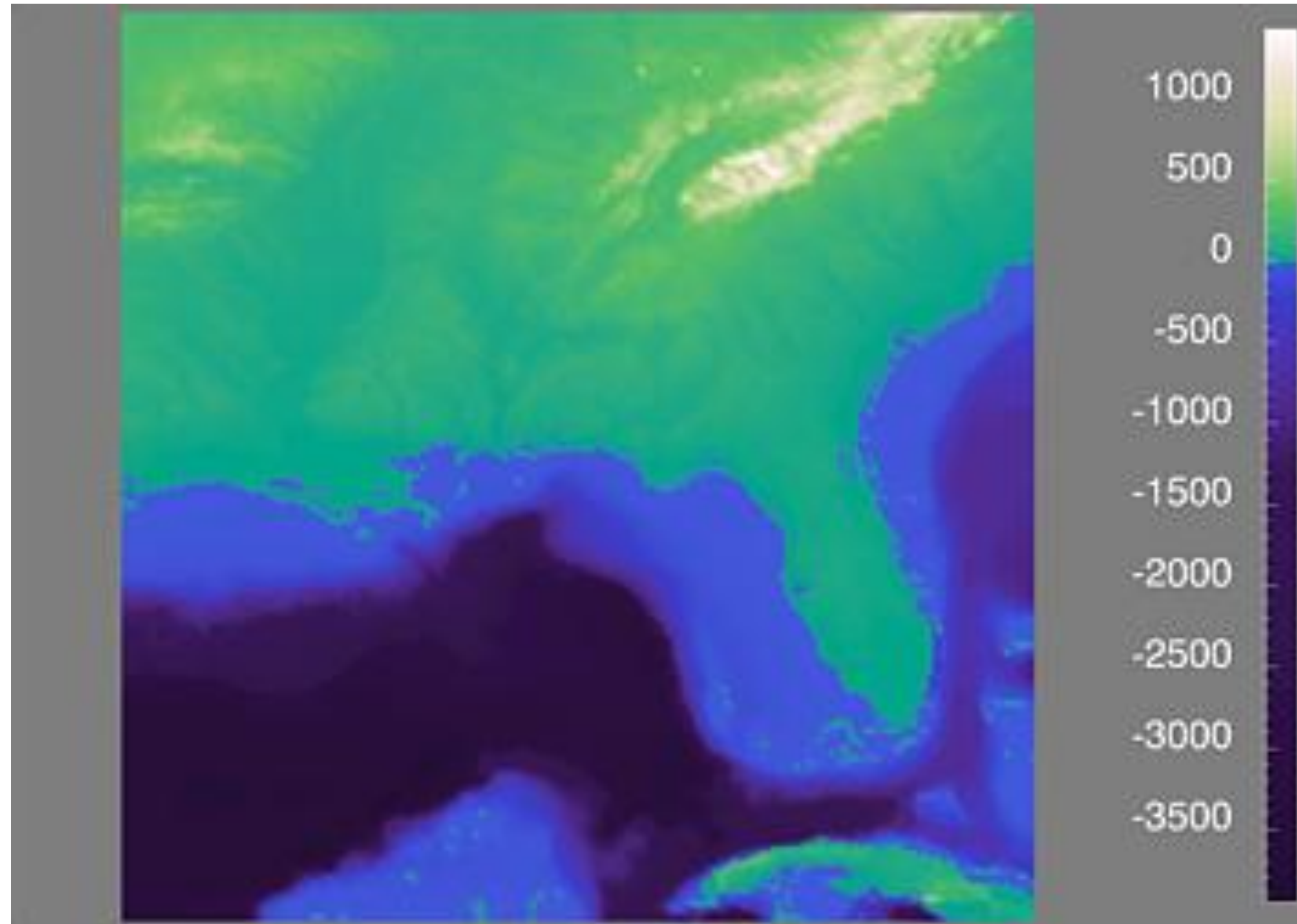
Why this color map is a poor choice for quantitative data...

- No perceptual ordering (confusing)
- No darkness variation (obscures details)
- Viewers perceive sharp transitions in color as sharp transitions in the data, even when this is not the case (misleading)

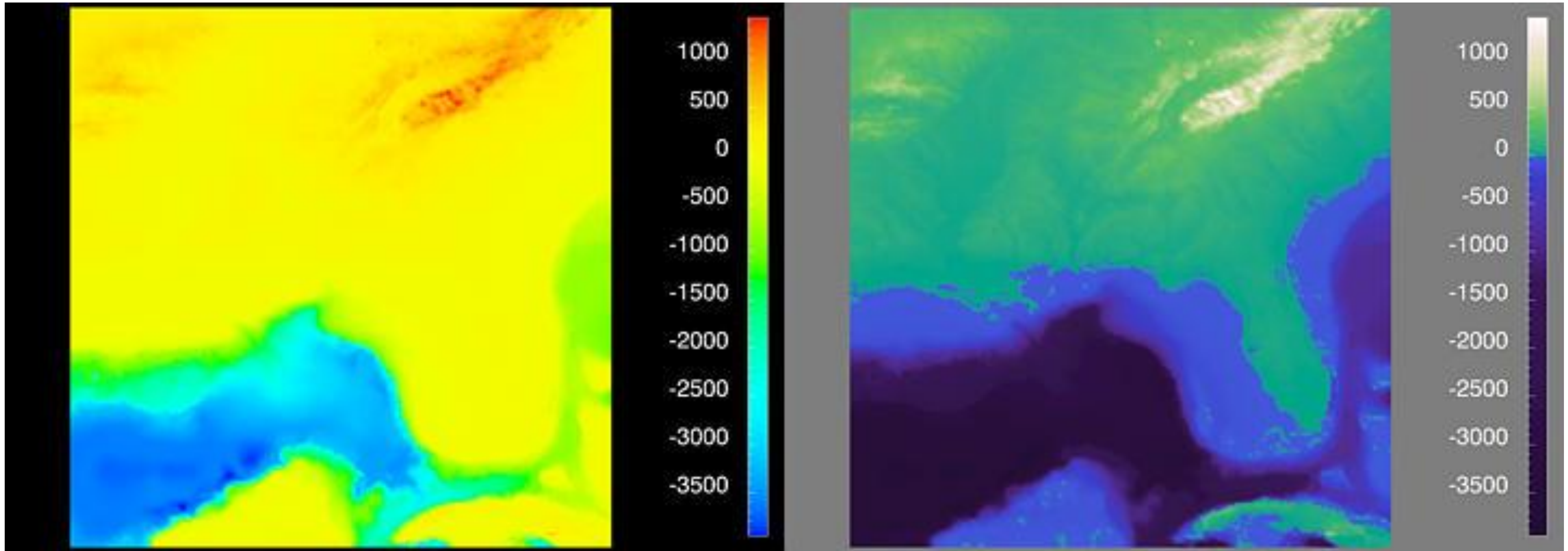
Color Maps



Color Maps



Color Maps

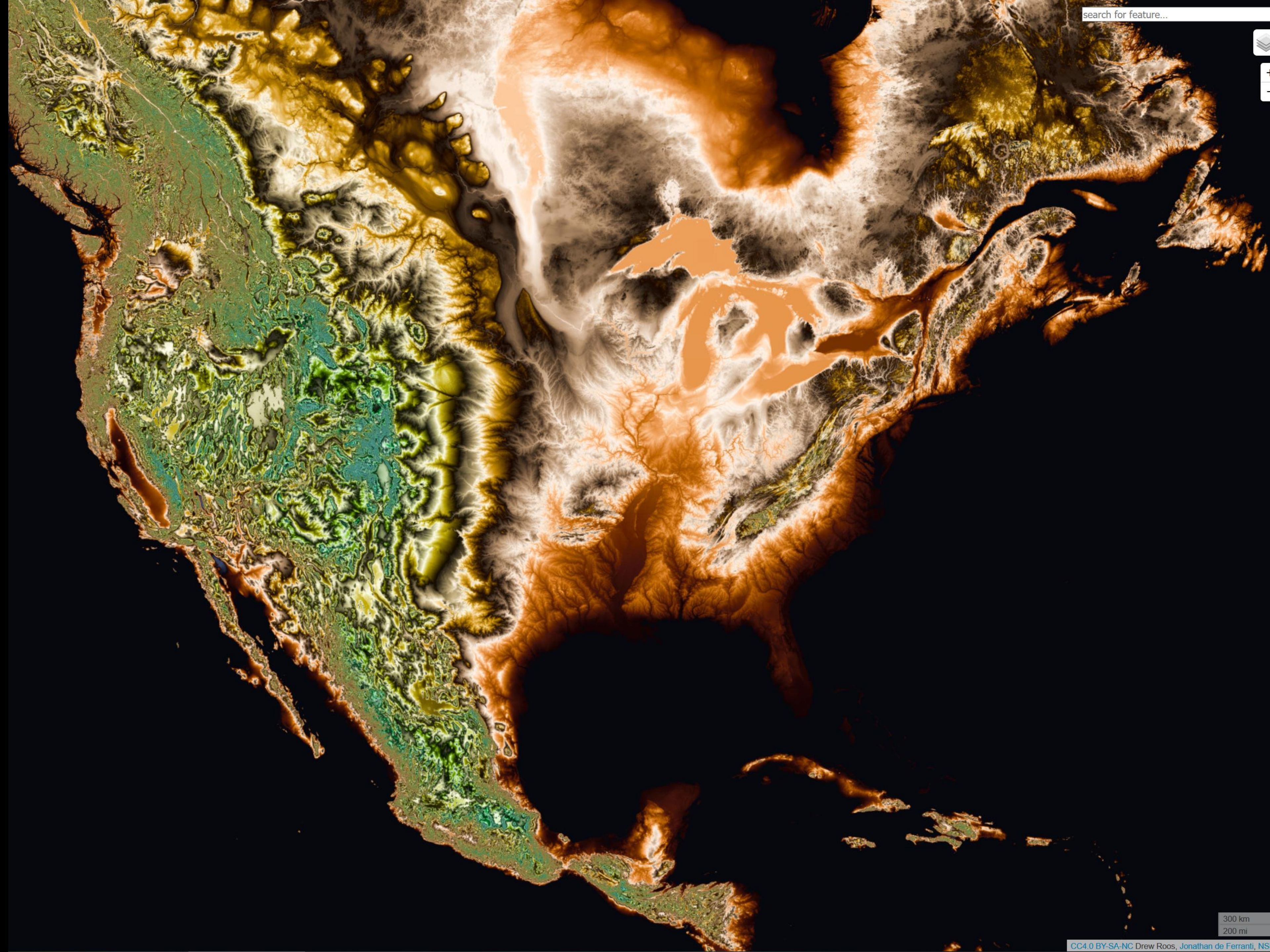


Sequential (possibly wrong)

Diverging

Sequential rainbow (wrong!)





search for feature...



300 km
200 mi

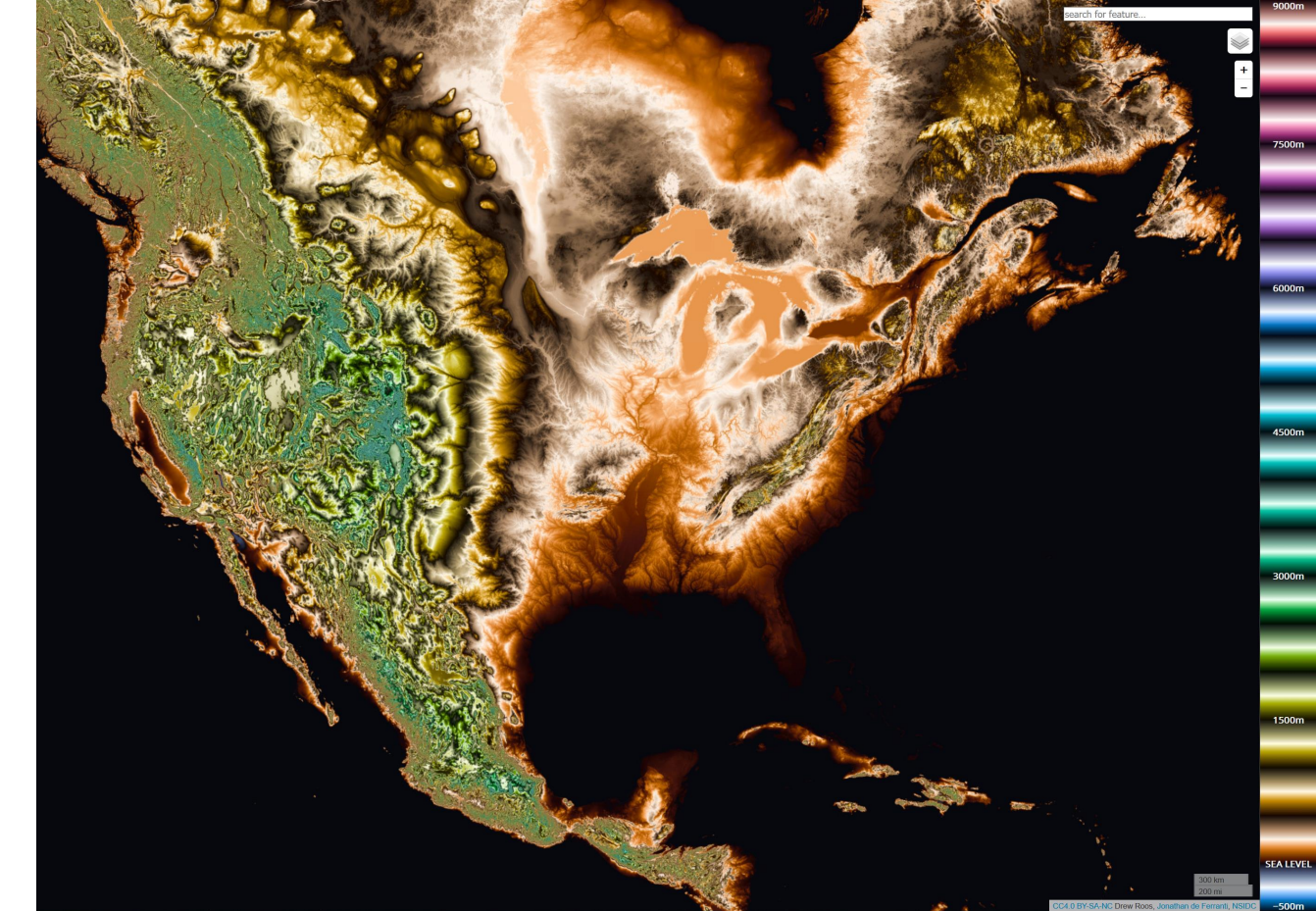
CC4.0 BY-SA-NC Drew Roos, Jonathan de Ferranti, NSIDC

