

Visual Encodings, Color

DS 4200

FALL 2020

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NORTHEASTERN UNIVERSITY

Slides and inspiration from Michelle Borkin, Krzysztof Gajos, Hanspeter Pfister, Miriah Meyer, Jonathan Schwabish, and David Sprague

CHECK-IN

PREVIOUSLY, ON DS 4200...

Analysis



What?

Why?

How?

DATA ABSTRACTION

TASK ABSTRACTION

VISUAL ENCODING

Analysis



What?

What data is shown?

Why?

Why is the user analyzing / viewing it?

How?

How is the data presented?

How?

Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



→ Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



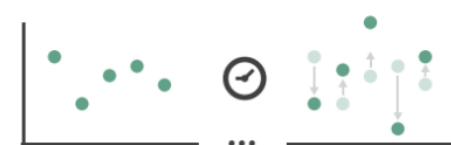
→ Motion

Direction, Rate, Frequency, ...



Manipulate

→ Change



→ Select



→ Navigate

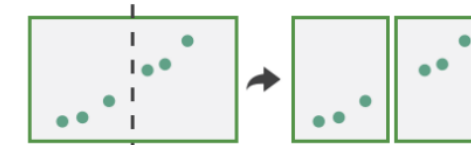


Facet

→ Juxtapose



→ Partition



→ Superimpose



Reduce

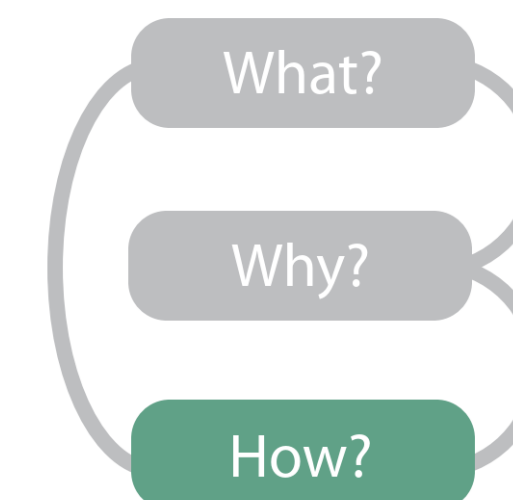
→ Filter



→ Aggregate



→ Embed



Arrange Tables

→ Separate, Order, Align Regions

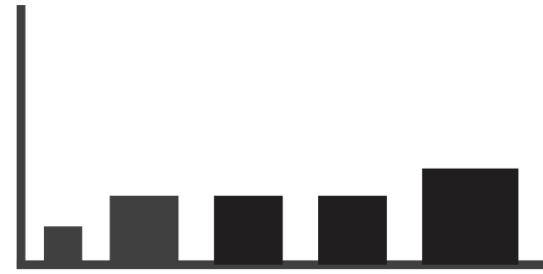
→ Separate



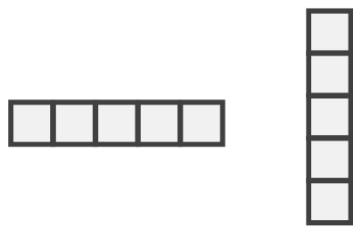
→ Order



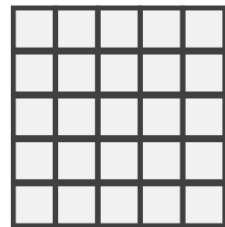
→ Align



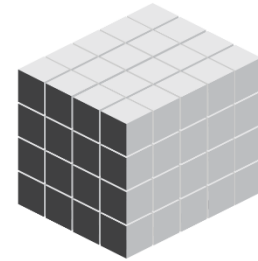
→ 1 Key
List



→ 2 Keys
Matrix



→ 3 Keys
Volume



→ Many Keys
Recursive Subdivision



Key: an independent attribute that can be used as a unique index (Tableau Dimension)

Value: a dependent attribute (i.e., cell in a table) (Tableau Measures)

Categorical or Ordinal

Categorical Ordinal, or Quantitative

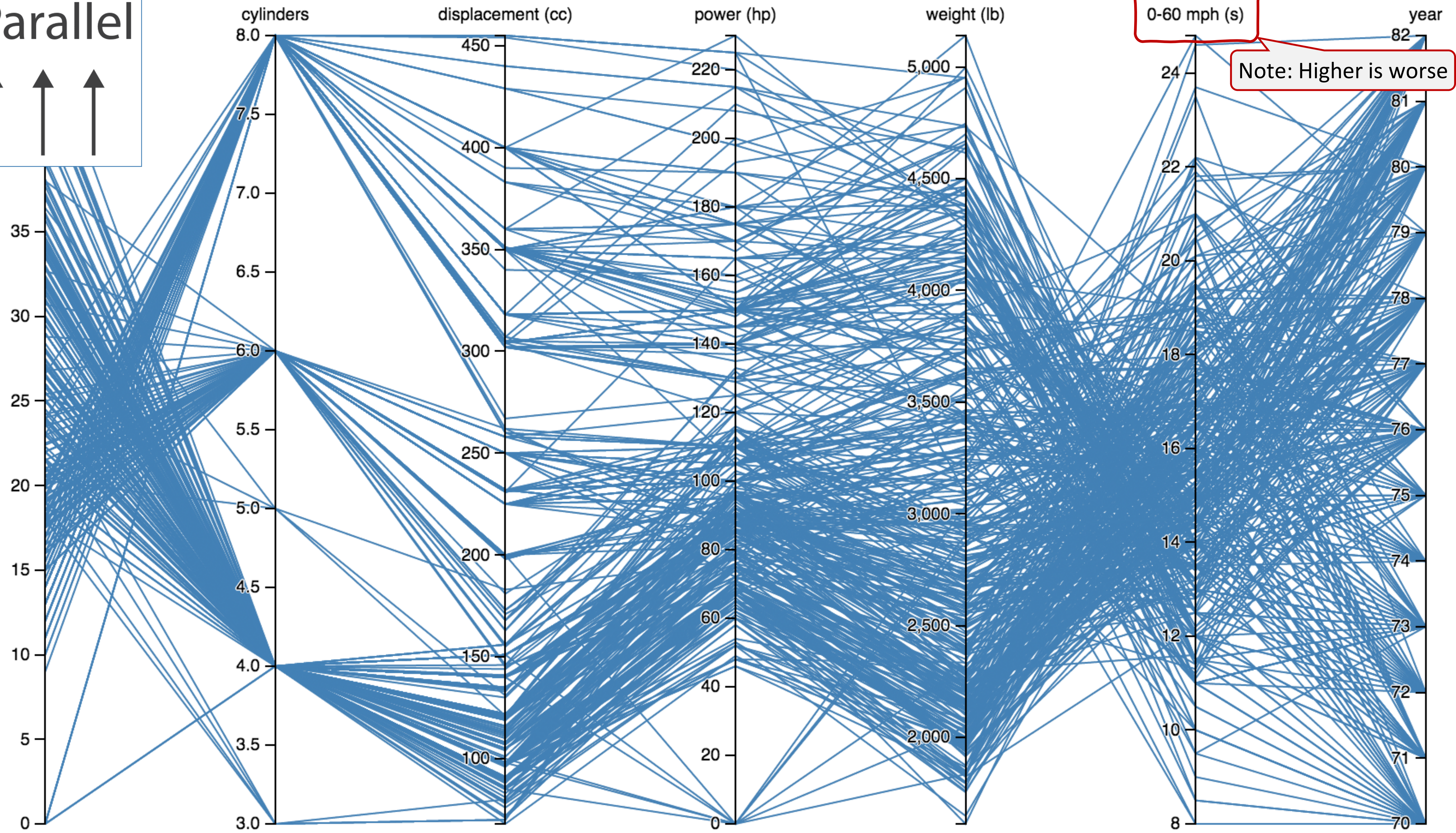
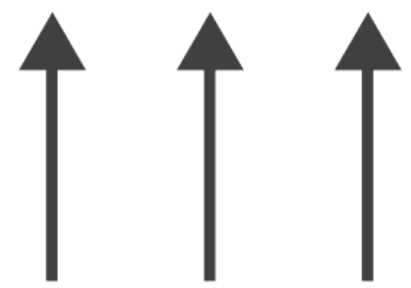
Now, ON DS 4200...

VISUAL ENCODING

GOALS FOR TODAY

- Learn (more) about visual encodings, esp. arranging tables
- Learn how to pick appropriate visual representations based on attribute type and perceptual properties

→ Parallel

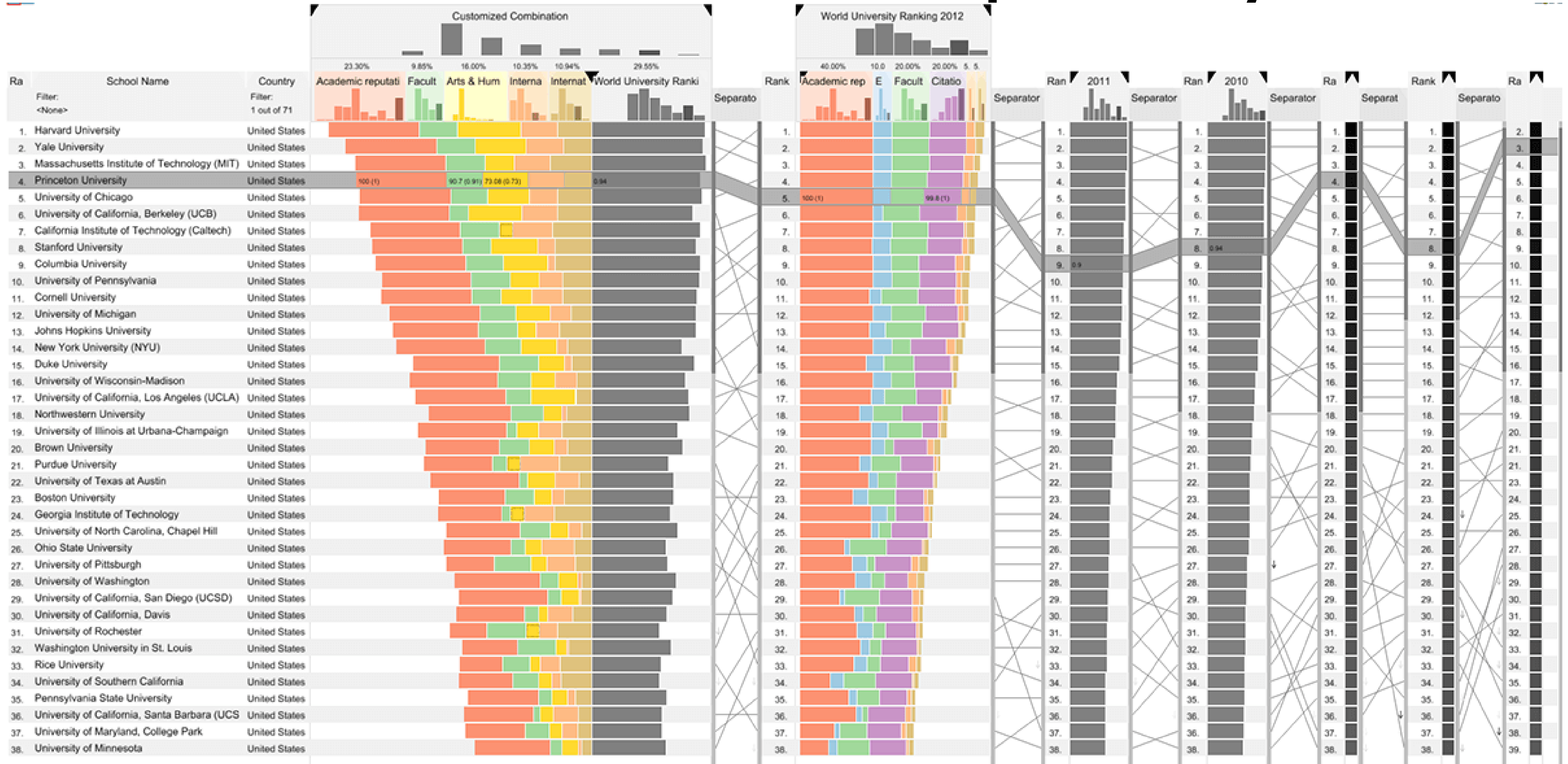


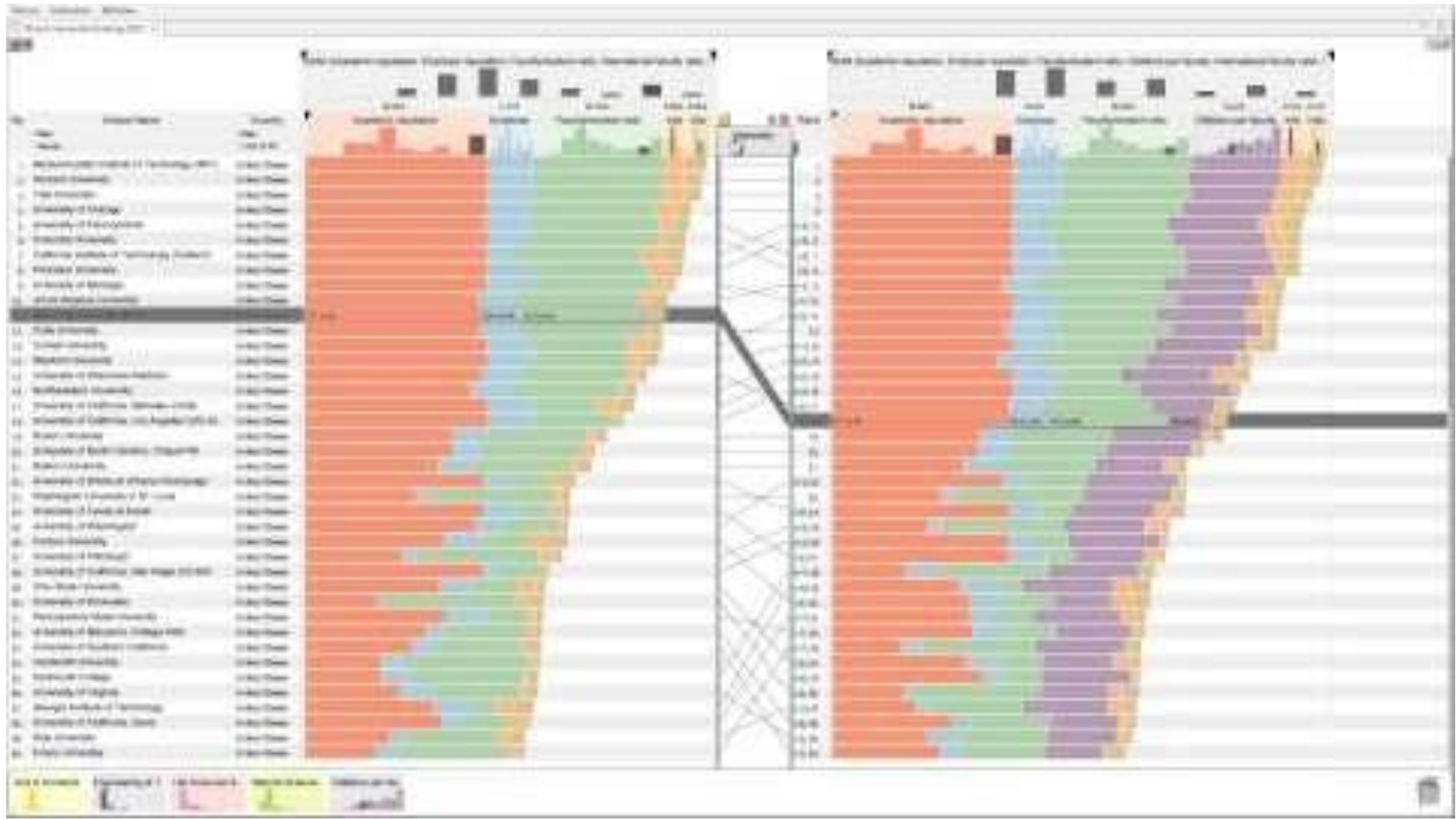
Arrange Tables — Many Keys (Tree)

→ Many Keys
Recursive Subdivision

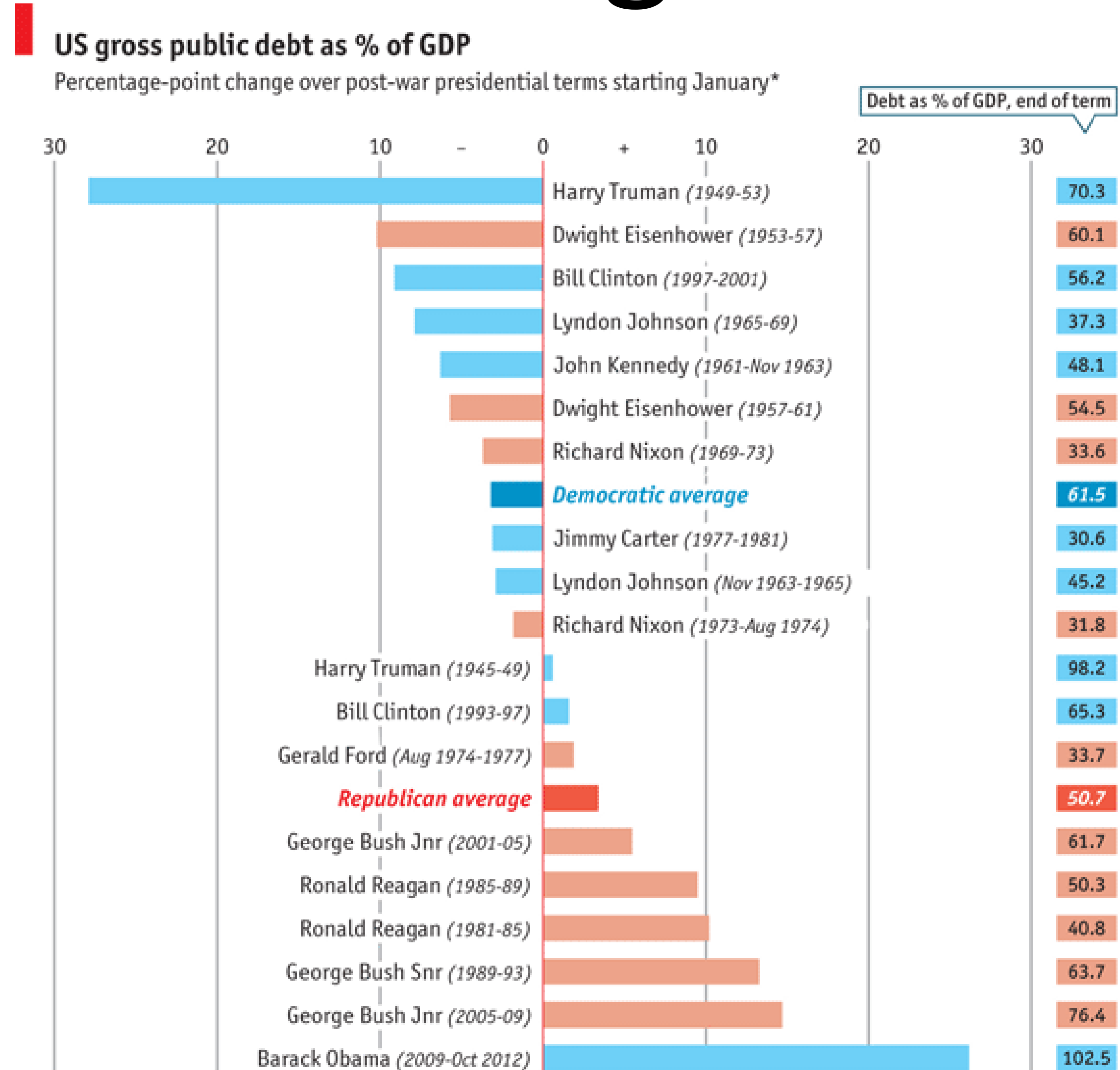


How to handle multiple keys...?





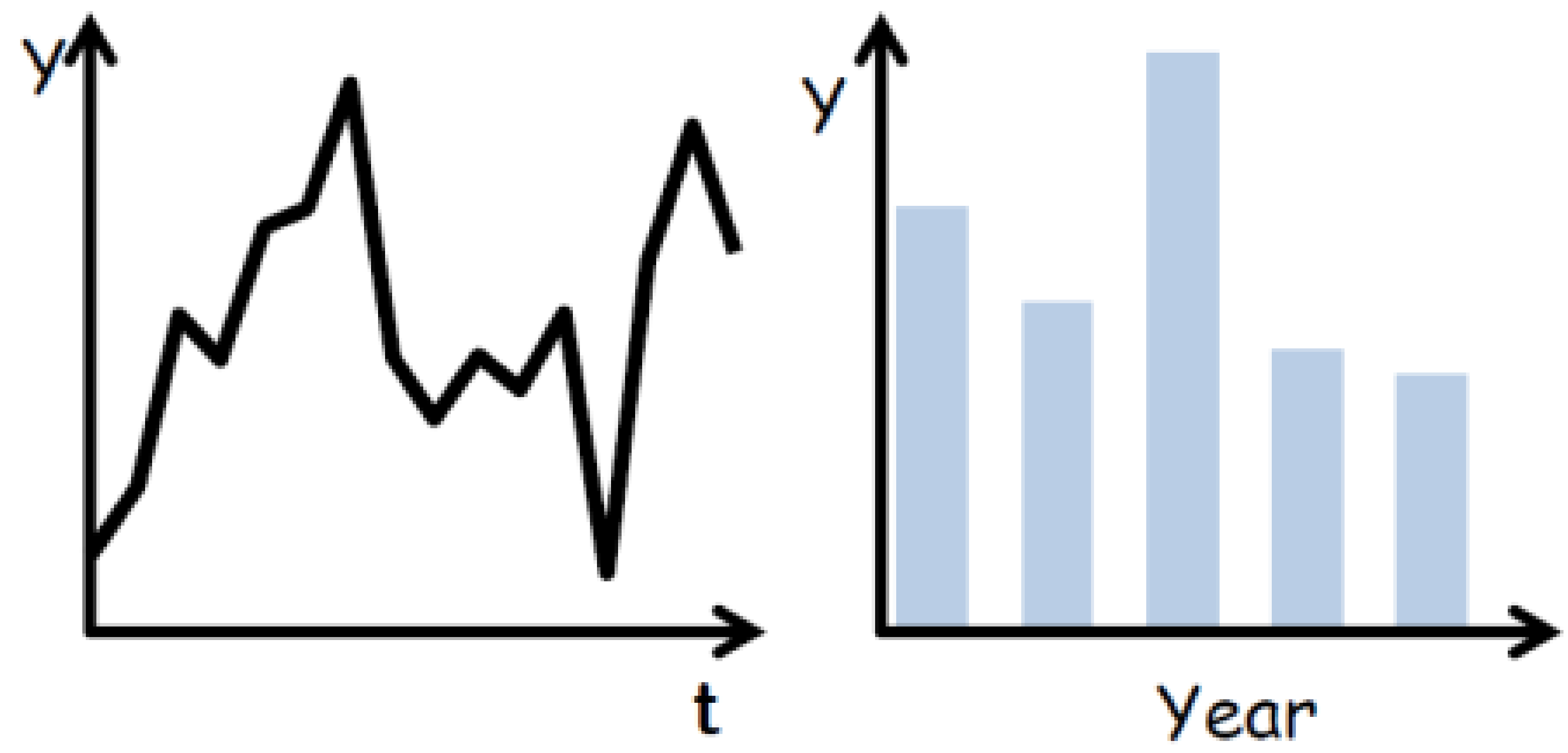
Divergent



Sources: Bureau of Economic Analysis; Thomson Reuters; White House; *The Economist*

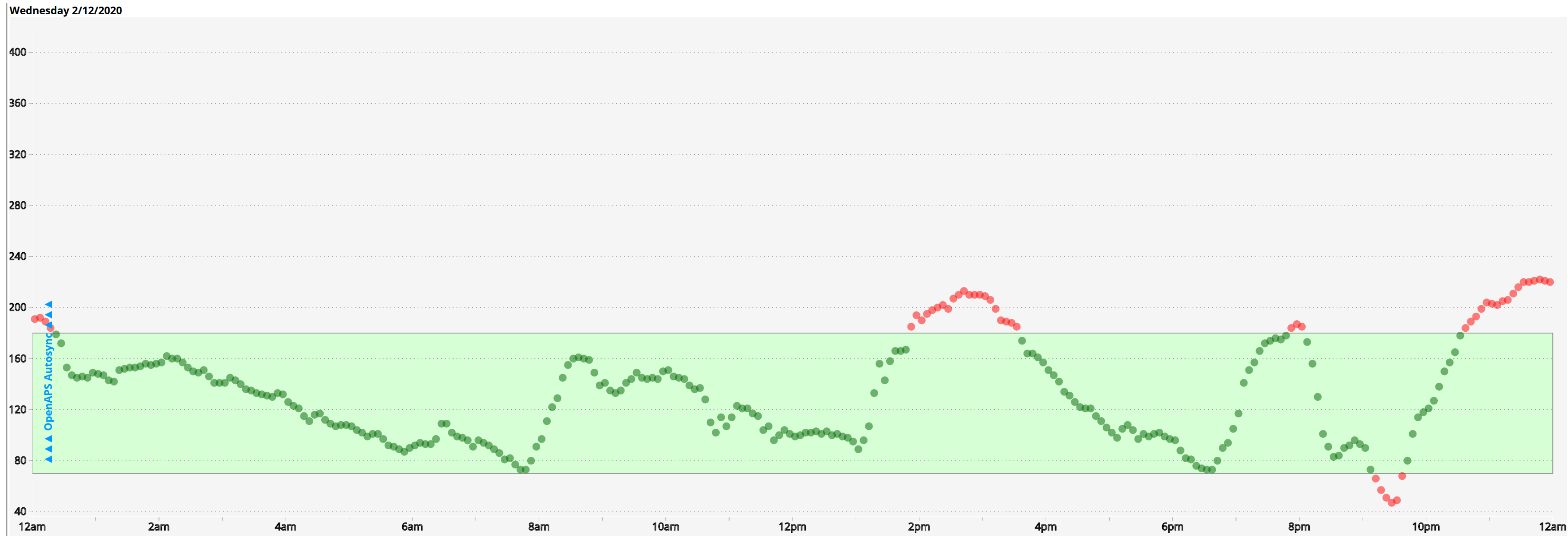
*Unless otherwise stated

Time Series



(Quantitative data over time)

