Cancer Research UK

Designing more effective scientific figures

(II)

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Structure of this course

	THEORY	PRACTICAL
Morning	1 Why figure design? Principles of figure design Elements of a figure Colour & ethics	2 **Gimp** – *bitmap (e.g. jpg)* Setting up a canvas Layers and importing files Editing colour Export formats and qualities
Afternoon	3 Dealing with complexity Choosing the right figure Typography Composition & layout	4 **Inkscape** – *vectorial (e.g. pdf)* Document properties Create & manipulate objects Composition Import & export for publication

Key ingredients: the tools

Elements: marks and channels

- Data
- Points, lines, areas
- Colour
- Typography

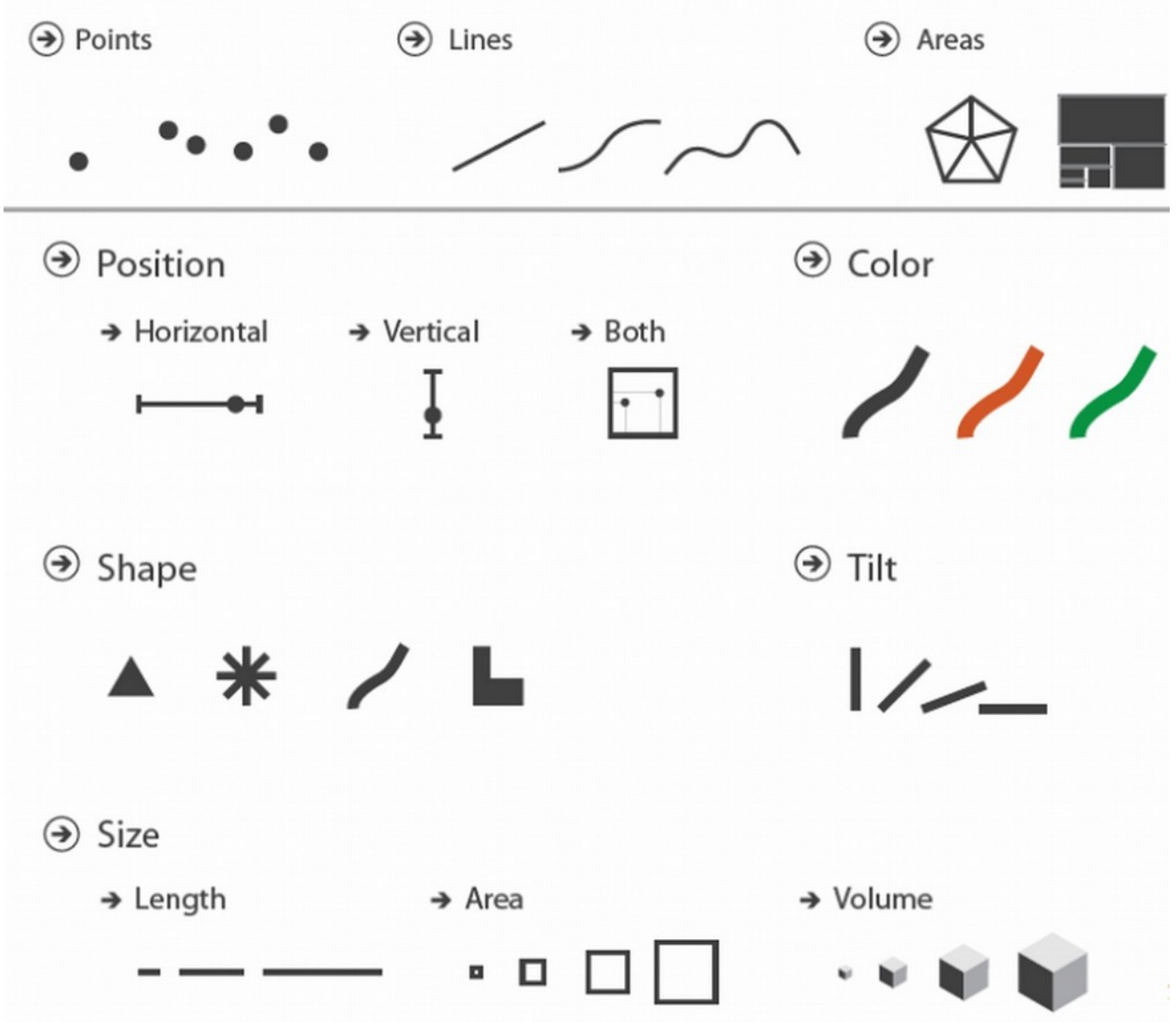
Composition

- Grid and alignments
- Balance
- Hierarchy and focus

Elements: Marks and channels

Marks (geometric primitives): used to **represent** data

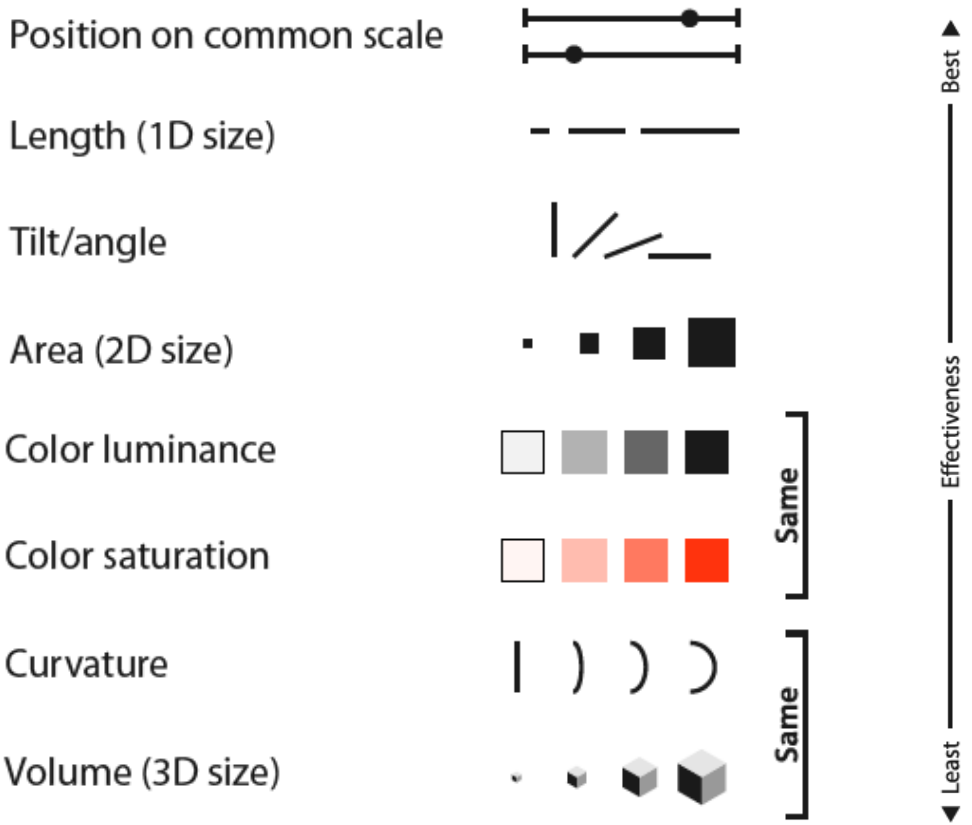
Channels control the graphical appearance of marks: used to **encode** data, can be combined



Images from Munzner

Types of channel

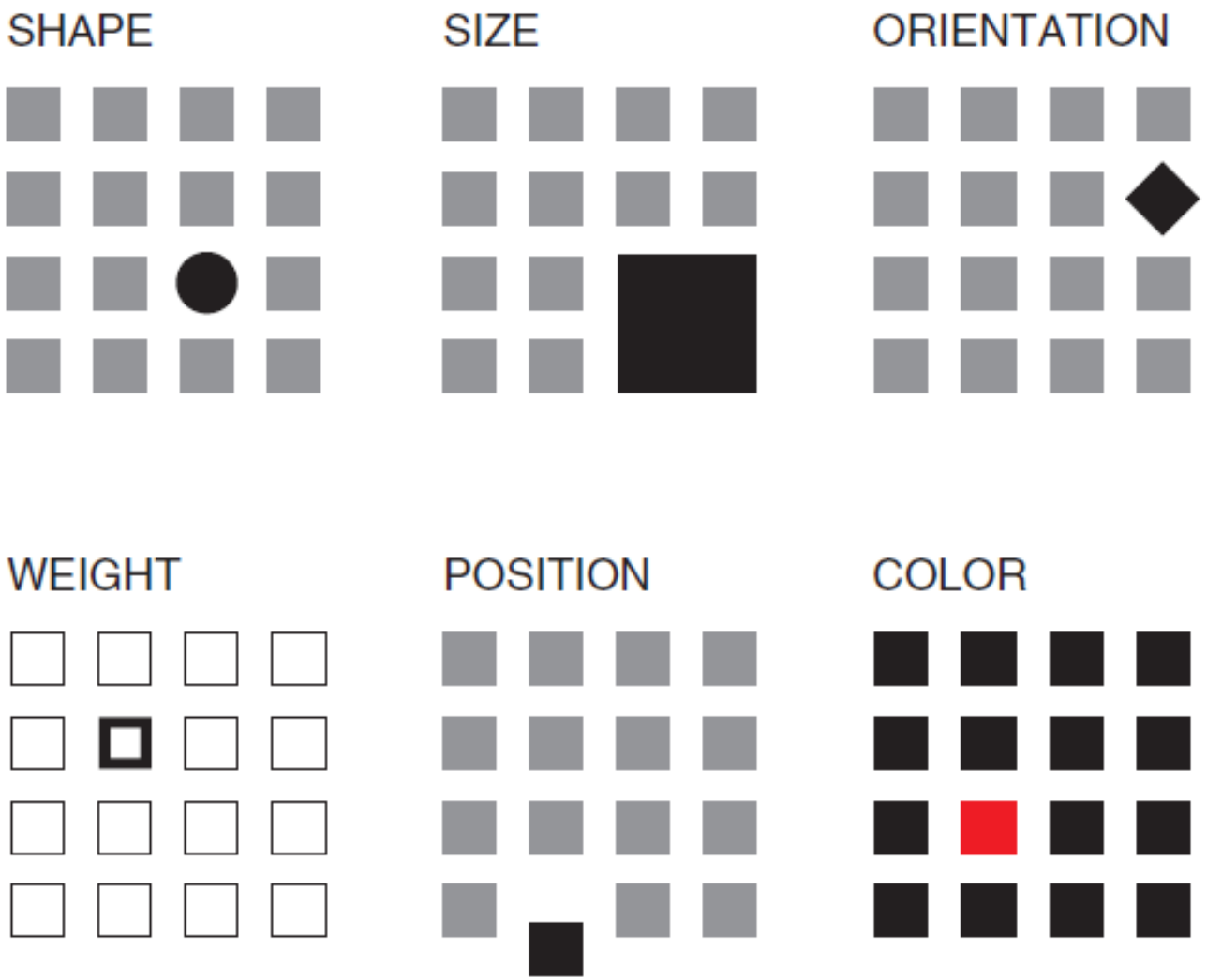
Identity channels: categorical/ **qualitative** attributes



Magnitude channels: ordered/ **quantitative** attributes

Images from Munzner

Types of channel (continued)



Rolandi et al 2011

Effectiveness of each channel: Quantitation perception

The perceived magnitude of sensory channels follows a power law: $S = I^N$

Depending on the **N** of a given type of sensation, its perception is magnified *(e.g. colour saturation)* or compressed *(e.g. brightness)*

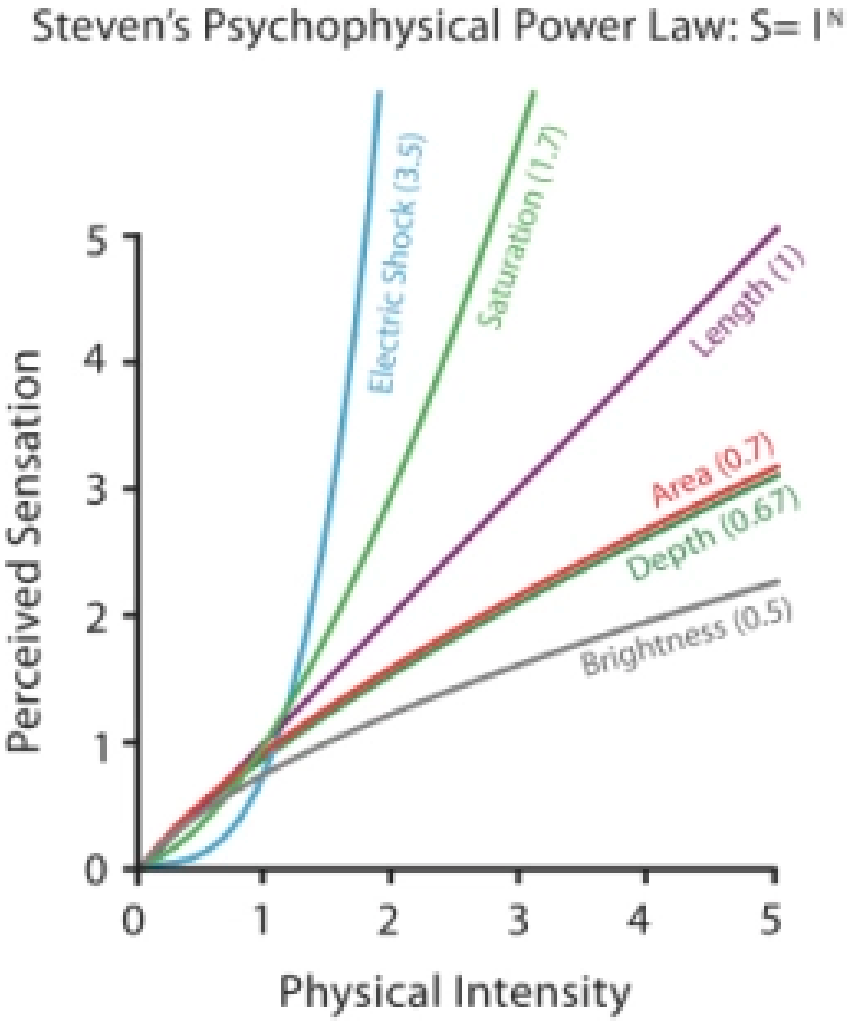
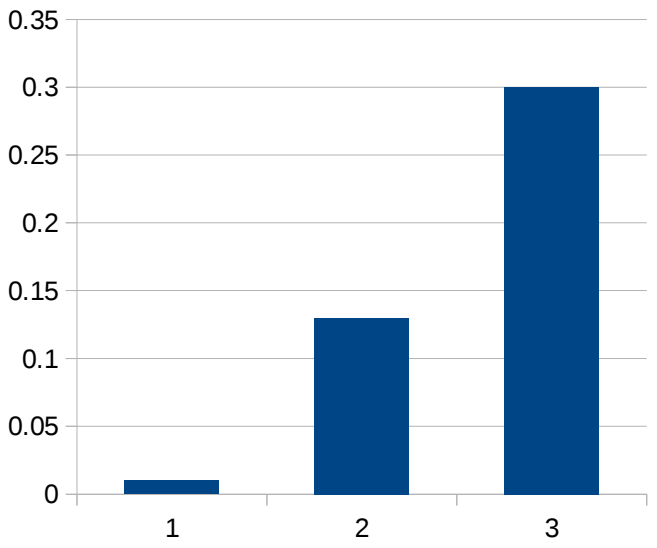