[Roos, 2015](#)

IN-CLASS EXERCISE

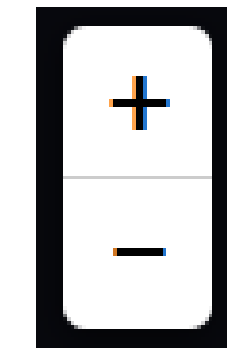
In-class exercise: Oilslick

10m

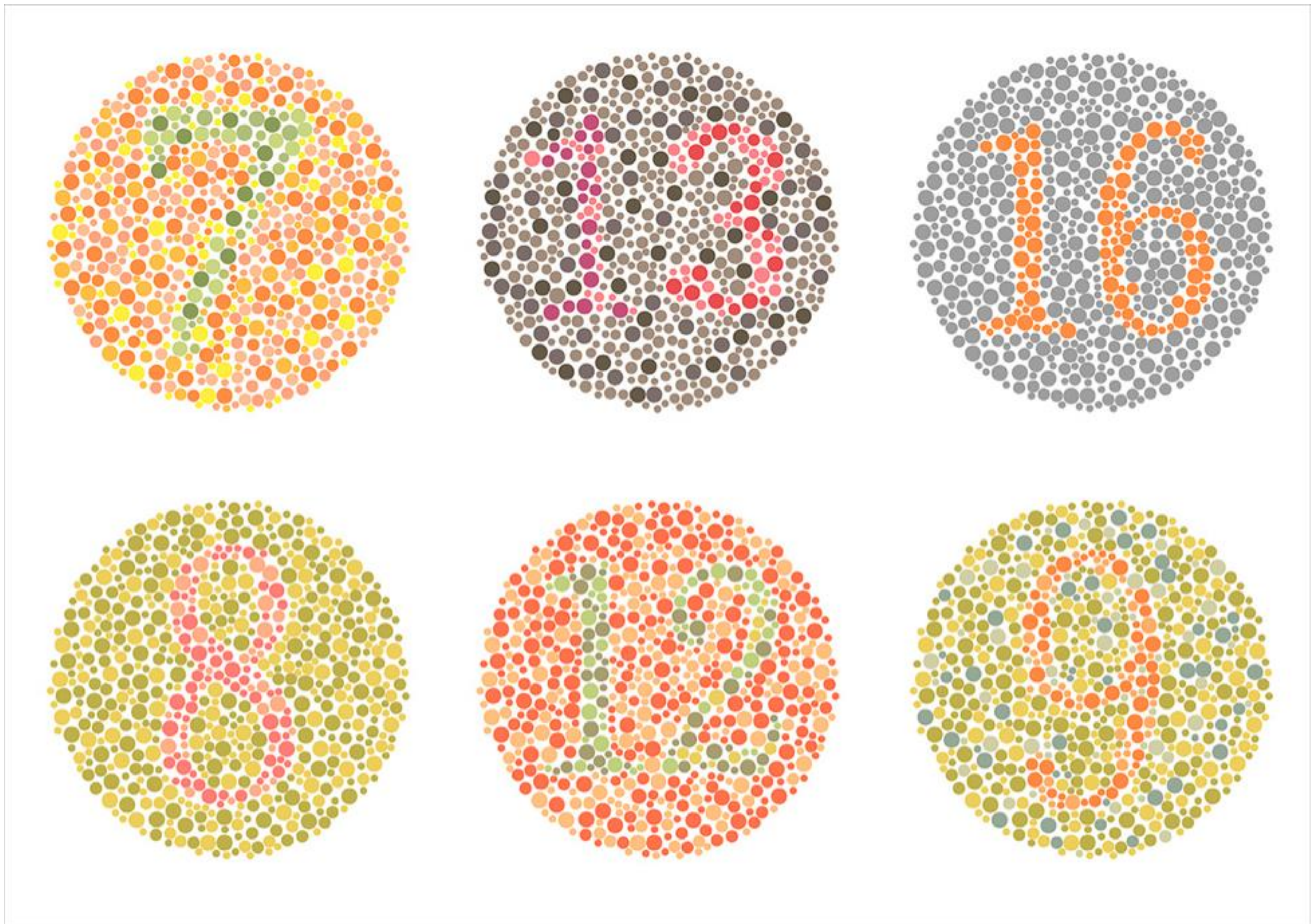


INSTRUCTIONS:

- Working individually, go to <https://mrgris.com/projects/oilslick/>
- Experiment with the different layers, different zoom levels, and different locations



- Think of answers to these questions:
 - What areas are particularly interesting?
 - Which layer / color scale works best, and for which tasks?
- Several of you will be asked to share your findings.



Those with deuteranope color blindness (red/green) will have difficulty seeing the numbers.

Color Deficiencies (Color Blindness)

Person with faulty cones (or faulty pathways):

Protanope = faulty red cones



Deuteranope = faulty green cones

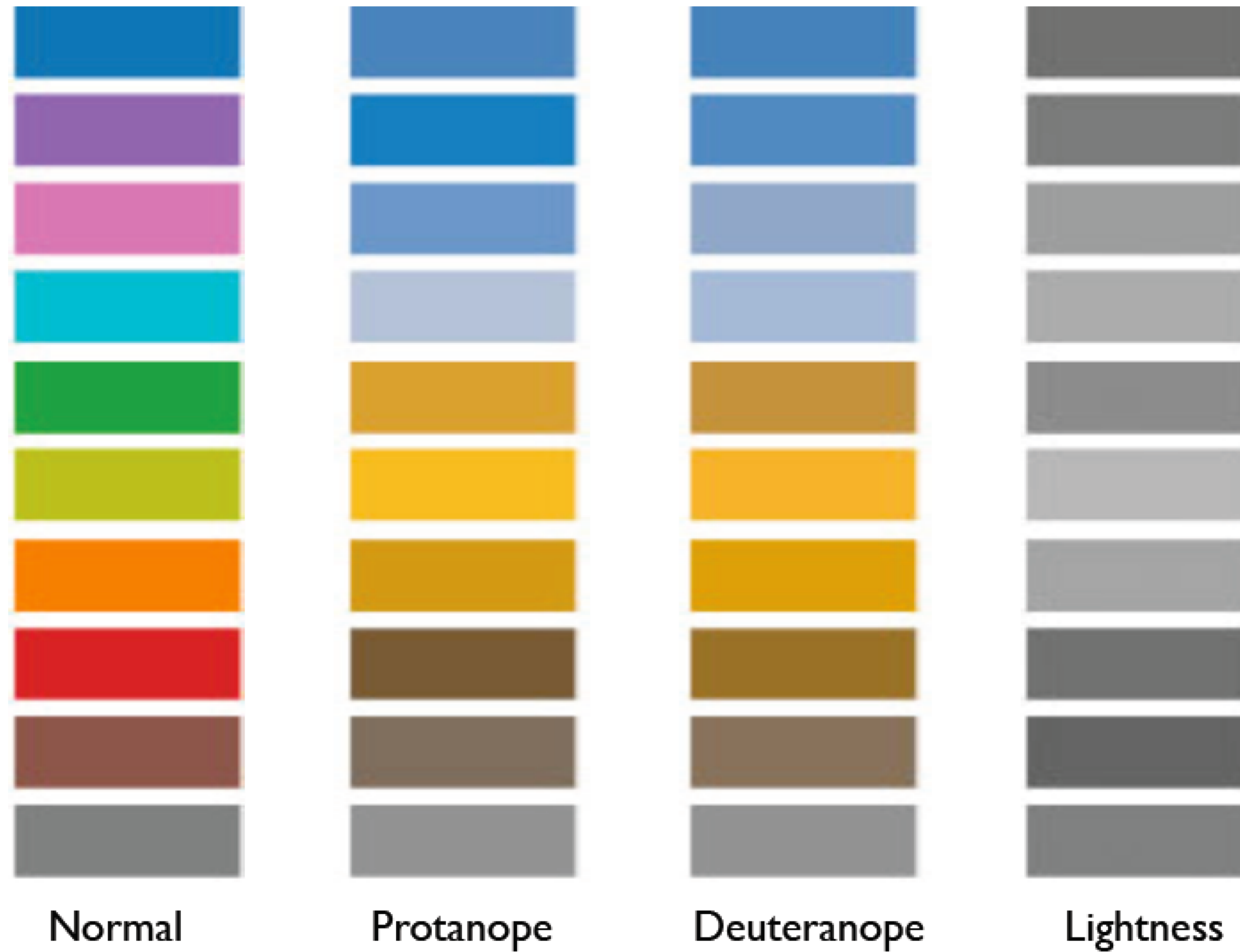


Tritanope = faulty blue cones

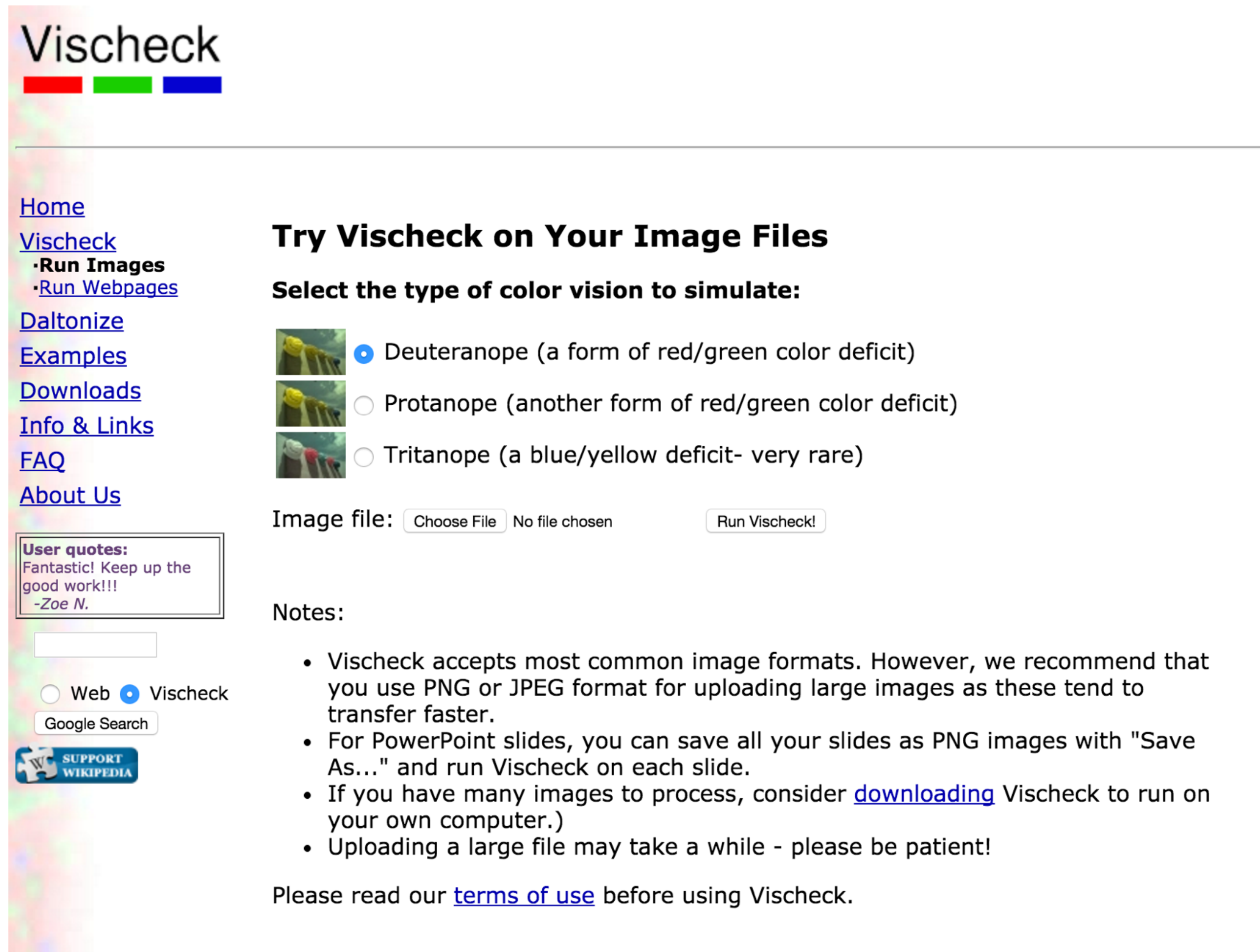


normal

Color Deficiencies (Color Blindness)



Check your images/colormaps for issues!



The screenshot shows the Vischeck website. At the top left is the Vischeck logo with three colored bars (red, green, blue). Below it is a navigation menu with links: Home, Vischeck, Run Images, Run Webpages, Daltonize, Examples, Downloads, Info & Links, FAQ, and About Us. A 'User quotes' box contains a testimonial from Zoe N. There are radio buttons for 'Web' and 'Vischeck', and a 'Google Search' button. A 'SUPPORT WIKIPEDIA' button is also visible. The main content area is titled 'Try Vischeck on Your Image Files' and includes a section 'Select the type of color vision to simulate:' with three options: Deuteranope (selected), Protanope, and Tritanope. Below this is an 'Image file:' section with a 'Choose File' button, 'No file chosen' text, and a 'Run Vischeck!' button. A 'Notes:' section contains a bulleted list of instructions. At the bottom, it says 'Please read our terms of use before using Vischeck.'

Vischeck

Home
Vischeck
•Run Images
•Run Webpages
Daltonize
Examples
Downloads
Info & Links
FAQ
About Us

User quotes:
Fantastic! Keep up the good work!!!
-Zoe N.

Web Vischeck

Google Search

SUPPORT WIKIPEDIA

Try Vischeck on Your Image Files

Select the type of color vision to simulate:

- Deuteranope (a form of red/green color deficit)
- Protanope (another form of red/green color deficit)
- Tritanope (a blue/yellow deficit- very rare)

Image file: No file chosen

Notes:

- Vischeck accepts most common image formats. However, we recommend that you use PNG or JPEG format for uploading large images as these tend to transfer faster.
- For PowerPoint slides, you can save all your slides as PNG images with "Save As..." and run Vischeck on each slide.
- If you have many images to process, consider [downloading](#) Vischeck to run on your own computer.)
- Uploading a large file may take a while - please be patient!

Please read our [terms of use](#) before using Vischeck.