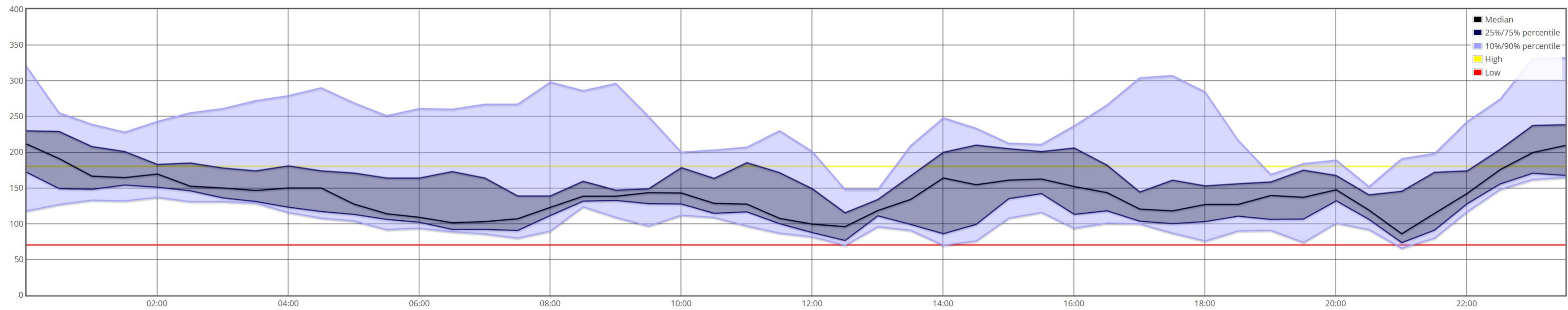
Time Series



(Quantitative data over time)

Time Series Distributions

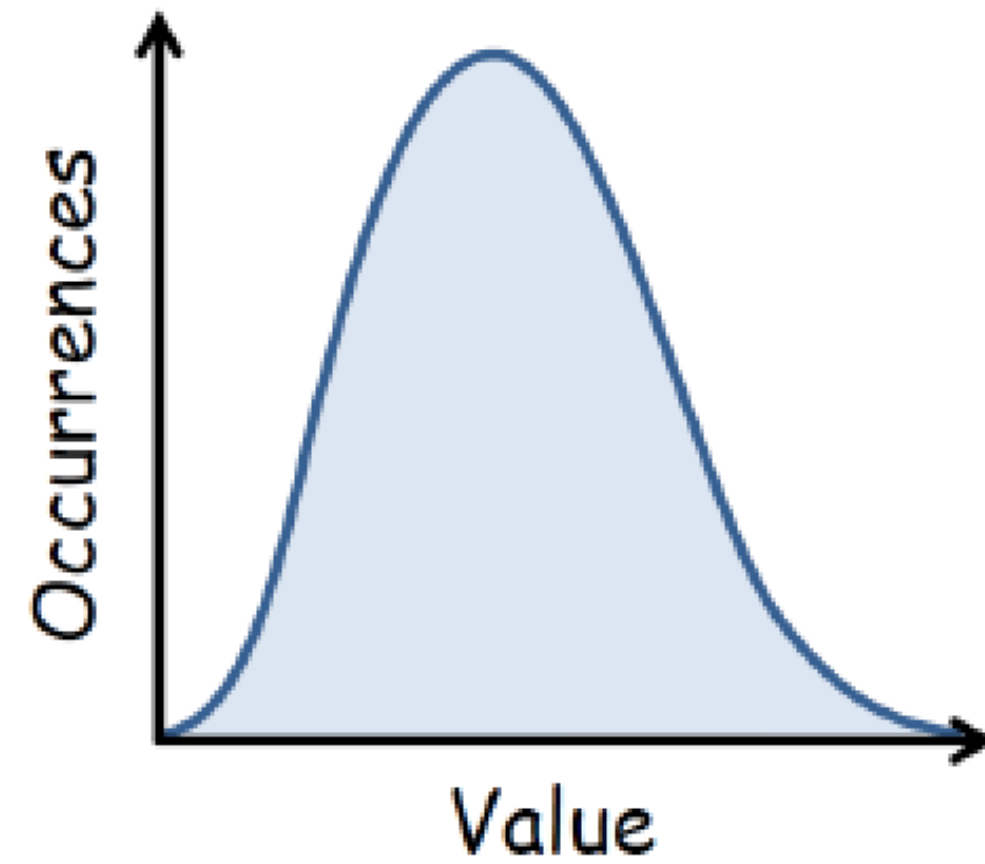
Glucose Percentile report



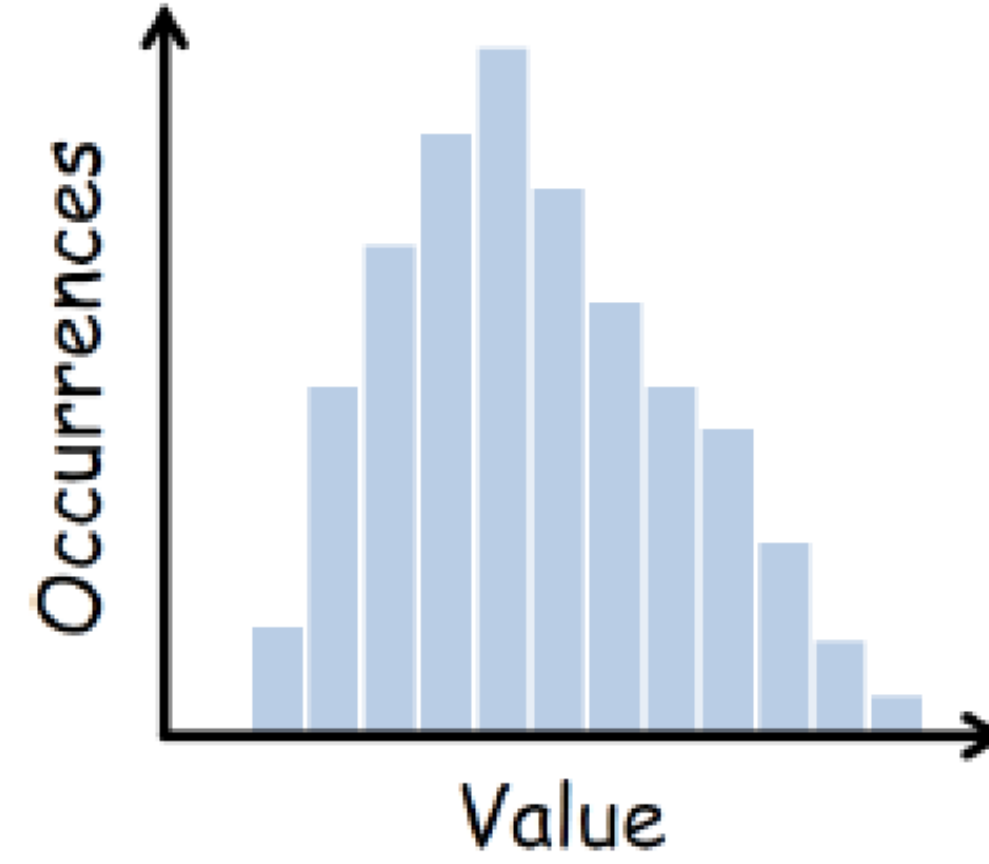
(Quantitative data over time)

Distributions & Correlations

Distribution Curve



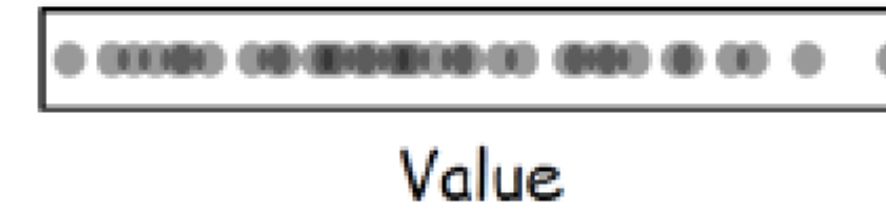
Histogram



Box-And-Whisker Plot



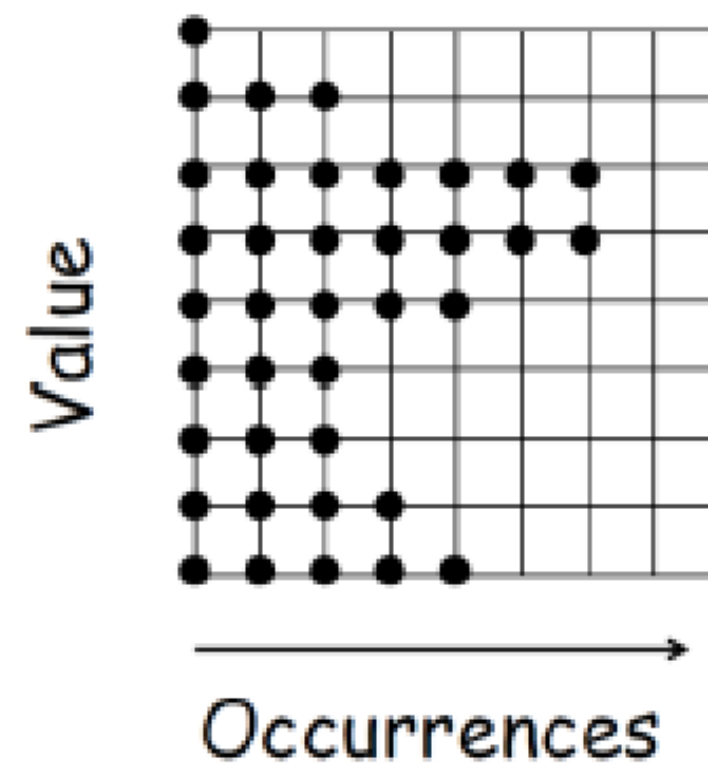
Point Graph



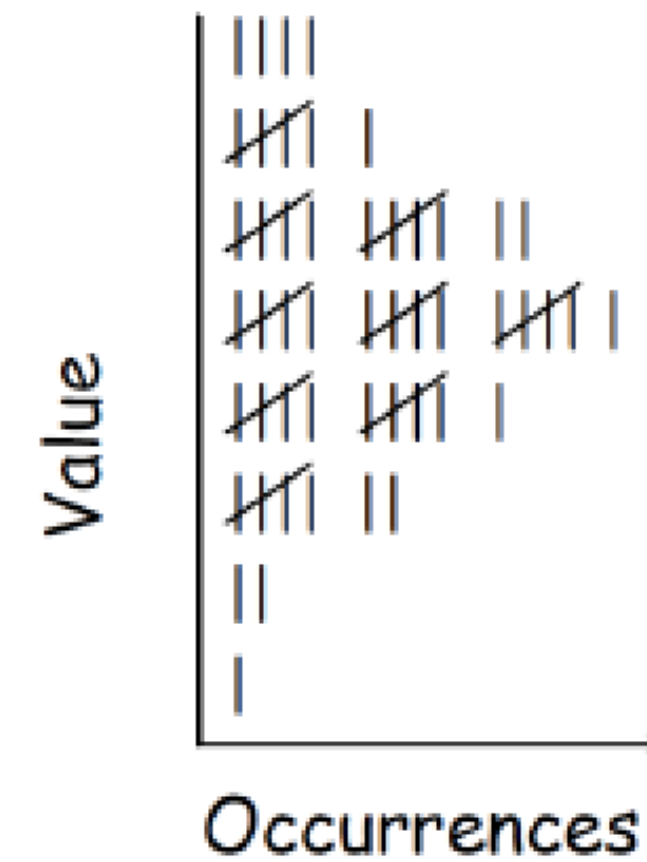
Stripe Graph



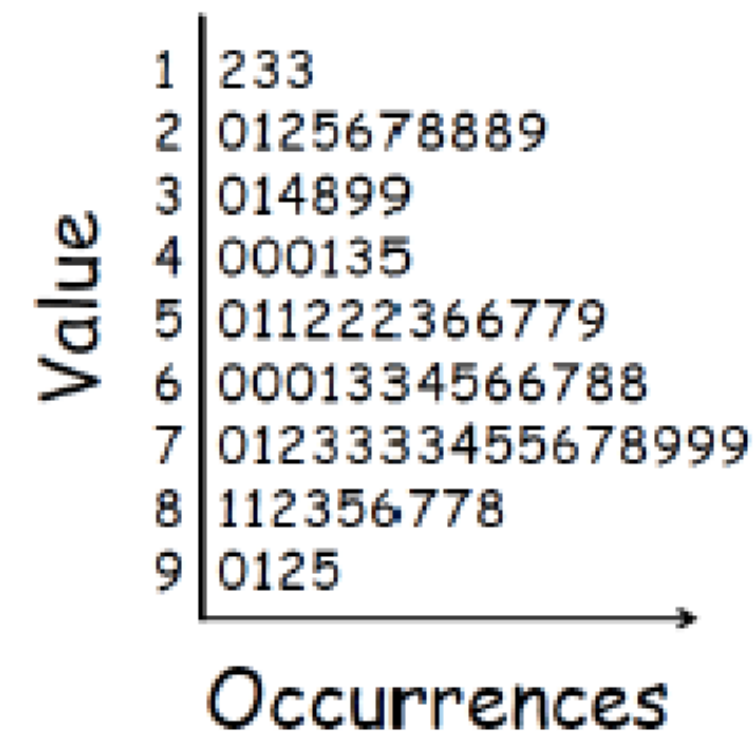
Dot Array



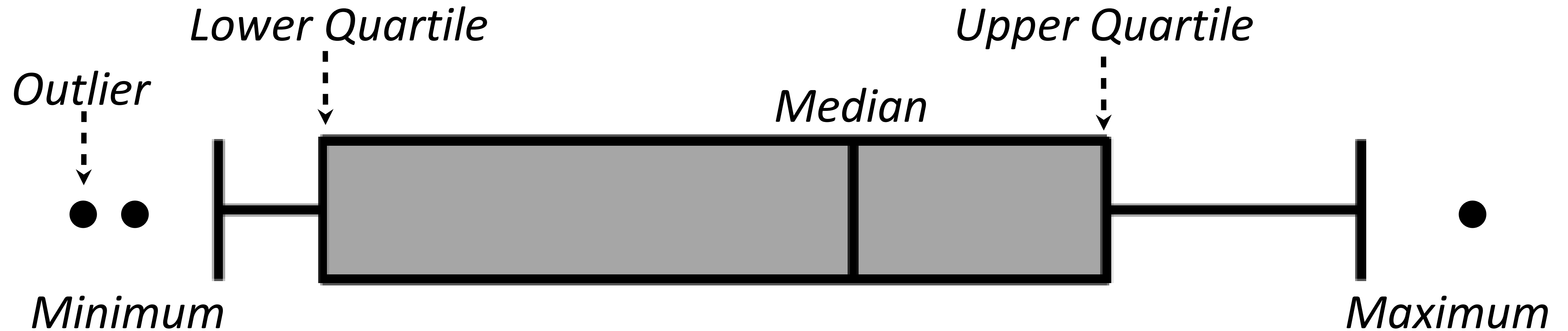
Tally Chart



Stem-And-Leaf Plot

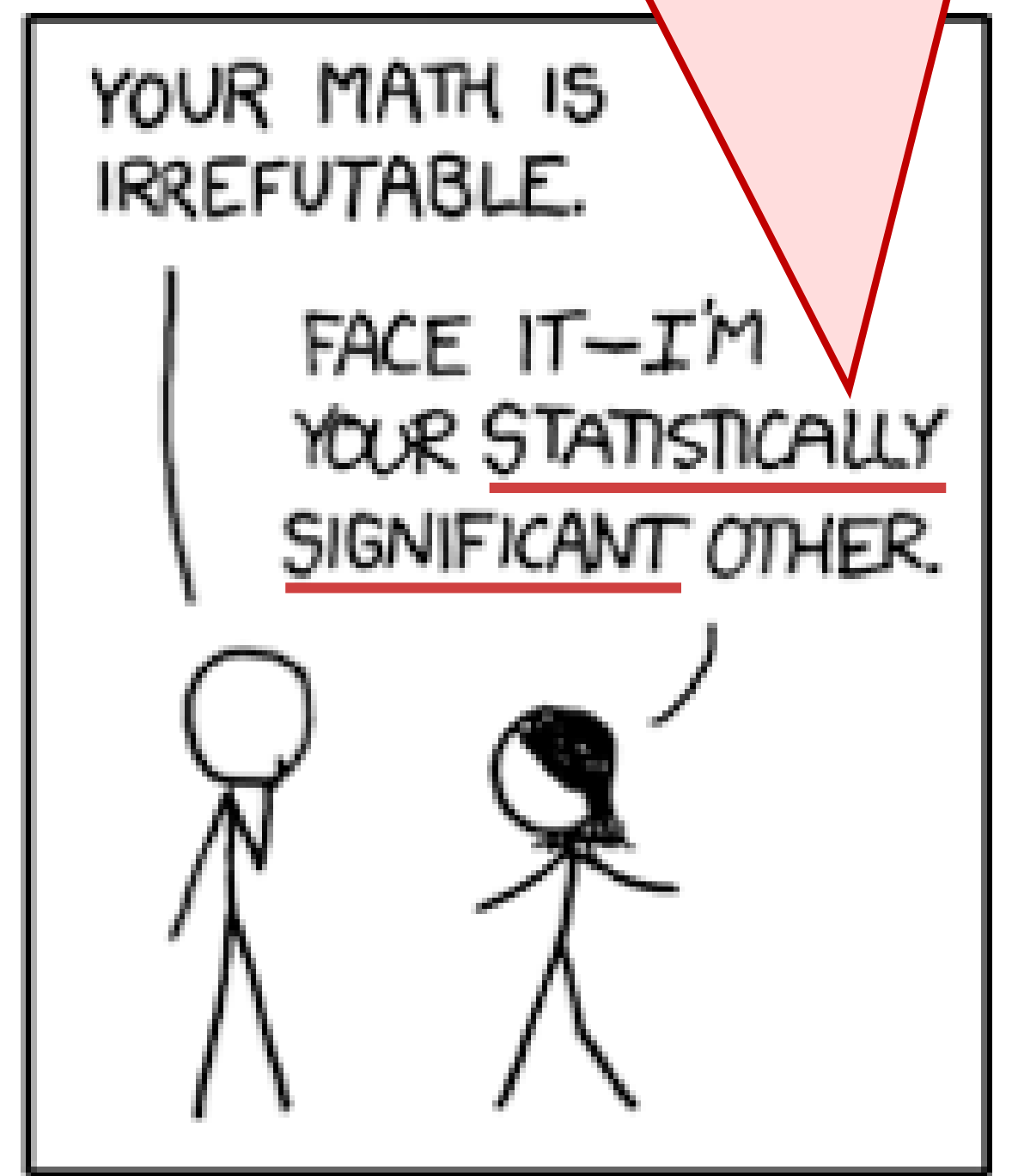
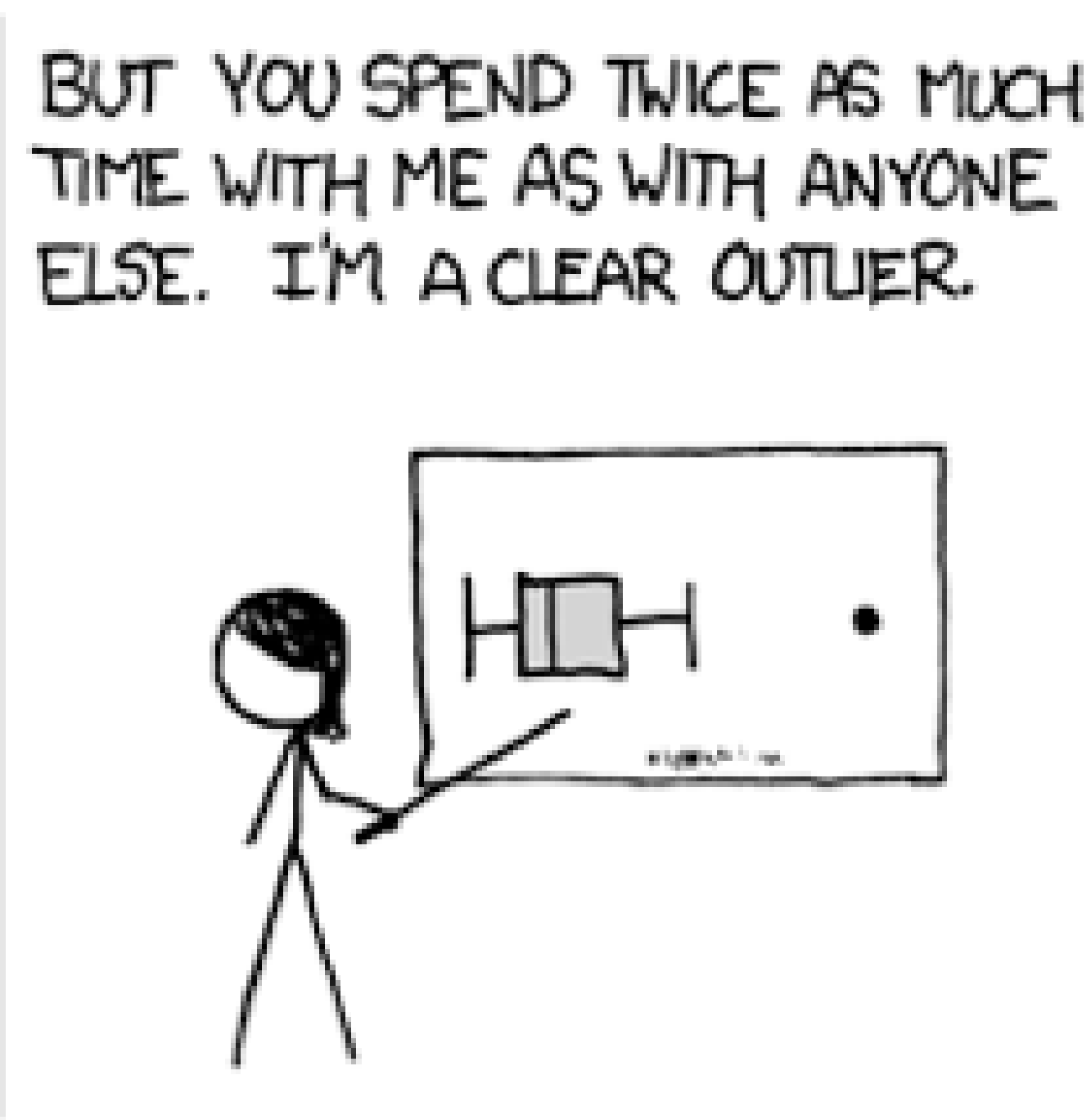
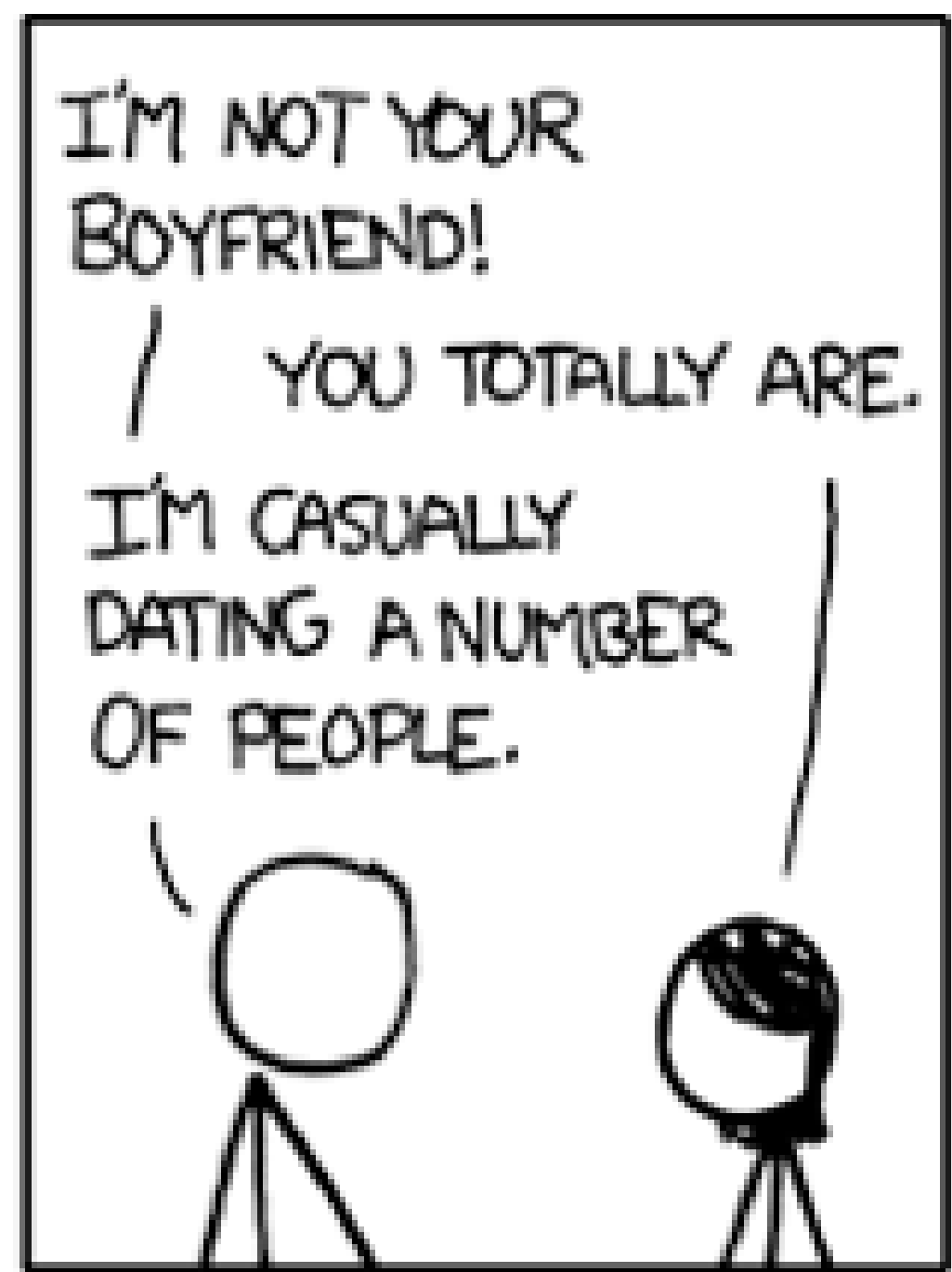
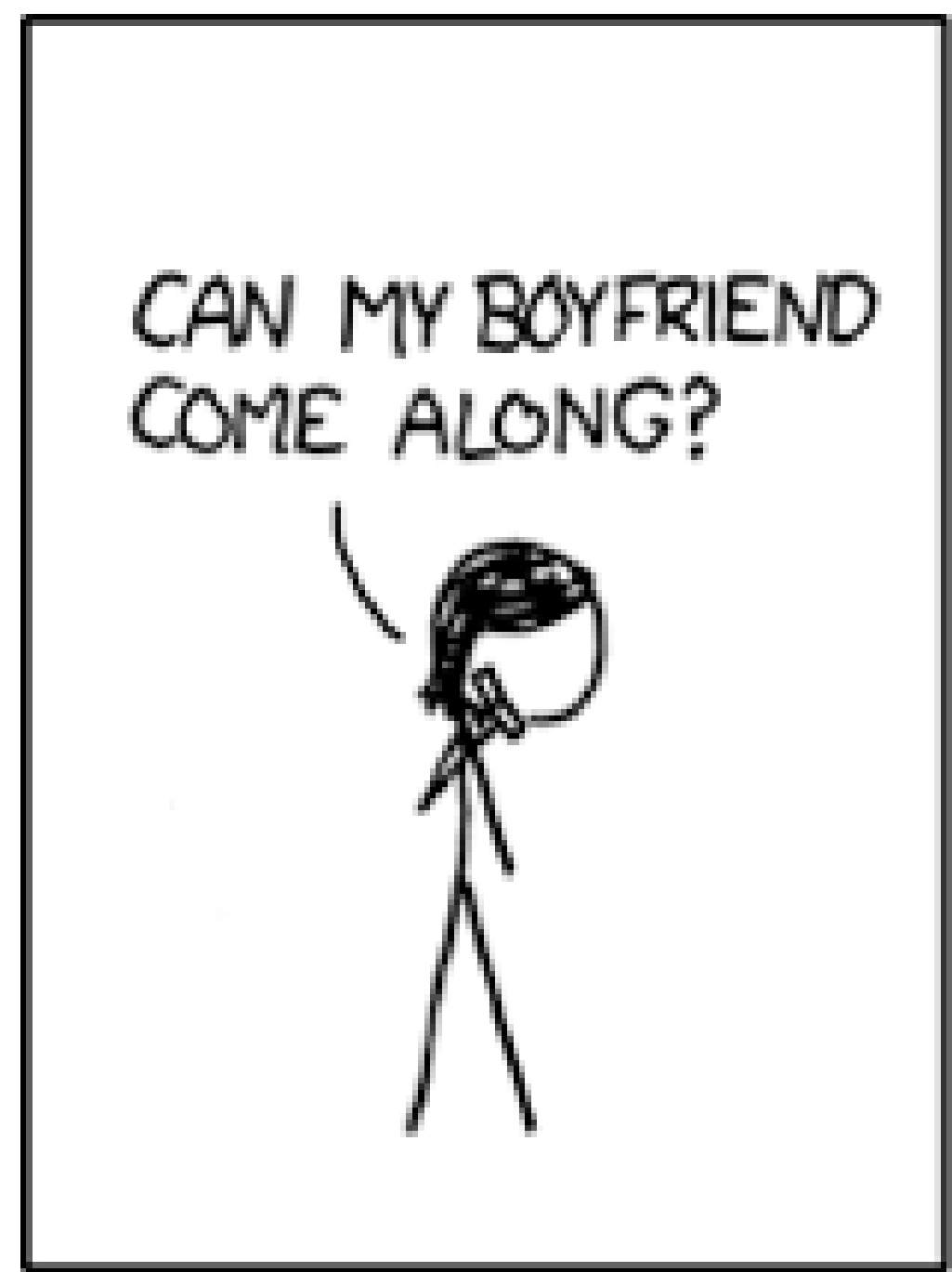