Image from Munzner 2015

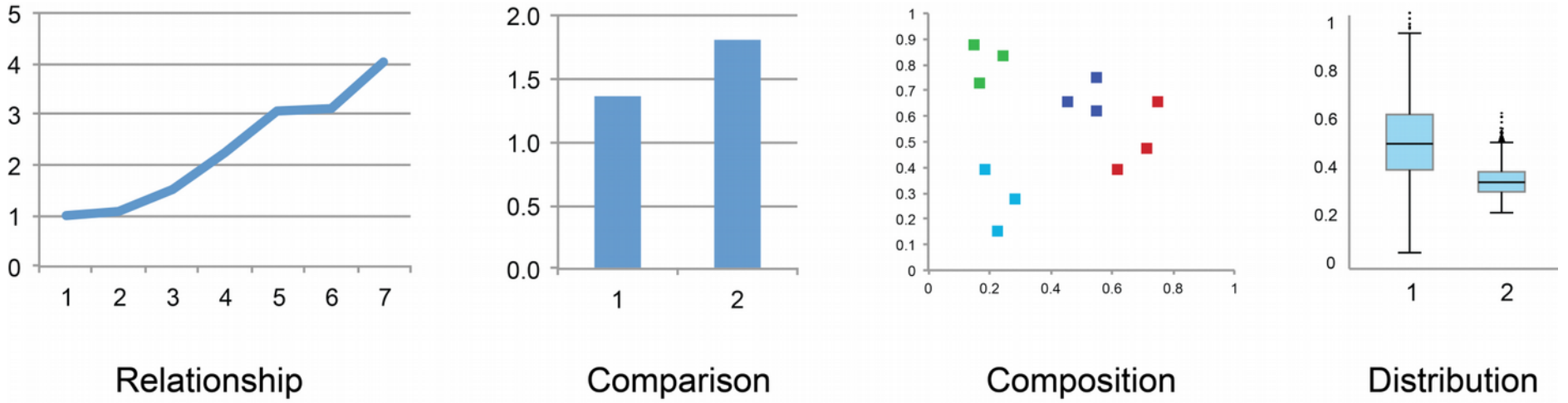
Choosing the type of figure

- Text, table or figure?
  - Text: one or two numbers
  - Table:
    - Exact numerical values
    - Small datasets (a figure may be best avoided if it has low data density)
    - When the data presentation requires many localised comparisons

