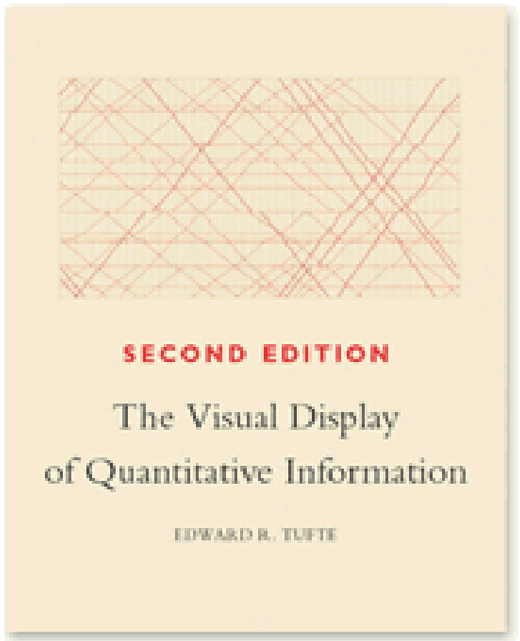
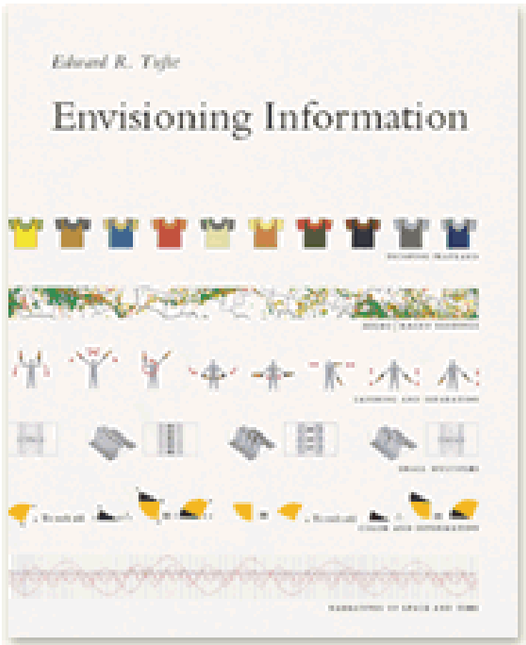
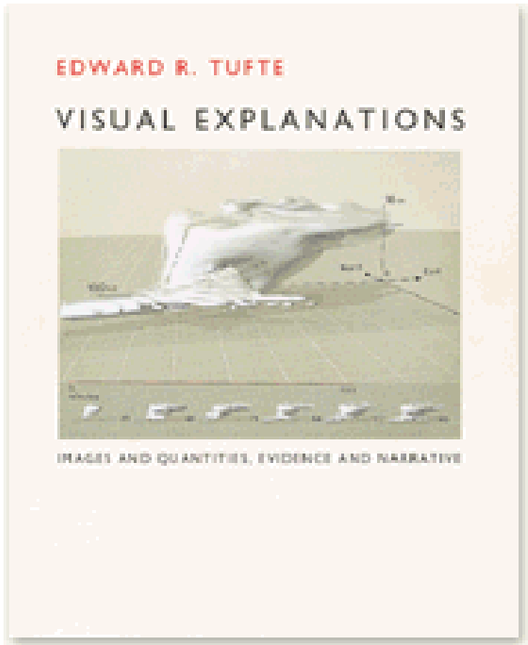






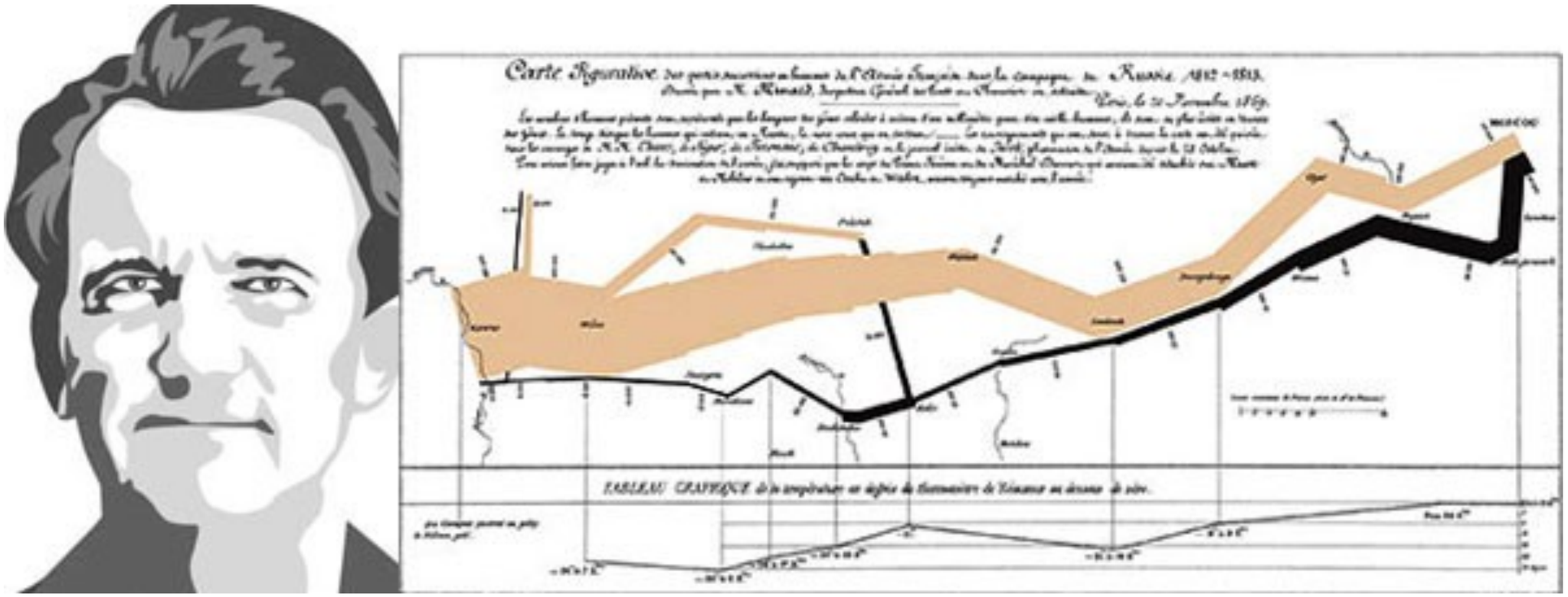
Thinking Graphically

Lessons From Edward Tufte

Slides adapted from presentation by Mika Aldaba, Graphic Designer

Who Is Edward Tufte?

an analytical design theorist, educator, and landscape sculptor best known for his self-published books on analytical design



Illustrated by Merchant
for the Brunswick Review

Anscombe's Quartet

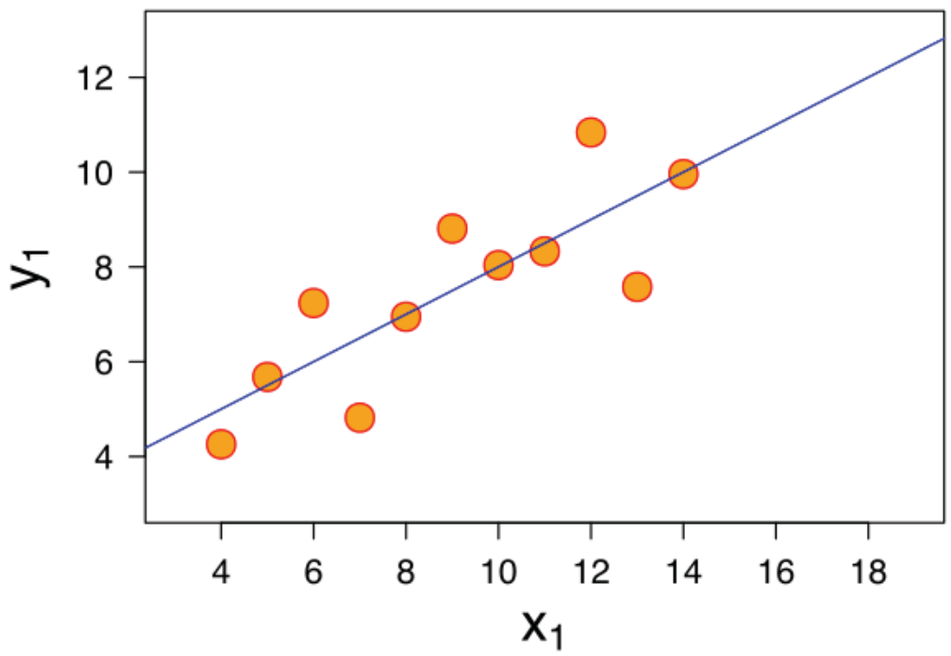
I		II		III		IV	
x	y	x	y	x	y	x	y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.7	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.1	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.1	4	5.39	19	12.5
12	10.8	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

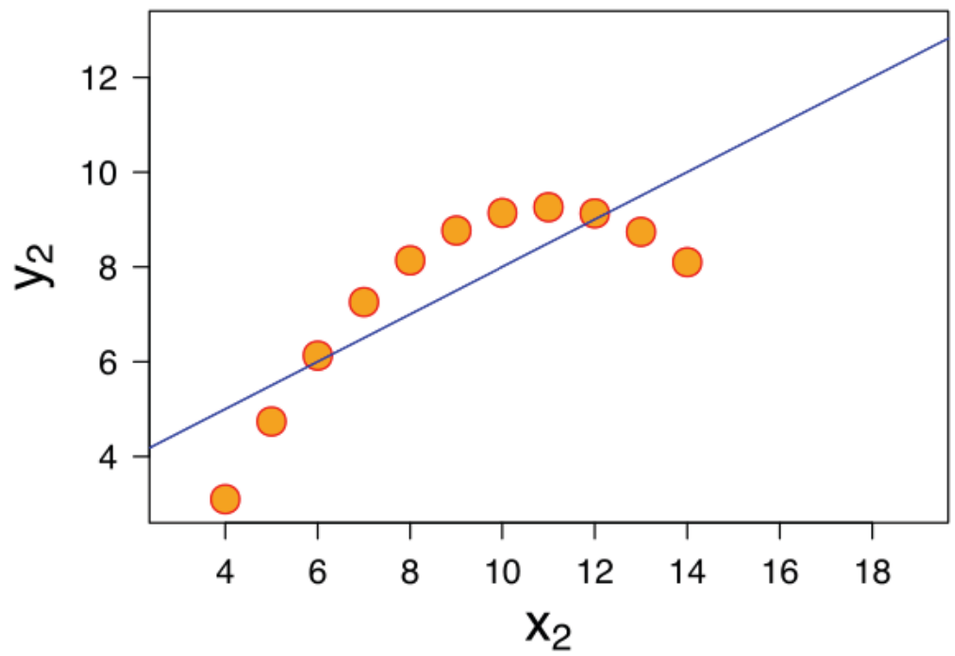
How would you describe the differences in these datasets?

Anscombe's Quartet

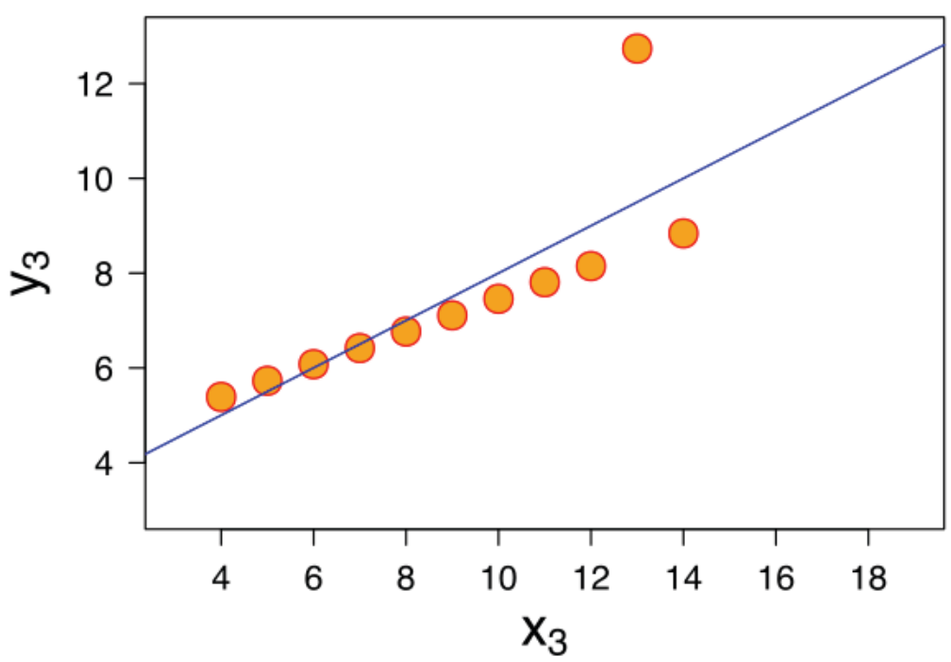
Metric	Value
mean of the y values	7.5
equation of the least-squared regression line	y = 3 + 0.5x
sums of squared errors (about the mean)	110
regression sums of squared errors (variance accounted for by x)	27.5
residual sums of squared errors (about the regression line)	13.75
correlation coefficient	0.82
coefficient of determination	0.67