Distributions & Correlations

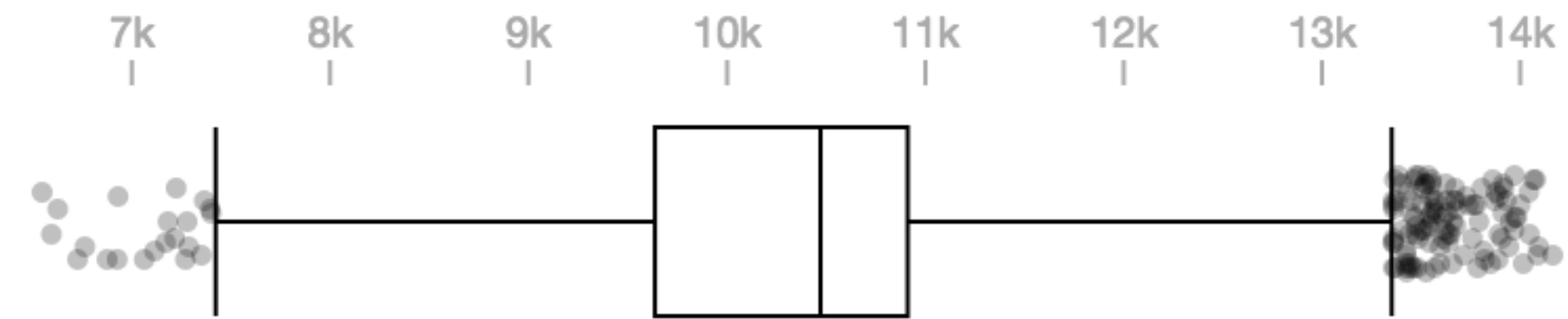
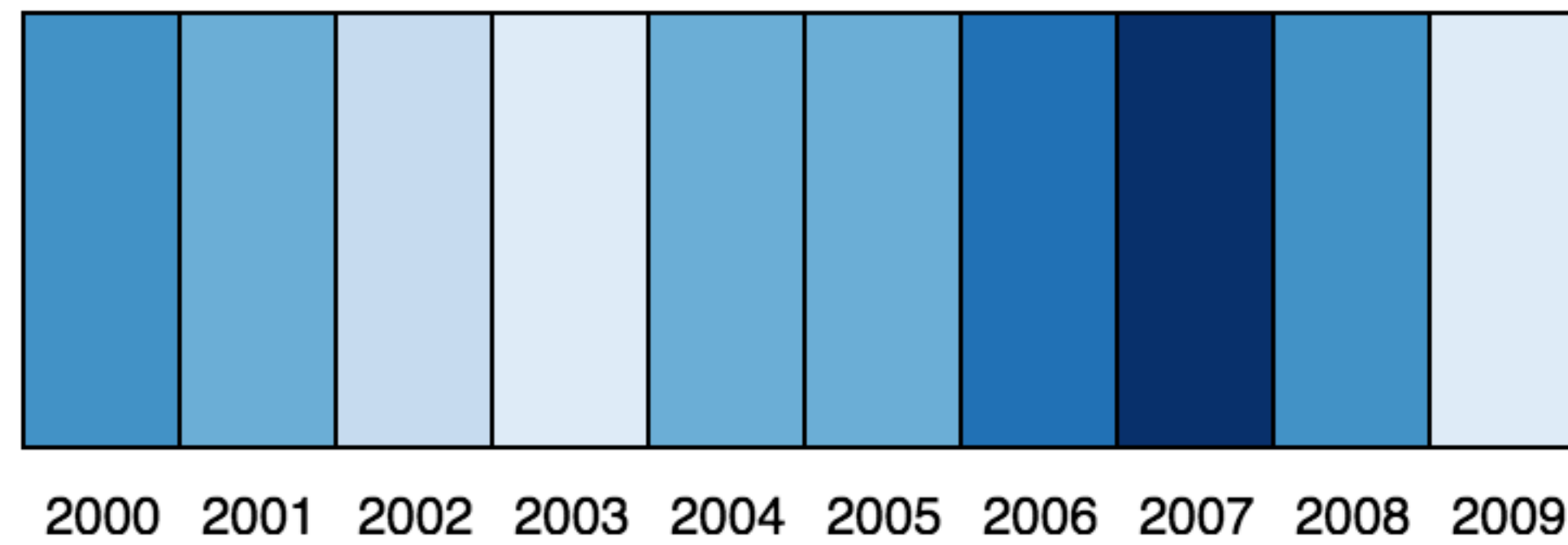


BOX AND WHISKER PLOT

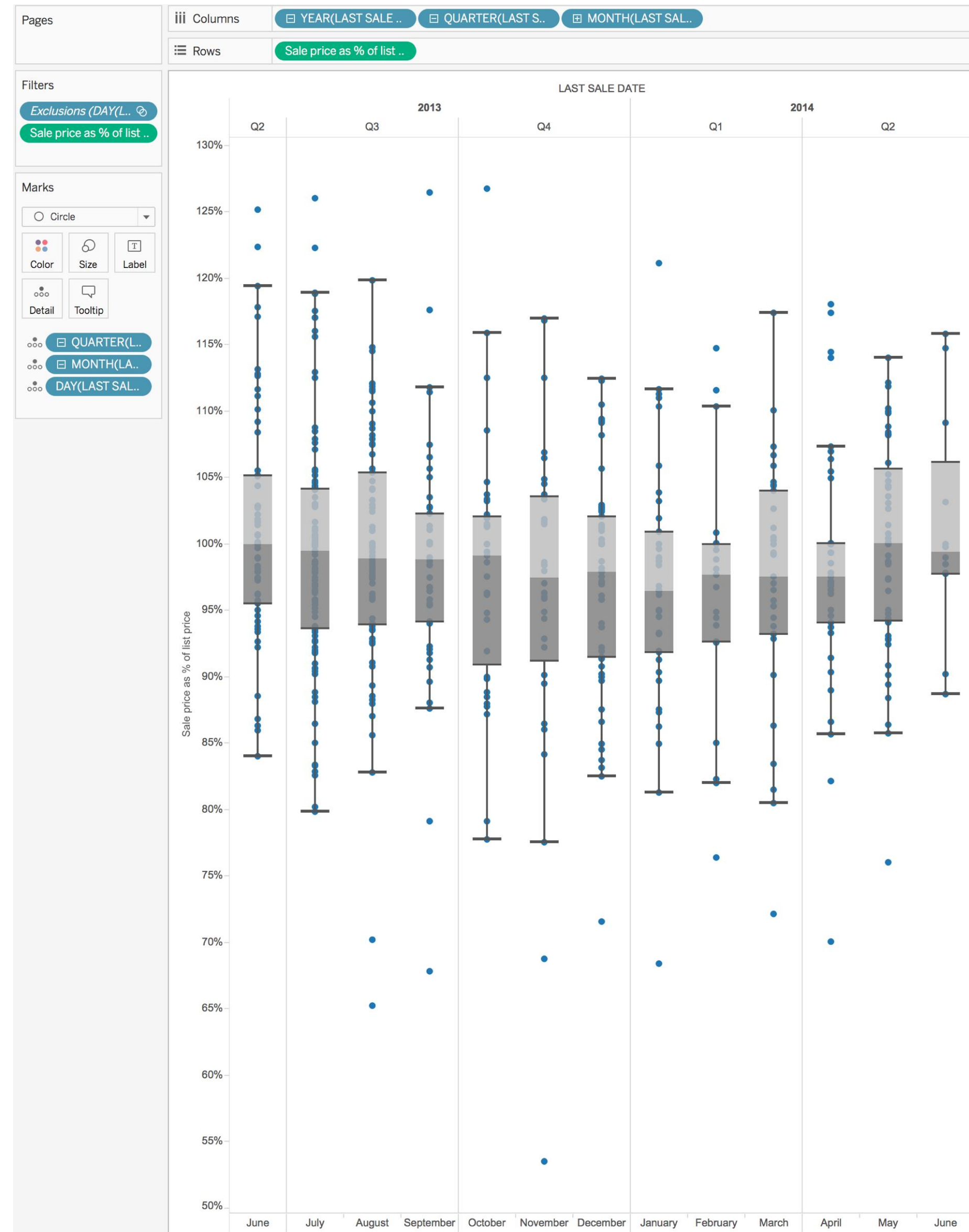
Dichotomous statistical thinking is problematic (e.g., $p < .05 = \text{significant}$)... and this means nothing w/o context about the tests used!!!



Distributions & Correlations

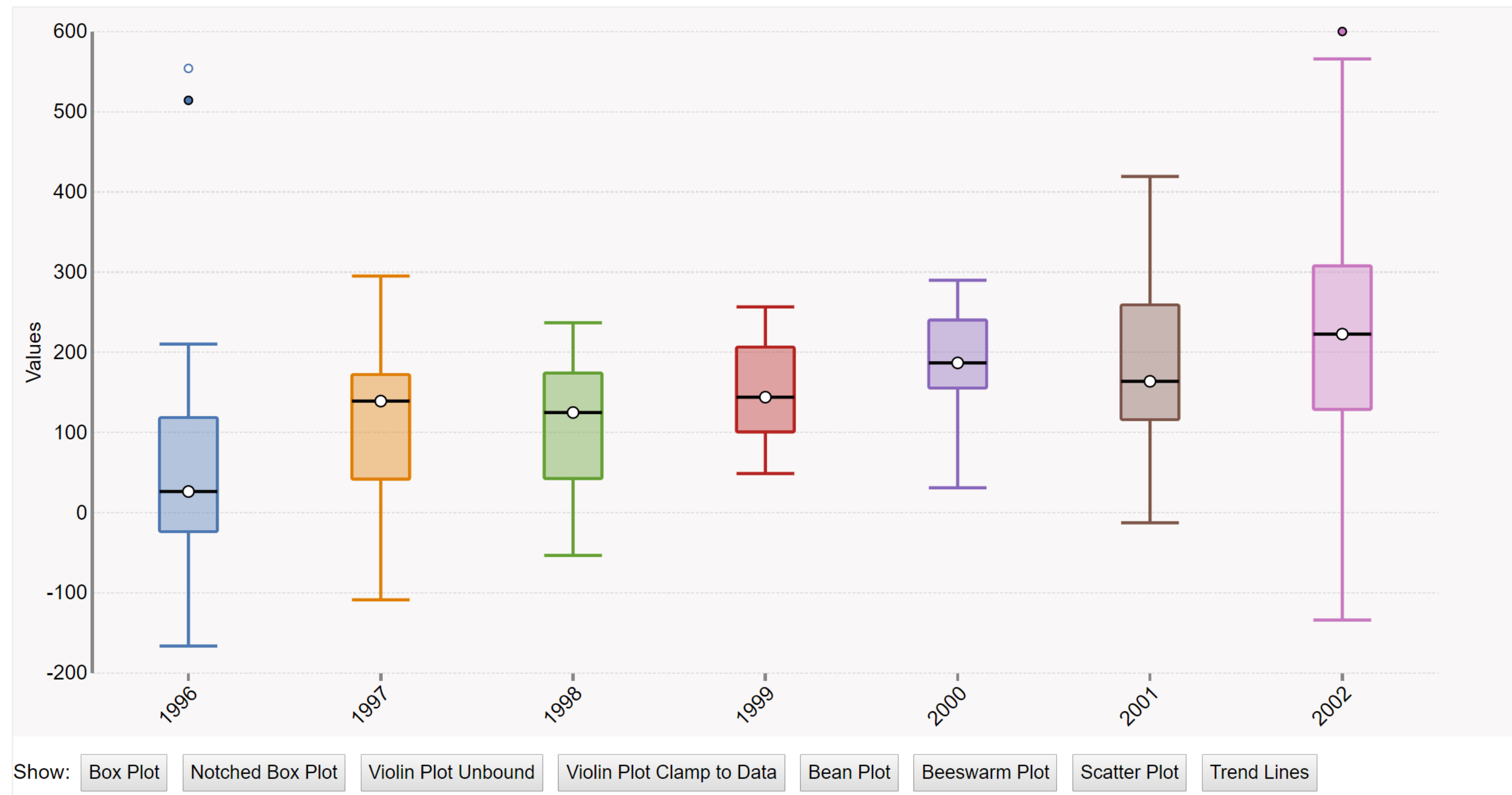


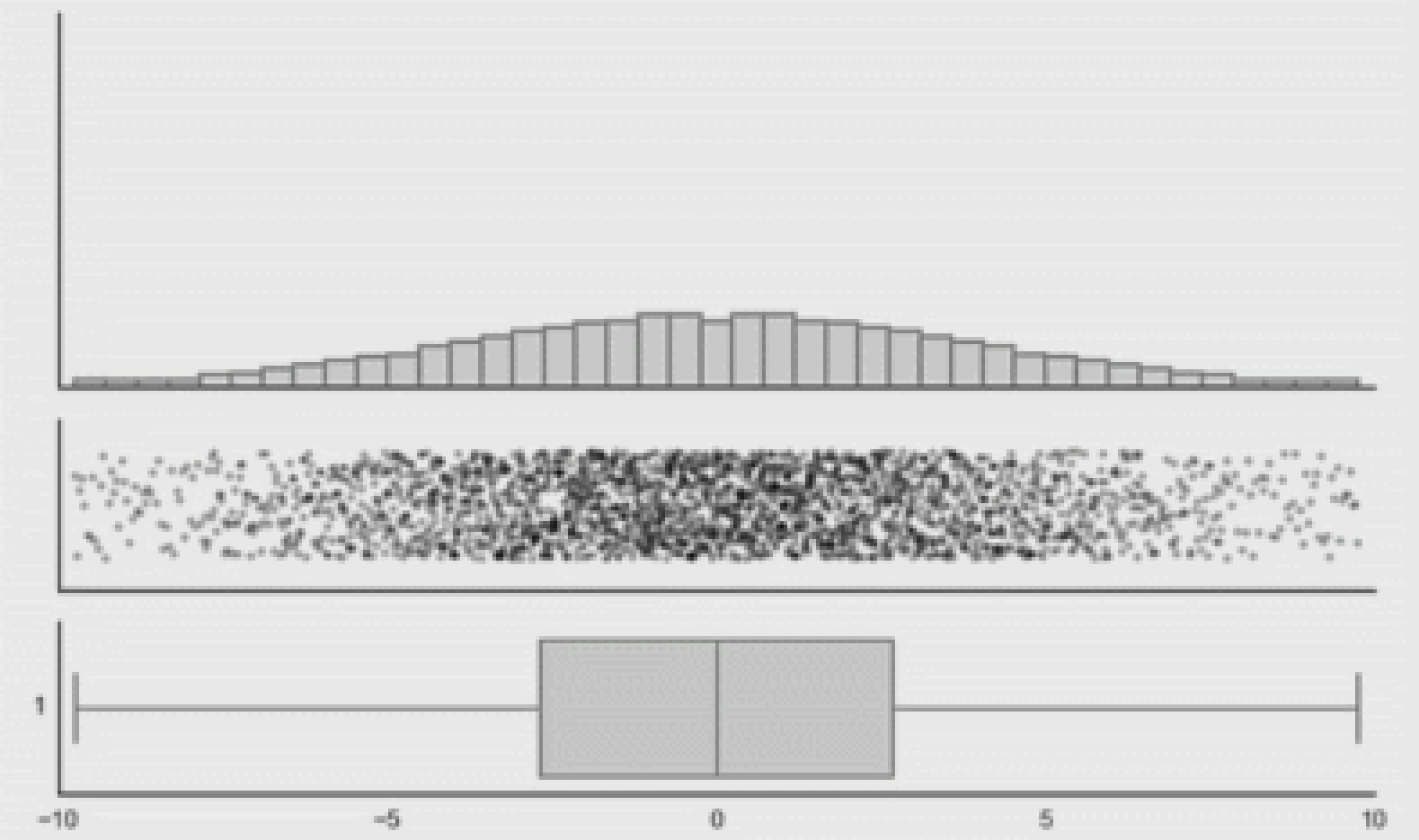
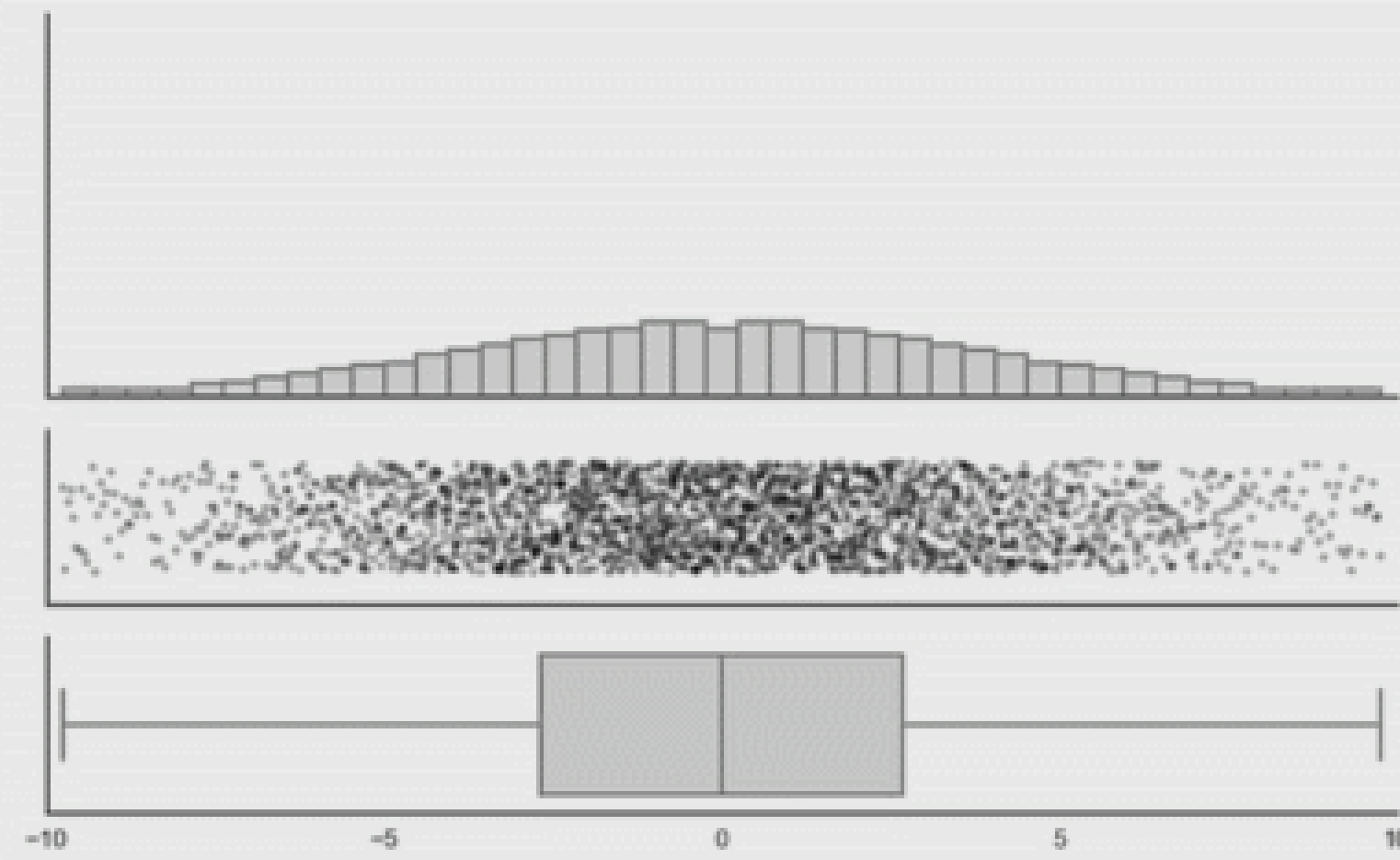
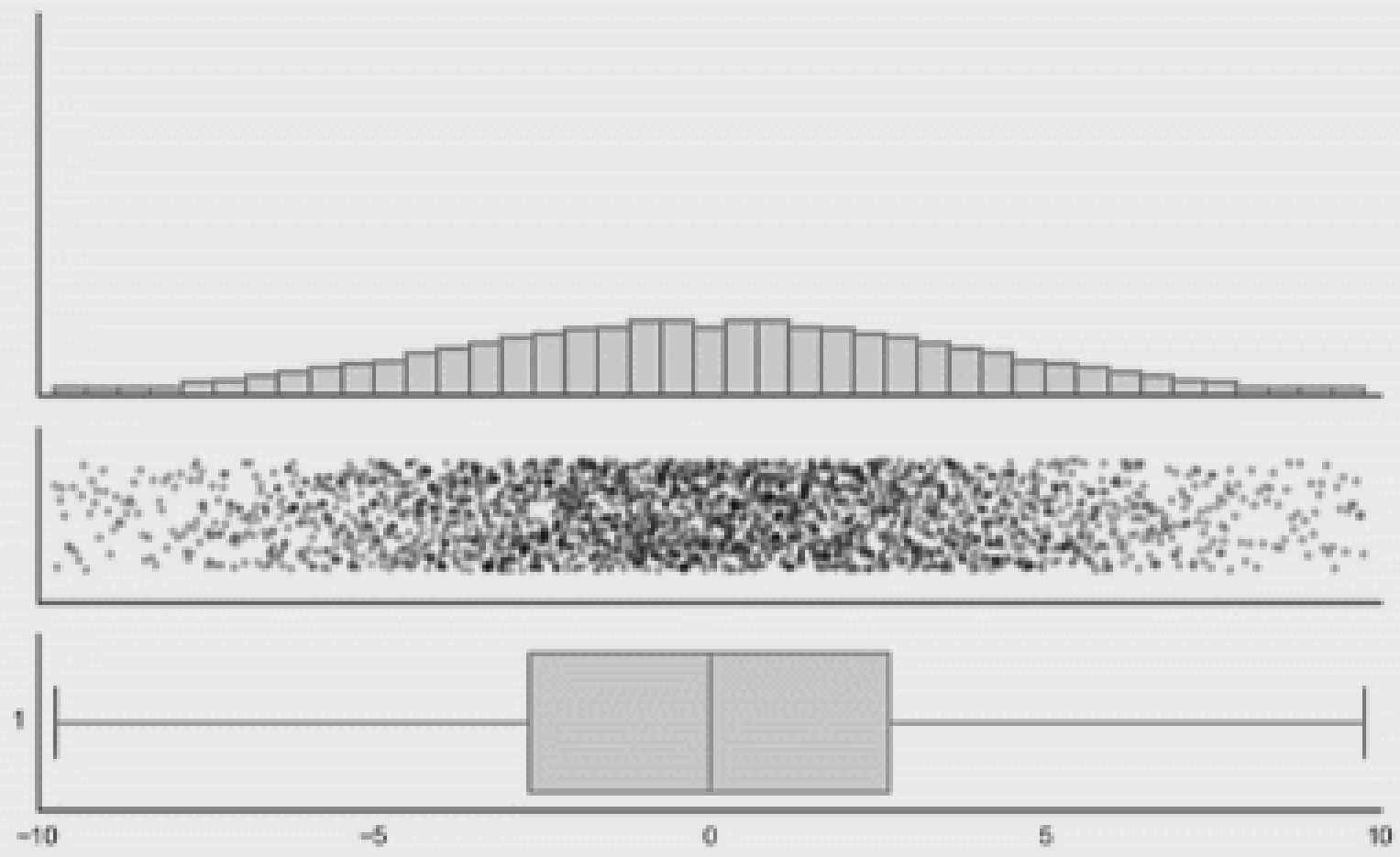
Distributions & Correlations



