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COLOR, ILLUSIONS

CHECKING IN

GOALS FOR TODAY: LEARN HOW...

- ...task analysis can lead to multiple designs
- ...to find visual idioms and ideas for inspiration.
- ...to effectively use color as a channel for visual encodings including different colormap types.
- ...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.

TASK ABSTRACTION → VISUAL
ENCODING

Analysis



What?

What data is shown?

DATA ABSTRACTION

Why?

Why is the user analyzing / viewing it?

TASK ABSTRACTION

How?

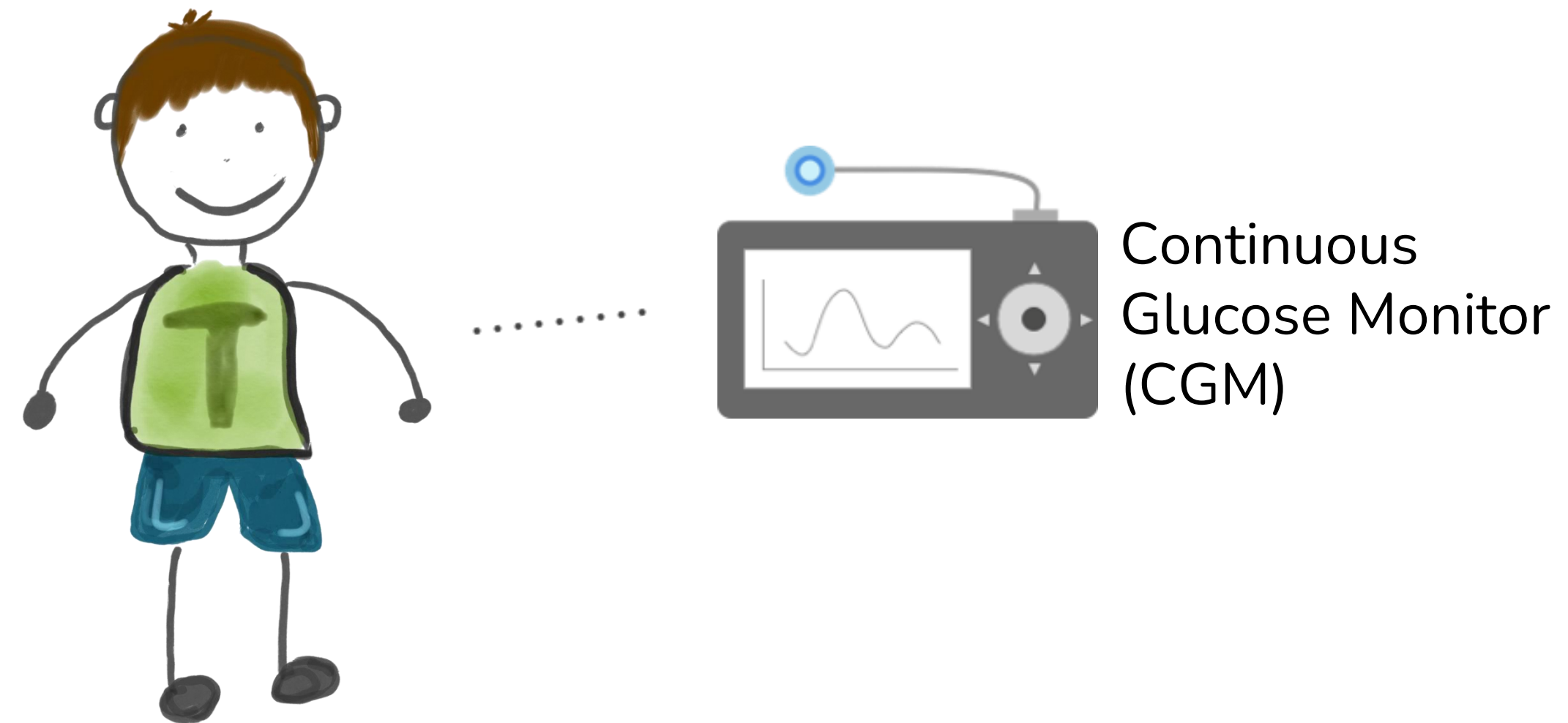
How is the data presented?

VISUAL ENCODING

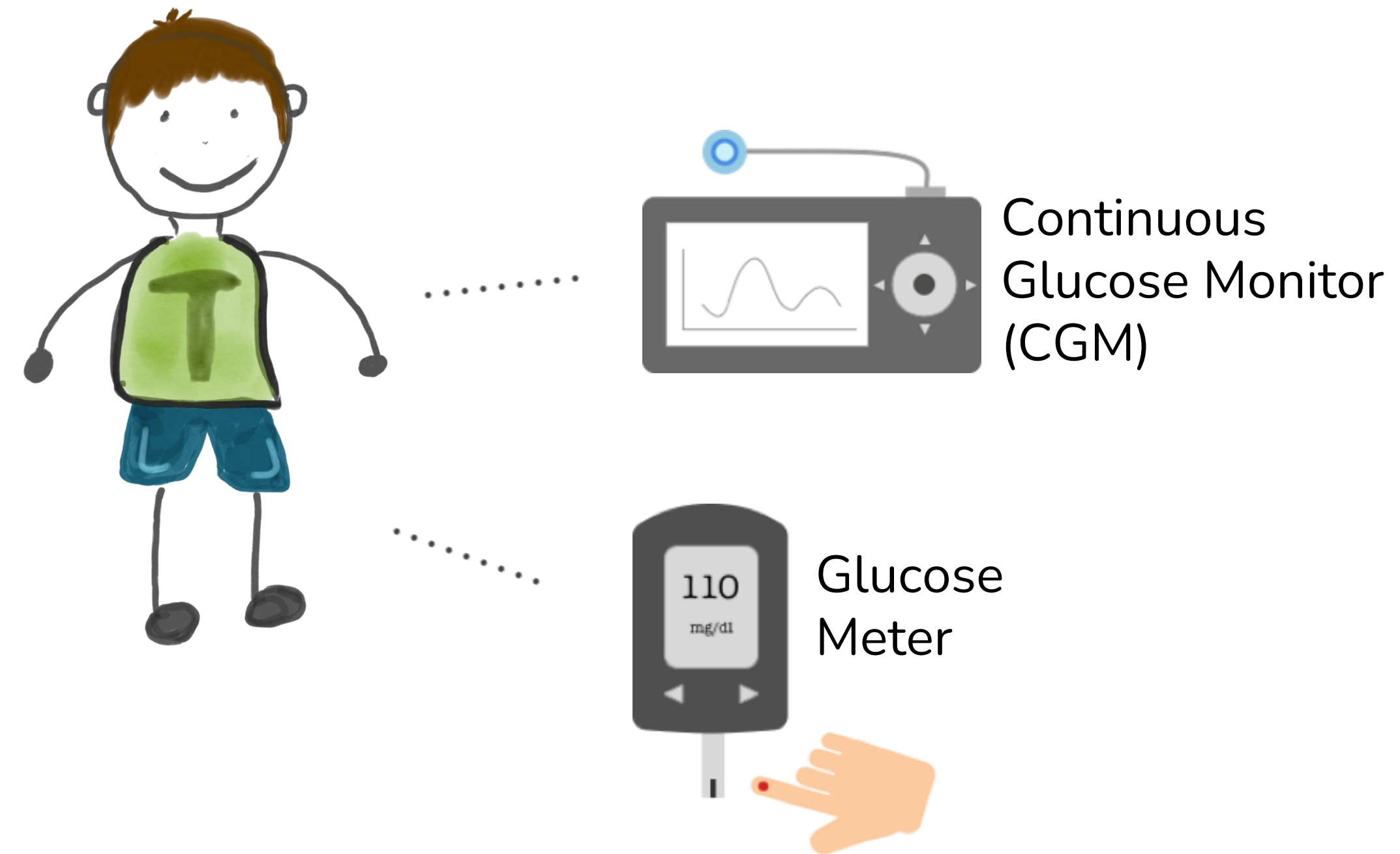
Imagine a 10-year-old kid, who has been diagnosed with type 1 diabetes...



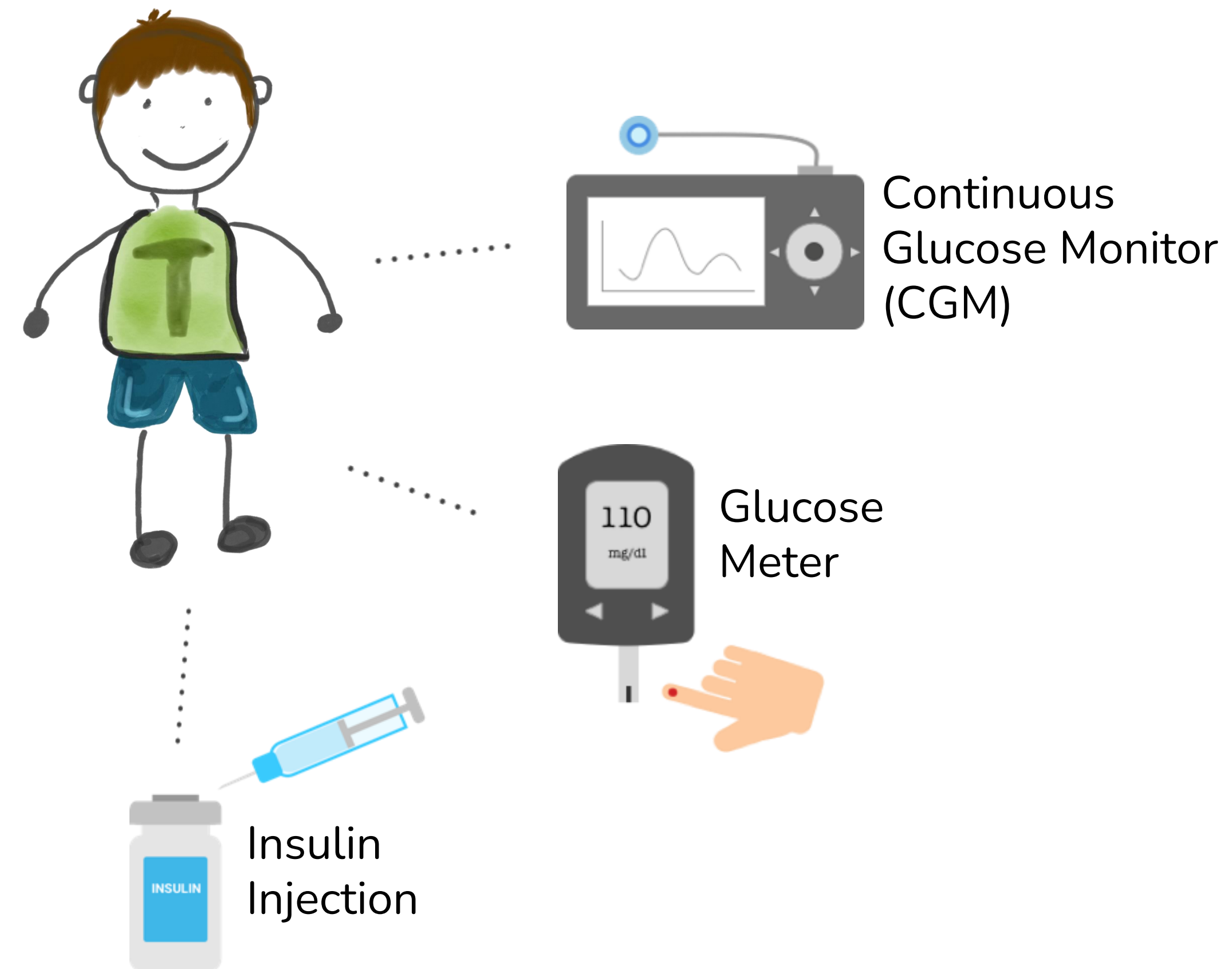
Imagine a 10-year-old kid, who has been diagnosed with type 1 diabetes...



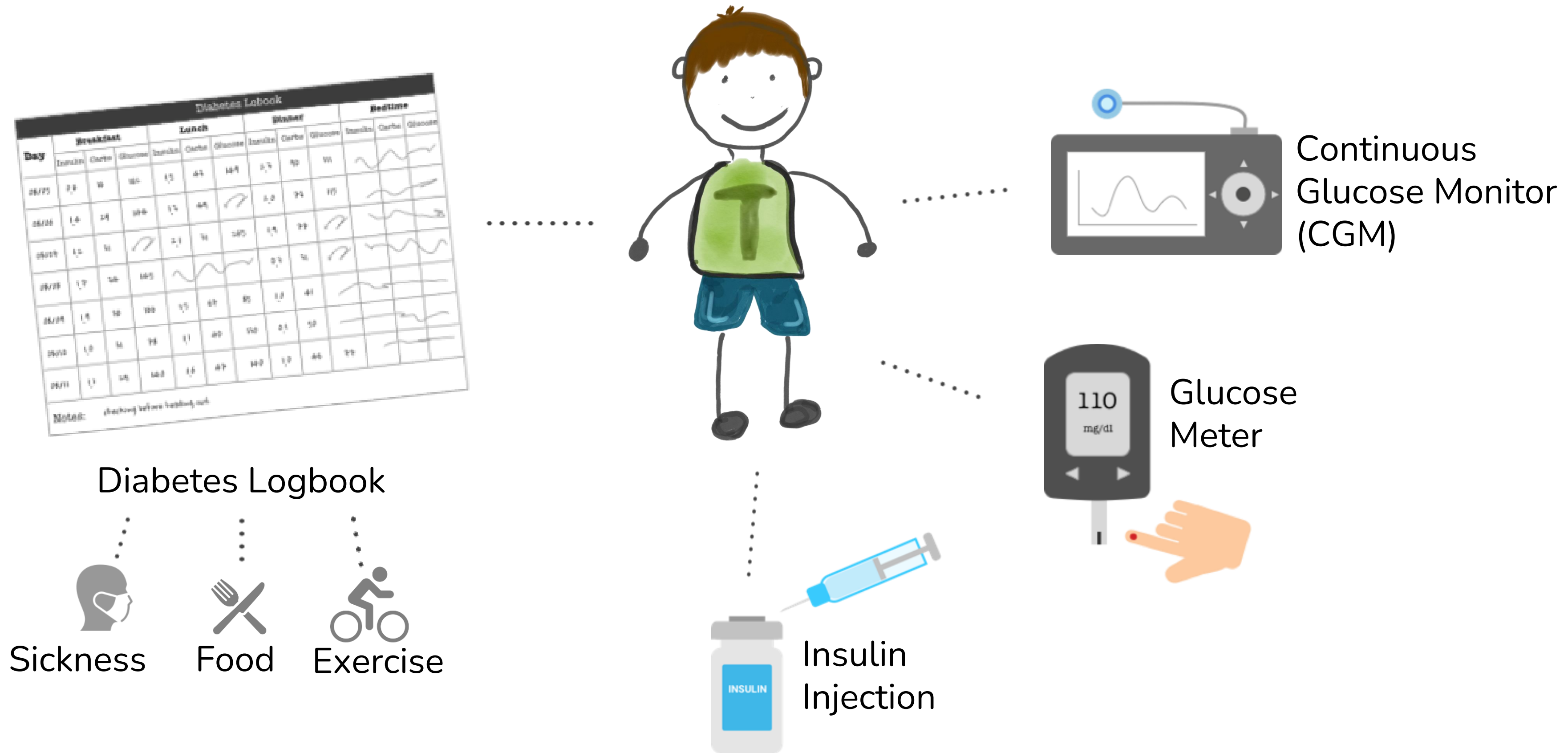
Imagine a 10-year-old kid, who has been diagnosed with type 1 diabetes...



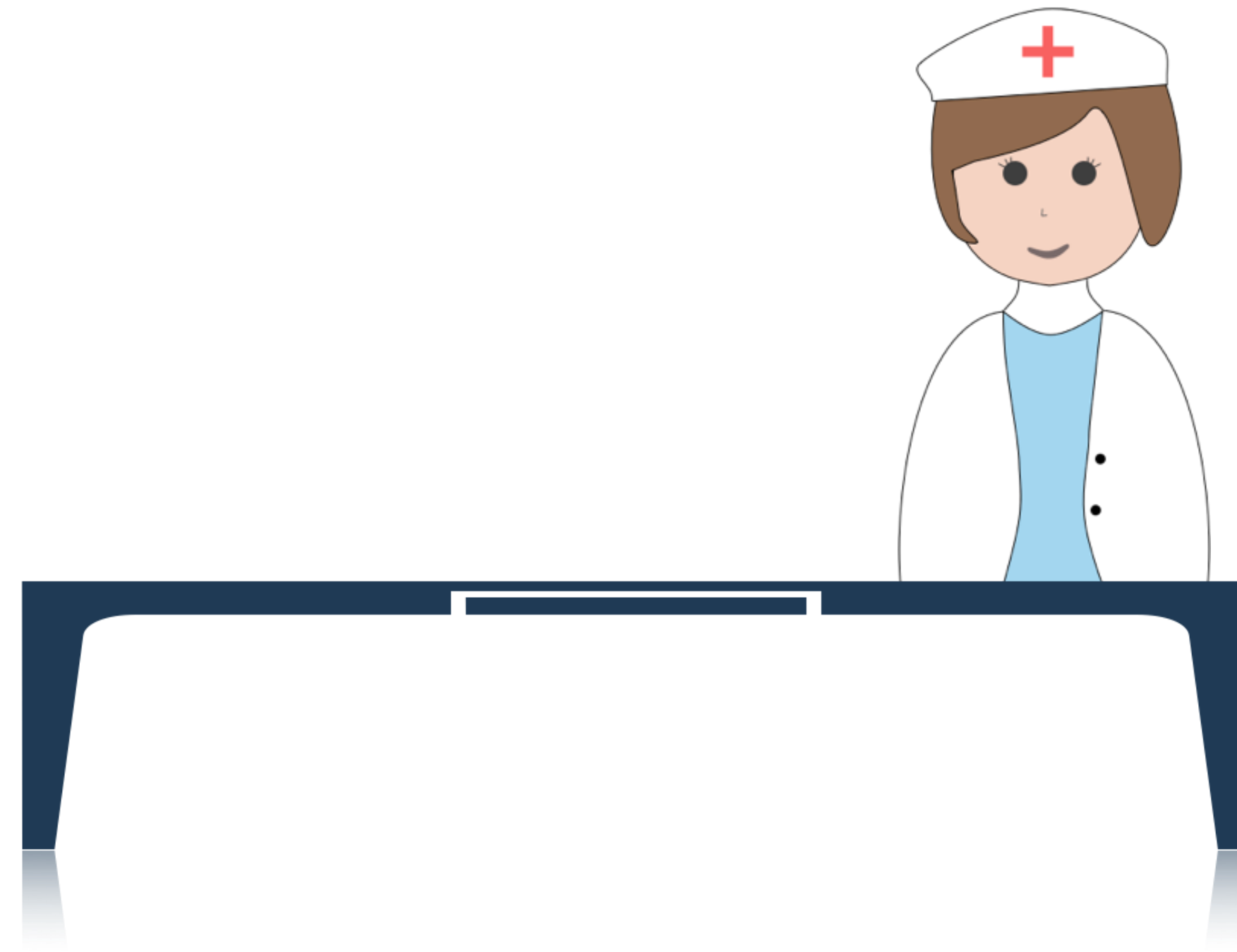
Imagine a 10-year-old kid, who has been diagnosed with type 1 diabetes...



Imagine a 10-year-old kid, who has been diagnosed with type 1 diabetes...



During a clinical visit ...

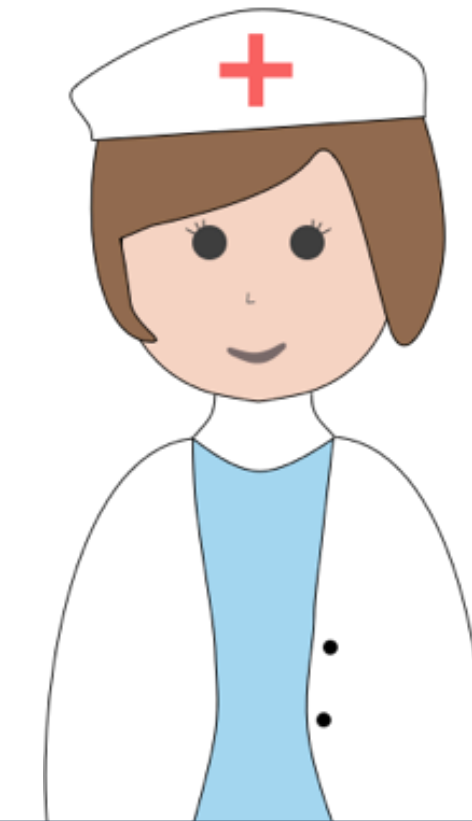


During a clinical visit ...



Day	Diabetes Logbook											
	Breakfast			Lunch			Dinner			Bedtime		
	Insulin	Carbs	Glucose	Insulin	Carbs	Glucose	Insulin	Carbs	Glucose	Insulin	Carbs	Glucose
08/25	2.0	50	165	1.5	45	145	1.5	50	150			
08/26	1.4	45	160	1.2	40	140	1.0	35	135			
08/27	1.5	50	165	1.3	45	145	1.5	50	150			
08/28	1.7	55	165	1.4	50	145	1.5	50	150			
08/29	1.8	60	165	1.5	55	145	1.5	50	150			
08/30	1.8	60	165	1.5	55	145	1.5	50	150			
08/31	1.8	60	165	1.5	55	145	1.5	50	150			

Note: checking before testing out.



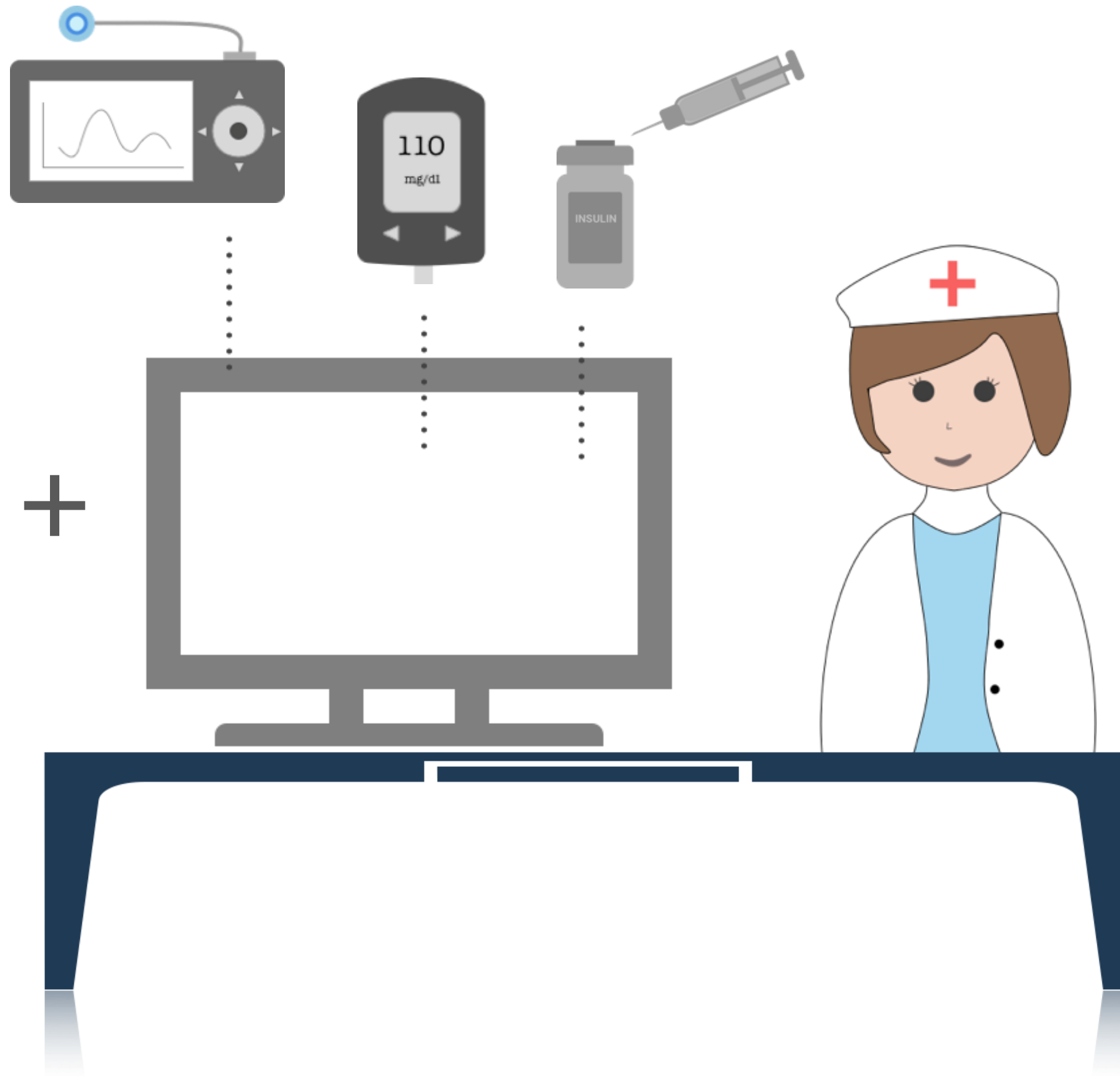
During a clinical visit ...



Diabetes Logbook

Day	Breakfast			Lunch			Dinner			Bedtime		
	Insulin	Carbs	Glucose	Insulin	Carbs	Glucose	Insulin	Carbs	Glucose	Insulin	Carbs	Glucose
08/25	2.0	30	100	1.5	45	105	1.5	30	100			
08/26	1.4	25	100	1.5	45	105	1.5	30	100			
08/27	1.5	30	100	2.1	50	105	1.5	30	100			
08/28	1.7	35	100			105	1.5	30	100			
08/29	1.8	30	100	1.5	45	105	1.5	30	100			
08/30	1.8	30	100	1.1	40	100	1.1	30	100			
08/31	1.1	25	100	1.8	45	100	1.5	30	100			

Note: checking before heading out.



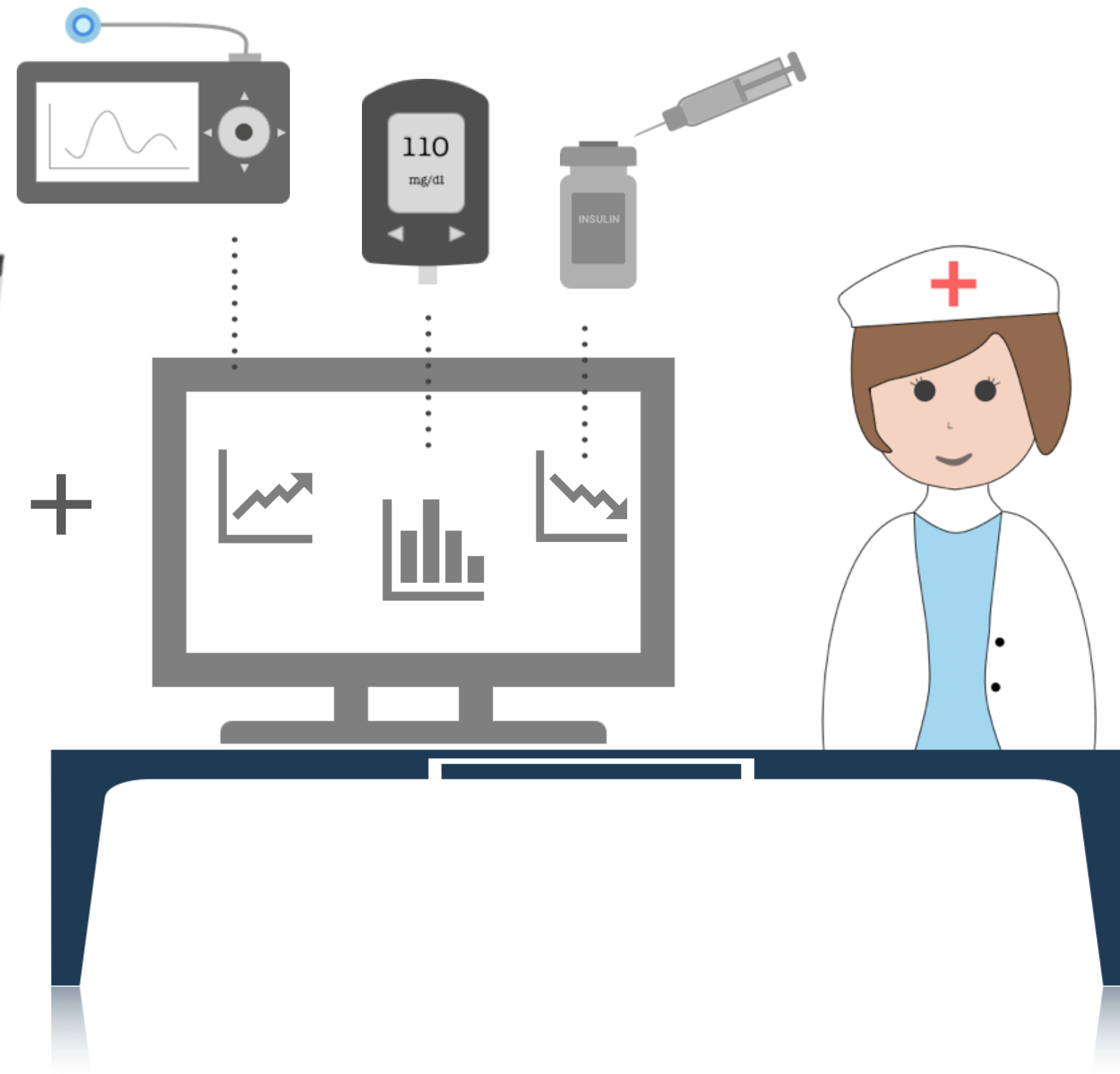
During a clinical visit ...



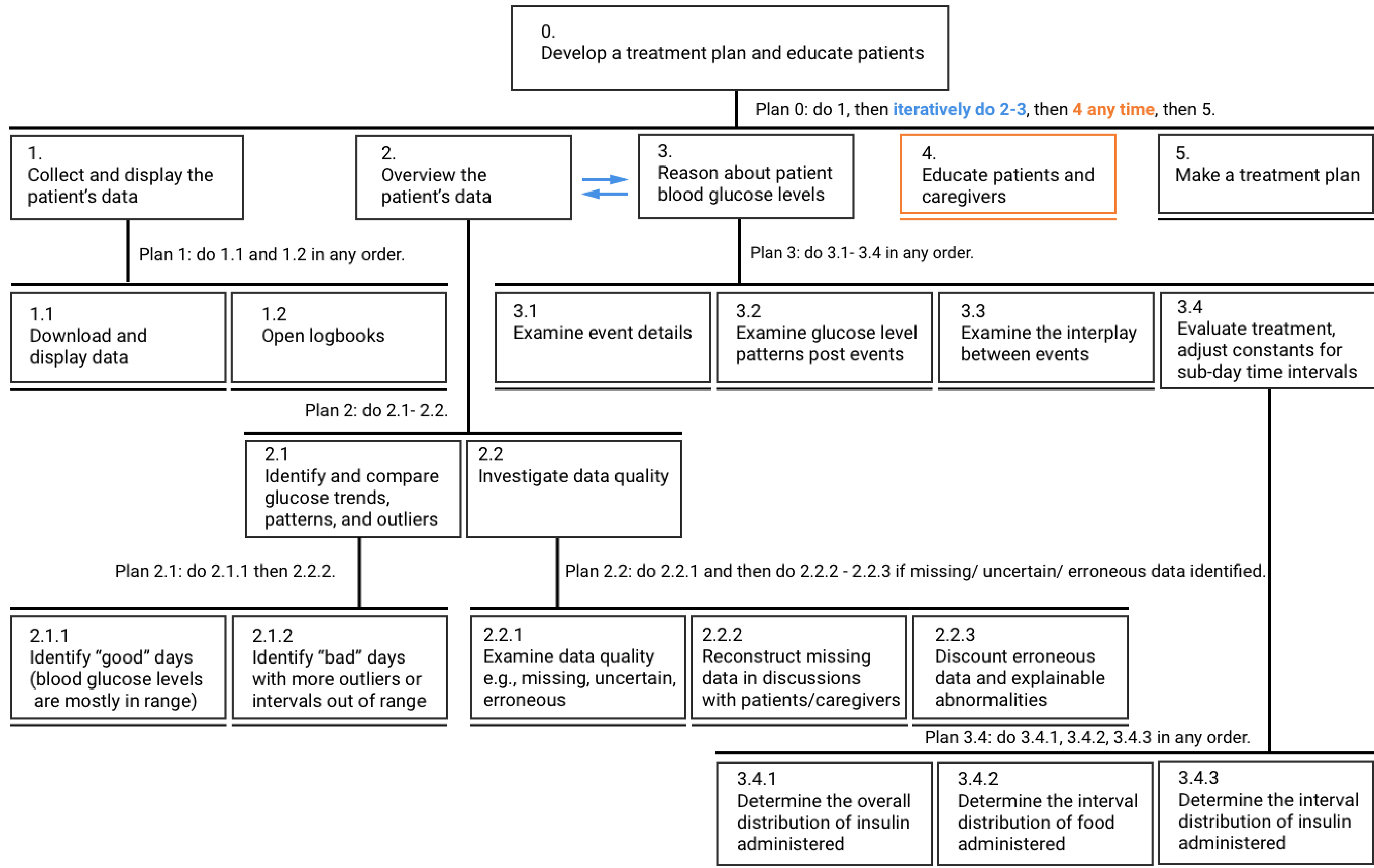
Diabetes Logbook

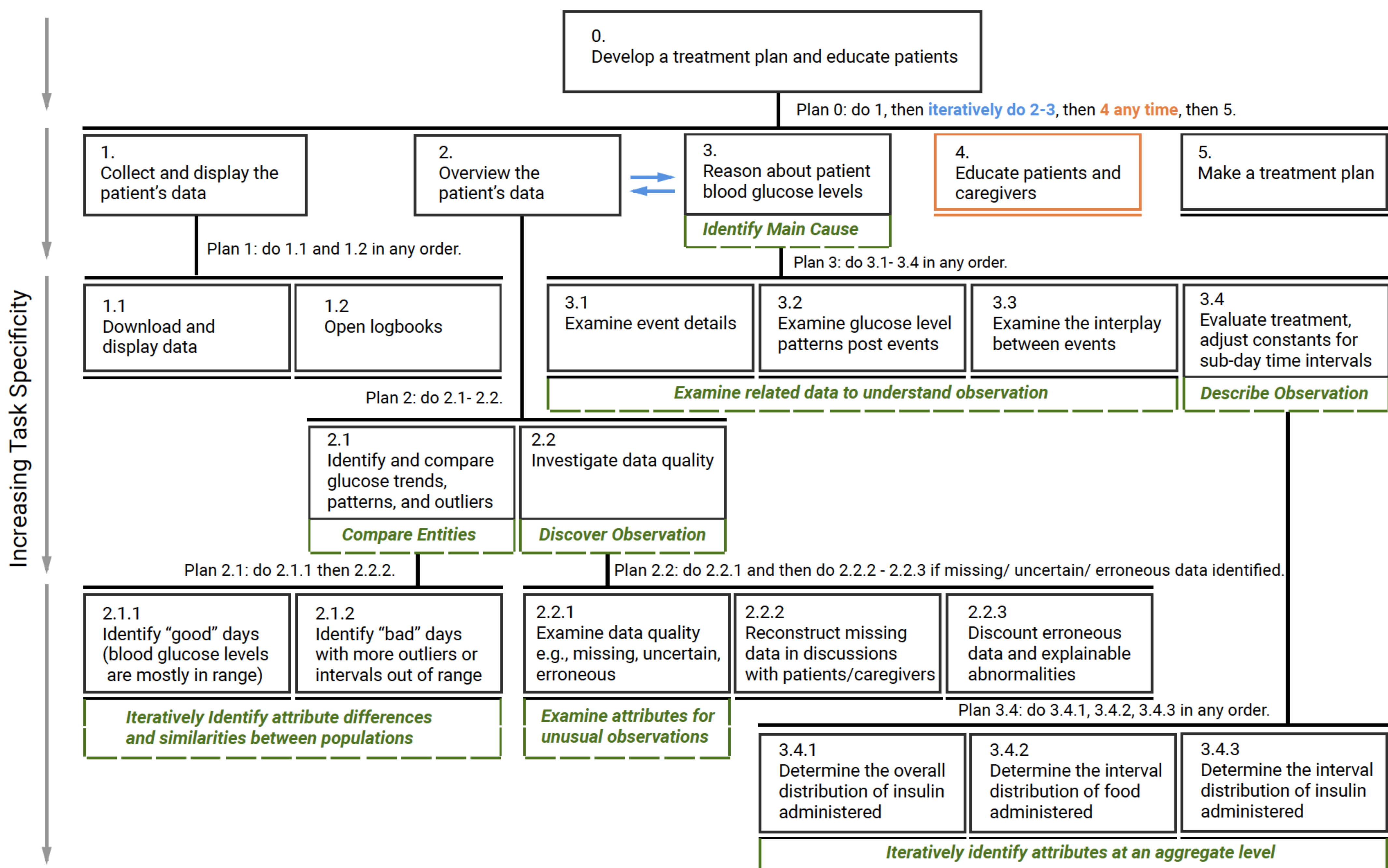
Day	Breakfast			Lunch			Dinner			Bedtime		
	Insulin	Carbs	Glucose	Insulin	Carbs	Glucose	Insulin	Carbs	Glucose	Insulin	Carbs	Glucose
08/25	2.0	30	100	1.5	45	105	1.5	30	100			
08/26	1.4	25	100	1.5	45	105	1.5	30	100			
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08/28	1.7	35	100	1.5	45	105	1.5	30	100			
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08/30	1.5	30	100	1.5	45	105	1.5	30	100			
08/31	1.5	30	100	1.5	45	105	1.5	30	100			

Note: checking before heading out.