The screenshot shows the Coblis website. At the top is the Coblis logo and a navigation menu with links: Home, CVD Essentials, Color Blindness Tests, Color Tools, and Contact. There are social media icons for Twitter, Google+, LinkedIn, YouTube, and Facebook. A search bar and a 'Subscribe' button are also present. The main content area is titled 'Coblis — Color Blindness Simulator' and includes a paragraph explaining the simulator's purpose. Below this is a section for image upload with a 'Browse...' button and 'No file selected' text. A 'Trichromatic view' section lists various color vision deficiencies with radio buttons. A 'Use lens to compare with normal view' section has radio buttons for 'No Lens', 'Normal Lens', and 'Inverse Lens'. At the bottom right, there is a 'FREE Color Blind Check' section with a target icon and text about testing color vision deficiency.

Coblis

Home CVD Essentials Color Blindness Tests Color Tools Contact

Coblis — Color Blindness Simulator

If you are not suffering from a color vision deficiency it is very hard to imagine how it looks like to be colorblind. The **Color BL**indness Simulator can close this gap for you. Just play around with it and get a feeling of how it is to have a color vision handicap.

As all the calculations are made on your local machine, no images are uploaded to the server. Therefore you can use images as big as you like, there are no restrictions. Be aware, there are some issues for the "Lens feature" on Edge and Internet Explorer. All others should support everything just fine.

So go ahead, choose an image through the upload functionality or just drag and drop your image in the center of our **Color BL**indness Simulator. It is also possible to zoom and move your images around using your mouse - try it out, I hope you like it.

Drag and drop or paste your file in the area below or: No file selected.

Trichromatic view: *Anomalous Trichromacy:* *Dichromatic view:* *Monochromacy:*

- Normal
- Red-Weak/Protanomaly
- Red-Blind/Protanopia
- Monochromacy
- Green-Weak/Deuteranomaly
- Green-Blind/Deuteranopia
- Blue-Weak/Tritanomaly
- Blue-Blind/Tritanopia
- Blue-Congenital

Use lens to compare with normal view: No Lens Normal Lens Inverse Lens

[Reset View](#)

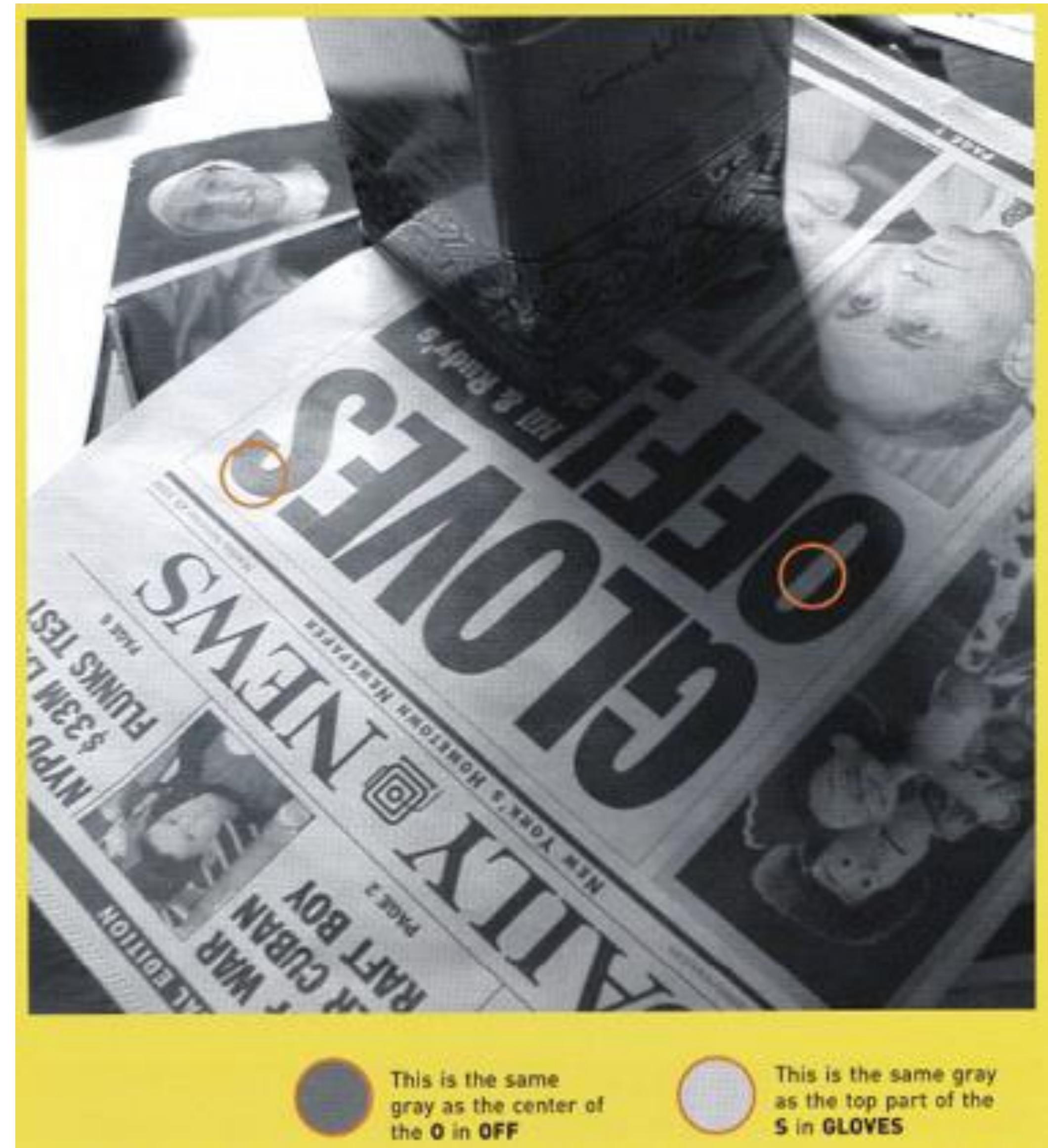
FREE Color Blind Check

New kind of color blindness test! Try **Color Blind Check** and test type and severity of your color vision deficiency.

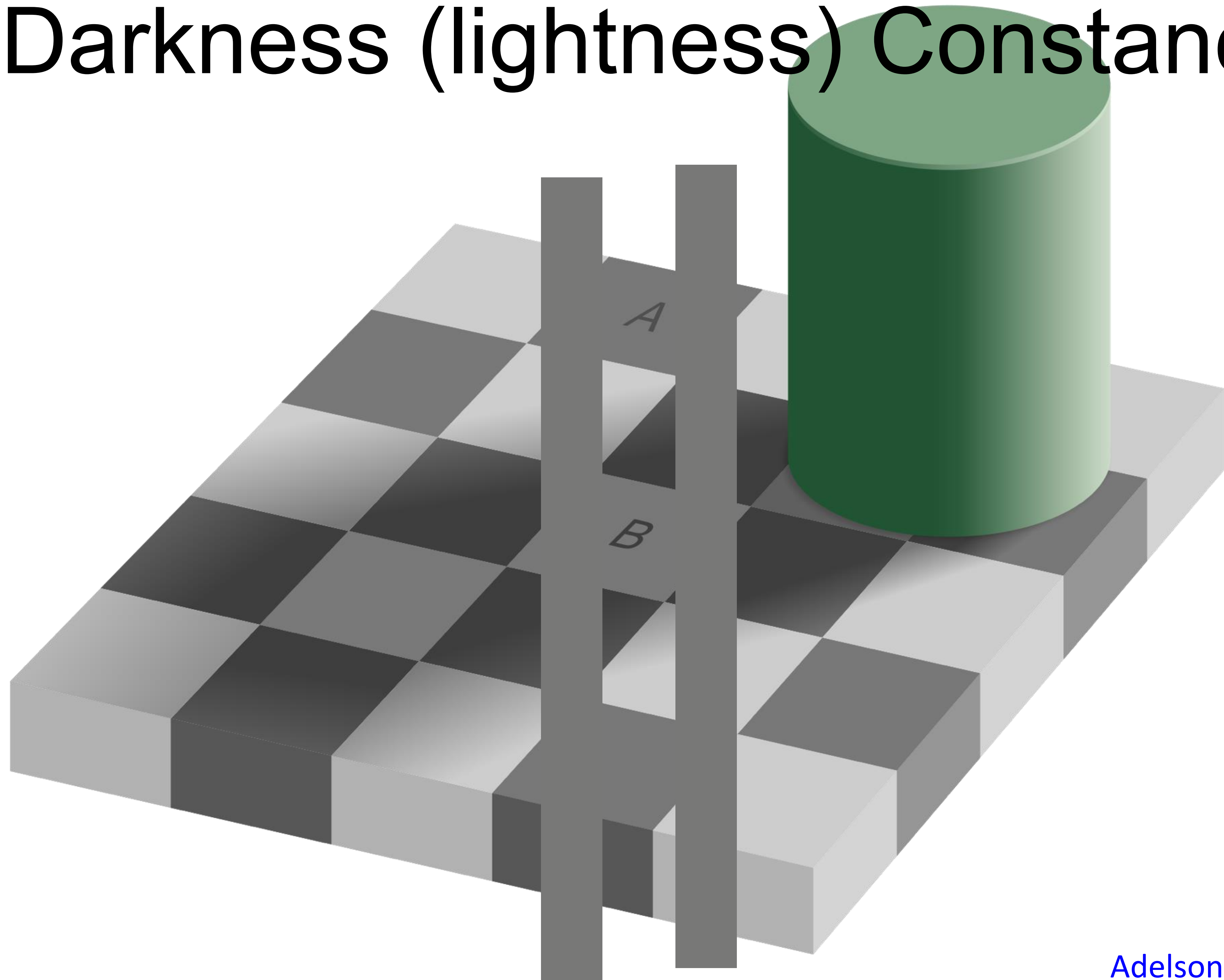
INTERACTIONS BETWEEN COLORS AND WITH LIGHTING

“Lightness Constancy”

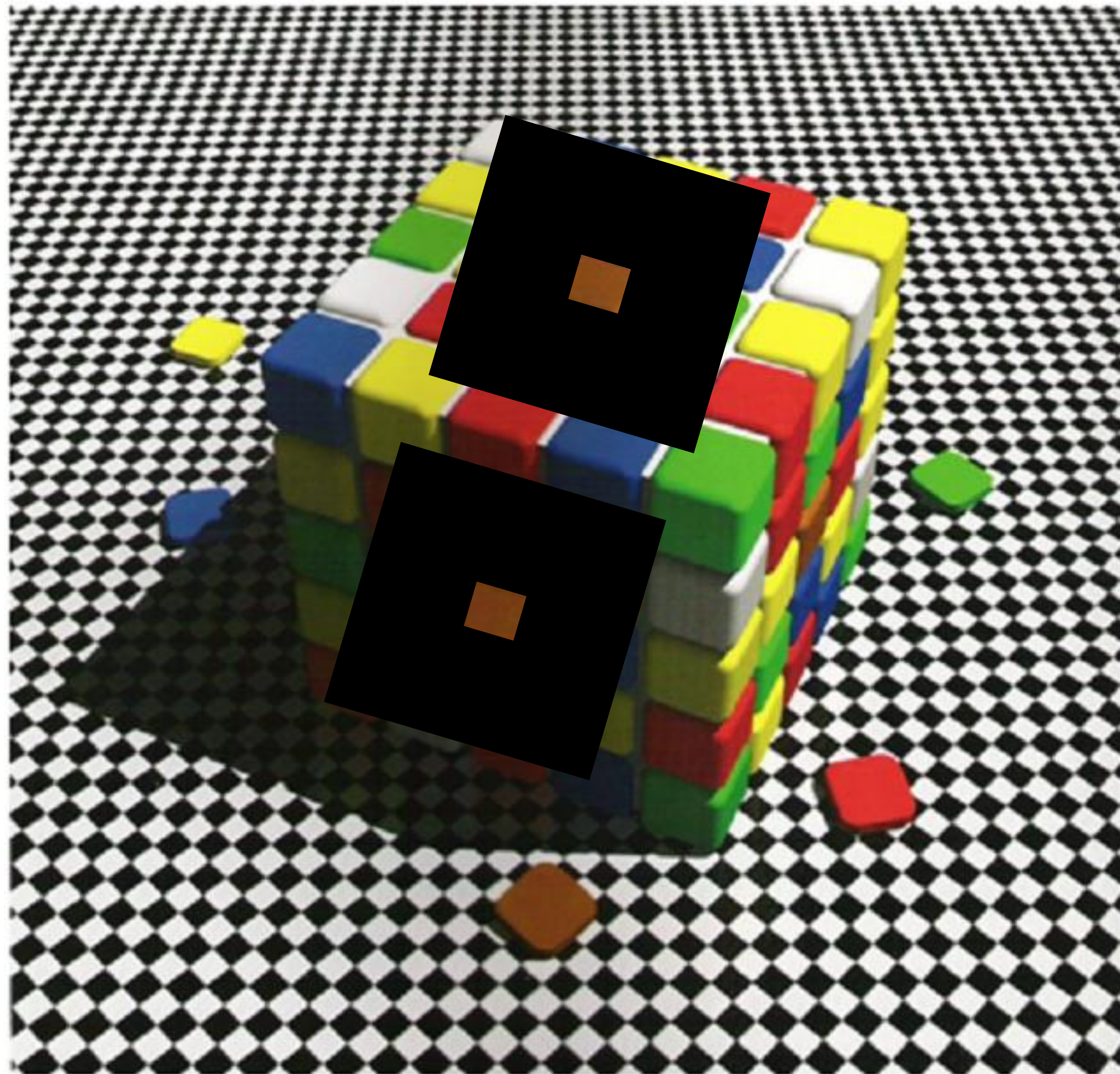
The perception that the apparent brightness of light and dark surfaces remains more or less the same under different luminance conditions is called **darkness (lightness) constancy**.