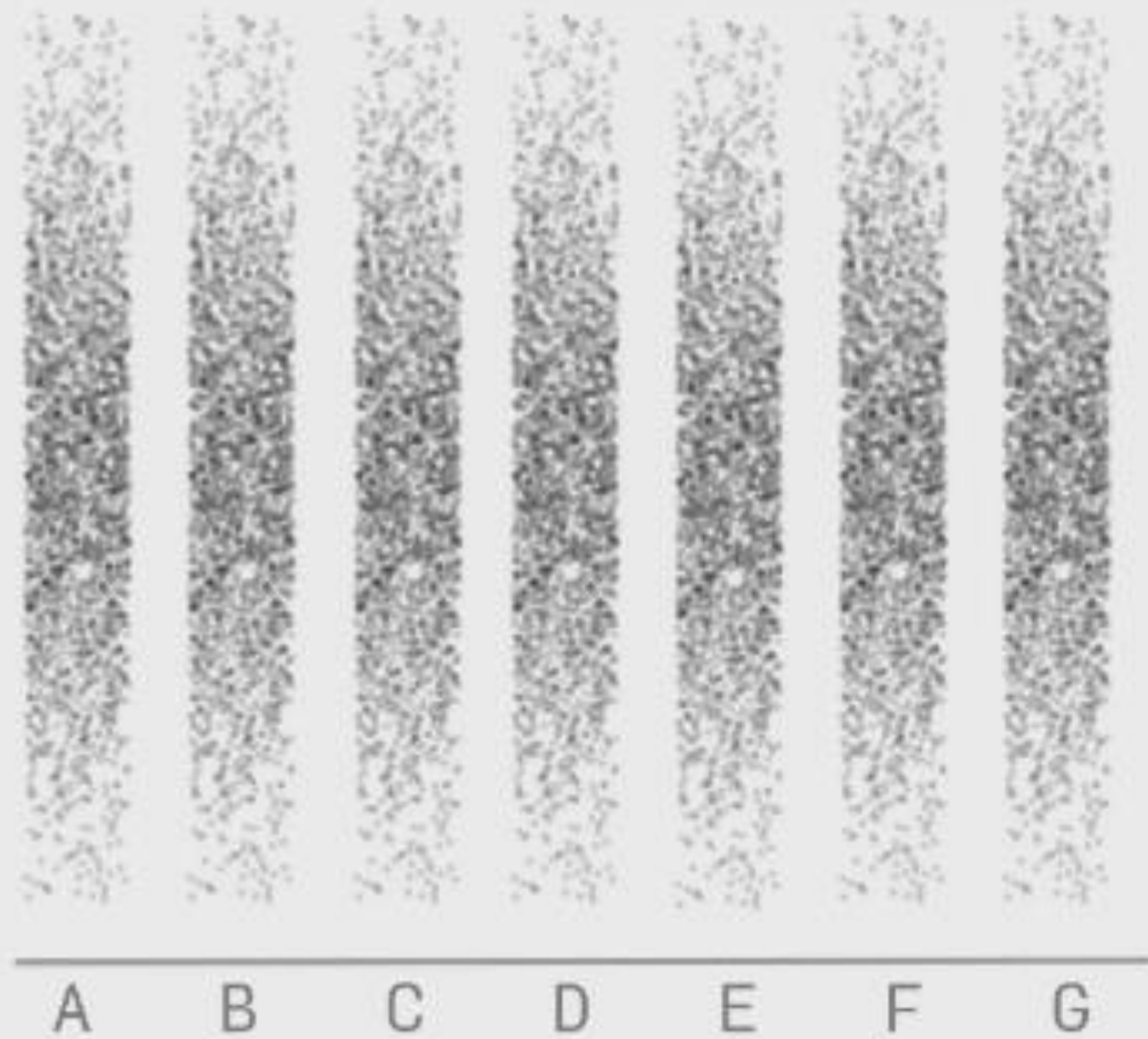
Distributions & Correlations

Violin Plot + Box Plot v3

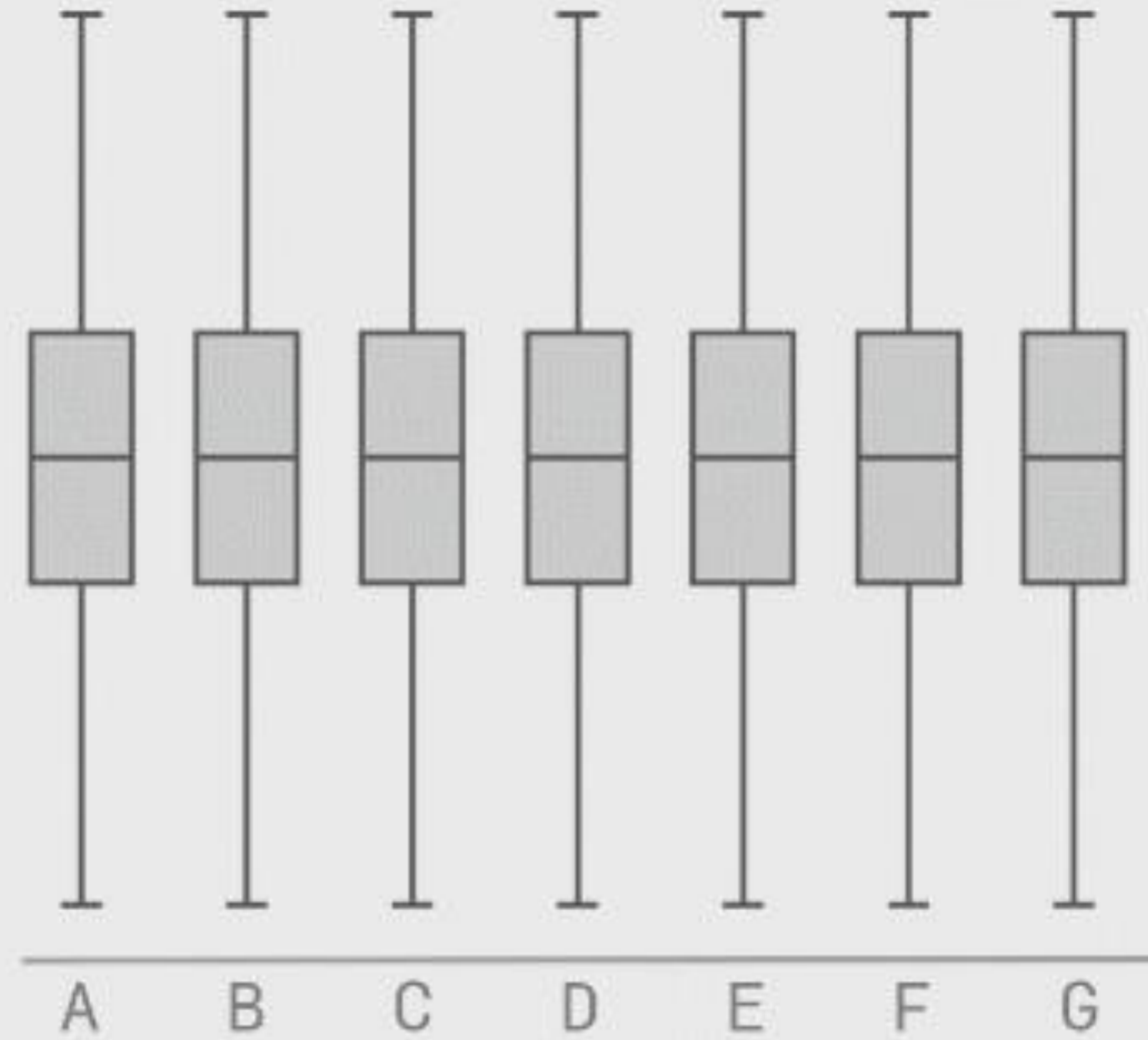




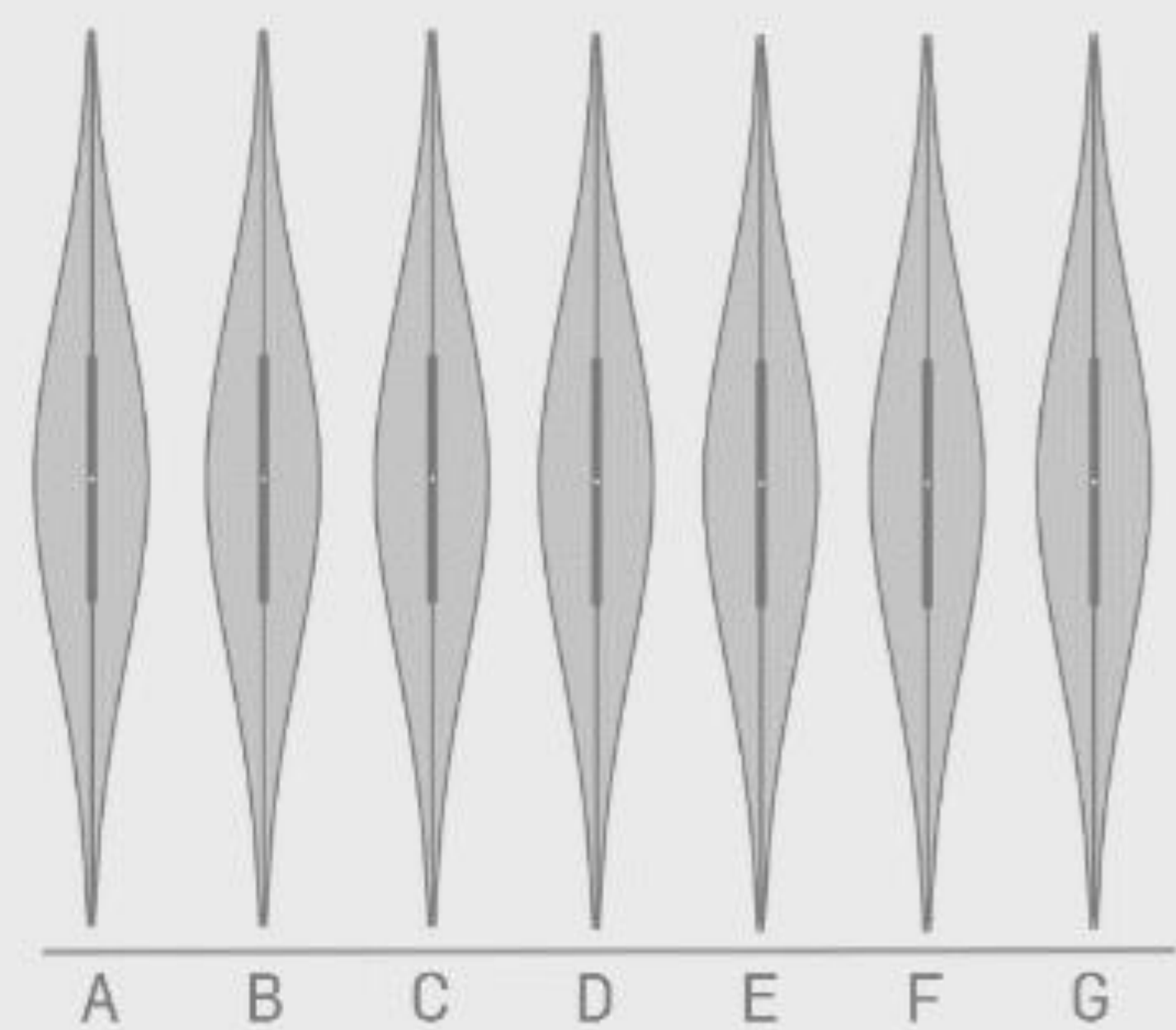
Raw Data



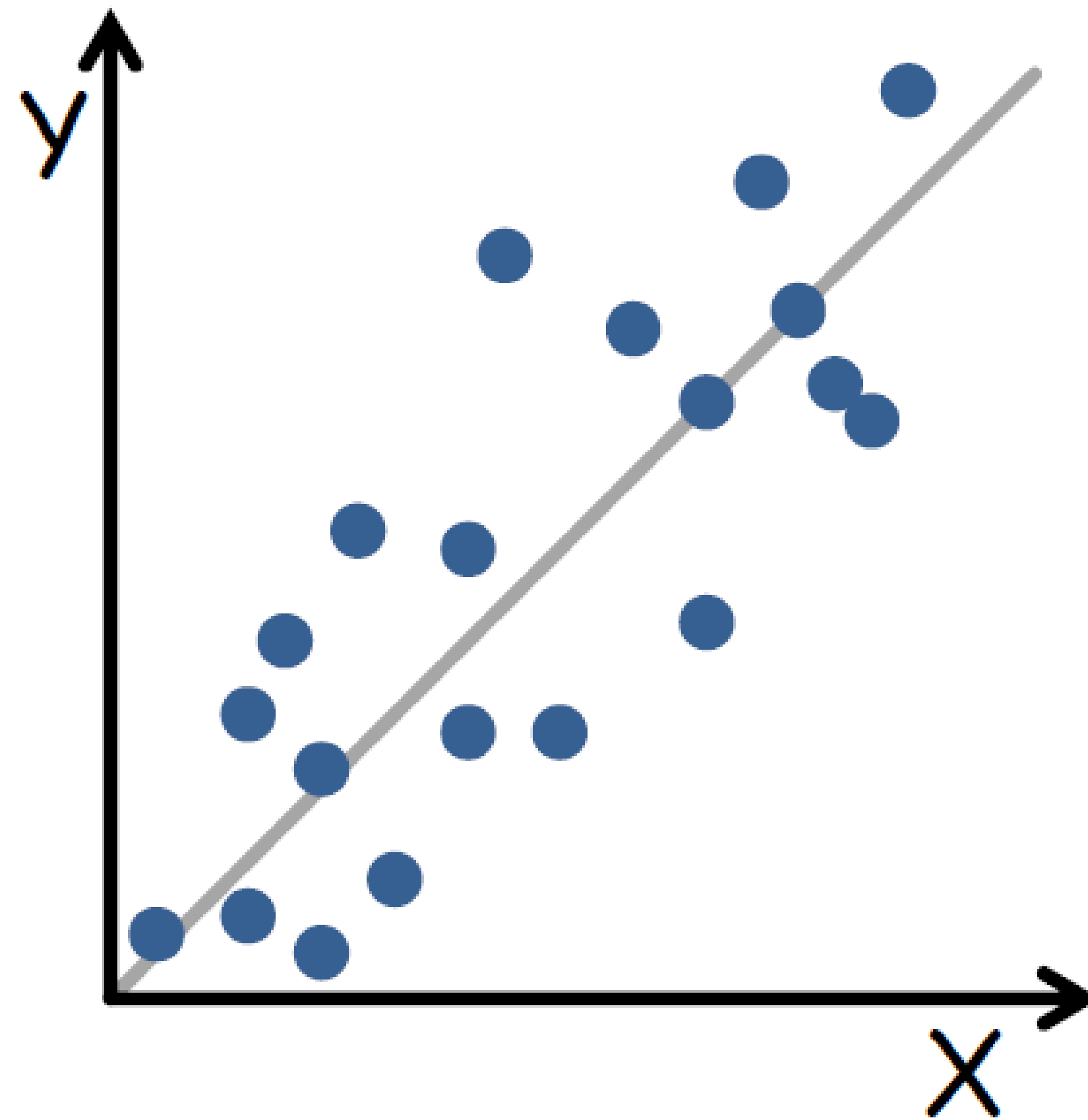
Box-plot of the Data



Violin-plot of the Data

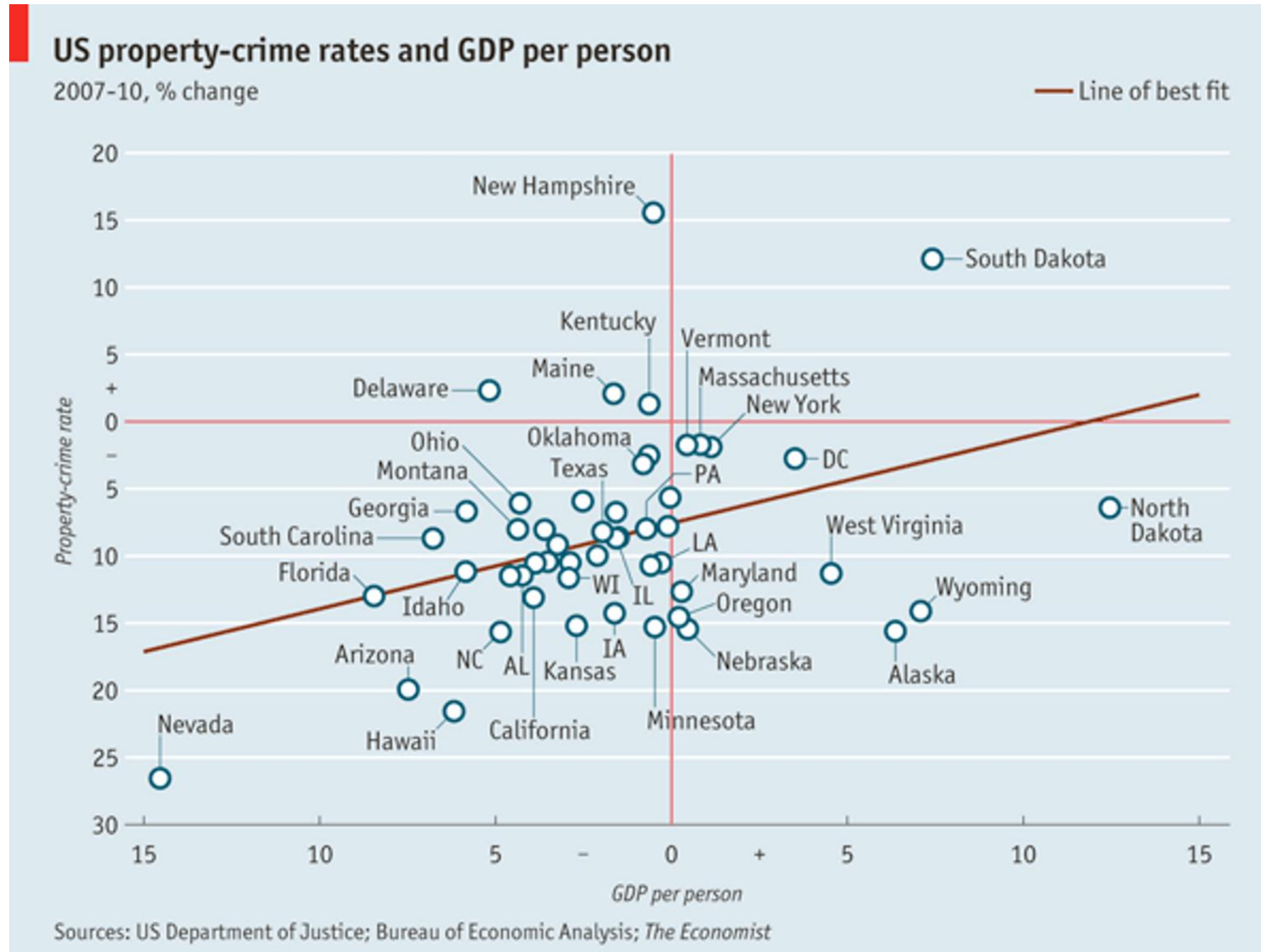


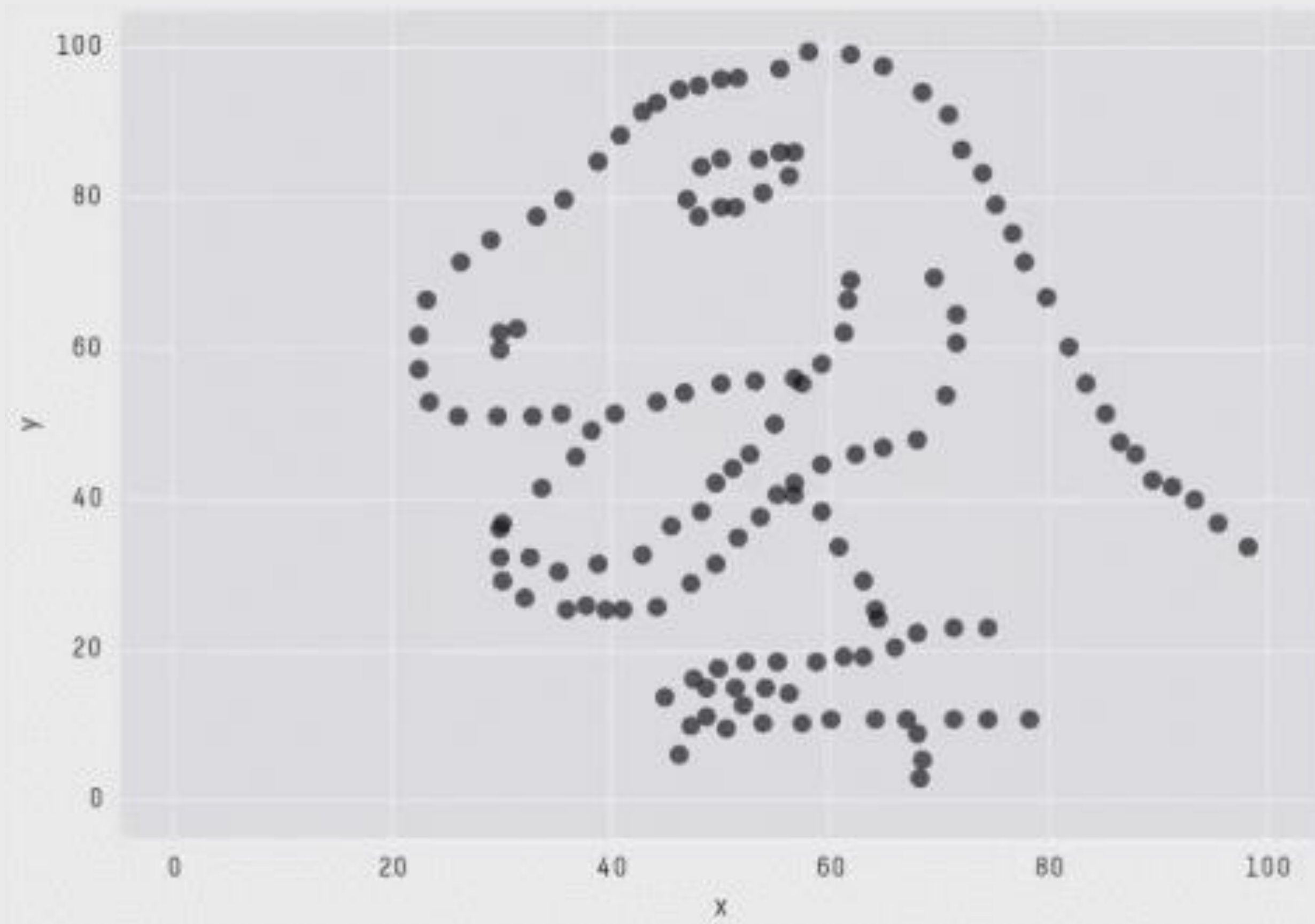
Distributions & Correlations



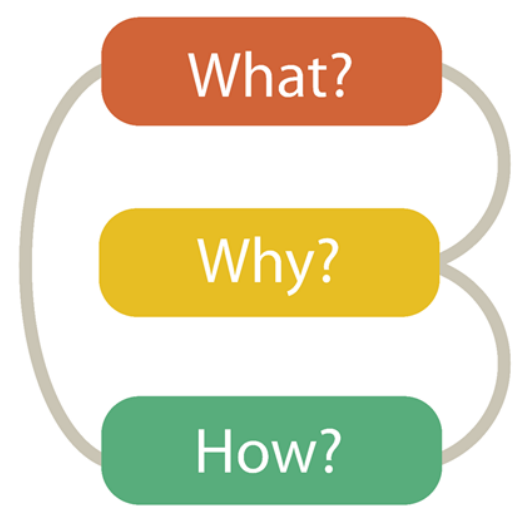
TREND/CORRELATION LINE

Distributions & Correlations



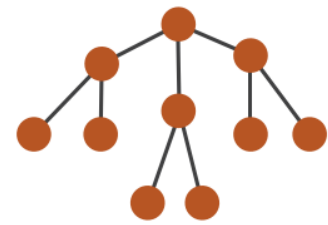


X Mean: 54.2659224
Y Mean: 47.8313999
X SD : 16.7649829
Y SD : 26.9342120
Corr. : -0.0642526



What?

→ Tree



Why?

→ Actions

→ Present → Locate → Identify



→ Targets

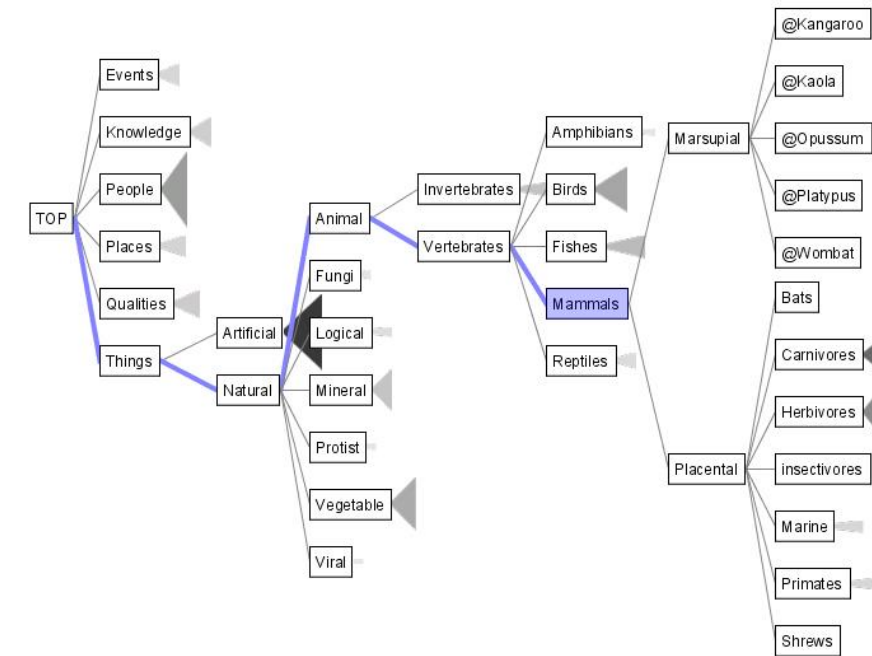
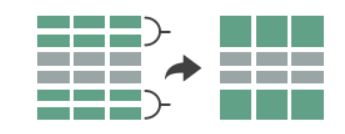
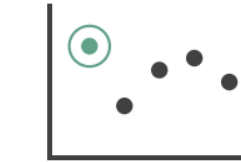
→ Path between two nodes



How?