Treatment 1	0.01
Treatment 2	0.13
Treatment 3	0.30

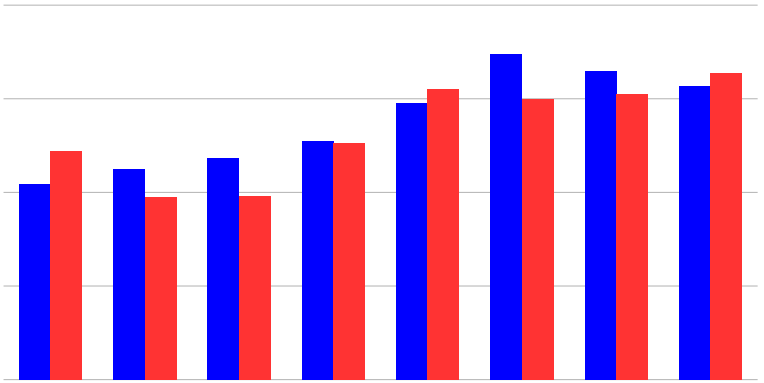


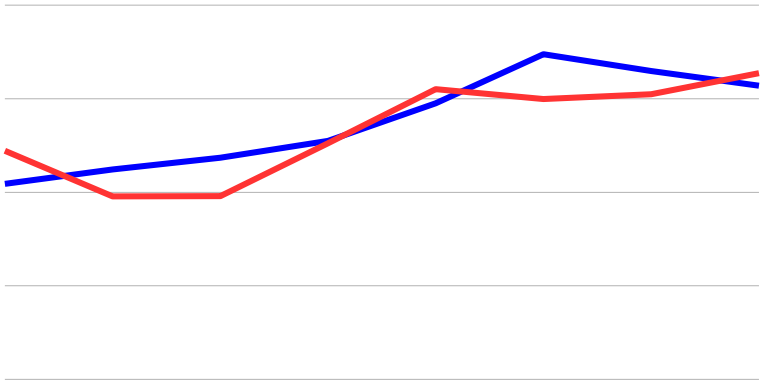
Things you can illustrate

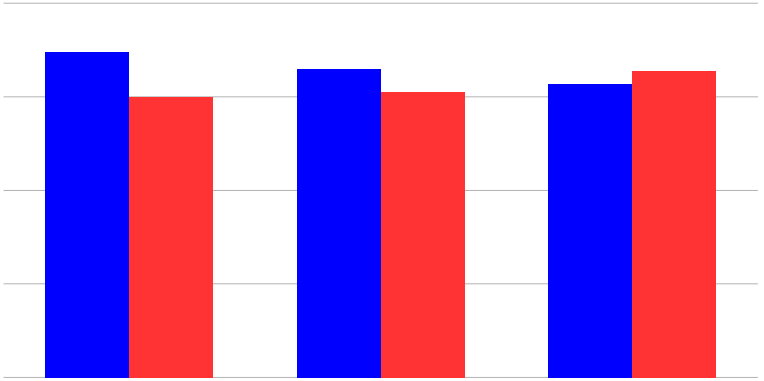


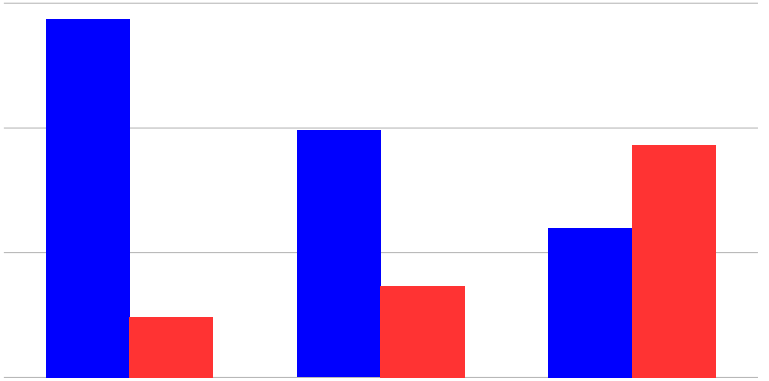
Slide from Babraham Bioinformatics

Each figure tells a different story

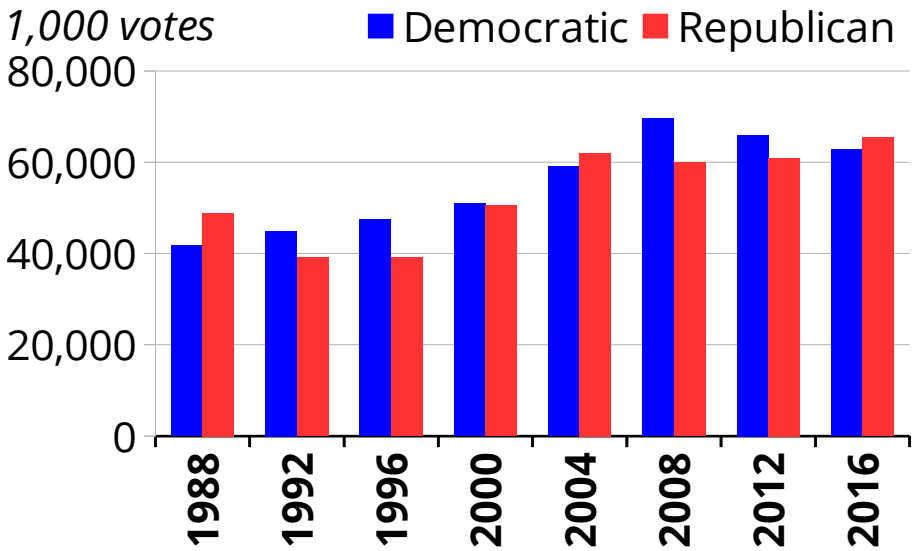


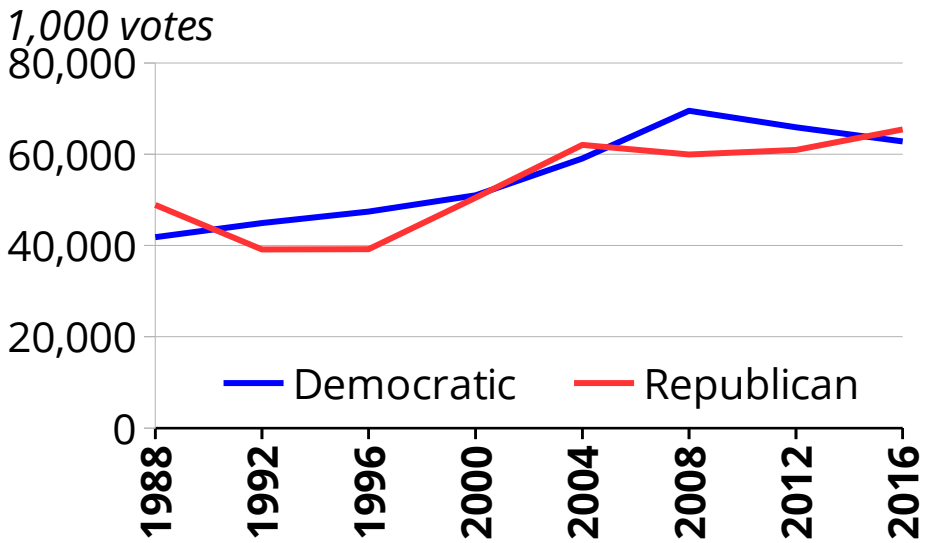


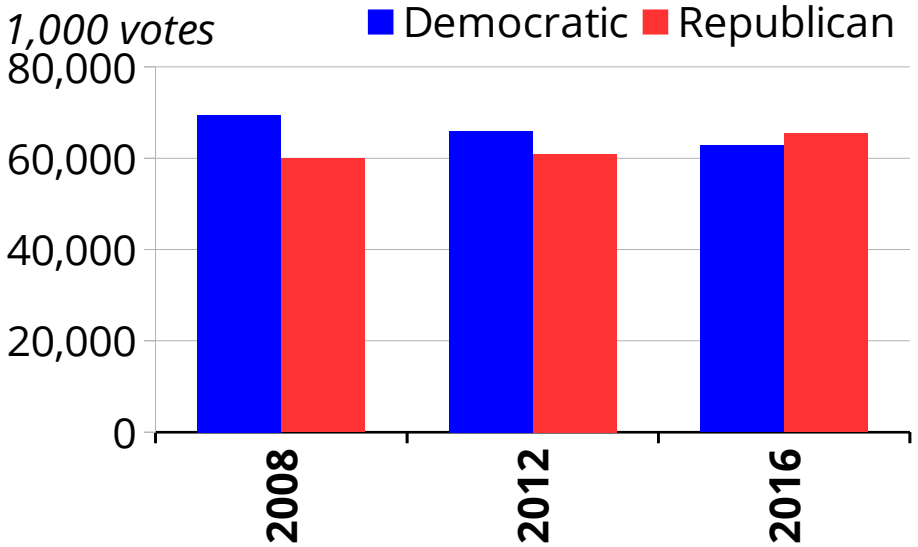


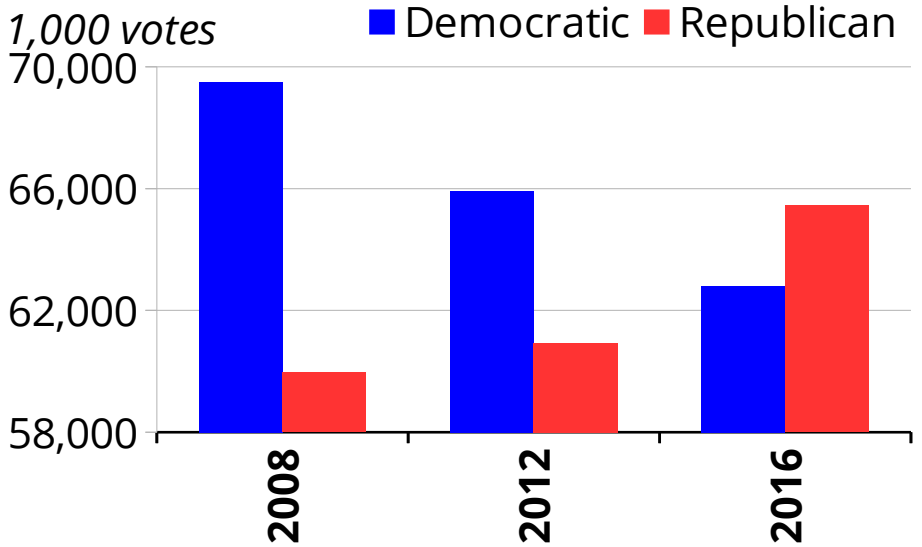


Each figure tells **a story differently**



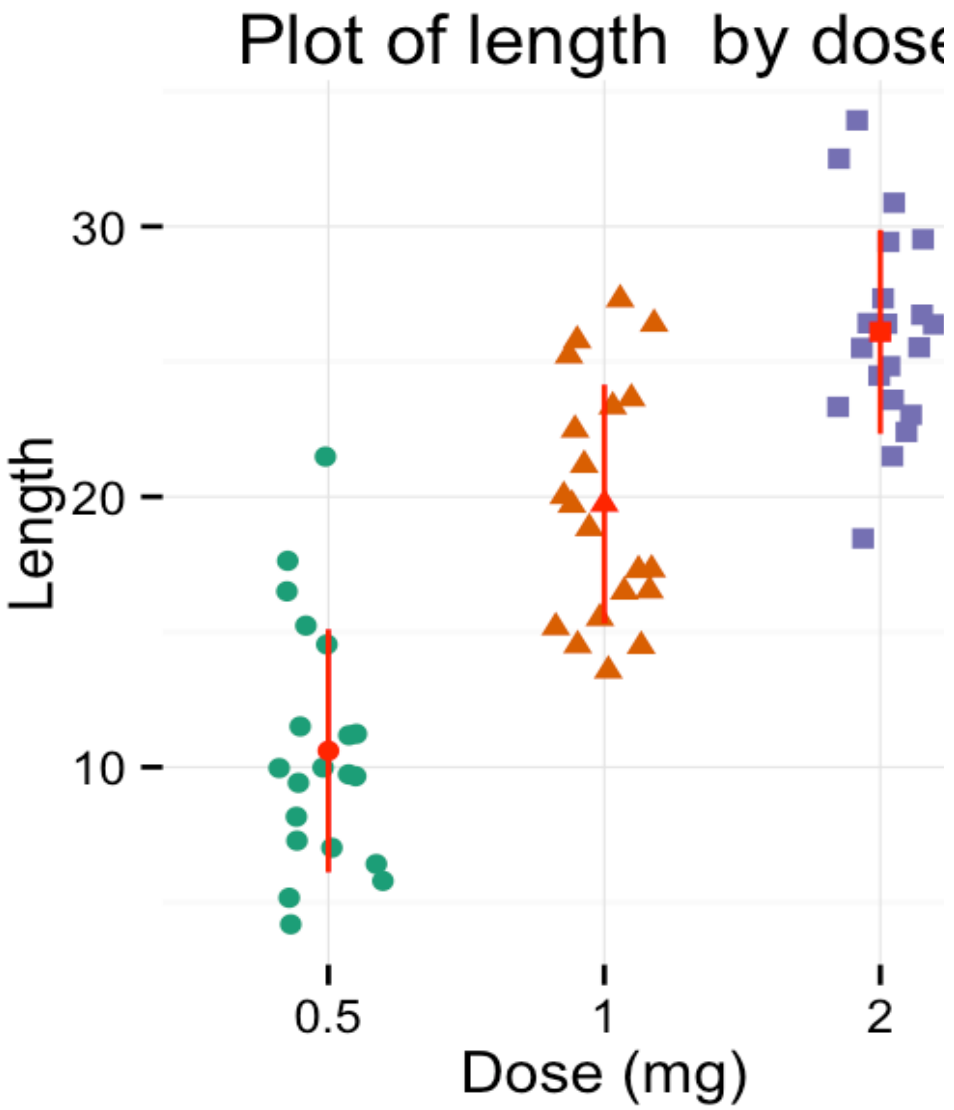






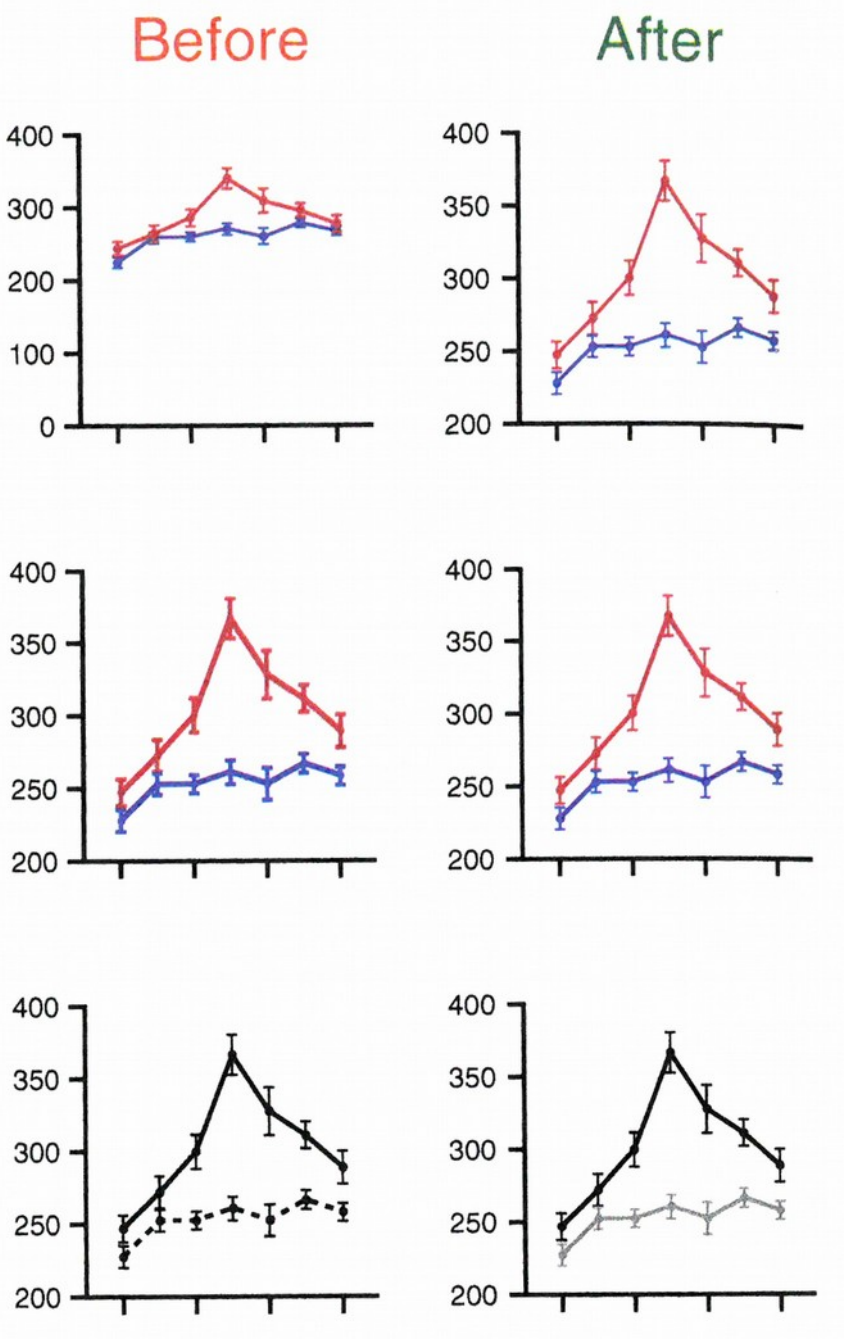
Stripchart – comparison

- Only one of the axis is meaningful
- To explore small datasets (n < 100) and compare categories
- The most basic plot (rarely in publications)



Line chart – relationships

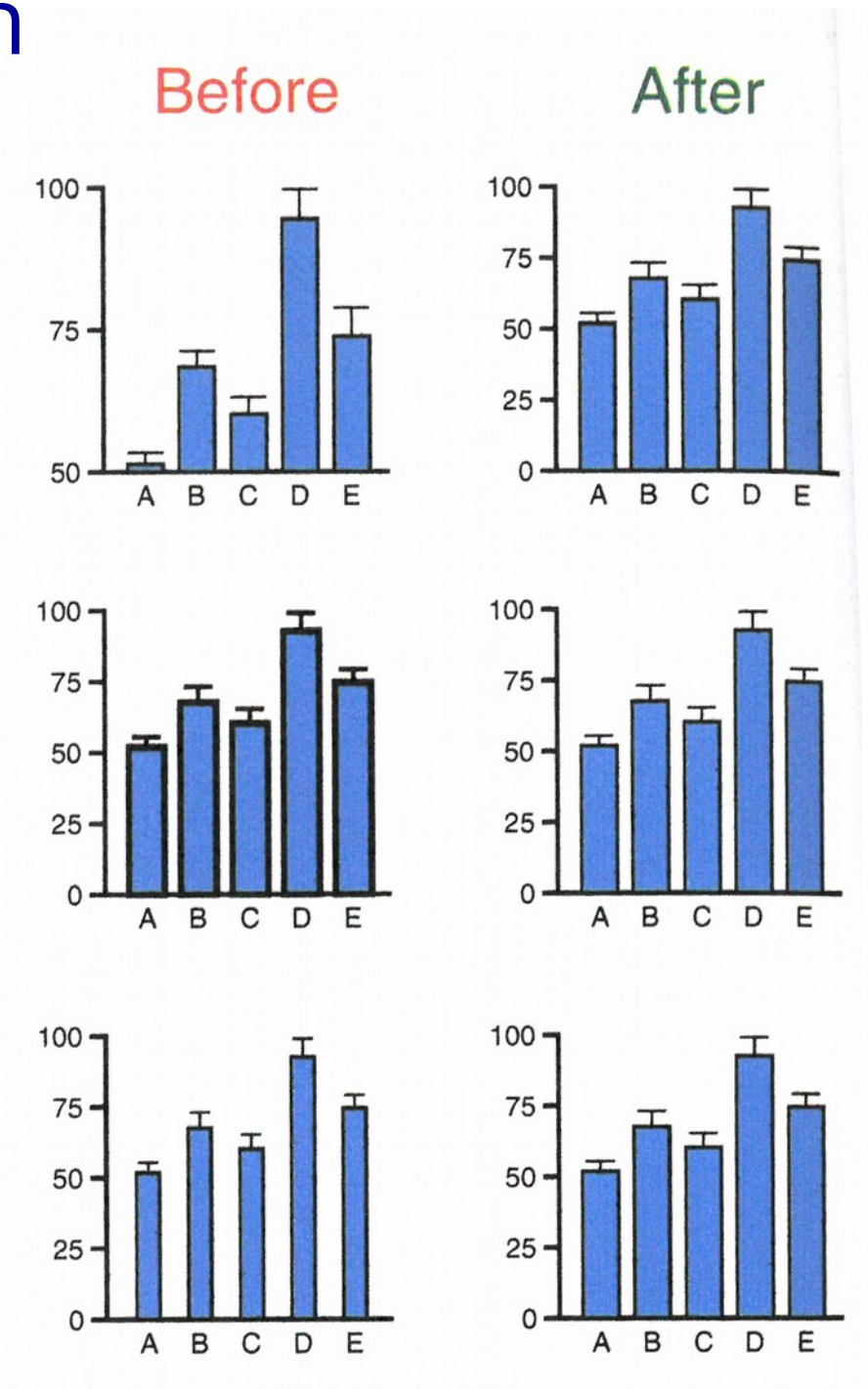
- To show a trend of **continuous** data (usually over time)
- For matched, paired or repeated data, and for time-series
- To tell a story: how data change, rather than the discrete values of the data



Carter 2013

Bar chart – comparison

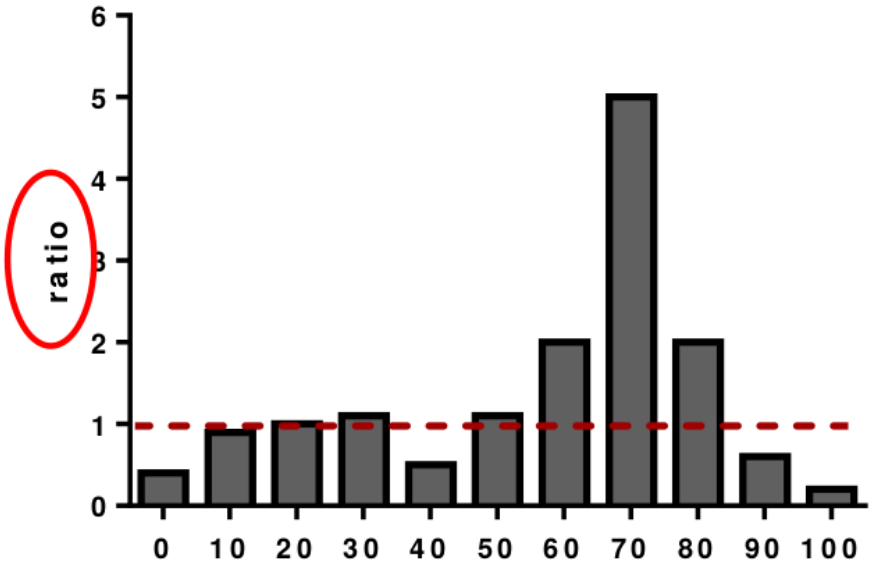
- To **compare** discrete quantities of **non-continuous** data
- For presenting results and emphasise differences (not so much to explore)

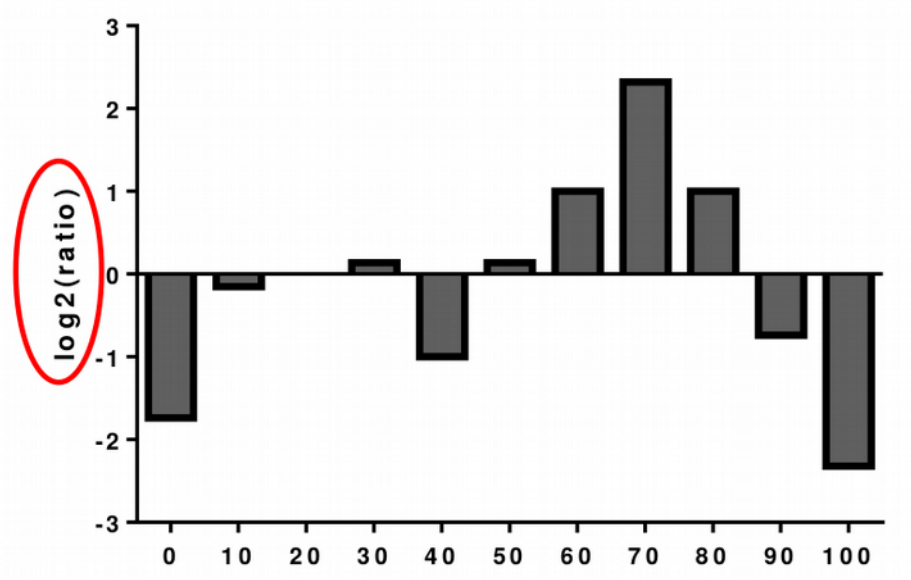


Carter 2013

Bar chart – comparison

The choice of the x axis and of point of reference can affect how comparisons are perceived