“Darkness (lightness) Constancy”



“Color Constancy”



“Simultaneous Contrast”



“Simultaneous Contrast”

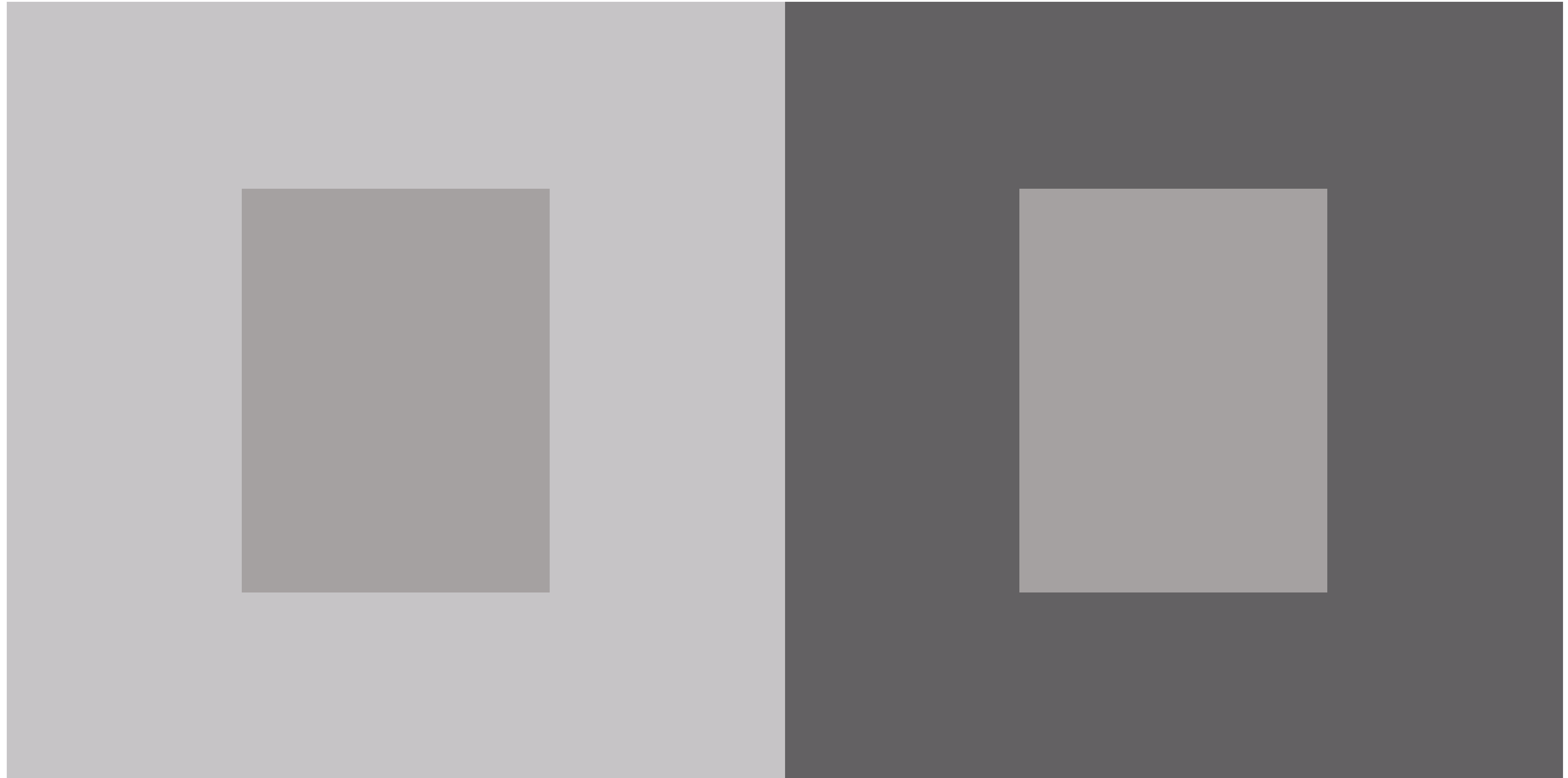


“Simultaneous Contrast”



Avoid gradients as backgrounds or bars!

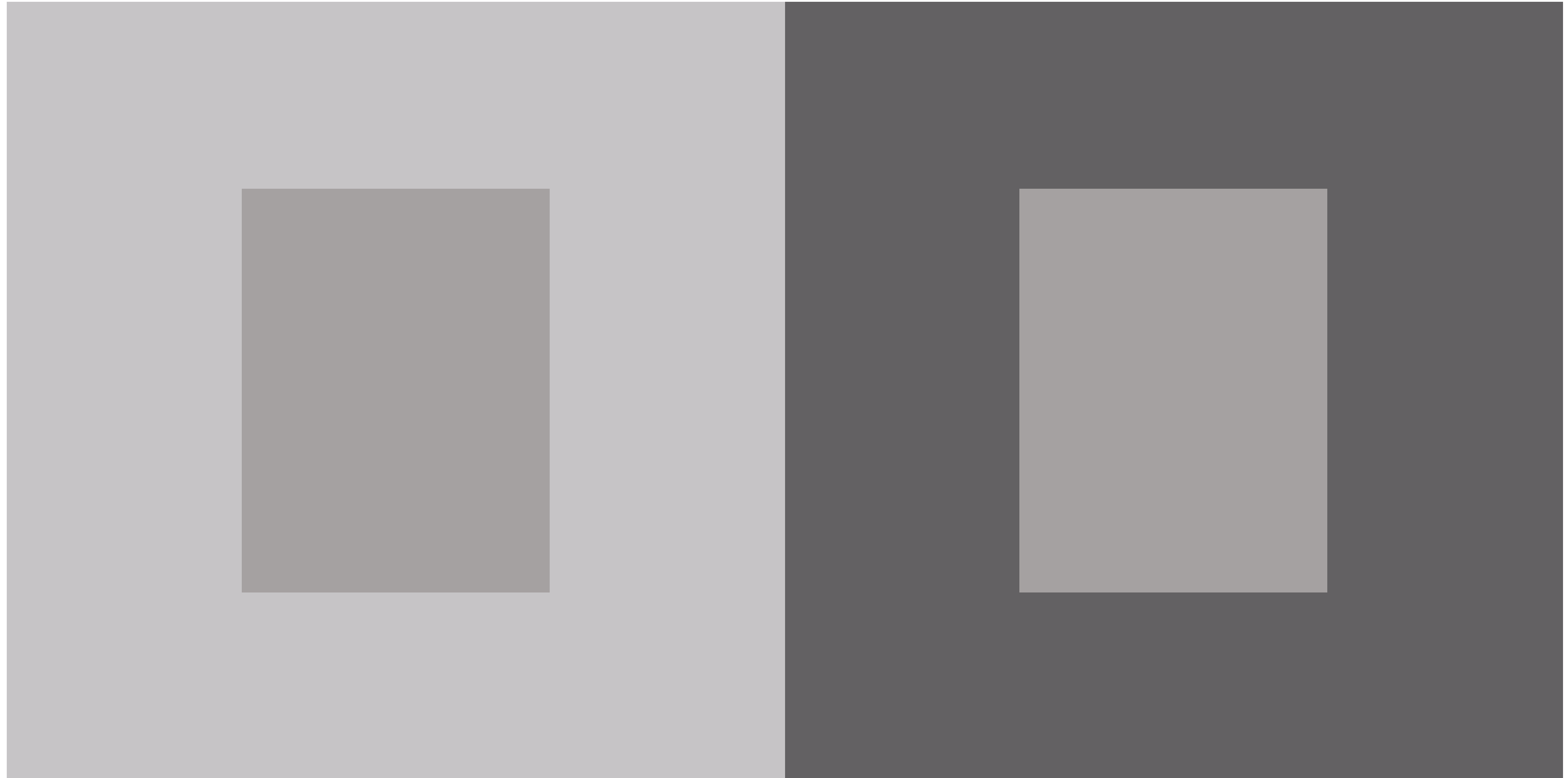
“Simultaneous Contrast”



“Simultaneous Contrast”



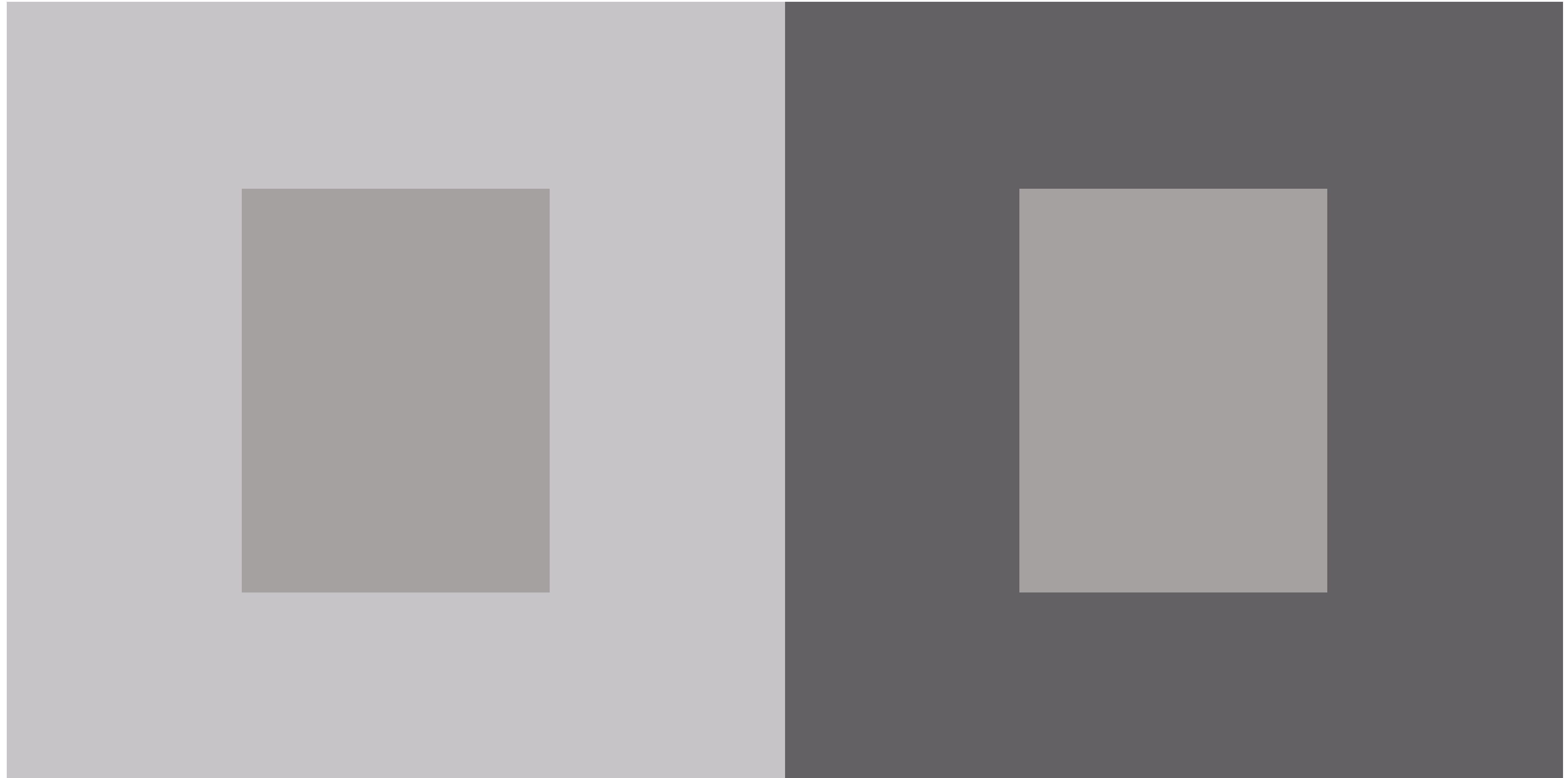
“Simultaneous Contrast”



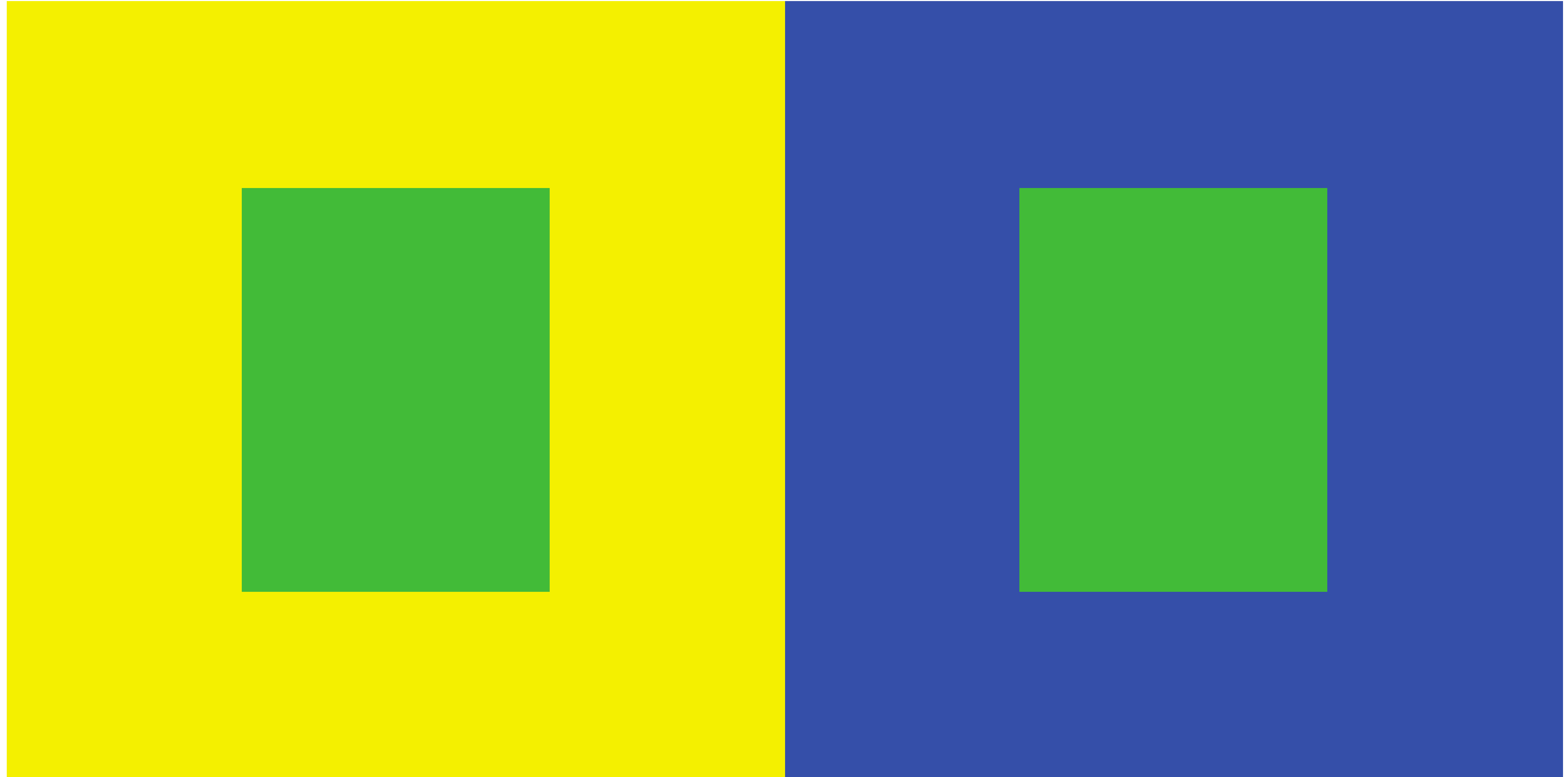
“Simultaneous Contrast”