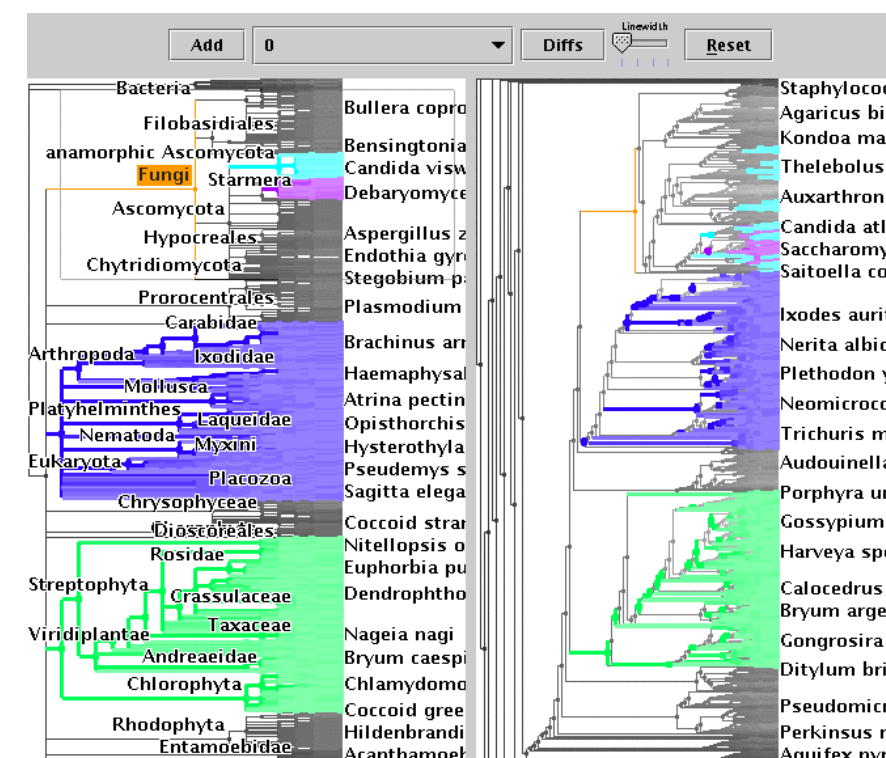
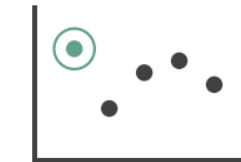
→ SpaceTree [SpaceTree \(Plaisant et al., 2002\) YouTube](#)

→ Encode → Navigate → Select → Filter → Aggregate



→ TreeJuxtaposer [TreeJuxtaposer \(Munzner et al., 2003\) YouTube](#)

→ Encode → Navigate → Select → Arrange





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.

Great resource for categorizing visualizations, and brainstorming!

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 tiles: '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' button. The bottom of the page features a grid of various chart types including a scatter plot, a line chart, a bar chart, and a pie chart.

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 16 different chart examples. These examples include bar charts, filled areas, line plots with various markers and styles, and scatter plots. Each example is labeled with a title such as 'barh_demo', 'fill_demo', 'line_demo_dash_control', 'line_styles_reference', 'linestyles', 'marker_fillstyle_reference', 'marker_reference', 'filled markers', and 'unfilled markers'.

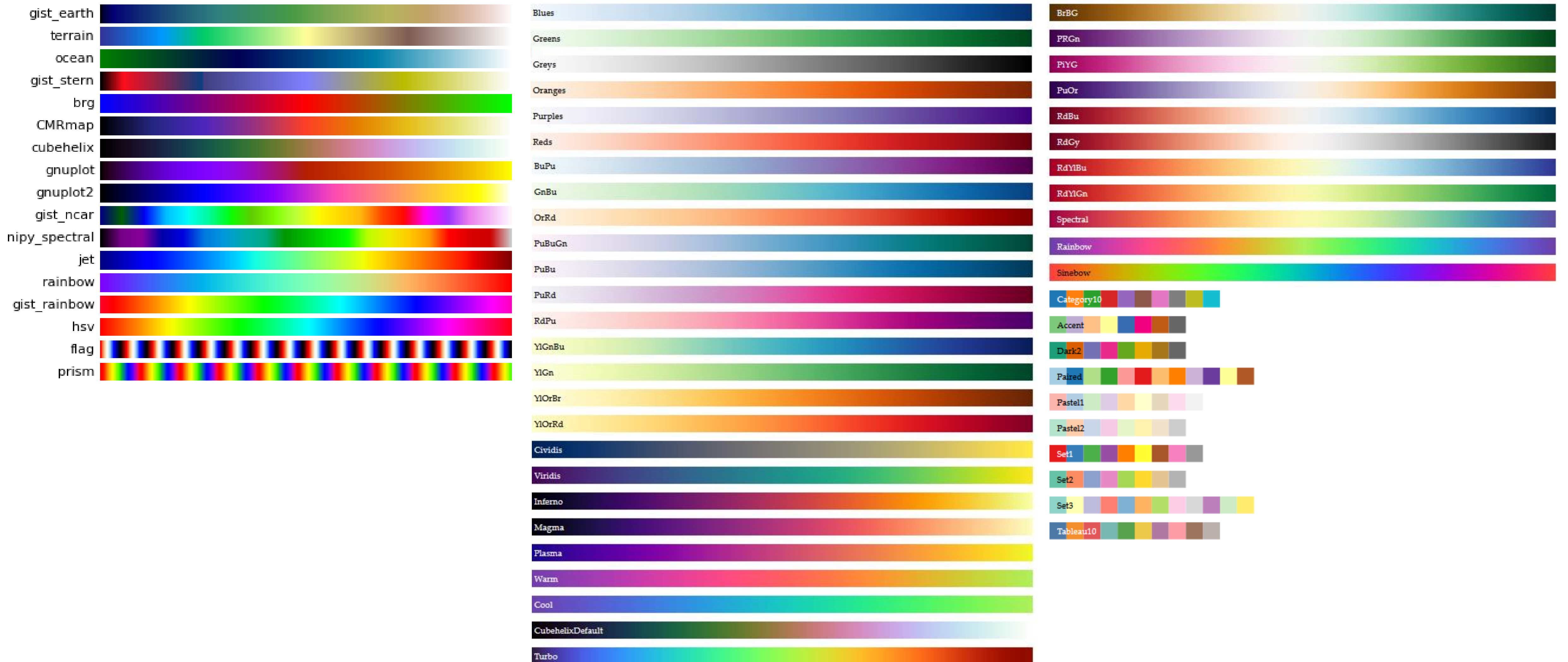
COLOR

GOALS FOR TODAY: LEARN HOW...

- ...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.

Color Maps

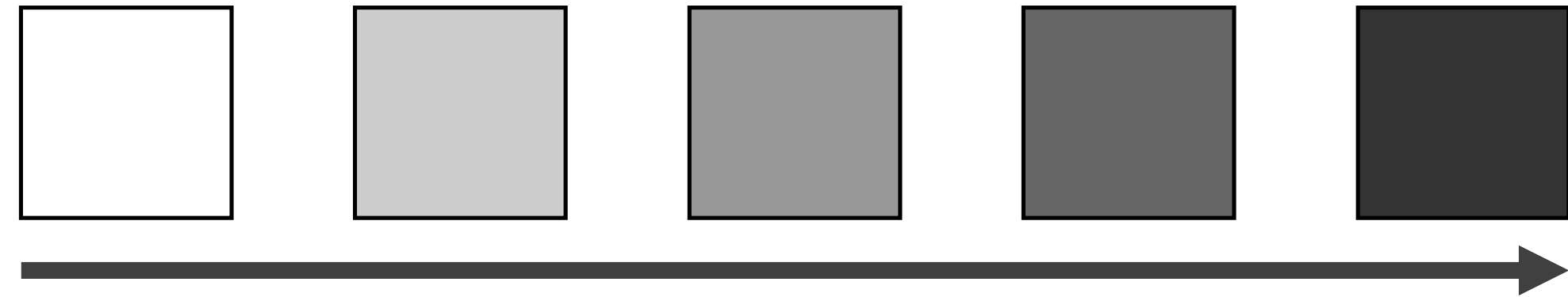
Color Map = map between value (domain) and color (range)



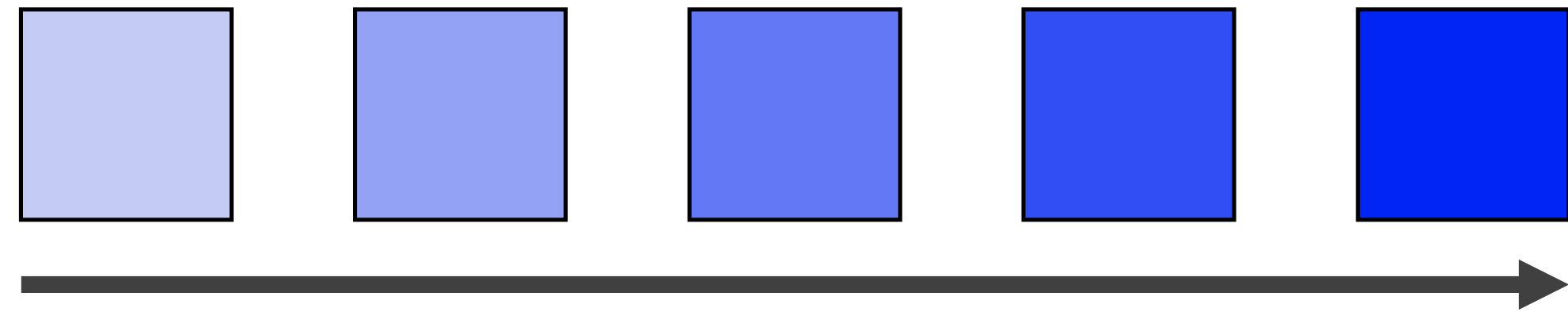
“...avoiding catastrophe becomes the first principle in bringing color to information: above all, do no harm.”
-Edward Tufte

Color Vocabulary and Perceptual Ordering

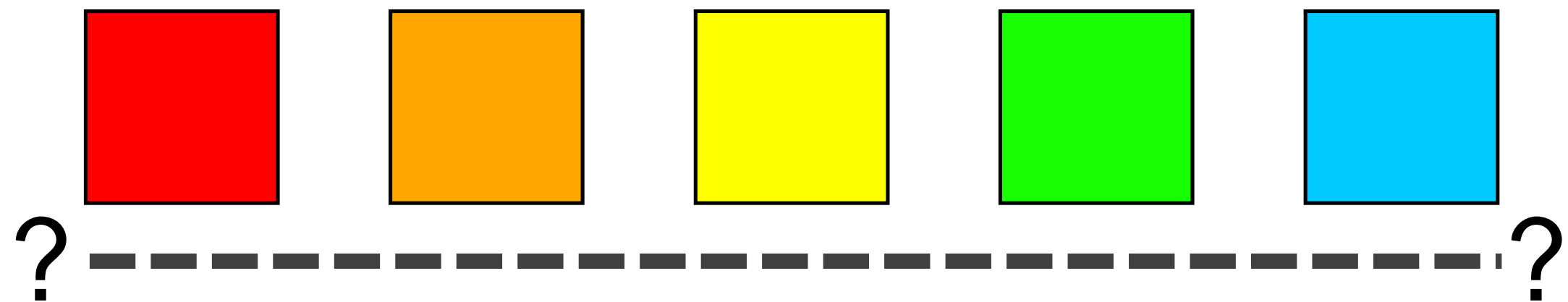
Darkness (Lightness)



Saturation



Hue



Encode > Map

➔ Color

➔ Color Encoding

➔ Hue



➔ Saturation



➔ Luminance



≈ Darkness
(Lightness)

➔ Color Map

➔ Categorical



➔ Ordered

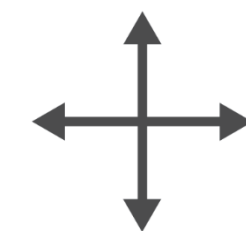
➔ Sequential



➔ Diverging



➔ Bivariate



➔ Size, Angle, Curvature, ...

➔ Length



➔ Angle



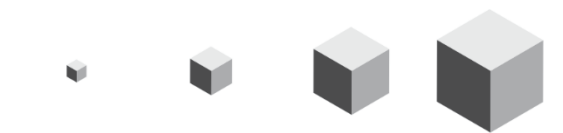
➔ Area



➔ Curvature



➔ Volume



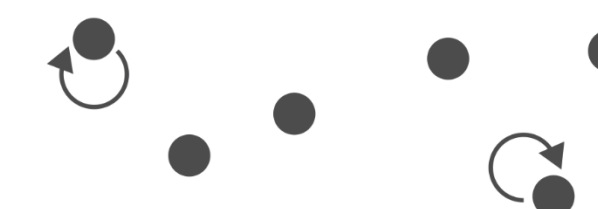
➔ Shape



➔ Motion

➔ Motion

Direction, Rate,
Frequency, ...



Color Maps

THREE MAIN TYPES:

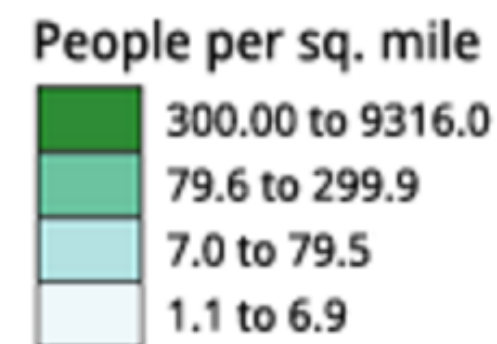
Categorical



Does not imply magnitude differences
(categorical/nominal data)

Distinct hues with similar emphasis

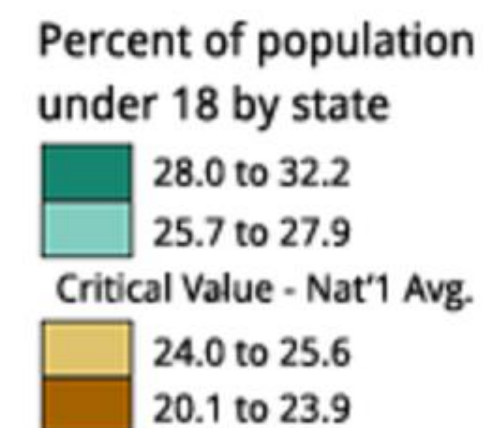
Sequential



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

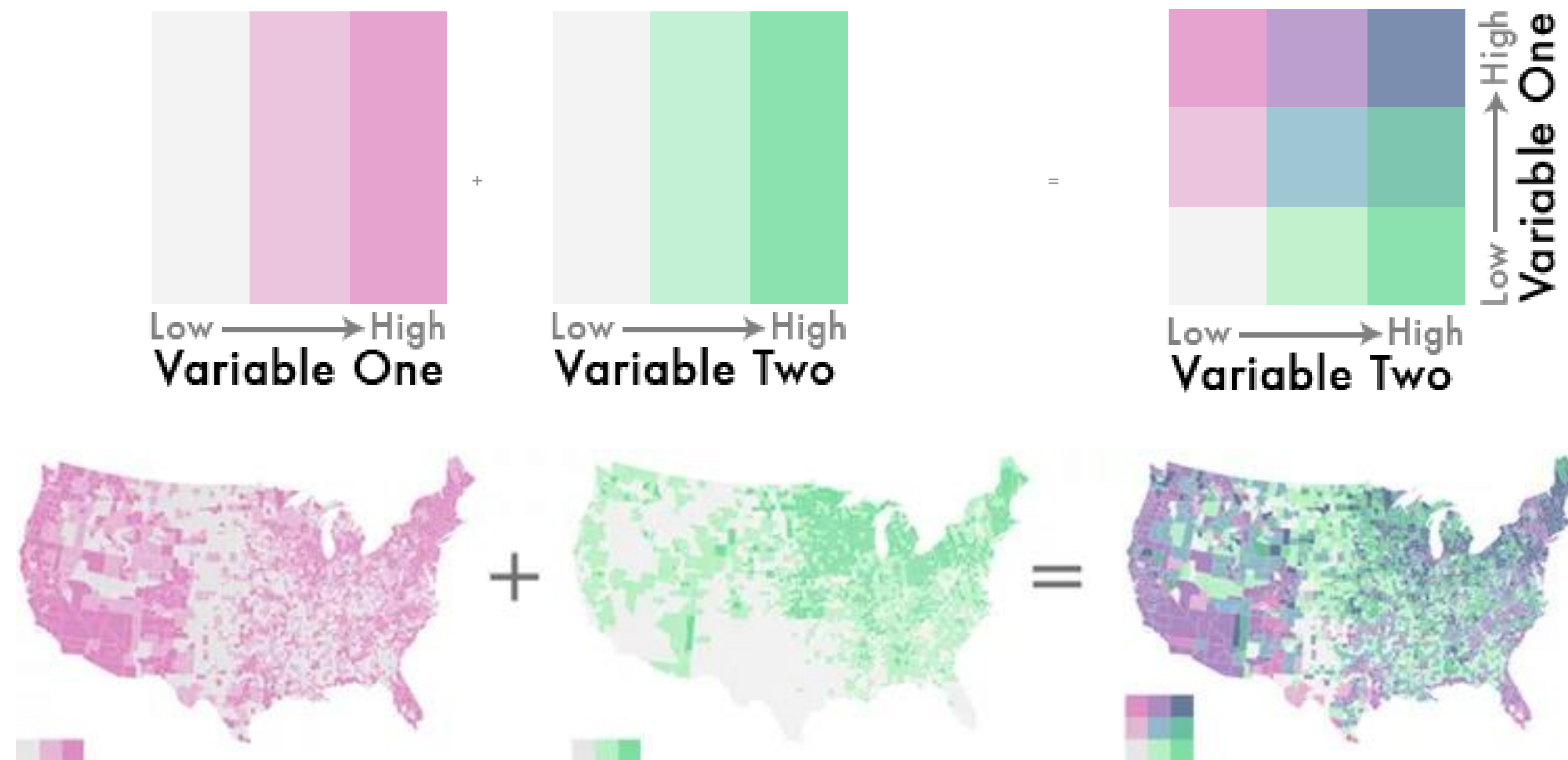
ALSO...

Bivariate

Displays two variables

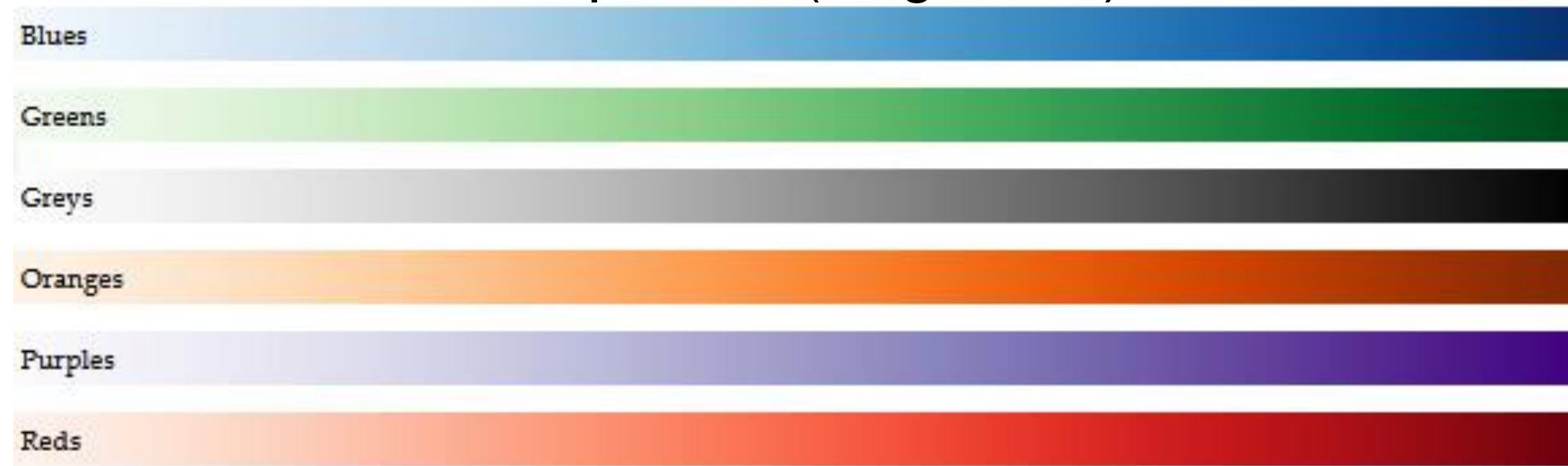
Combination of two sequential color schemes

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



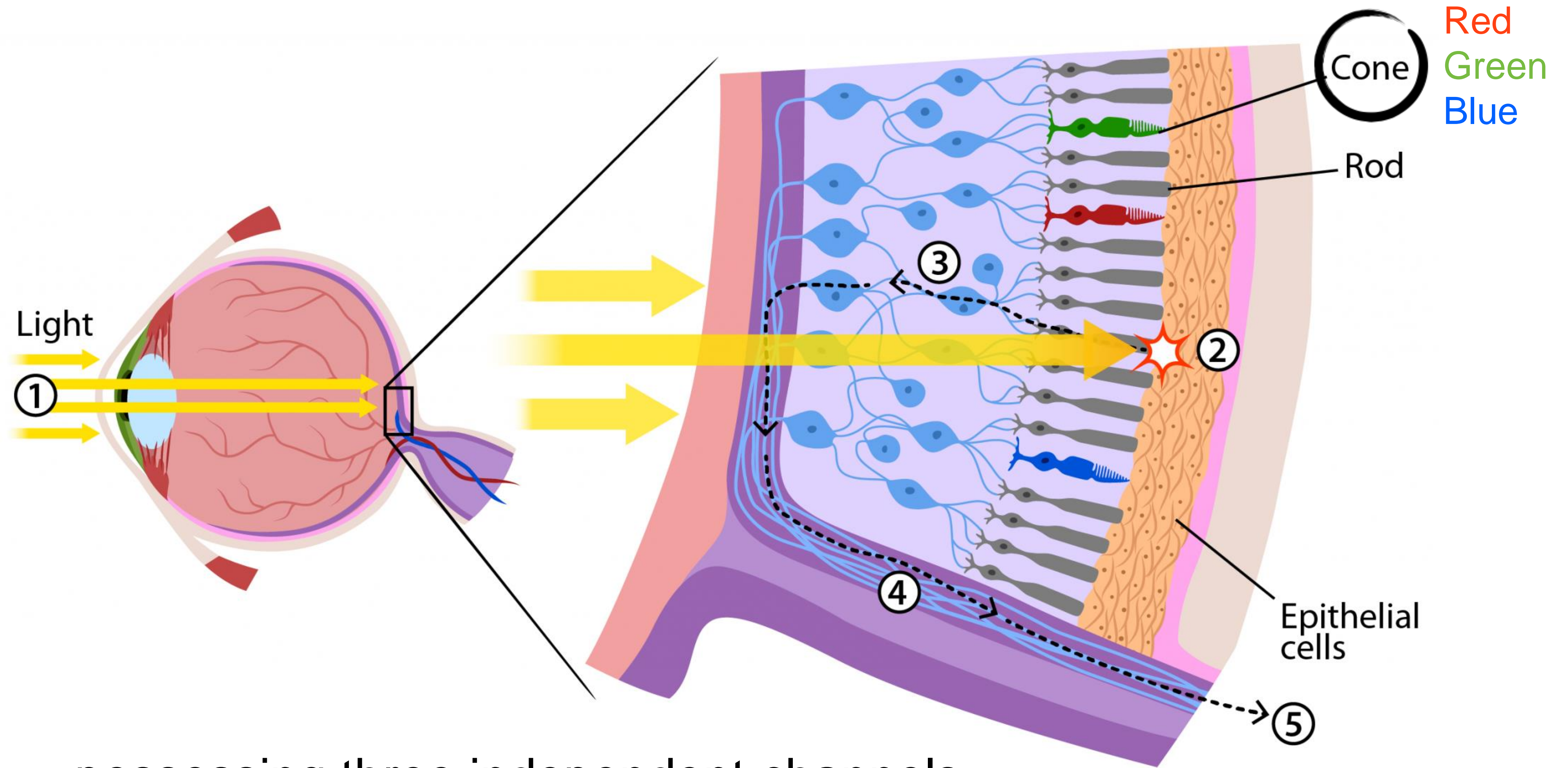
Categorical



Cyclical

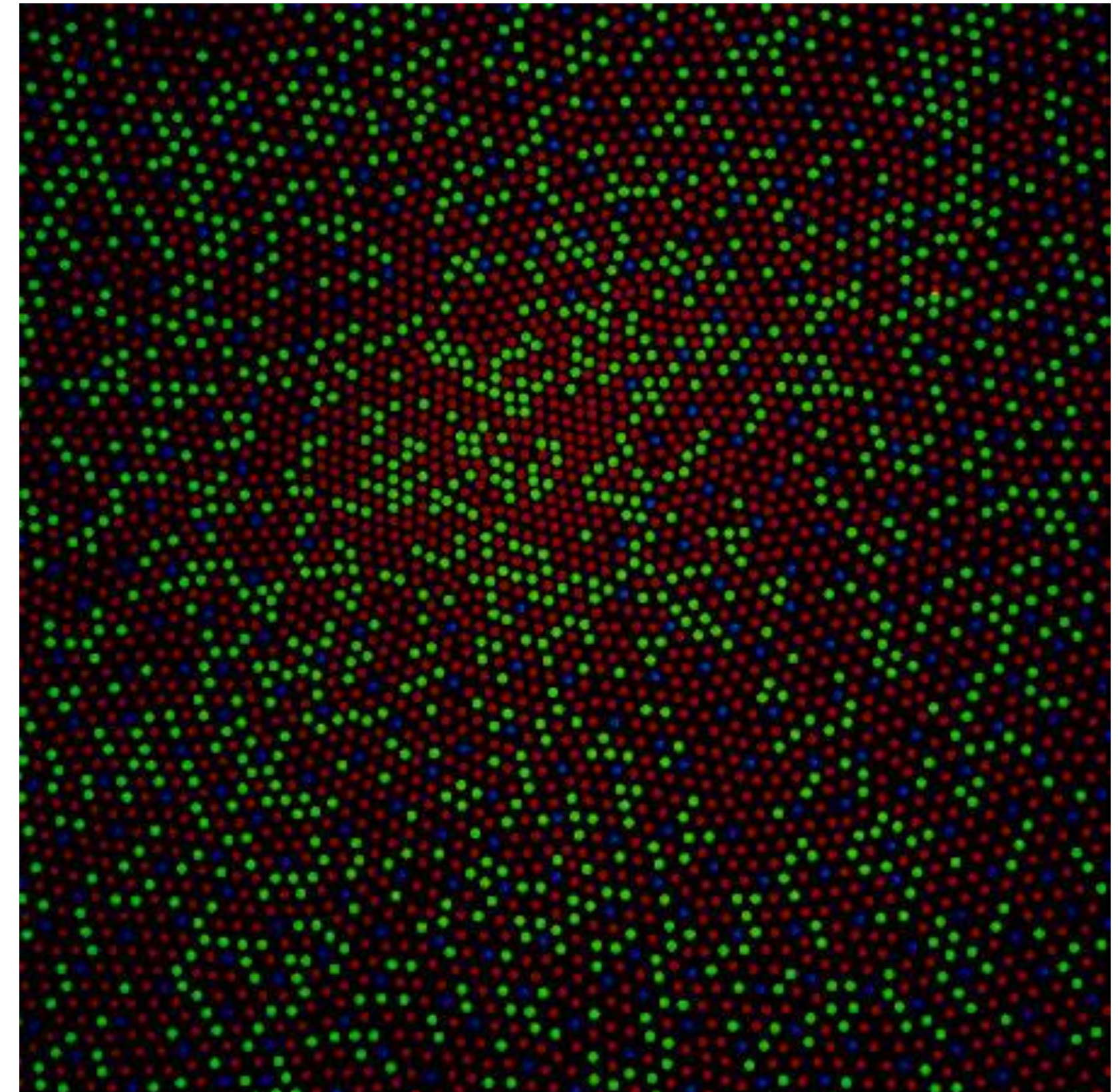
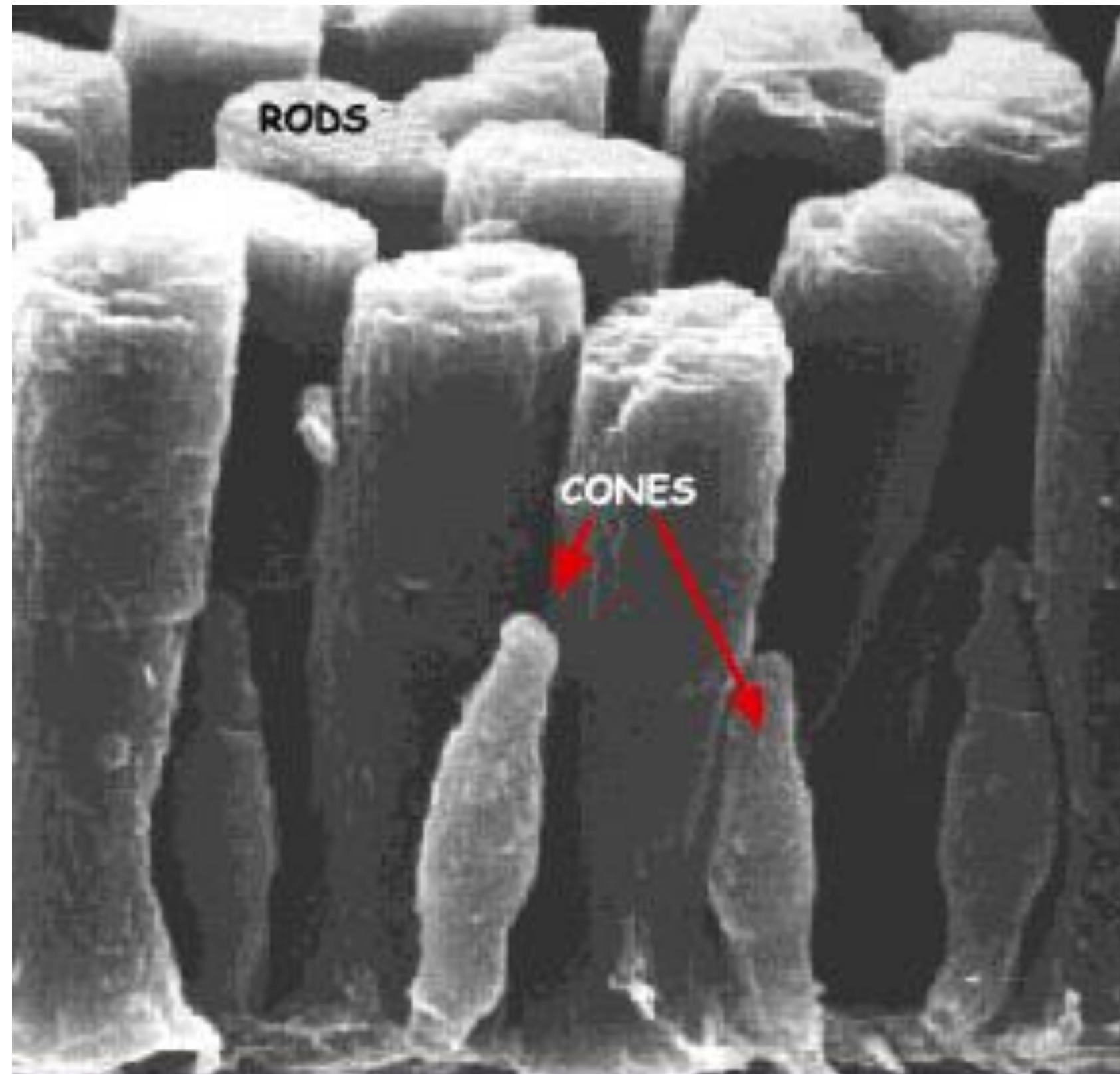