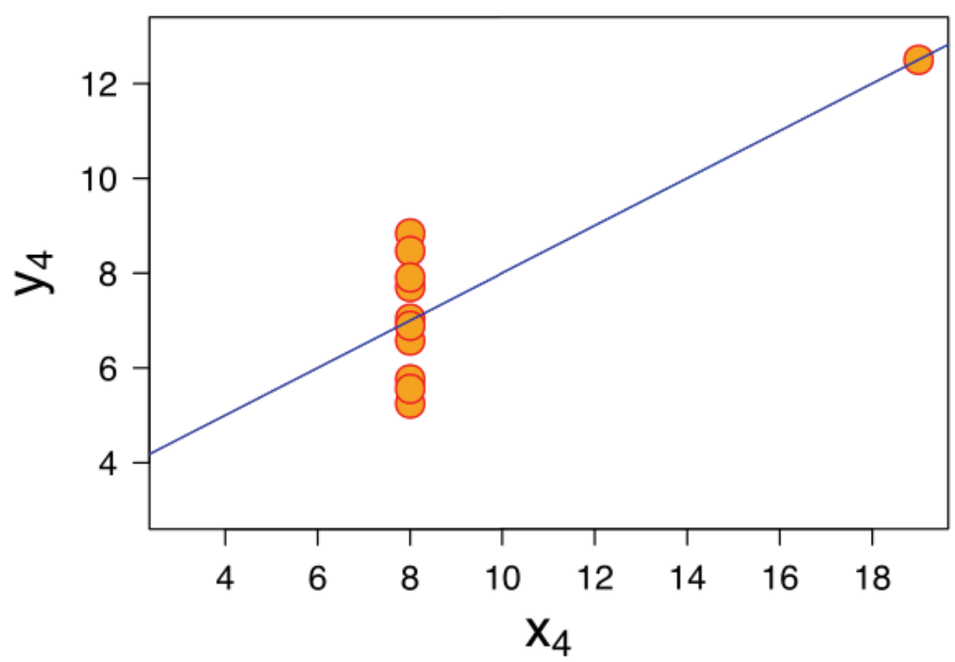
Anscombe's Quartet



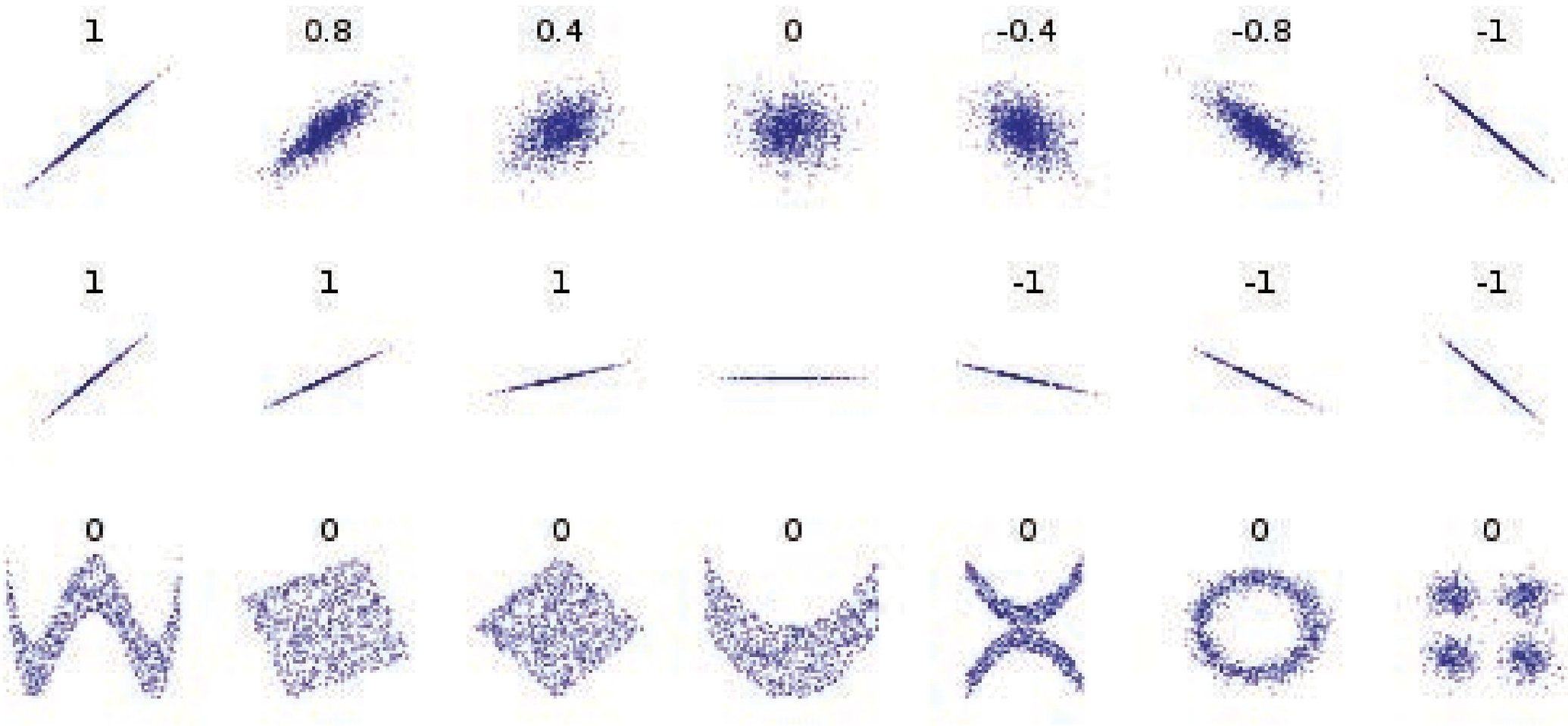


Graphics *reveal* data





Another example: Pearson Correlation



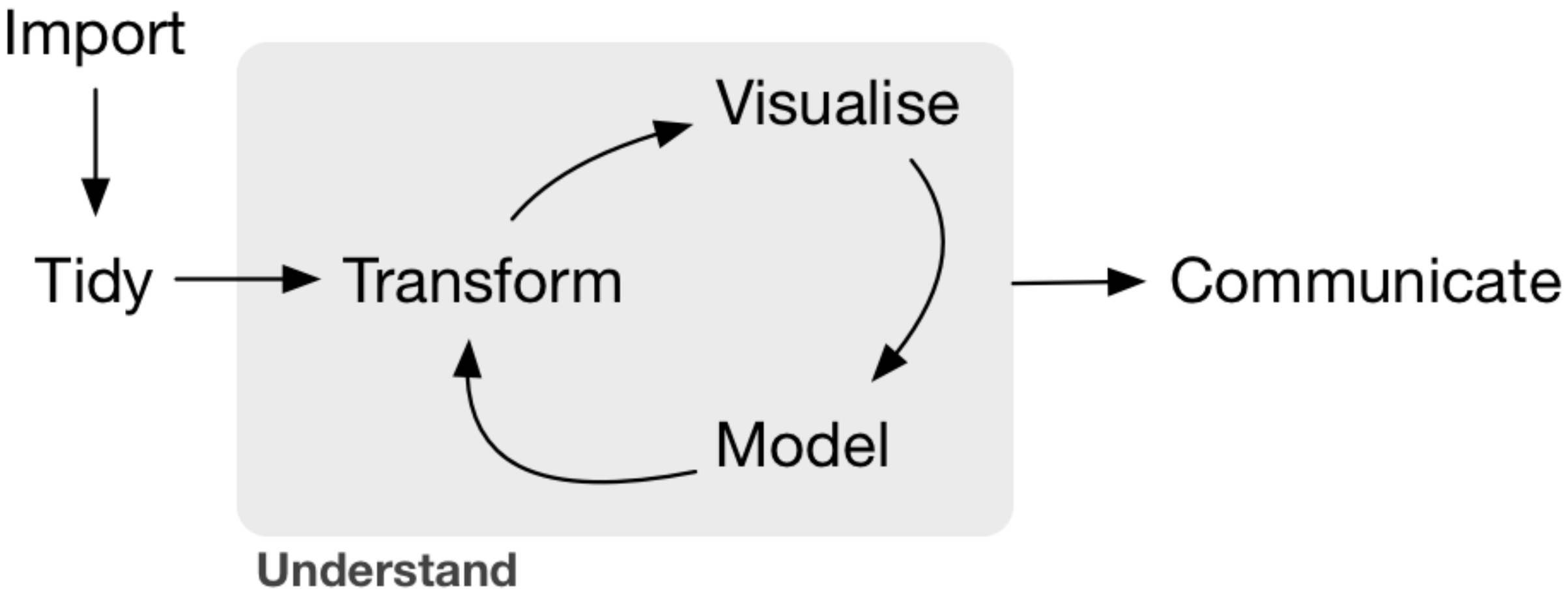
Other reasons?

Visualization is the highest bandwidth channel into the human brain

As data volumes grow, visualization becomes a necessity rather than a luxury.

- “A picture is worth a thousand words”

Visualization is important…



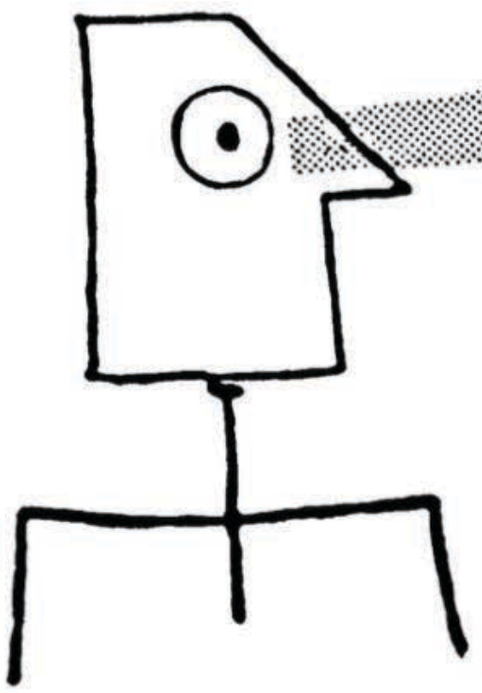
--Grolemund & Wickham, R for Data Science, O'Reilly 2016

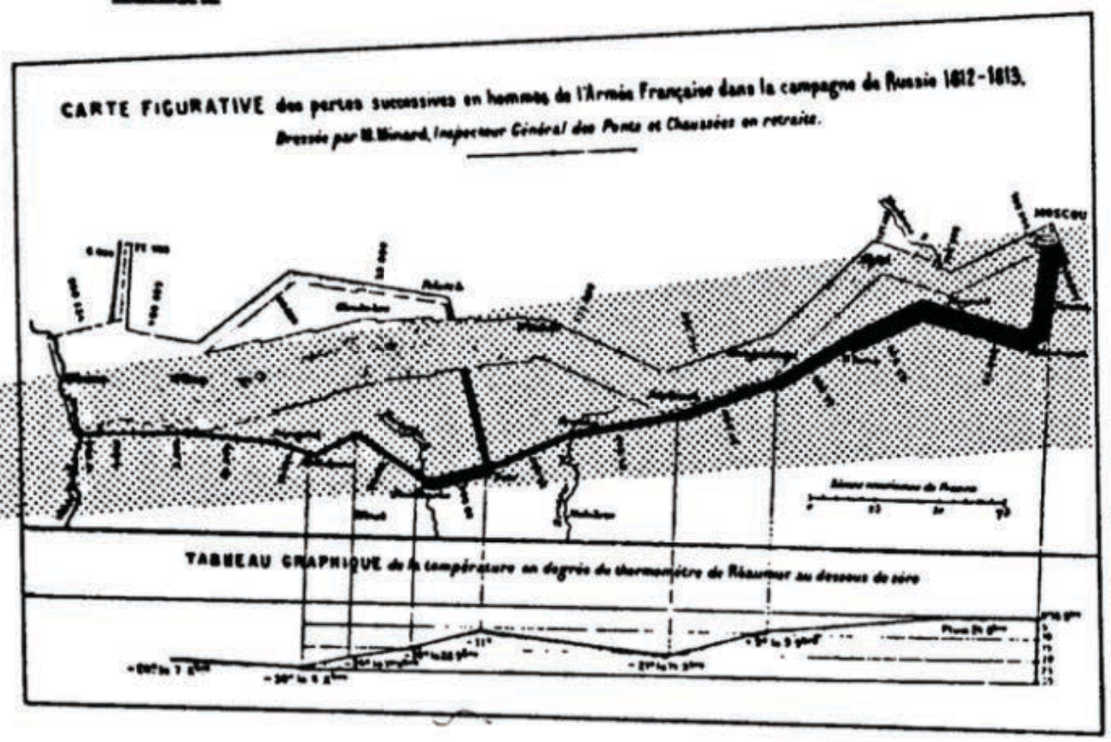
Graphical Excellence

1. Show the data
2. Induce the viewer to think about substance rather than methodology
3. Avoid distortion
4. Present many numbers in a small space
5. Make large data sets coherent
6. Encourage comparisons
7. Reveal the data at several levels from broad overview to fine structure
8. Serve a purpose
9. Be integrated with statistical and verbal descriptions of data

-- Principles of *Graphical Excellence, Edward Tufte*

ideas time ink space





Graphical excellence gives the viewer:

- the greatest # of ideas
- in the shortest time
- with the least ink
- in the smallest space.