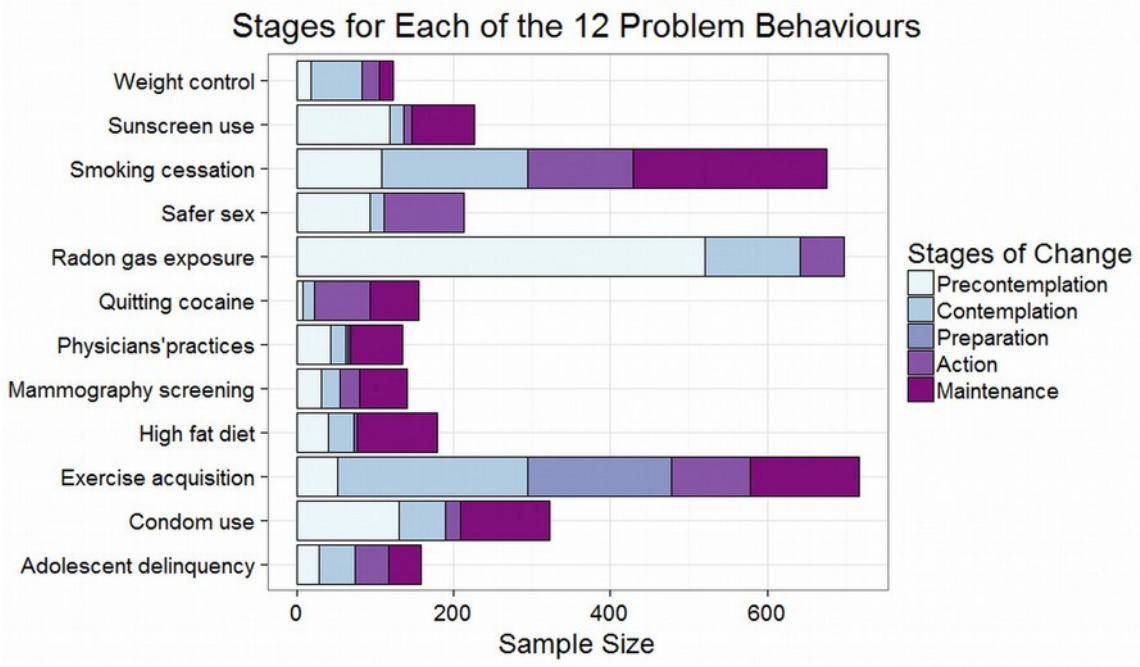




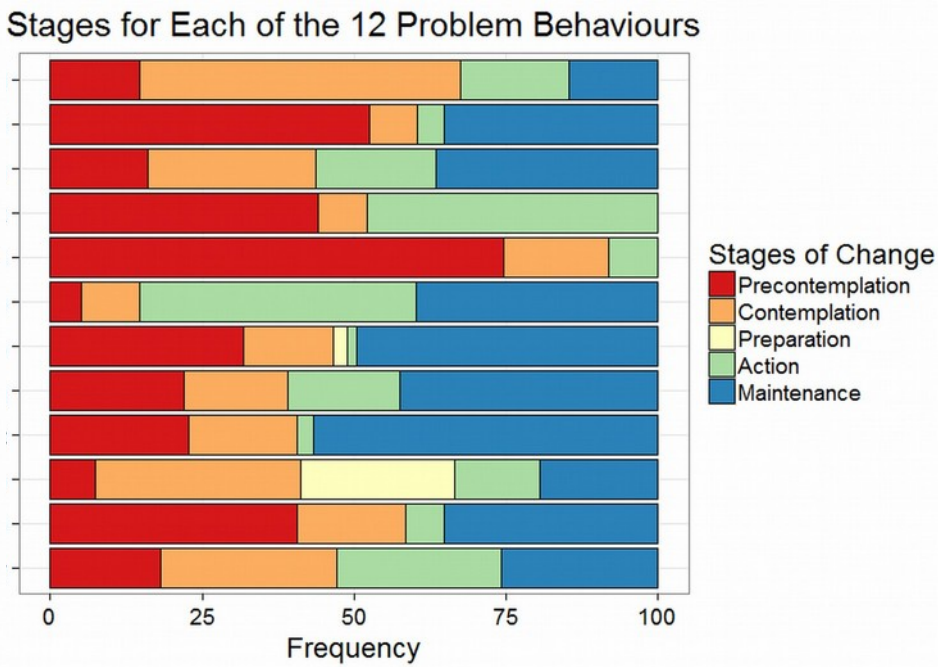
Slide from Babraham Bioinformatics

Bar chart variations

Stacked bar chart



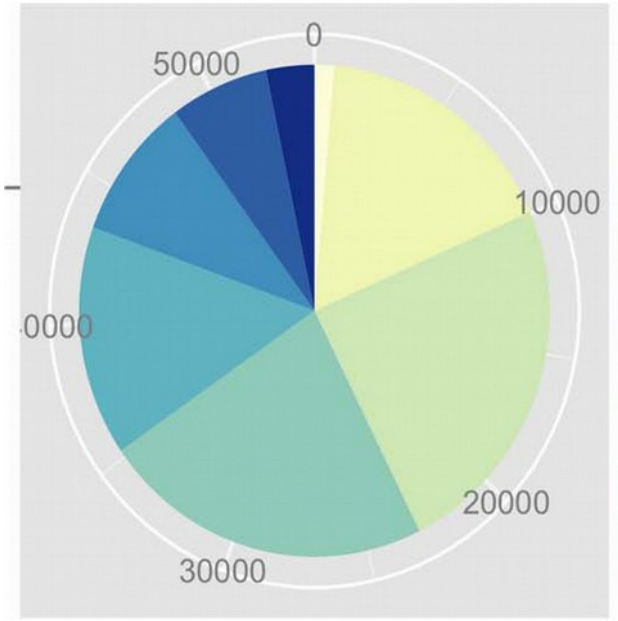
Normalised stacked bar chart

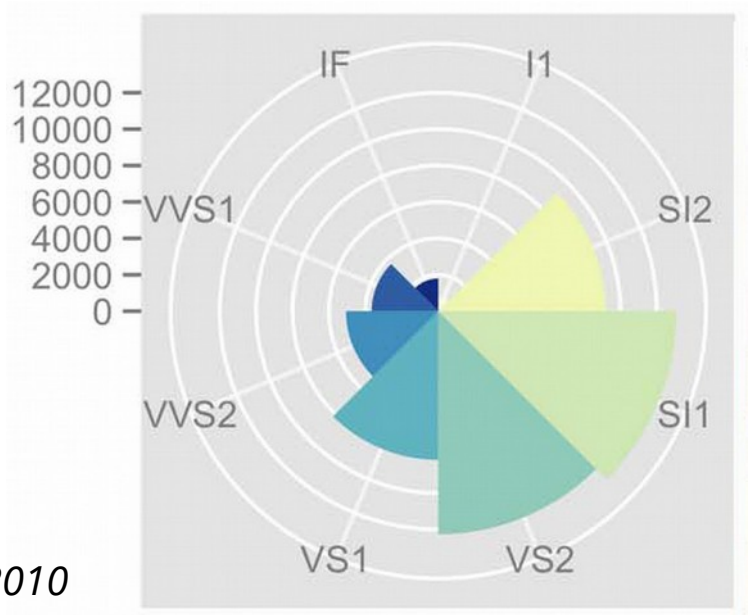


- For categorical data; heed the sample size

Pie chart – composition/ proportion

- To show relative proportions of a whole
- Not a great idea, ‘given their low data-density and failure to order numbers along a visual dimension’ (Tufte)





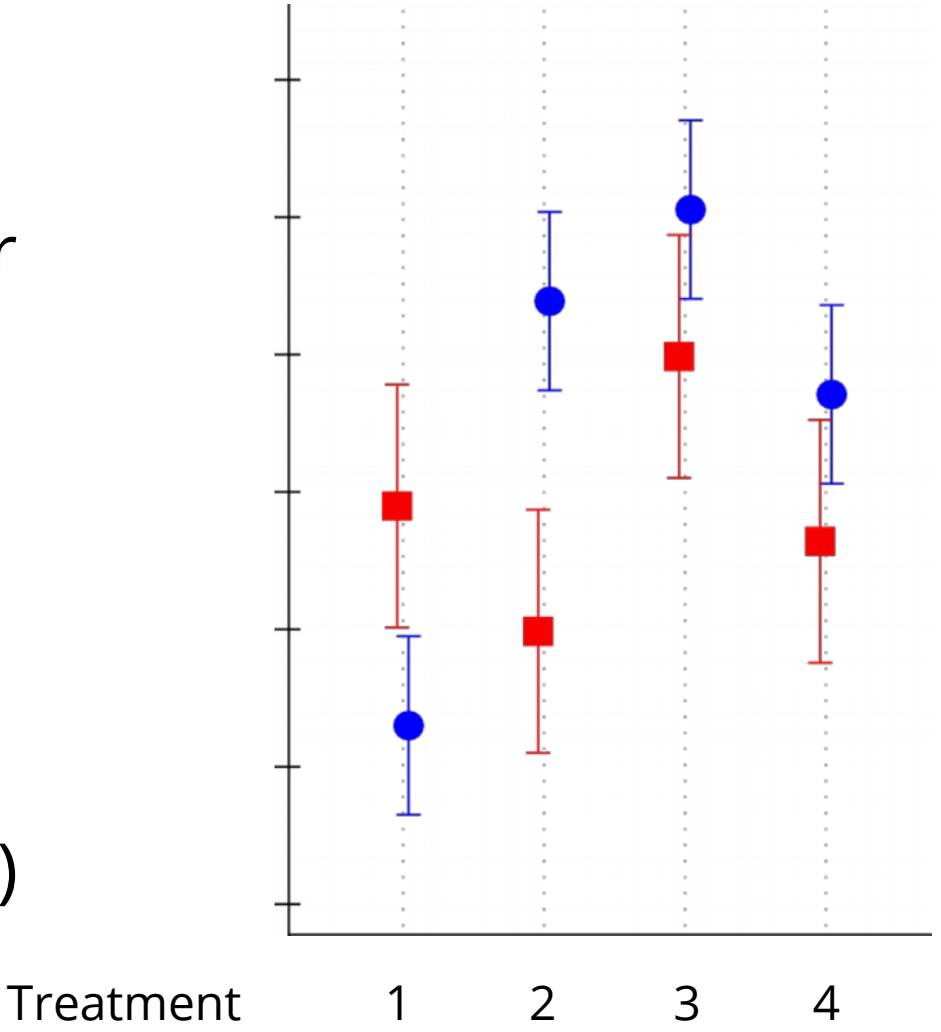
Alternative:

Polar area chart

Wickham, 2010

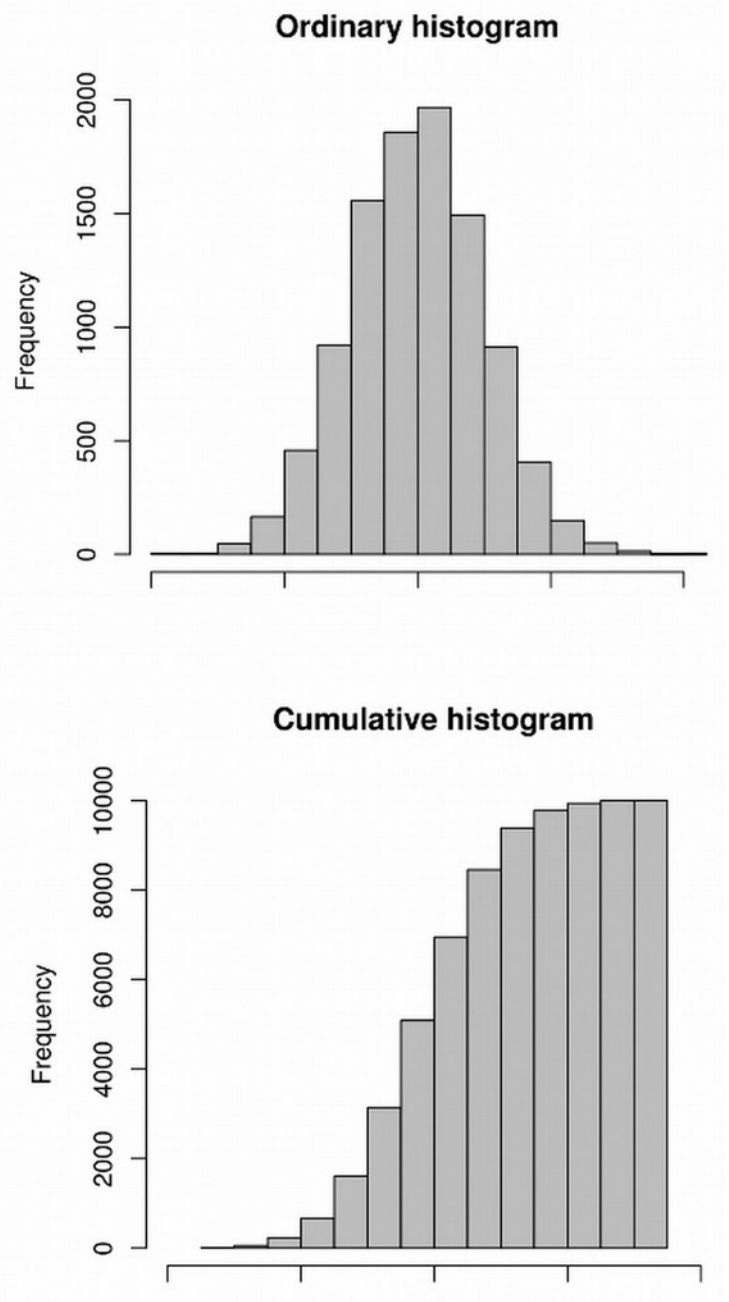
Bar chart alternative for comparisons: **Dotchart with confidence intervals**

- Focuses attention on the **relative values** and their measure of **variability**, rather than on the absolute values
- (absolute values are better conveyed using the heights – in a barplot)



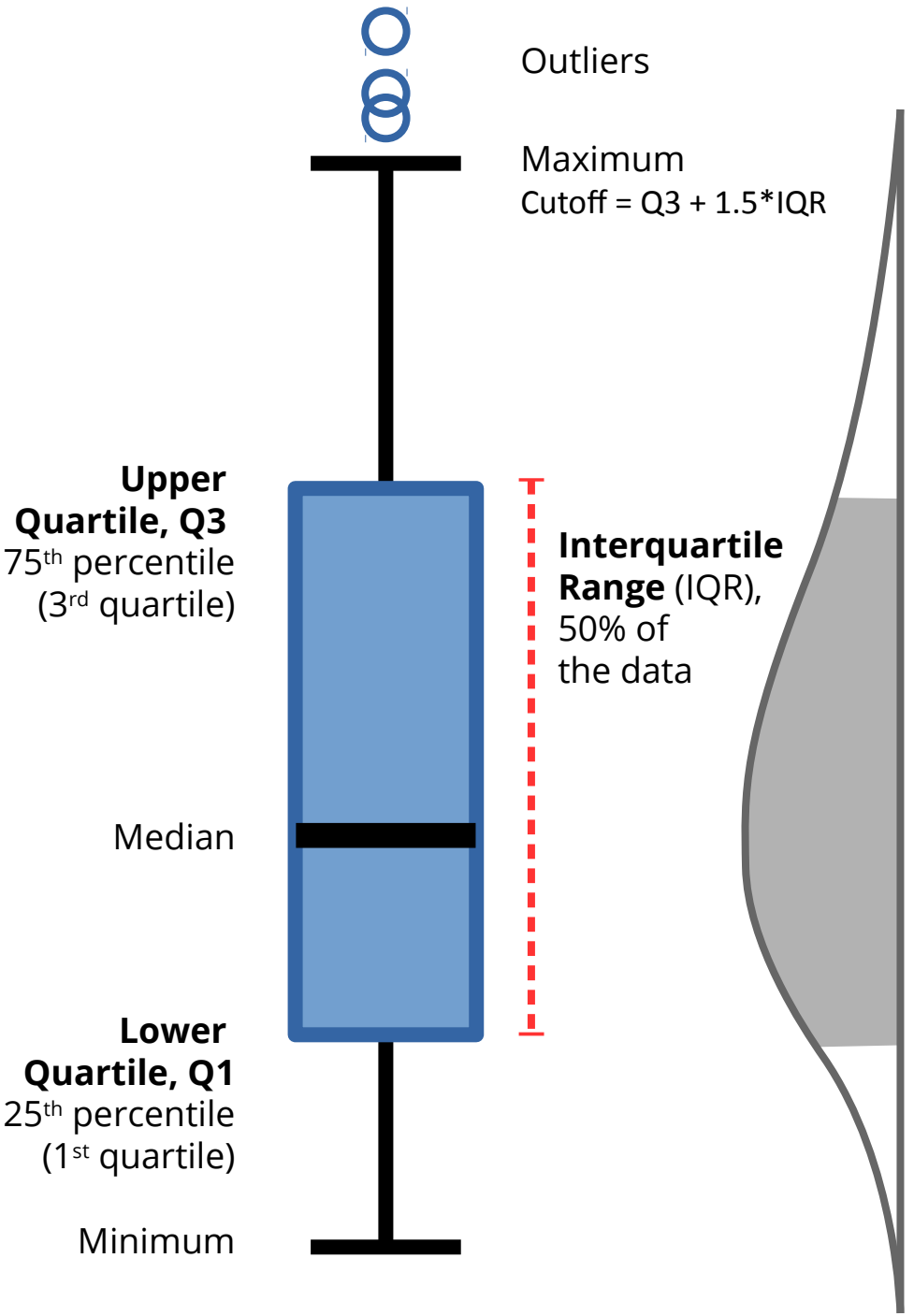
Histogram – distribution

- To show the distribution of a variable and the relative frequency of values; to explore the data
- Better on big datasets
- Estimate of the probability distribution of the variable
- The number of bins (resolution) affects the perceived shape of the distribution; the same perceptive distortion can occur when using histograms with discrete data
- Rules: Number of intervals ≈√N and Interval width ≈ Range ÷√N



Boxplot – distribution

- Also ***box-and-whisker*** plot
- Shows the central value, the extremes, and the area where 50% of the values are located.
  - Usually median, minimum, maximum, lowest and highest quartiles
- Particularly useful to understand distribution of not-normal data



Boxplot variation: **Violin/ Bean plots**

- To the above, it adds a **stripchart** of the actual datapoints
- Shows the data **density**
- To understand the distribution in more detail