RODS & CONES

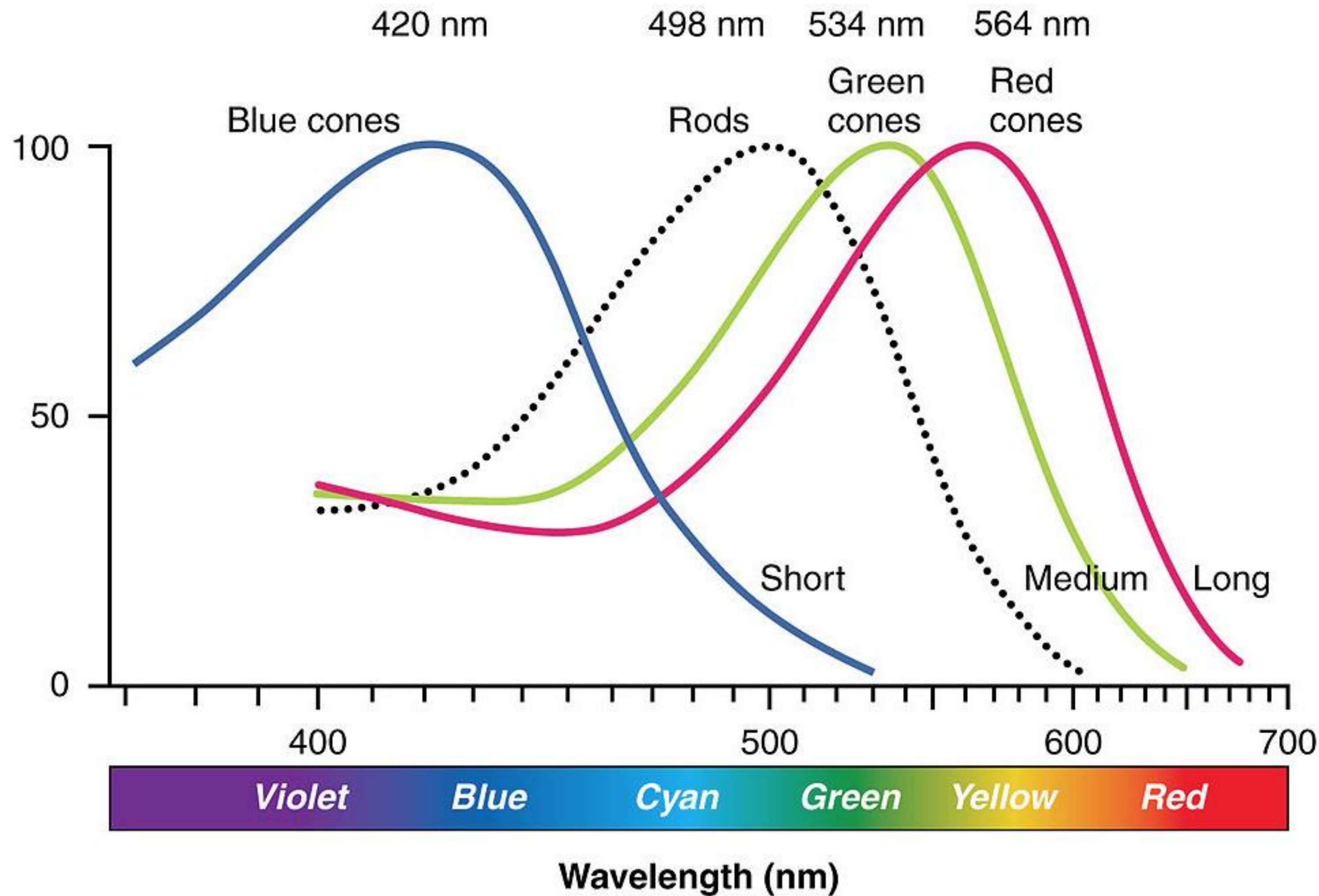


trichromacy = possessing three independent channels for conveying color information

RODS & CONES



CONES & RODS



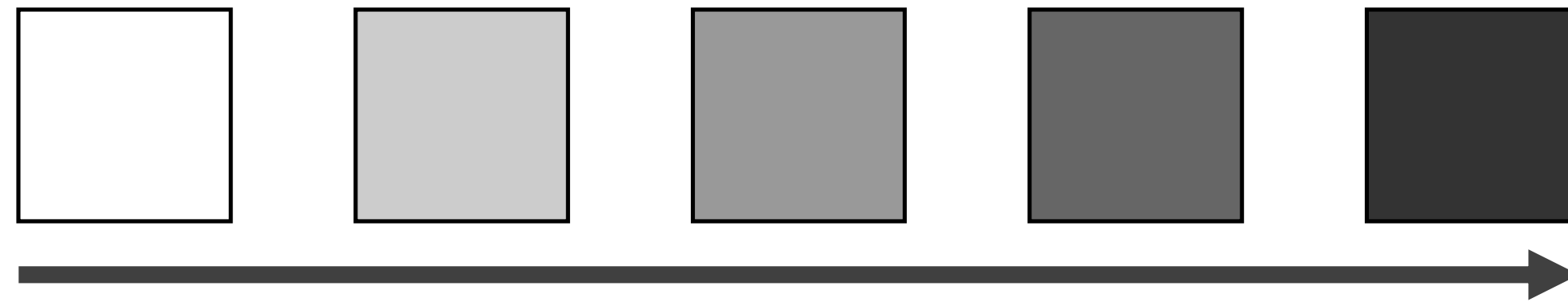
This is why darkness (lightness) is an effective encoding channel!

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.

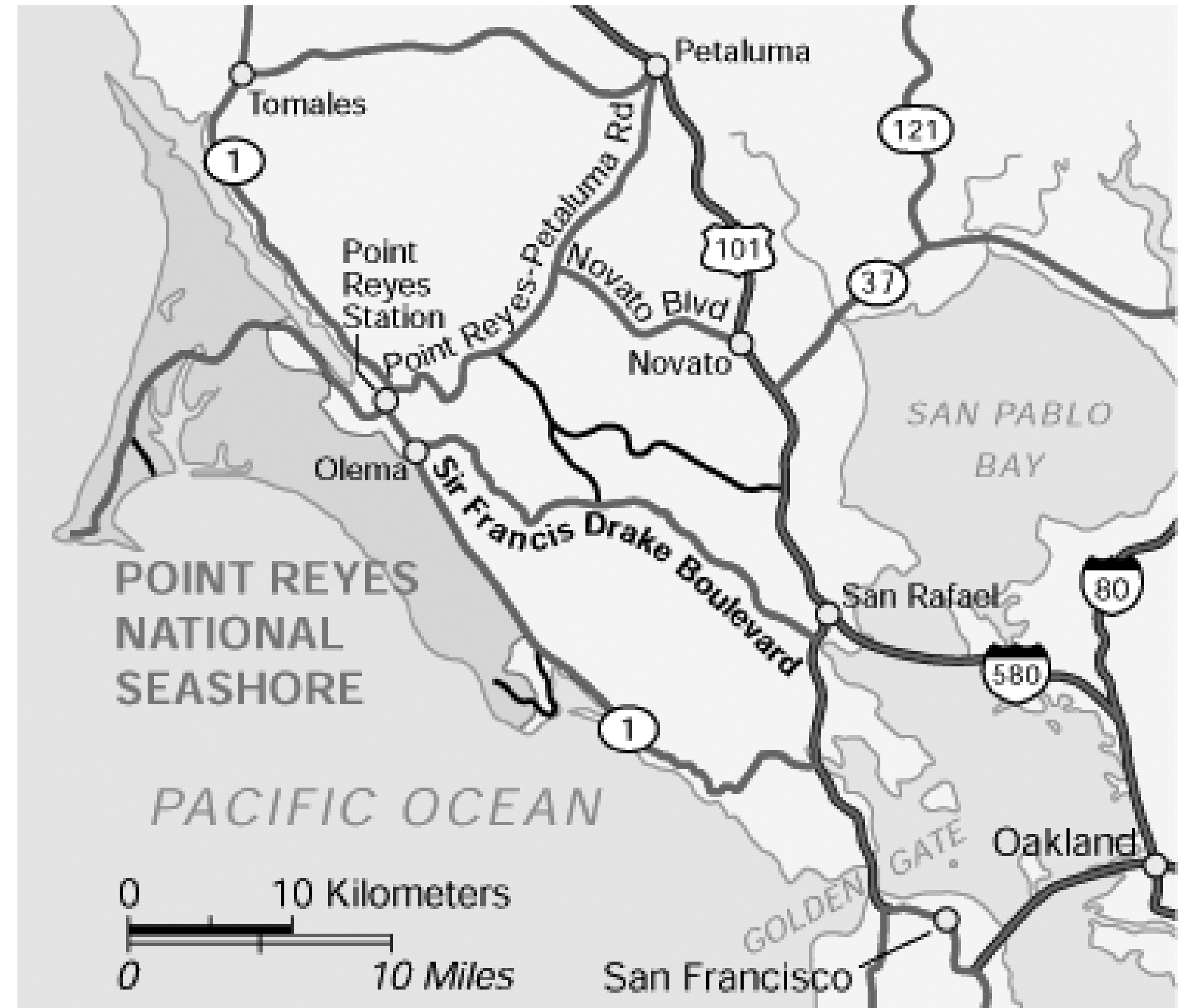
Darkness (Lightness) Channel



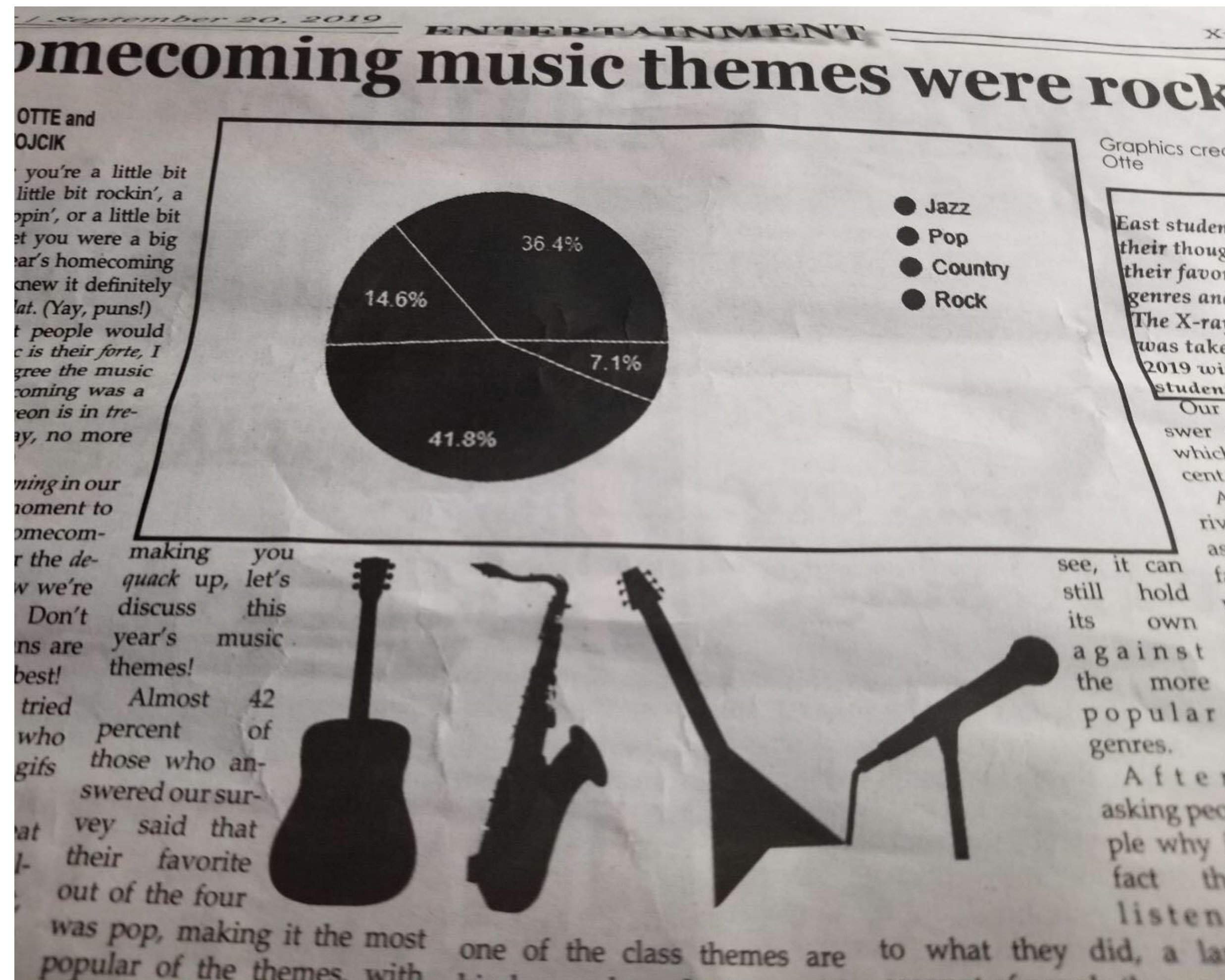
- No edges without darkness difference
- No shading without darkness variation
- Has higher spatial sensitivity than color channels
- Contrast defines legibility, attention, layering
- Controlling darkness is primary rule of design

“Get it right in black and white.”

-Maureen Stone



Understanding your medium matters



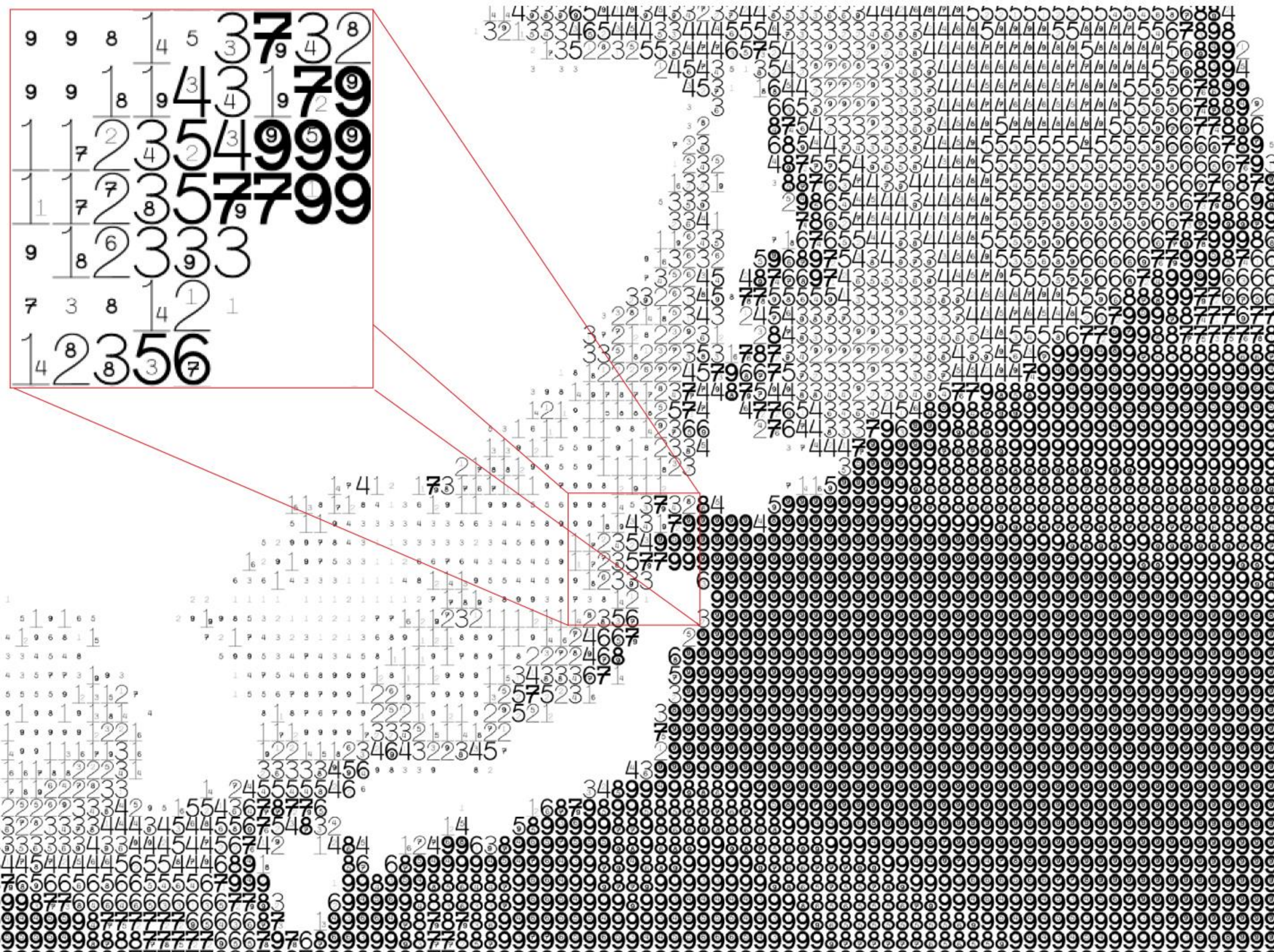
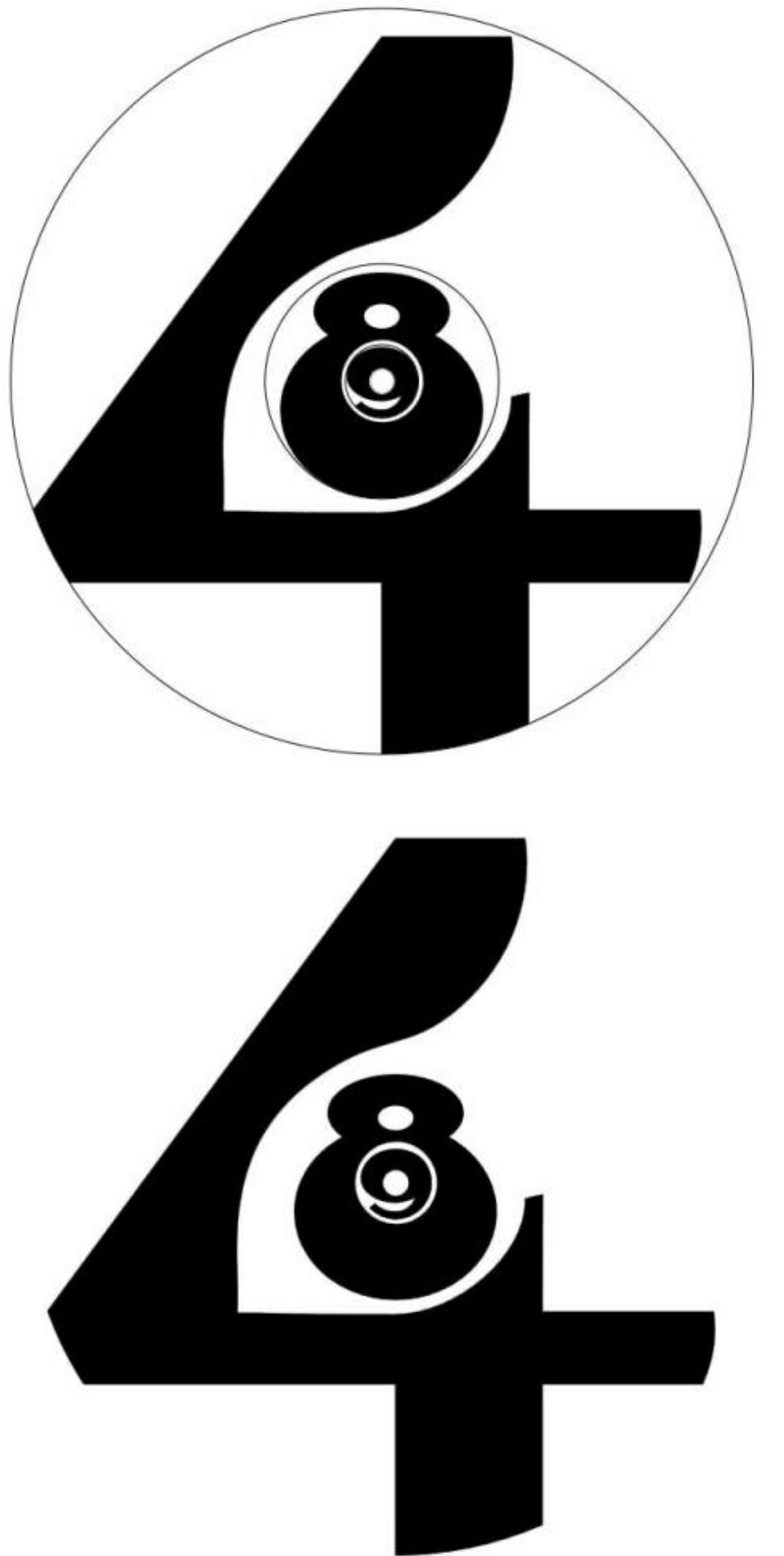
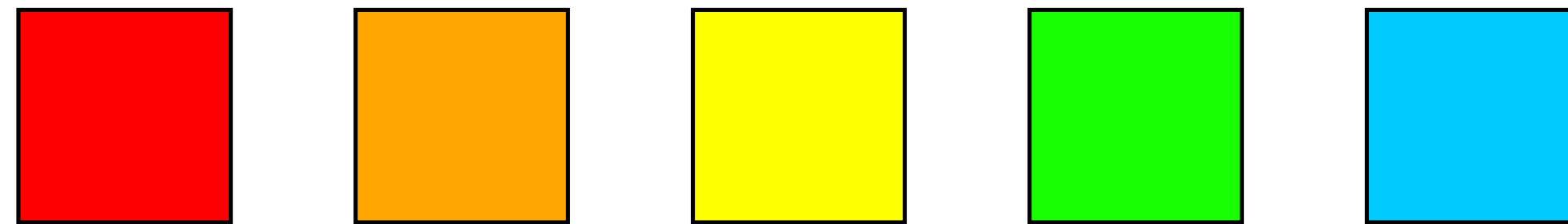


Figure 8: Maximum wave amplitudes for the Japan 2011 tsunami. Amplitudes were clipped at 99cm. Data adapted from NOAA; <http://www.noaa.gov/>.