Increasing Task Specificity





Design Requirements

- DR1. Composite Visualization of **Integrated Data**
- DR2. Visualization of **Folded Temporal Data**
- DR3. **Align and Scale** Temporal Data
- DR4. **Summary** Statistics

14-Day Overview



Detail View

Summary Statistics Panel

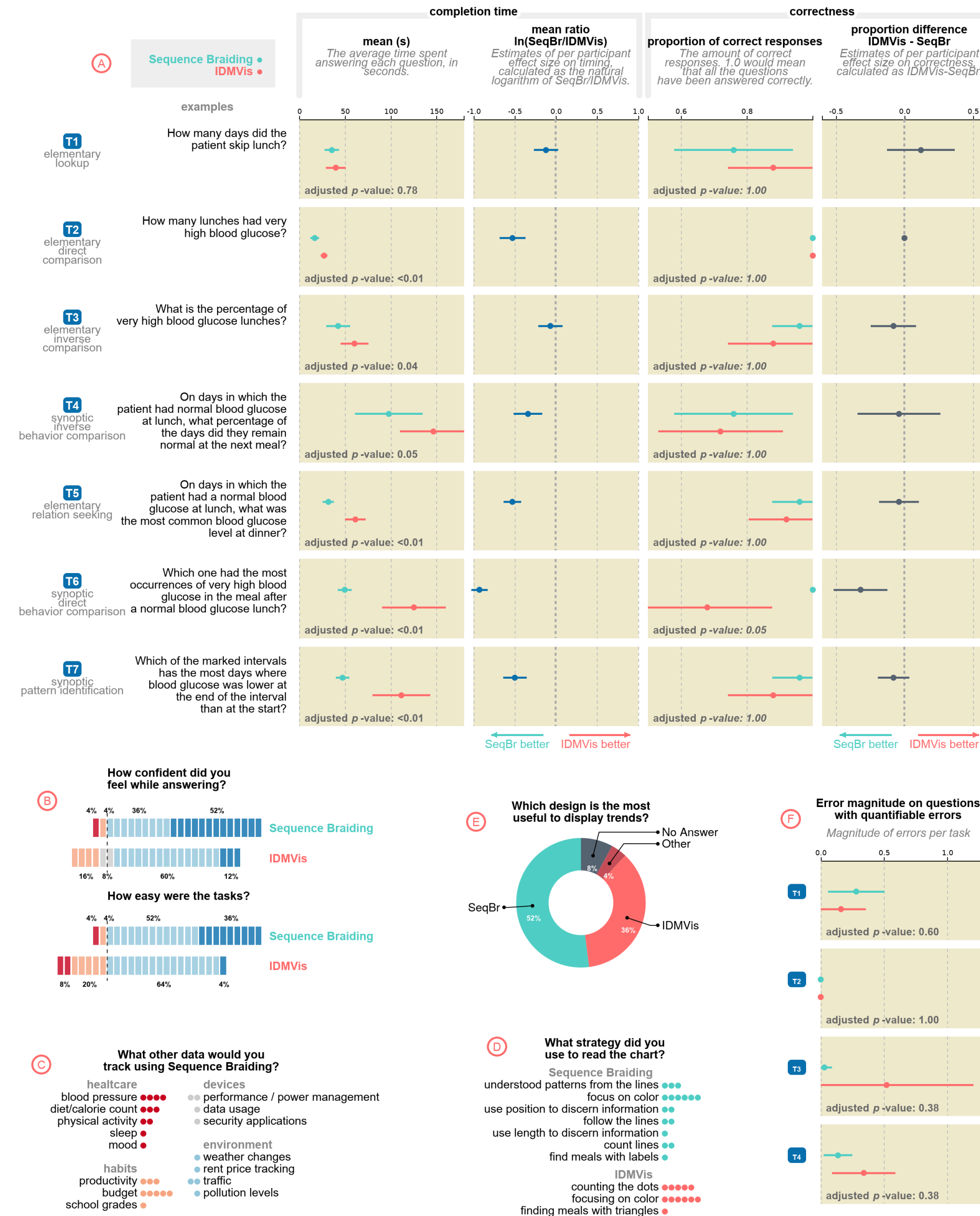


Fig. 9: Results of our evaluation comparing SEQUENCE BRAIDING vs. IDMVis [63]. **A** Completion time and correctness per task. Each row corresponds to the task at left, which is classified based on Andrienko & Andrienko [3]. The specific question instantiating that task for the study is in the second column. **B** Participants' Likert scale responses regarding confidence and ease of use. **C** Participants' answers when asked what other types of data would they use with SEQUENCE BRAIDING. **D** Participants' reported strategies used. **E** Participants' preference for which method was most useful for displaying trends. **F** Error magnitude per task, for those which are quantifiable.

A

Sequence Braiding •
IDMVis •

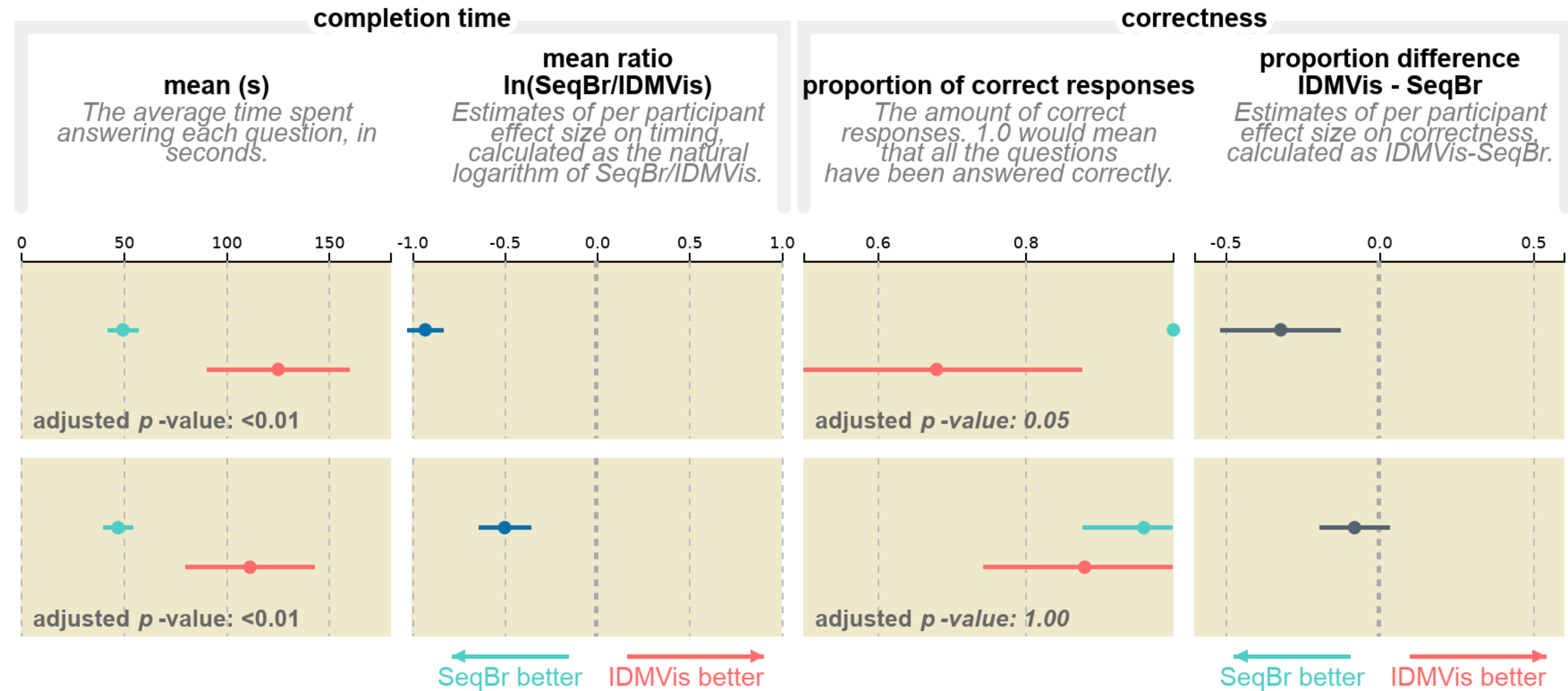
examples

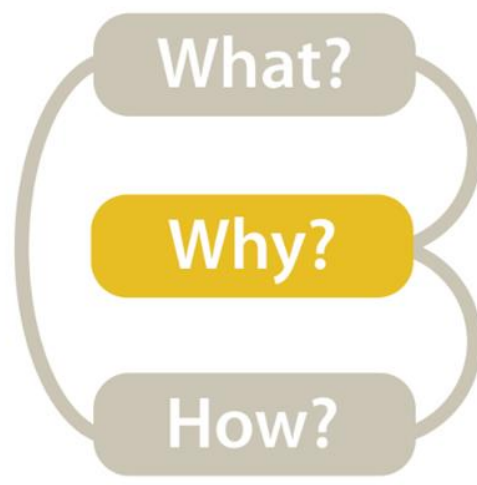
T6
synoptic
direct
behavior comparison

Which one had the most occurrences of very high blood glucose in the meal after a normal blood glucose lunch?

T7
synoptic
pattern identification

Which of the marked intervals has the most days where blood glucose was lower at the end of the interval than at the start?





Interview Advice

- Have a designated note-taker and designated leader
- Be prepared. (Have some questions prepared in advance.)
- Start slow, safe, and personal.
- Coax, don't hammer.
- Make some questions open ended.
- Ask what you don't know.
- Let the interviewees wander a bit—but be careful.
- Listen, really listen.
- For software, look for “work arounds” and hacks.
- Make sure to write down your thoughts and impressions immediately after the interview.
- You are the visualization expert – don't ask them what vis they want, don't think too early about what vis to build.

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/>

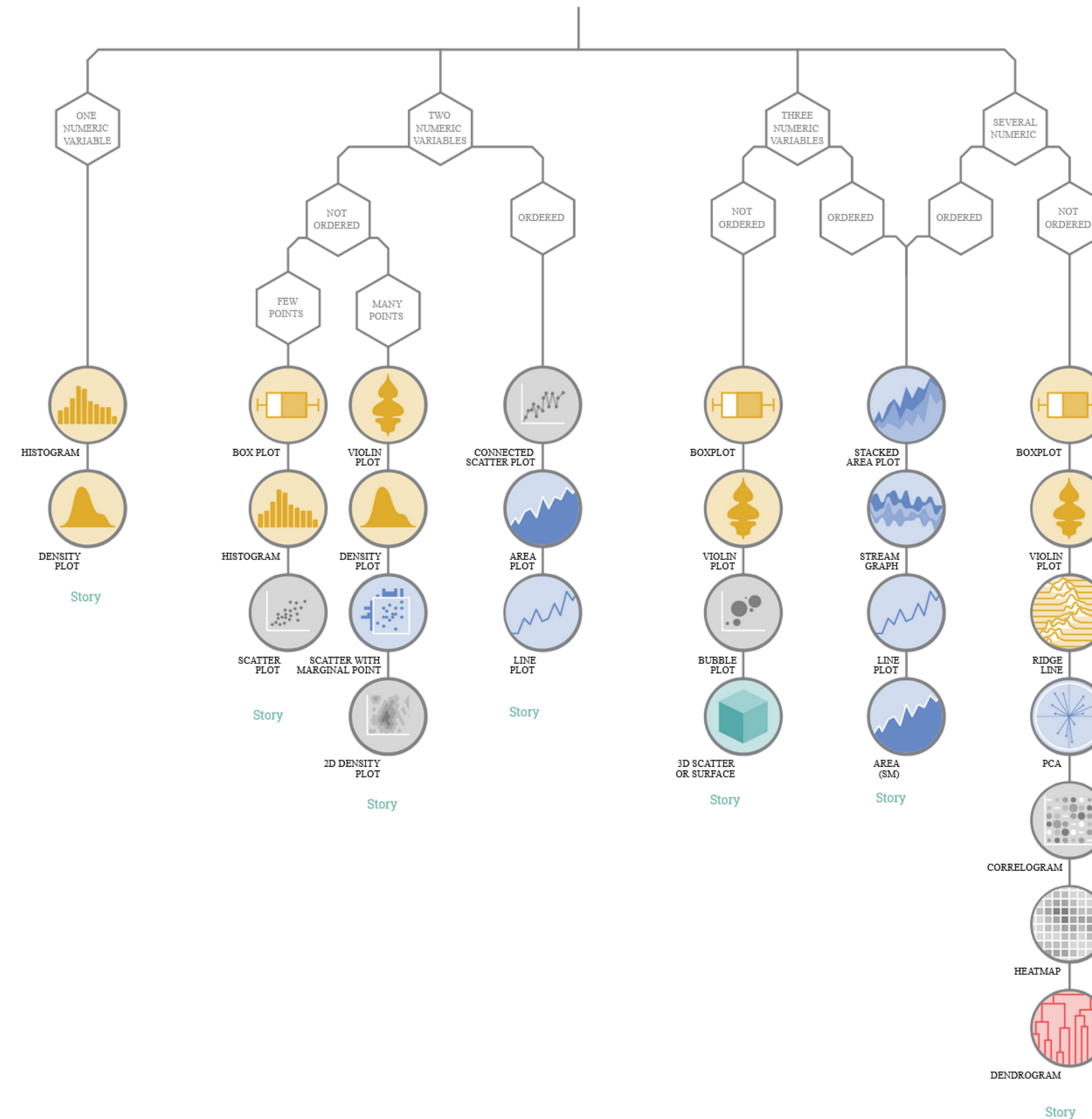
Borkin, M., Vo, A., Bylinskii, Z., Isola, P., Sunkavalli, S., Oliva, A., & Pfister, H., 2013, "[What Makes a Visualization Memorable?](#)", IEEE Transactions on Visualization and Computer Graphics (Proceedings of InfoVis 2013), 19, 12, 2306-2315.

More visualization “catalogs”

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.

Data to Viz

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



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 a grid of various chart examples. The examples include: 'barh_demo' (horizontal bar chart), 'fill_demo' (filled area chart), 'fill_demo_features' (filled area chart with multiple series), 'line_demo_dash_control' (line chart with dashed lines), 'line_styles_reference' (reference for line styles), 'linestyles' (reference for line styles), 'marker_fillstyle_reference' (reference for marker fill styles), 'marker_reference' (reference for marker styles), and 'filled markers' (reference for filled markers).

COLOR

Visual Perception and Cognition

Pre-Attentive Processing

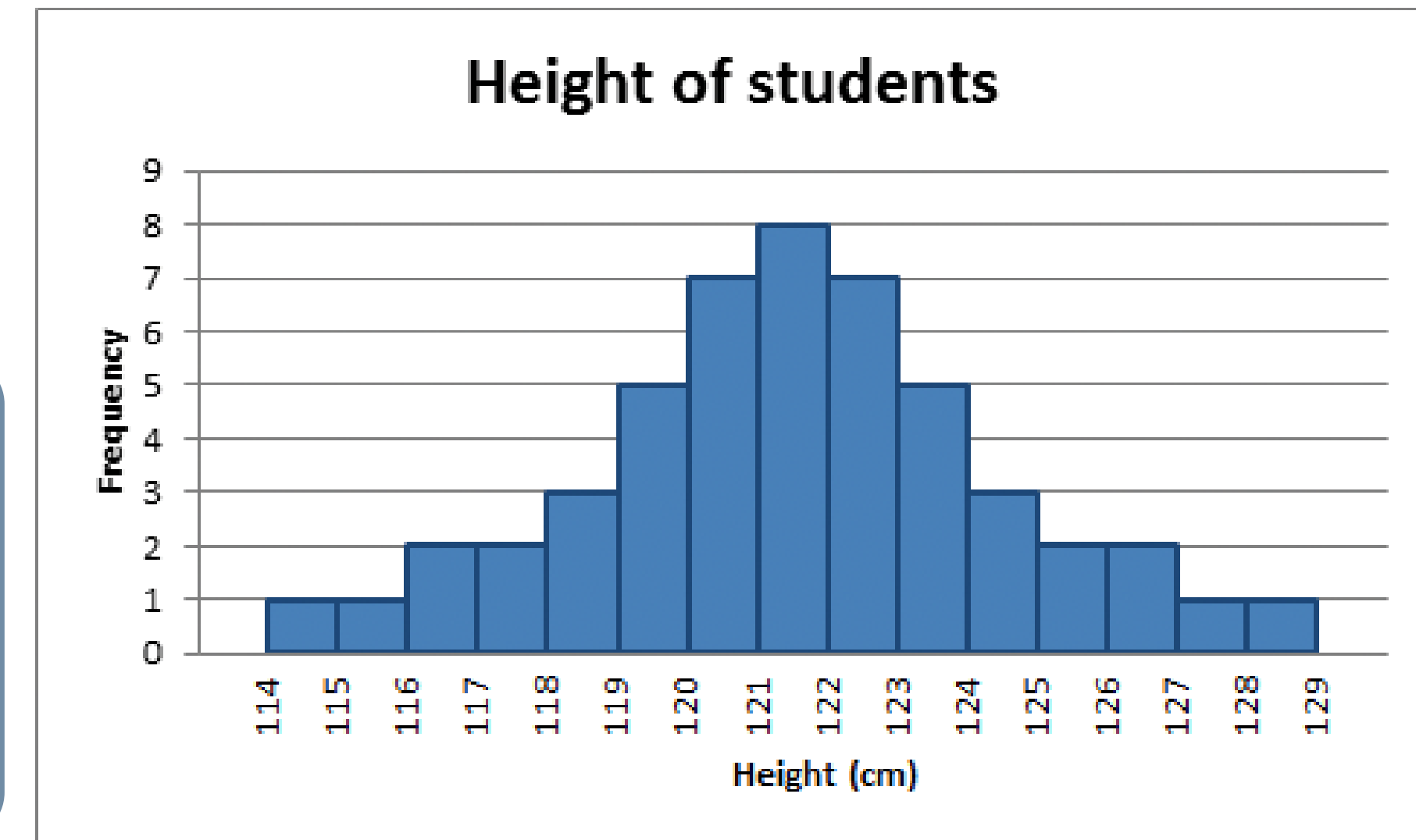
- Automatic
- Lasts < 1 second

Working Memory / Short-Term Memory

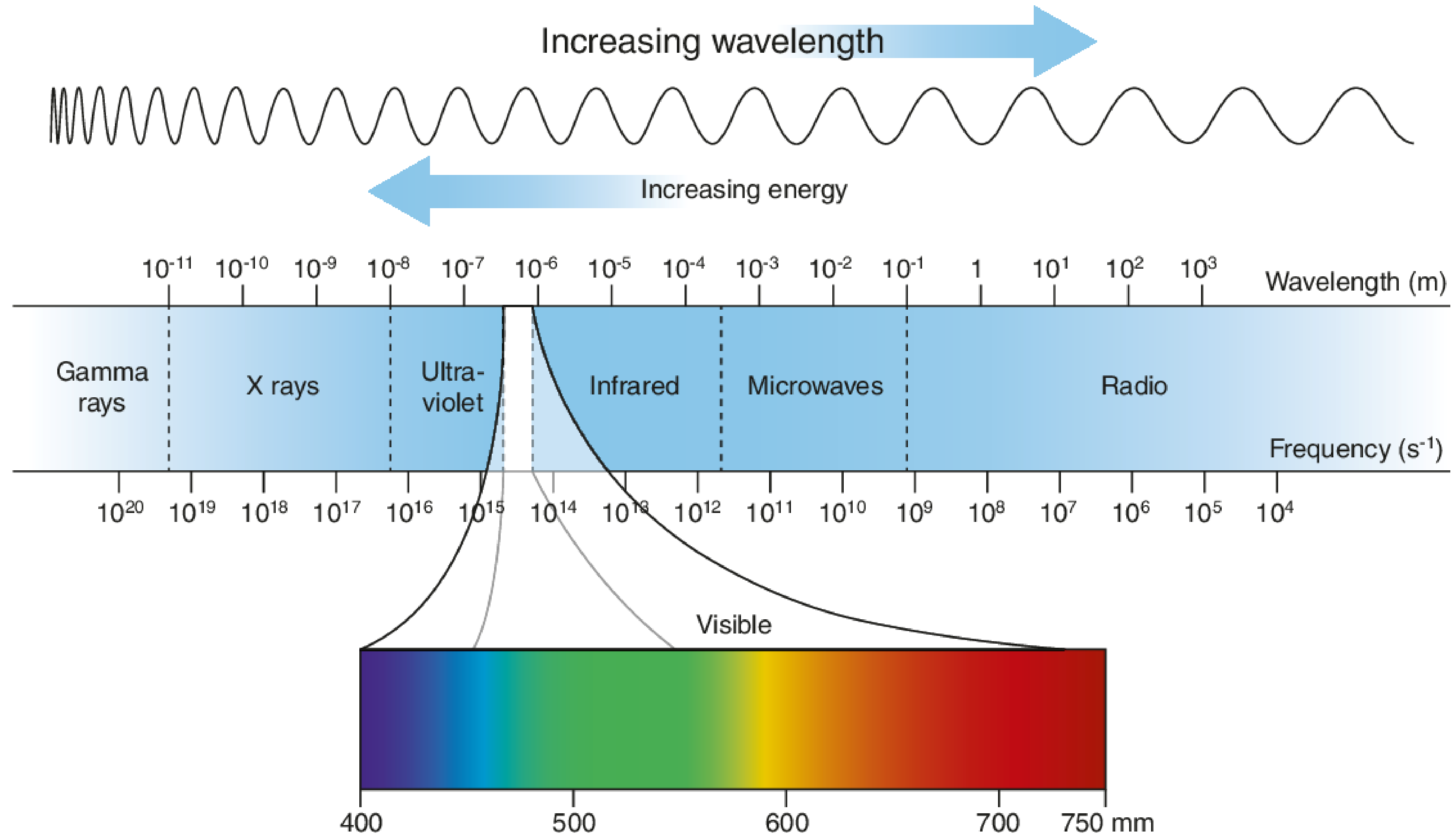
- Conscious
- Limited (information retained for seconds)

Long-Term Memory

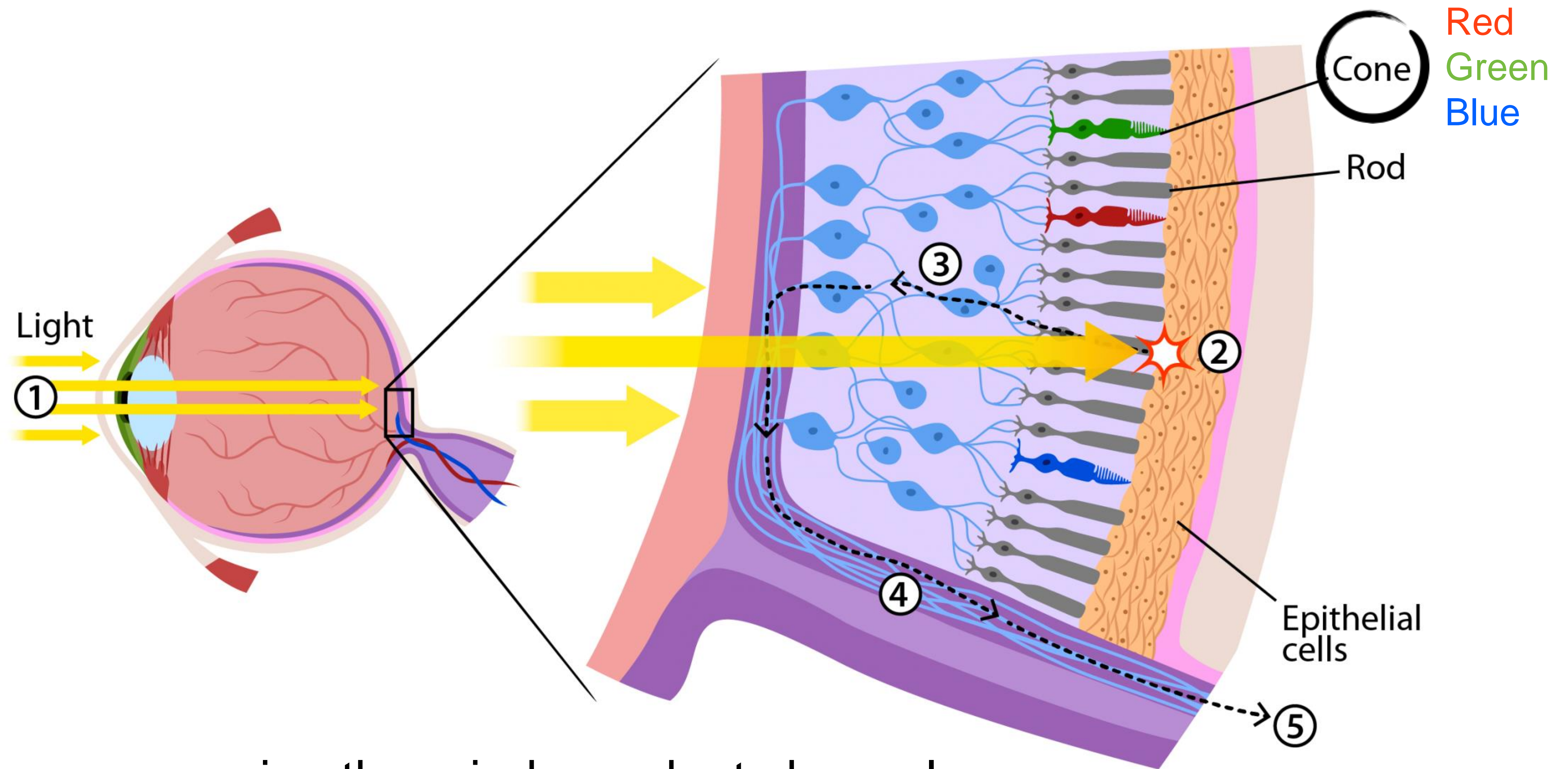
- Storage of repeated working memory tasks
- Can be consciously retrieved



Color = Wavelength

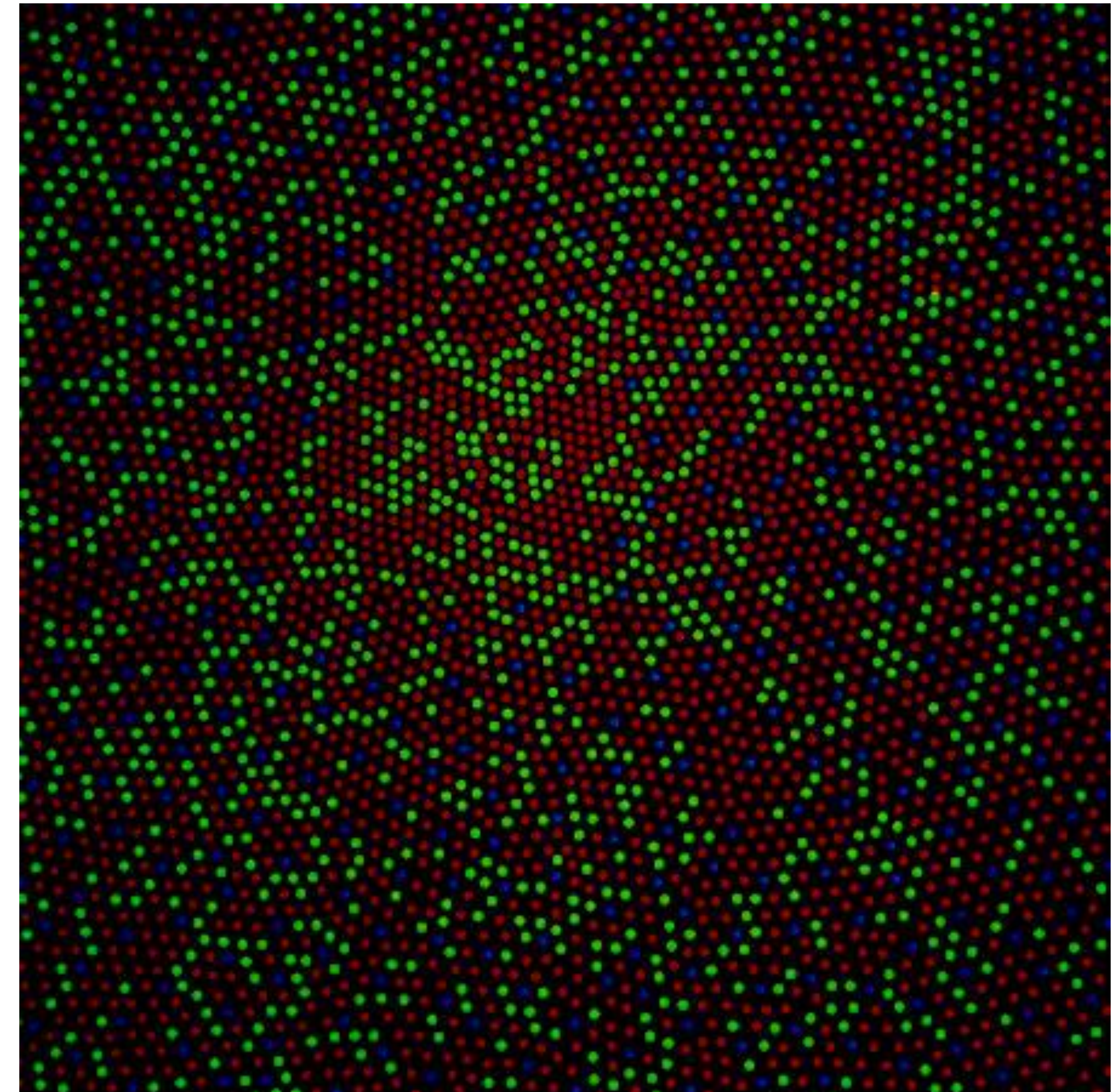
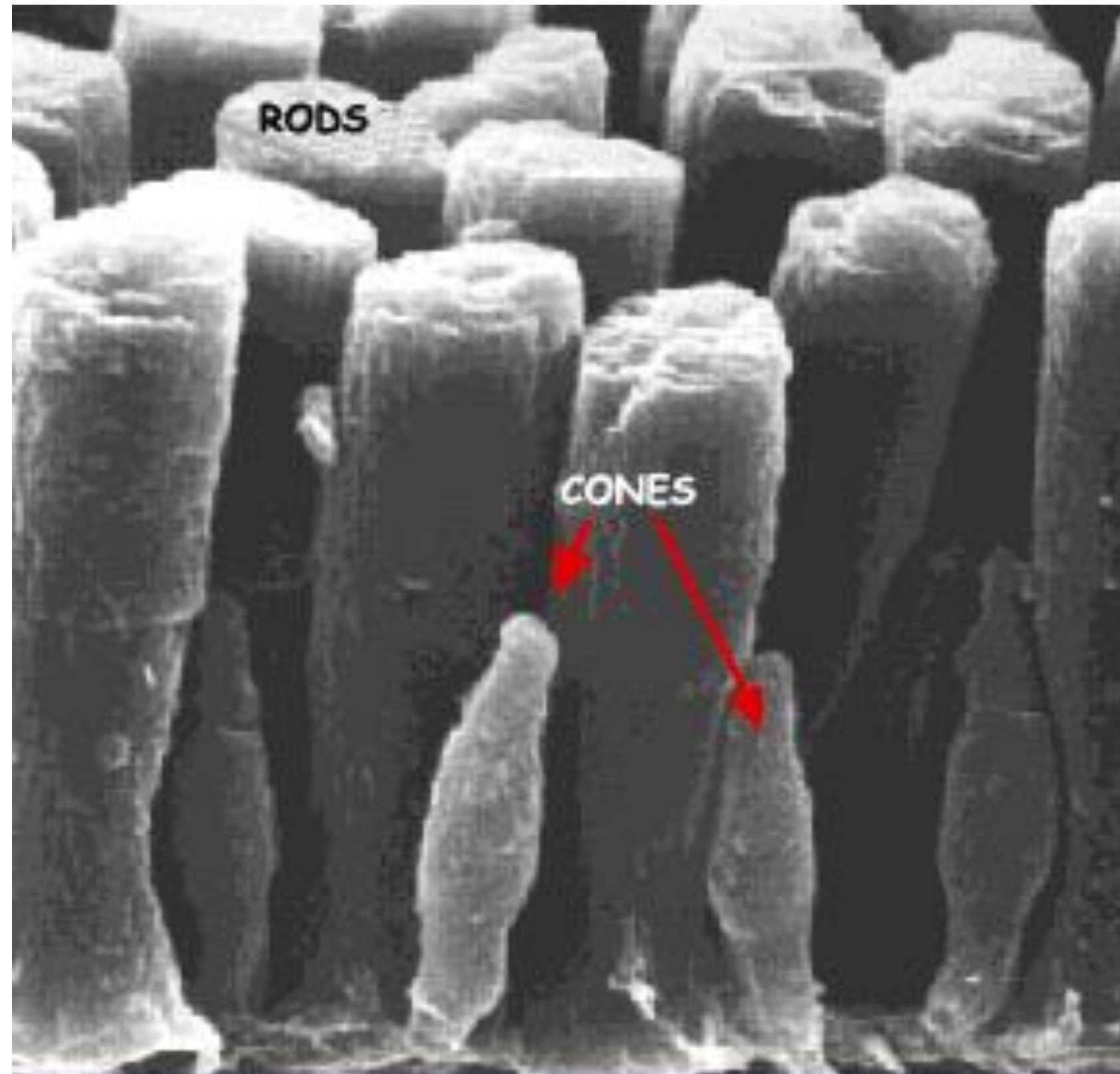


WAVELENGTH → SIGNALS

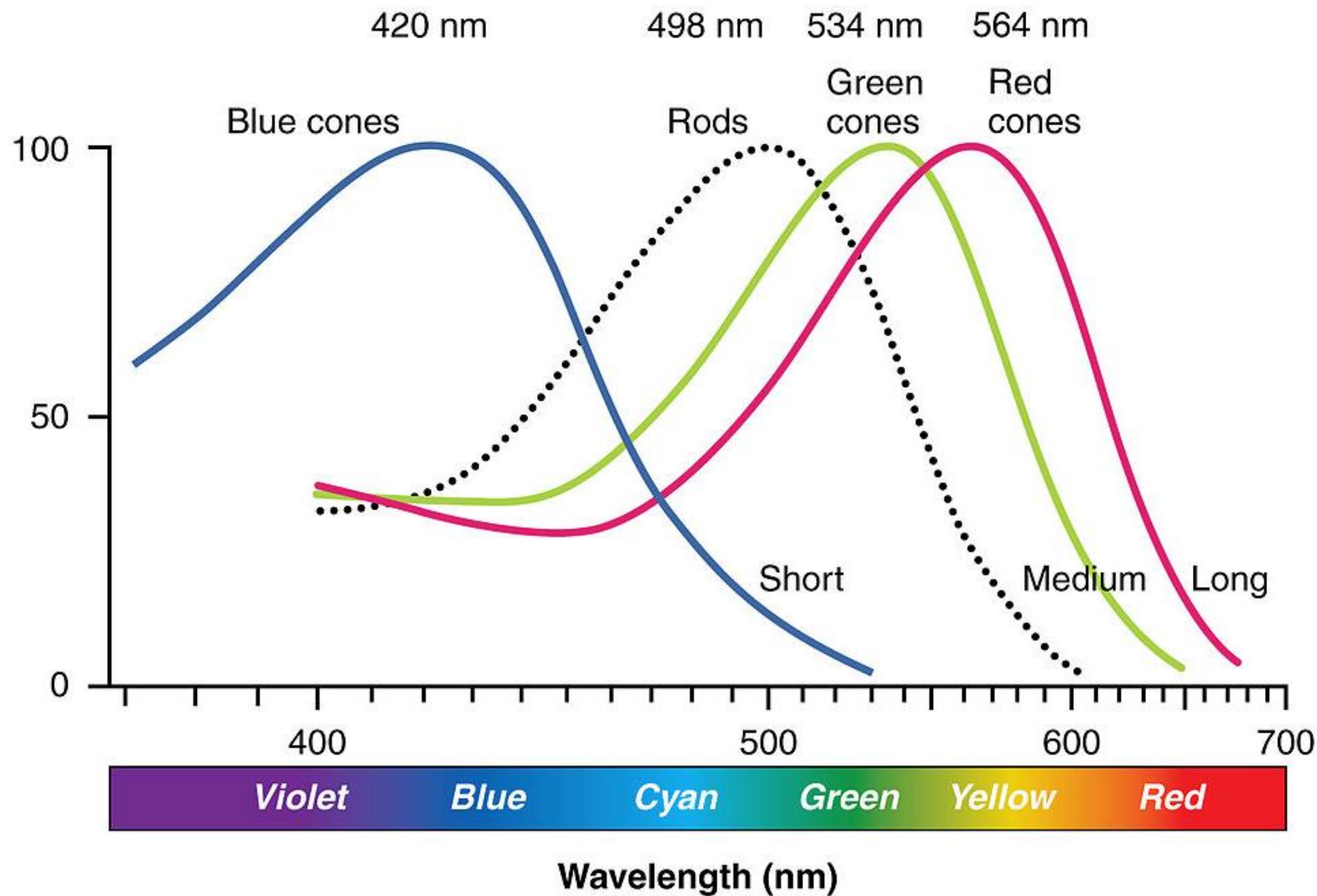


trichromacy = possessing three independent channels for conveying color information

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!