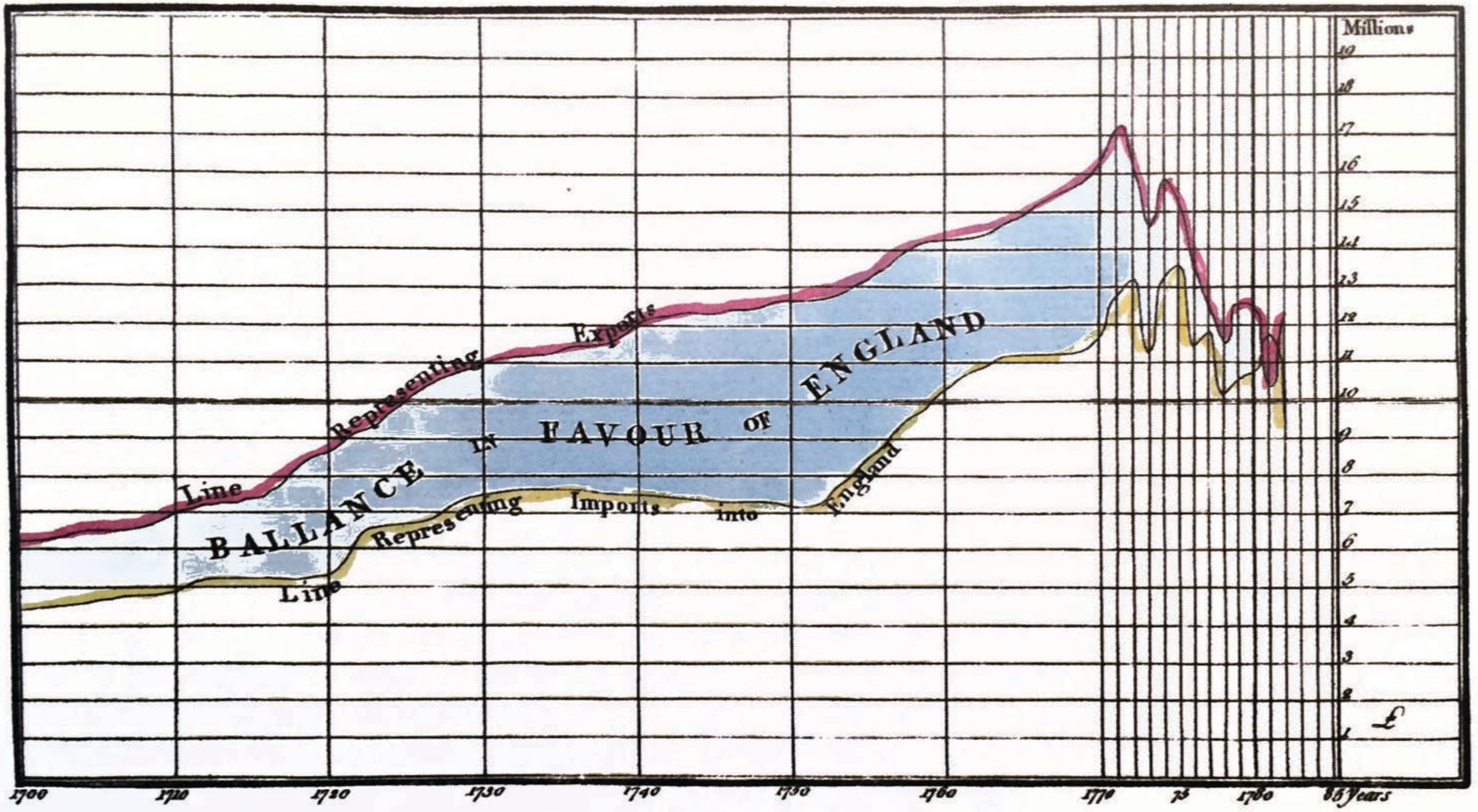
One of the oldest graphical displays

Yu Chi Thu
Map of the tracks of Yu the Great

Carved in stone in 1137 A.D.
(idea probably older)

Nothing similar in Europe until ~1550

CHART of all the IMPORTS and EXPORTS to and from ENGLAND
From the Year 1700 to 1782 by W. Playfair



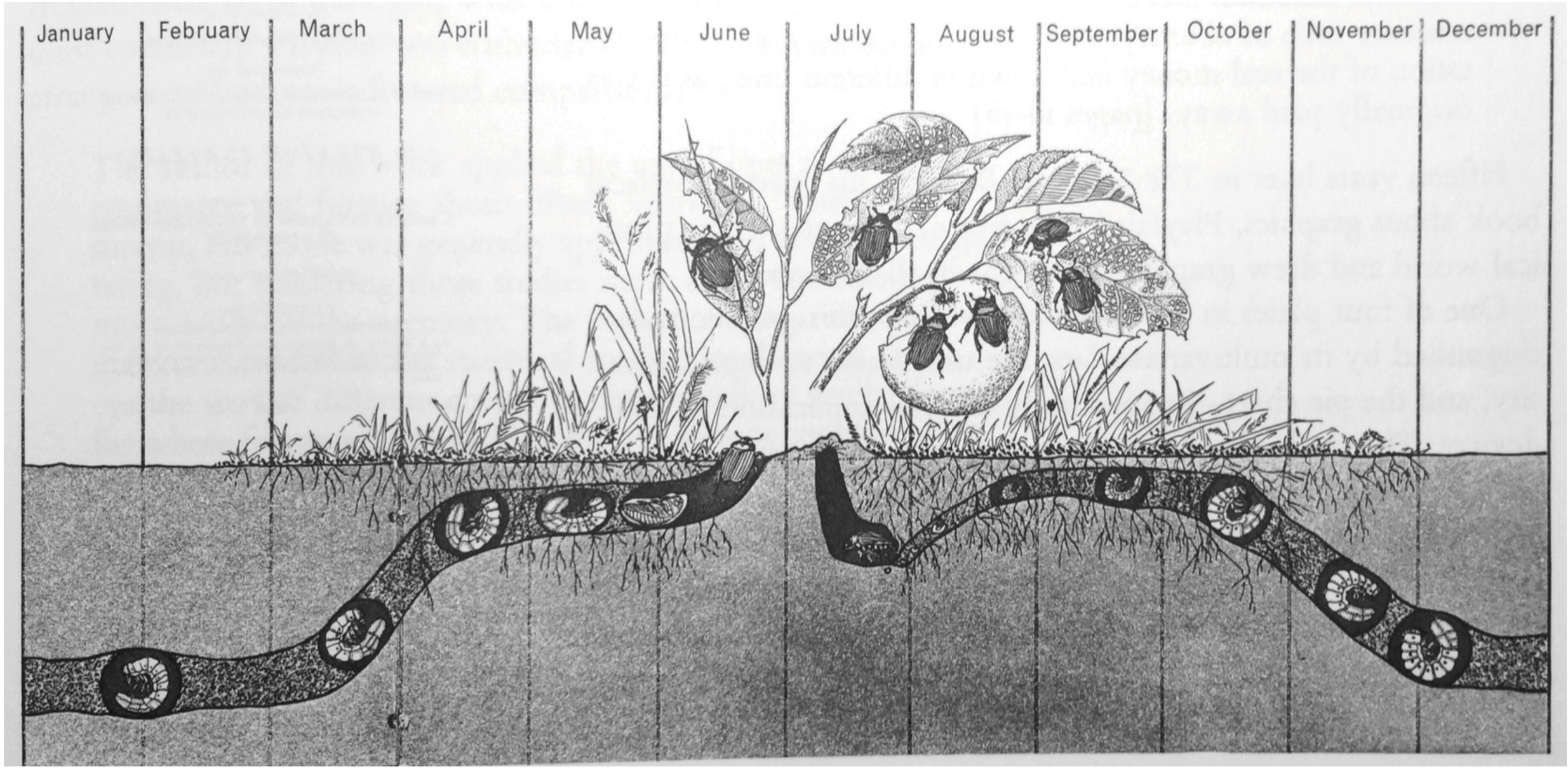
The Divisions at the Bottom, express YEARS, & those on the Right hand MILLIONS of POUNDS

J. Ainslie Sculp.t

Publish'd as the Act directs. 20.th Augt. 1785

One of the earliest timeseries charts

Life-cycle of the Japanese Beetle



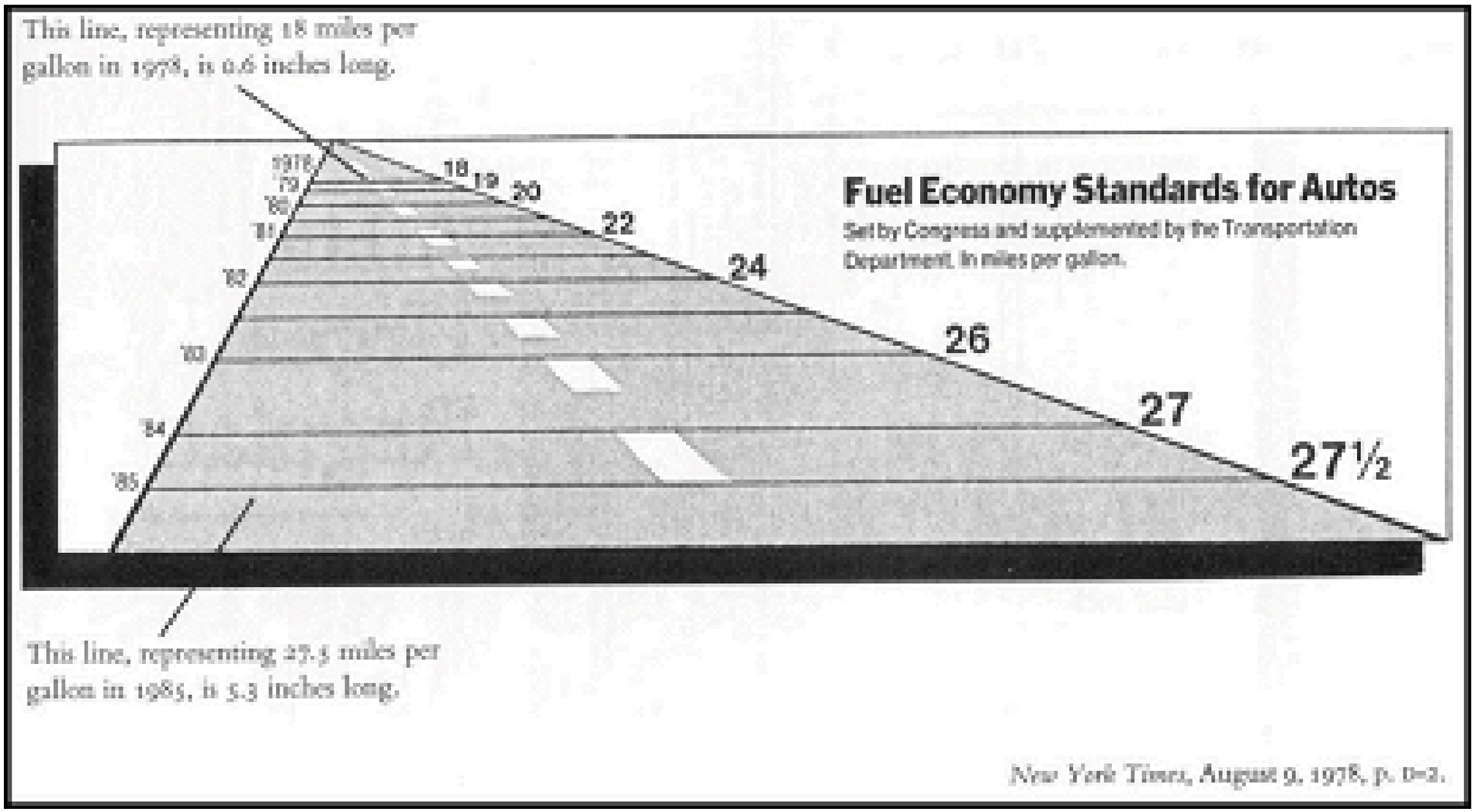
L. Hugh Newman *Man and Insects (London, 1965), pp 104-105*

Strive For Graphical Integrity

Visual representations of data must tell the truth.

The Lie Factor

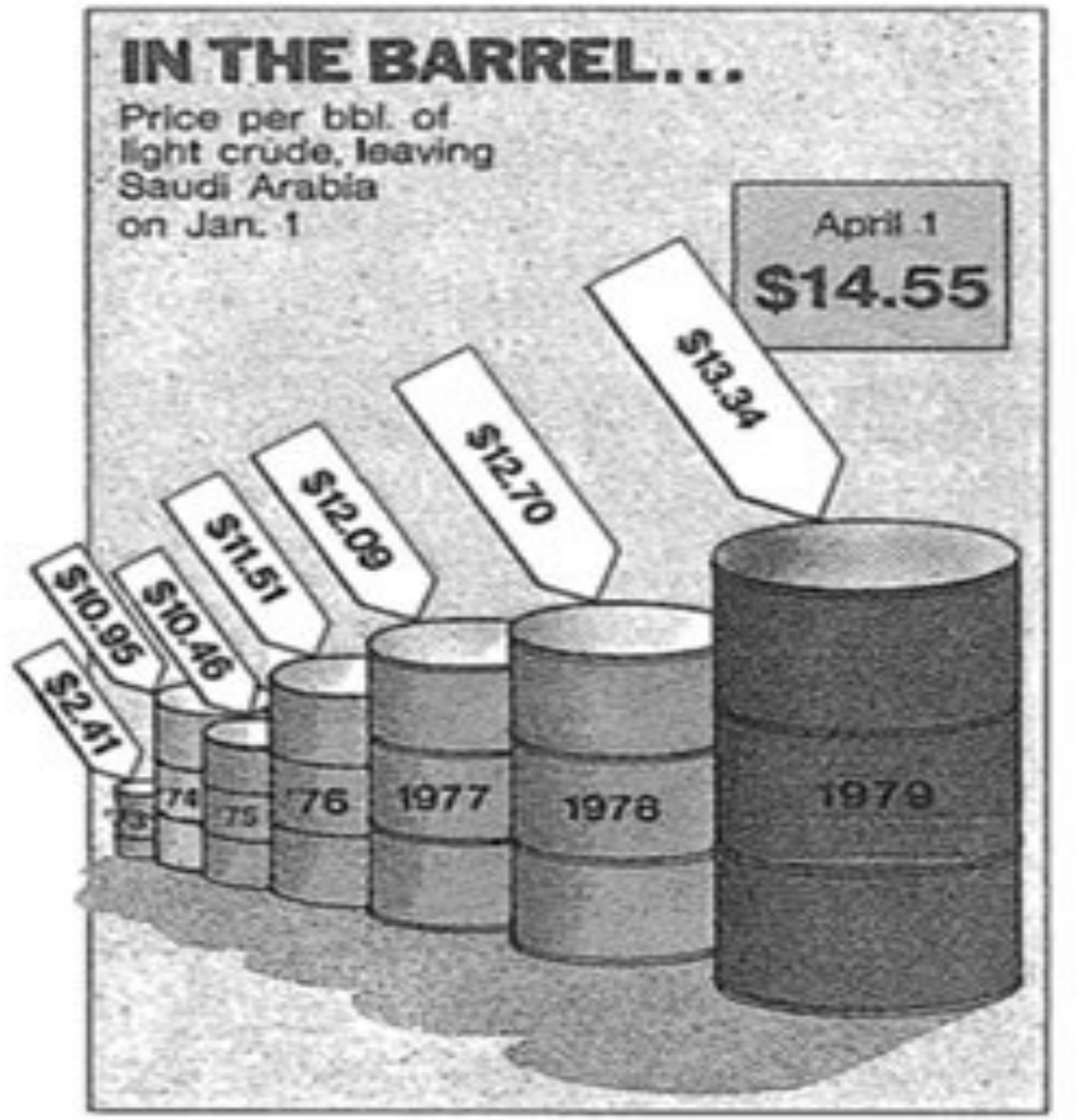
$$\text{Lie Factor} = \frac{\text{Size of effect in the visualization}}{\text{Size of effect in the data}}$$



According to Tufte the Lie Factor of this graph is 14.8. A numerical change of 53% is represented by a graphical change (size of horizontal lines) of 783%.