“Simultaneous Contrast”



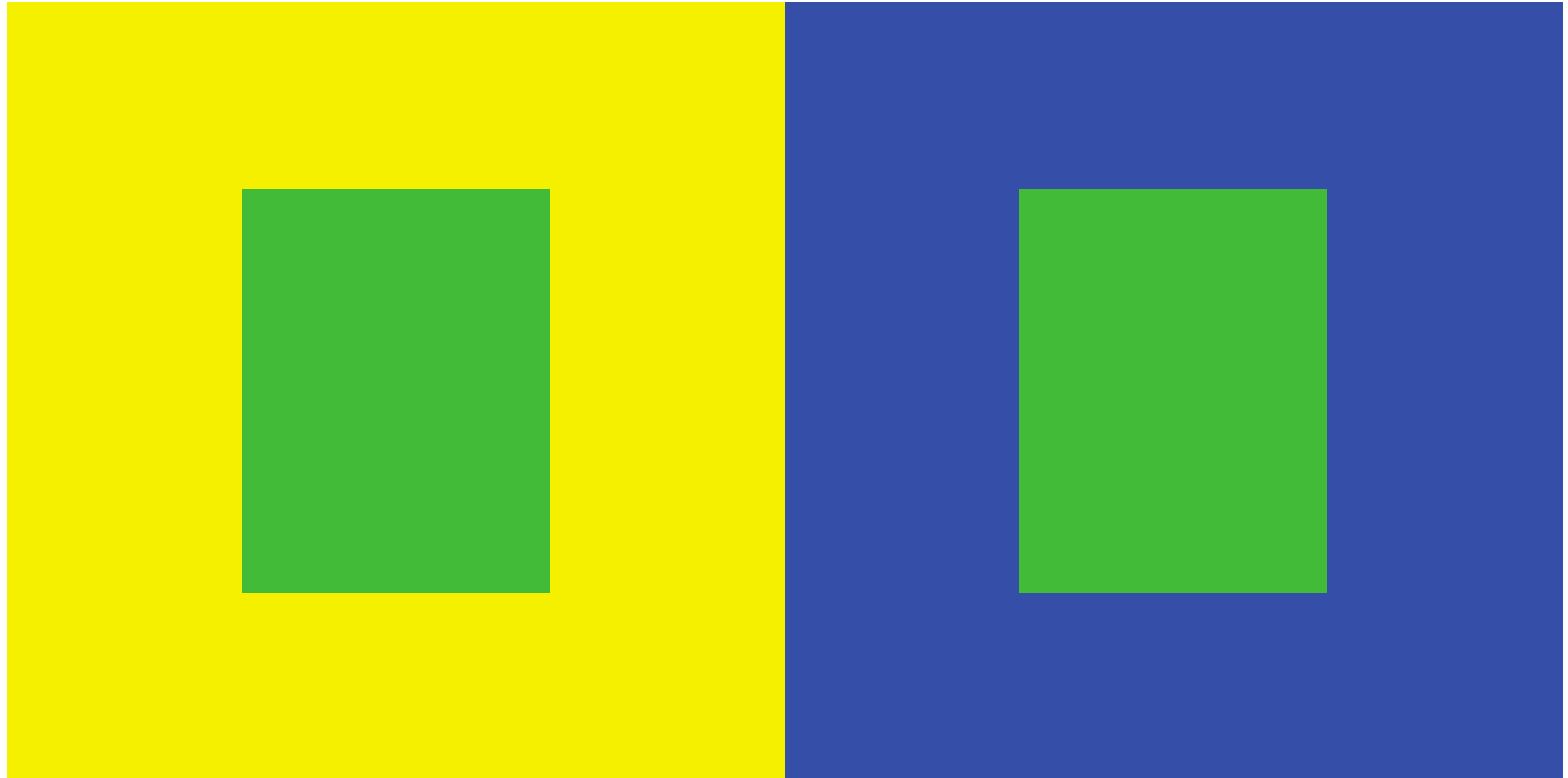
“Simultaneous Contrast”



“Simultaneous Contrast”



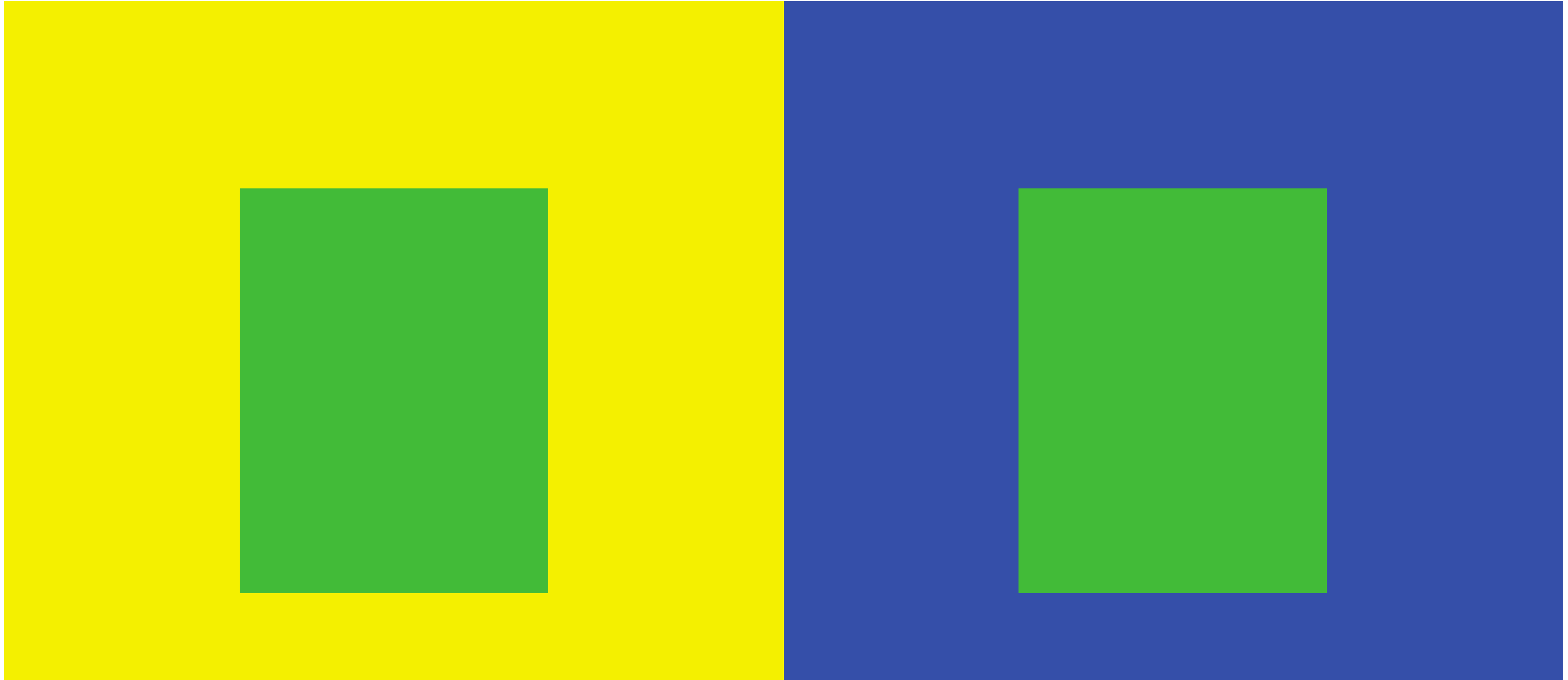
“Simultaneous Contrast”



“Simultaneous Contrast”



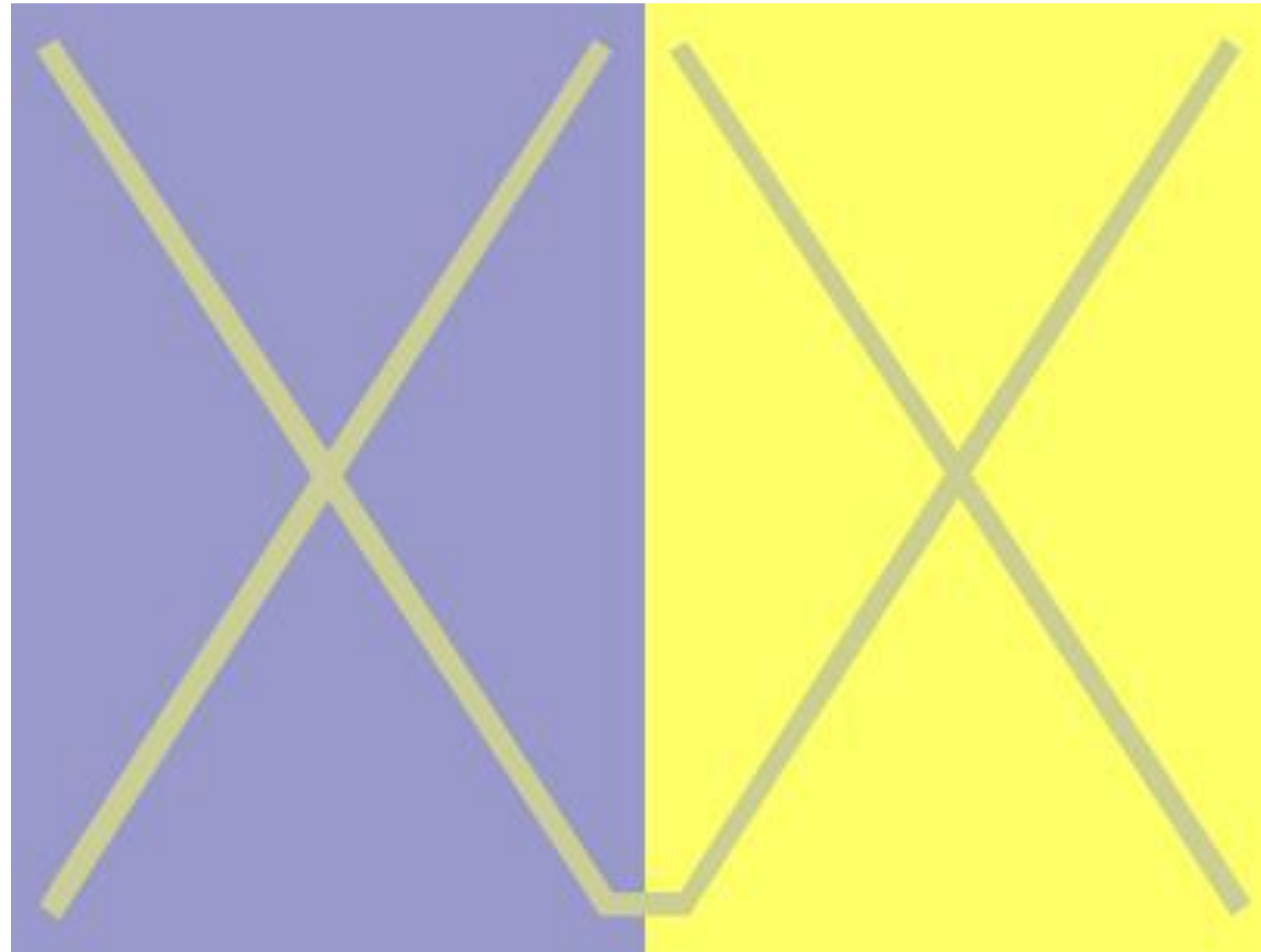
“Simultaneous Contrast”



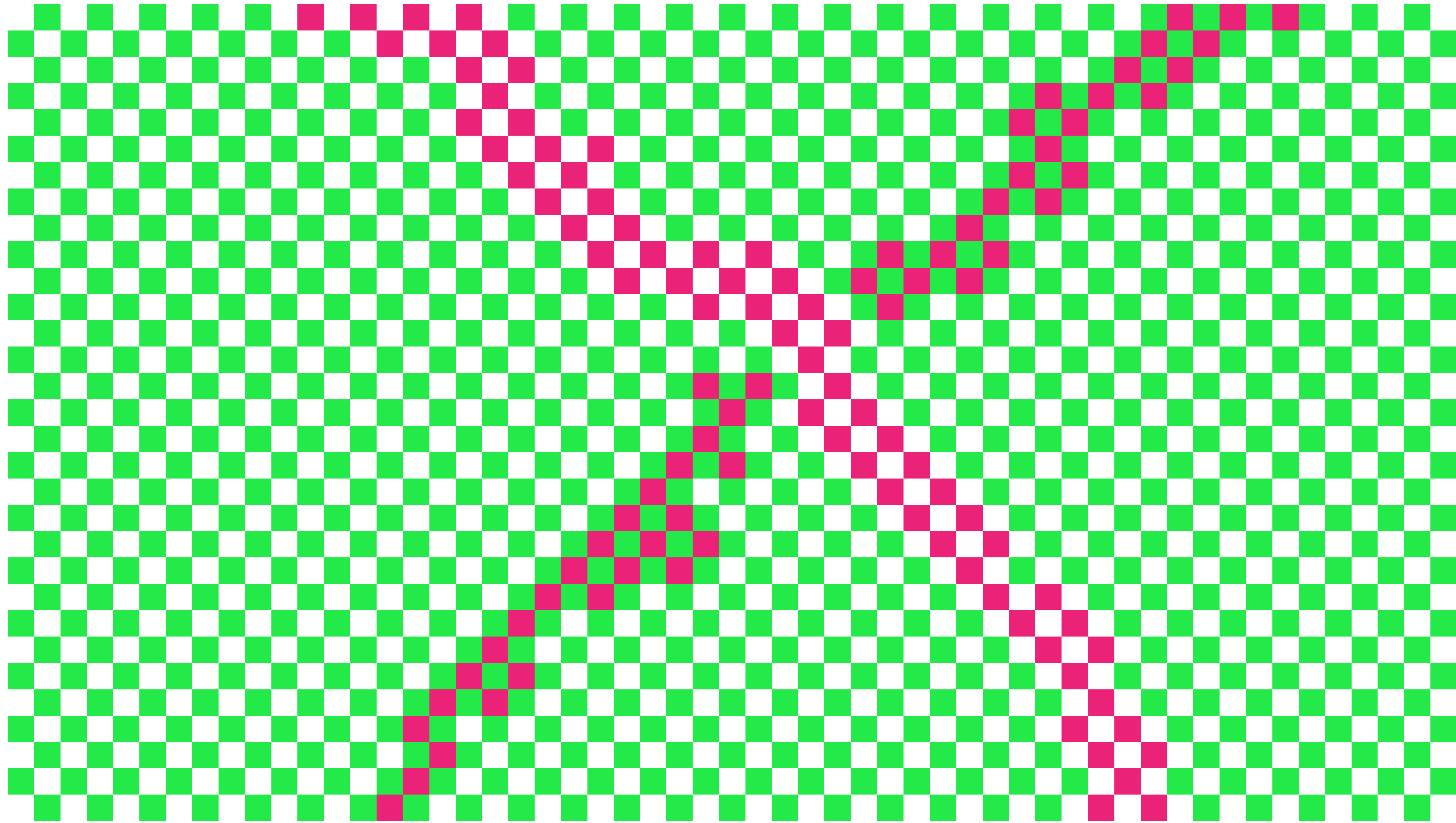
Be careful with bars and scatter plot points - the colors may appear differently with different background colors and neighboring colors!