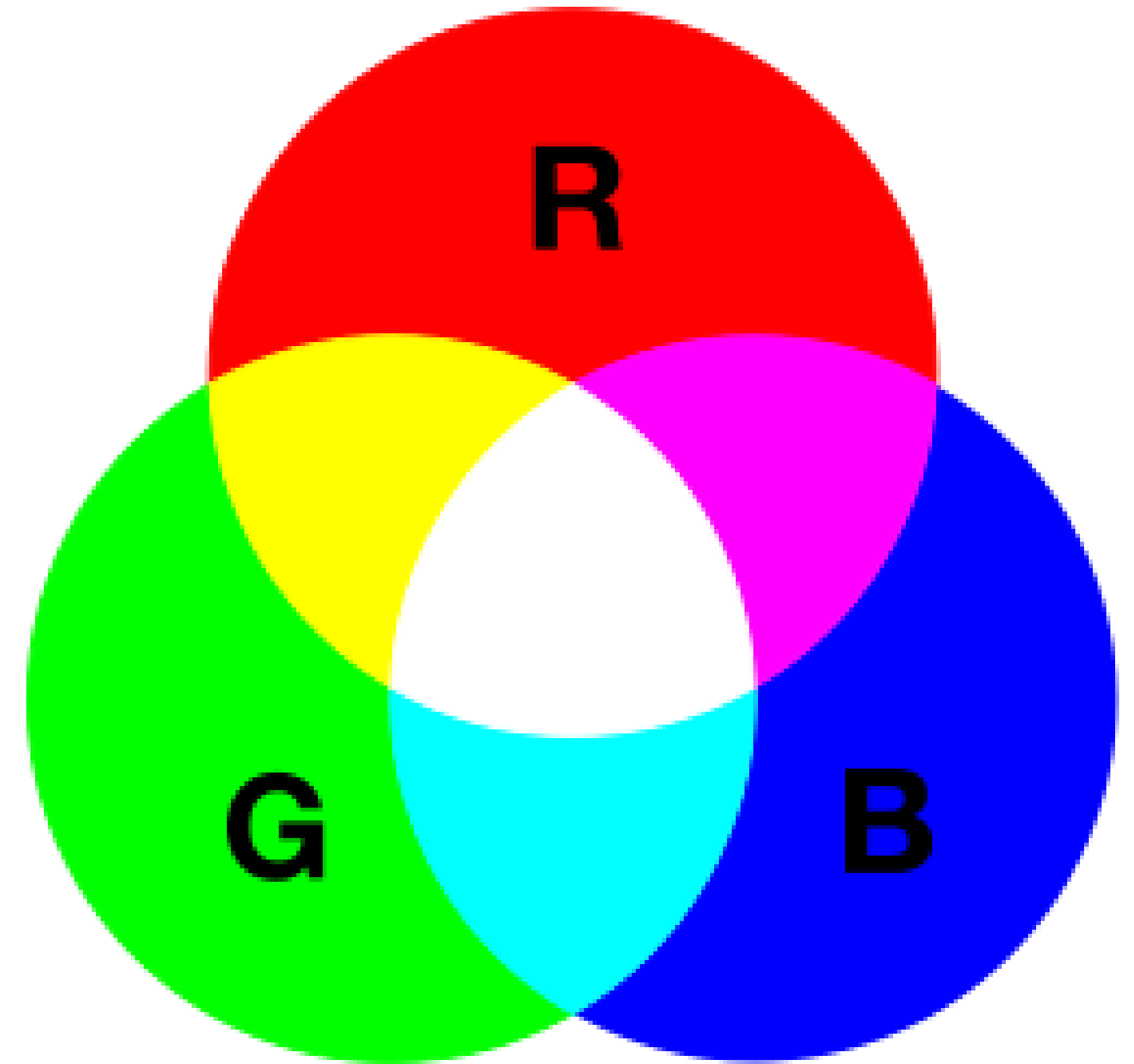
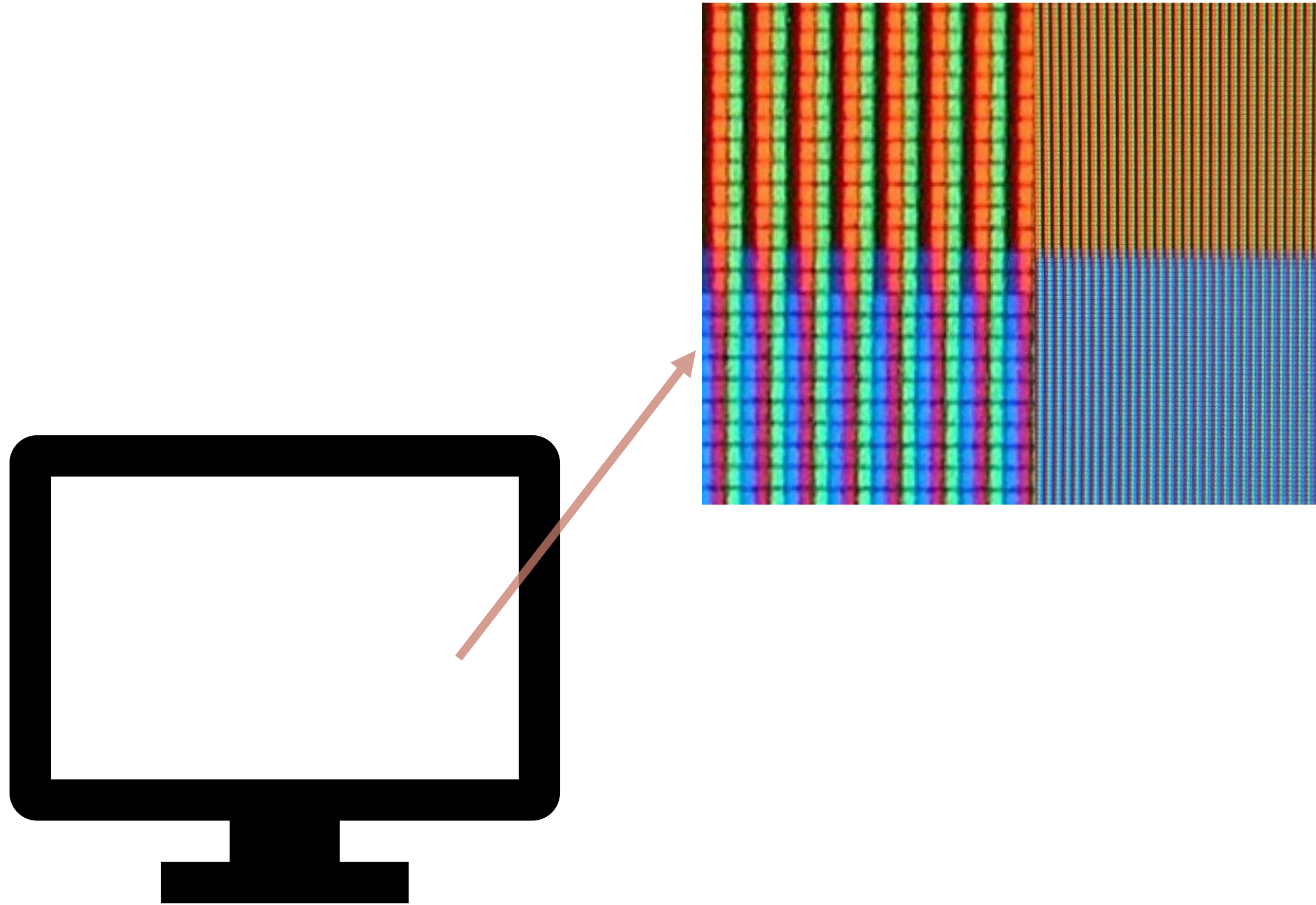
Cones:

64% red-sensitive

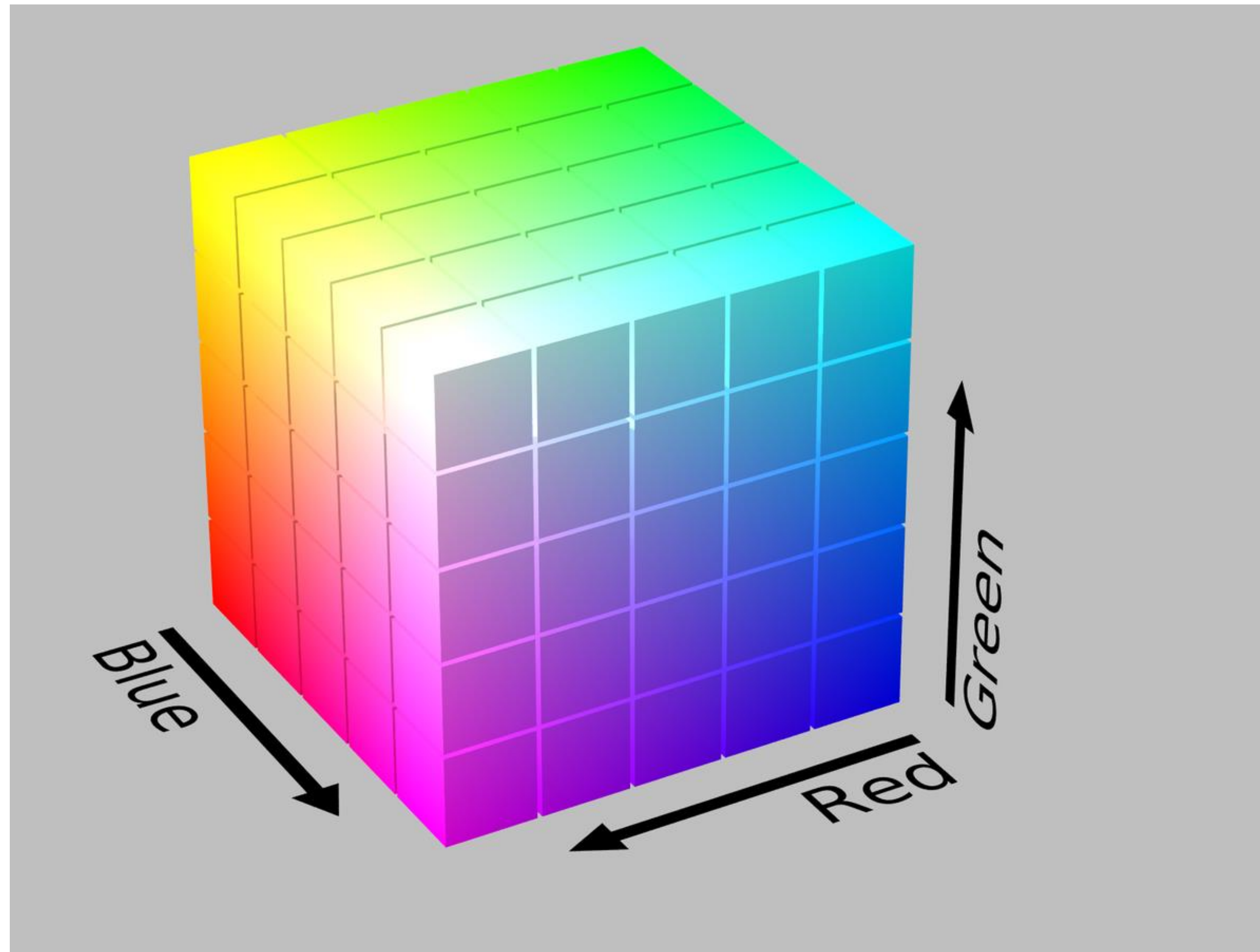
32% green-sensitive

2% blue-sensitive.

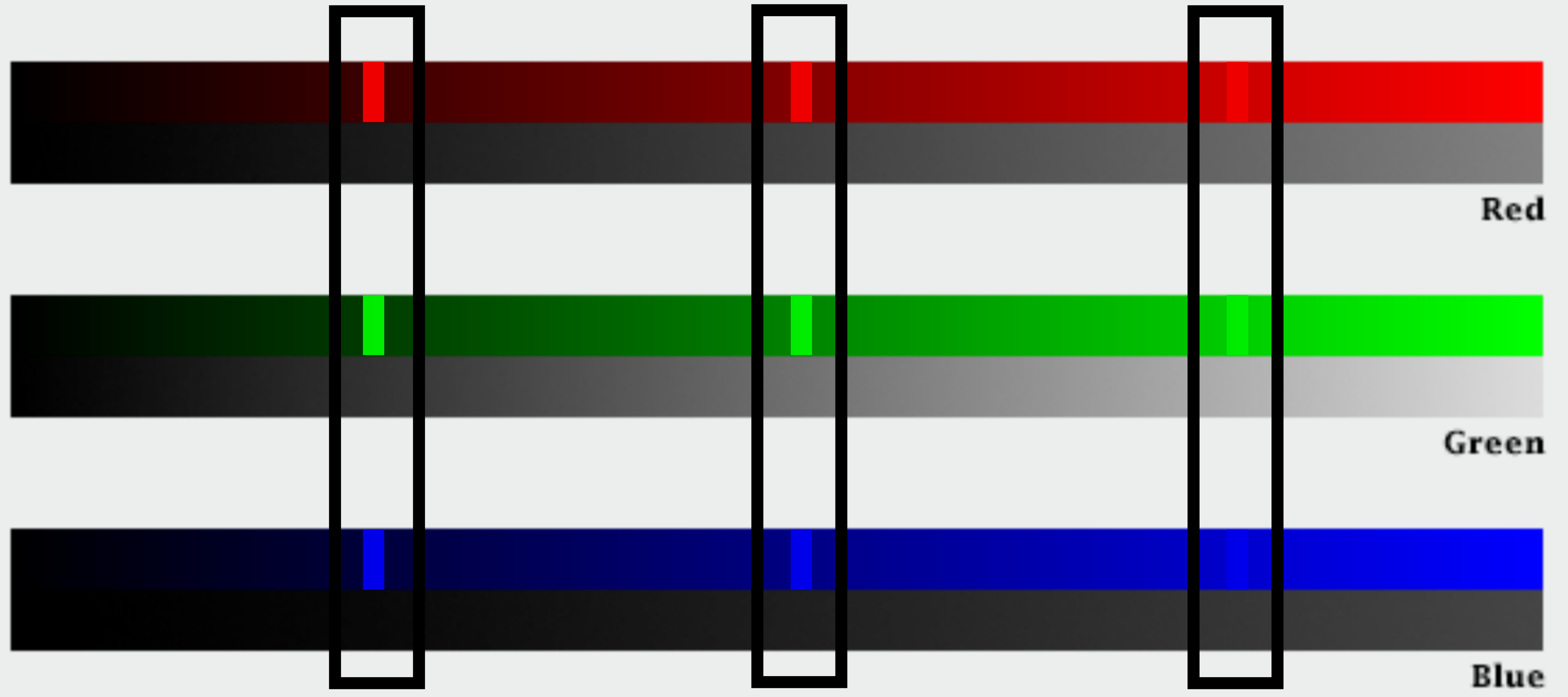
Modeling Color with RGB



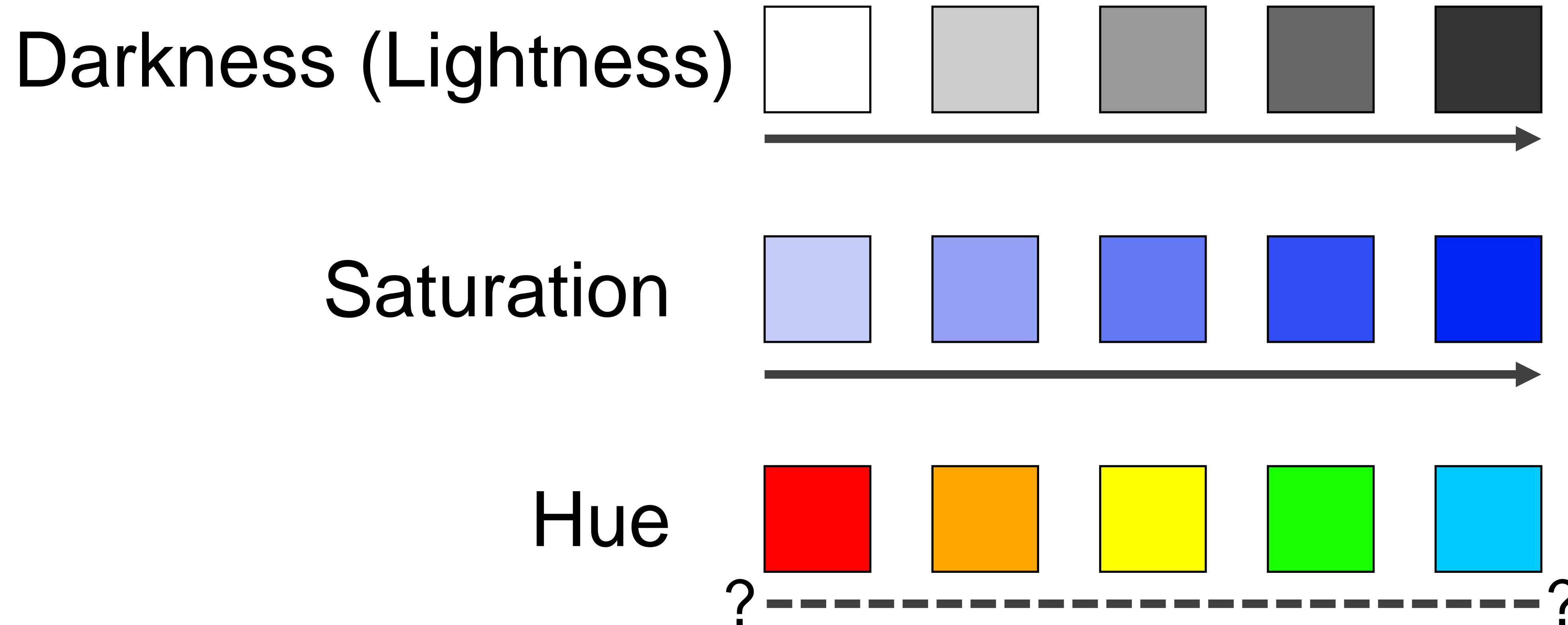
Modeling Color with RGB



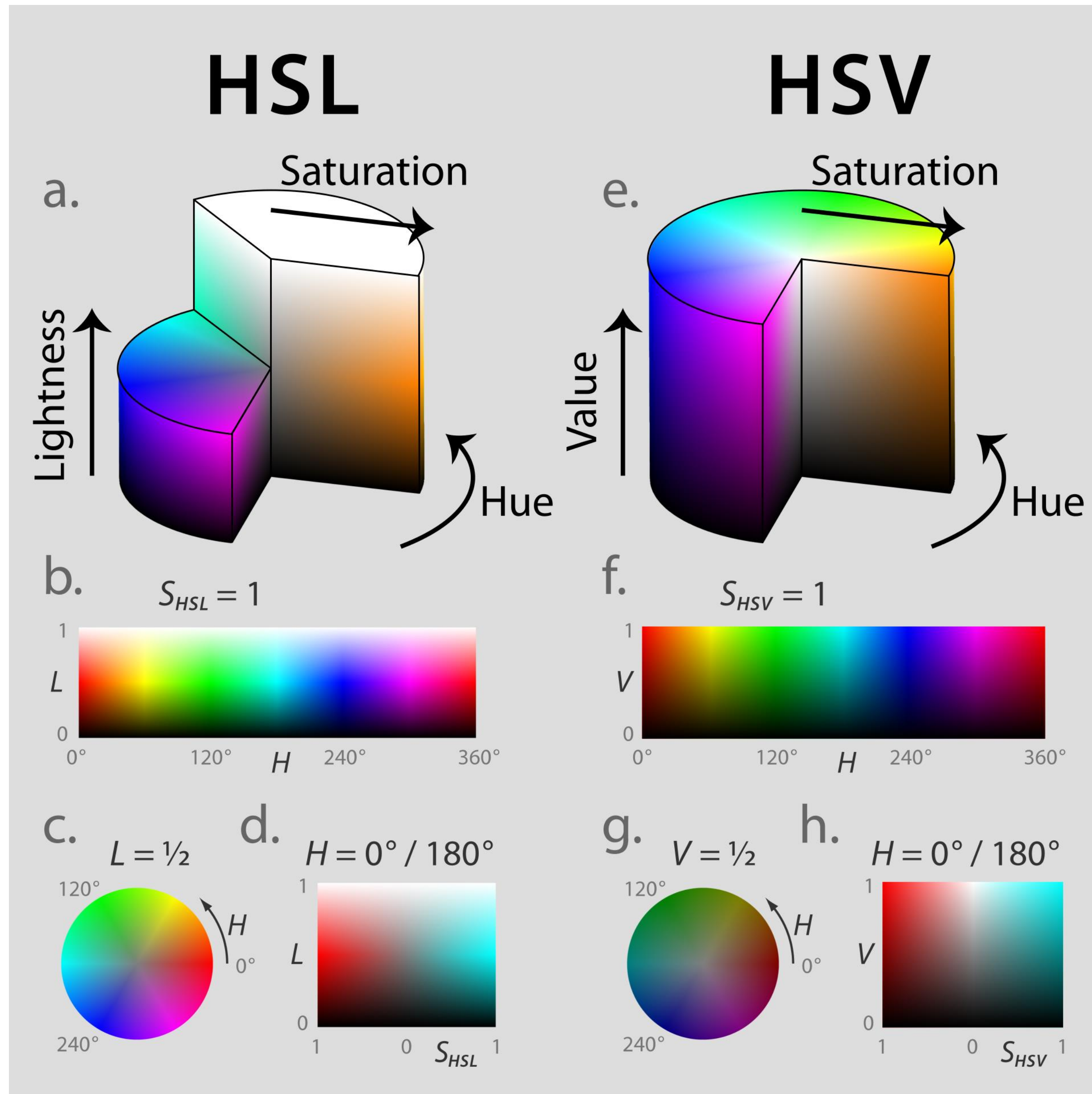
Modeling Color with RGB: Problematic



Color Vocabulary and Perceptual Ordering



Modeling Color with HSL or HSV

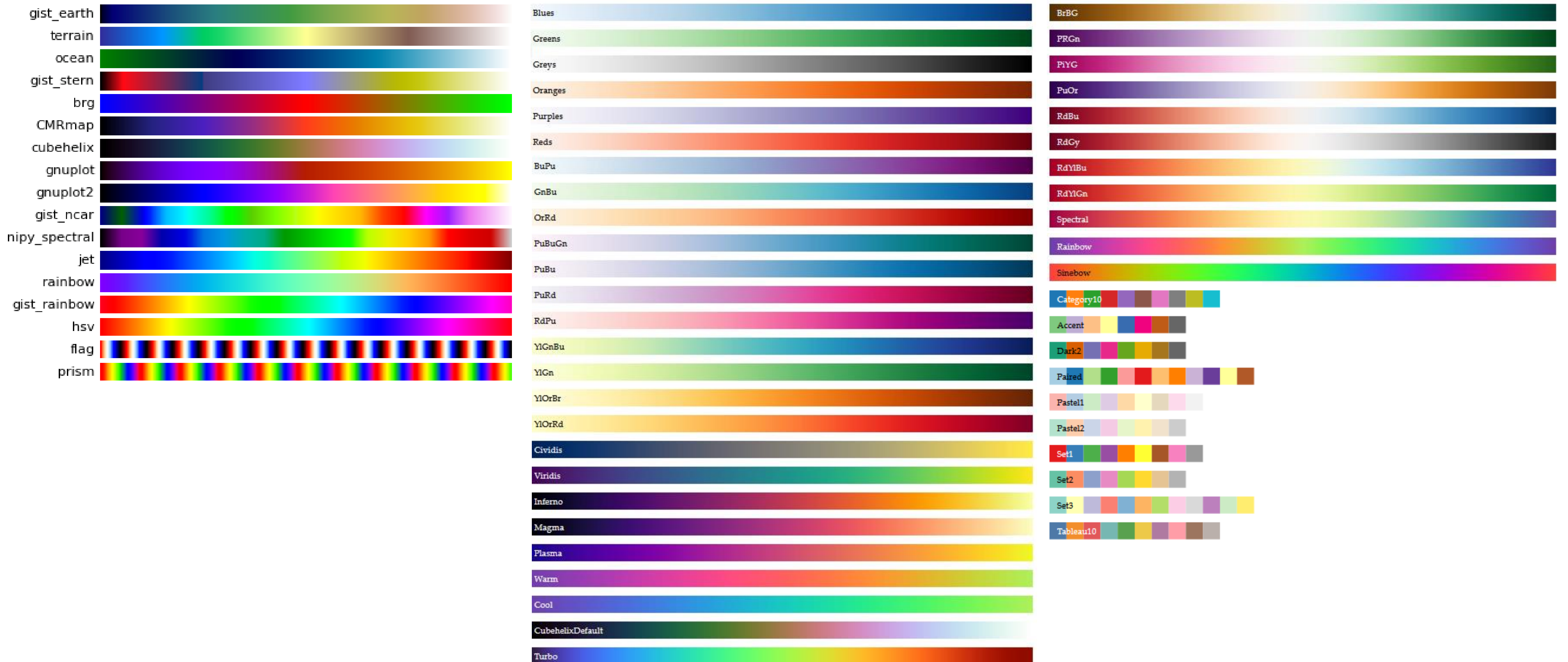


Still Imperfect

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

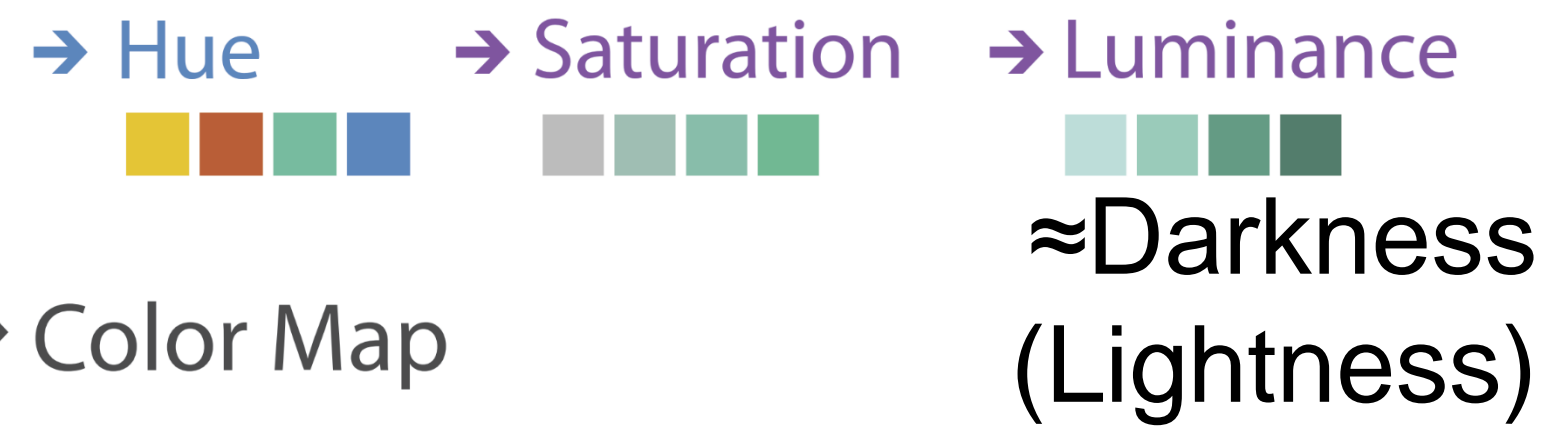
Color Maps

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



➔ Color

➔ Color Encoding



➔ Color Map

➔ Categorical



➔ Ordered

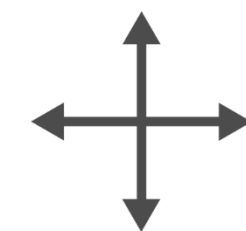
➔ *Sequential*



➔ *Diverging*



➔ Bivariate



➔ Size, Angle, Curvature, ...

➔ Length



➔ Angle



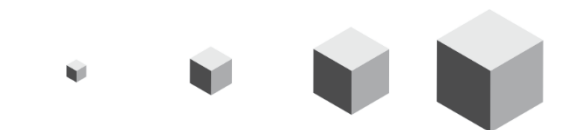
➔ Area



➔ Curvature



➔ Volume

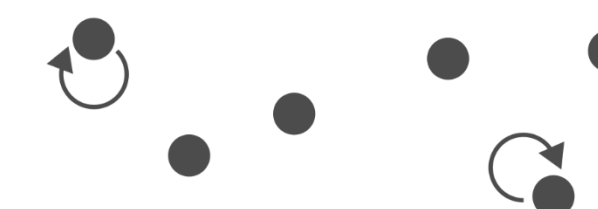


➔ Shape



➔ Motion

➔ Motion
*Direction, Rate,
Frequency, ...*



Color Maps

THREE MAIN TYPES:

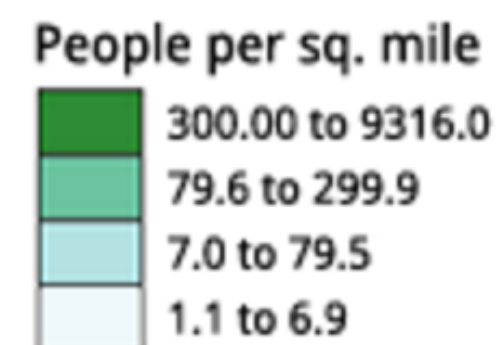
Categorical



Does not imply magnitude differences (categorical/nominal data)

Distinct hues with similar emphasis

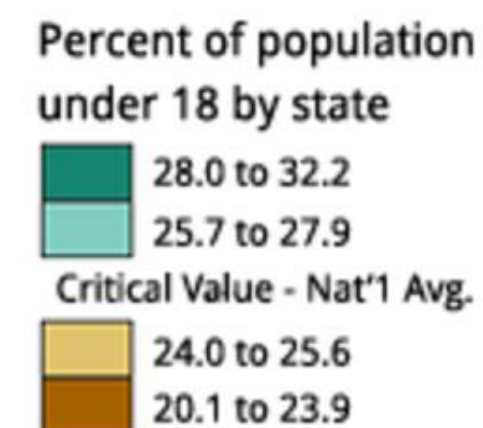
Sequential



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

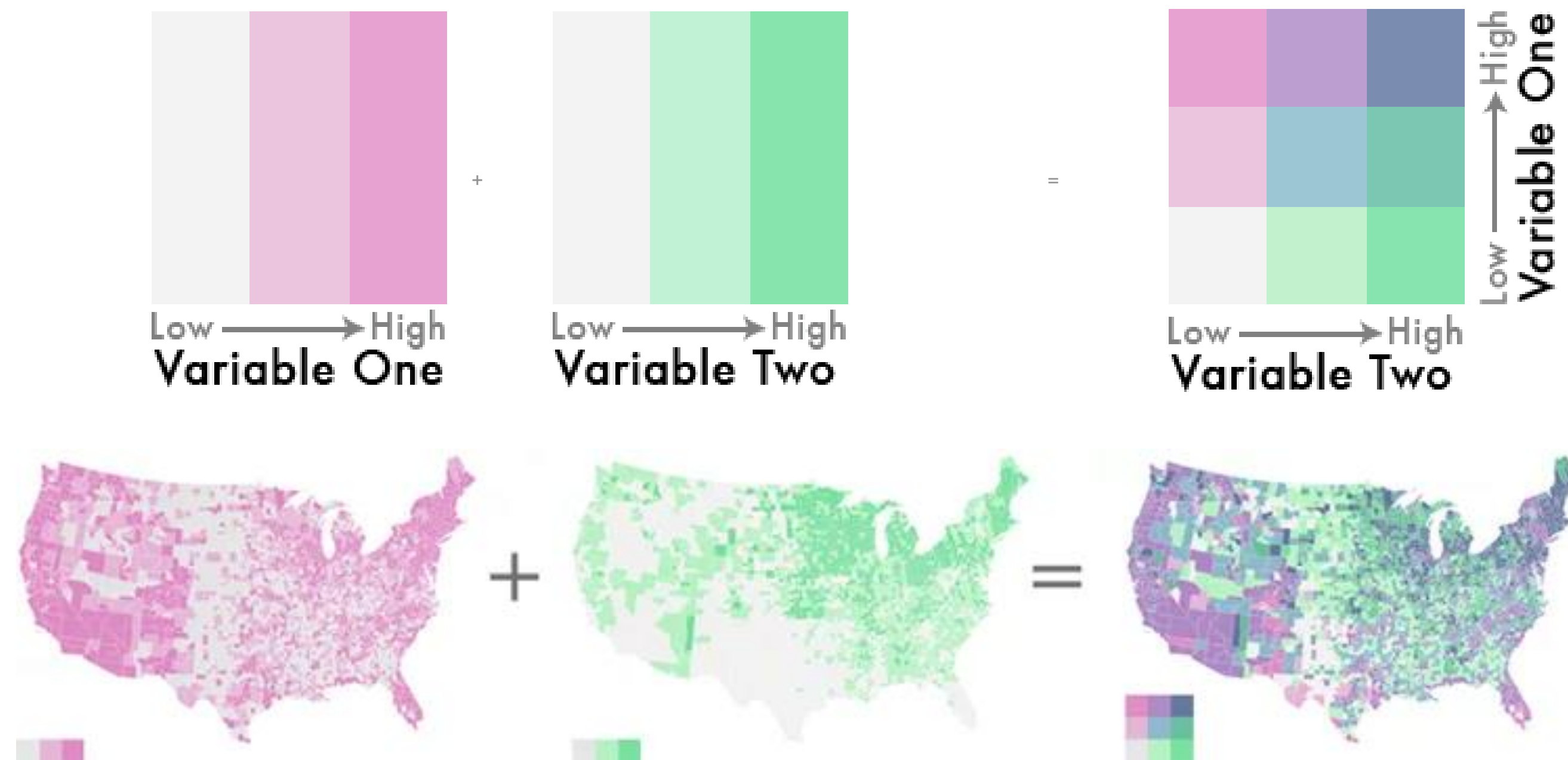
ALSO...