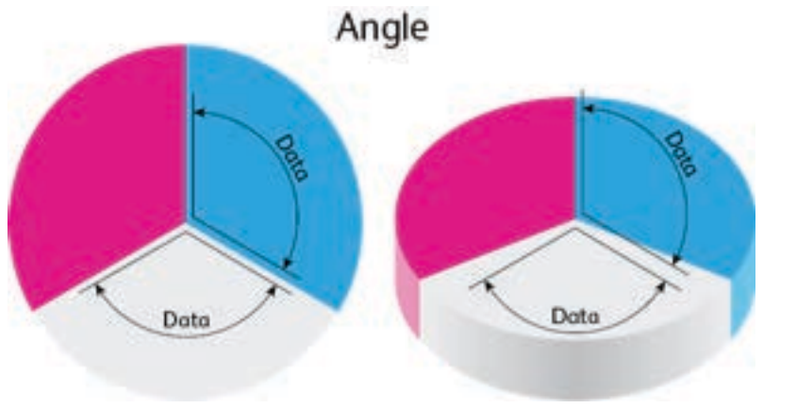
Graphical Integrity

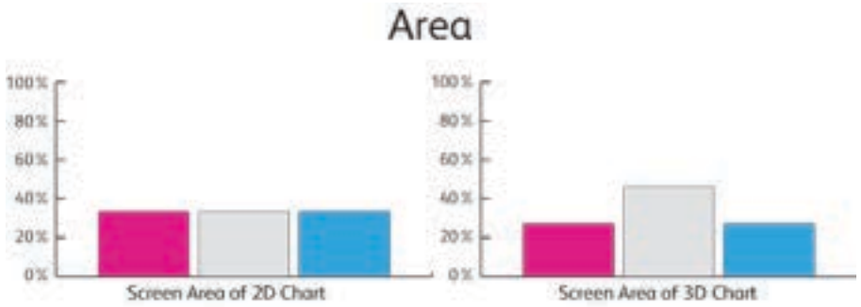
The representation of numbers, as physically measured on the surface of the graph itself, should be directly proportional to the numerical quantities represented



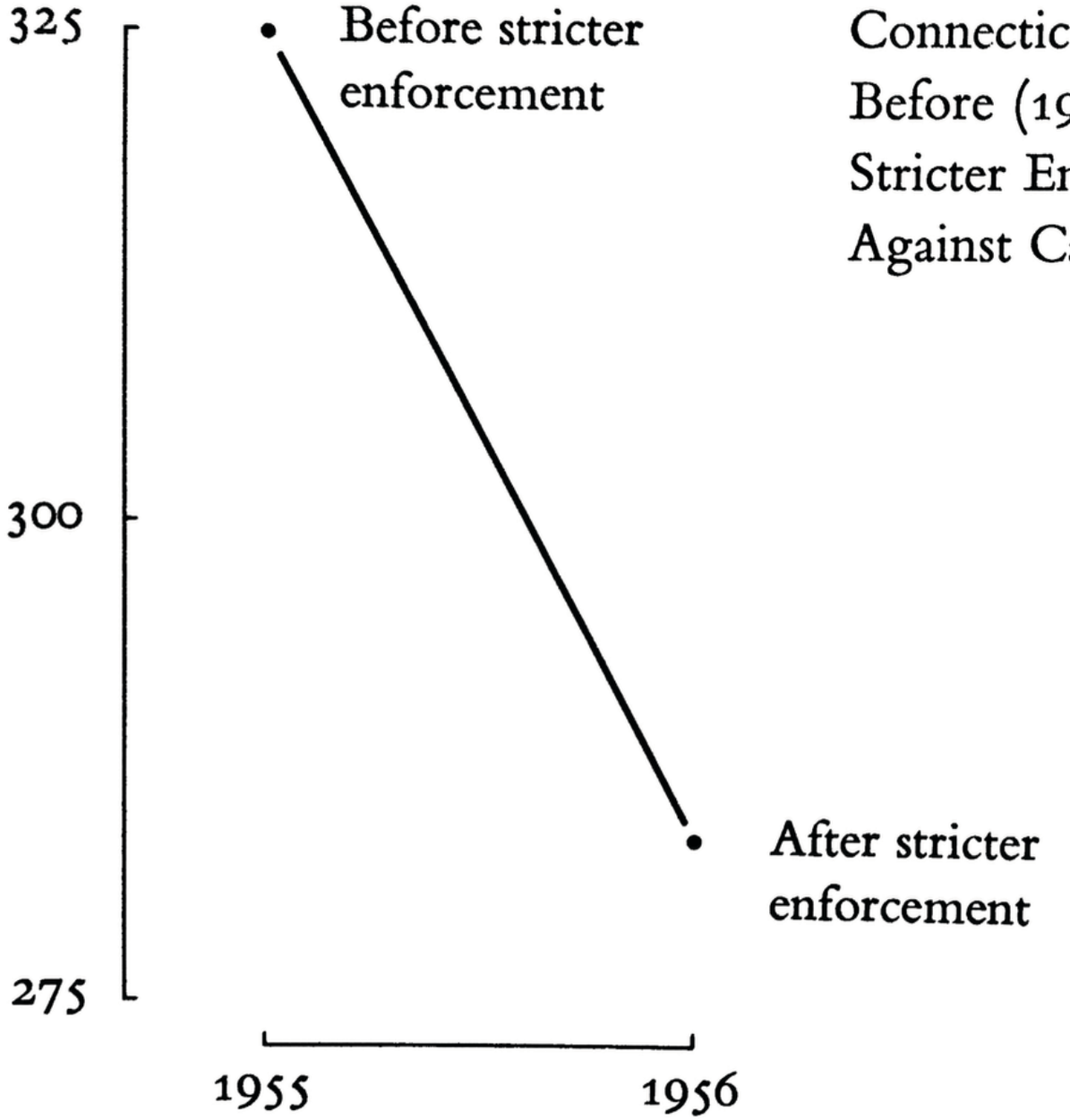
Graphical Integrity

The number of information carrying (variable) dimensions depicted should not exceed the number of dimensions in the data.





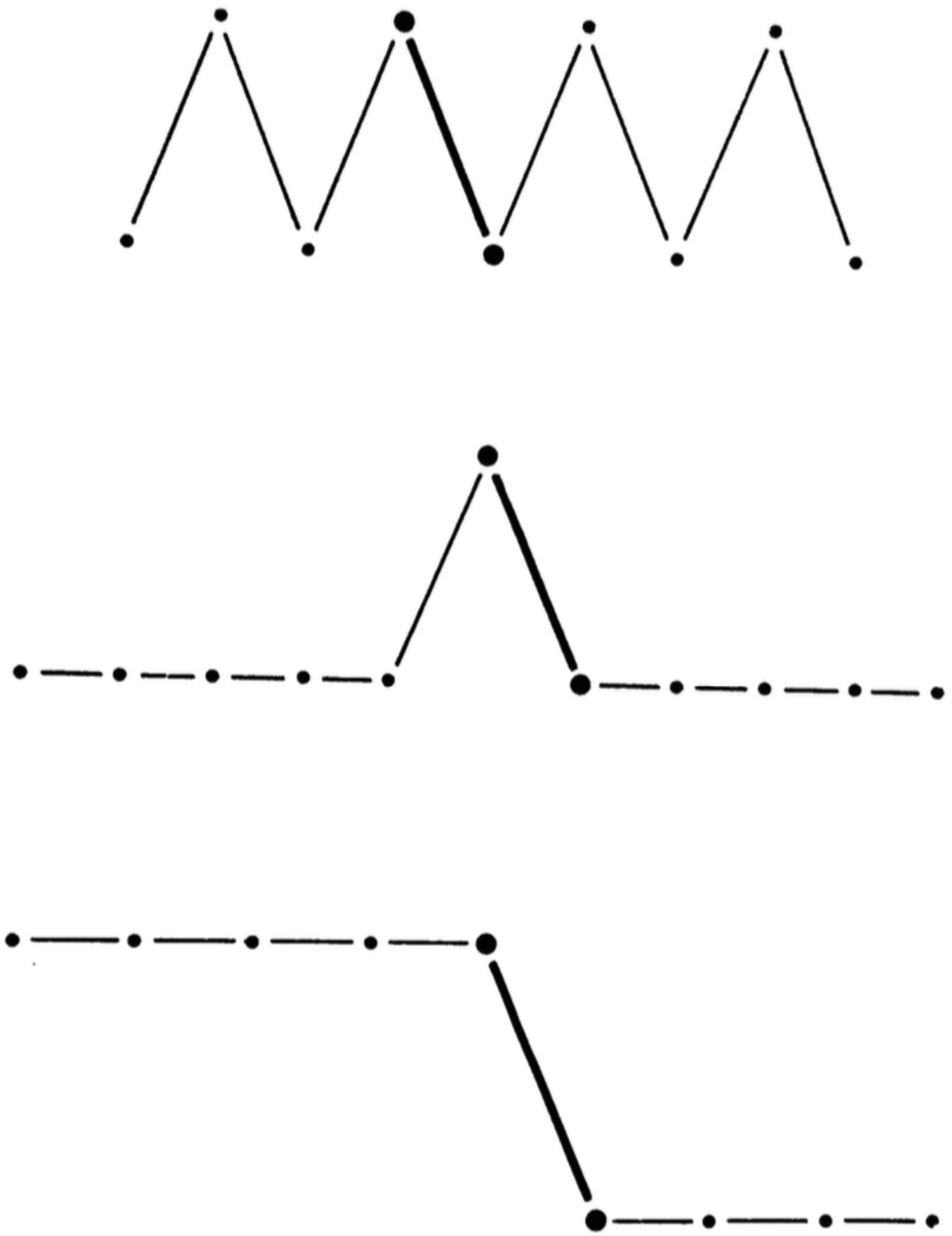
Graphical Integrity



Connecticut Traffic Deaths,
Before (1955) and After (1956)
Stricter Enforcement by the Police
Against Cars Exceeding Speed limit

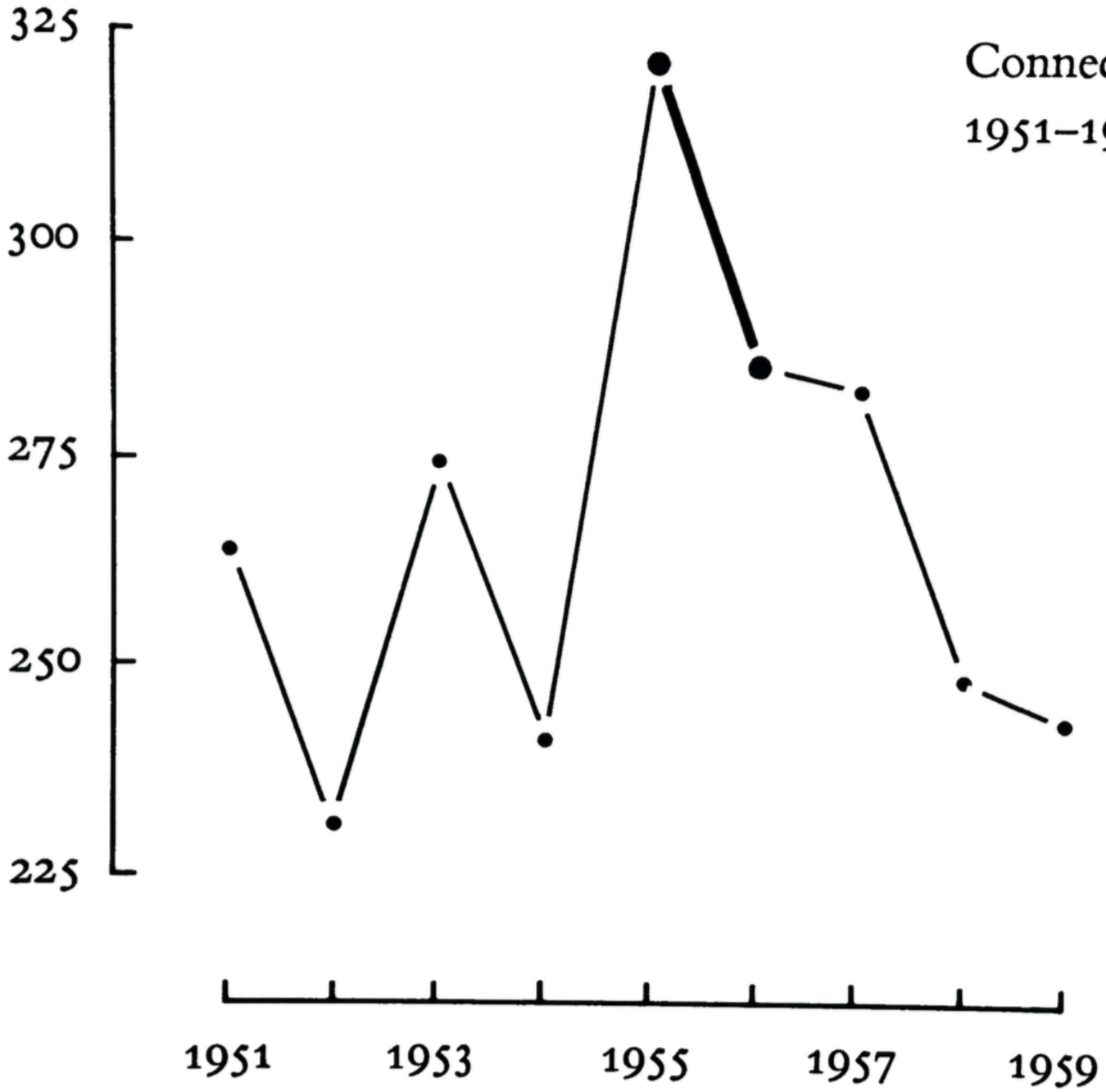
Graphics must not quote data out of context.