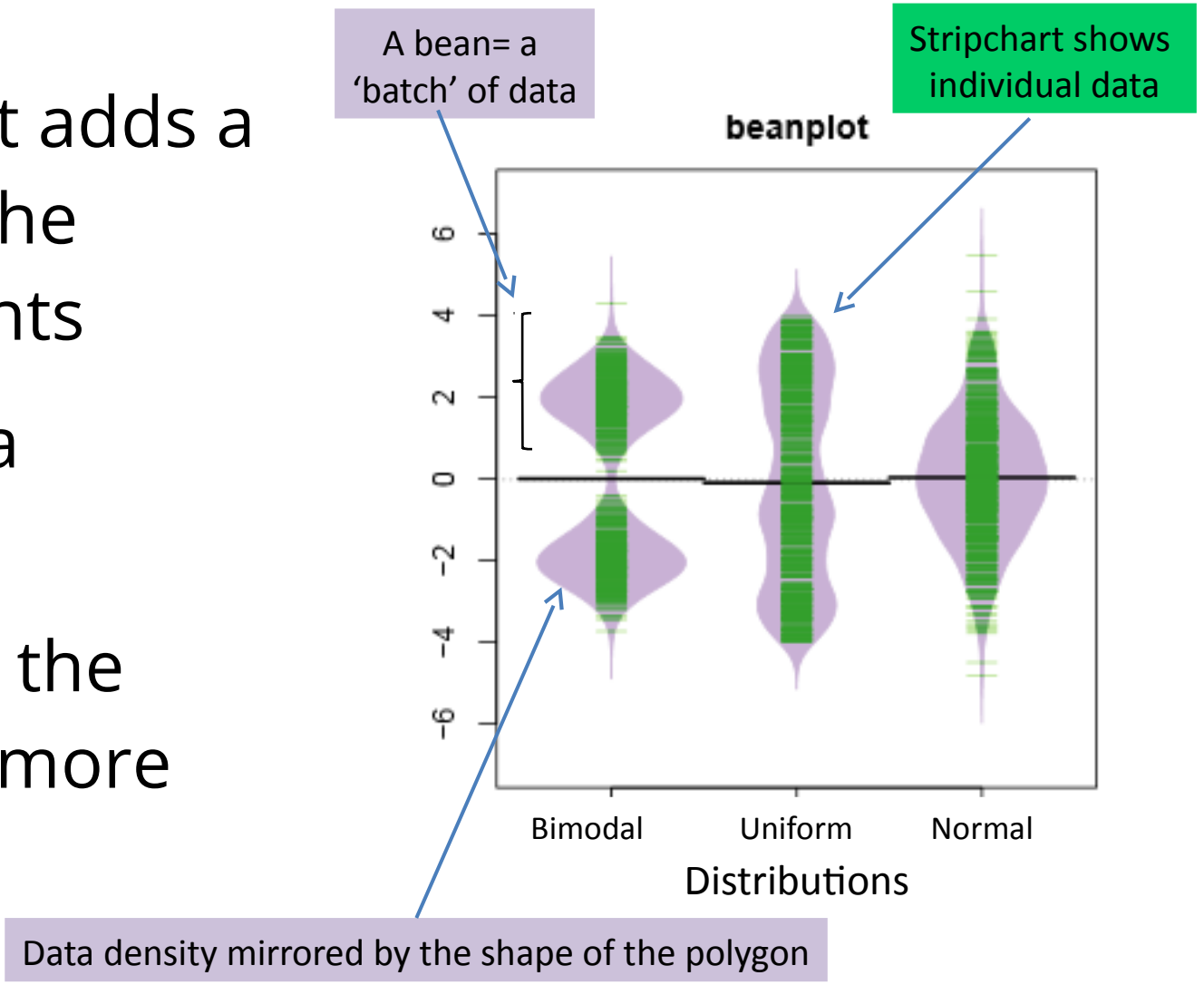
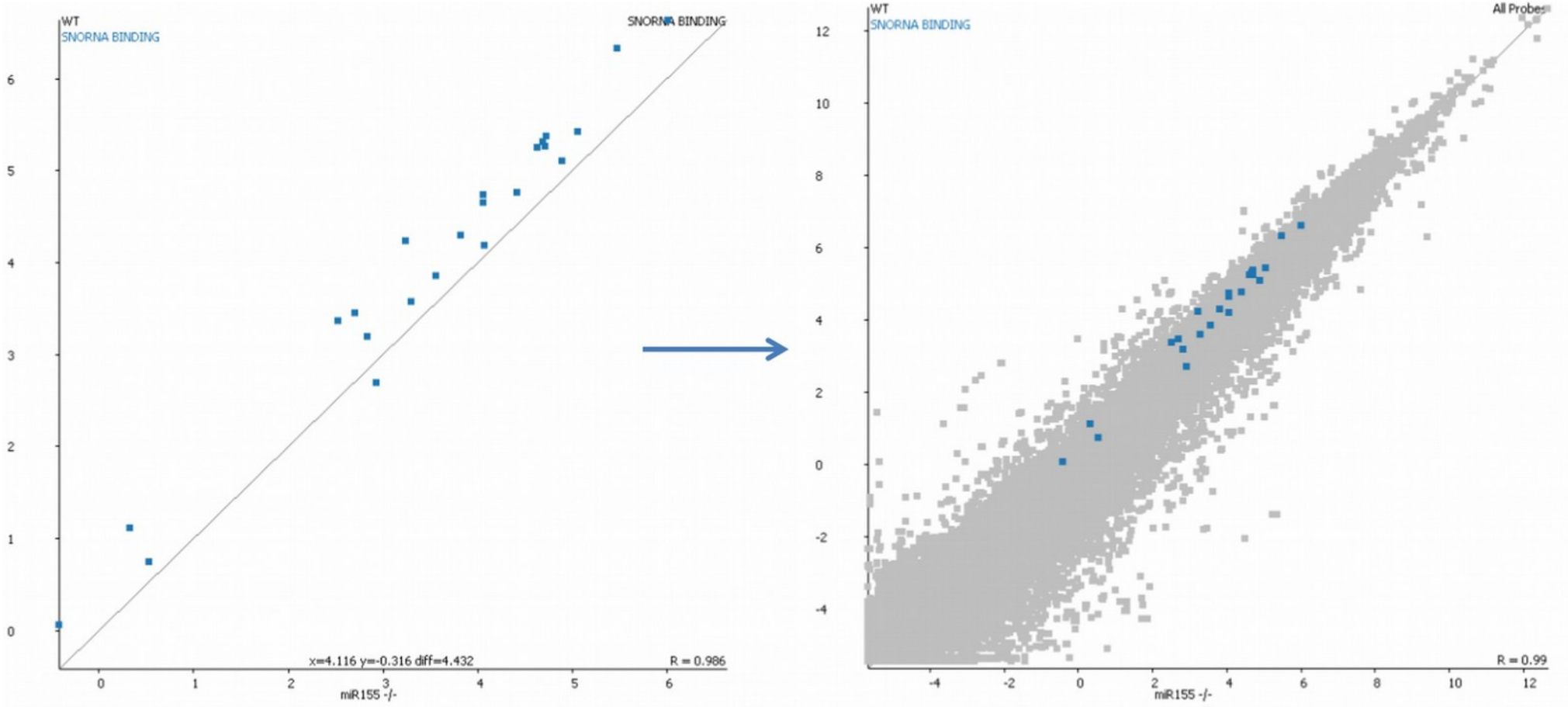


Image from Babraham Bioinformatics

Scatterplot – relationships

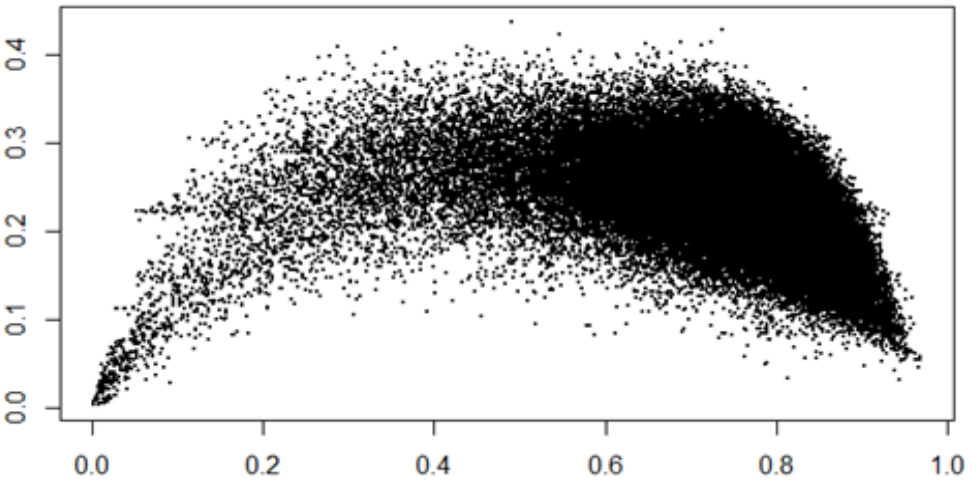
To show the relationship between two continuous variables



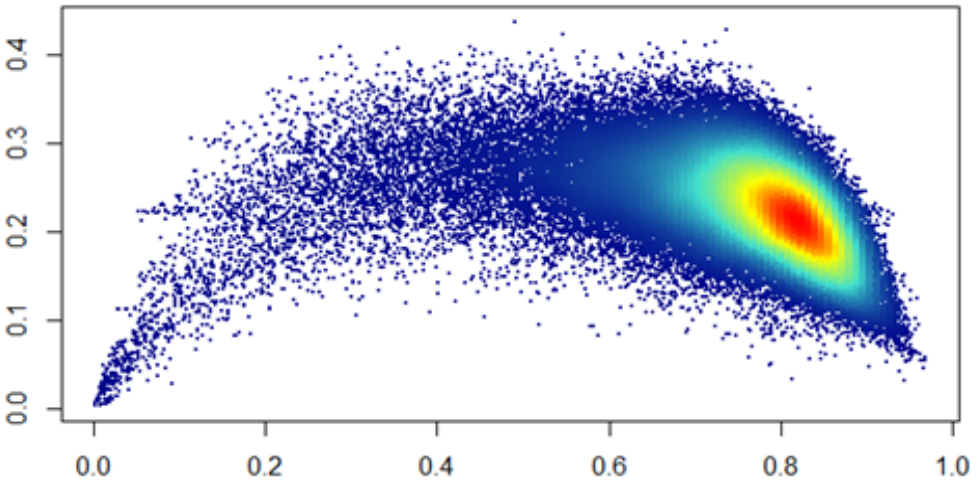
Scatterplot – relationships

For high-density data: use colours or transparency

Problem: very big dataset



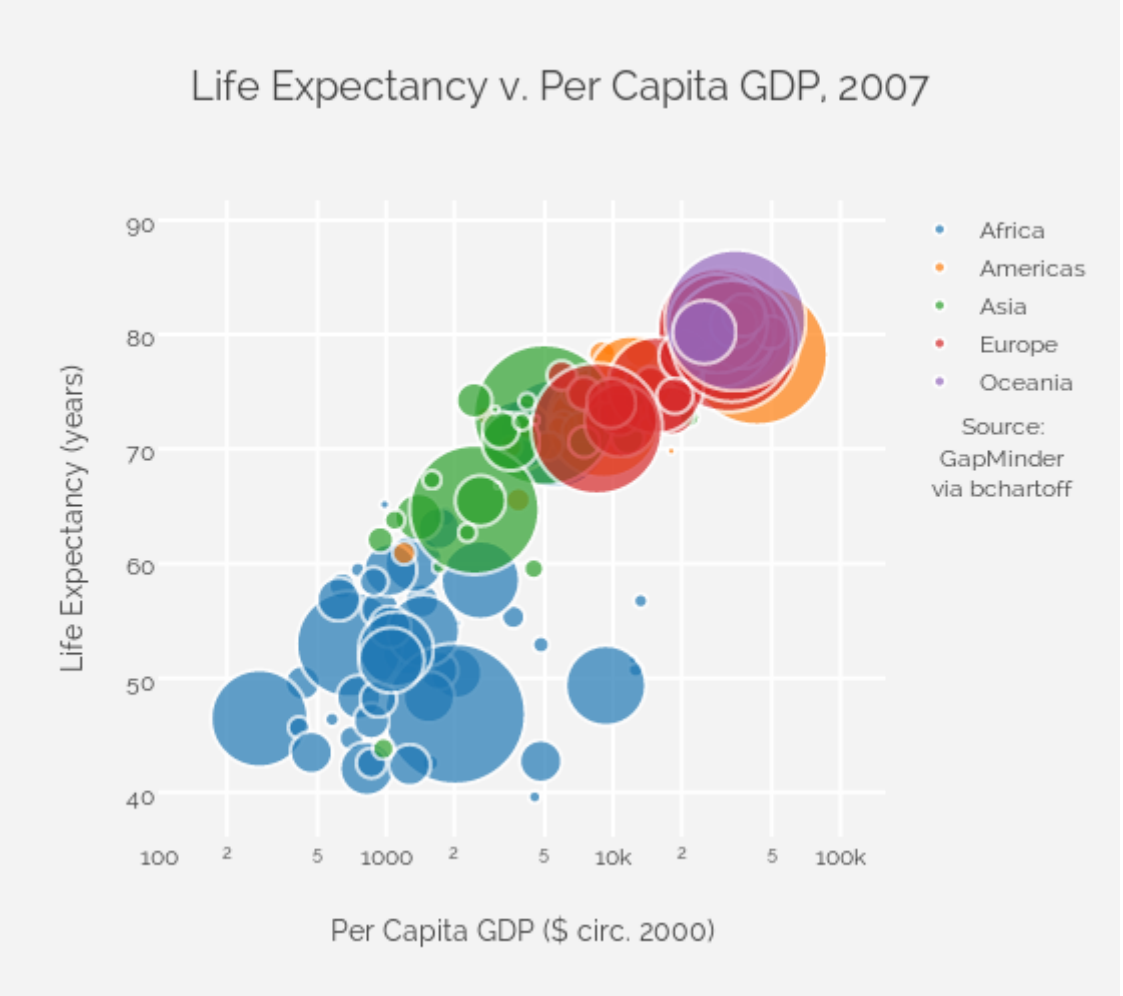
Solution: smoothed **densities** colour representation



Scatterplot variations

Bubble scatterplot

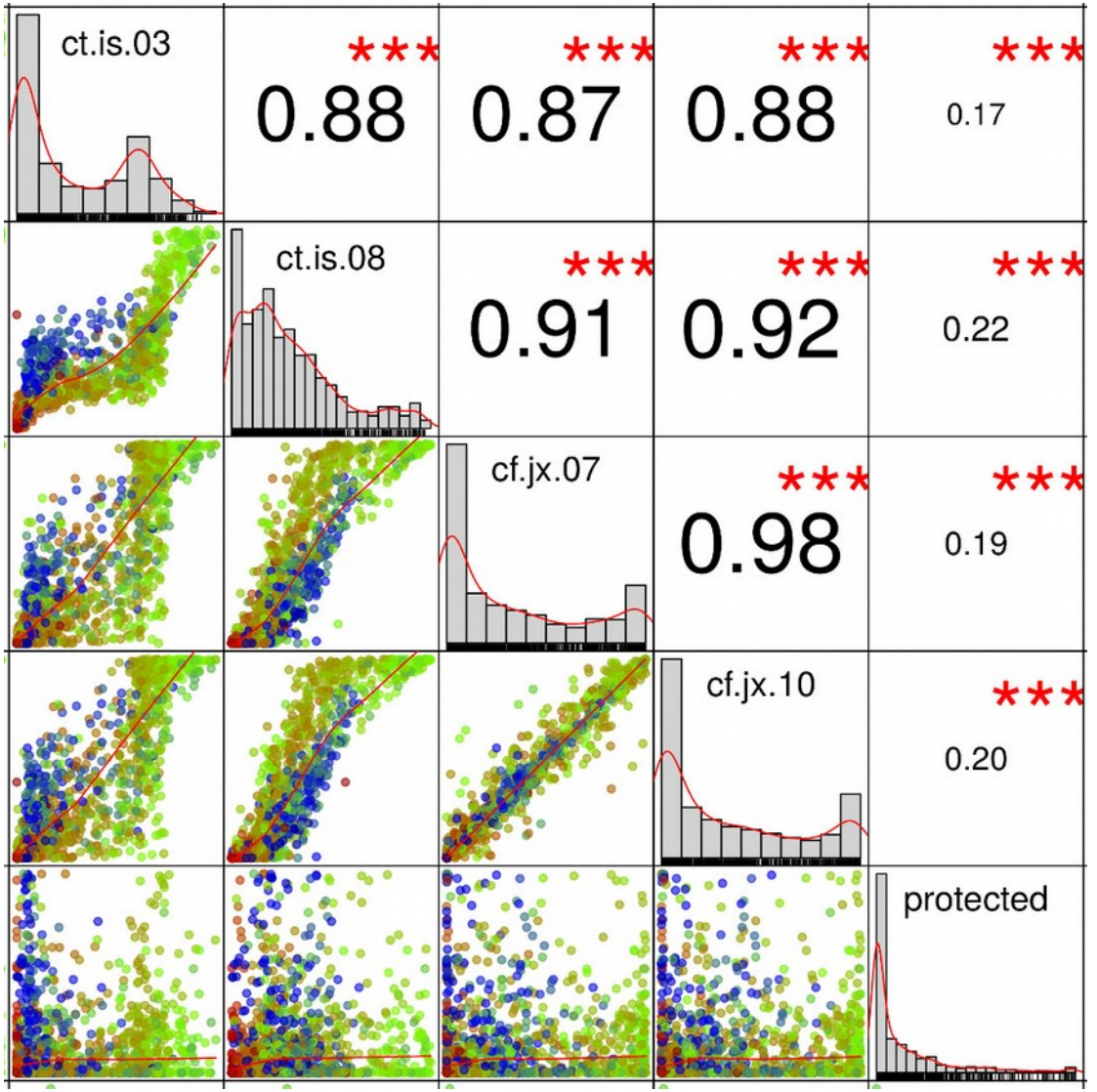
It adds a 3rd dimension (but only for small datasets)