Bivariate

Displays two variables

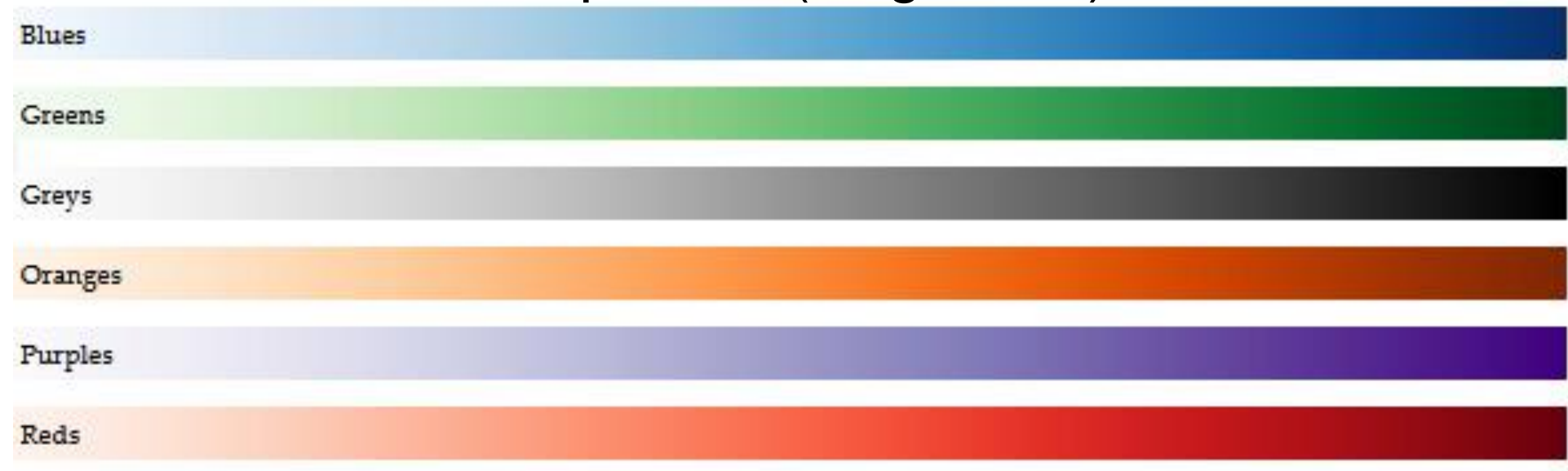
Combination of two sequential color schemes

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



Types of Color Maps

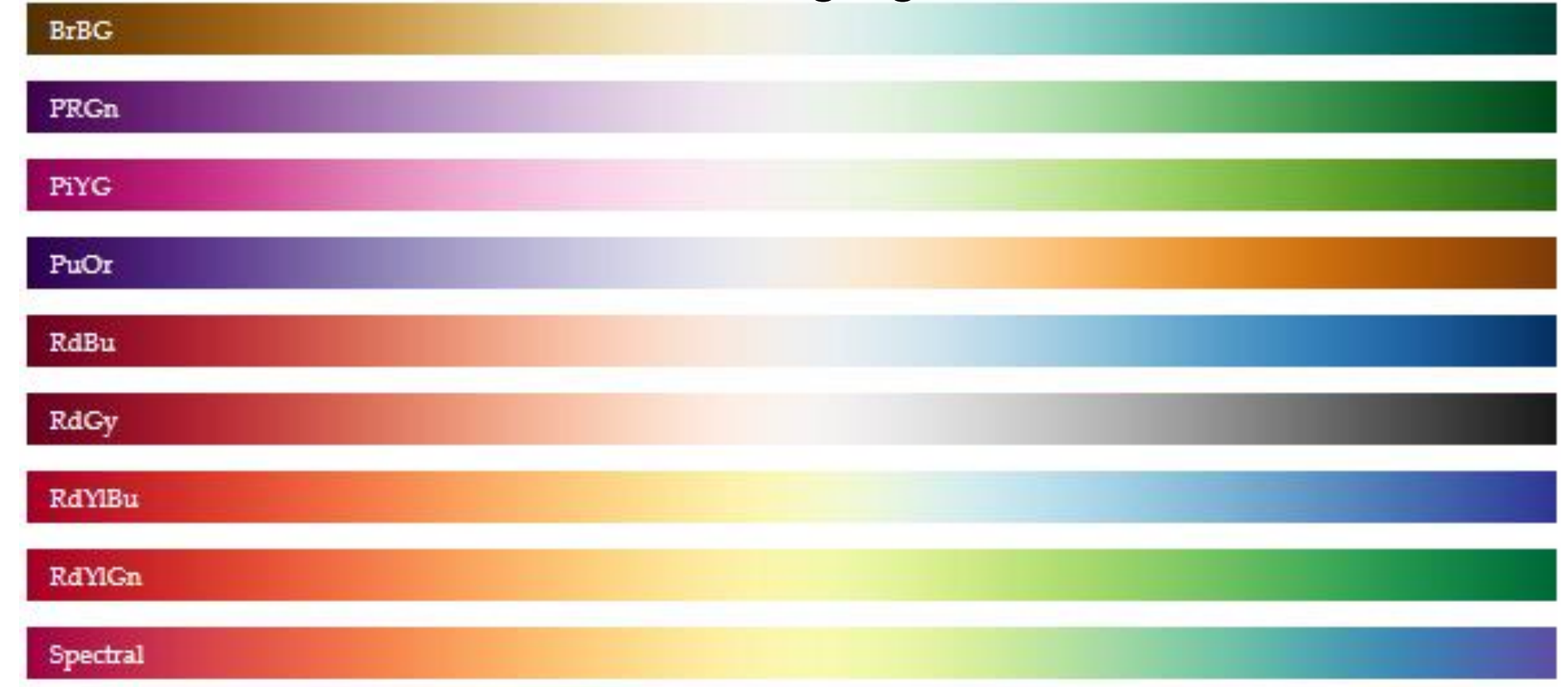
Sequential (single hue)



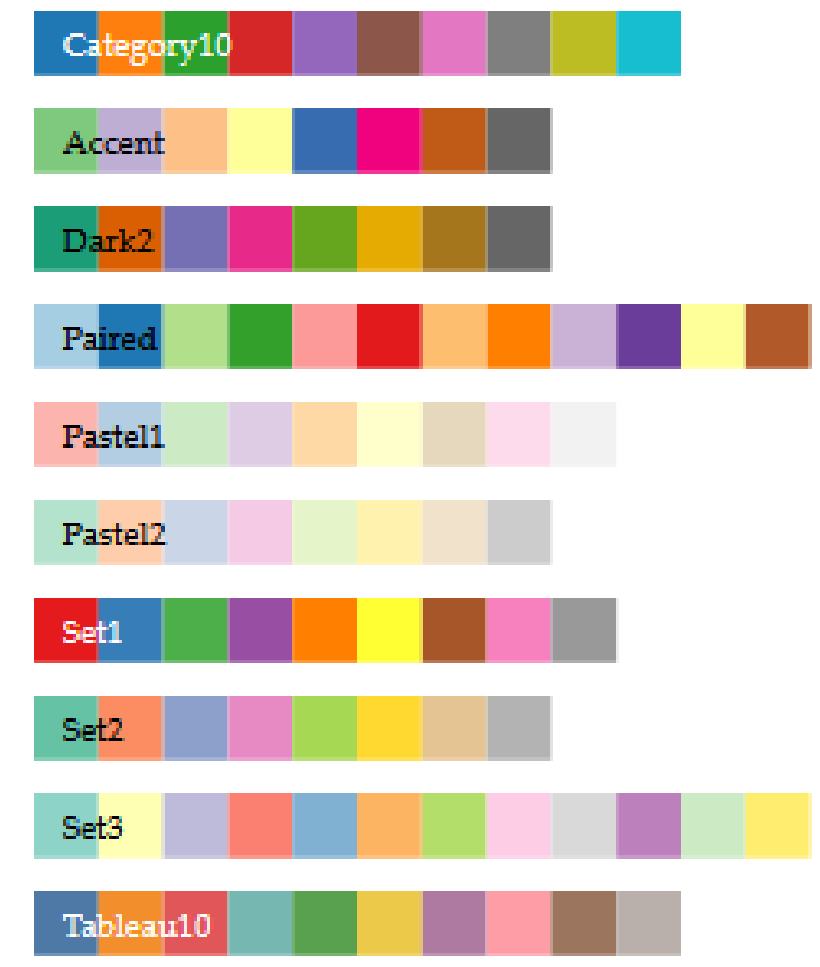
Sequential (multiple hue)



Diverging



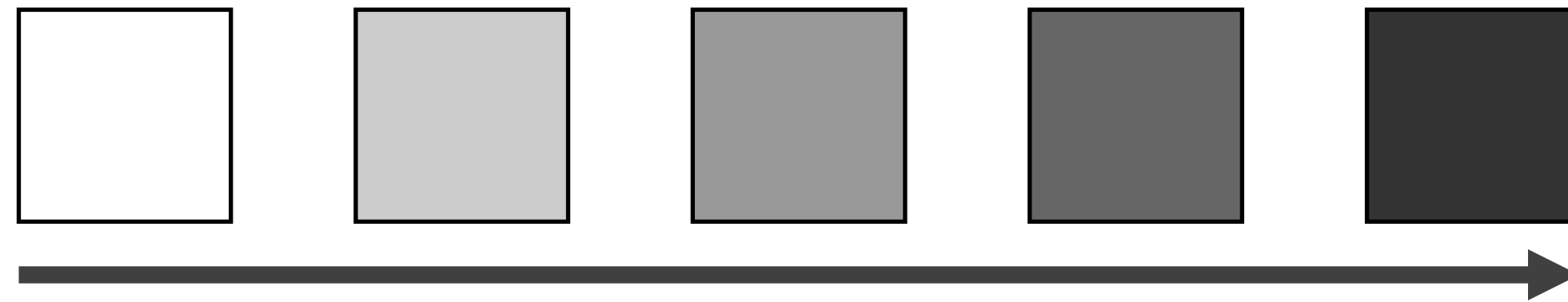
Categorical



Cyclical



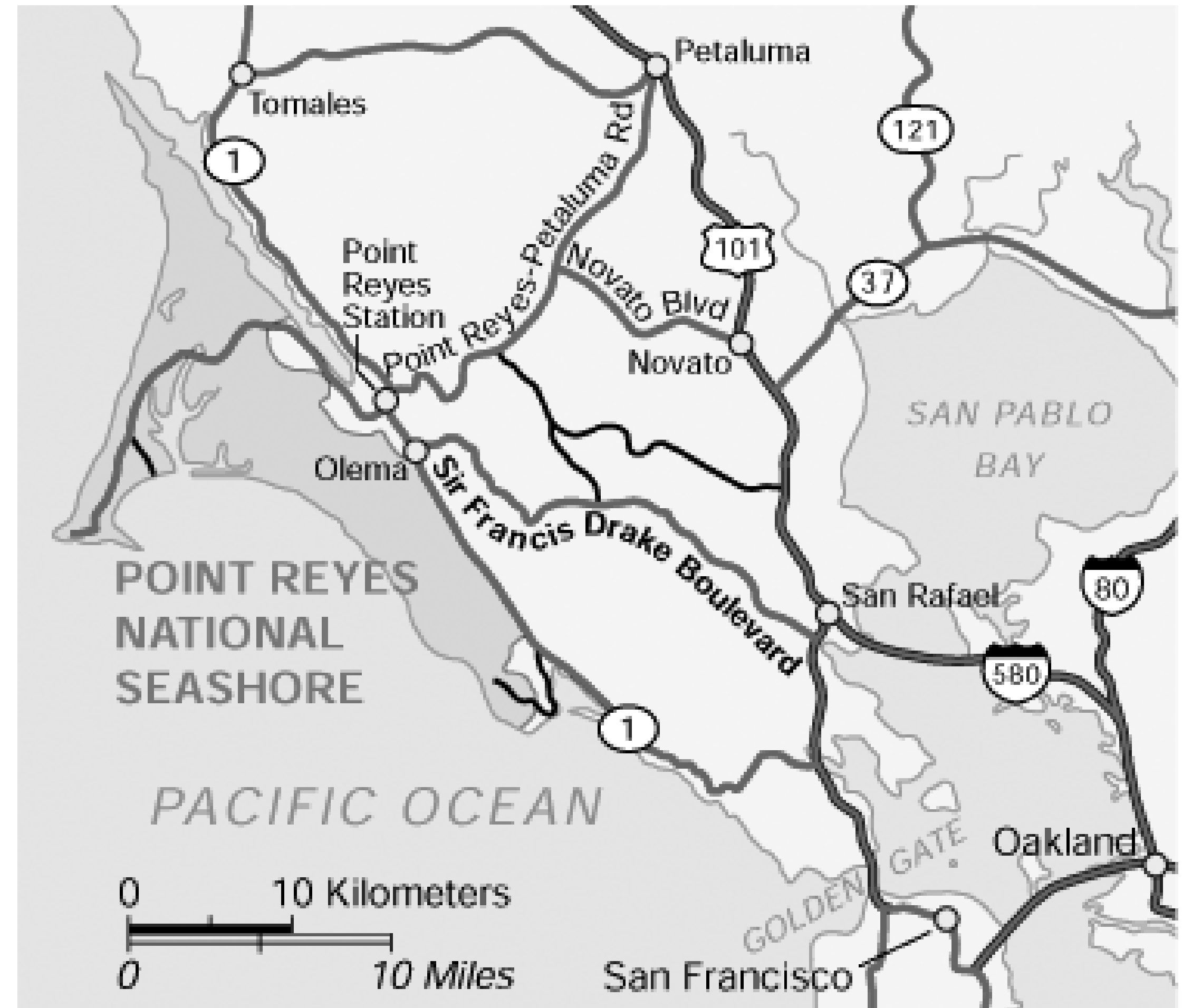
Darkness (Lightness) Channel



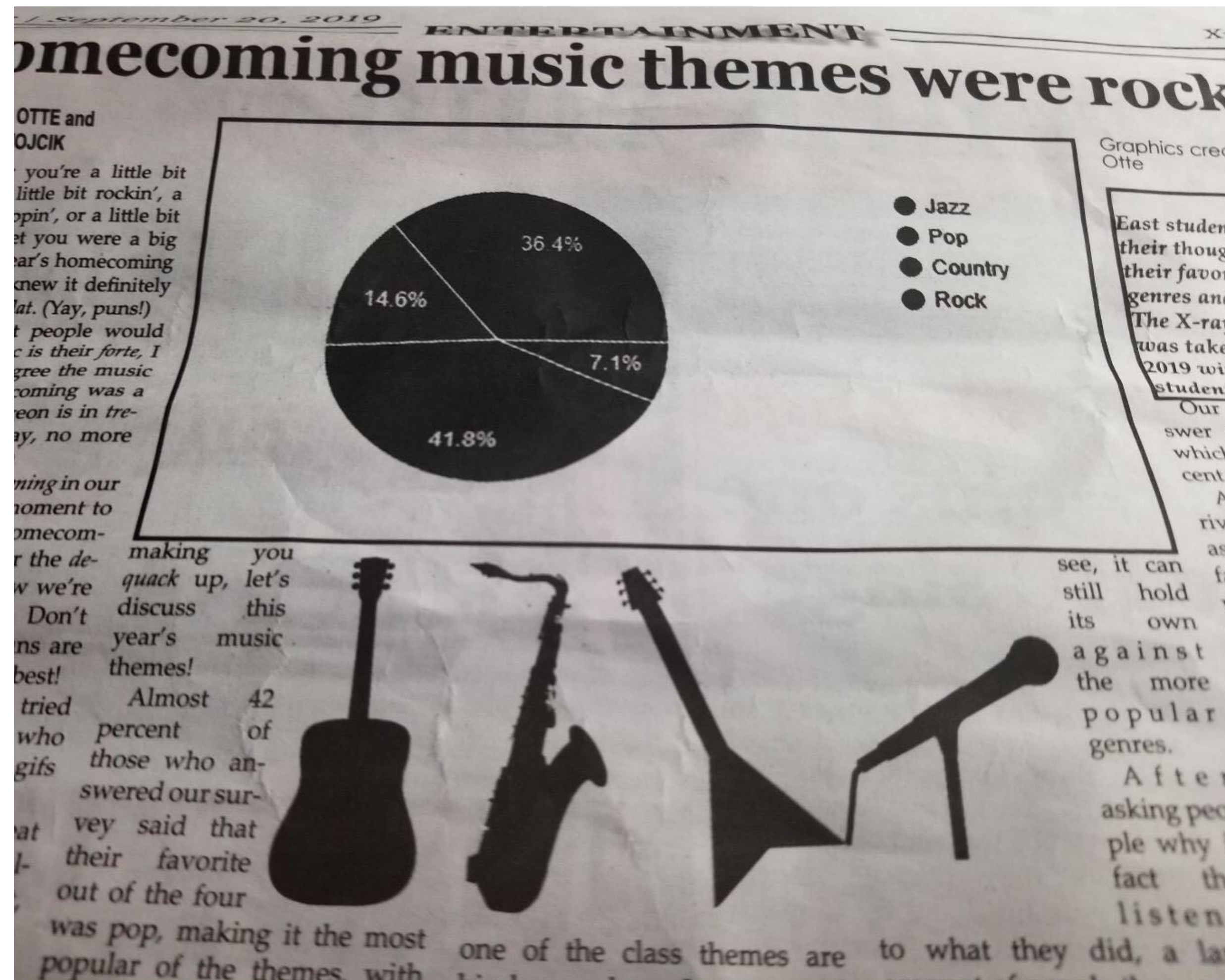
- No edges without darkness difference
- No shading without darkness variation
- Has higher spatial sensitivity than color channels
- Contrast defines legibility, attention, layering
- Controlling darkness is primary rule of design

“Get it right in black and white.”

-Maureen Stone



Understanding your medium matters



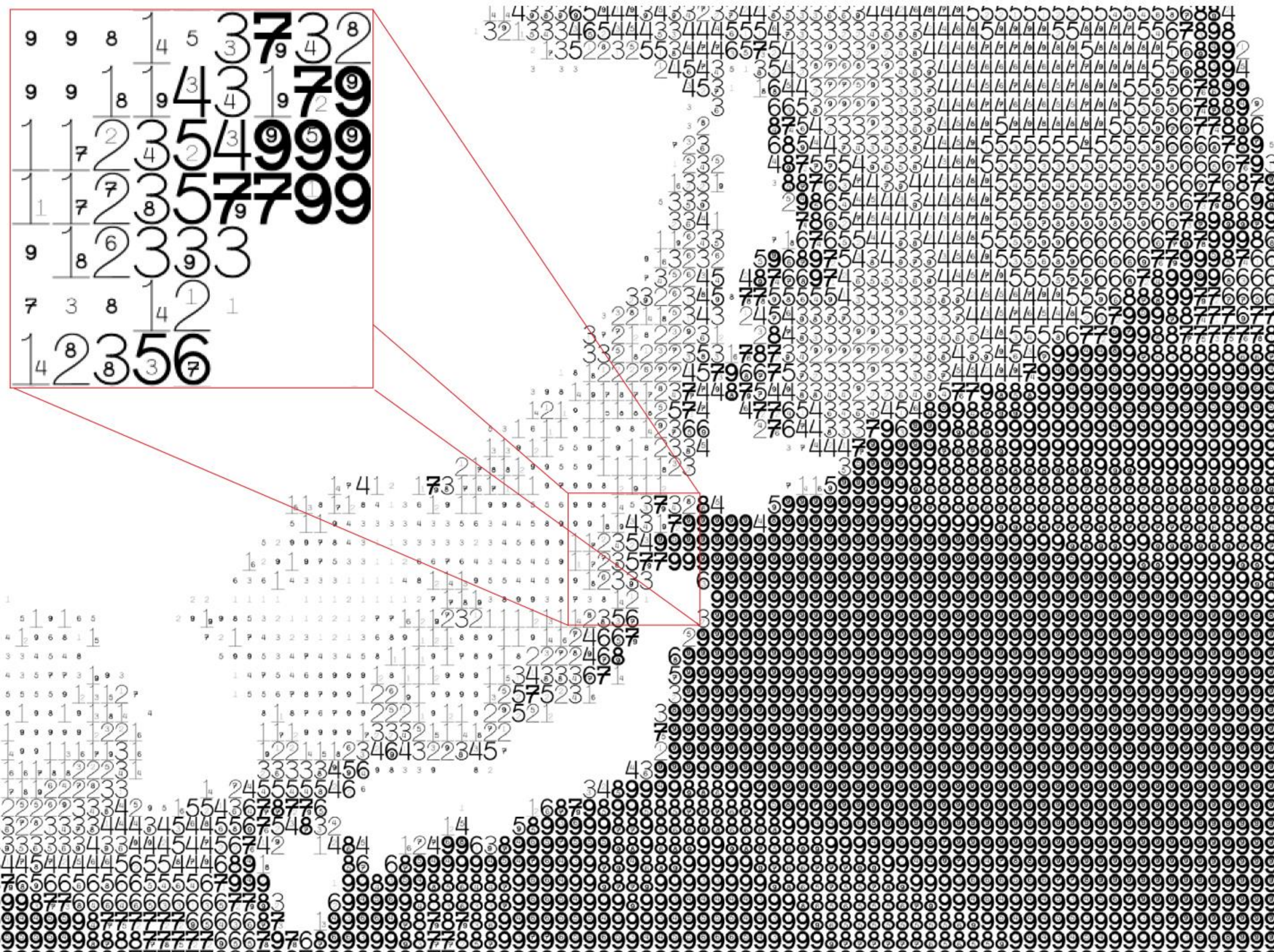
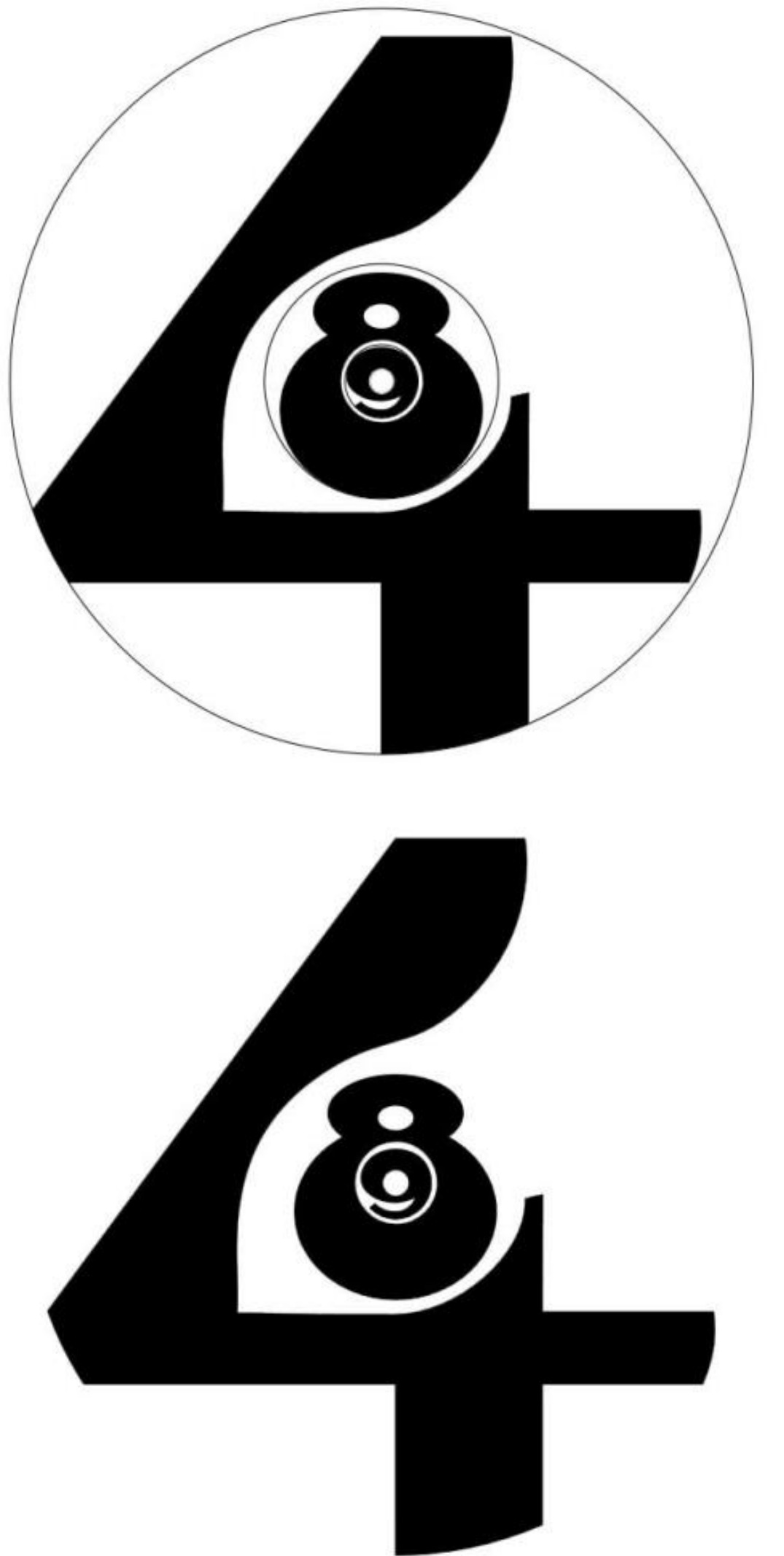
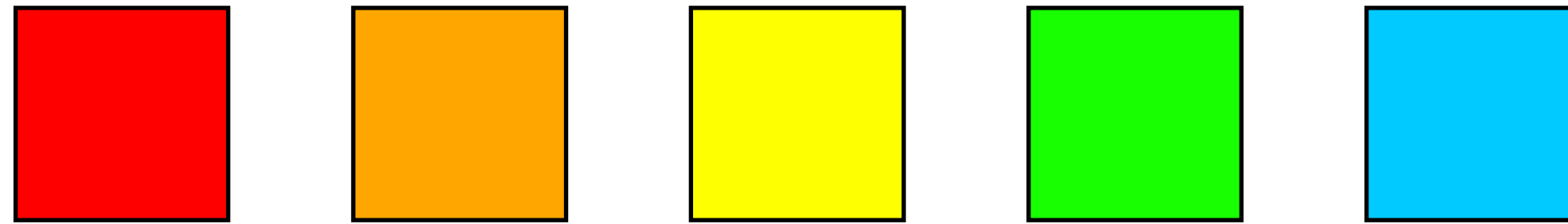


Figure 8: Maximum wave amplitudes for the Japan 2011 tsunami. Amplitudes were clipped at 99cm. Data adapted from NOAA; <http://www.noaa.gov/>.

FatFonts



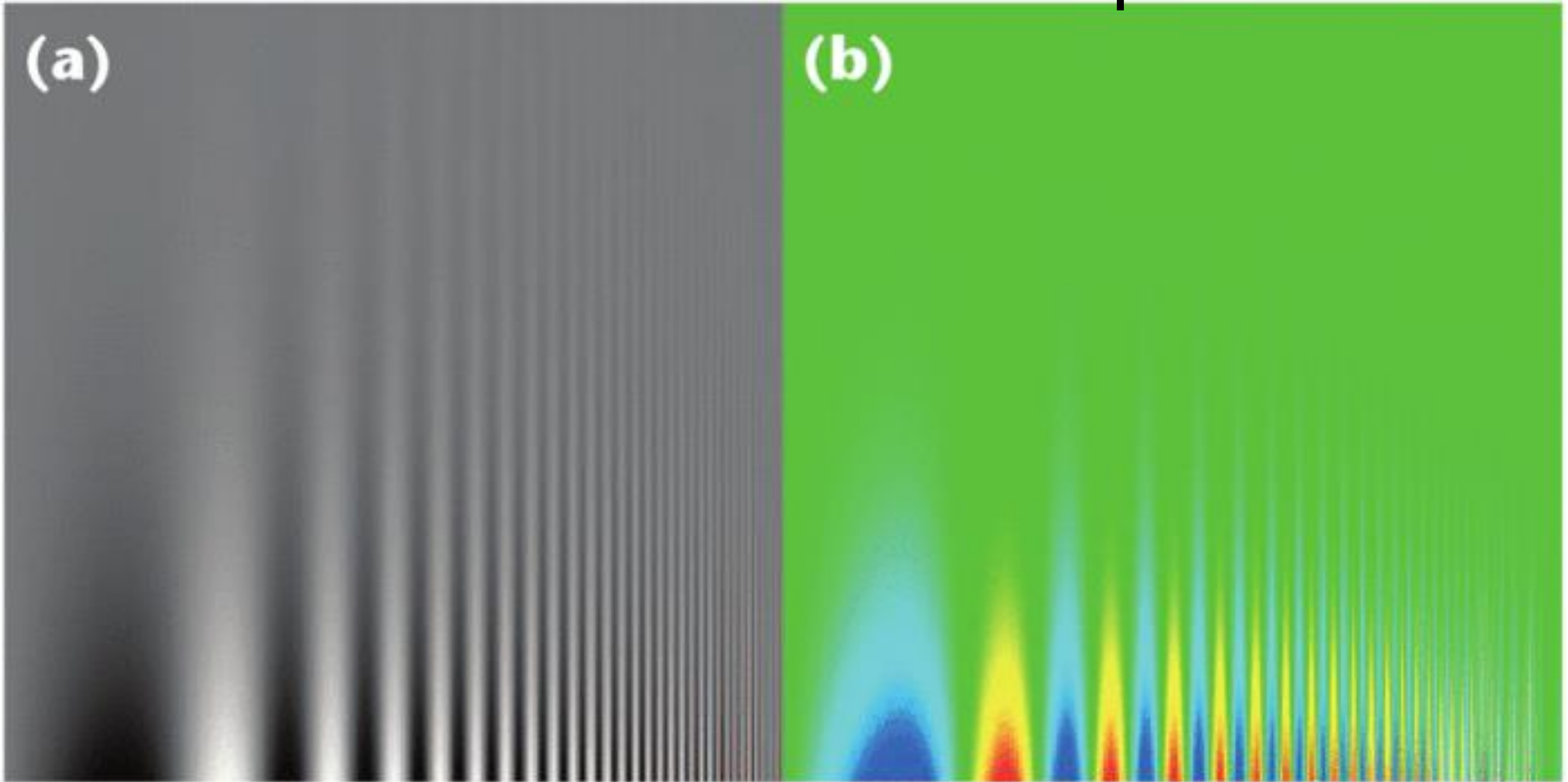
Rainbow Color Map (Hue)



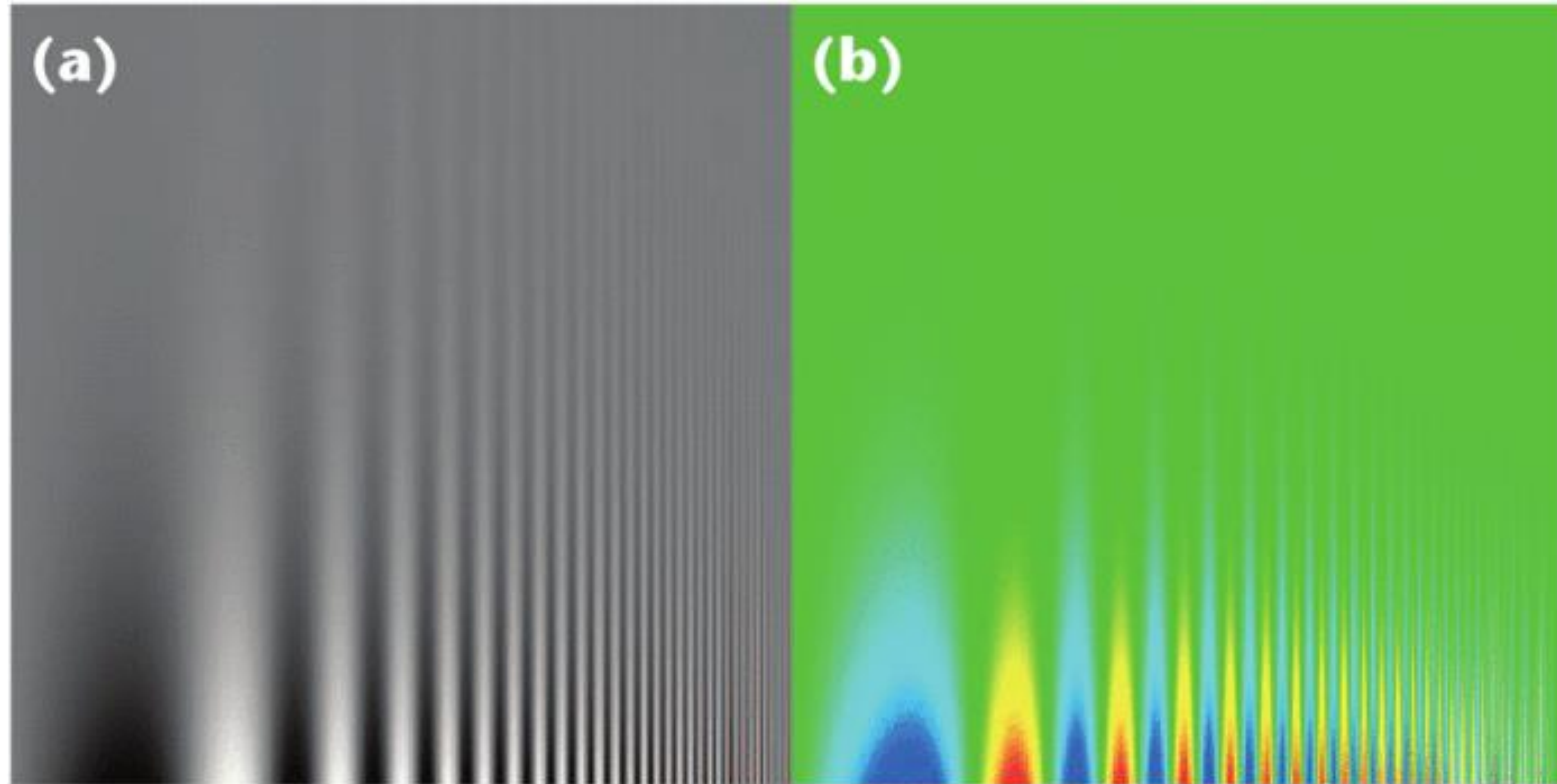
Rainbow Color Map

(a)

(b)



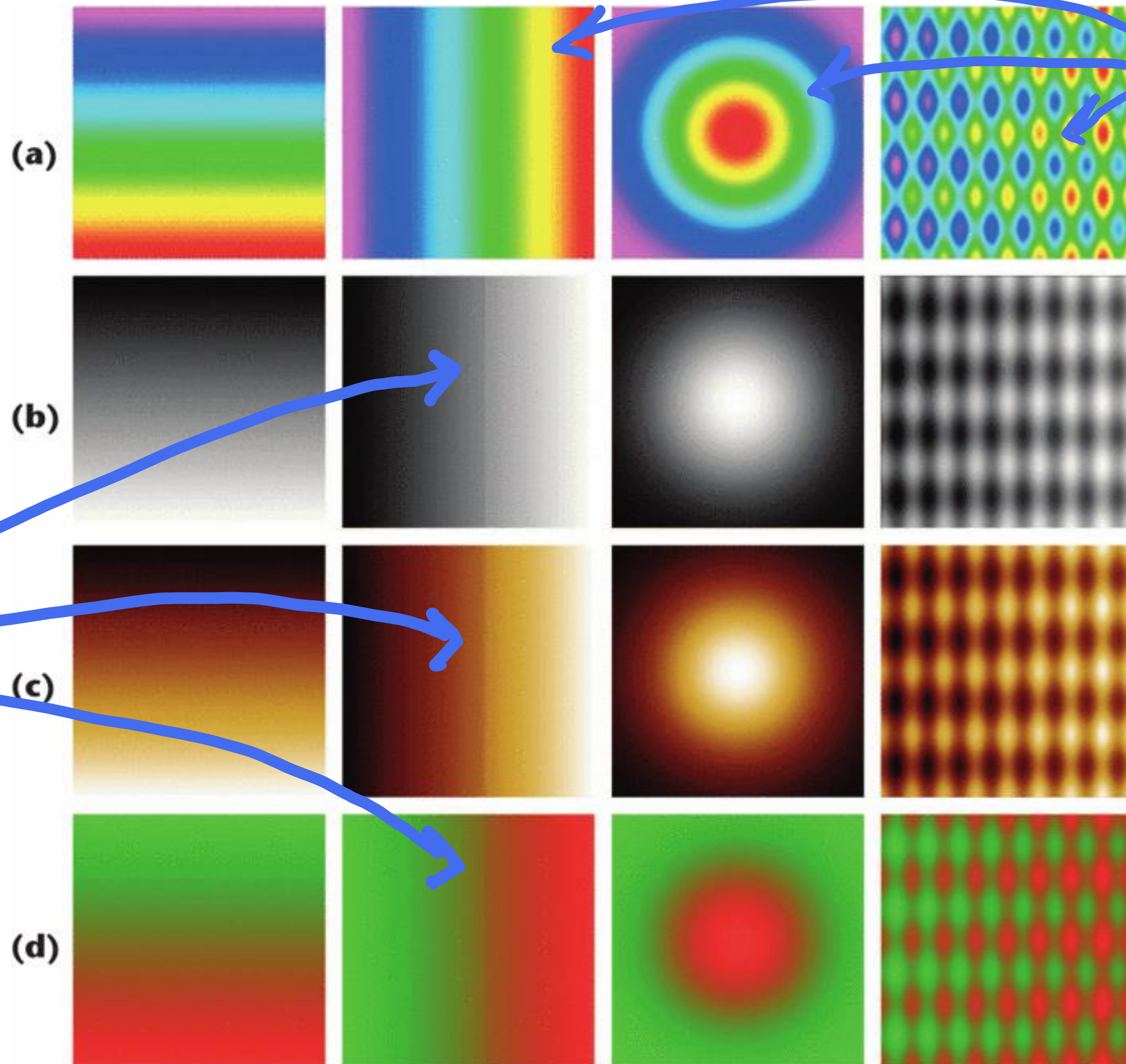
Rainbow Color Map



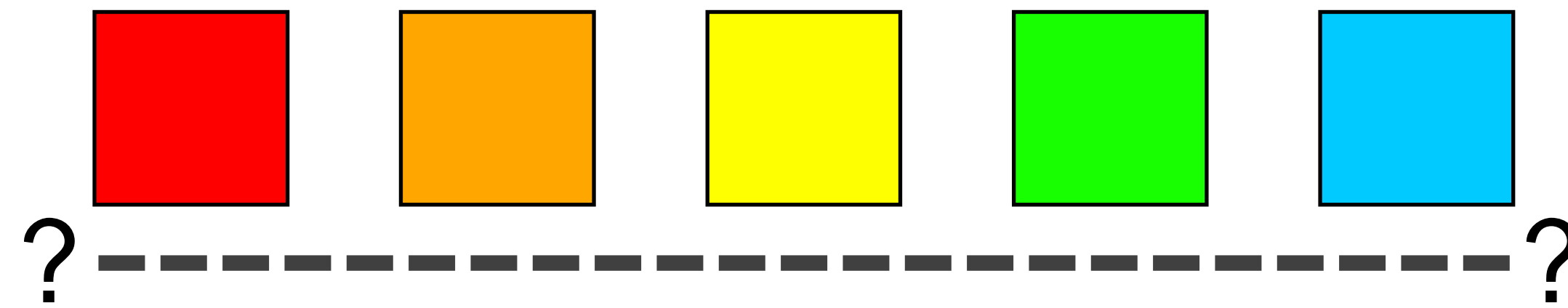
- No darkness variation (obscures details)
- Viewers perceive sharp transitions in color as sharp transitions in the data, even when this is not the case (misleading)

Real!