Graphical Integrity



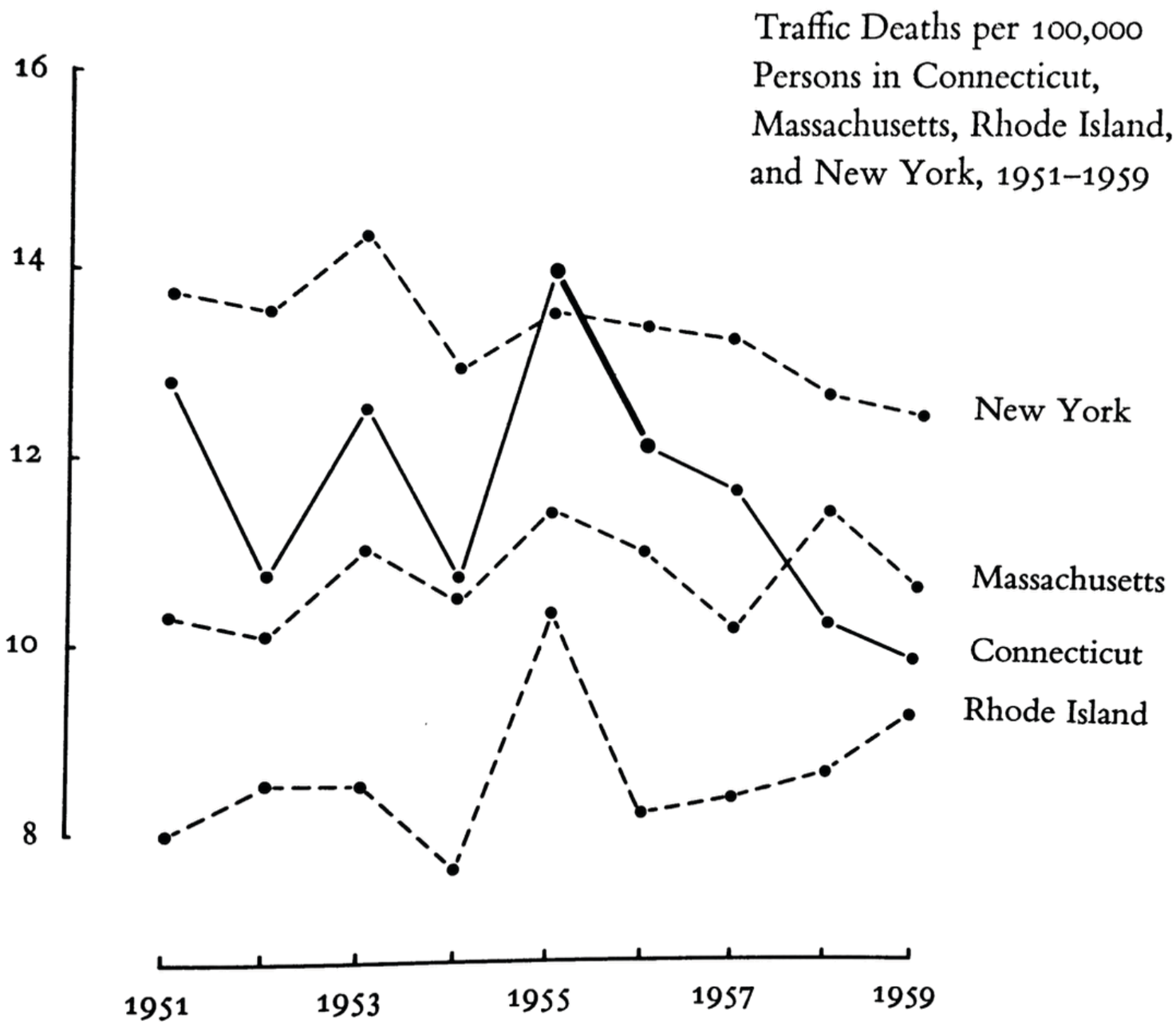
Graphics must not quote data out of context.

Graphical Integrity



Graphics must not quote data out of context.

Graphical Integrity



Graphics must not quote data out of context.

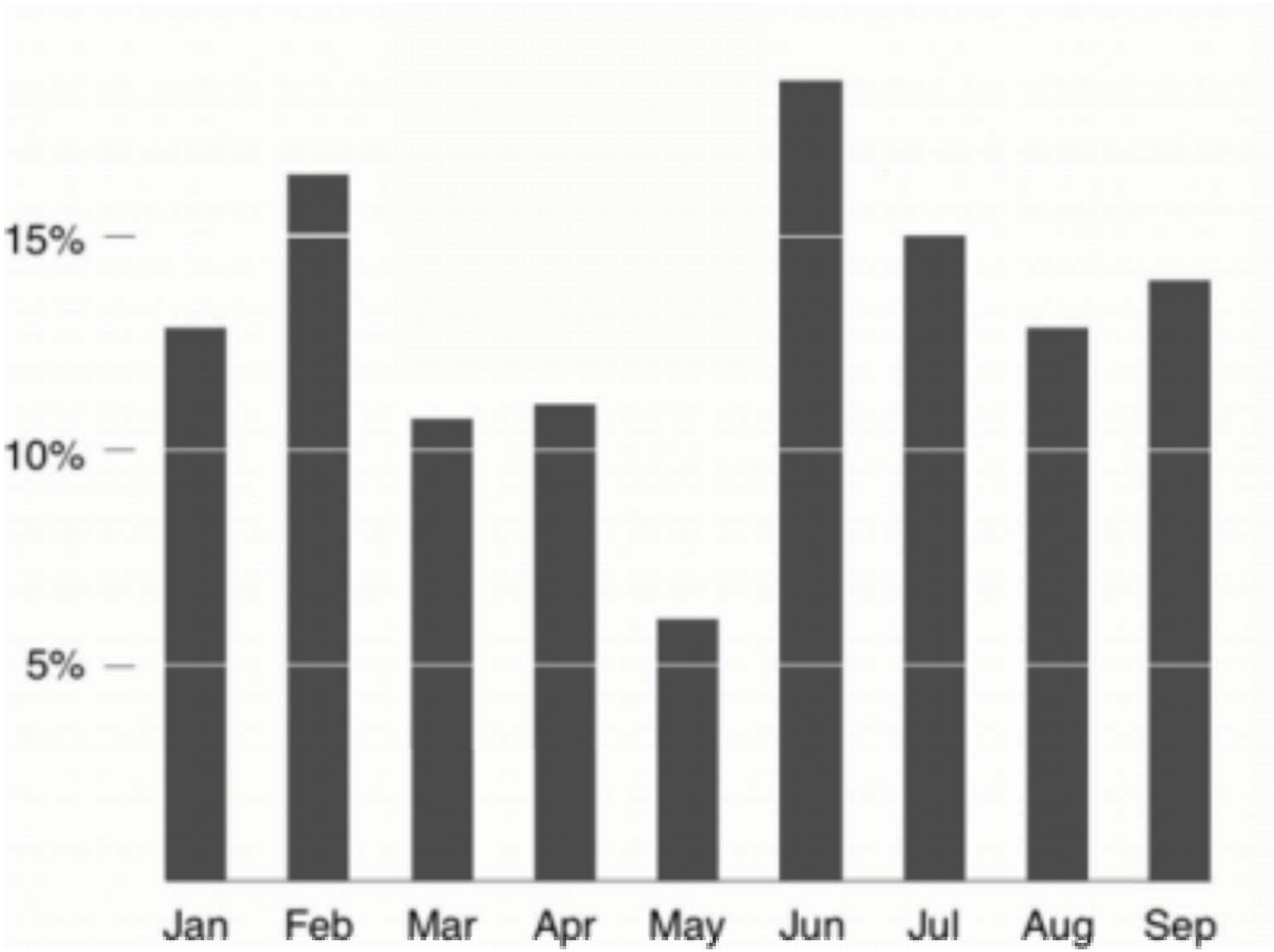
Maximize Data Ink

$$\text{Data-ink ratio} = \frac{\text{Data-ink}}{\text{Total ink used to print the graphic}}$$

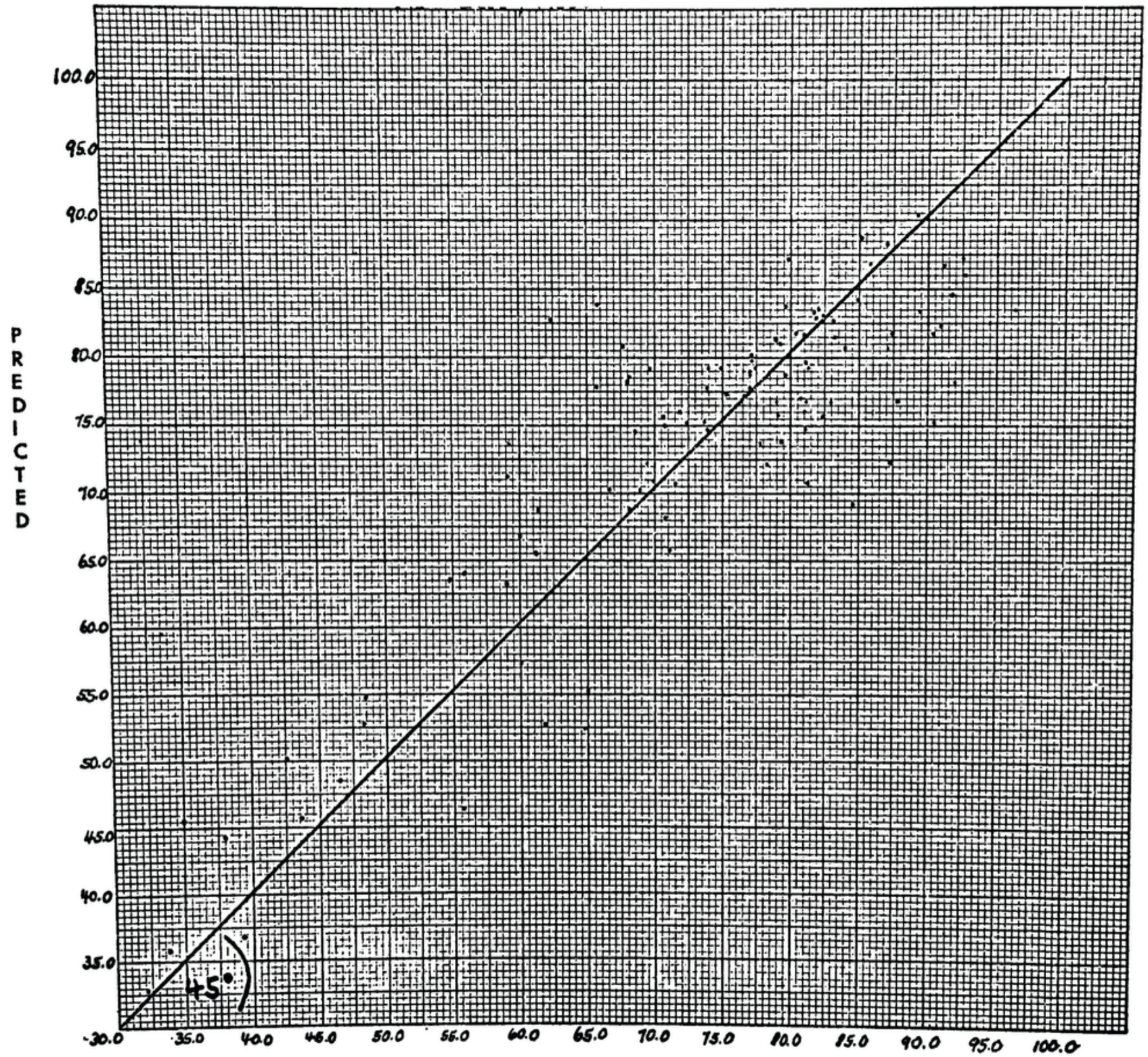
$$= \text{proportion of a graphic's ink devoted to the non-redundant display of data-information}$$

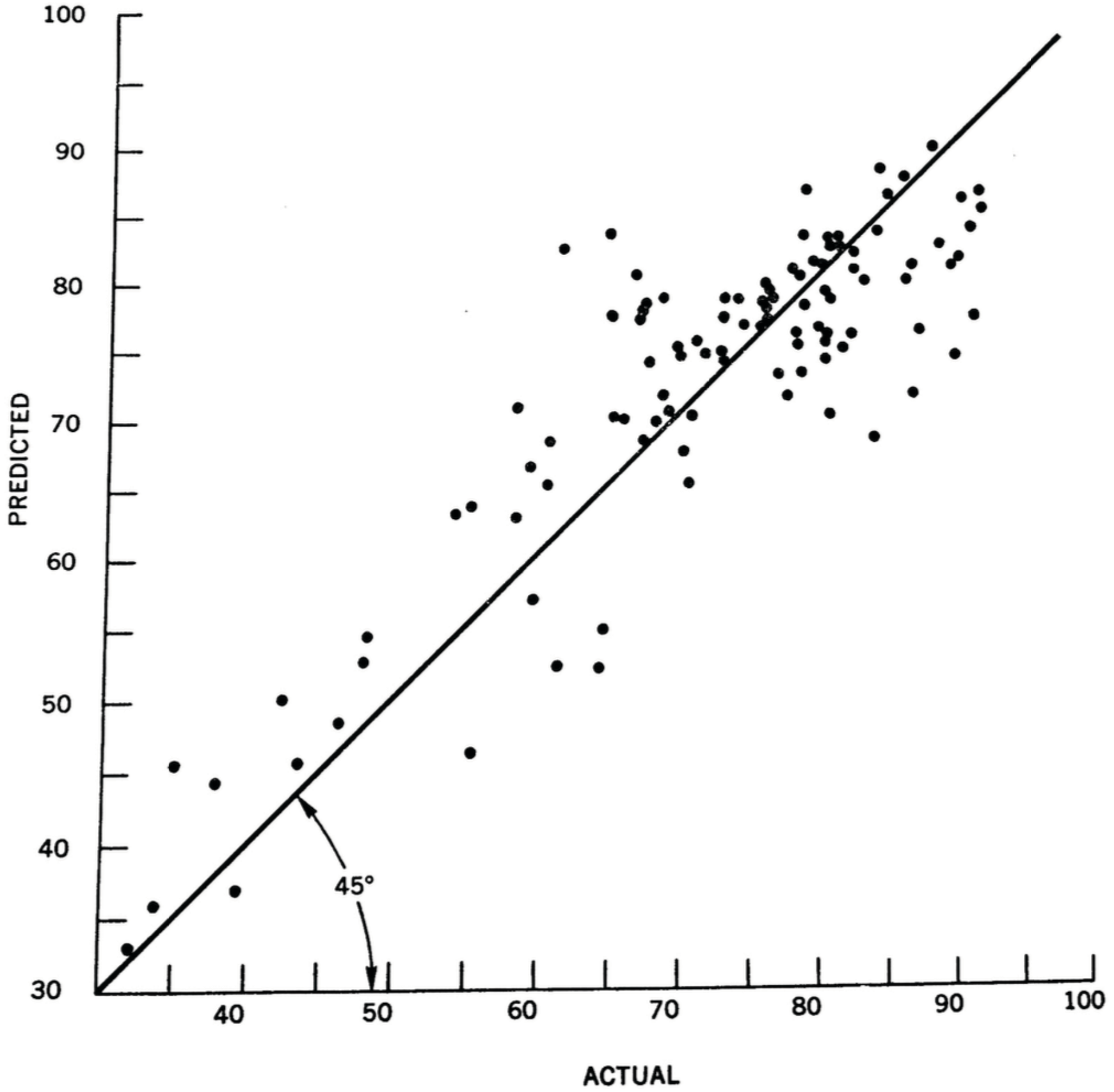
$$= 1.0 - \text{proportion of a graphic that can be erased}$$

Example: High or Low Data Ink ratio?