Be aware that colors in legends may appear different than on the plot!

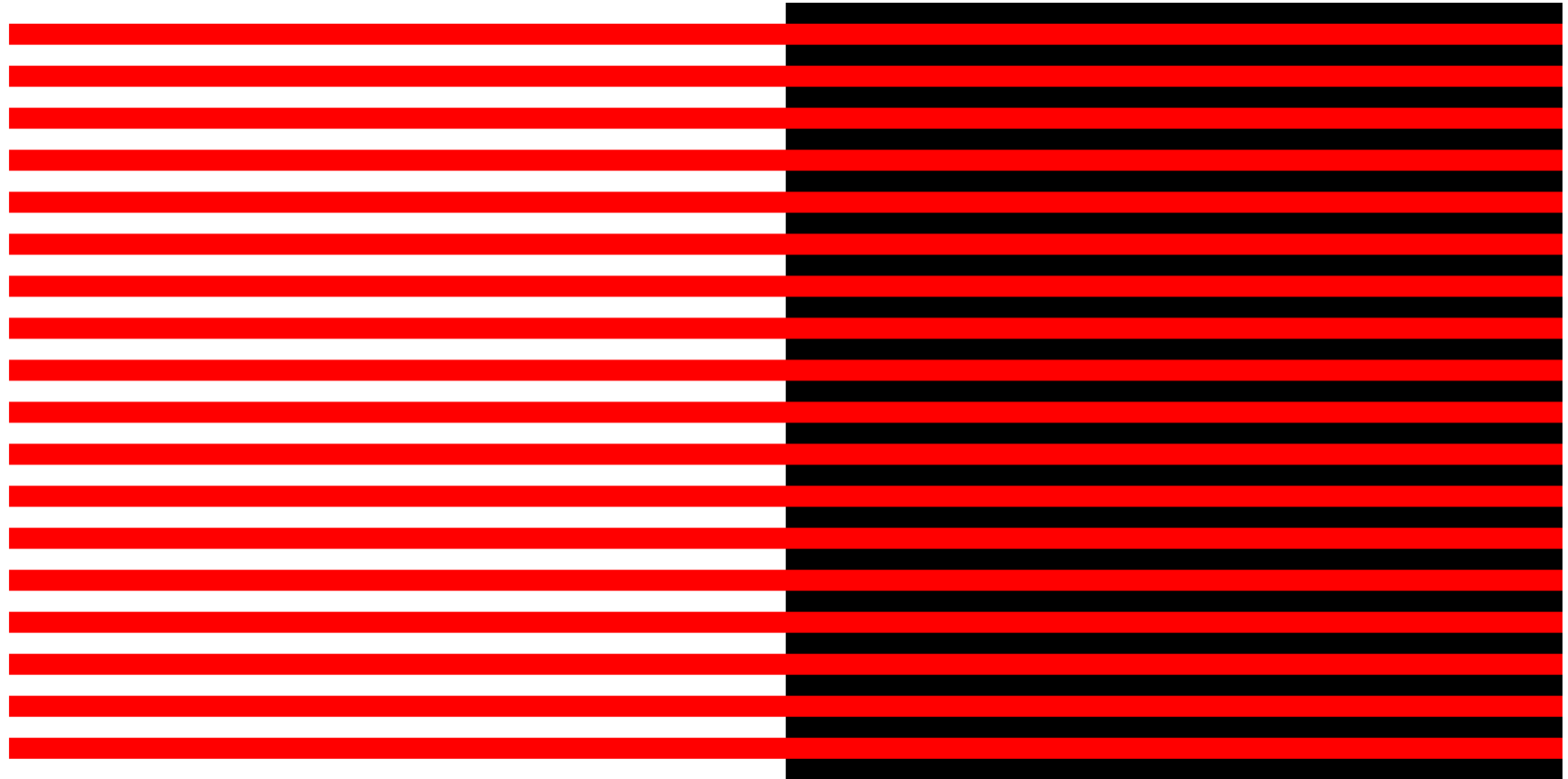
“Simultaneous Contrast”



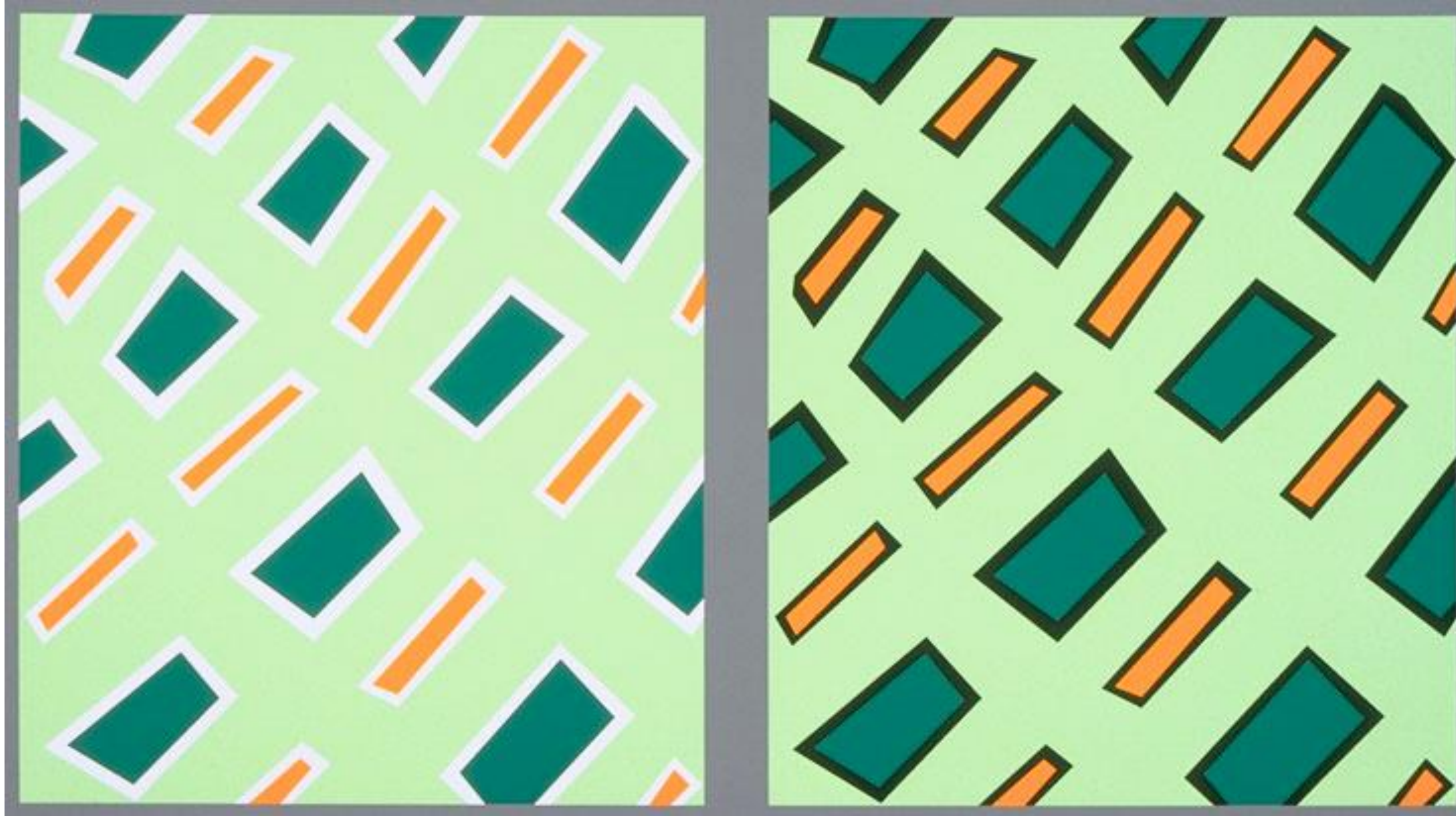
“Simultaneous Contrast”



“von Bezold Spreading Effect”



“von Bezold Spreading Effect”



Be careful with colors in scatter plots!

Be aware of color changes when adding borders around bars and plots!

Be aware that colors in legends may appear different than on the plot!

Which area is larger
(green or red)?

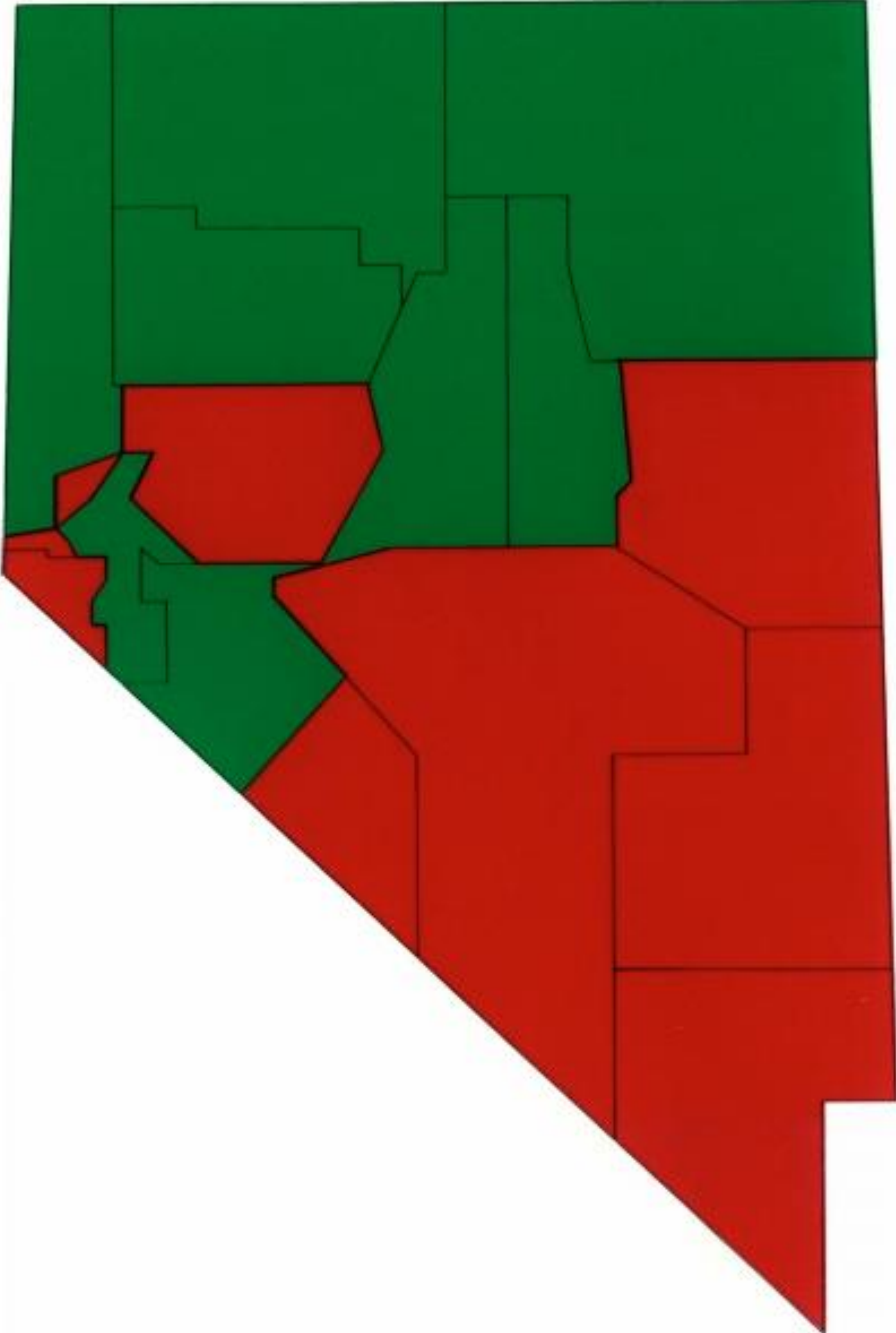


Figure 1. Stimulus From the High-Saturation Group

Which area is larger?

Areas are equal(!).