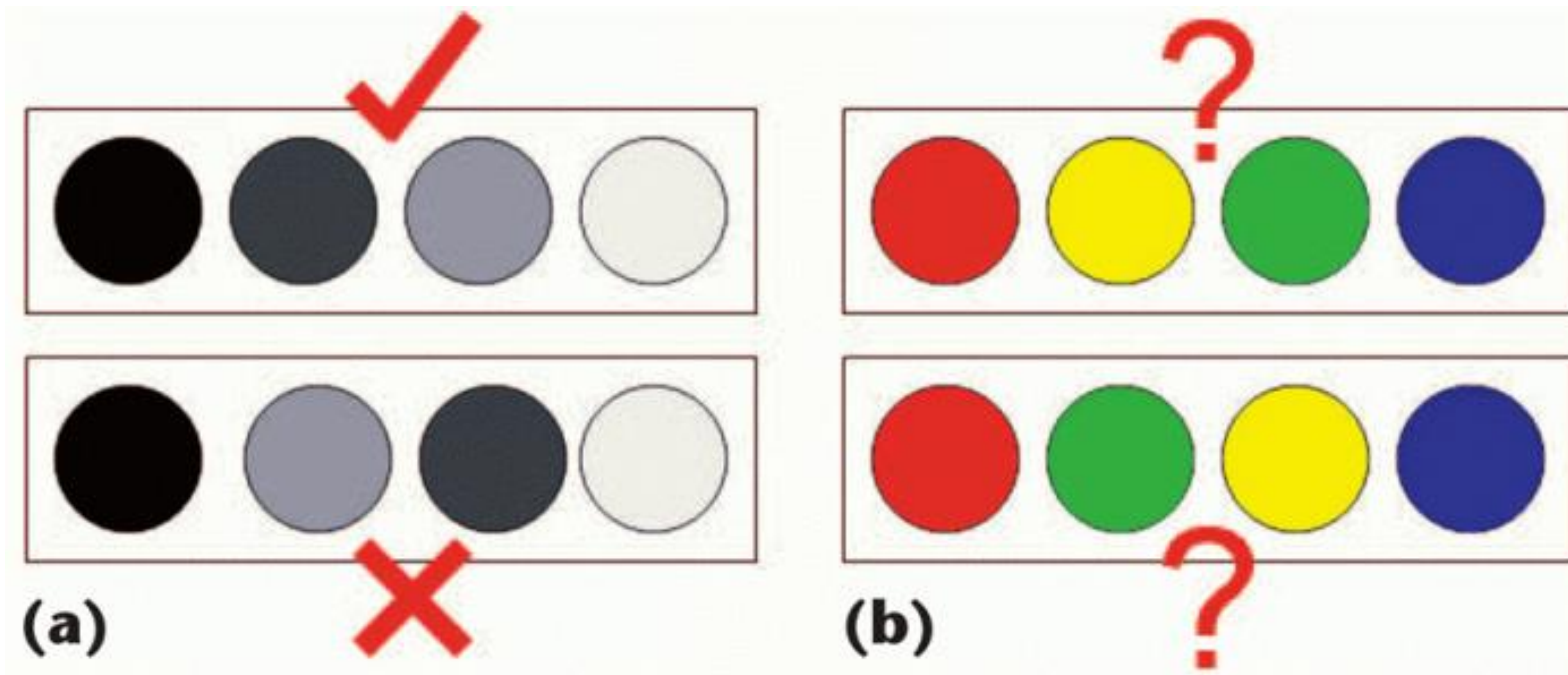
False



Rainbow Color Map (Hue)



No perceptual ordering (confusing)

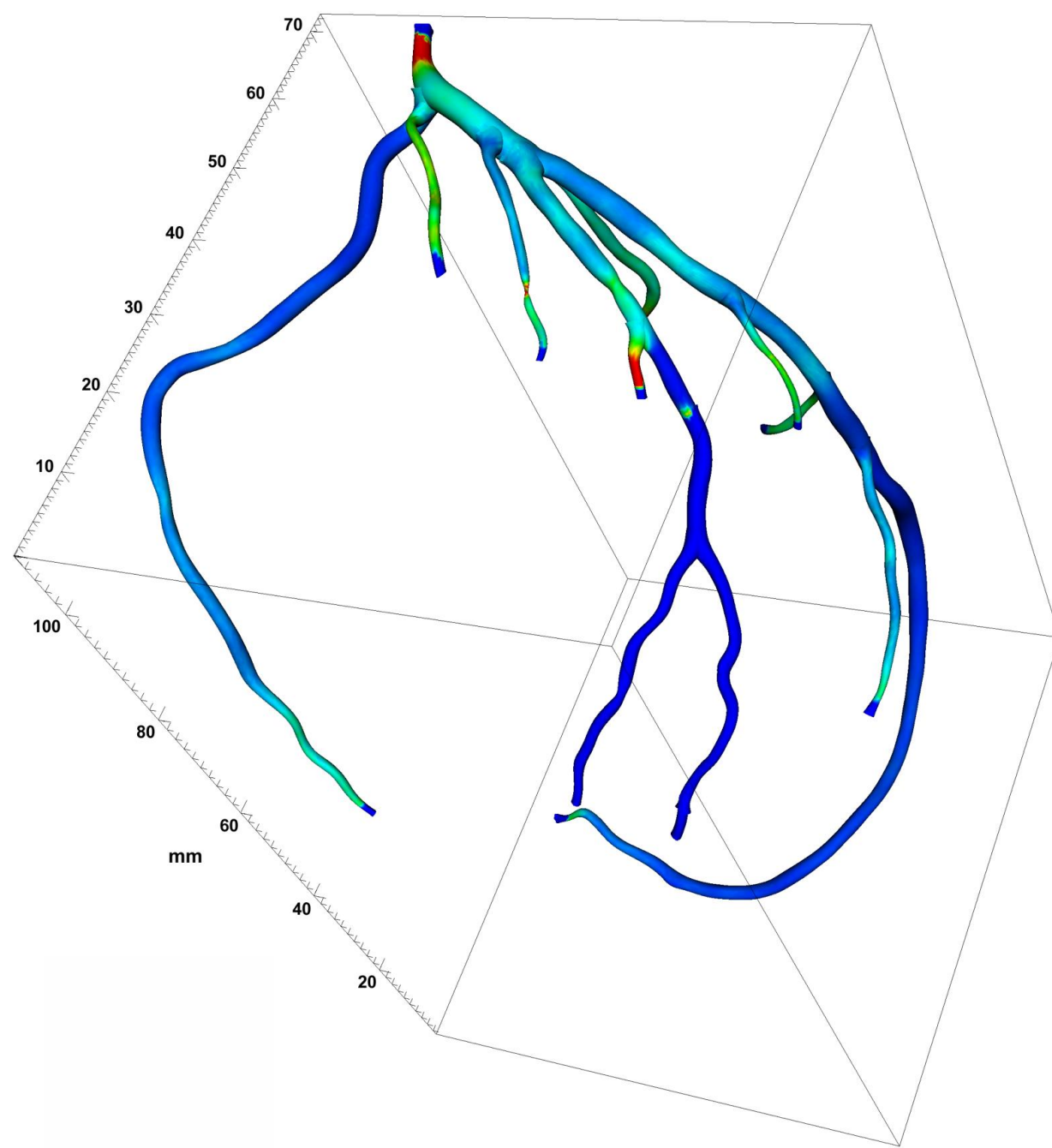


Rainbow Color Map

Rainbow:

3D: 39%

2D: 62%

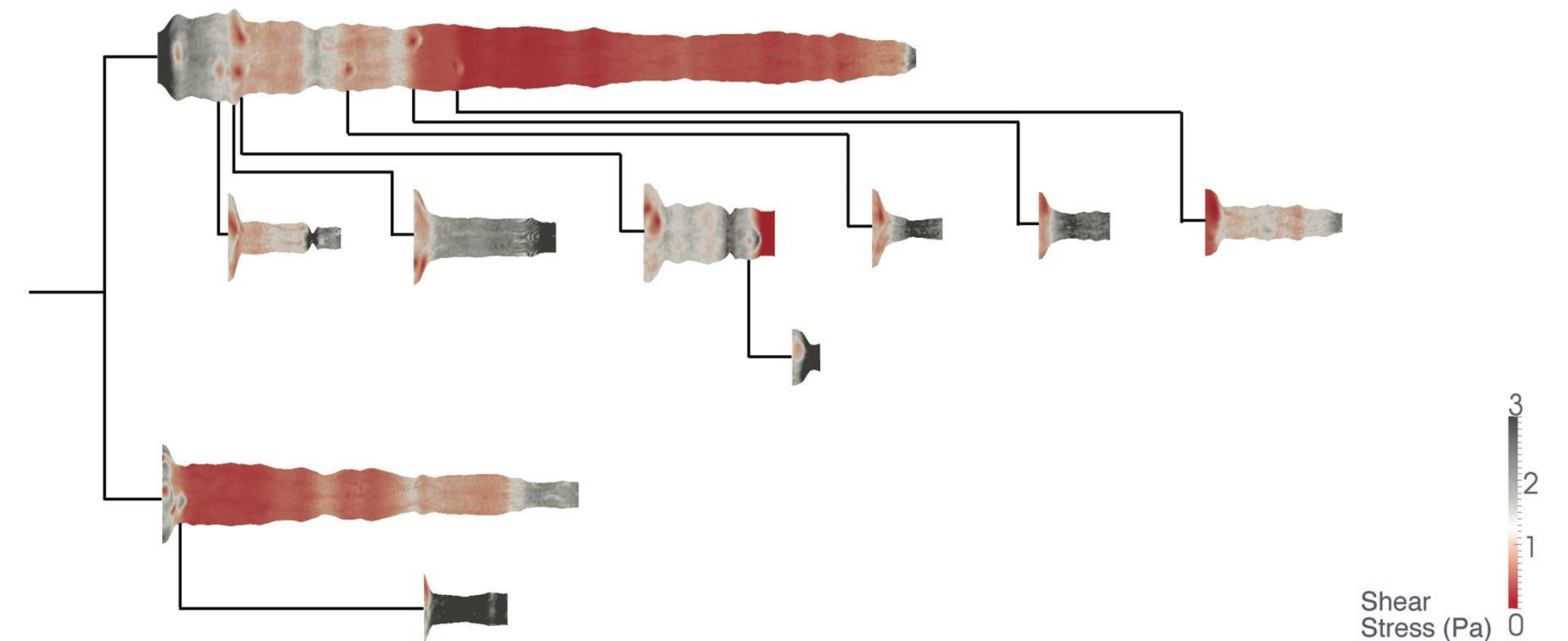


How many diseased regions found?

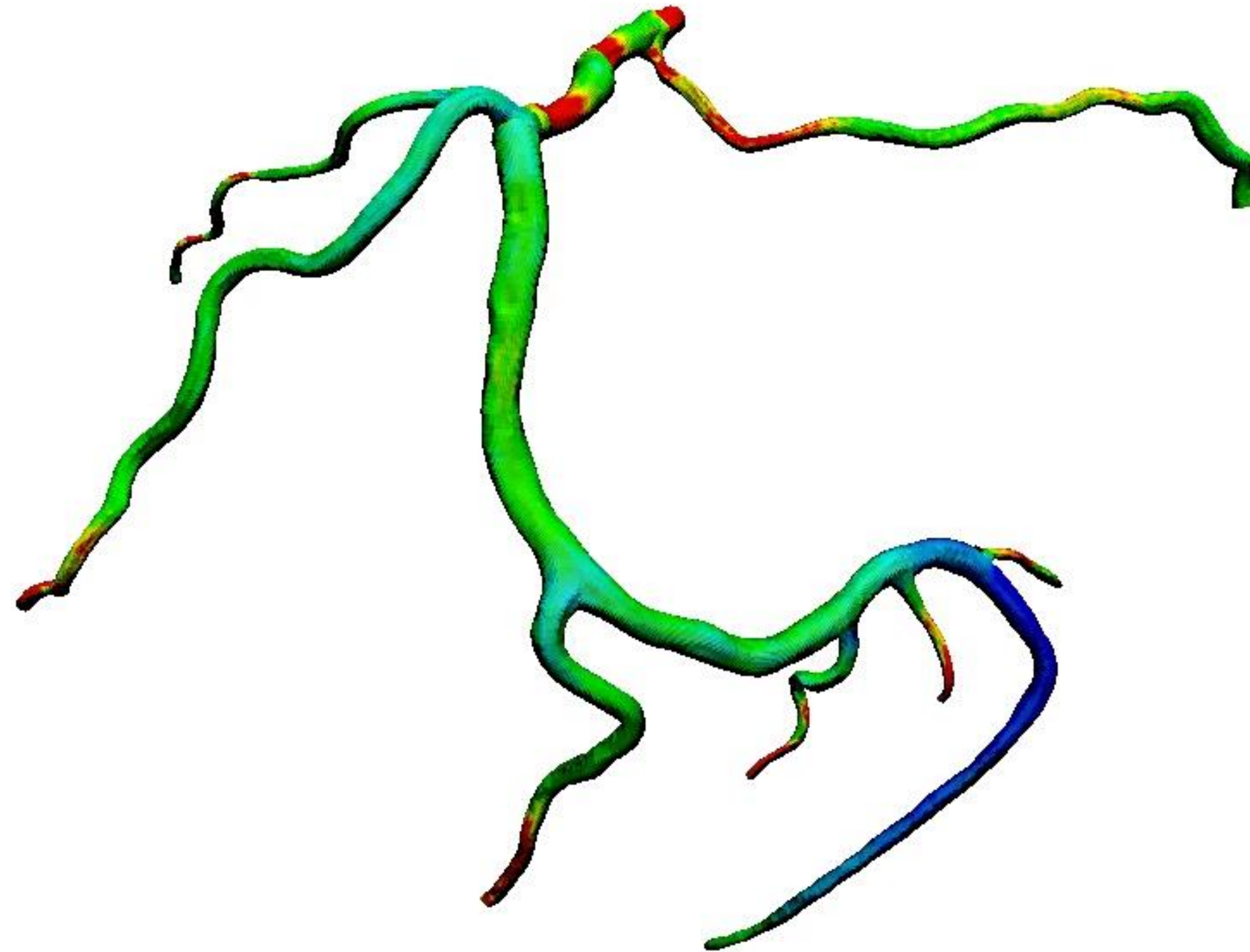
Diverging:

3D: 71% (Δ +31%)

2D: 91% (Δ +29%)

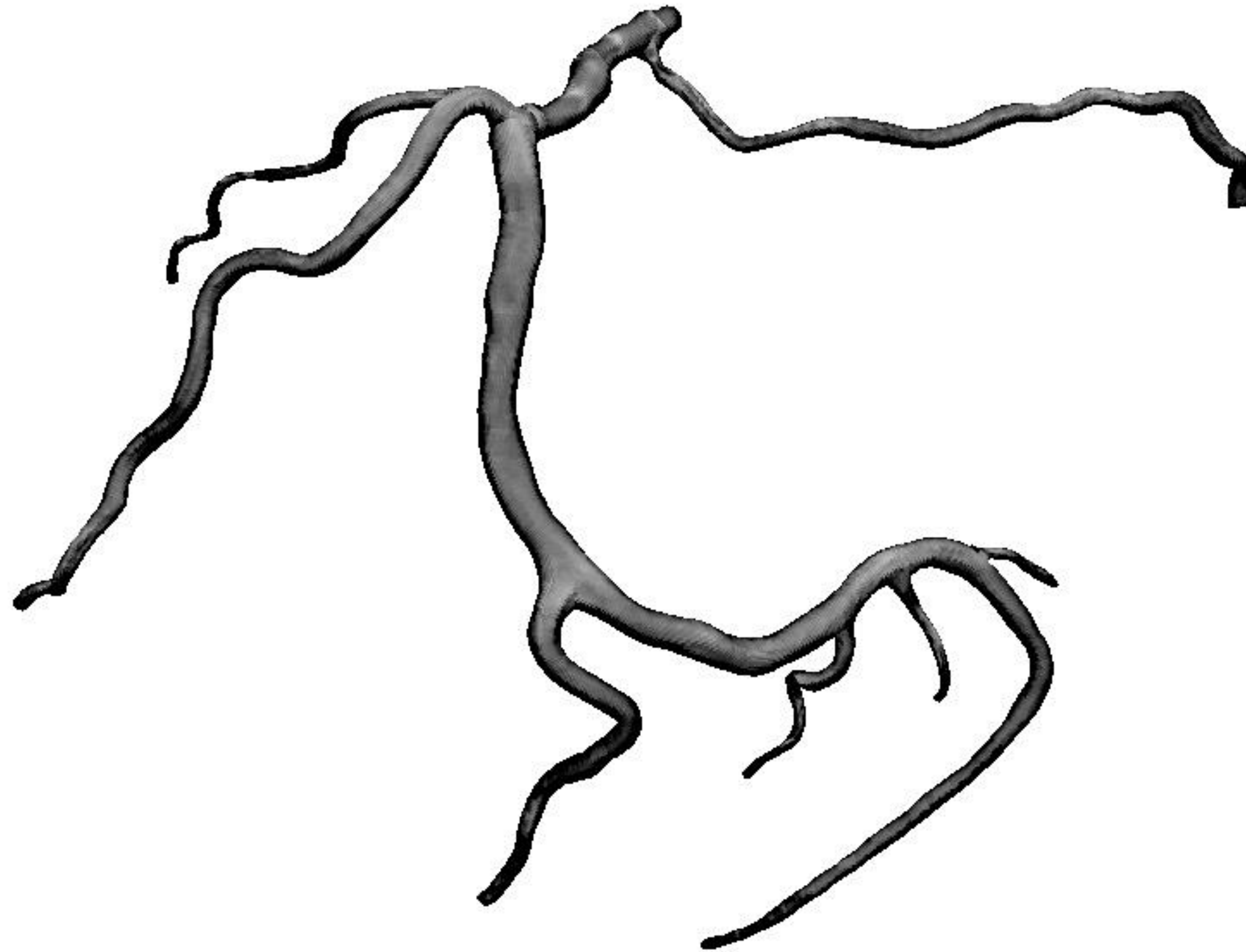


“Get it right in black and white.”

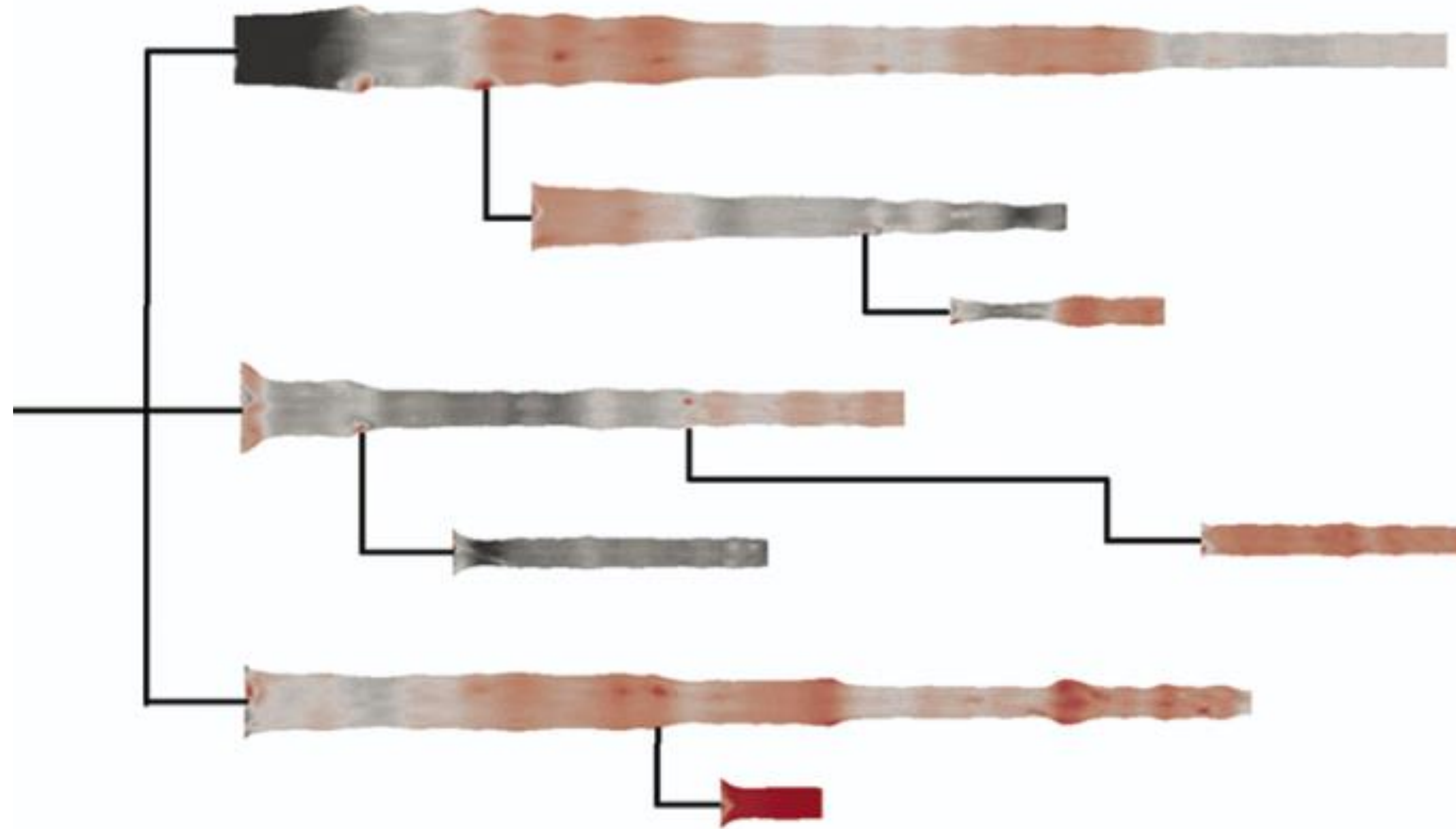


39% Diseased Regions Found

“Get it right in black and white.”

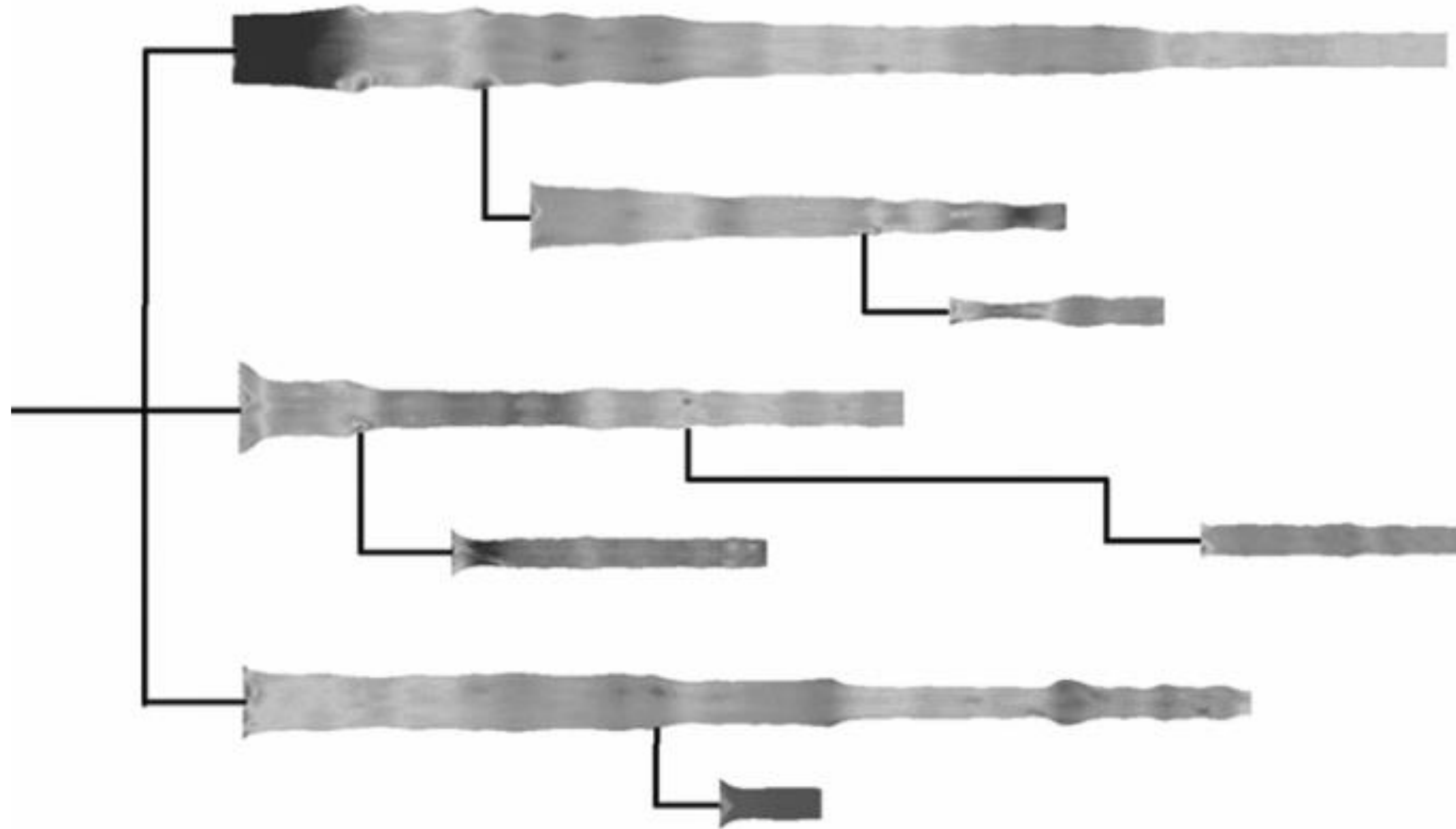


“Get it right in black and white.”



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?

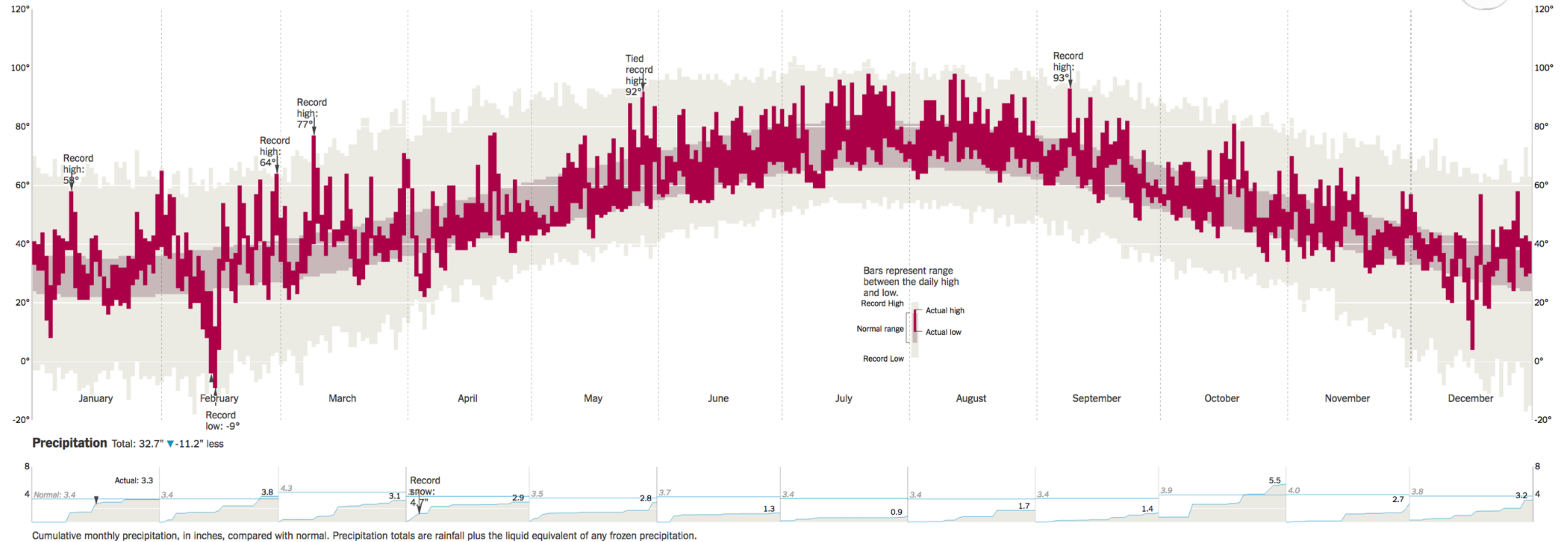
By K.K. REBECCA LAI JAN. 18, 2017

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?

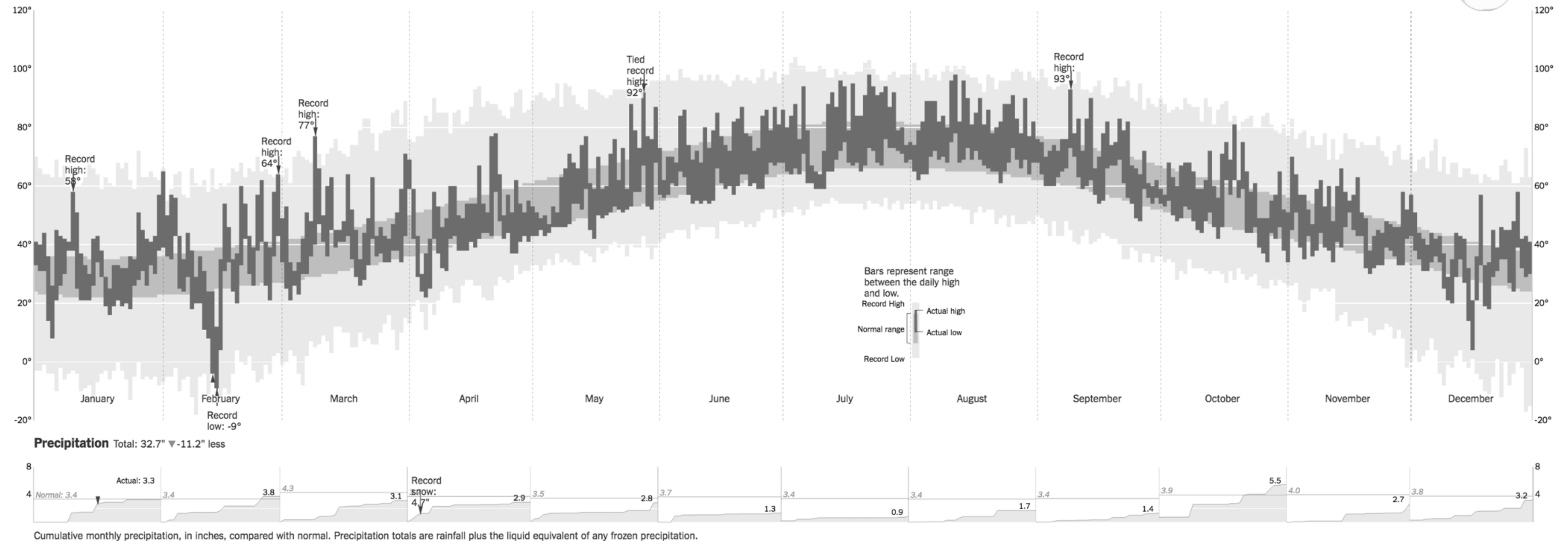
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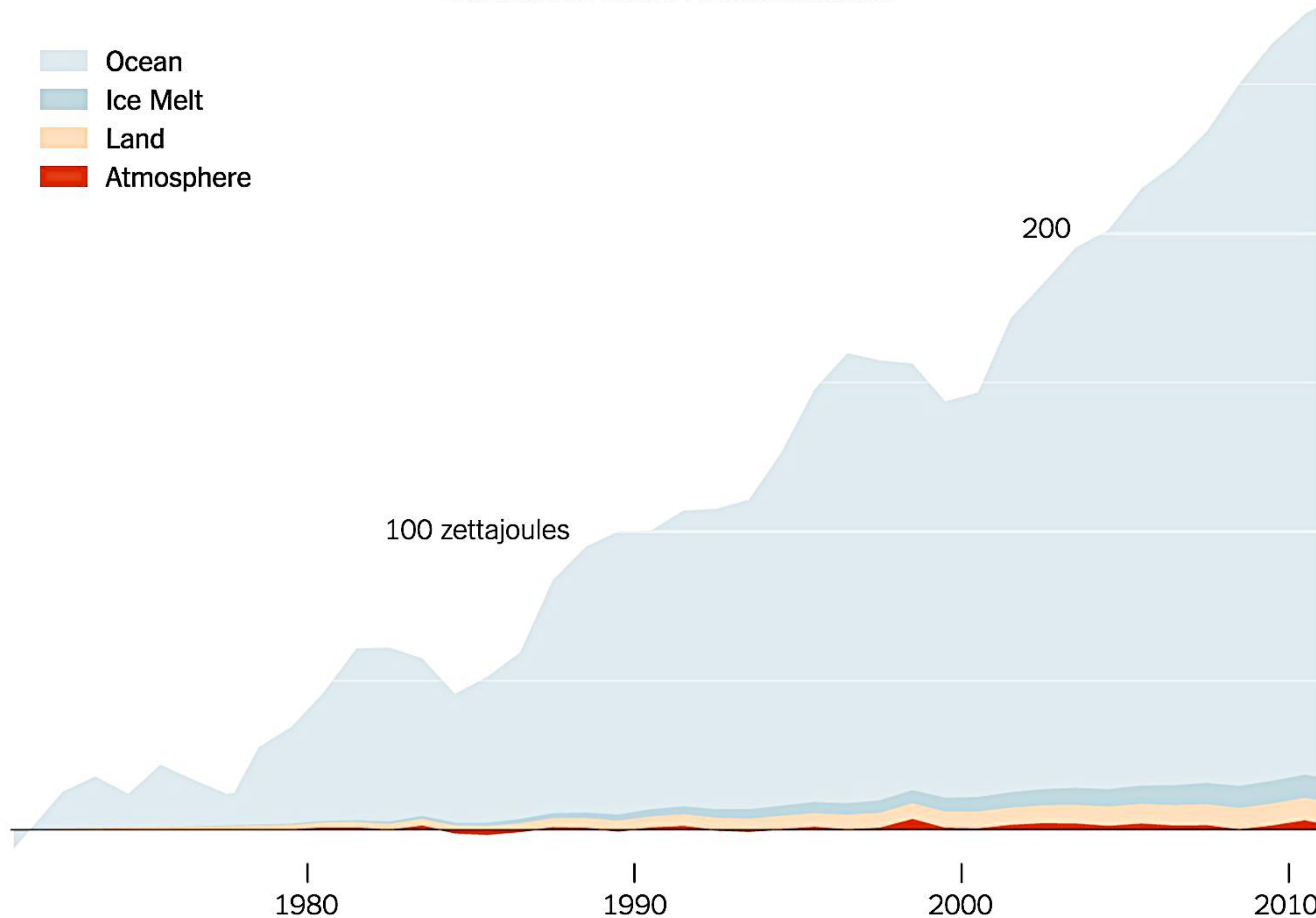
°F °C



“Get it right in black and white.”