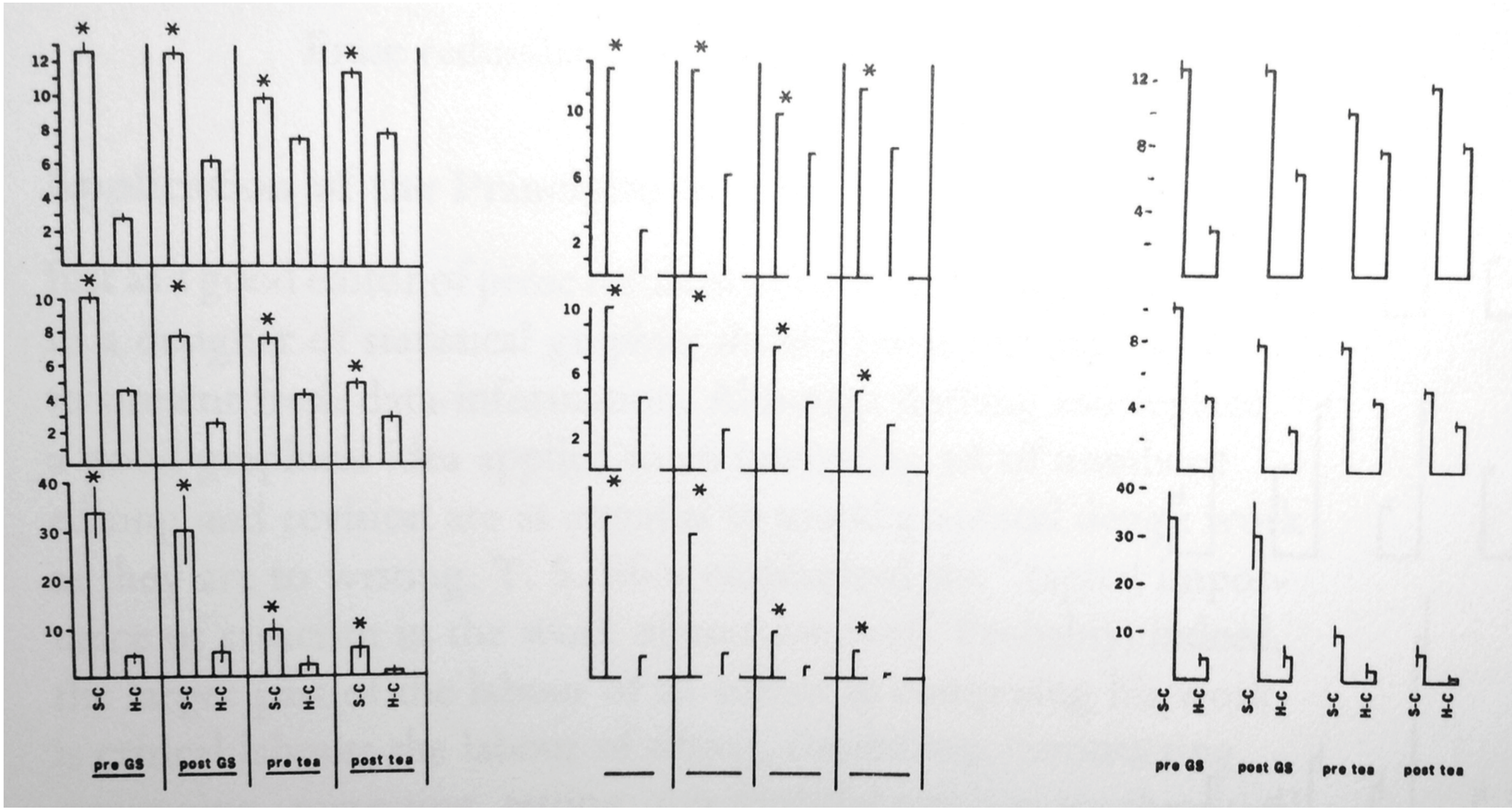


Relationship of Actual Rates of Registration to Predicted Rates
(104 cities 1960).




100
90
80
70
60
50
40
30
PREDICTED
40
50
60
70
80
90
100
ACTUAL
45°

Maximize Data Ink

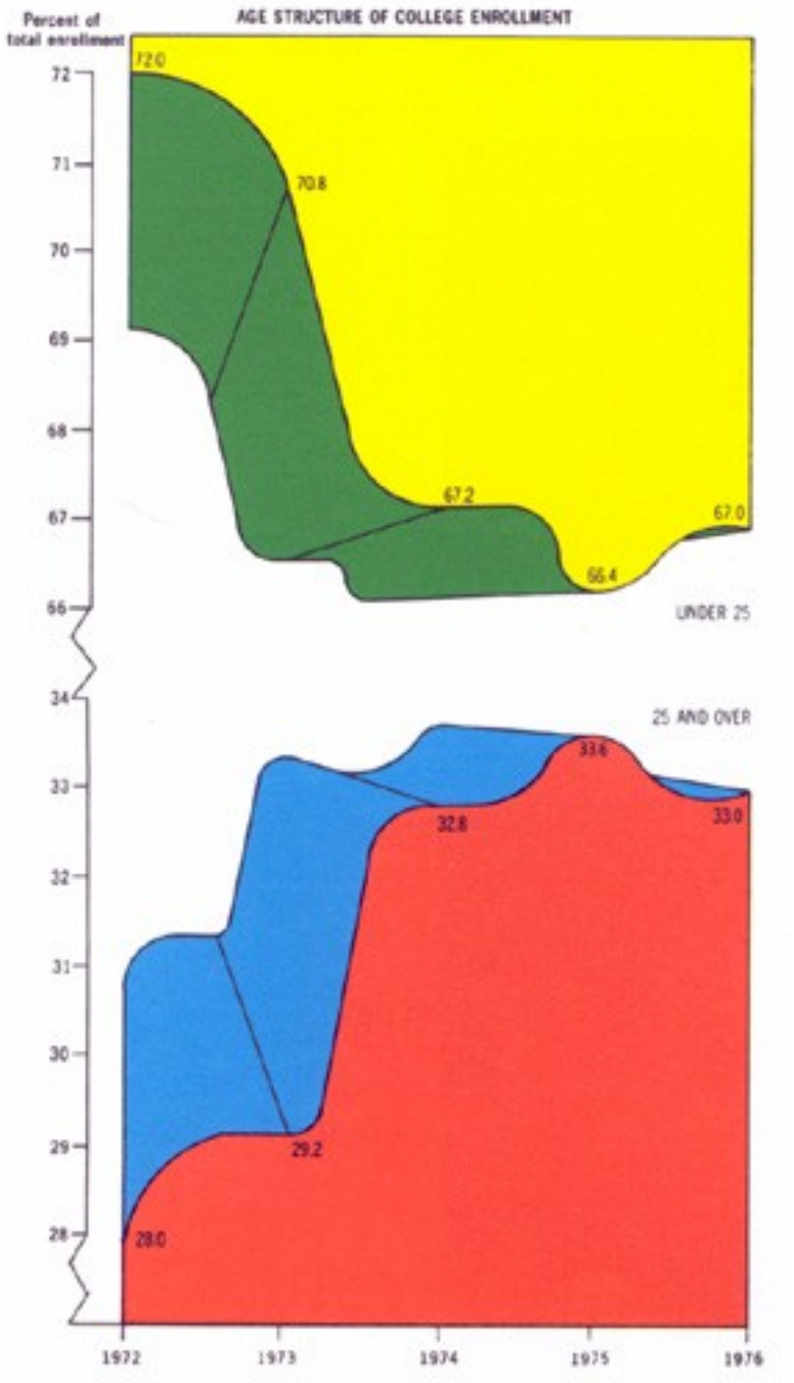


Trim the fluff from your graphics as much as possible!

Avoid Chart Junk

The excessive and unnecessary use of graphical effects in graphs used to demonstrate the graphic ability of the designer rather than display the data.

CHART JUNK



5 Colors

2 Curvy lines

2 Polygons

2 Broken Axis

3 Dimensions

To display: 5 numbers

Possibly the worst graph ever made

MONSTROUS COSTS

Total House and Senate campaign expenditures, in millions

Aim for high data density

The proportion of the total size of the graph that is dedicated displaying data.