From plot.ly

Scatterplot variations

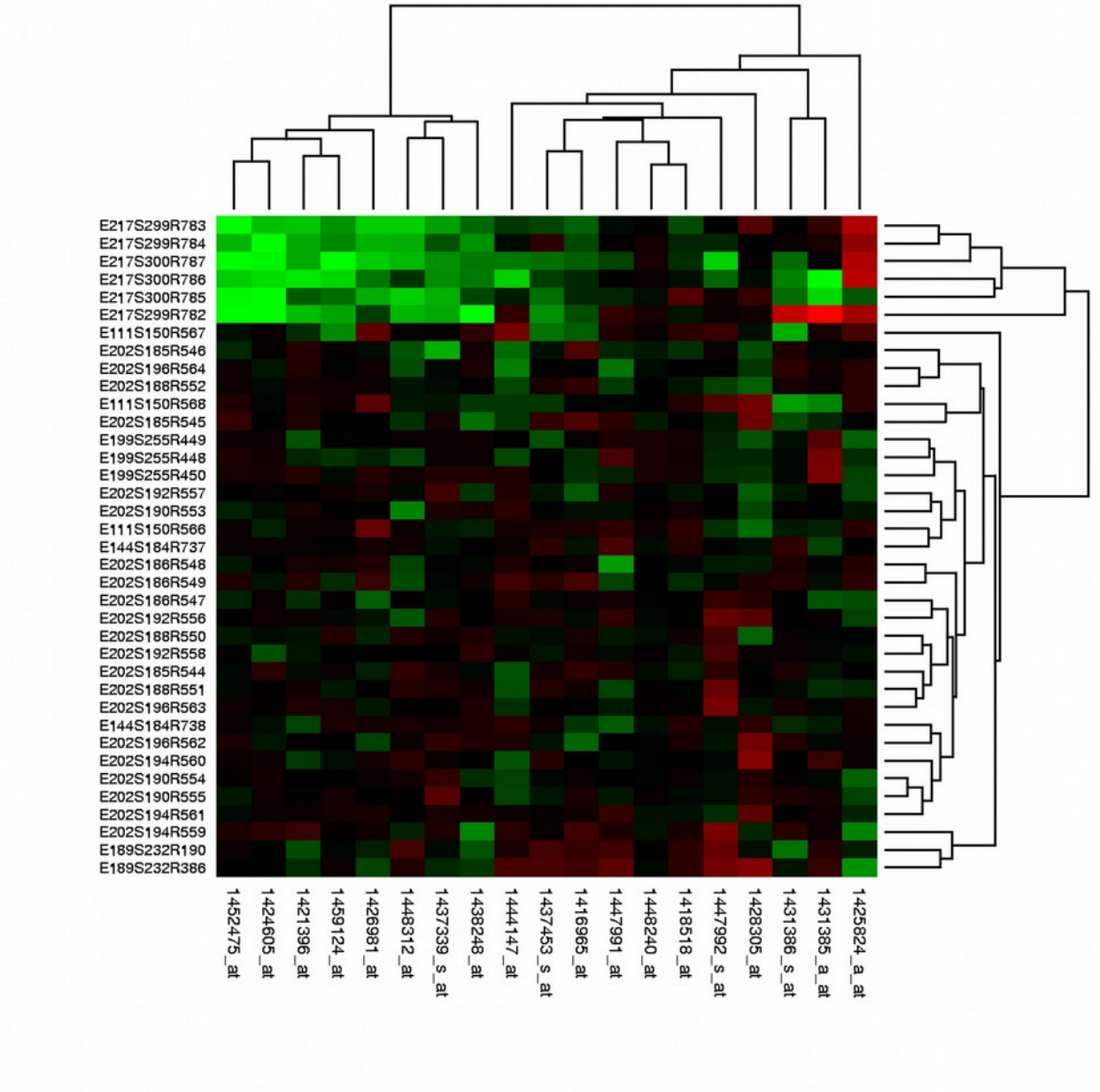
Scatterplot matrix
(correlogram)
Useful to explore
bivariate associations
in a large dataset



*Built using **corrgram** package for R*

Heatmap – relationship

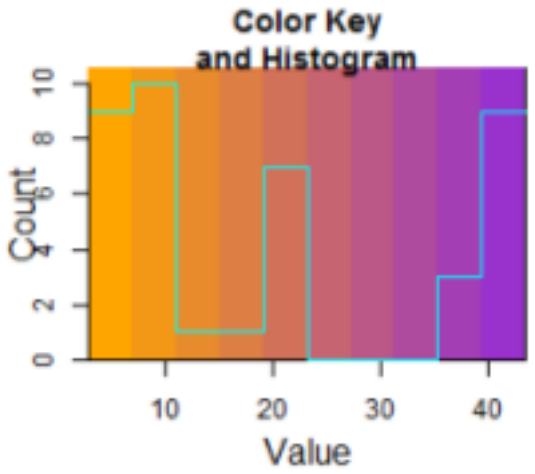
- Shows more complex relationships, e.g. many conditions
- *Steps:* normalisation, clustering
- *Representation:* colouring, filtering

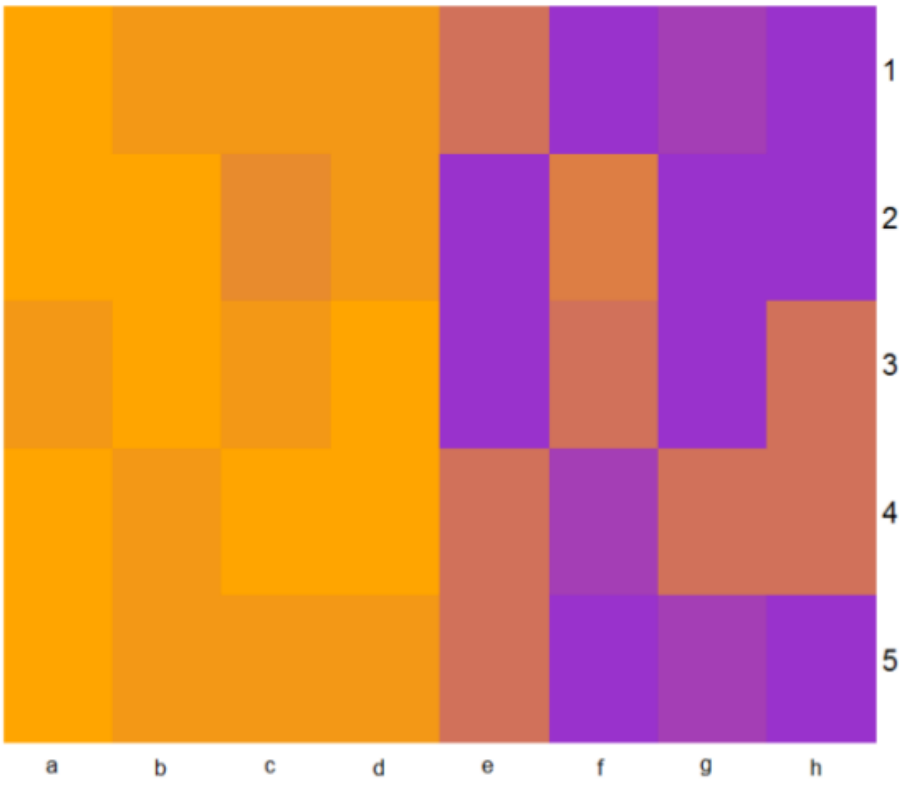


Heatmap

A heatmap is basically
a table that has colours
in place of numbers

	a	b	c	d	e	f	g	h
1	3.7	10.8	8.4	10.4	19.5	40.6	39.0	40.1
2	6.9	4.7	11.7	10.7	40.8	18.7	39.9	40.4
3	9.9	6.2	9.7	4.0	43.4	19.9	39.9	20.3
4	5.6	7.8	5.2	6.0	19.8	39.2	20.5	20.0
5	3.0	8.9	9.3	8.7	20.7	41.2	38.6	39.8

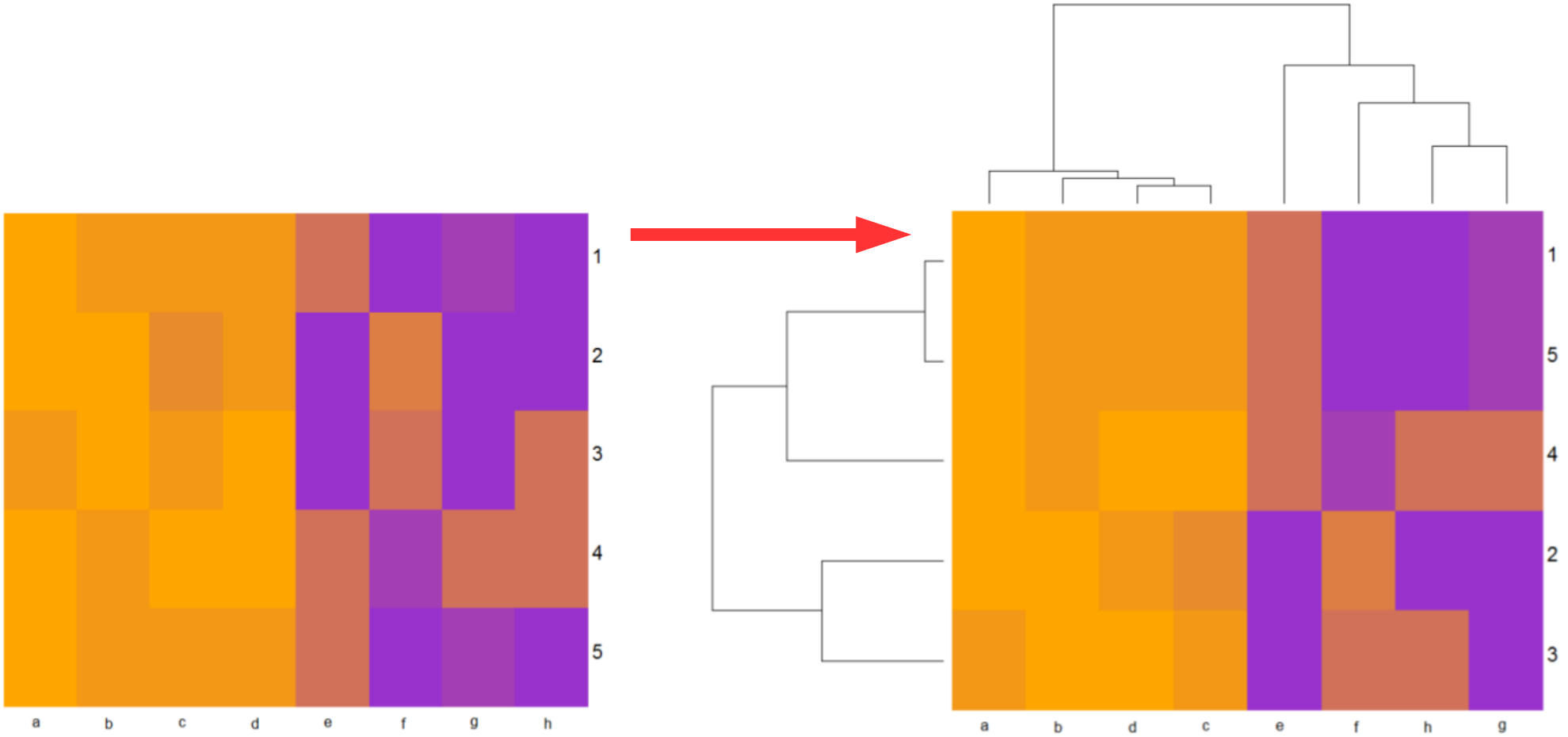




Babraham Bioinformatics

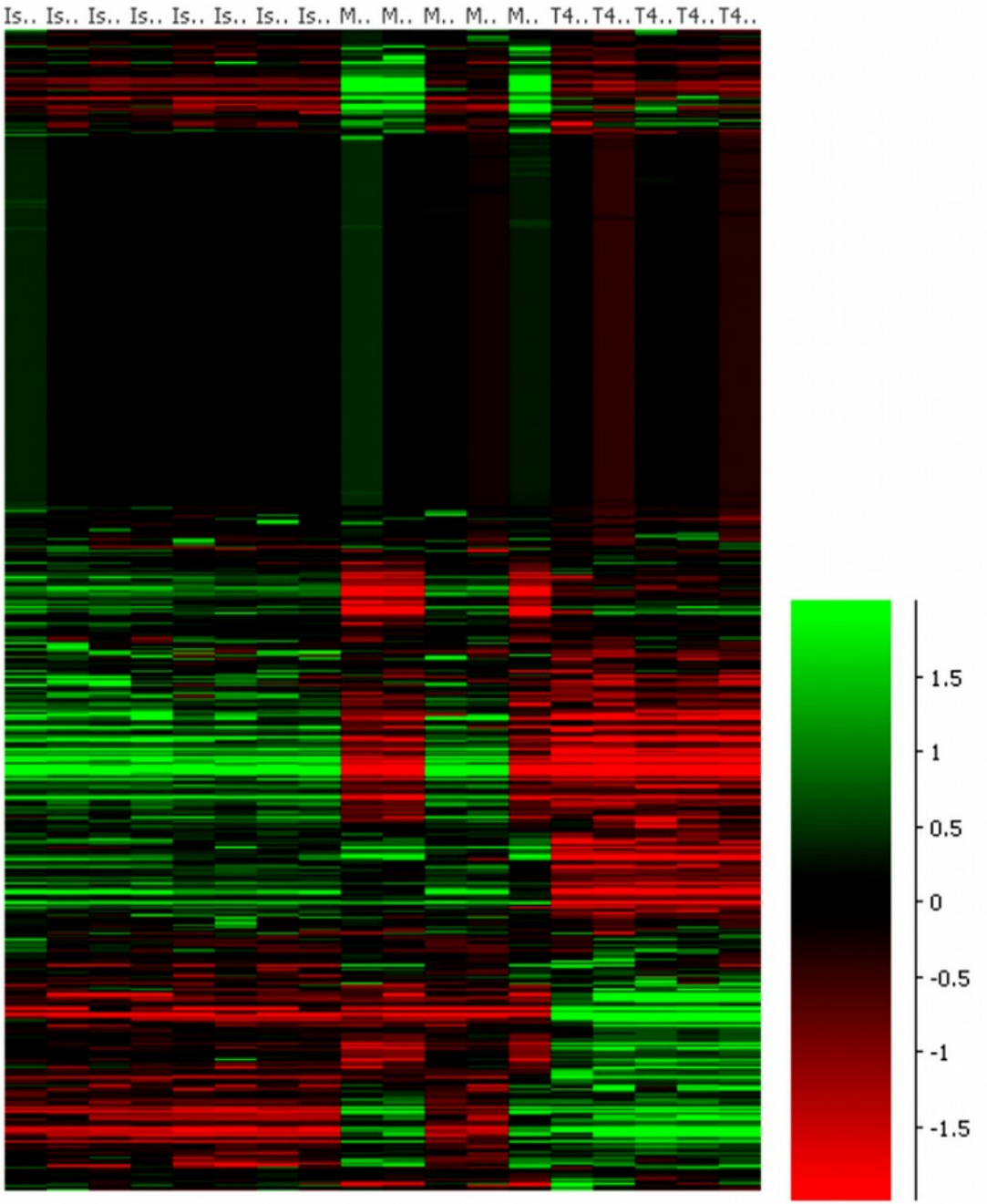
Heatmap

Colour scheme for grouping: **Clustering** (done usually via Euclidean distances –differences between values)