Estimated Heat Accumulation

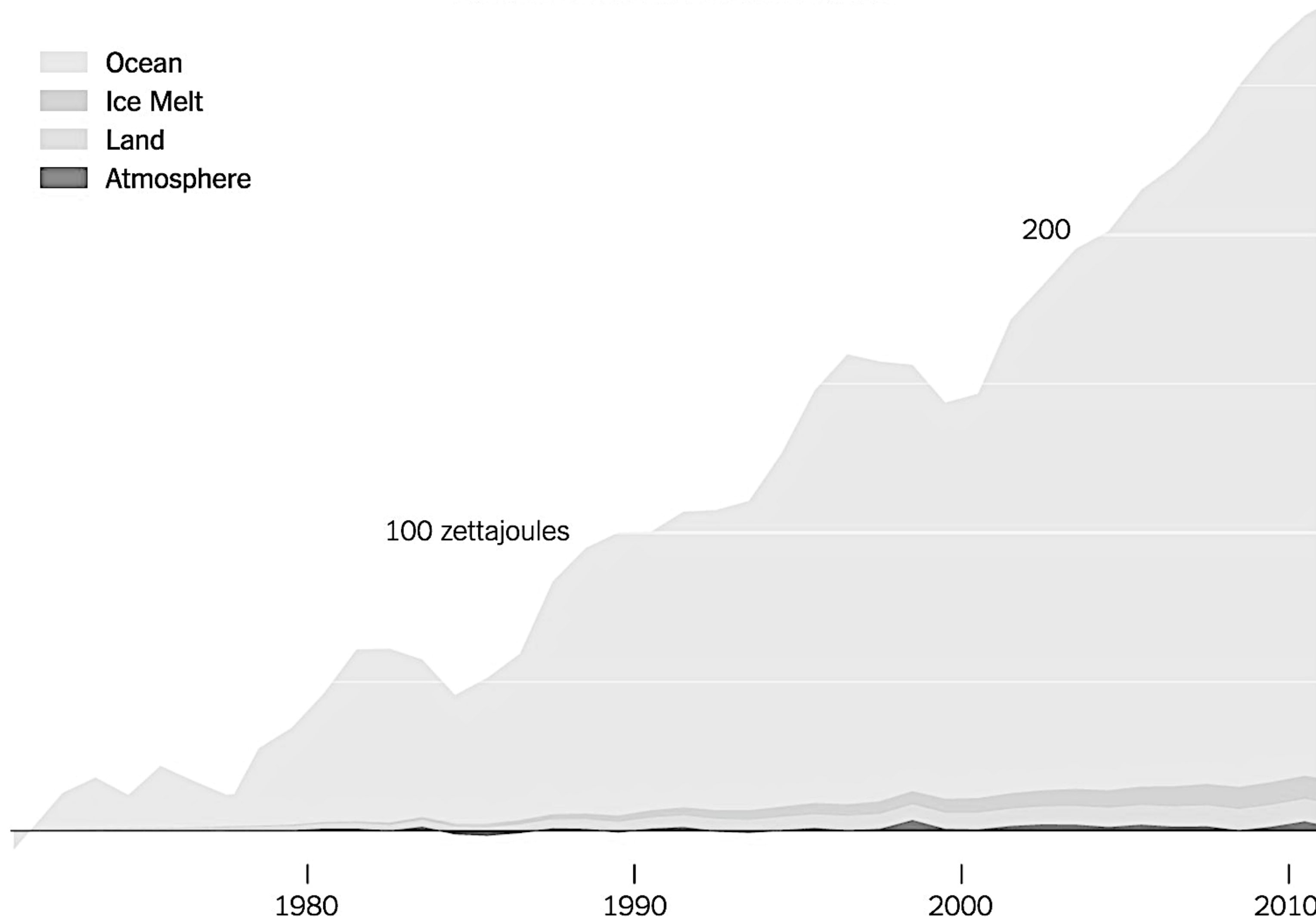
- Ocean
- Ice Melt
- Land
- Atmosphere



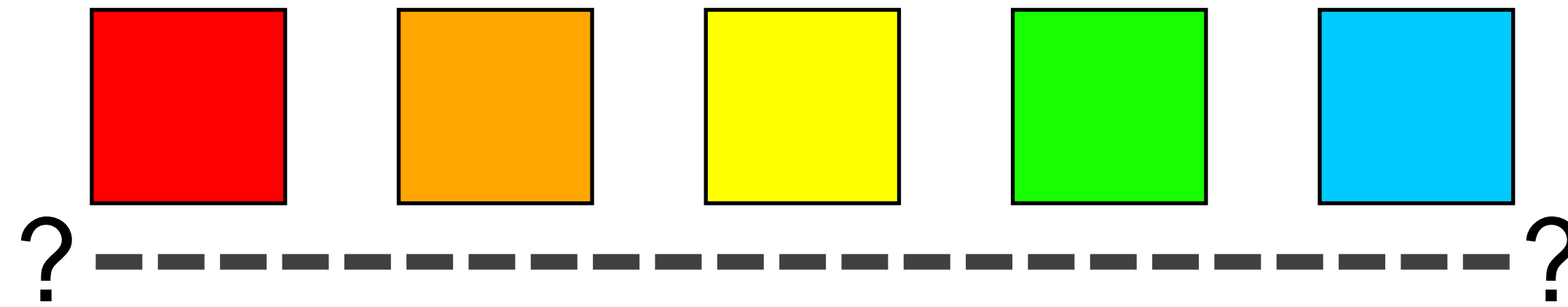
“Get it right in black and white.”

Estimated Heat Accumulation

- Ocean
- Ice Melt
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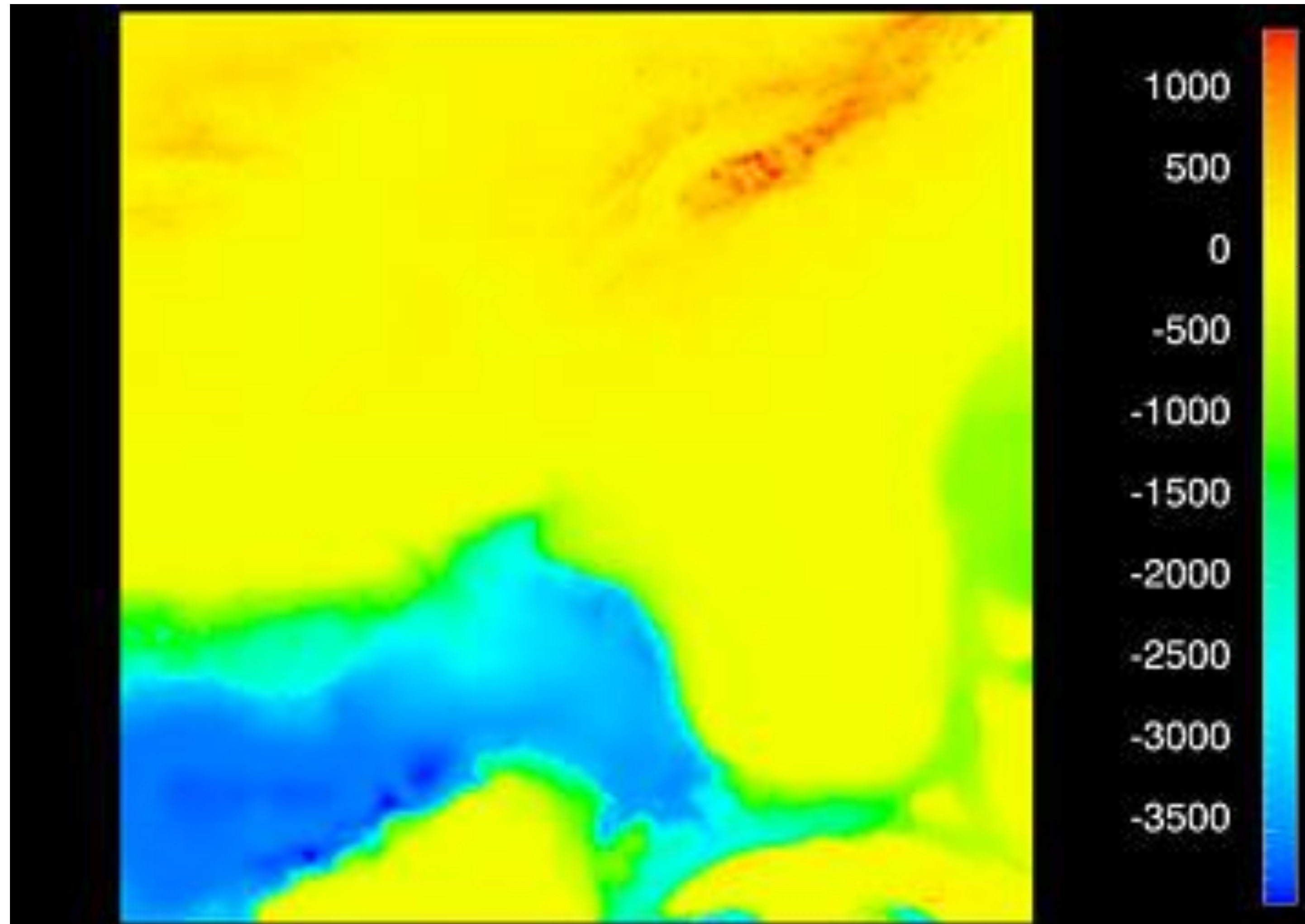
Rainbow Color Map (Hue)



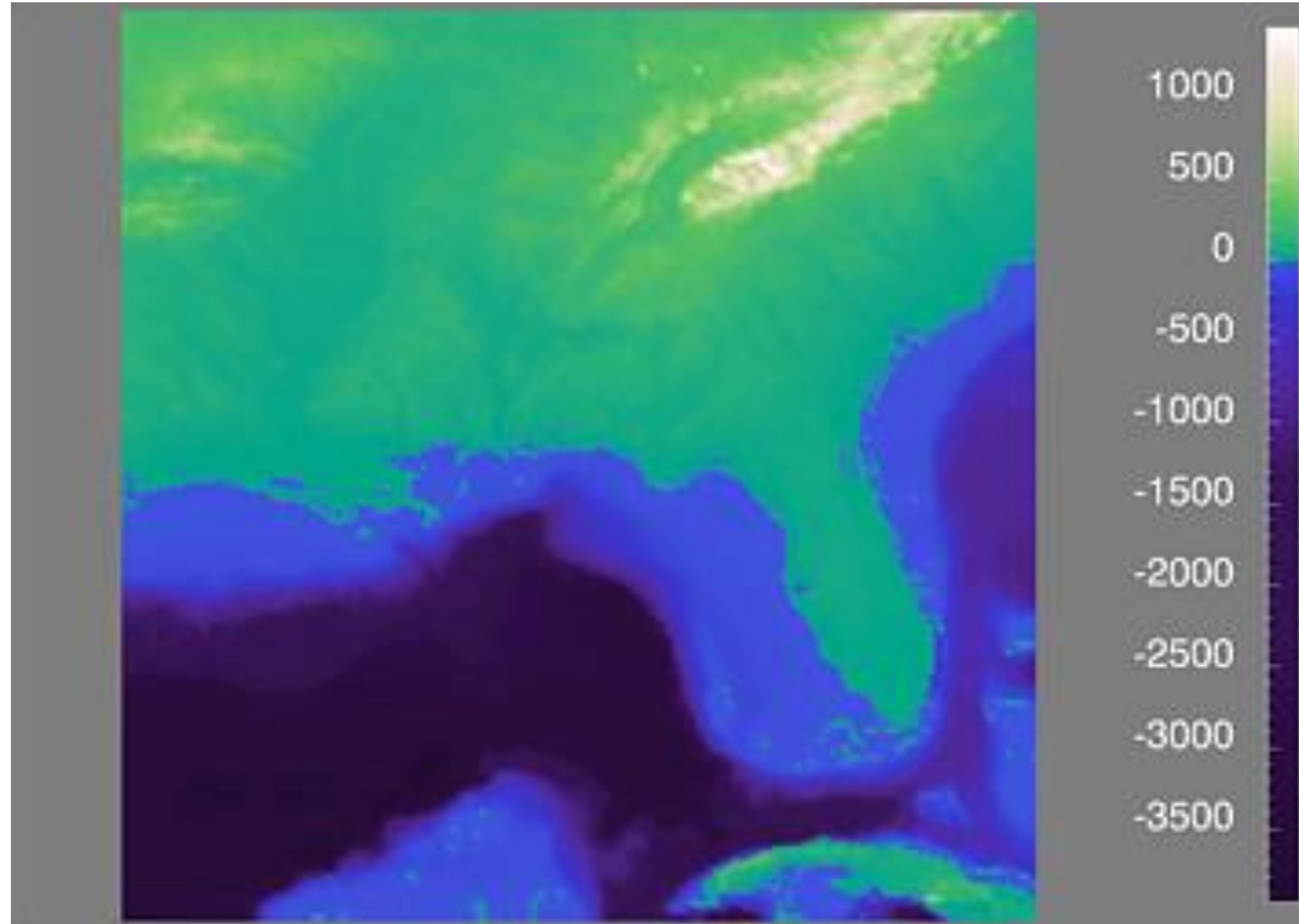
Why this color map is a poor choice for quantitative data...

- 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)

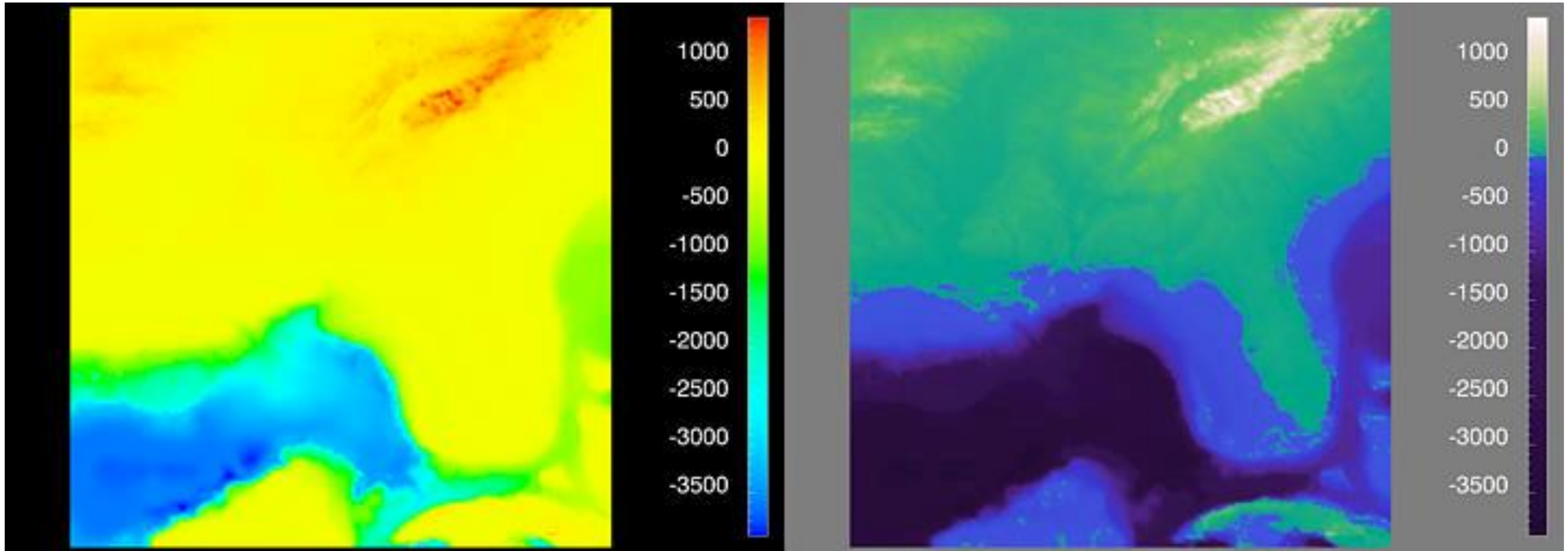
Color Maps



Color Maps



Color Maps

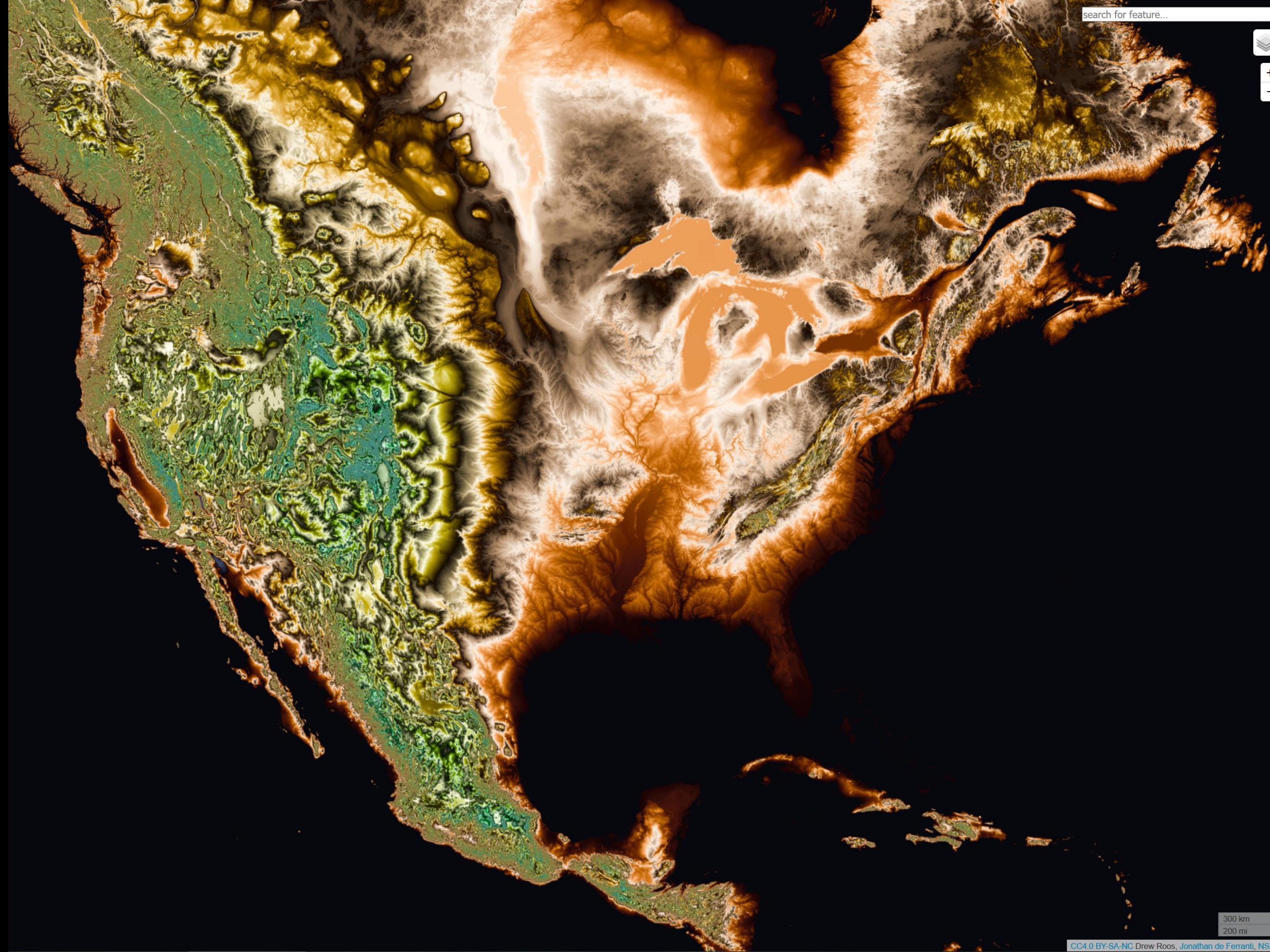


Sequential (possibly wrong)

Diverging

Sequential rainbow (wrong!)





search for feature...



300 km
200 mi

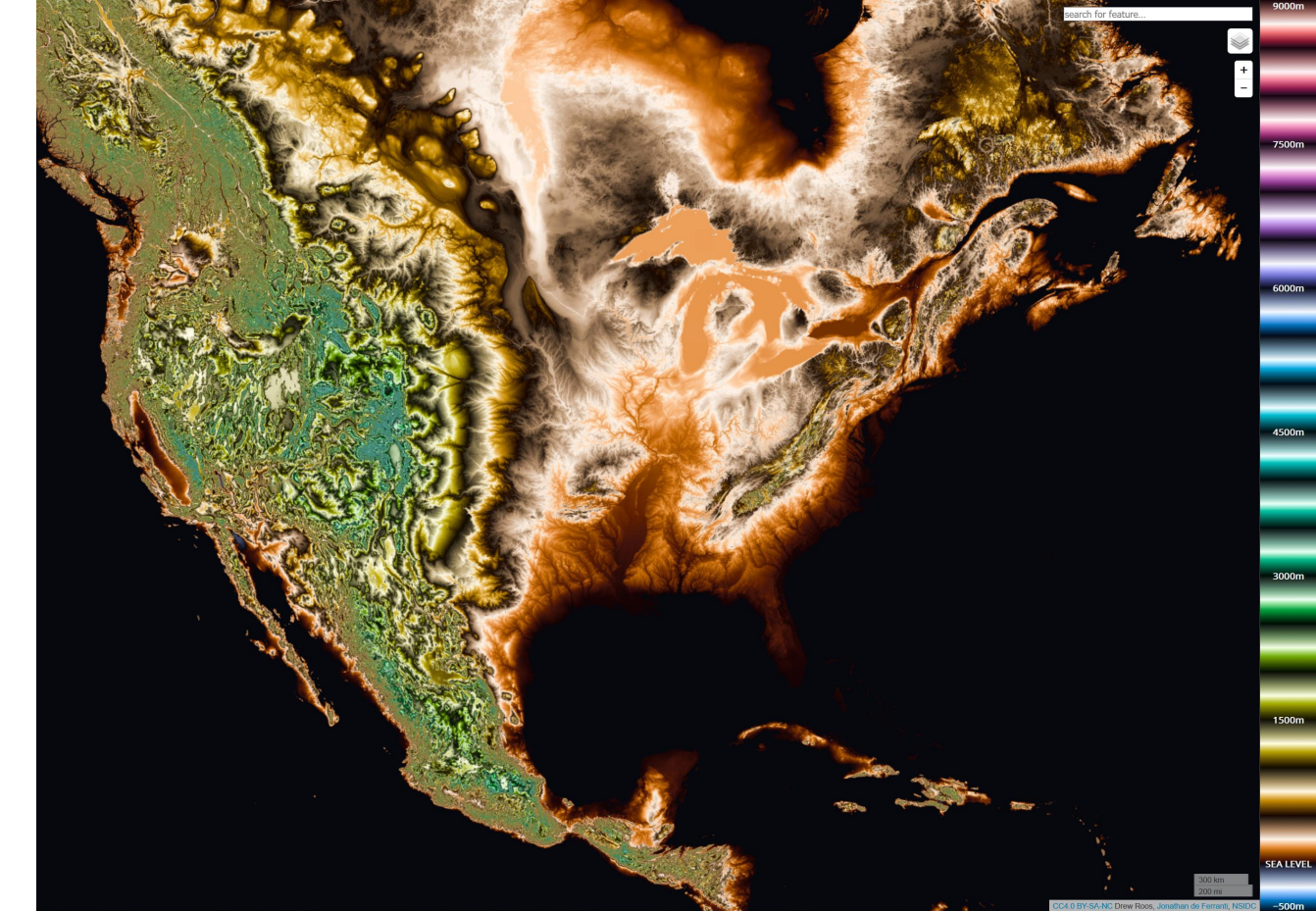
CC4.0 BY-SA-NC Drew Roos, Jonathan de Ferranti, NSIDC

[Roos, 2015](#)

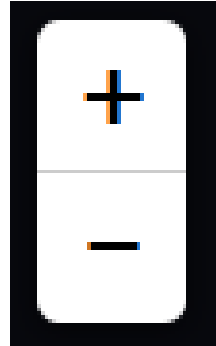

IN-CLASS EXERCISE

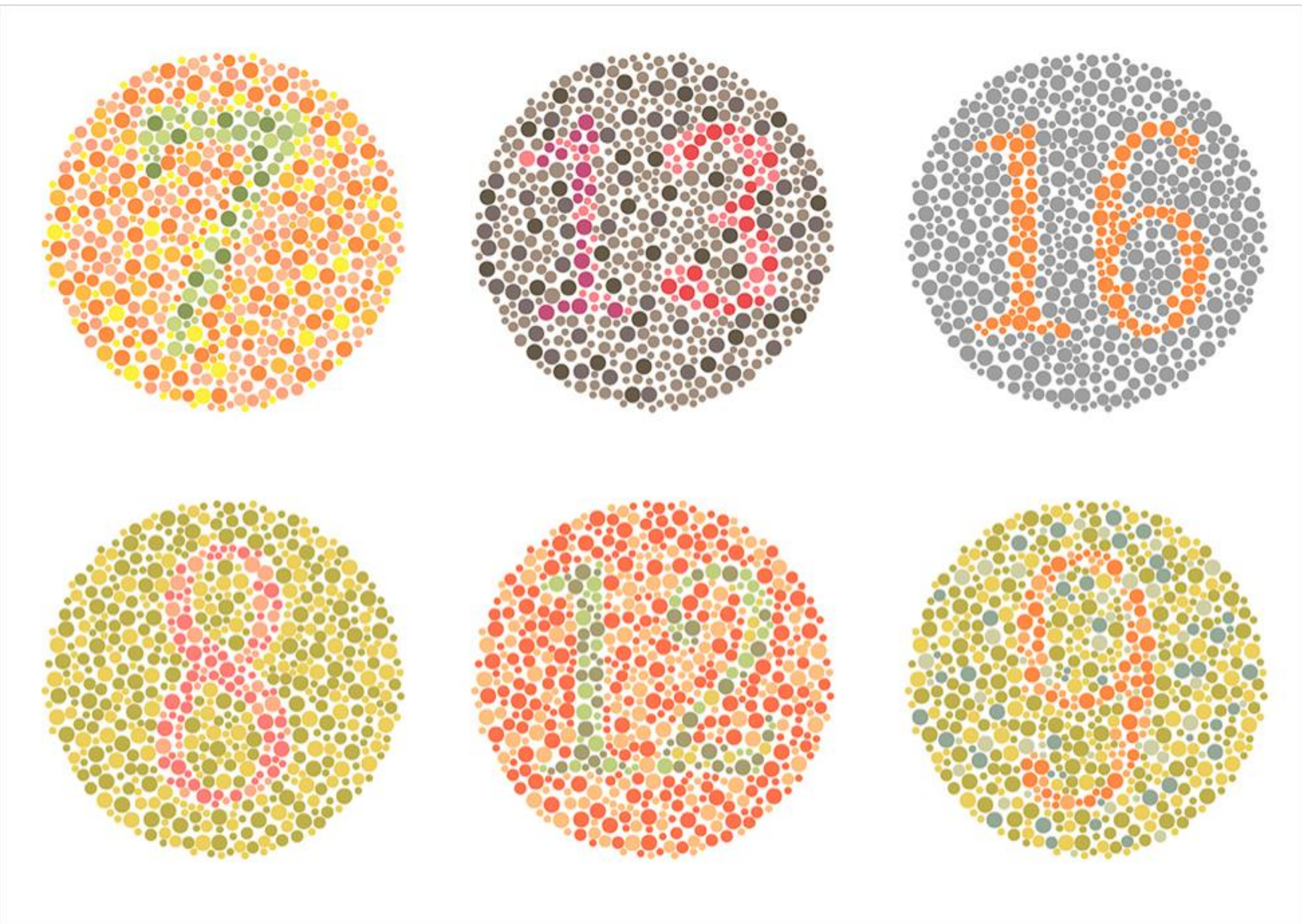
In-class exercise: Oilslick

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



Tritanope = faulty blue cones

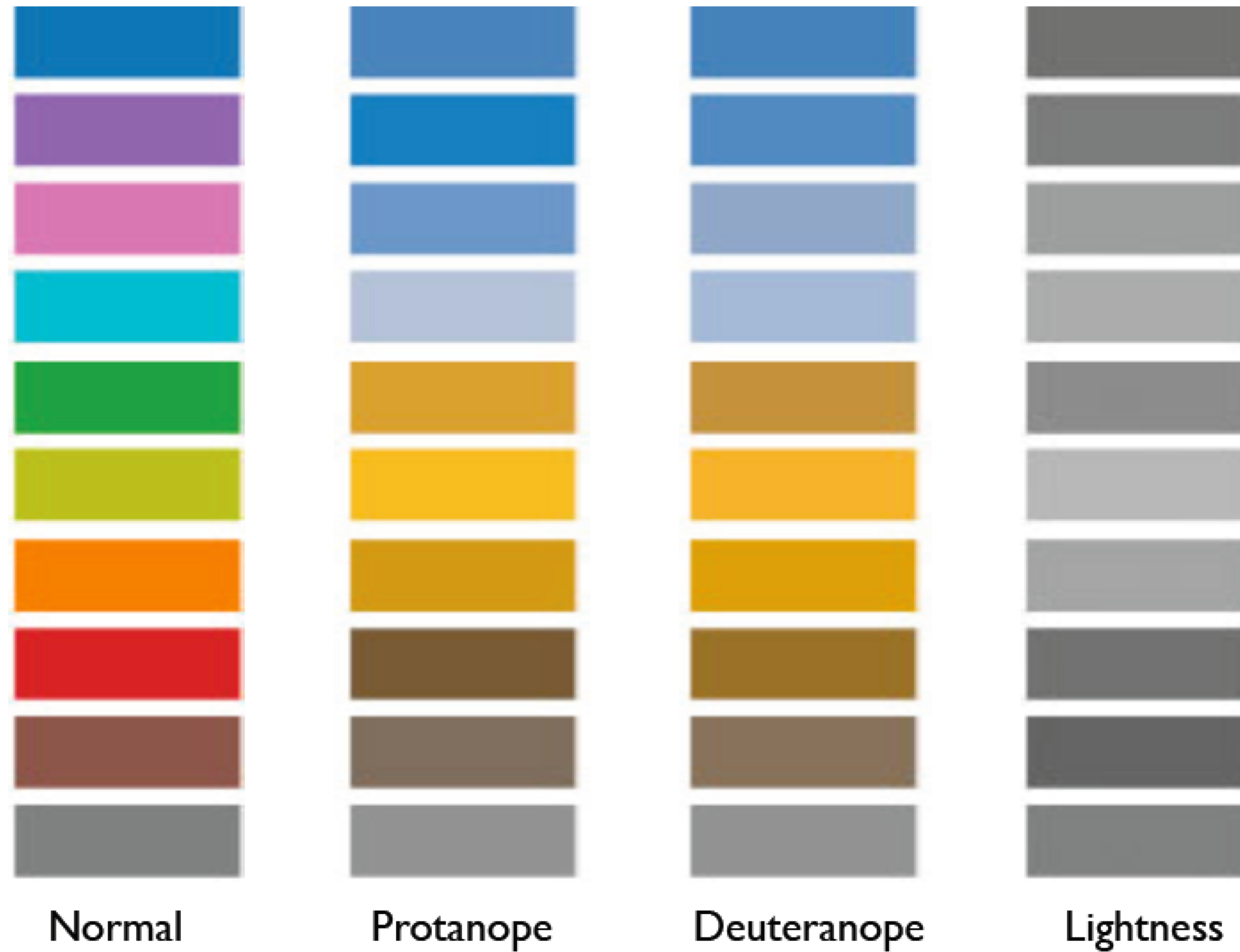


Deuteranope = faulty green cones

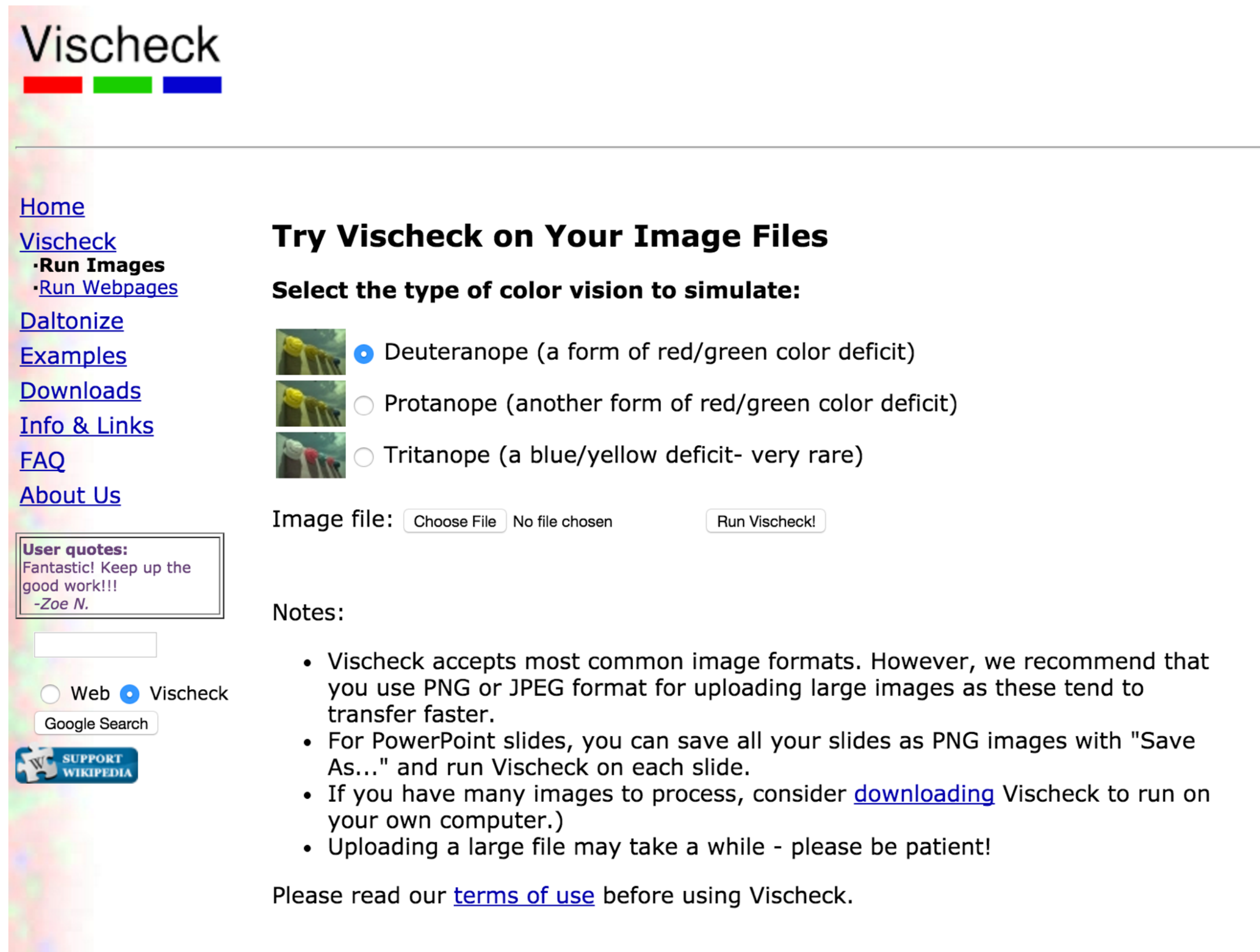


normal

Color Deficiencies (Color Blindness)



Check your images/colormaps for issues!



Vischeck

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

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.

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

Web Vischeck





Colblindor

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:
<input checked="" type="radio"/> Normal	<input type="radio"/> Red-Weak/Protanomaly	<input type="radio"/> Red-Blind/Protanopia	<input type="radio"/> Monochromacy
	<input type="radio"/> Green-Weak/Deuteranomaly	<input type="radio"/> Green-Blind/Deuteranopia	<input type="radio"/> Blue-Congenital
	<input type="radio"/> Blue-Weak/Tritanomaly	<input type="radio"/> Blue-Blind/Tritanopia	

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.