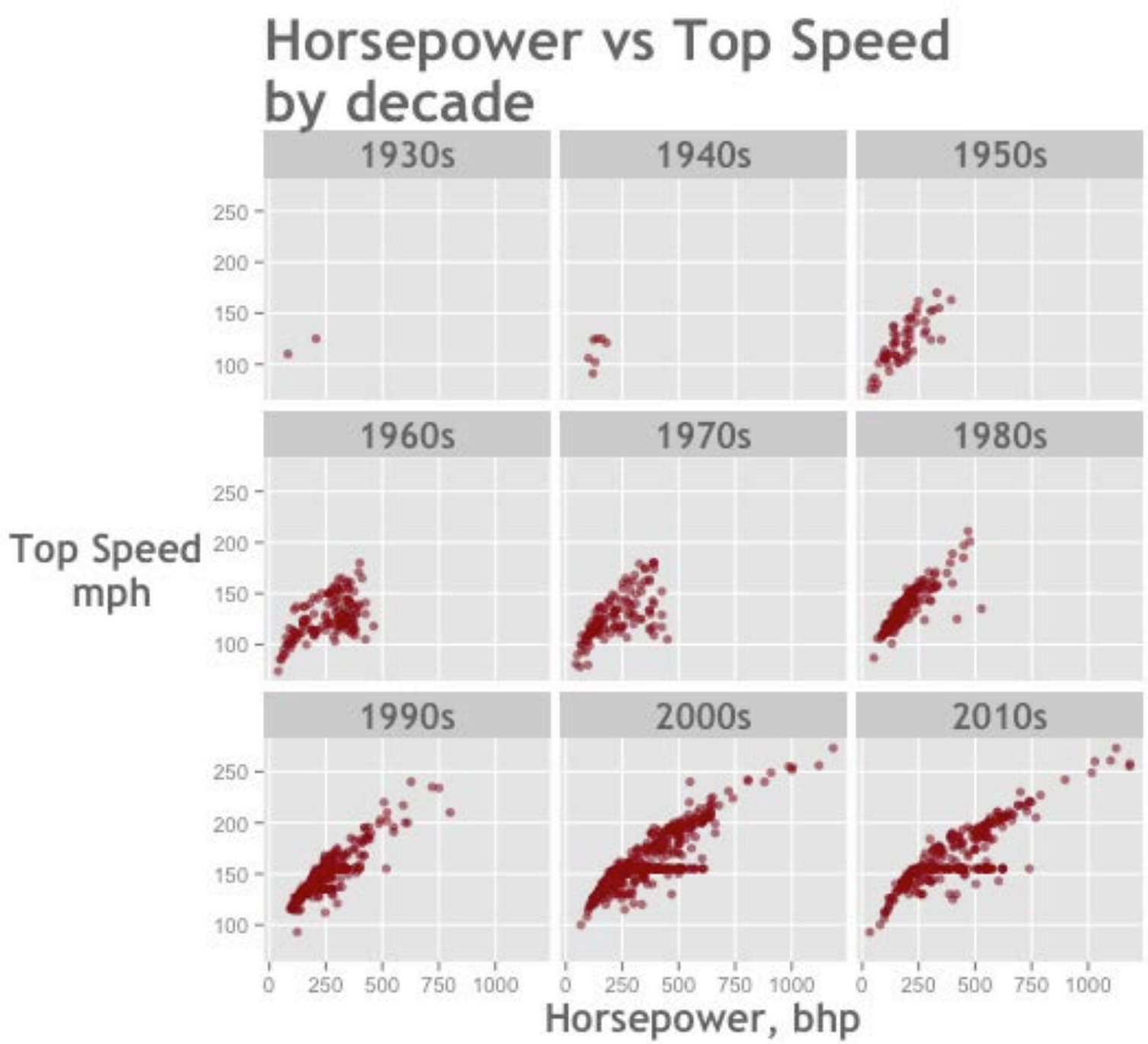
Shrink

Principle

Many graphs can be shrunk way down without losing legibility or information

Small Multiples

Series of the same small graph repeated in one visual

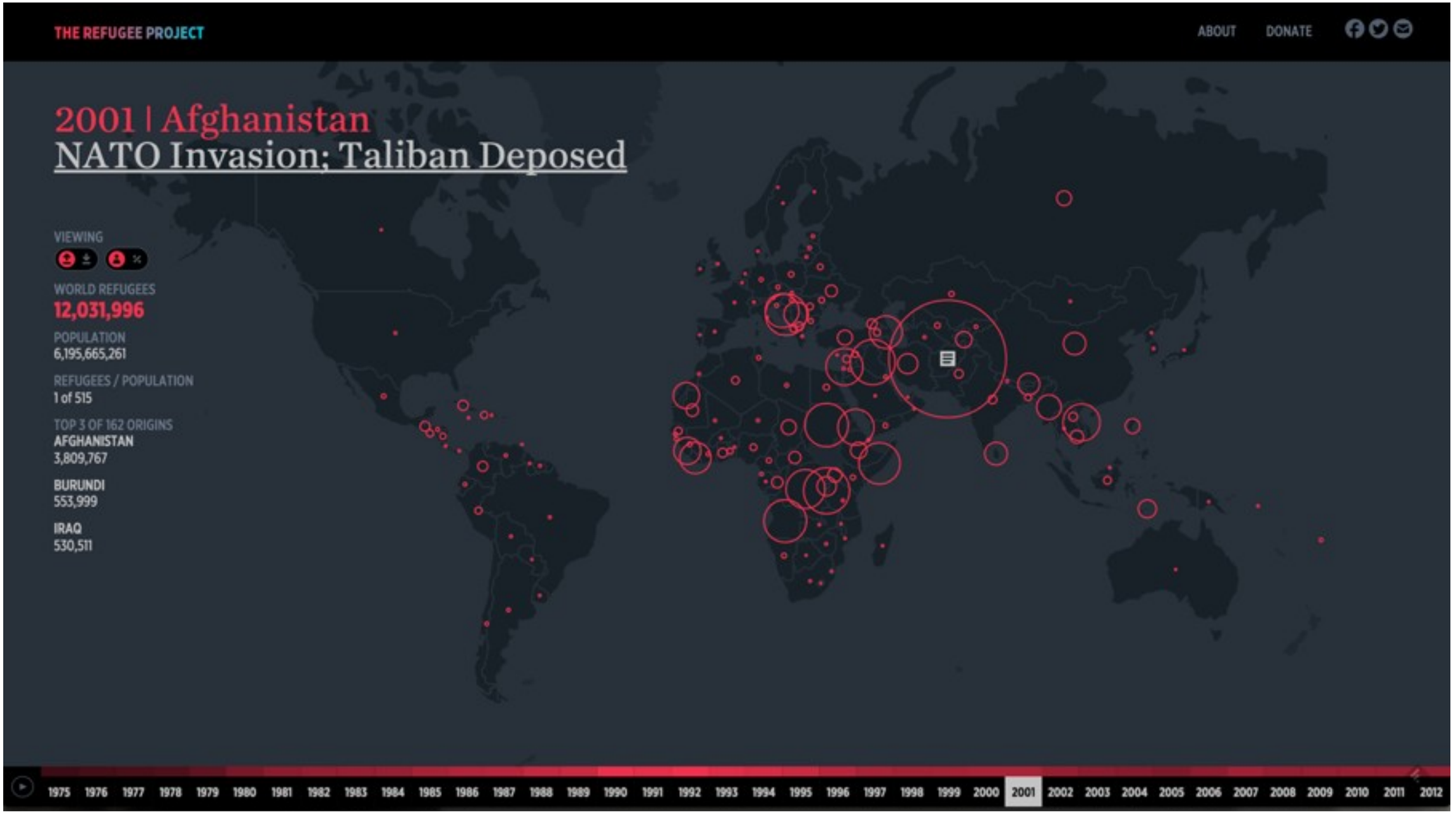


Clutter

Visualization too cluttered?

Don't remove data, change the design.

Credibility comes from detail and in many cases one can clarify a design by adding detail.



Hyperakt and Ekene Ijeoma visualized migrations over time and space in The Refugee Project

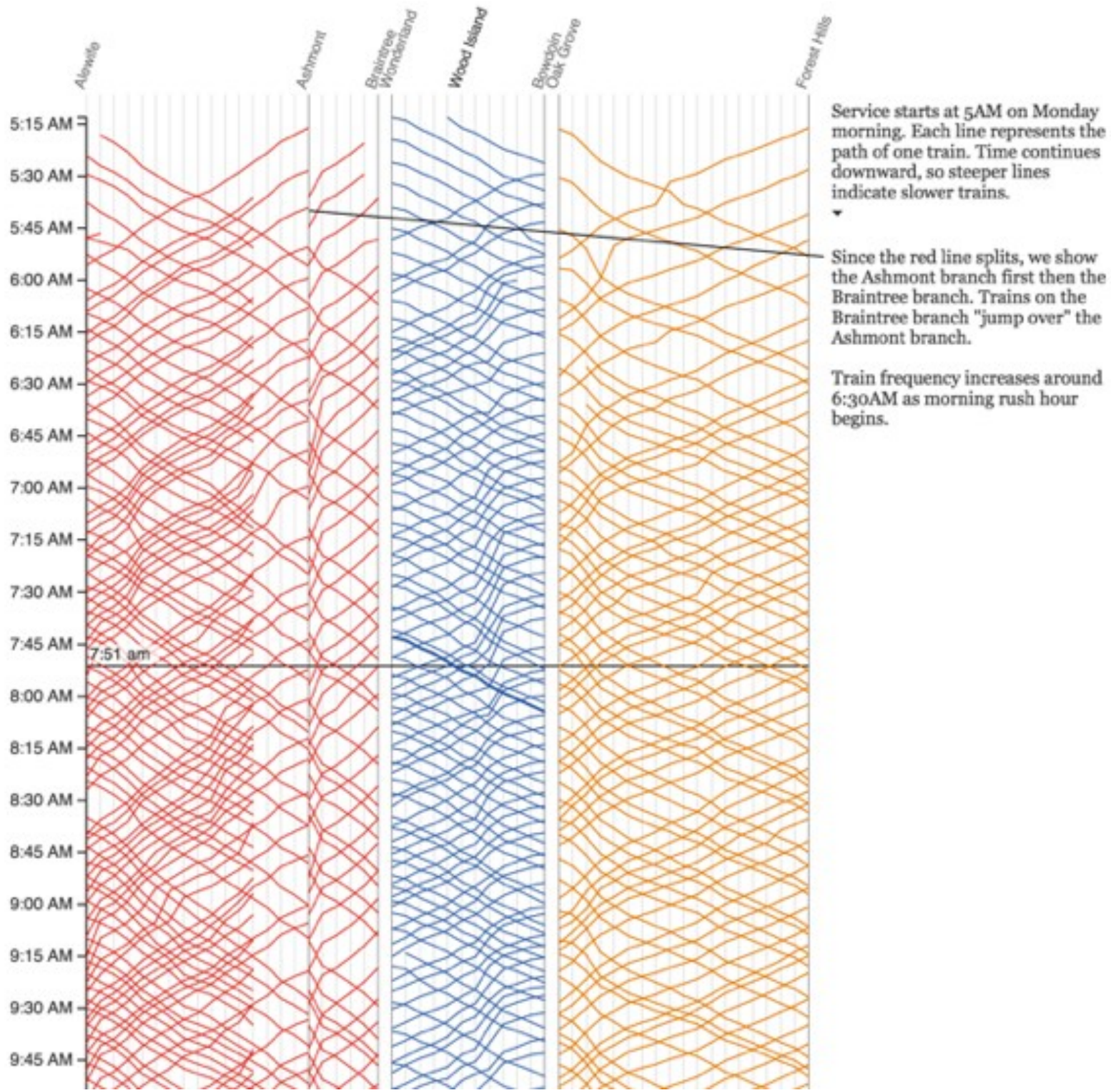
http://www.therefugeeproject.org

Subway Trips on Monday February 3, 2014

Locations of each train on the red, blue, and orange lines at 7:51 am. Hover over the diagram to the right to display trains at a different time.

Trains are on the right side of the track relative to the direction they are moving.

See the morning rush-hour, midday lull, afternoon rush-hour, and the evening lull.



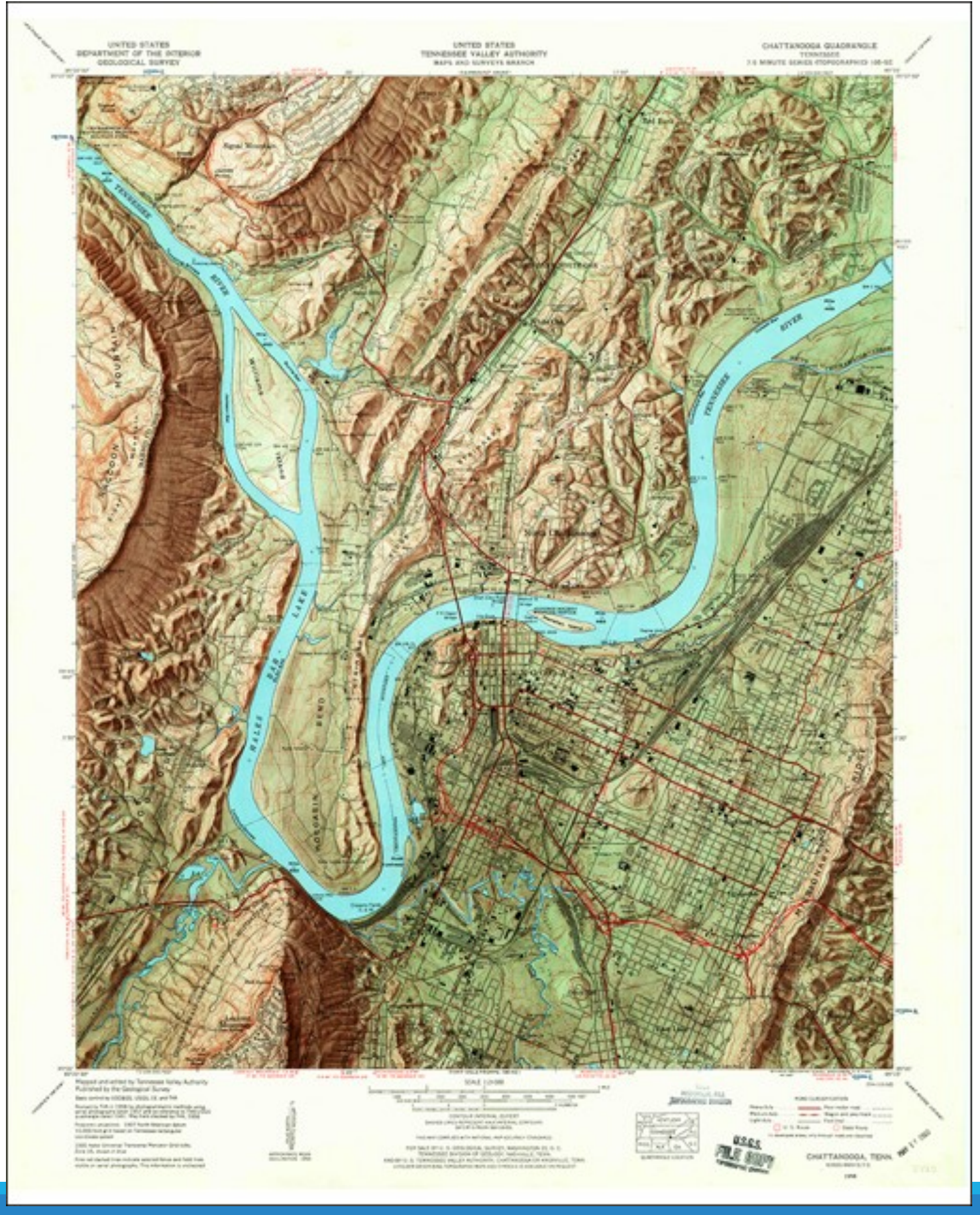
Service starts at 5AM on Monday morning. Each line represents the path of one train. Time continues downward, so steeper lines indicate slower trains.

Since the red line splits, we show the Ashmont branch first then the Braintree branch. Trains on the Braintree branch "jump over" the Ashmont branch.

Train frequency increases around 6:30AM as morning rush hour begins.

Layering & Separation

Use color or other differentiation to separate important classes of information.

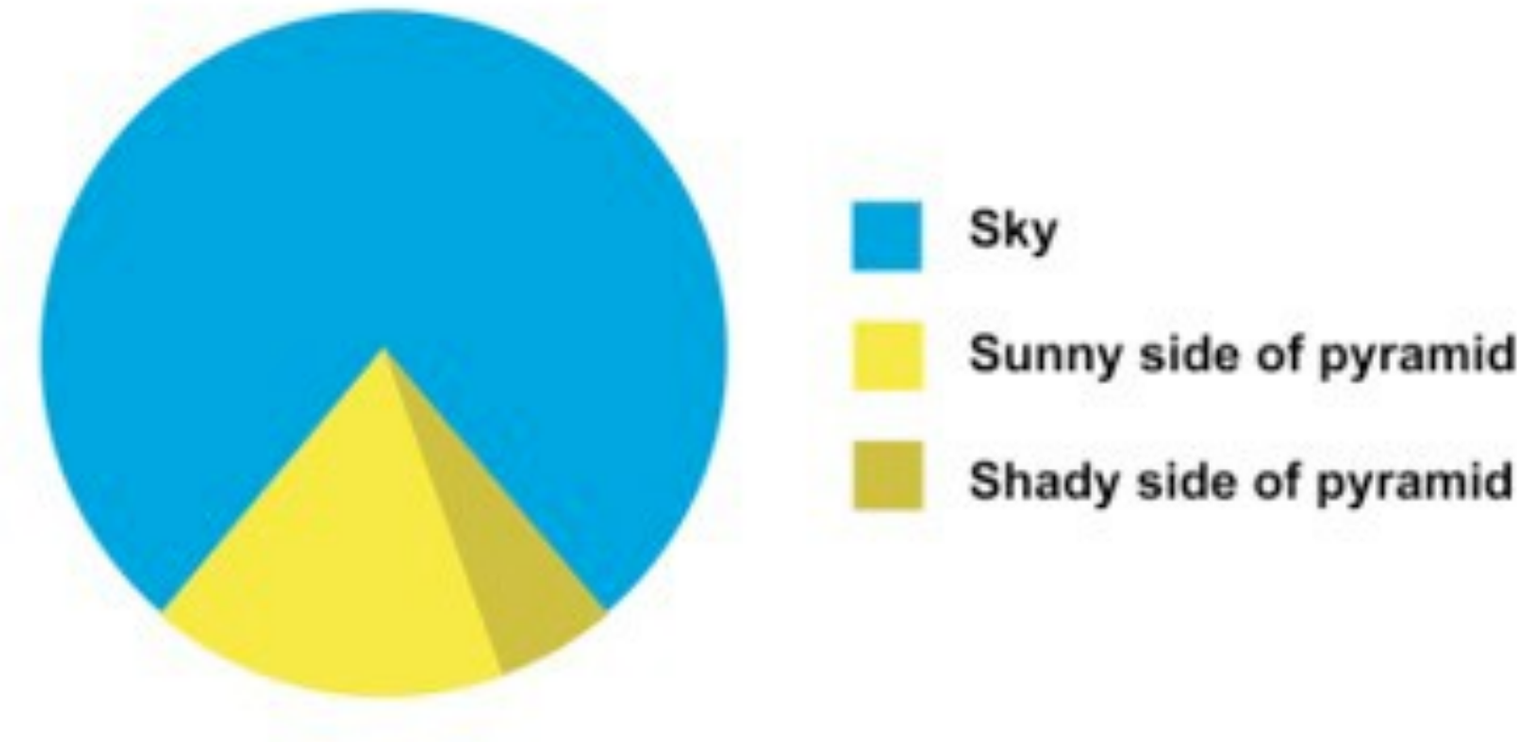


Muted colors, subtle shading and thin contour lines allow multiple types of data to be layered together in this 1958 topographic map of Chattanooga, Tennessee.