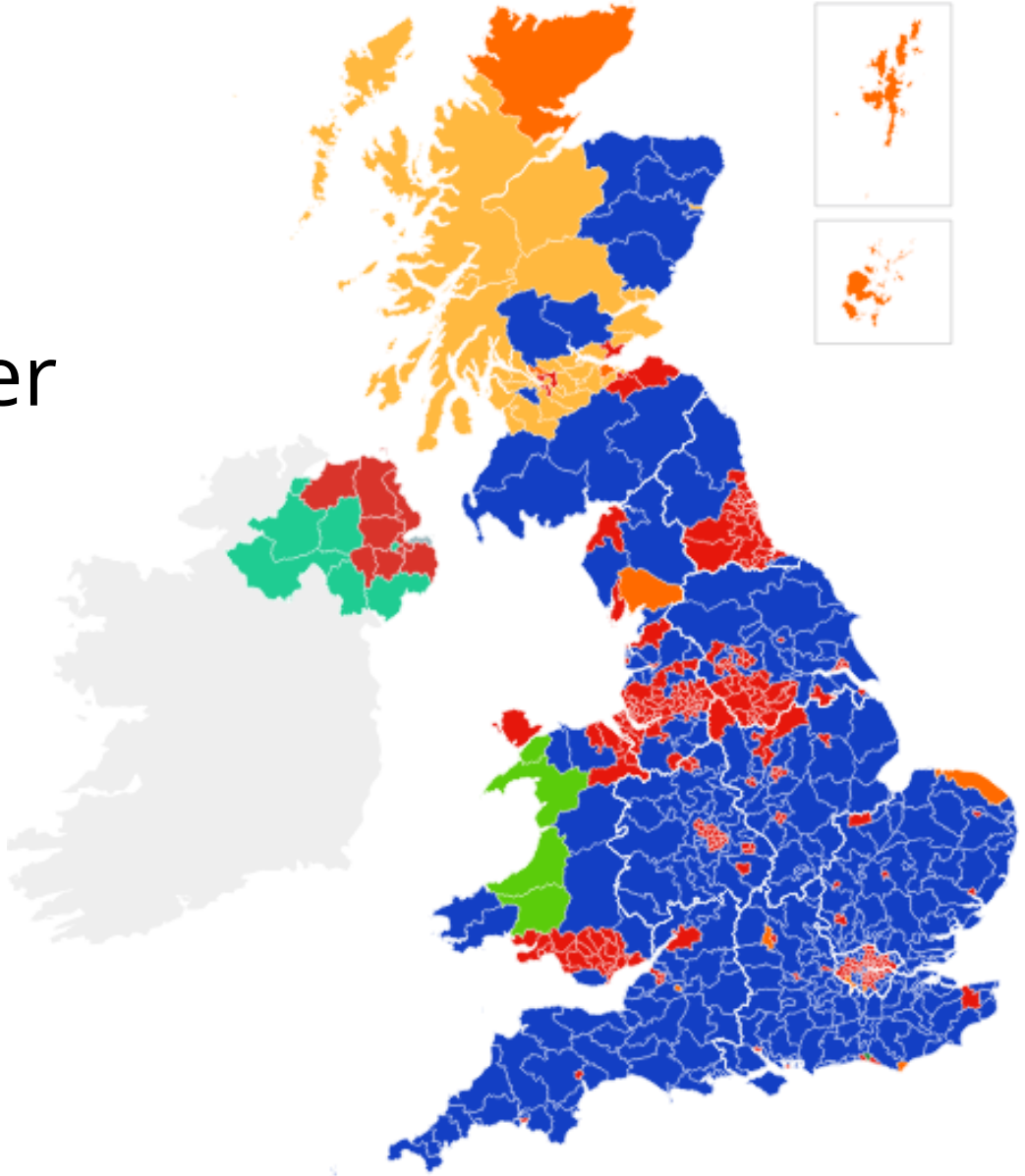
Heatmap

- Heatmaps are great but:
  - Careful with clustering
  - Plot data that are changing
- Remove unchanging points to focus on differences



Maps (a very quick look)

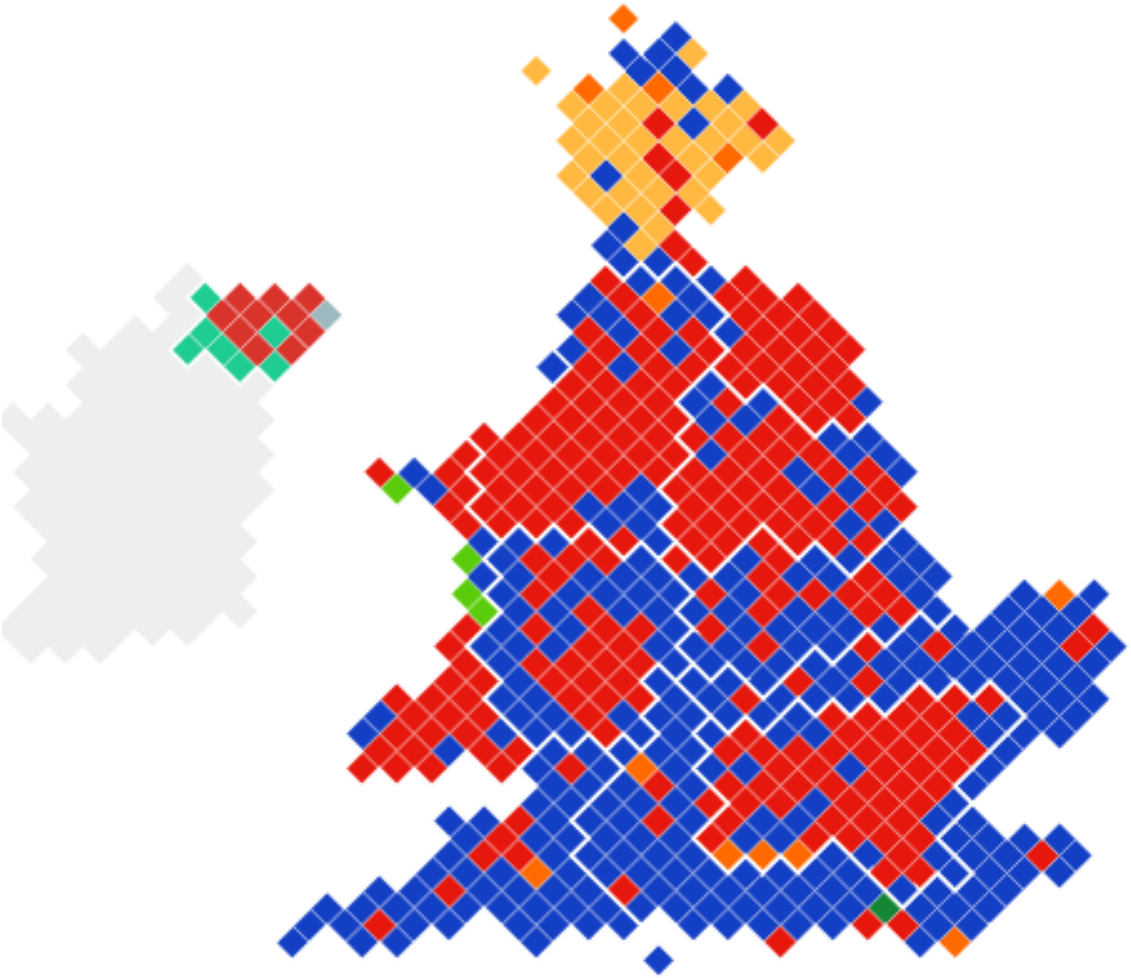
Information shown over maps has great communication power



Telegraph

Maps (a very quick look)

But they are also highly prone to distortions and to biasing perceptions

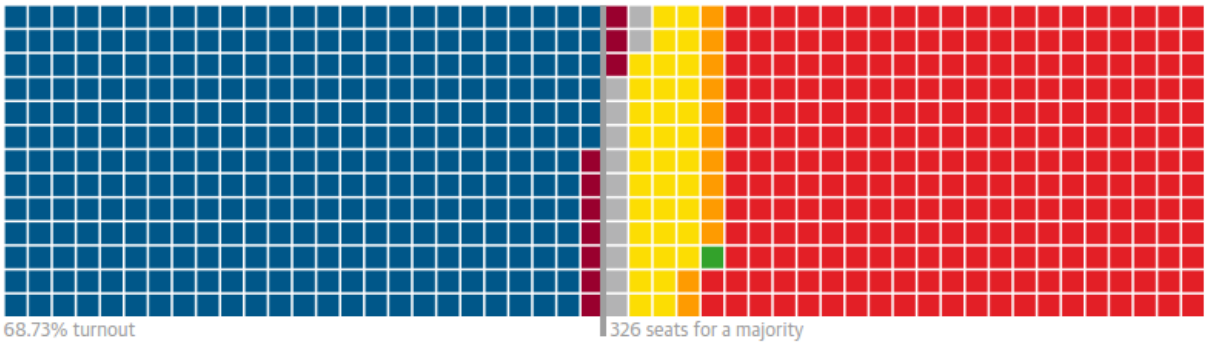


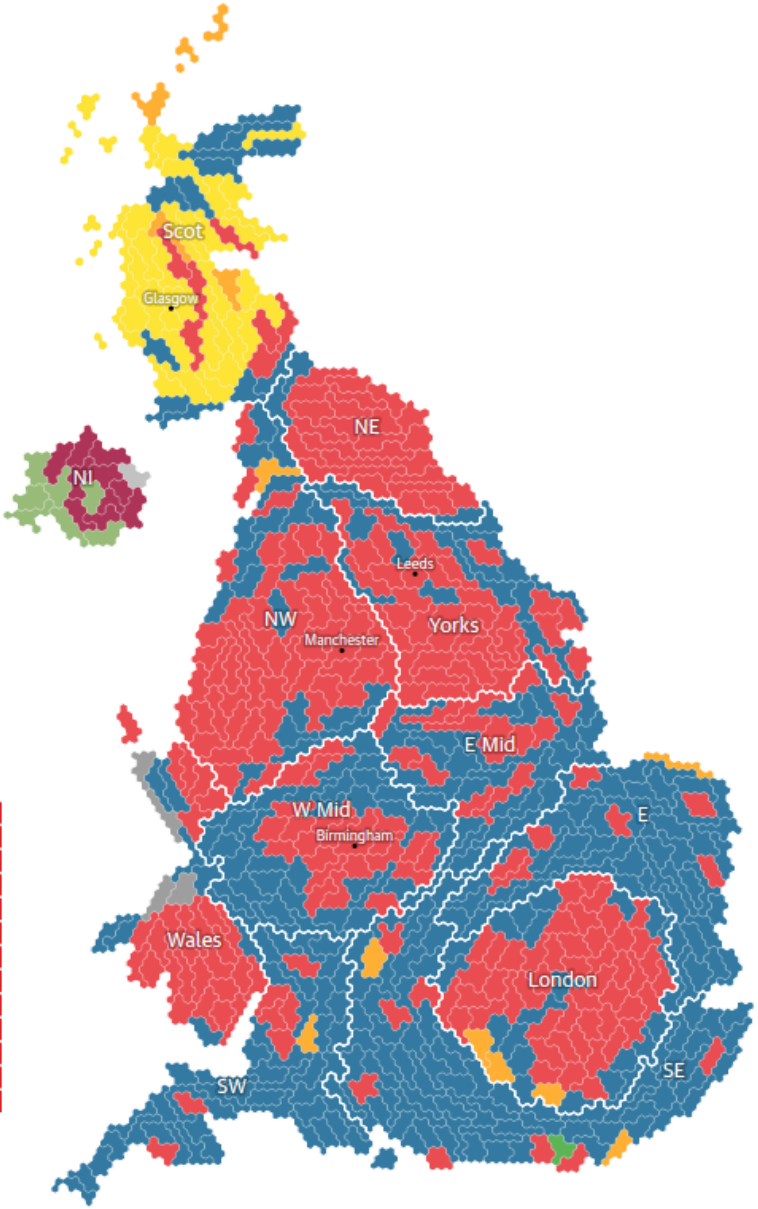
Telegraph

Maps (a very quick look)

What is the message you want to emphasise?

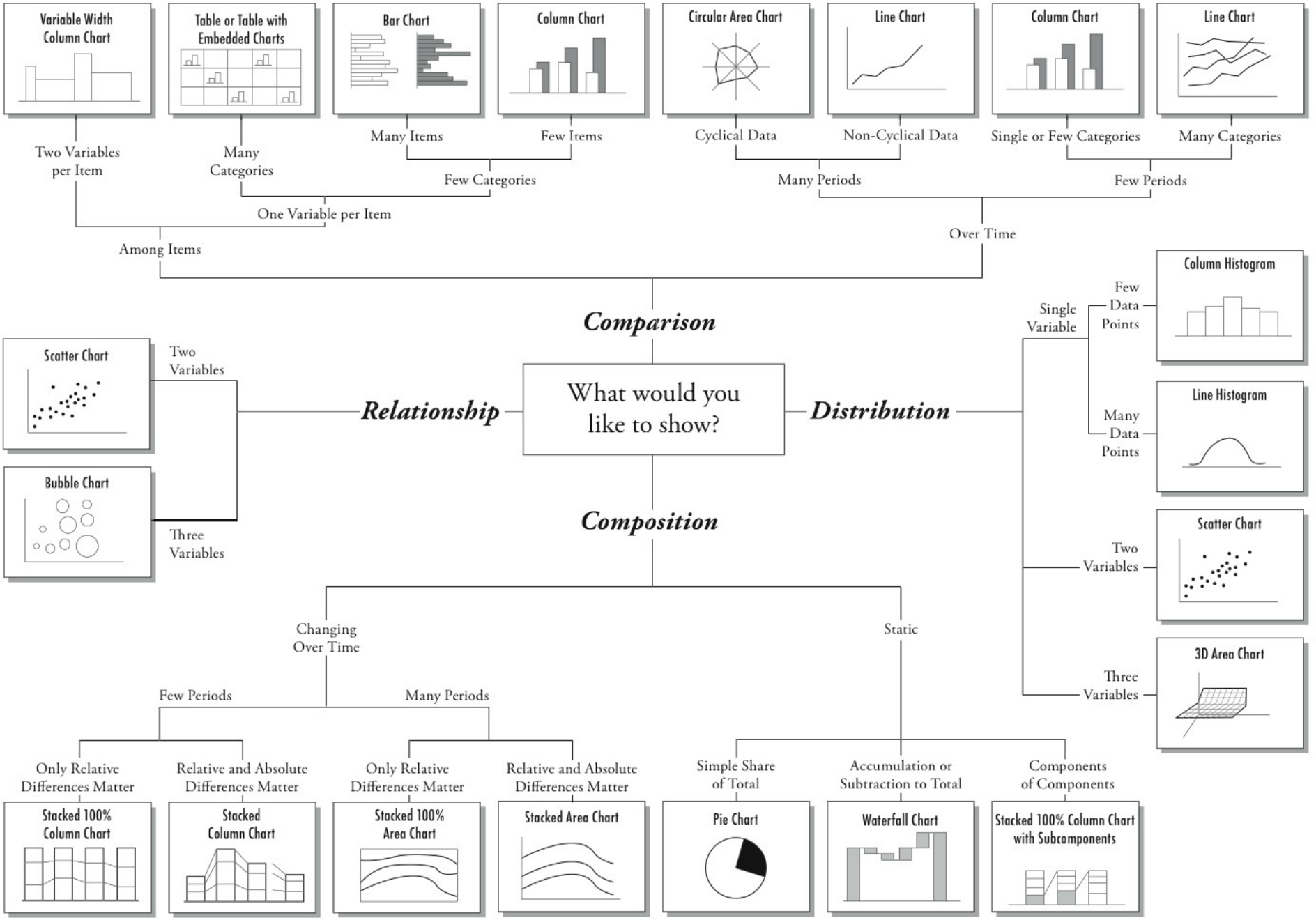
Geographical distribution? →
Proportions? ↓