FatFonts



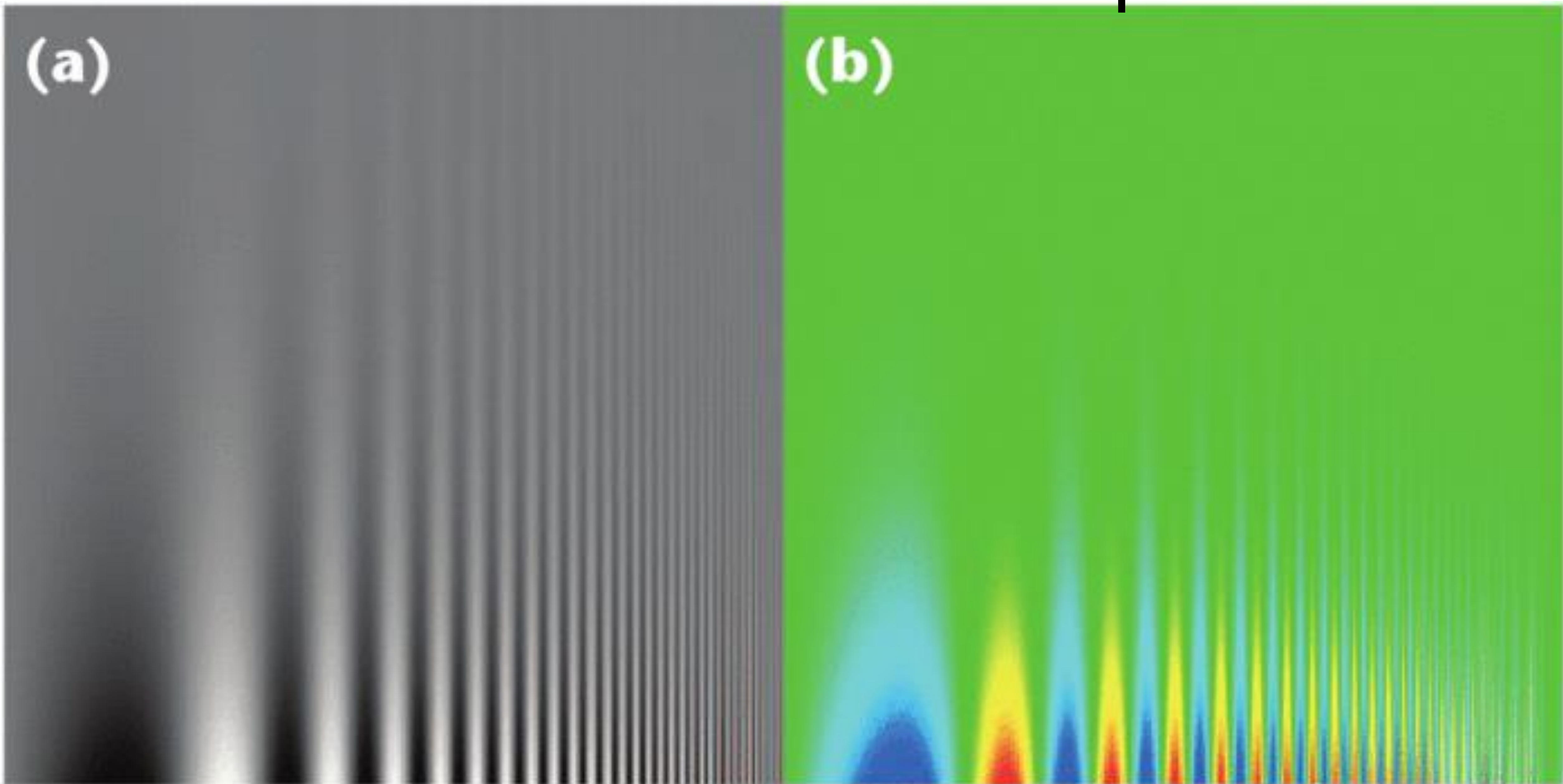
Rainbow Color Map (Hue)



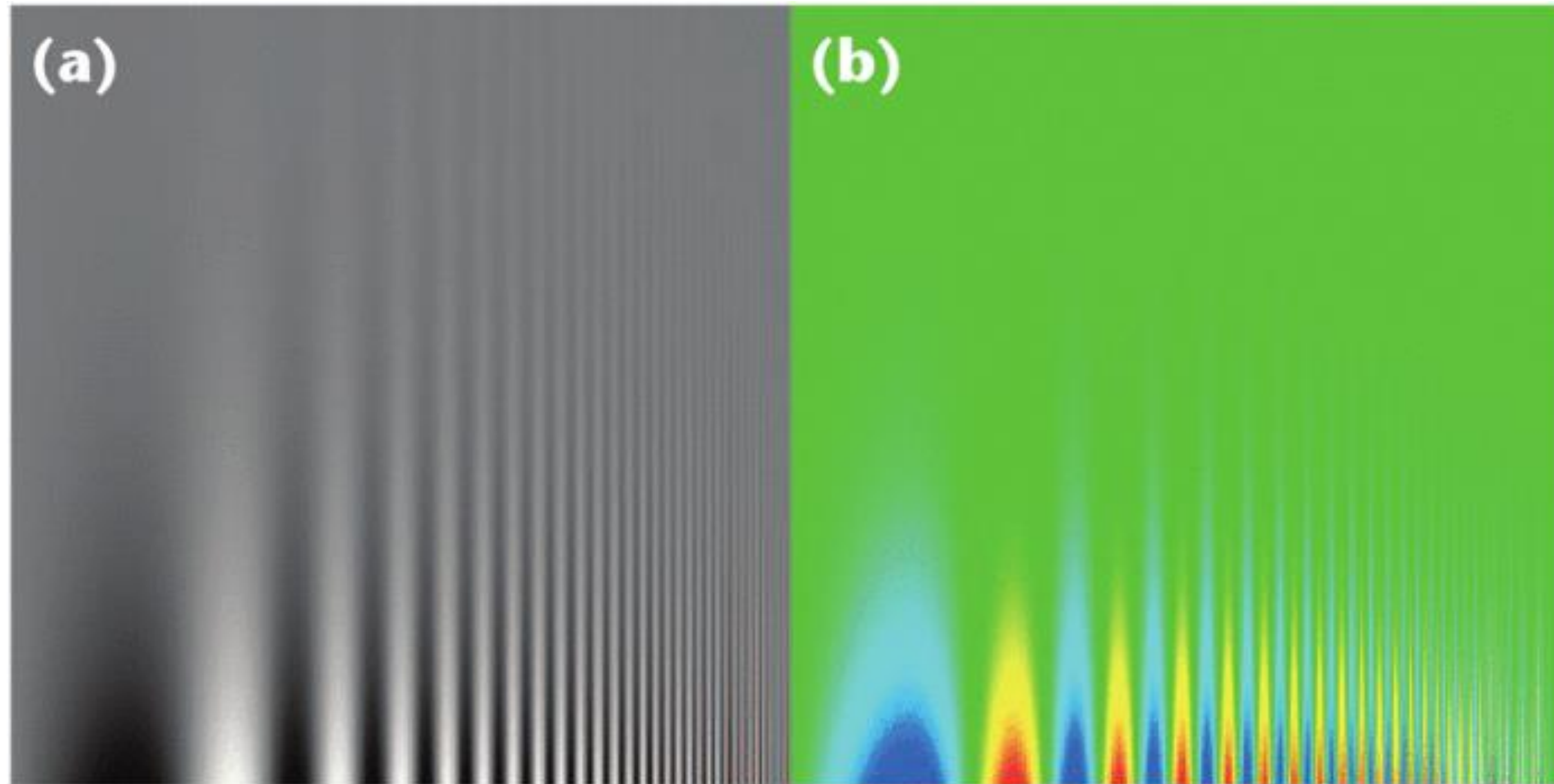
Rainbow Color Map

(a)

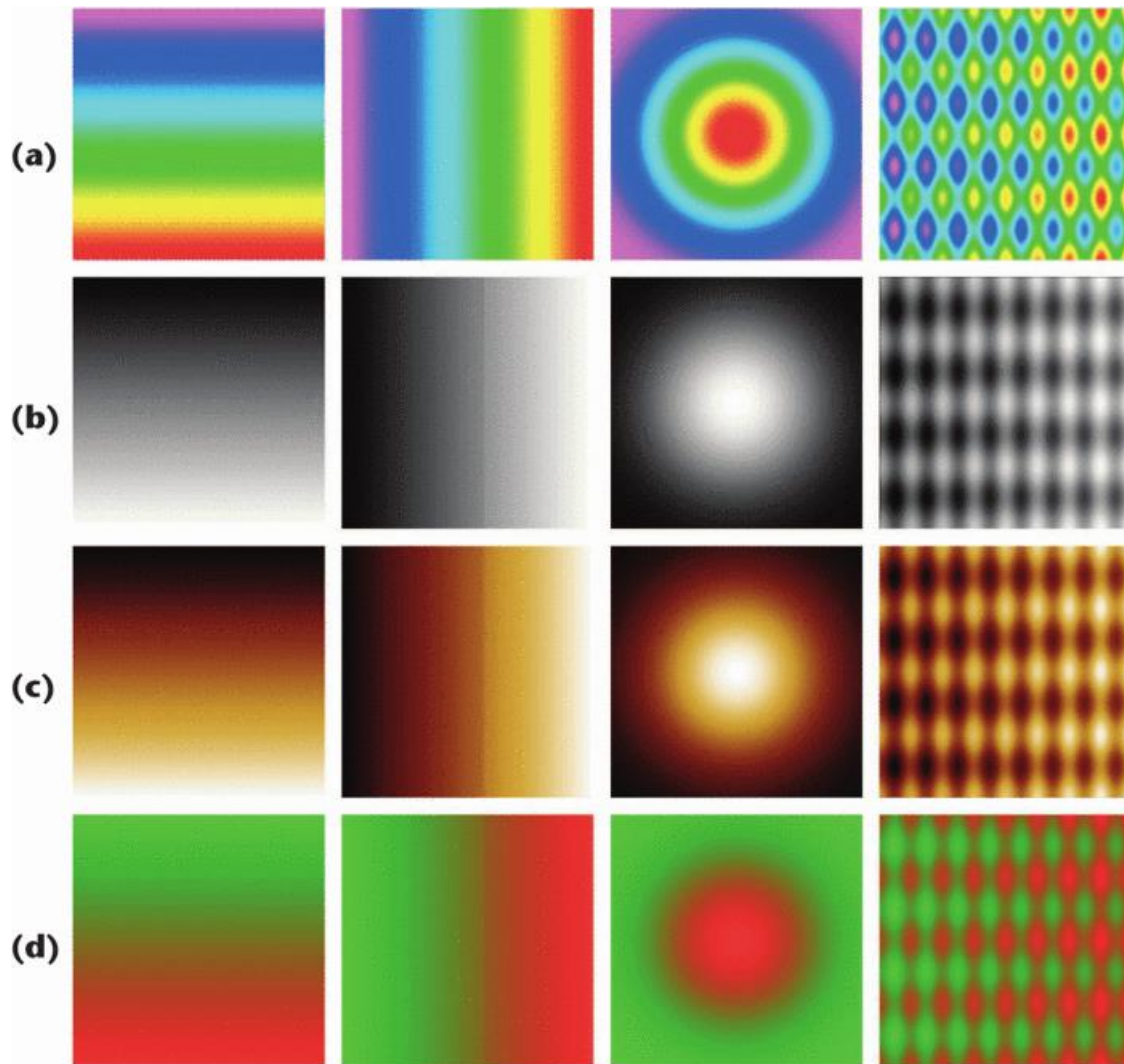
(b)



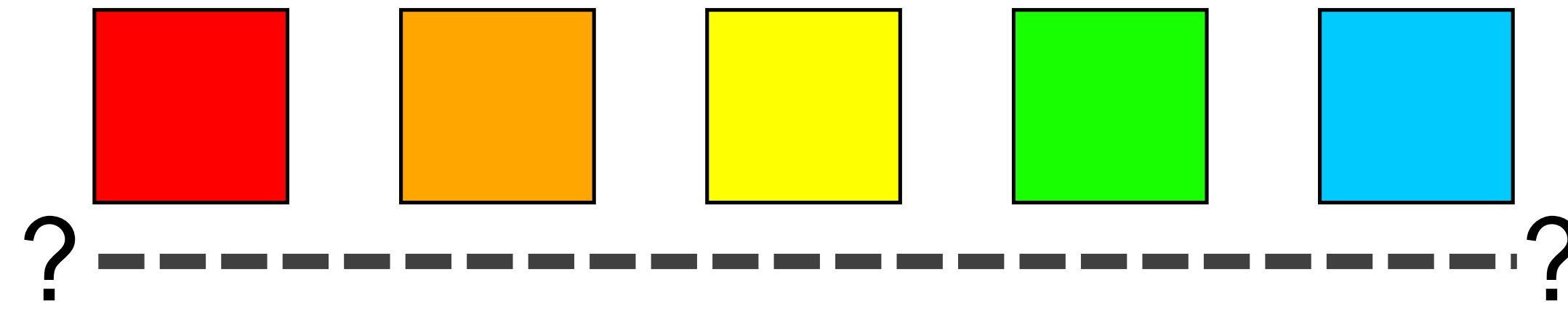
Rainbow Color Map



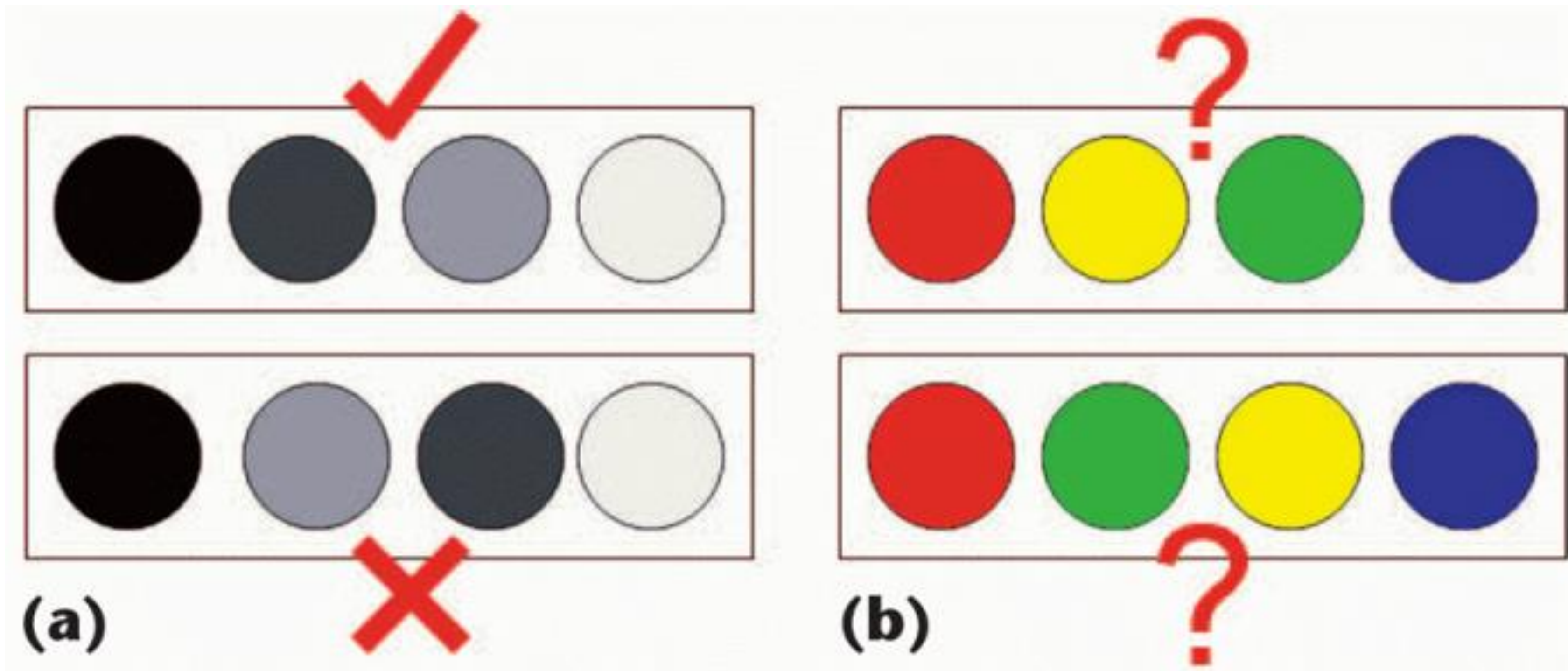
- No darkness variation (obscures details)
- Viewers perceive sharp transitions in color as sharp transitions in the data, even when this is not the case (misleading)



Rainbow Color Map (Hue)



No perceptual ordering (confusing)

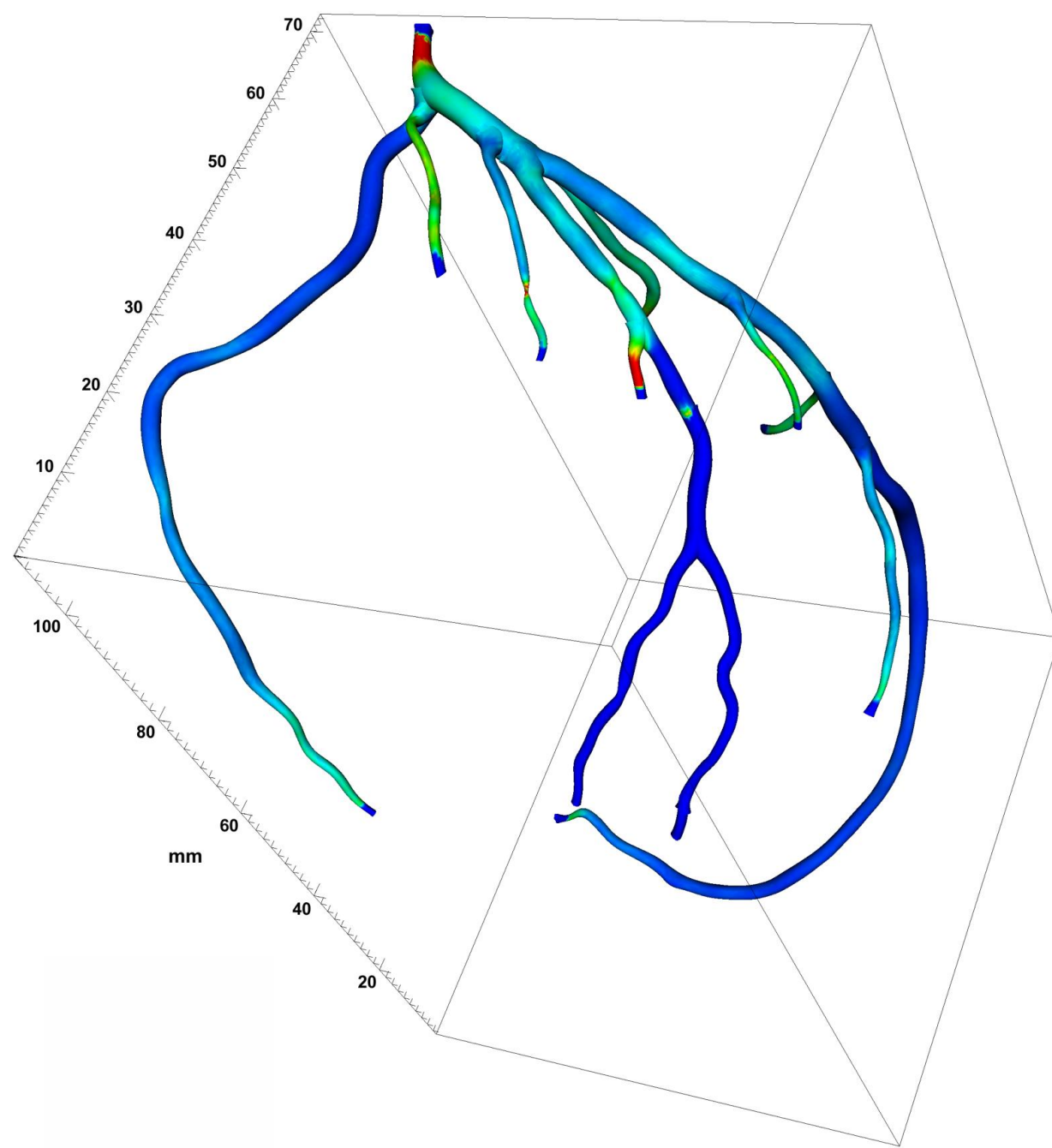


Rainbow Color Map

Rainbow:

3D: 39%

2D: 62%

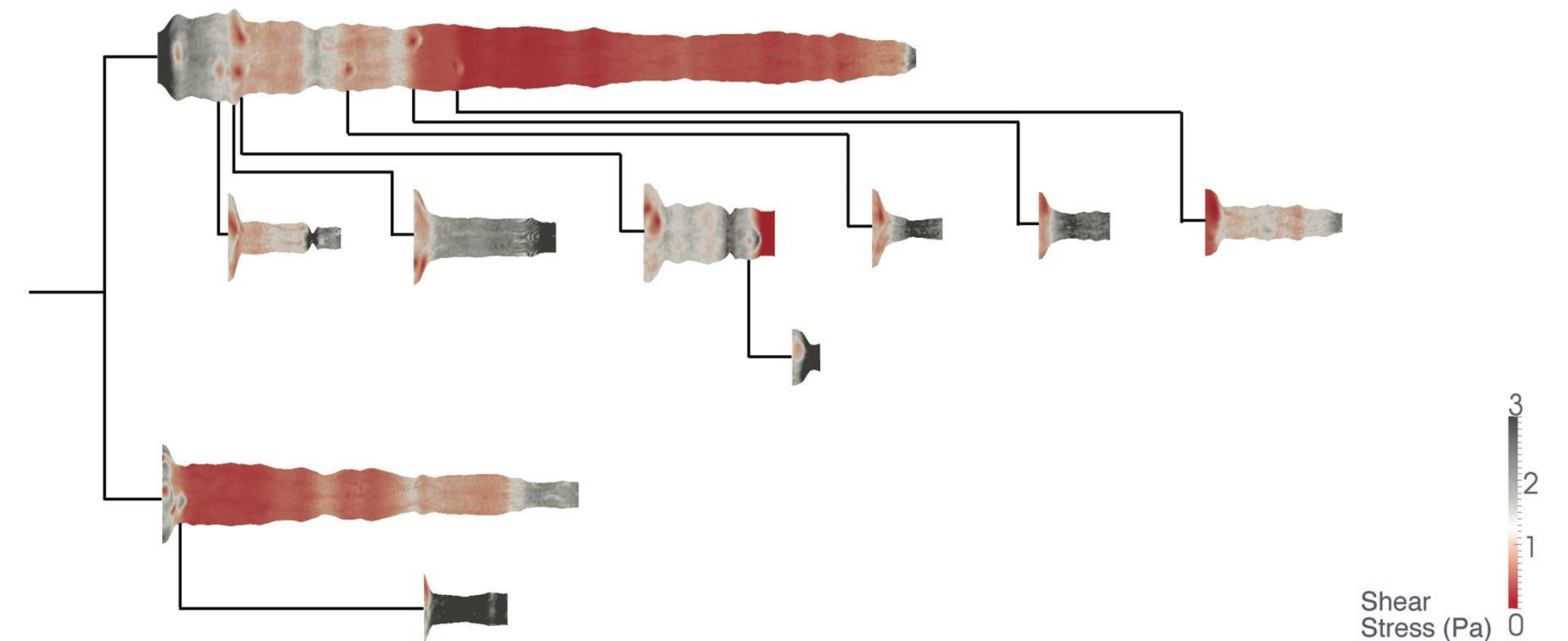


How many diseased regions found?

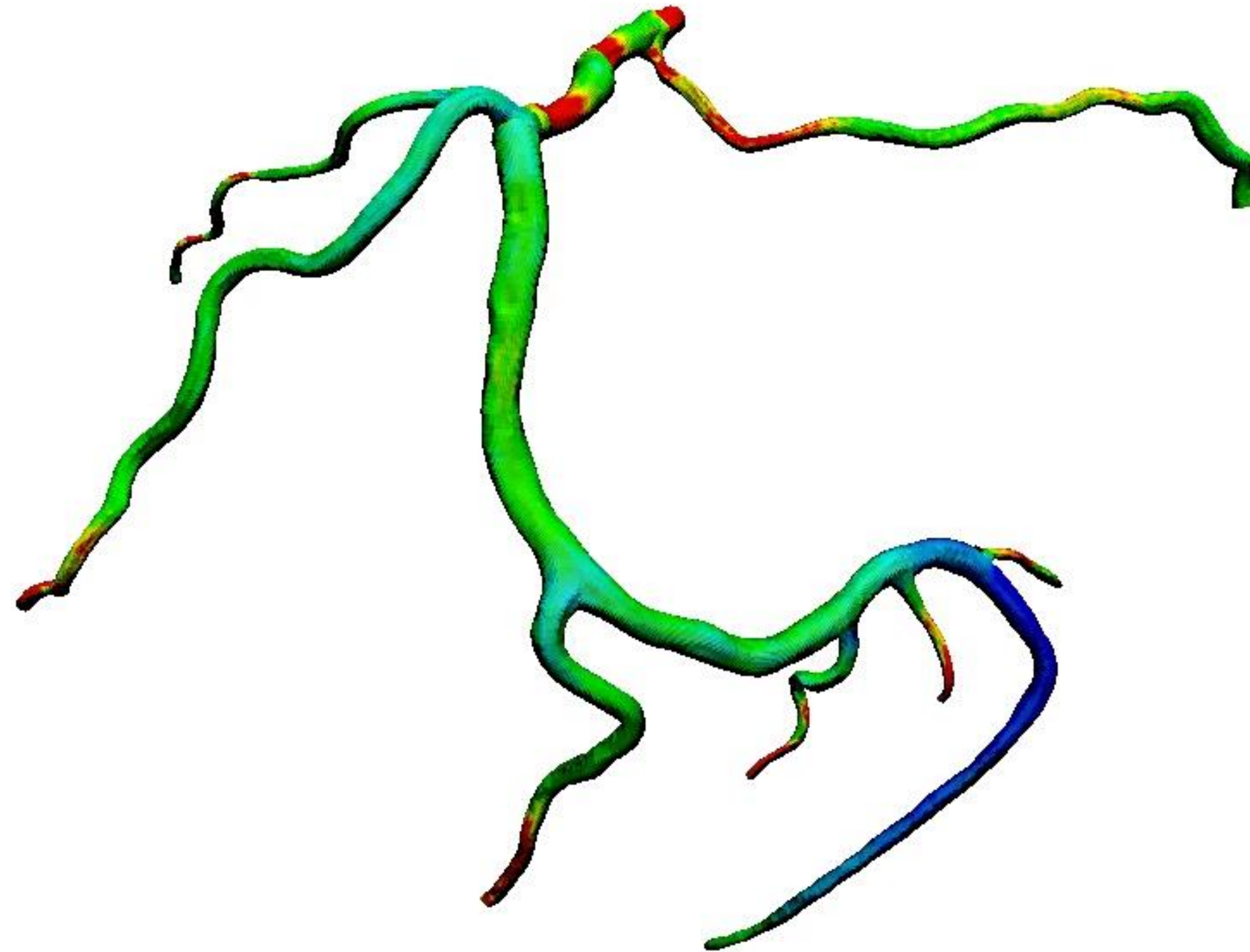
Diverging:

3D: 71% (Δ +31%)

2D: 91% (Δ +29%)

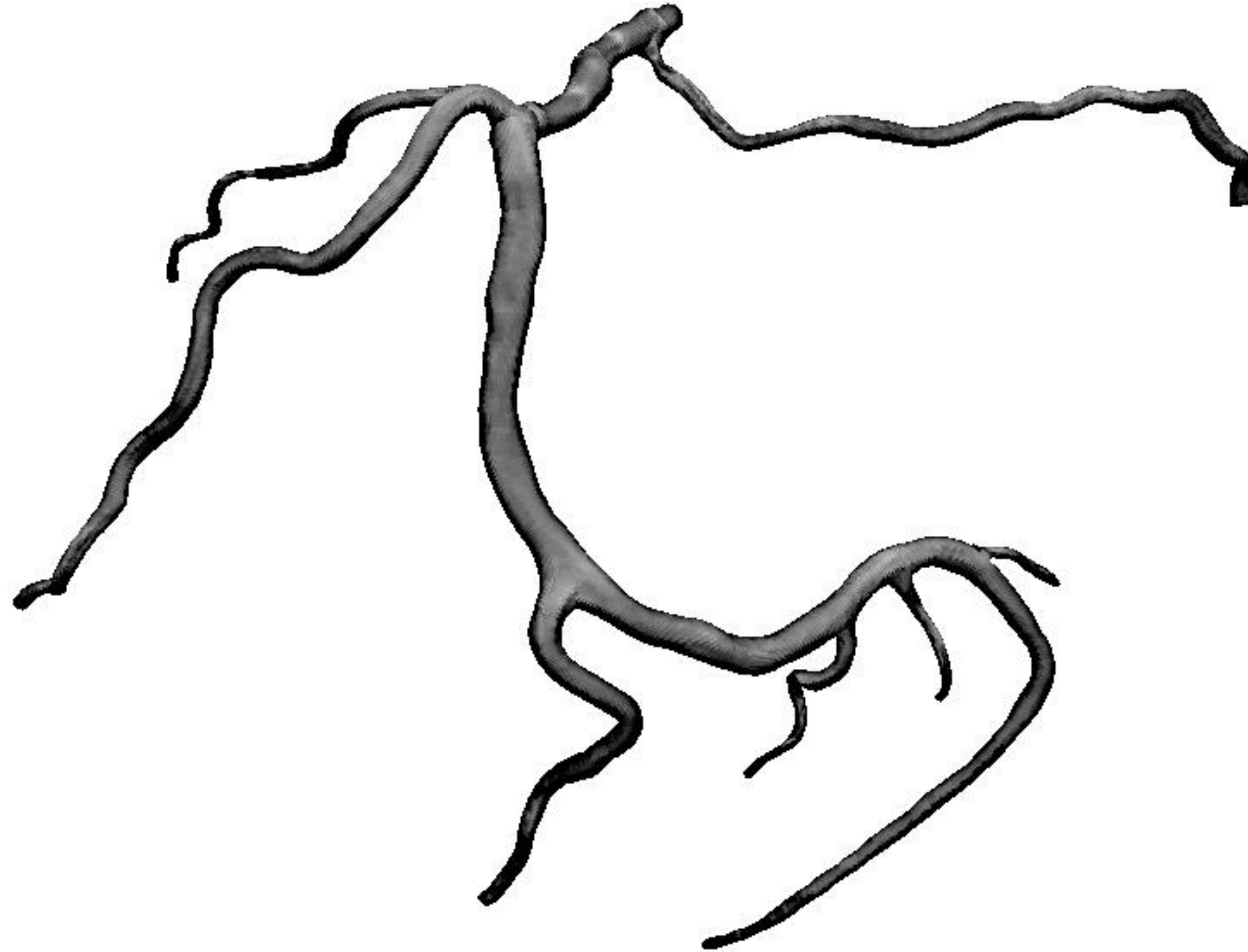


“Get it right in black and white.”