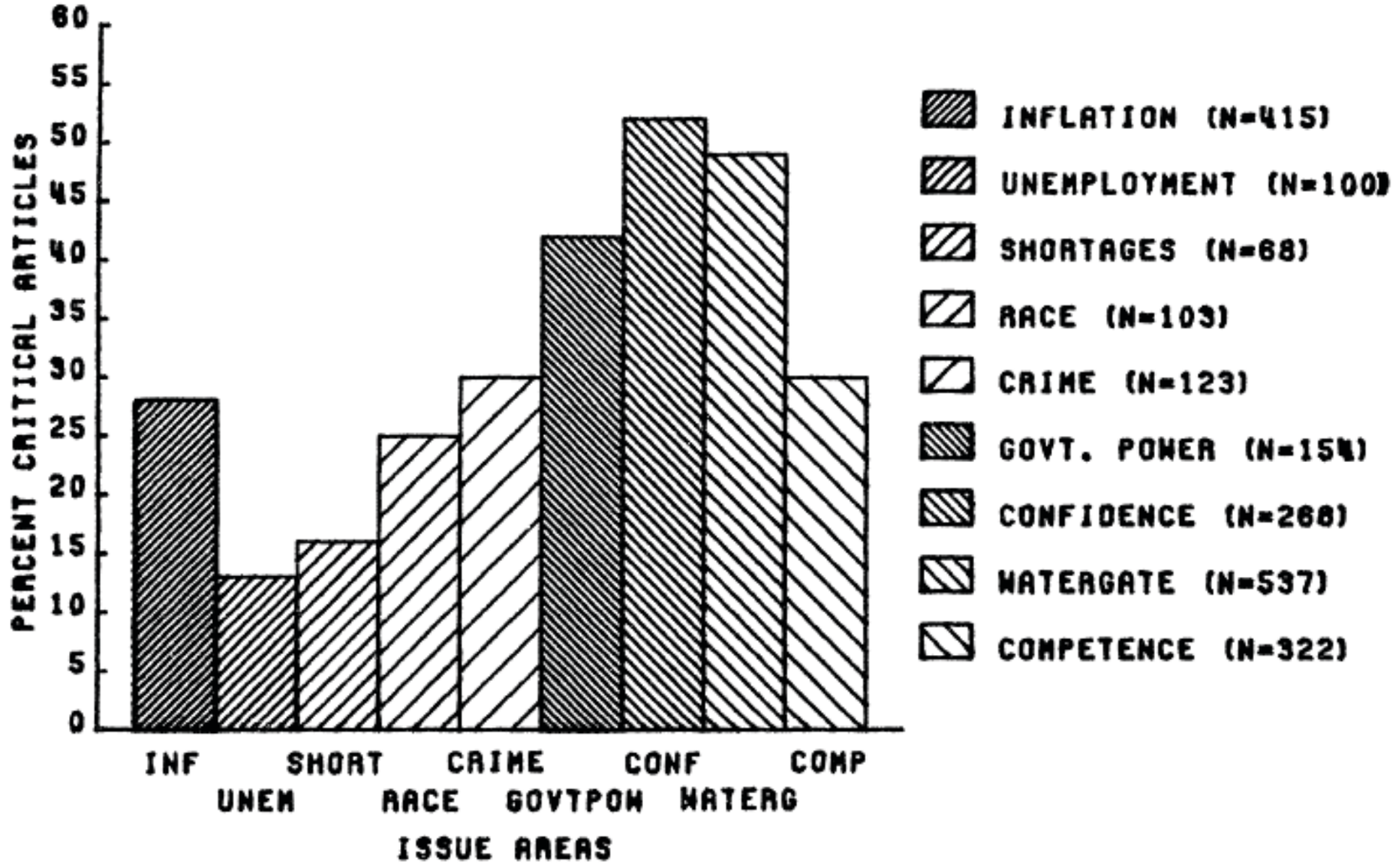
1 + 1 = 3 (or more)

Effective layering of information is difficult because of interactions

Can create non-information patterns and texture



Moire effect



Source: Center for Political Studies Media Content Analysis Study, 1974; available through the University of Michigan, ICPSR. Not to be cited without full bibliographical reference to the present article.

Select the appropriate graphic for the data & analysis

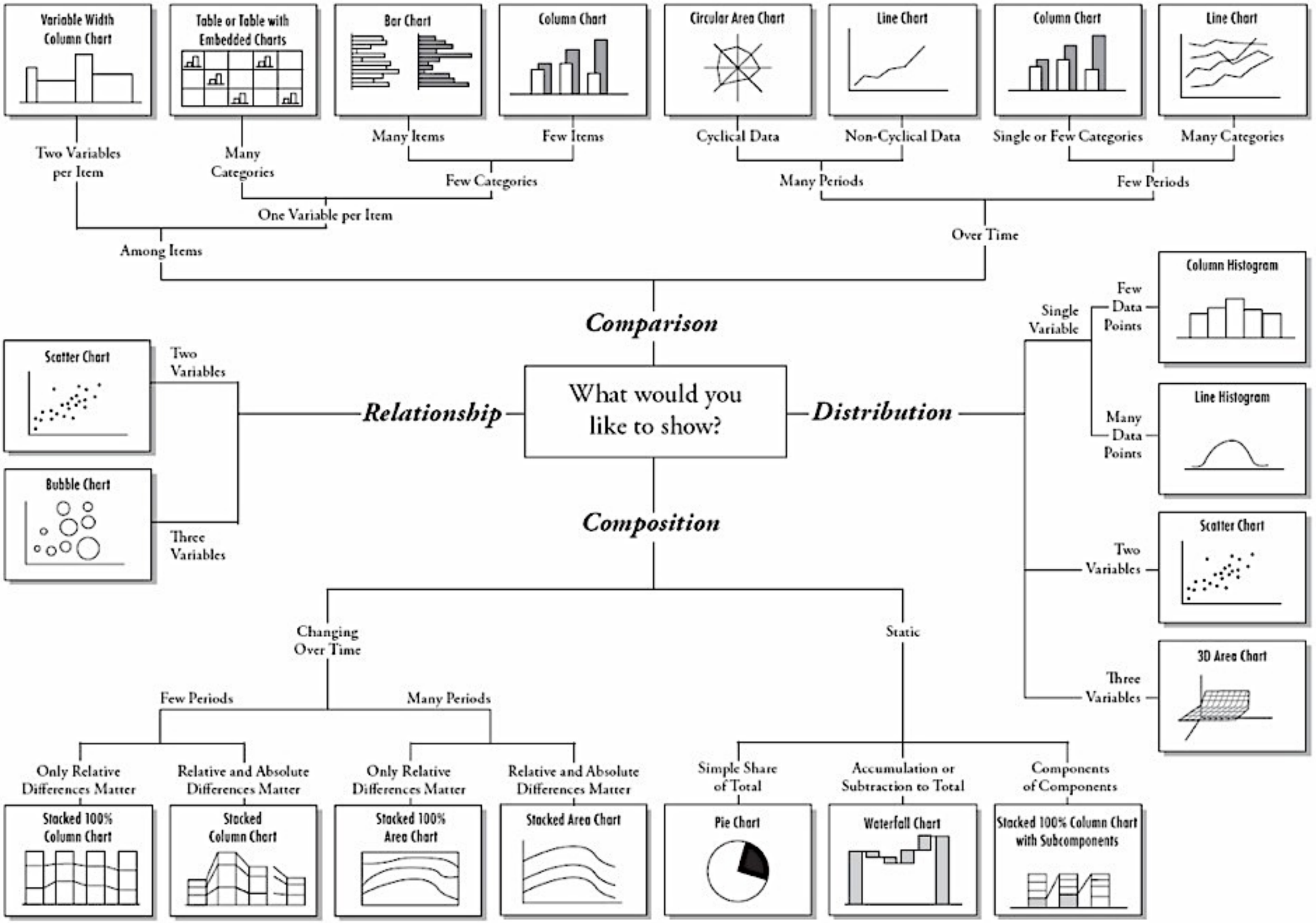


Chart by Andrew Abela

Aesthetics & Technique

Carefully chosen graphical format

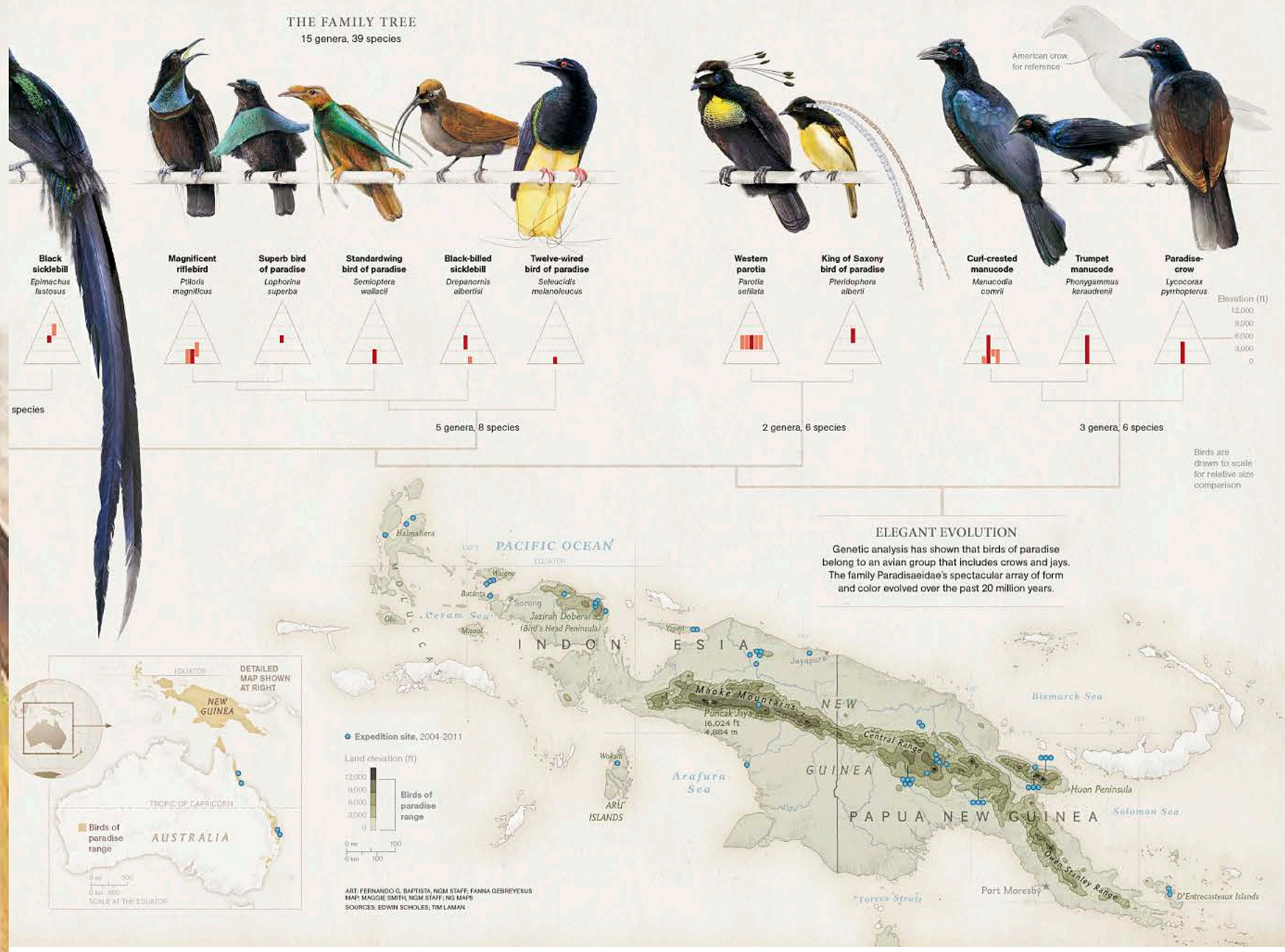
Design uses words, numbers, and drawings

Displays an accessible complexity of detail

Has a narrative quality, a story to tell about the data

Technical details of production done with care

Avoid content-free decoration, including chartjunk



Juan Velasco. Cornell ornithologist Edwing Scholes and biologist/photographer Tim Laman. Senior Graphics Editor Fernando Baptista, Graphics Specialist Maggie Smith and freelance researcher Fanna Gebreyesus. *National Geographic*

The final word…

The principles should not be applied rigidly or in a peevish spirit; they are not logically or mathematically certain; and *it is better to violate any principle than to place graceless or inelegant marks on paper*

--*Tufte,* Visual Display of Quantitative Information, *page 191*