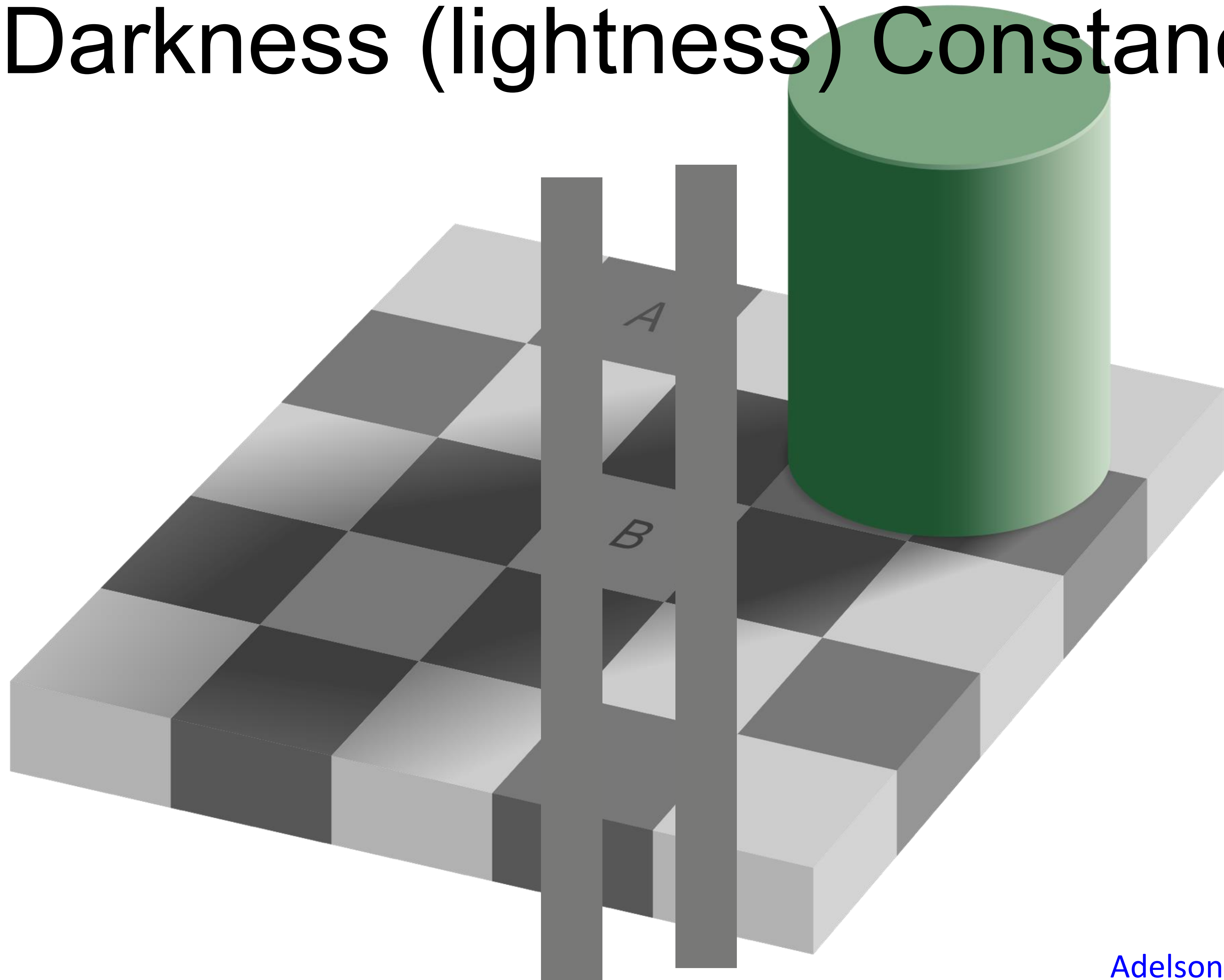
INTERACTIONS BETWEEN COLORS AND WITH LIGHTING

“Lightness Constancy”

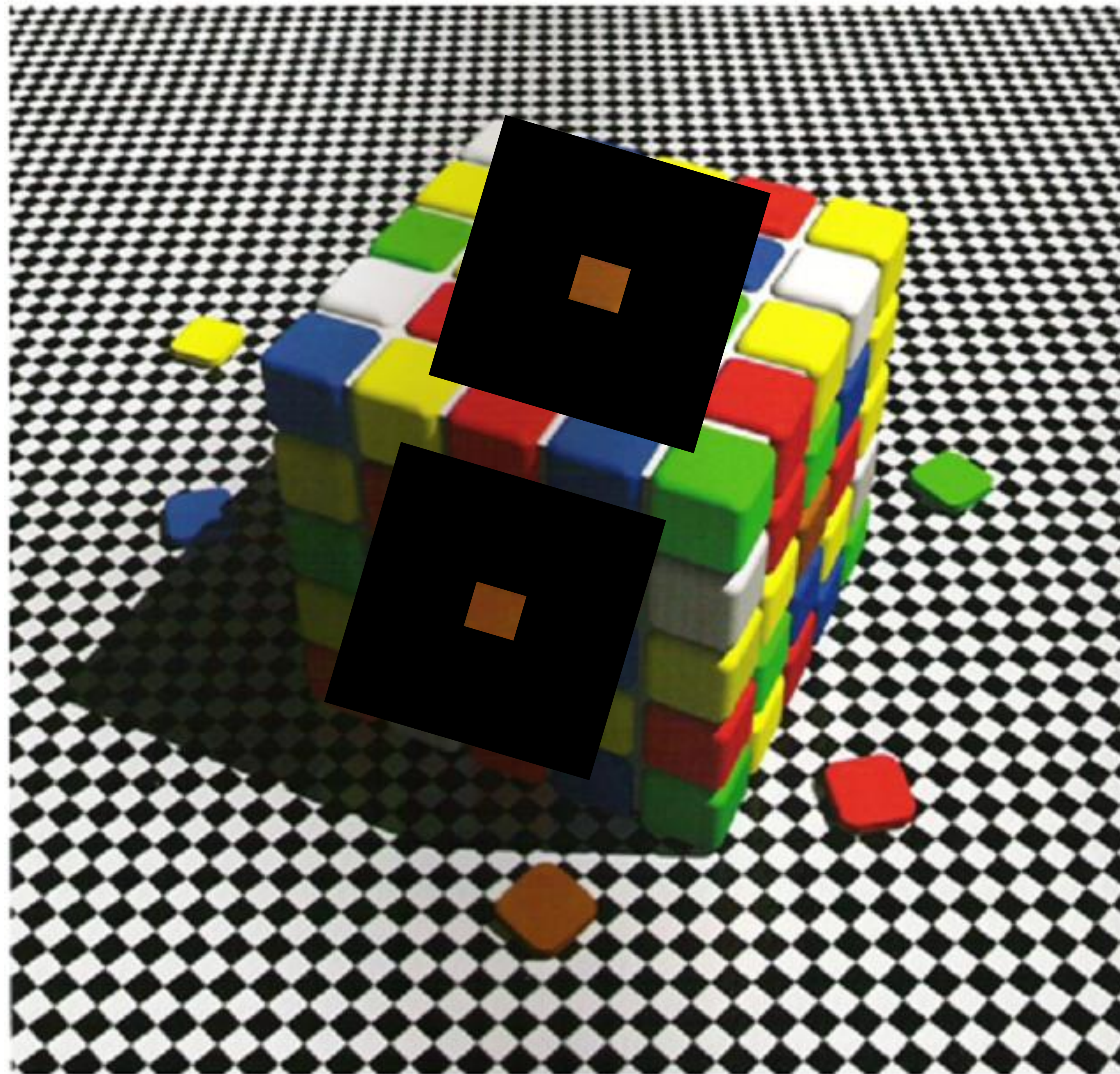
The perception that the apparent brightness of light and dark surfaces remains more or less the same under different luminance conditions is called **darkness (lightness) constancy**.



“Darkness (lightness) Constancy”



“Color Constancy”



“Simultaneous Contrast”



“Simultaneous Contrast”

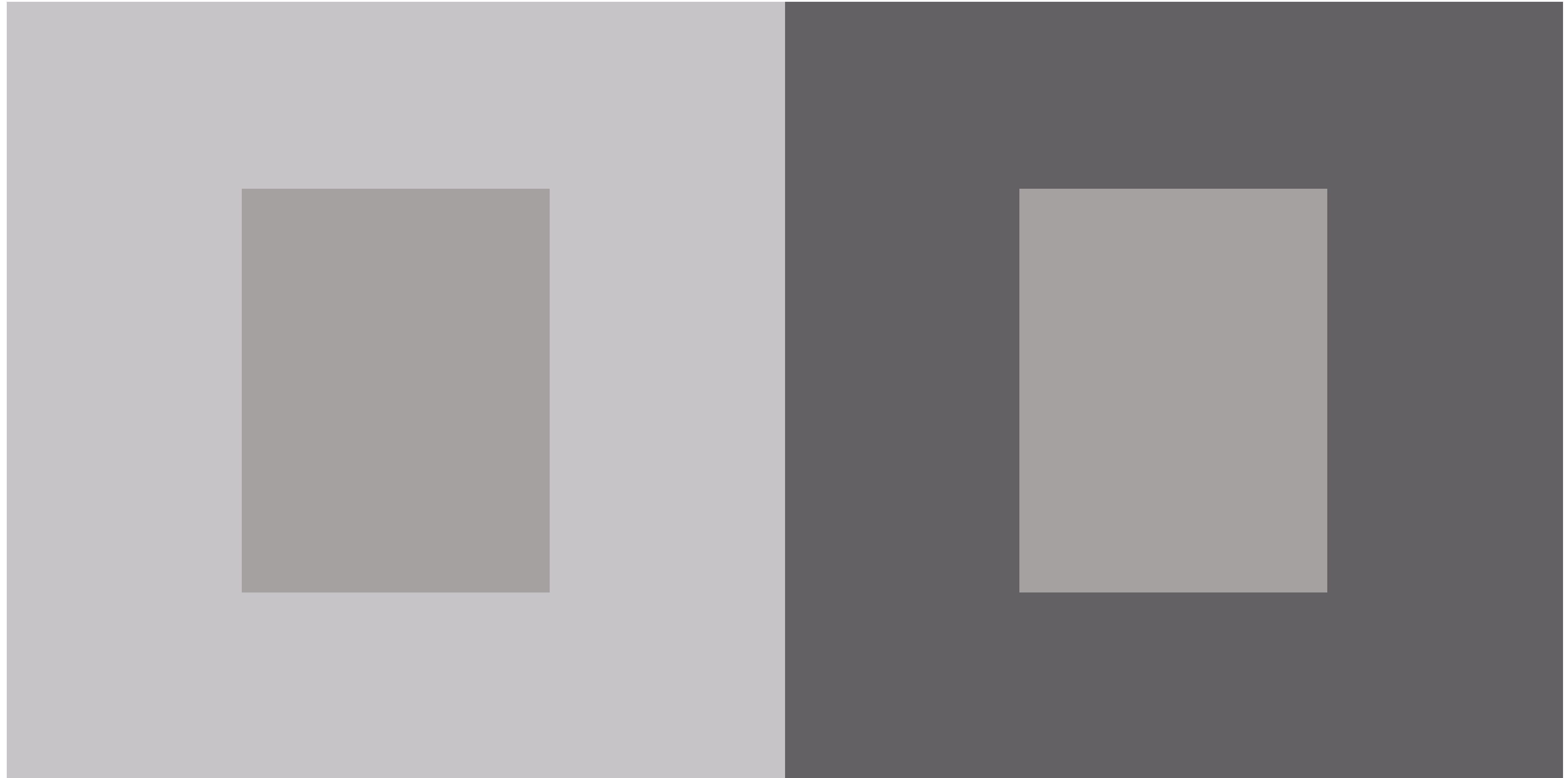


“Simultaneous Contrast”

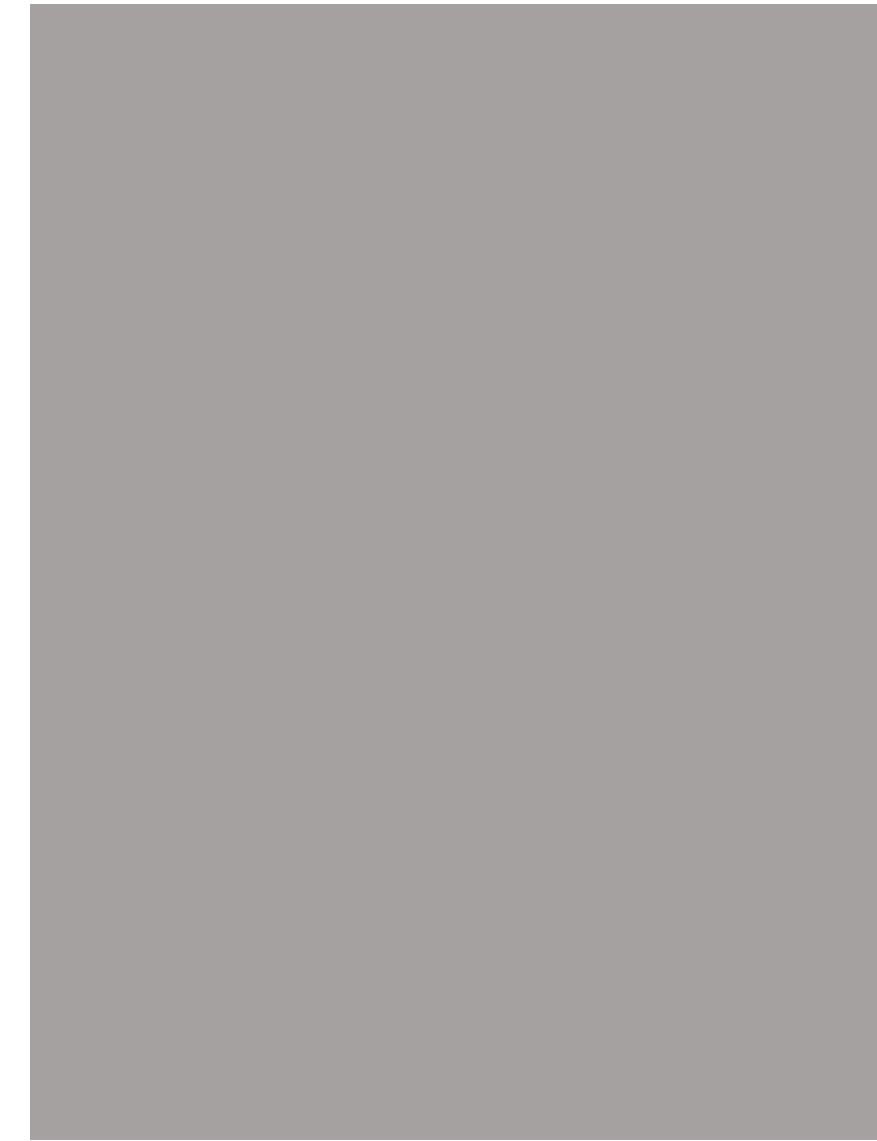
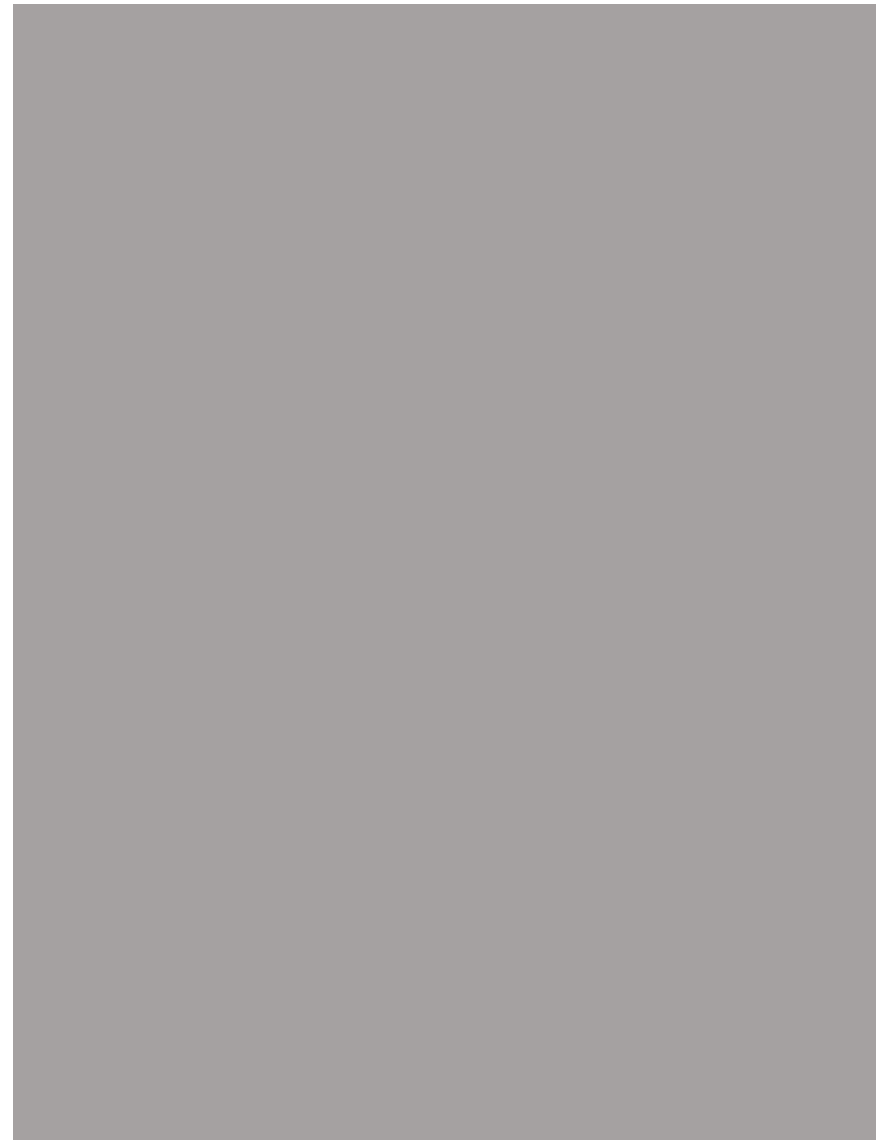


Avoid gradients as backgrounds or bars!

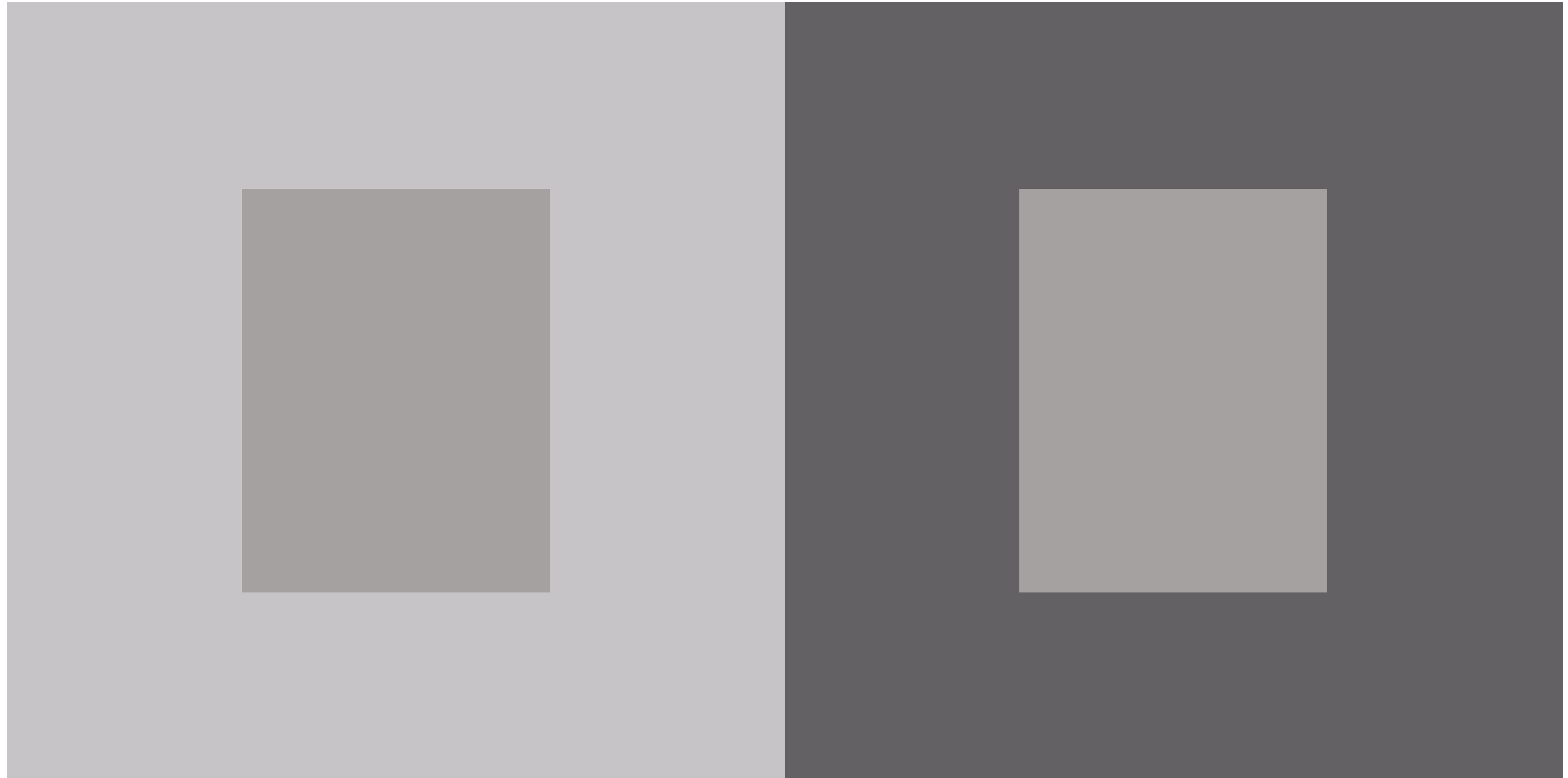
“Simultaneous Contrast”



“Simultaneous Contrast”



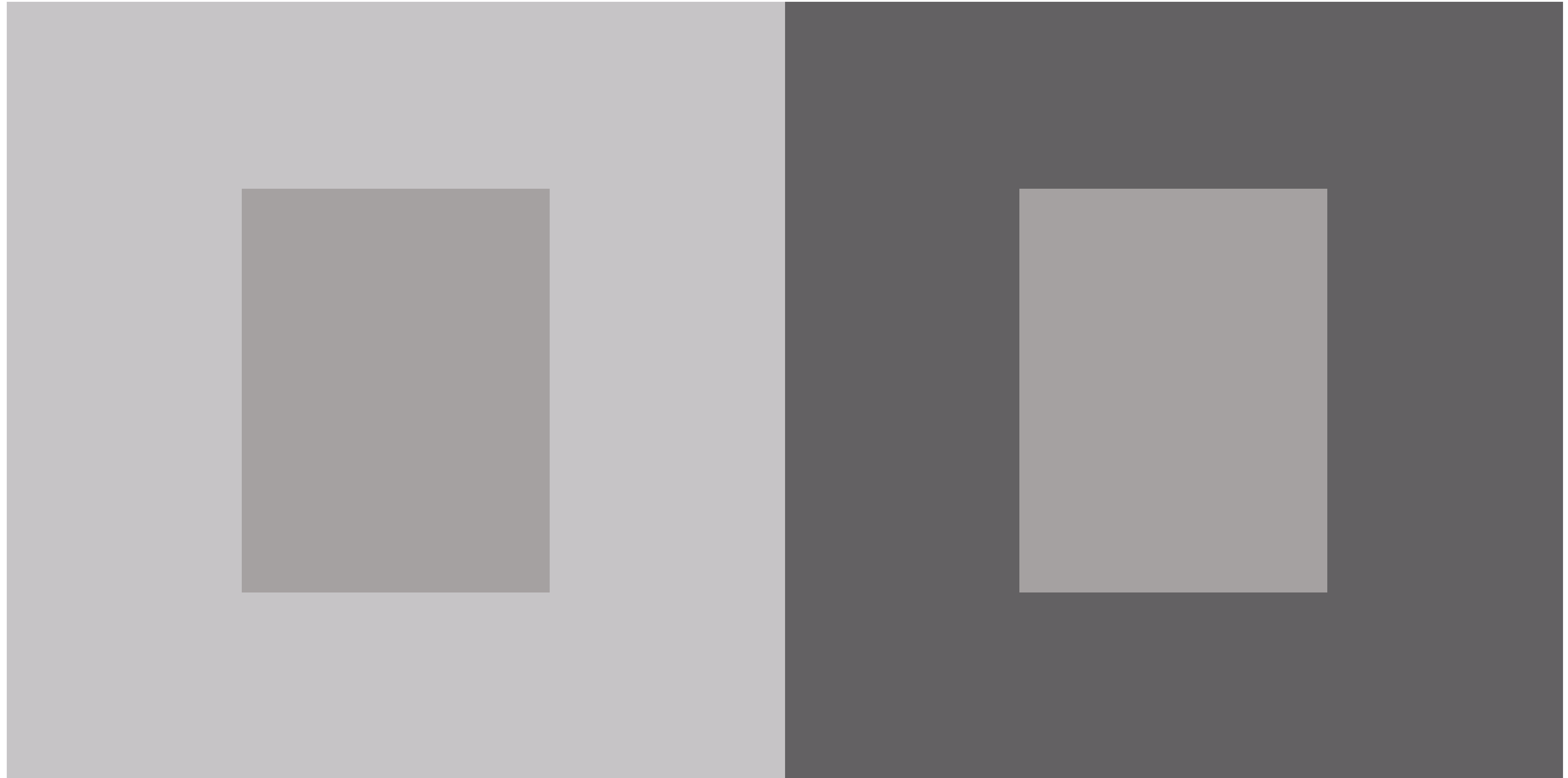
“Simultaneous Contrast”



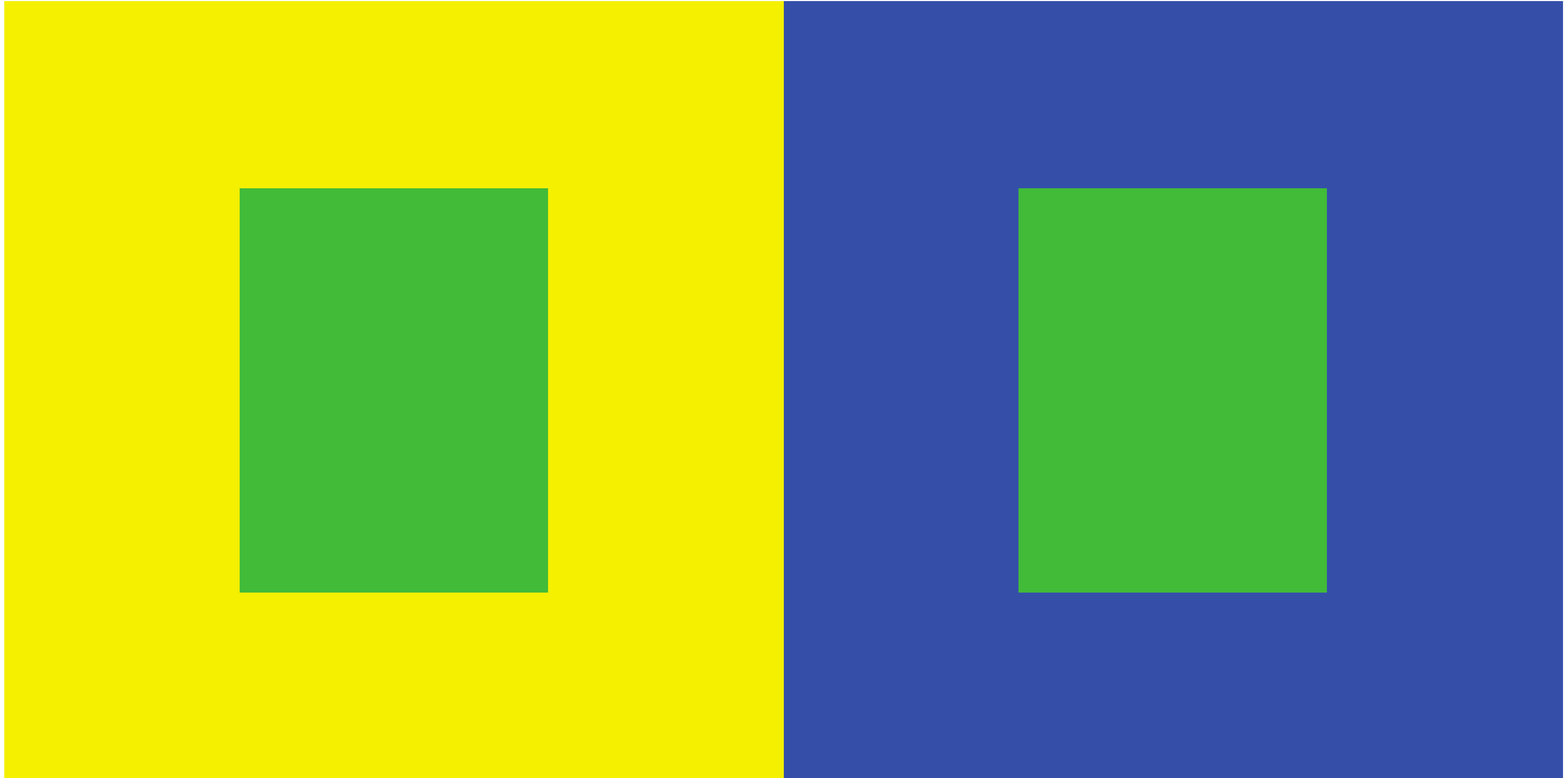
“Simultaneous Contrast”



“Simultaneous Contrast”



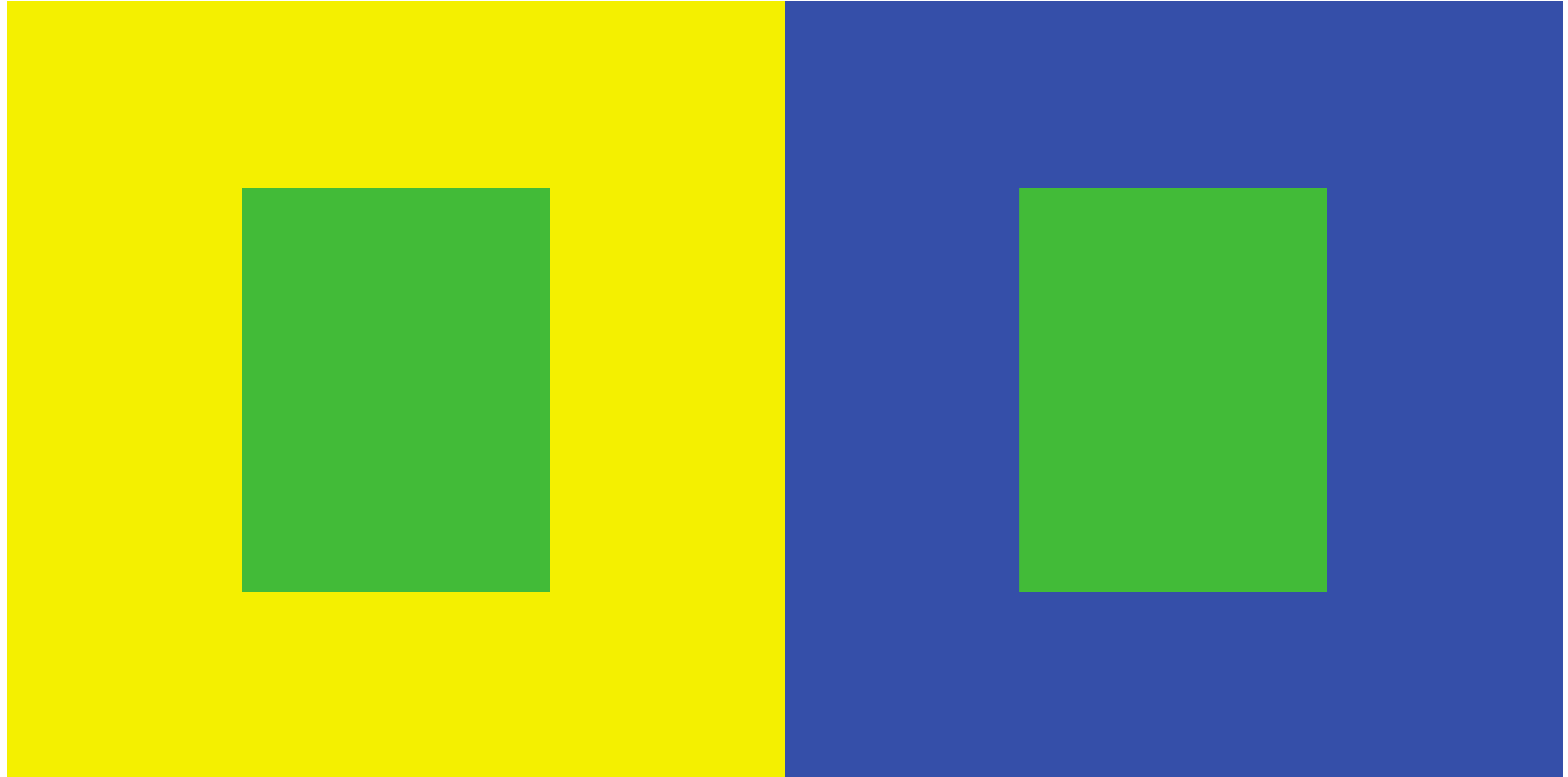
“Simultaneous Contrast”



“Simultaneous Contrast”



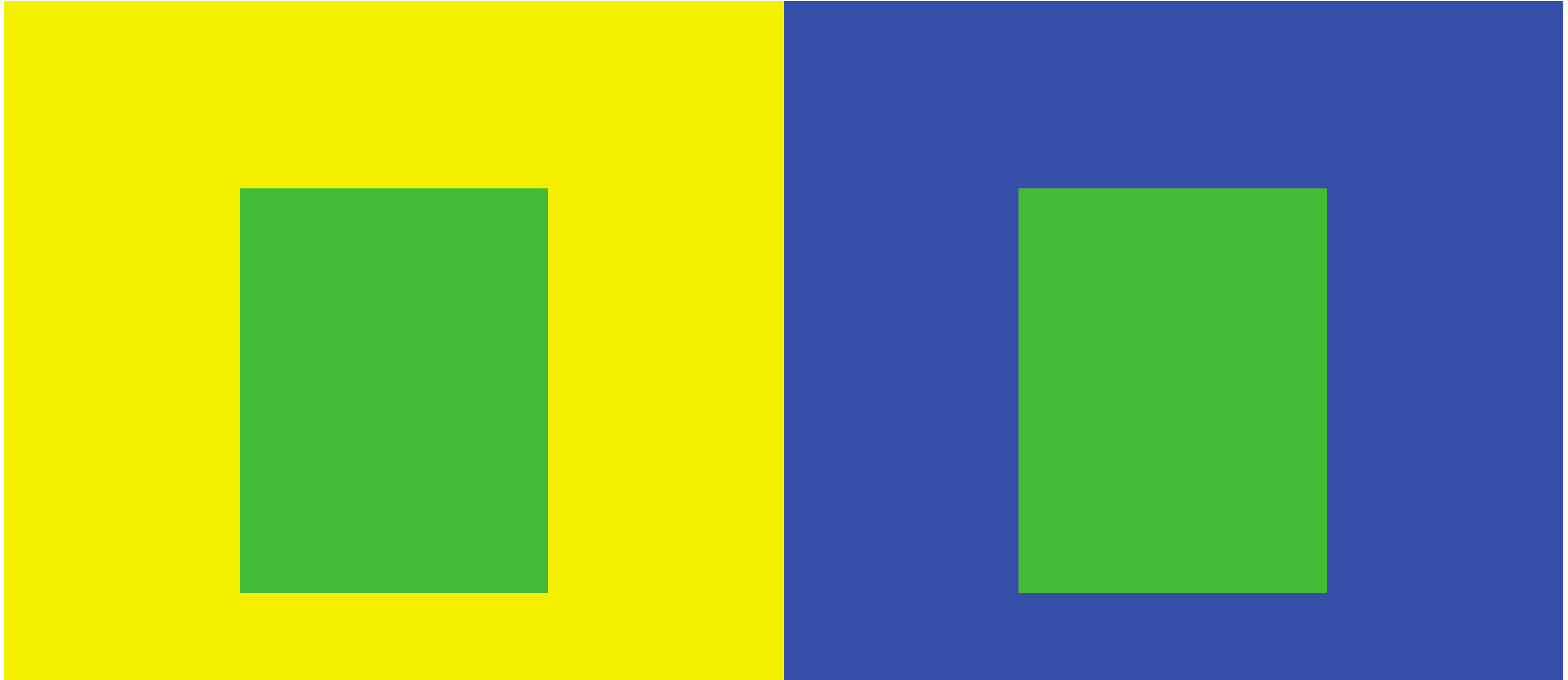
“Simultaneous Contrast”



“Simultaneous Contrast”



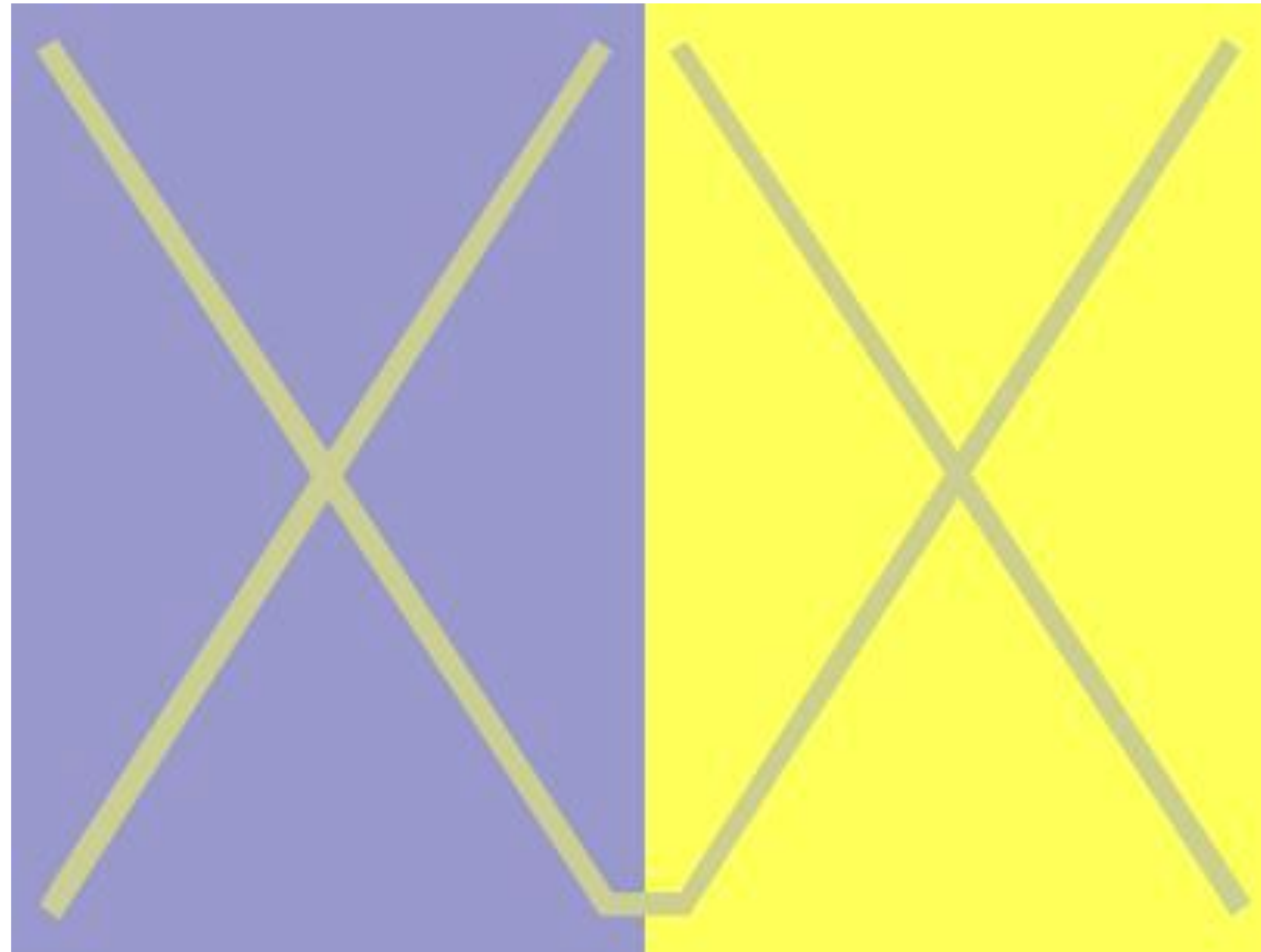
“Simultaneous Contrast”



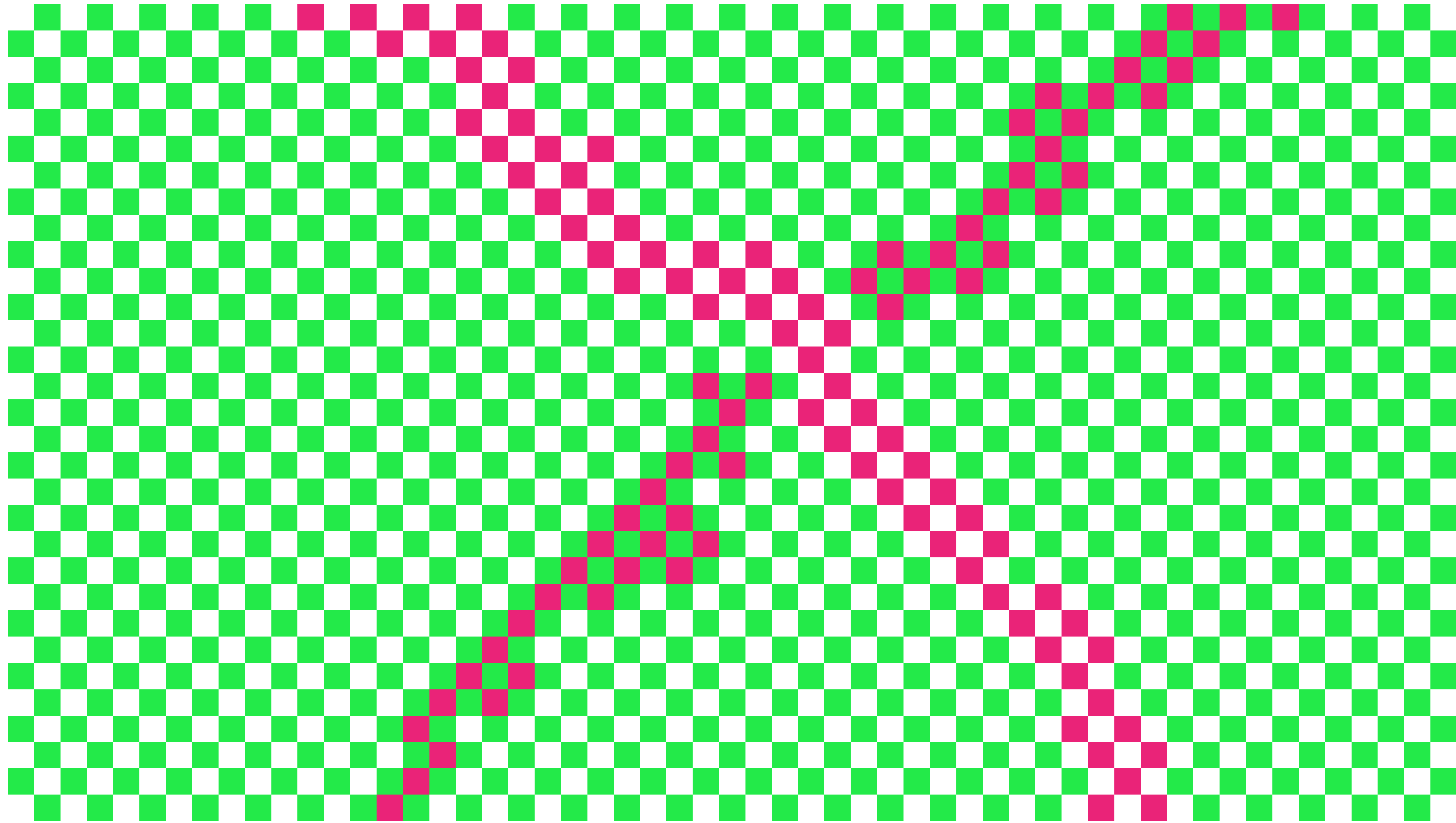
Be careful with bars and scatter plot points - the colors may appear differently with different background colors and neighboring colors!