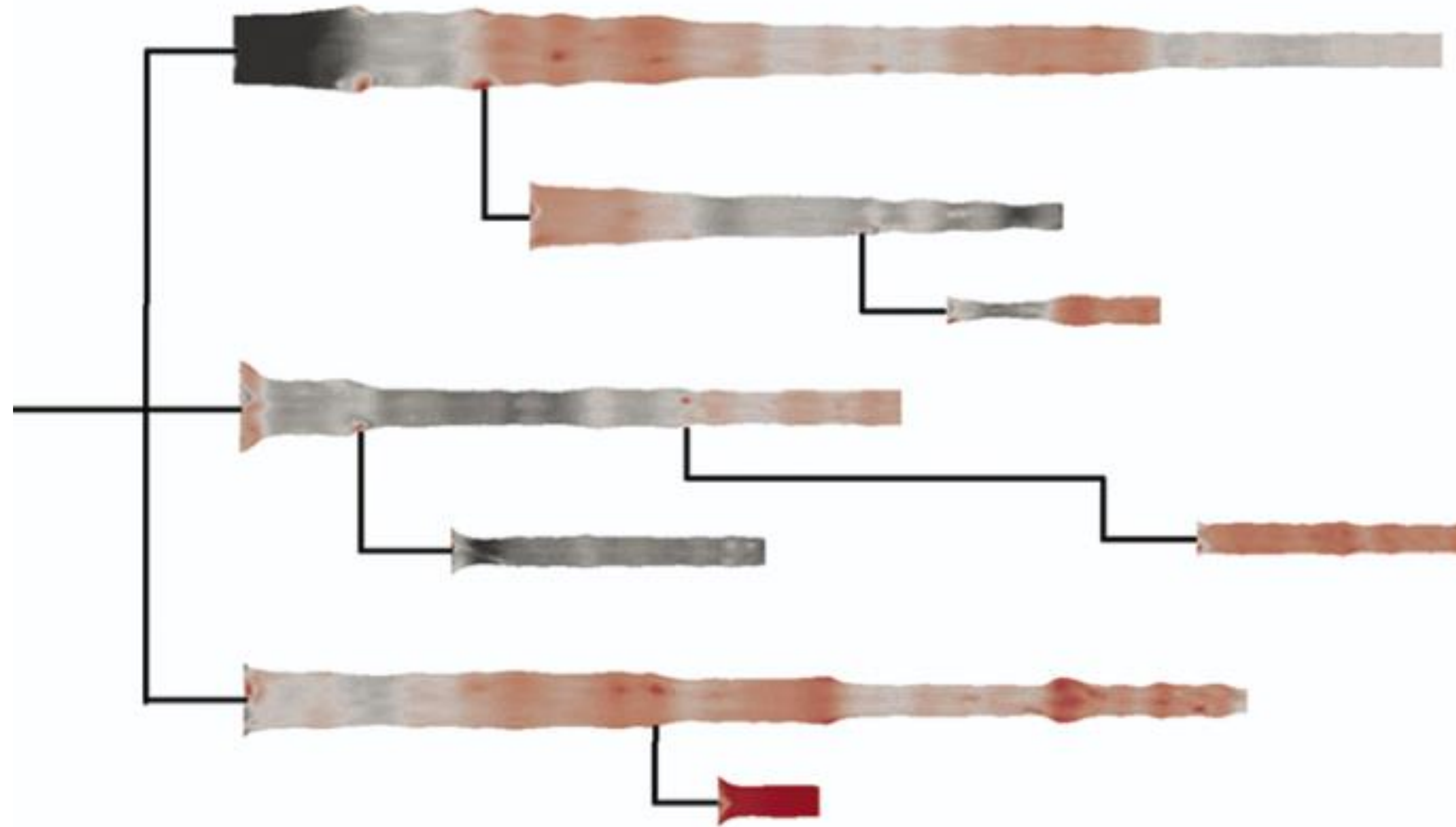


39% Diseased Regions Found

“Get it right in black and white.”

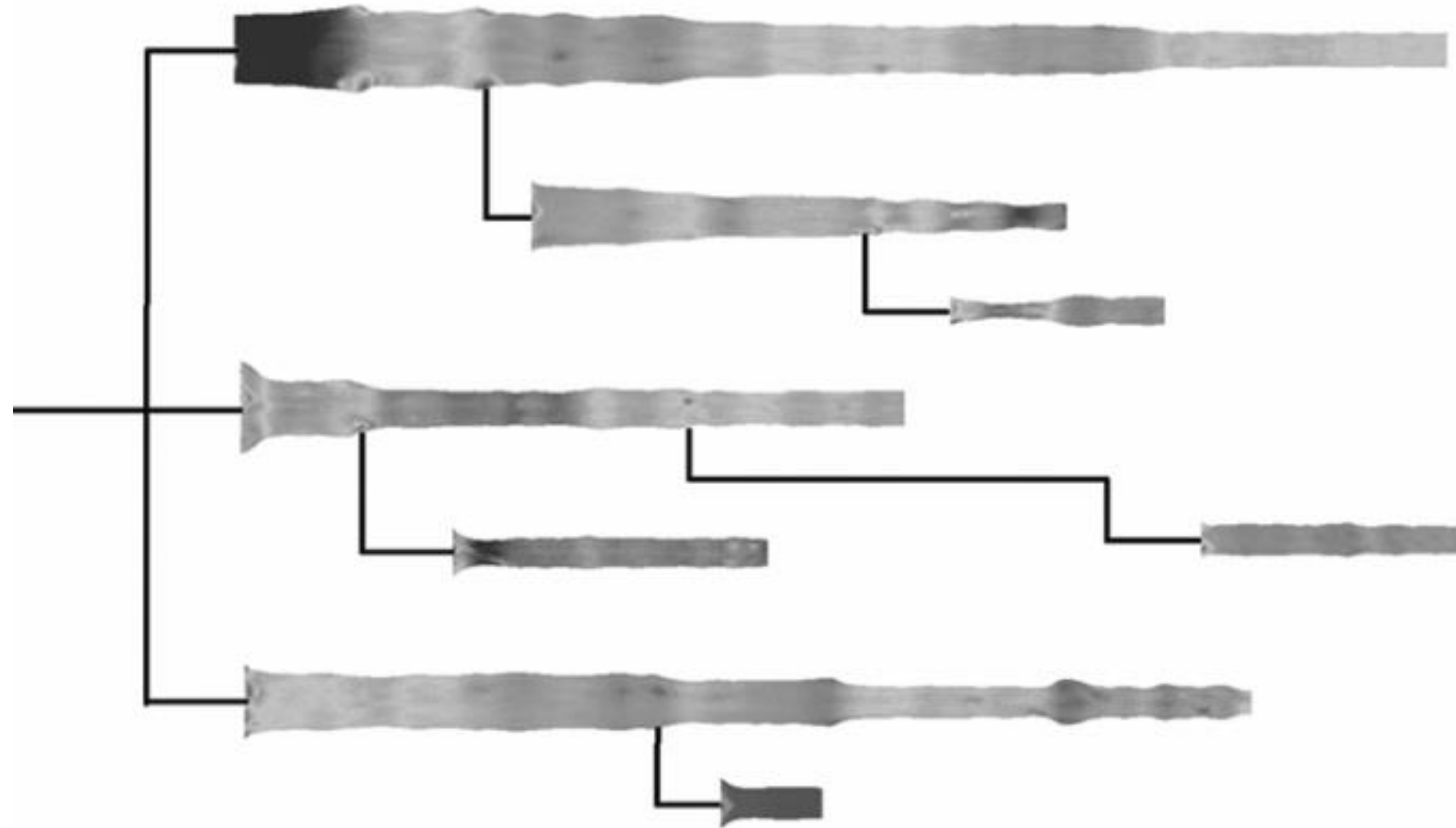


“Get it right in black and white.”



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?

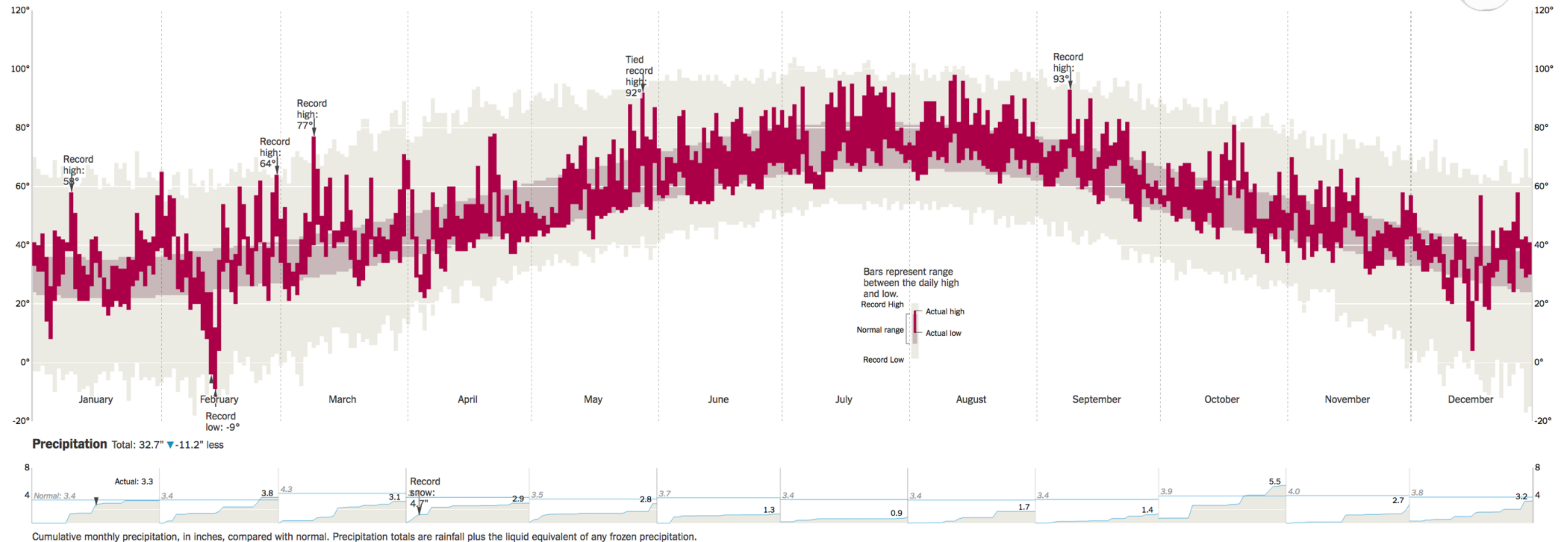
By K.K. REBECCA LAI JAN. 18, 2017

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?

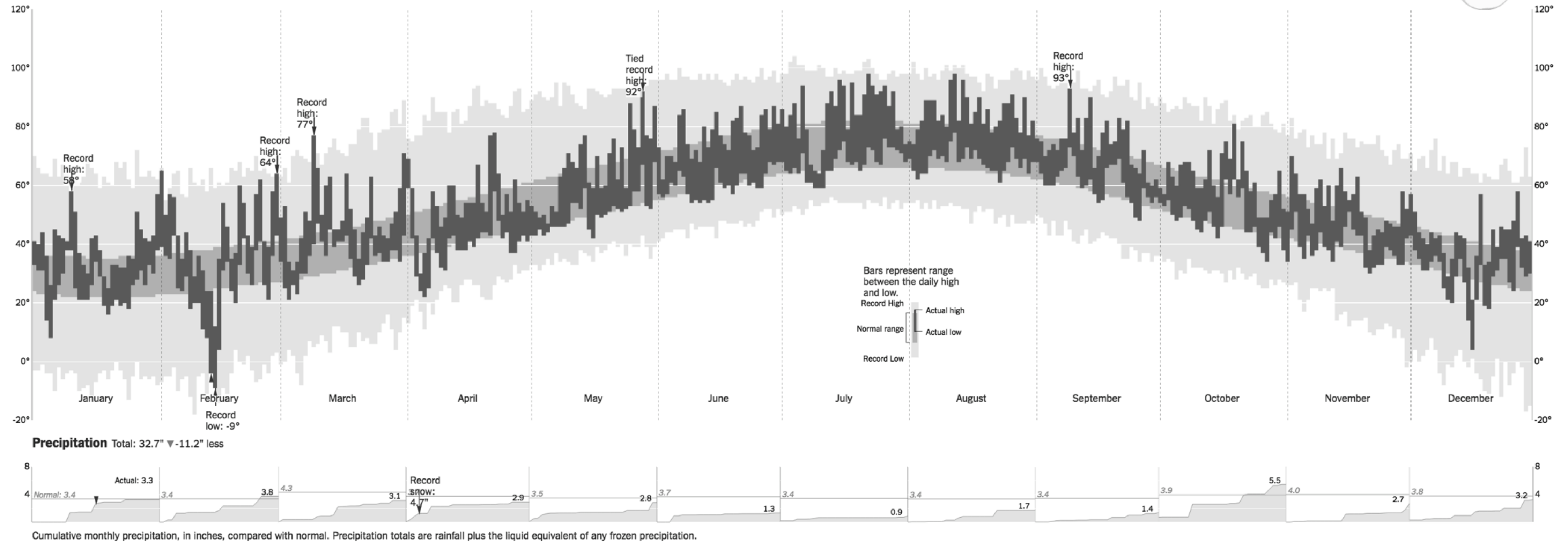
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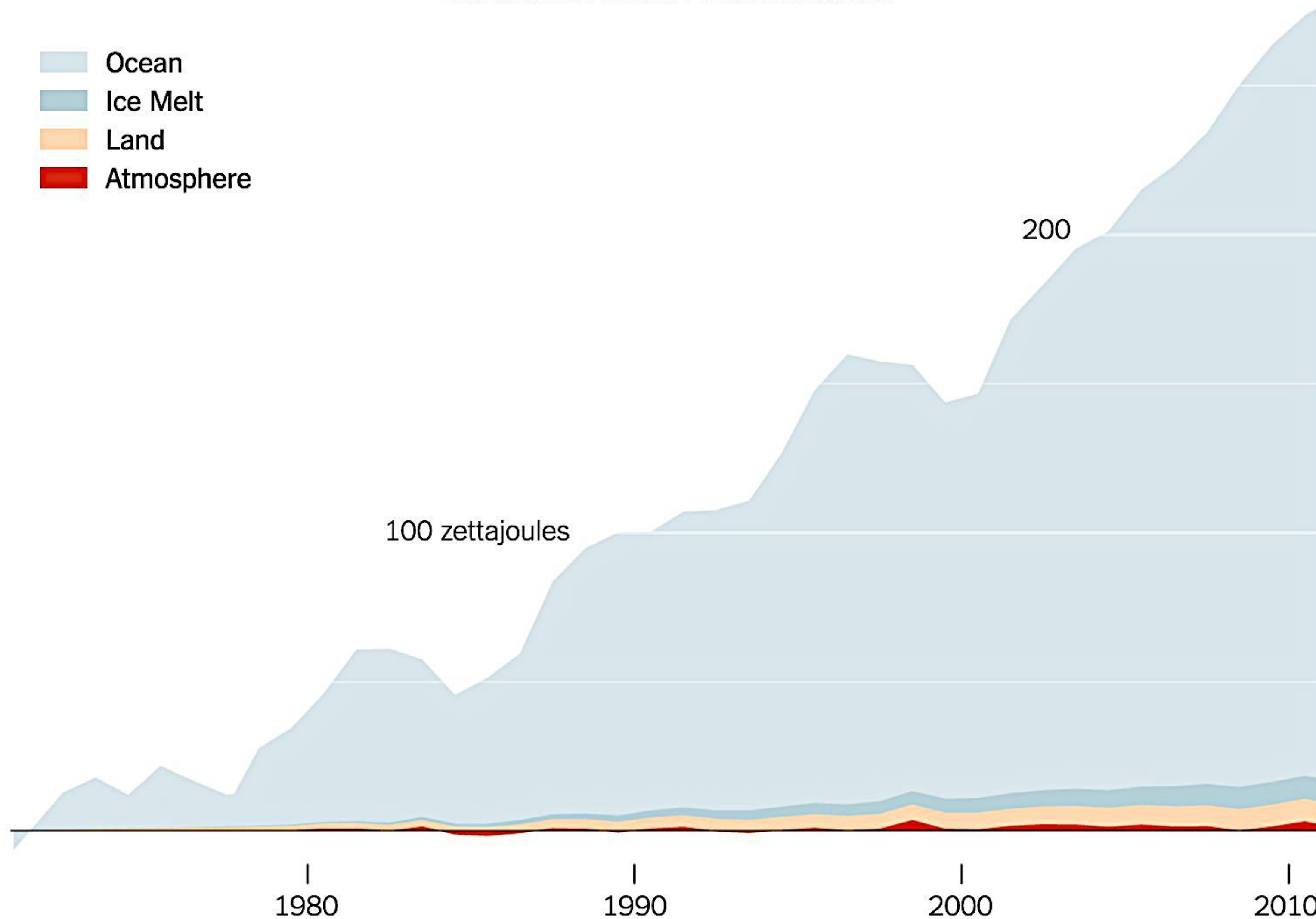
°F °C



“Get it right in black and white.”

Estimated Heat Accumulation

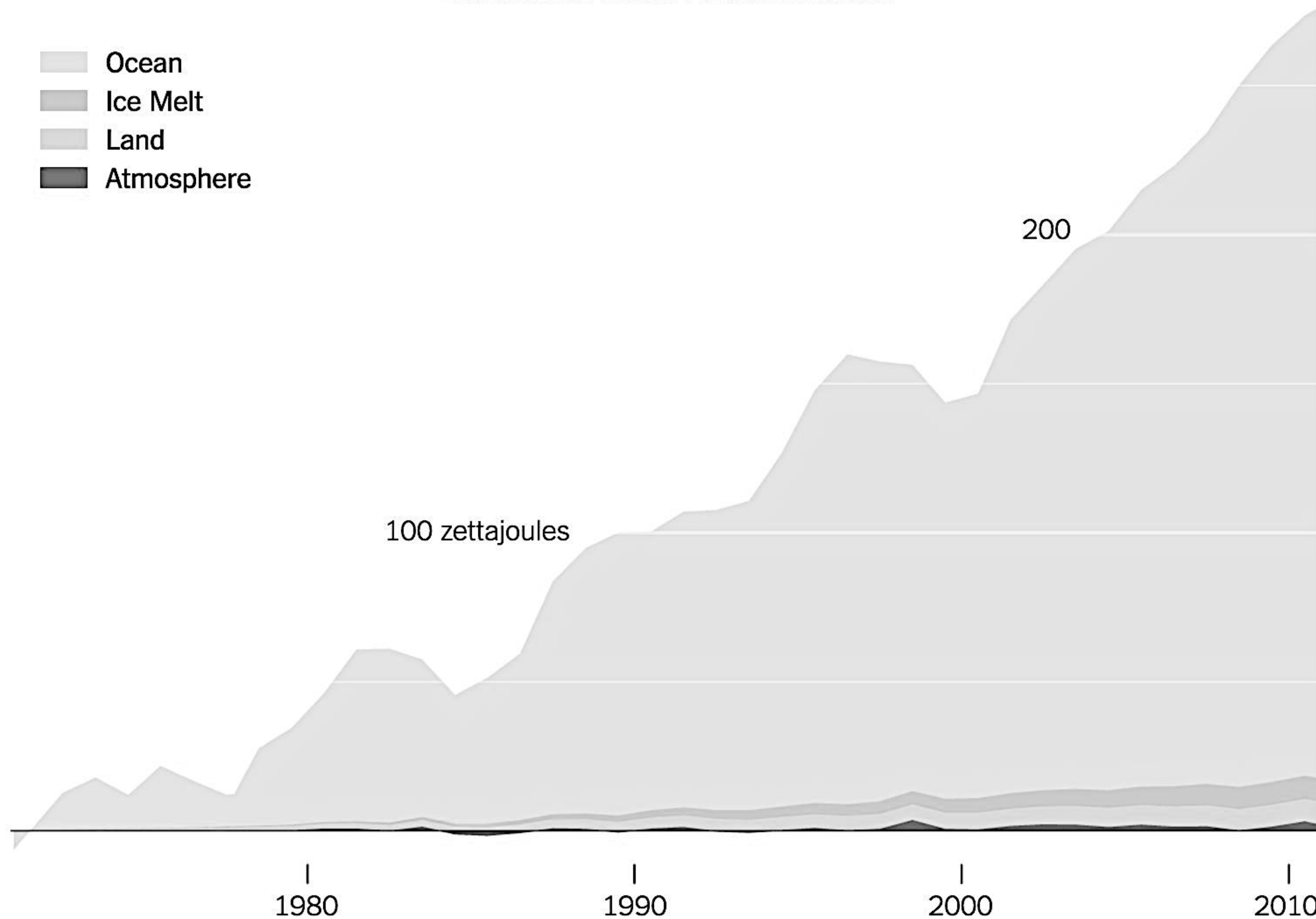
- Ocean
- Ice Melt
- Land
- Atmosphere



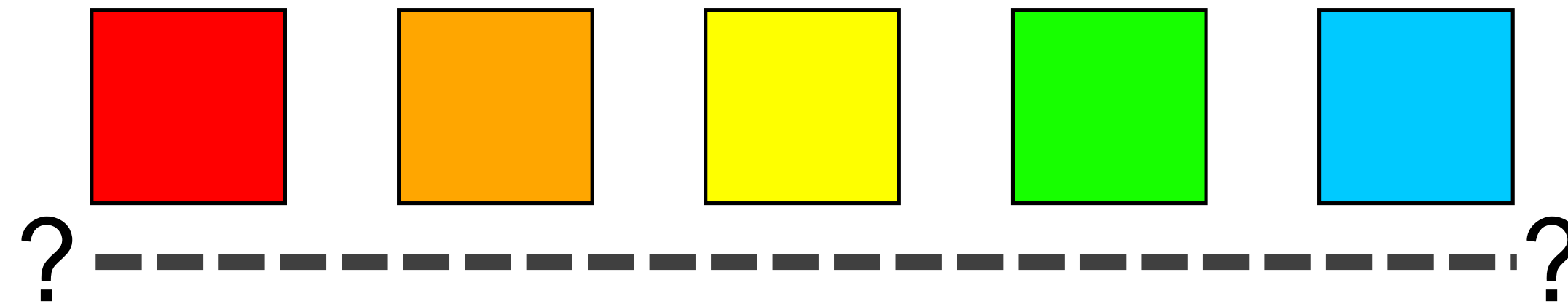
“Get it right in black and white.”

Estimated Heat Accumulation

- Ocean
- Ice Melt
- 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)

Upcoming Assignments & Communication

A look at the upcoming assignments and deadlines

- Textbook, Readings & Reading Quizzes
- 2020-11-03 **! PAST !**
[Assignment 8 — Brushing and Linking in D3](#)
- 2020-11-10 [Project 6 — Sprint 1](#)
- 2020-11-11 **No Class — Veterans' Day**
- 2020-11-17 [Project 7 — Sprint 2 & Paper Draft](#)
- 2020-11-18 [In-Class Validation — Final Project Evaluation](#)
- 2020-11-24 [Project 8 — Sprint 3 & Prep for Usability Testing](#)
- 2020-11-25 **No Class — Thanksgiving**
- 2020-11-30 [In-Class Usability Testing — Final Projects](#)
- 2020-12-06 [Project 9 — Presentation and Video](#)
- 2020-12-07 In-Class Project Presentations
- 2020-12-09 In-Class Project Presentations
- 2020-12-15 [Project 10 — Final Project Deliverables and Sharing with Partners](#)

<https://c.dunne.dev/ds4200f20>

Everyday Required Supplies:

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

Use **Canvas Discussions** for general questions, email the **instructor & TAs** for questions **specific to you**.

If you're emailing about a particular assignment, please include the URL of the Submission Details page. ([Canvas documentation](#).)

If you have a project question, **give us your group number**. E.g., include: `Group ## — Topic` with `##` replaced by your group number and `Topic` replaced by your topic.