Study participants favored red in the highly saturated case (left) but were more correct with the desaturated case (right)

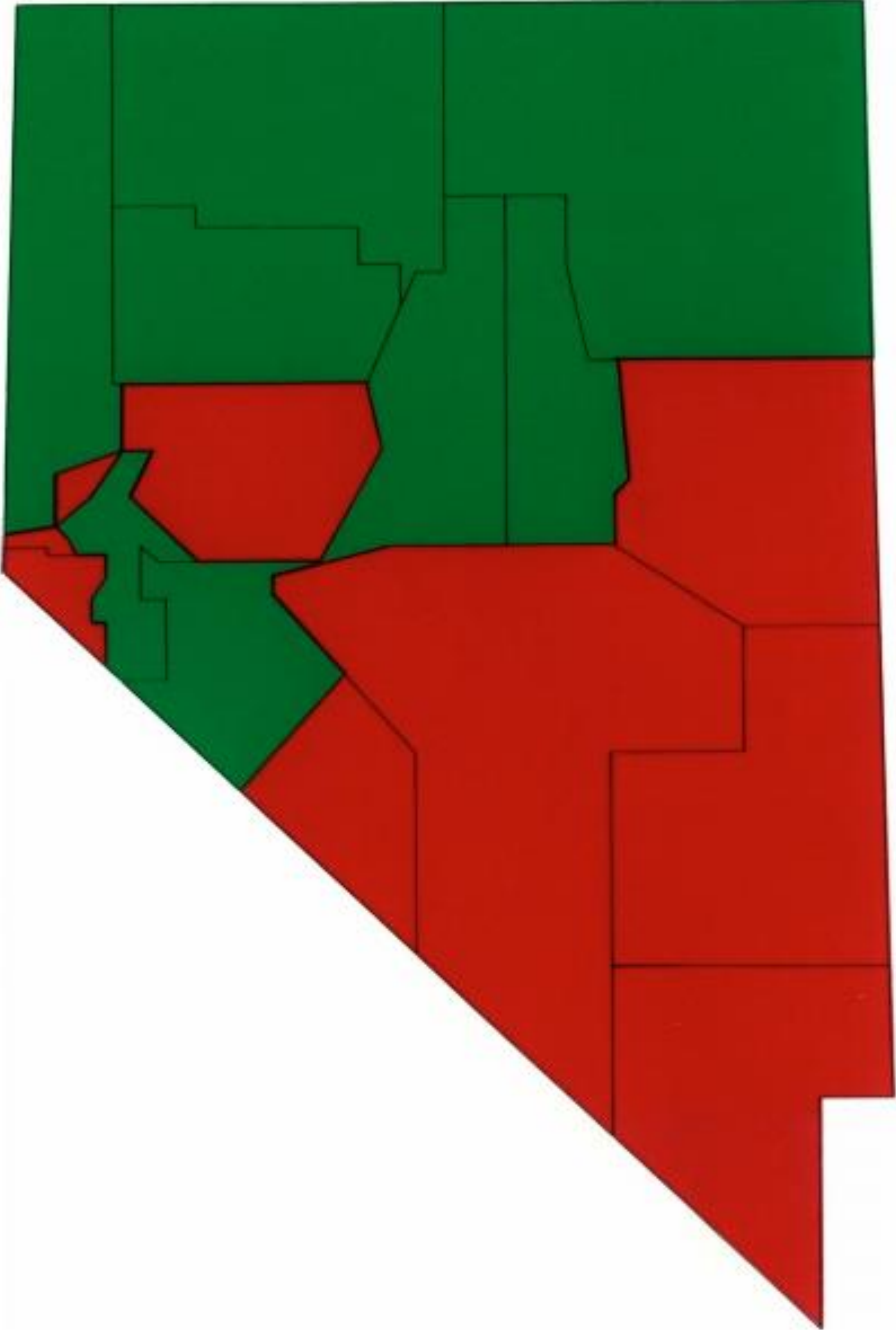


Figure 1. Stimulus From the High-Saturation Group

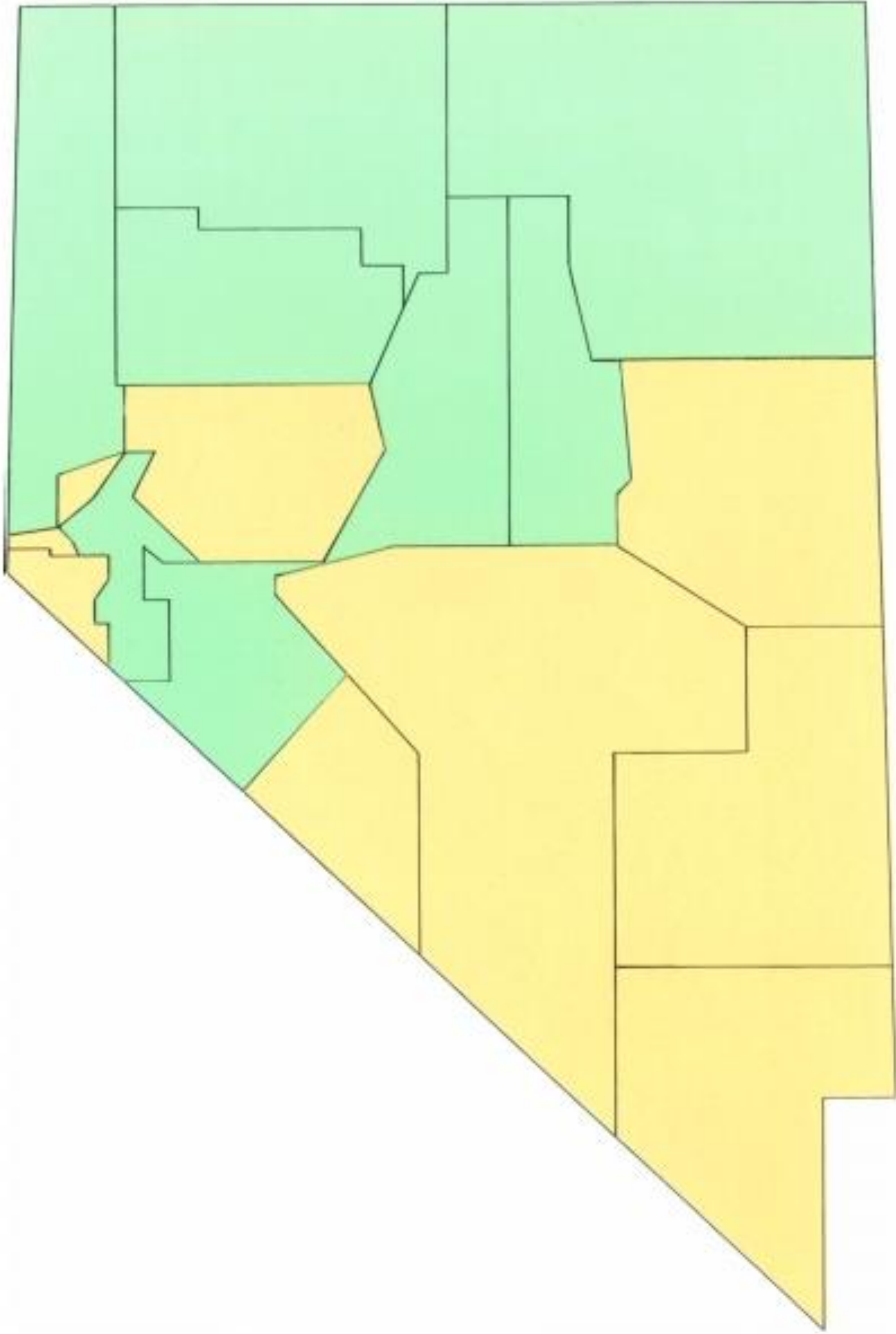
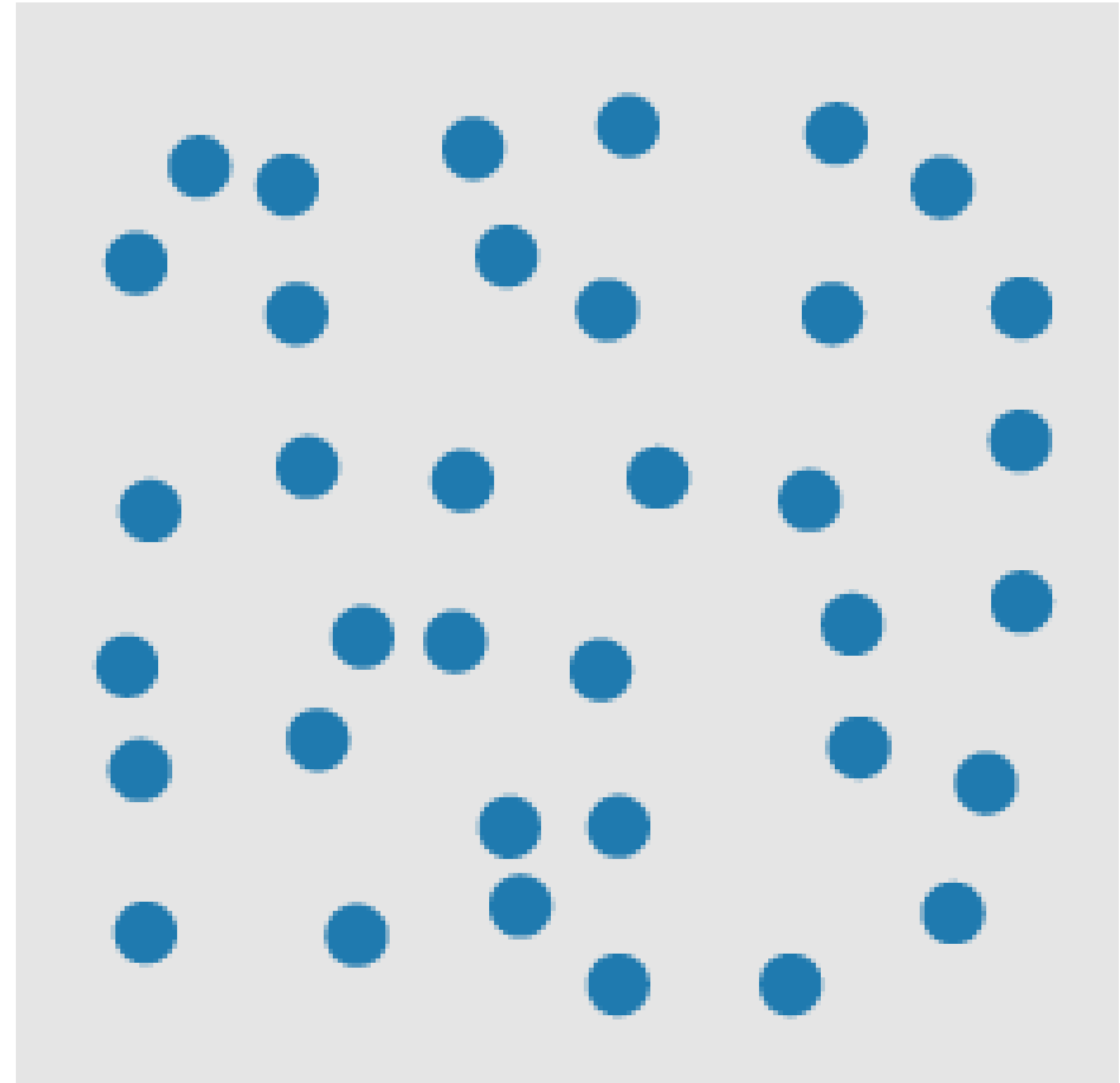
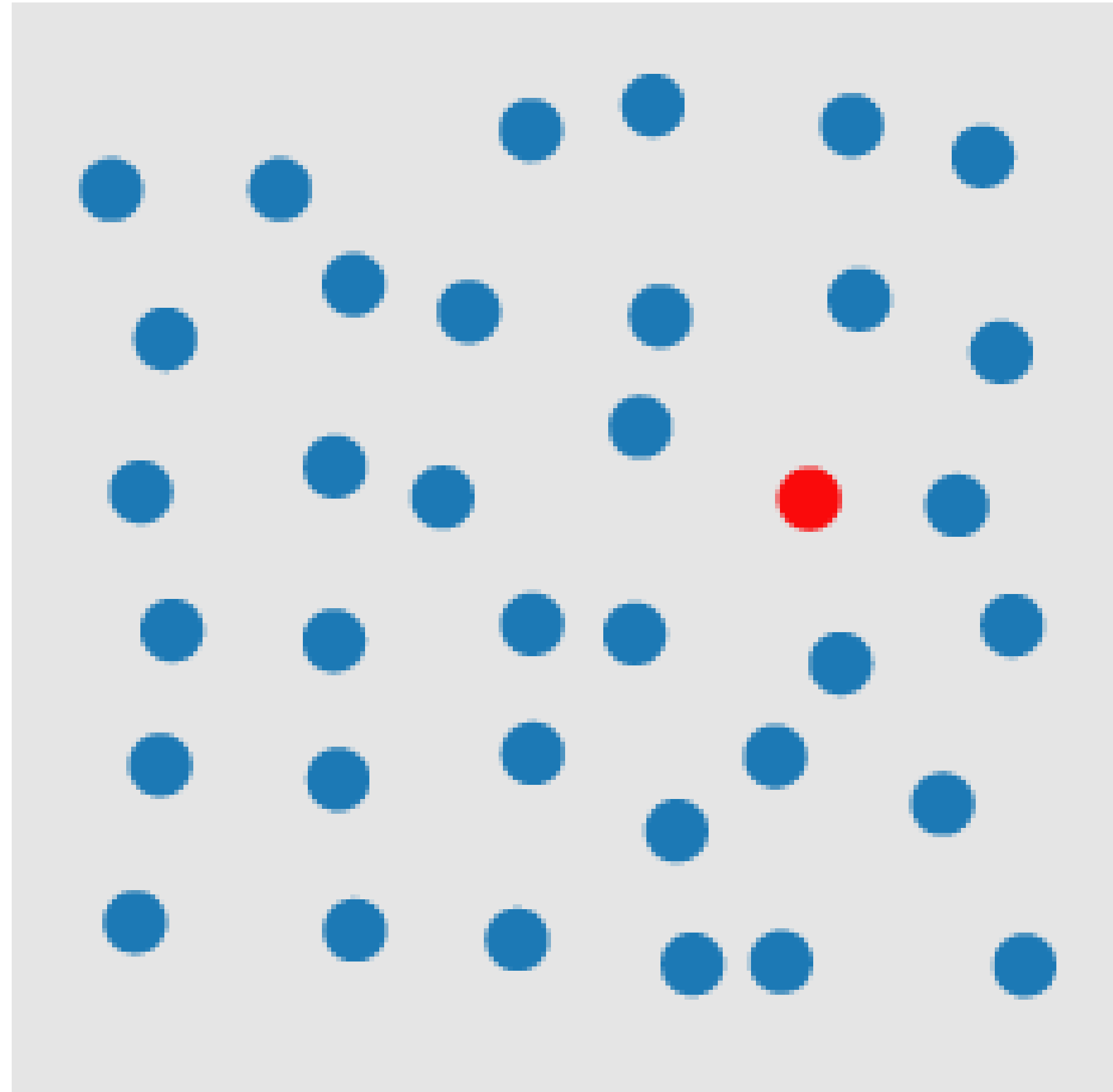