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

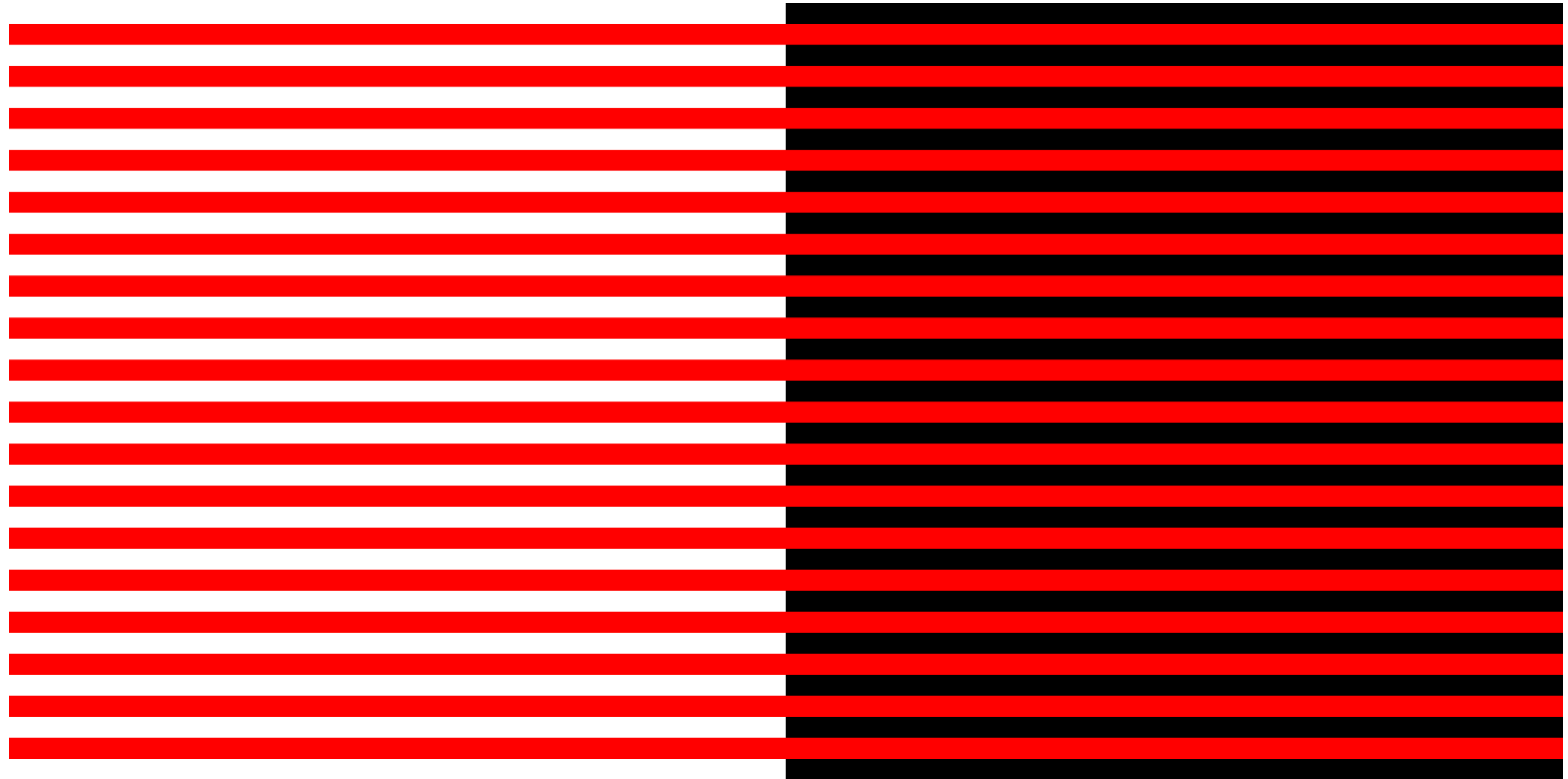
“Simultaneous Contrast”



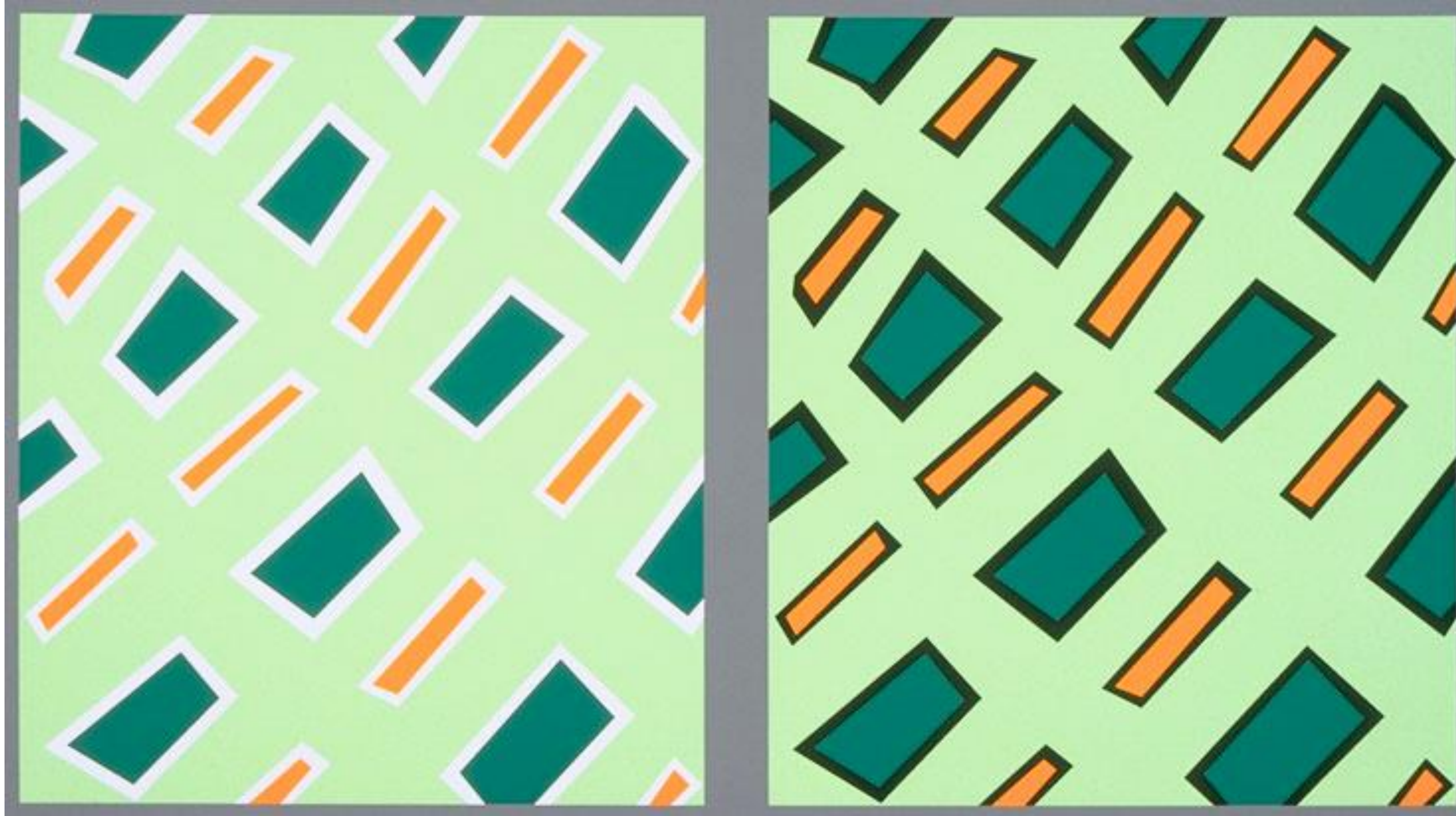
“Simultaneous Contrast”



“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)?

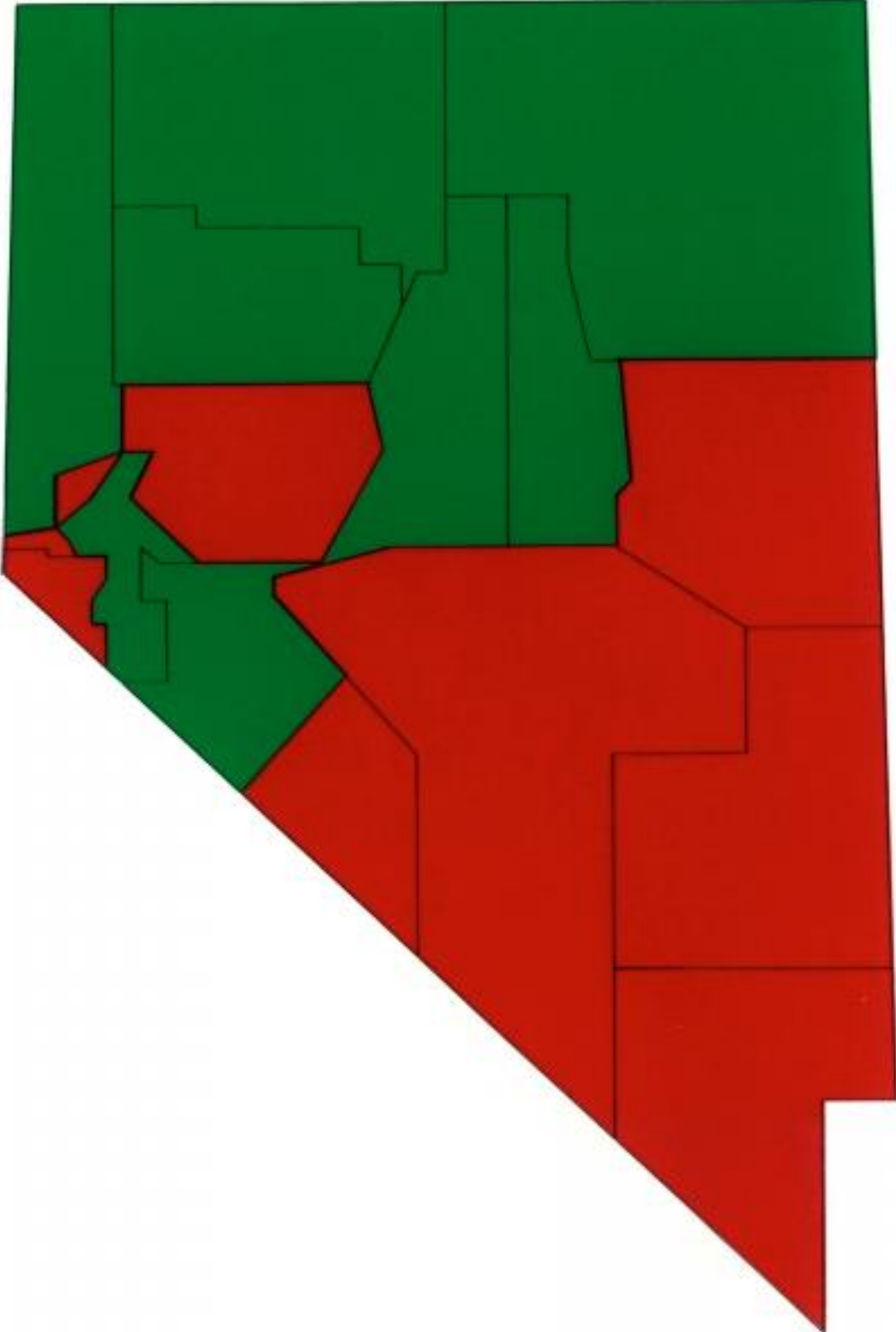


Figure 1. Stimulus From the High-Saturation Group

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)

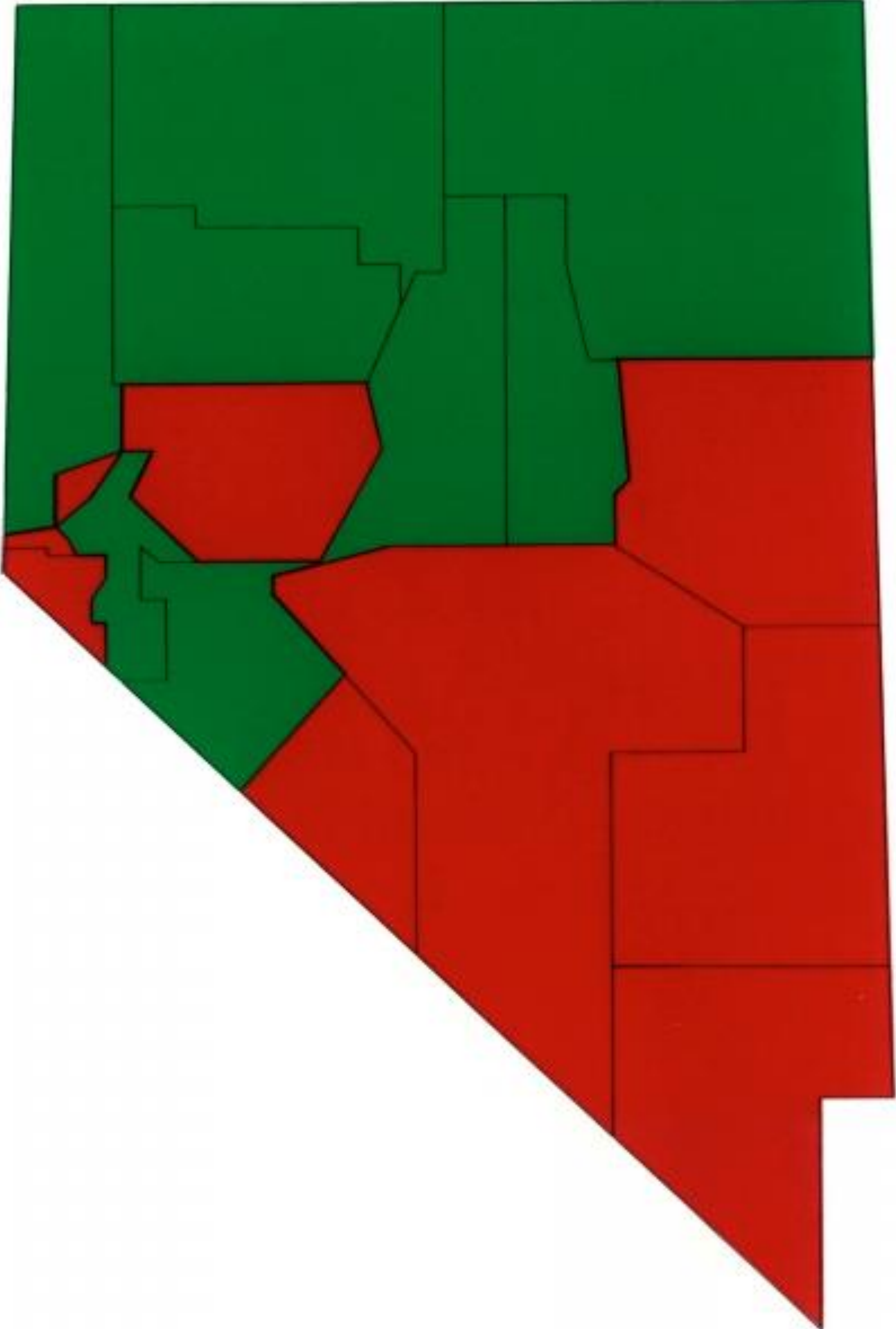


Figure 1. Stimulus From the High-Saturation Group

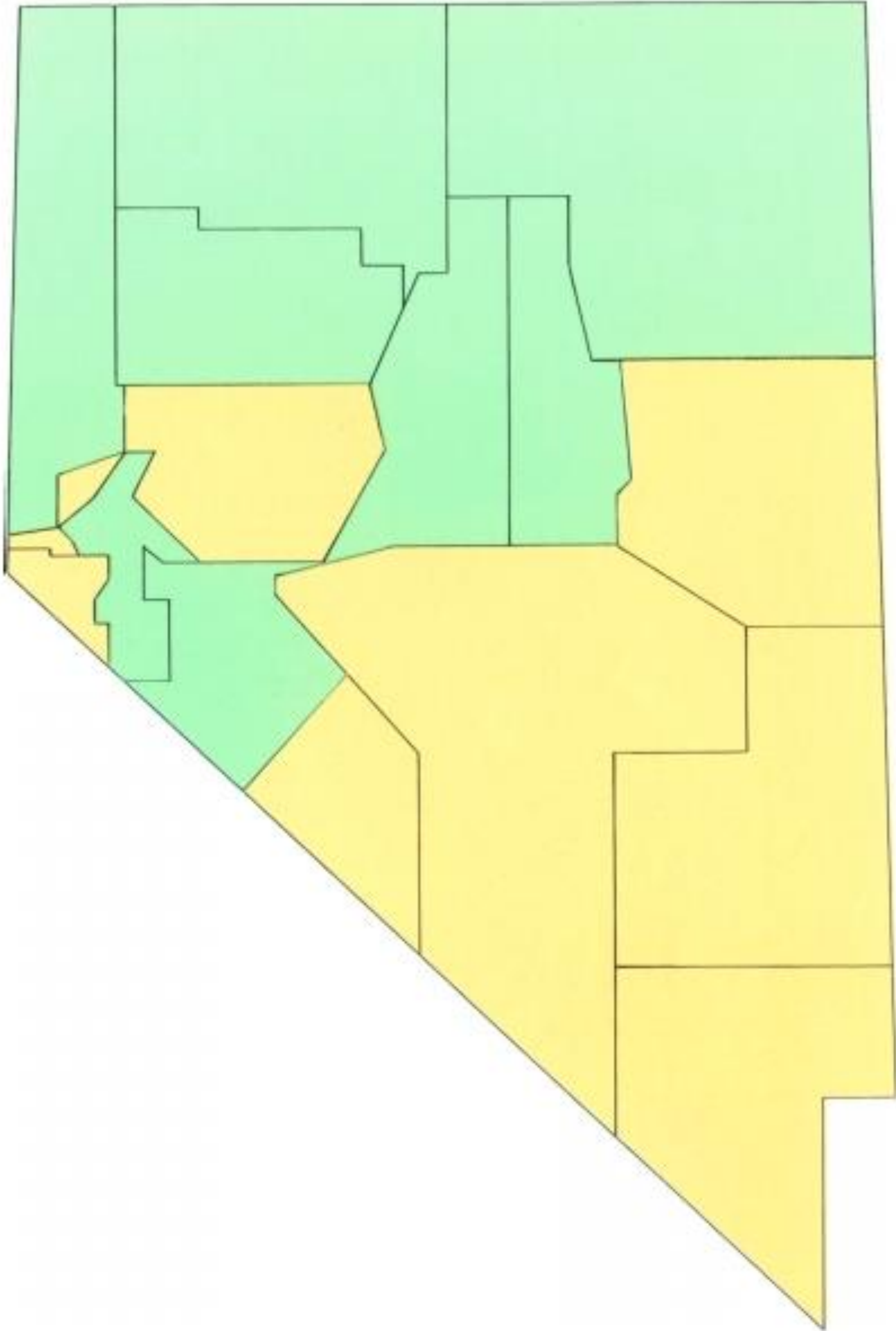
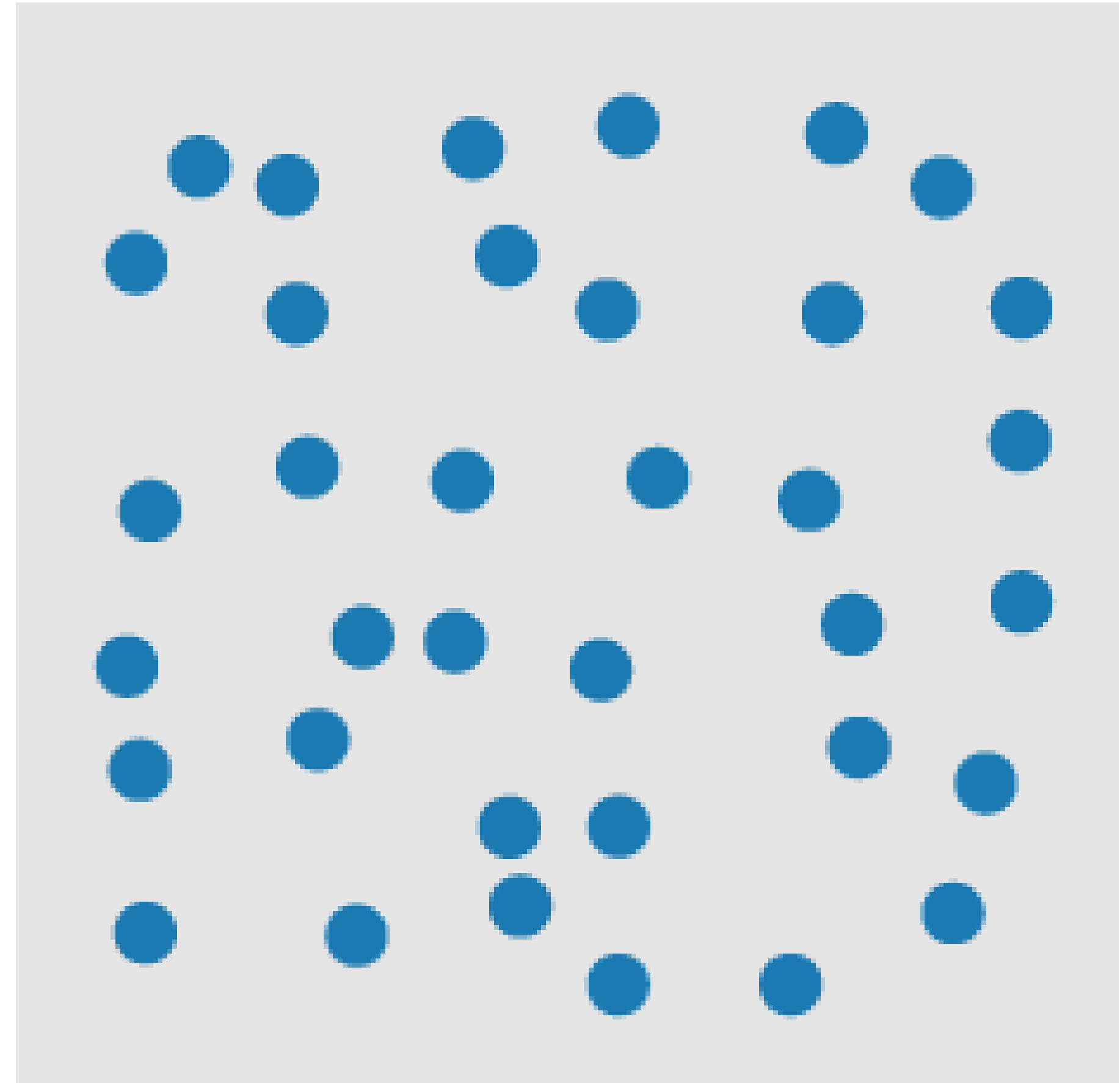
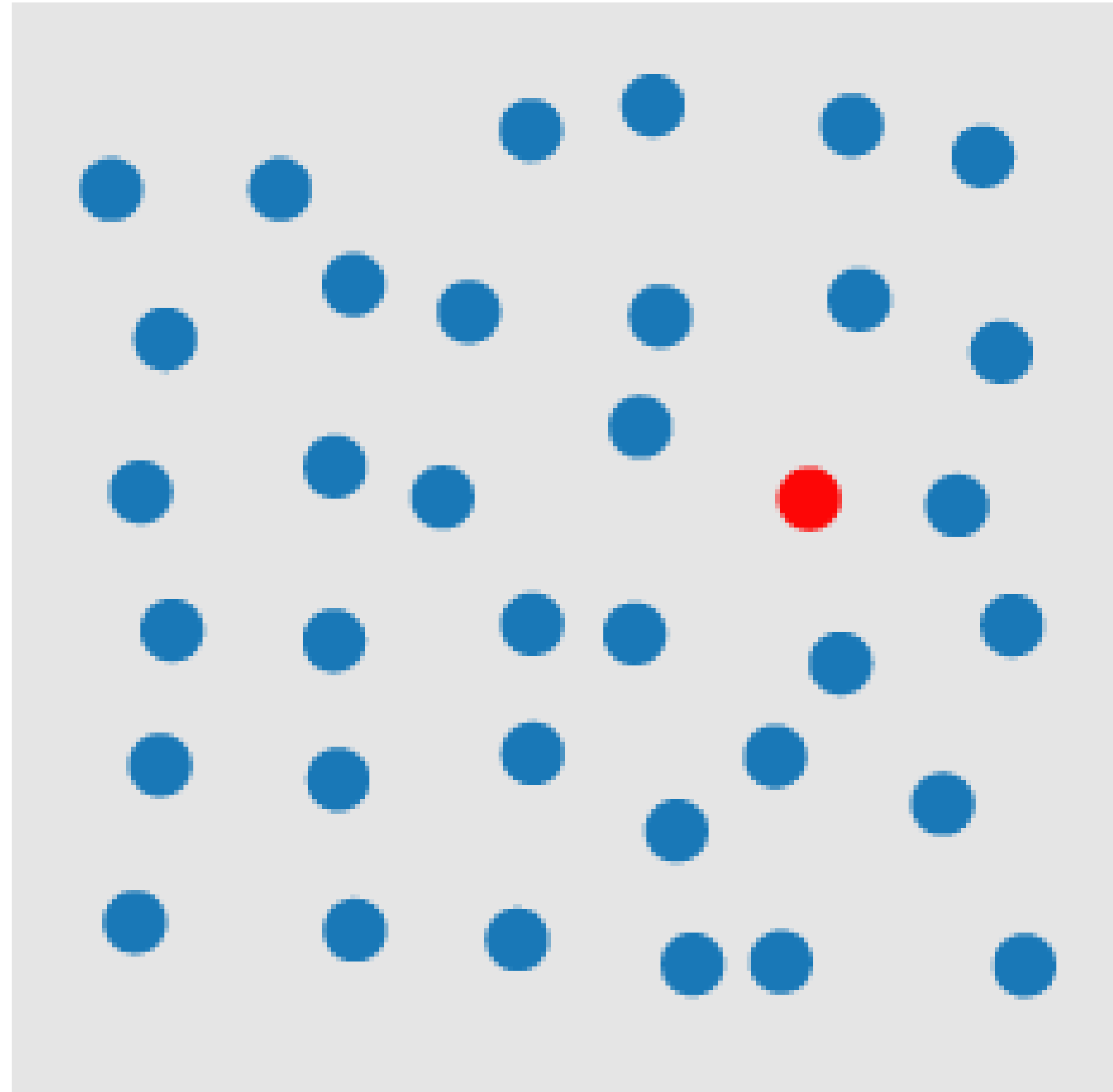


Figure 2. Stimulus From the Low-Saturation Group

POP-OUT EFFECTS



COLOR

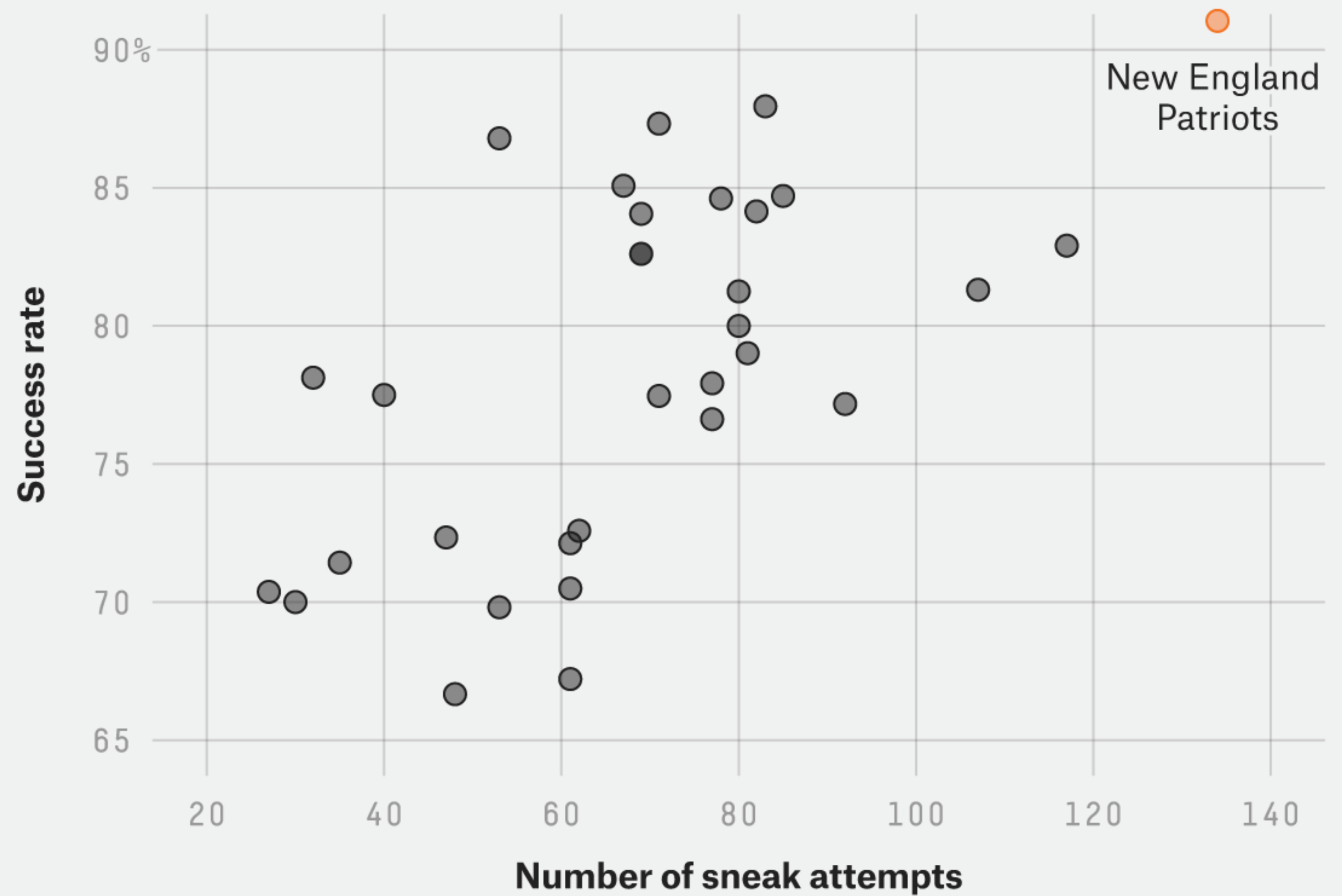
A quarterback sneak is a [play](#) in [American football](#) and [Canadian football](#) in which the [quarterback](#), upon taking the center snap, dives ahead while the offensive line surges forward. It is usually only used in very short yardage situations.

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

For Next Time

neu-ds-4200-f23.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 or marker
- White paper
- Laptop and charger

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

Week 5: Reduce and Embed; Spatial, 3D, and SciVis	
Tue, Oct 03 <i>Reduce and Embed</i> Required Readings: 1 VAD Chapter 13—Reduce Items and Attributes 2 VAD Chapter 14—Embed: Focus + Context	Fri, Oct 06 <i>Spatial, 3D, and scientific visualization</i> Required Readings: 1 VAD Chapter 8—Arrange Spatial Data 4—Altair basic charts due at 11:59pm
Week 6: Networks and Trees, validation and evaluation	
Tue, Oct 10 <i>Networks and Trees</i> Required Readings: 1 VAD Chapter 9—Arrange Networks and Trees	Fri, Oct 13 <i>Validation and evaluation</i> Required Readings: 1 VAD Chapter 4—Analysis: Four Levels for Validation