Figure 2. Stimulus From the Low-Saturation Group

POP-OUT EFFECTS



COLOR

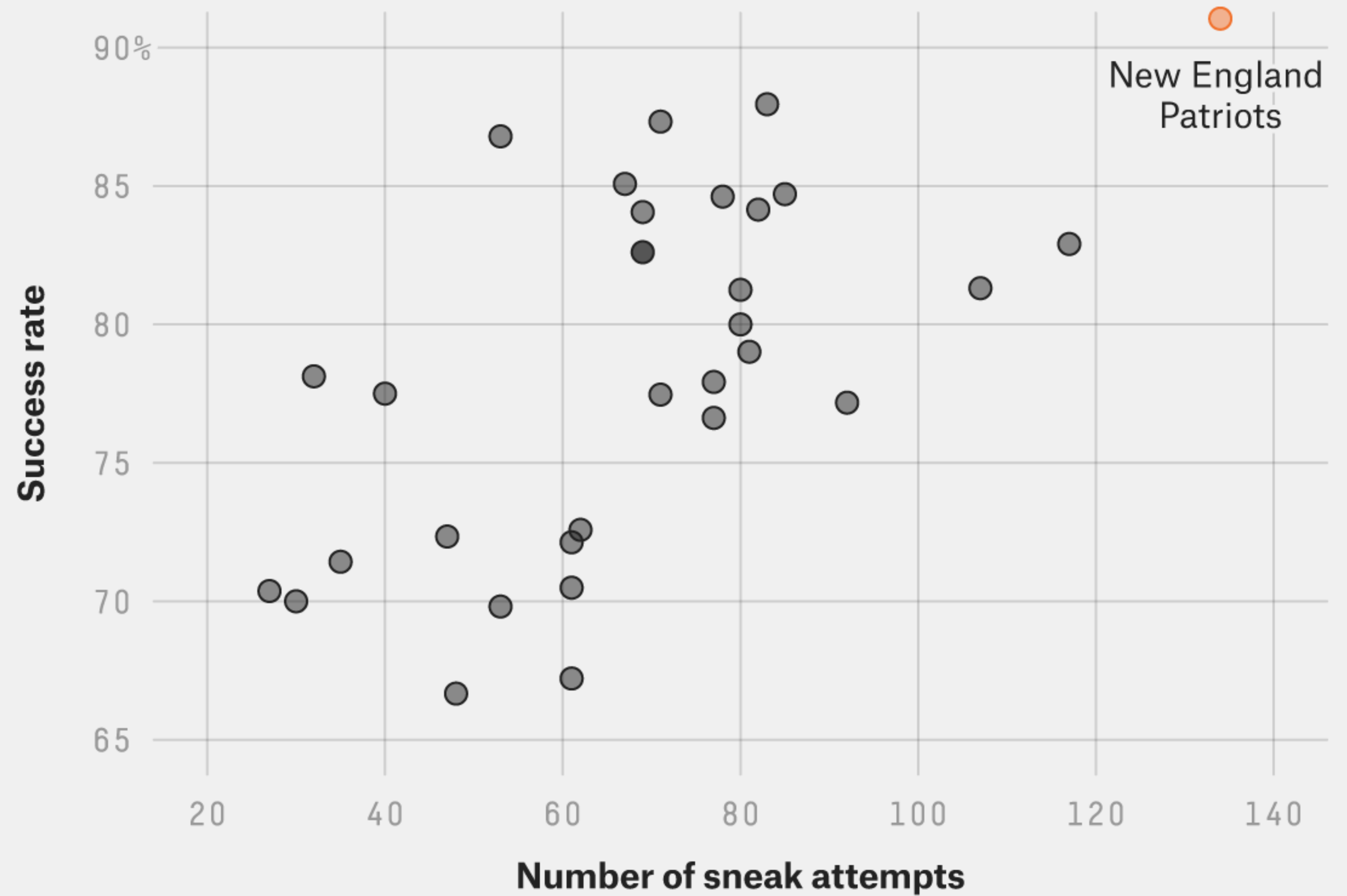
A quarterback sneak is a [play](#) in [American football](#) and [Canadian football](#) in which the [quarterback](#), upon taking the center snap, dives ahead while the offensive line surges forward. It is usually only used in very short yardage situations.

https://en.wikipedia.org/wiki/Quarterback_sneak

Which pop-out effects are used in this example visualization?

The Patriots' QB sneaks stand out

QB sneak success rate versus number of attempts on 1- and 2-yard plays on third and fourth down, 2001-15



FiveThirtyEight

SOURCE: ARMCHAIR ANALYSIS



Desaturated
background,
light blue

NASA/ESA/Hubble
Heritage Team (STScI/AURA) /
Hester & Scowen

Color Mixing Pitfalls

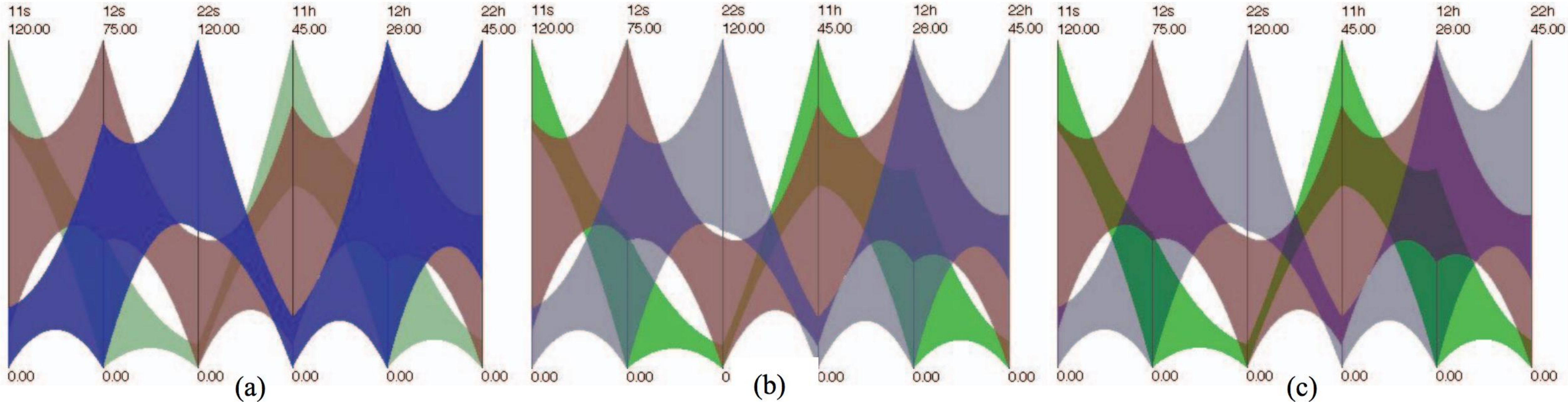


Fig. 12: Illustrative visualizations of a six-dimensional dataset using illustrative parallel coordinates. (a) Ideal visualization with appropriate weightings and color choices, and the use of the local model in overlapping areas. (b) Improper weightings are employed. The blue cluster no longer seems to be in front. (c) The use of improper weightings and the disabling of the local model results in a confusing visualization.

“Aimed at reducing false colors in the overlap regions. ...[Reduce] saturation of the color in the rear object only in the overlap region while keeping its lightness.”

Note the swap in blue/red for foreground/background vs. NASA

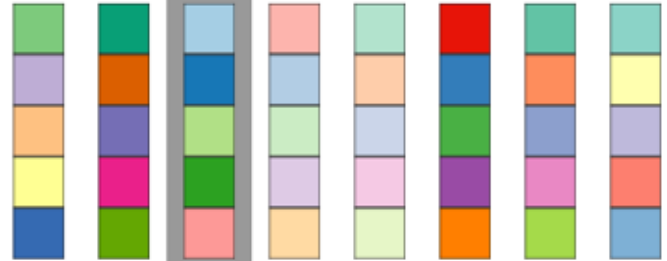
TOOLS FOR PICKING COLOORMAPS

Color Brewer

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

Nature of your data: sequential diverging qualitative

Pick a color scheme:



Only show: colorblind safe print friendly photocopy safe

Context: roads cities borders

Background: solid color terrain

color transparency

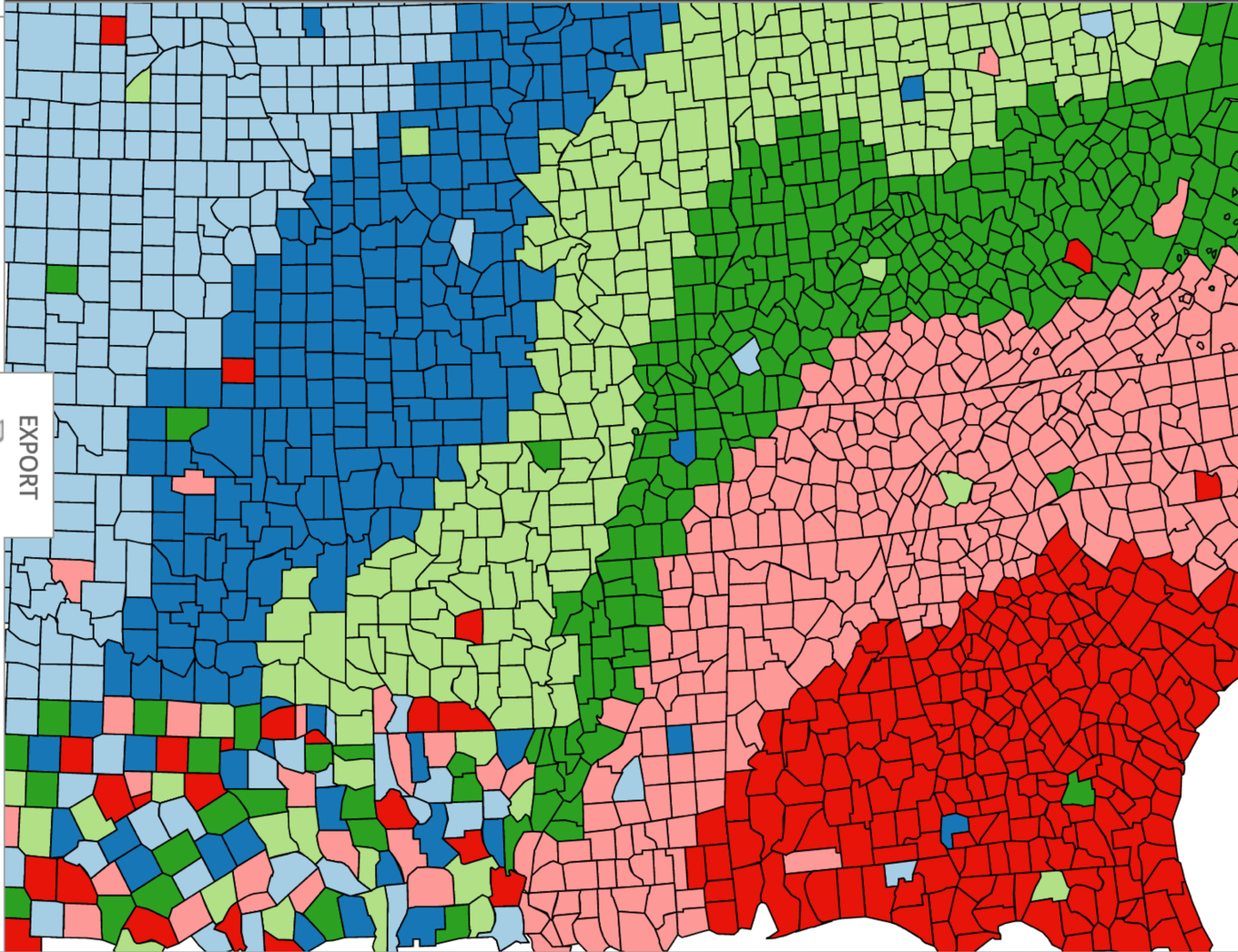
6-class Paired

EXPORT

HEX

- #a6cee3
- #1f78b4
- #b2df8a
- #33a02c
- #fb9a99
- #e31a1c

COLORBREWER 2.0
color advice for cartography



<http://colorbrewer2.org>

Colorgorical

Colorgorical Source

Generate

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

Number of colors: 5

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

Select hue filters

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

rgb(57,146,131) + start

rgb(148,210,207) + start

rgb(25,79,70) + start

rgb(57,238,192) + start

Instructions

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

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

Score Importance

Perceptual Distance

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

Name Difference

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

About

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

Documentation

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

If you use Colorgorical, please use the following citation:

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

Other Useful Tools

- Get a list of colors from an image:
<https://html-color.codes/color-from-image>
- Analyze your palette: <https://projects.susielu.com/viz-palette>
- Analyze the name similarity of colors in your palette:
<http://vis.stanford.edu/color-names/analyzer/>
- Details on multi-hued color scales:
<https://www.vis4.net/blog/2013/09/mastering-multi-hued-color-scales/#combining-bezier-interpolation-and-lightness-correction>
- Easy picking a multi-hued color scale: <http://tristen.ca/hcl-picker/>
- Easily correcting darkness (lightness) for a scale: <http://gka.github.io/palettes/>
- Do a ton programmatically: <https://gka.github.io/chroma.js/>
- viridis colors:
<https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html>

Color Advice Summary

Use a limited hue palette

- Control color “pop out” with low-saturation colors
- Avoid clutter from too many competing colors

Use neutral backgrounds

- Control **impact** of color
- Minimize simultaneous contrast

Use Color Brewer etc. for picking scales

Don't forget aesthetics!

For Next Time

neu-ds-4200-s22.github.io/schedule

Look at the upcoming assignments and deadlines

- Textbook, Readings, & Reading Quizzes—Variable days
- In-Class Activities—If due, they are due 11:59pm the same day as class

Everyday Required Supplies:

- 5+ colors of pen/pencil
- White paper
- Laptop and charger

Use Canvas Discussions for general questions, email codydunne-and-tas@ccs.neu.edu for questions specific to you.



Week	Topics	Assignments
#1: Jan 17–21	What is visualization Design rules of thumb	A1—Setting up
#2: Jan 24–28	JS development, projects Marks & channels	A2—Encodings & xenographics
#3: Jan 31–Feb 04	Data types and tasks, Tableau D3 tutorial 1/2	P1—Pitches★
#4: Feb 07–11	In-class group formation D3 tutorial 2/2	A3—Tableau analysis P2—Proposal★
#5: Feb 14–18	Altair and JupyterLab Arrange tables	A4—D3 basic charts
#6: Feb 21–25	Color Pop-out, illusions	A5—Altair basic charts P3—Interview & tasks
#7: Feb 28–Mar 04	Interaction & animation (2)	A6—D3 event handling P4—Data, Initial sketches
#8: Mar 07–11	Trees & networks (2)	P5—Final sketches & plan★
<i>Mar 14–18</i>	<i>Spring Break</i>	
#9: Mar 21–25	Project feedback & work Spatial, 3D, and scientific vis.	A7—D3 Brushing & linking 1 P6—Implementation 1
#10: Mar 28–Apr 01	Validation & evaluation Flex day	A8—Brushing & linking 2 P7—Implementation 2
#11: Apr 04–08	Project usability testing, how to give a talk Storytelling	
#12: Apr 11–15	Project presentations 1/2 Project presentations 2/2	P8—Presentations★☒
#13: Apr 18–22	Flex day	P9—Presentation peer review
#14: Apr 25–29	Reflecting & project work	
<i>May 02–06</i>		P10—Video & Final Deliverables★☒