The Guardian

Chart Suggestions—A Thought-Starter



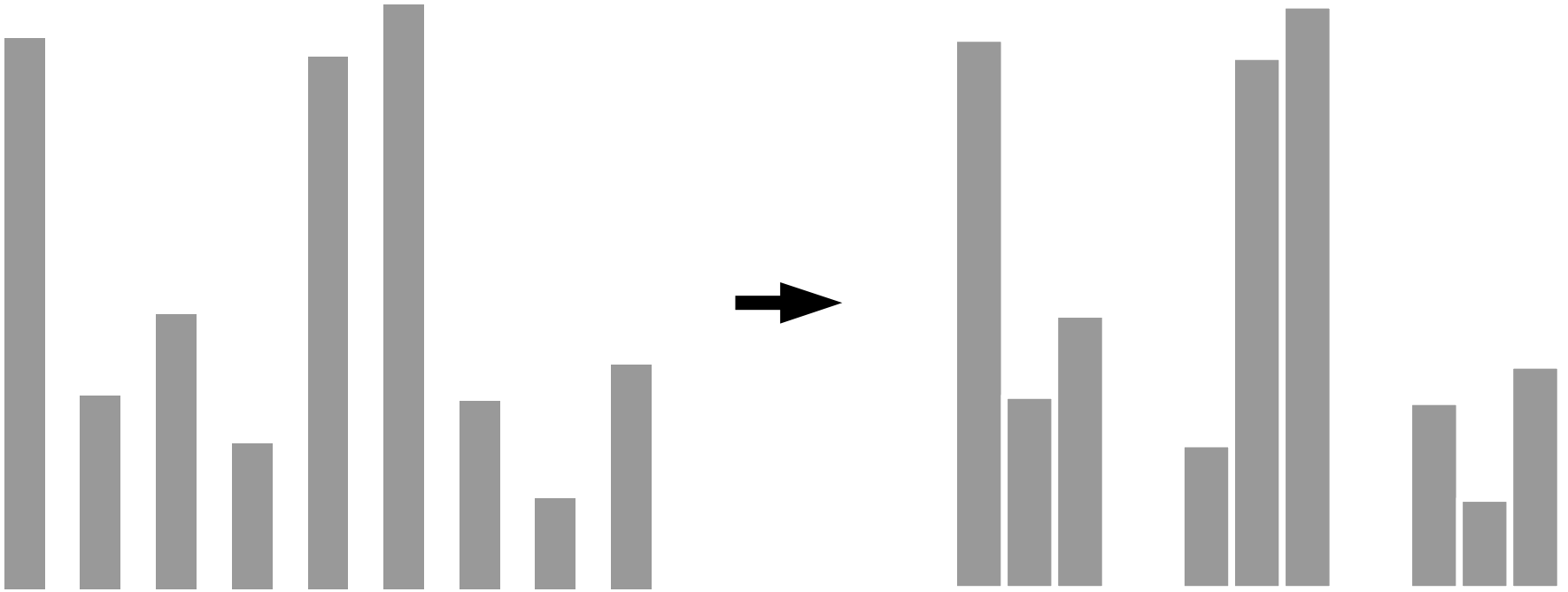
Summary

Plot	*Aim*	*Main R function*
Stripchart	distribution	`stripchart()`
Line chart	relationships	`plot(type="l")`
Bar chart (stacked, norm. stacked)	comparison (and composition)	`barplot()`
Dotchart with CI	comparison	`dotchart()`
Histogram	distribution	`hist()`
Boxplot (violin/ bean)	distribution	`boxplot()`, `vioplot()`
Scatterplot (correlogram)	relationships	`plot(x, y)`, `corrgram package`
Pie chart	composition	`pie()`
Heatmap	relationship	`heatmap()`

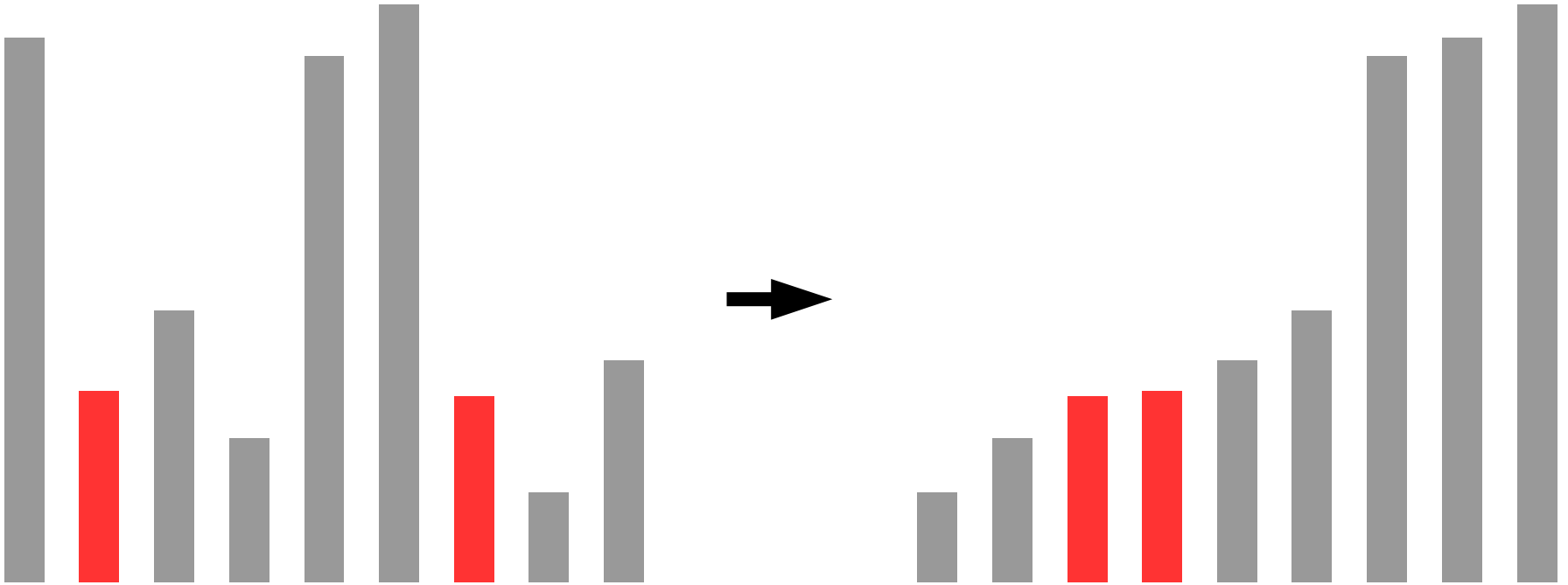
Dealing with complexity

- To focus the viewer's attention onto the main point you want to convey (e.g. on specific subsets of data)
- To require less cognitive load for the viewer to understand the message

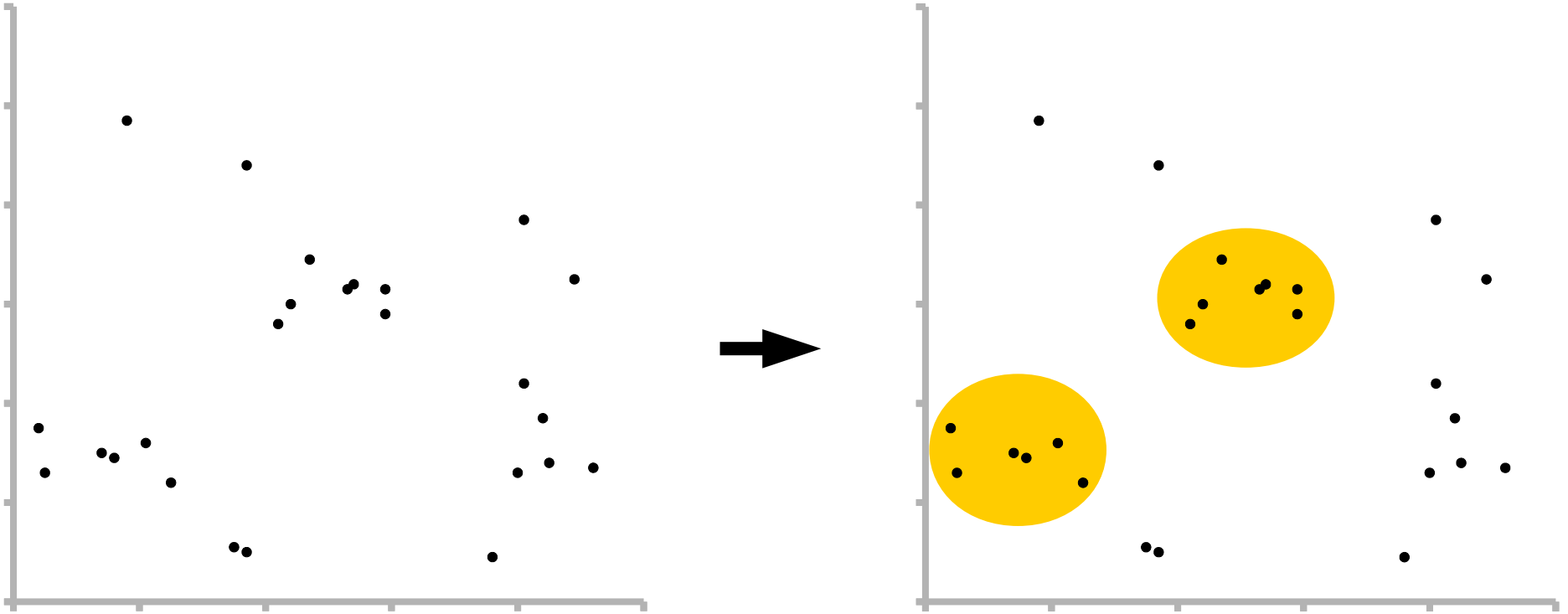
Grouping



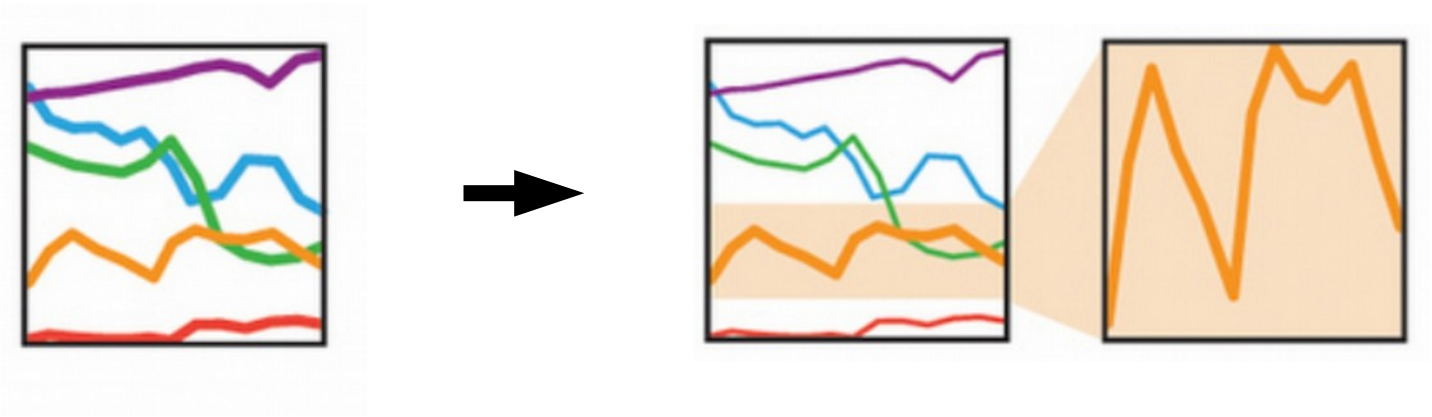
Ordering (only for categories)



Containment

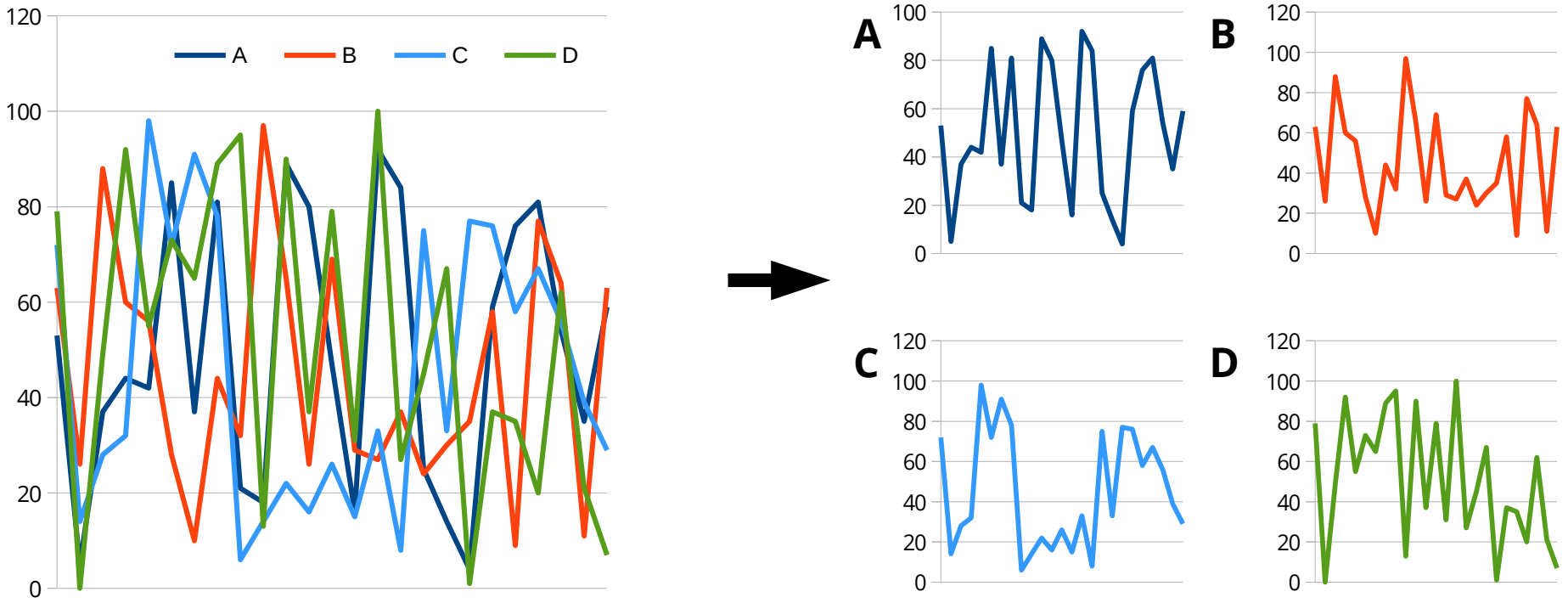


Filter, link, embed

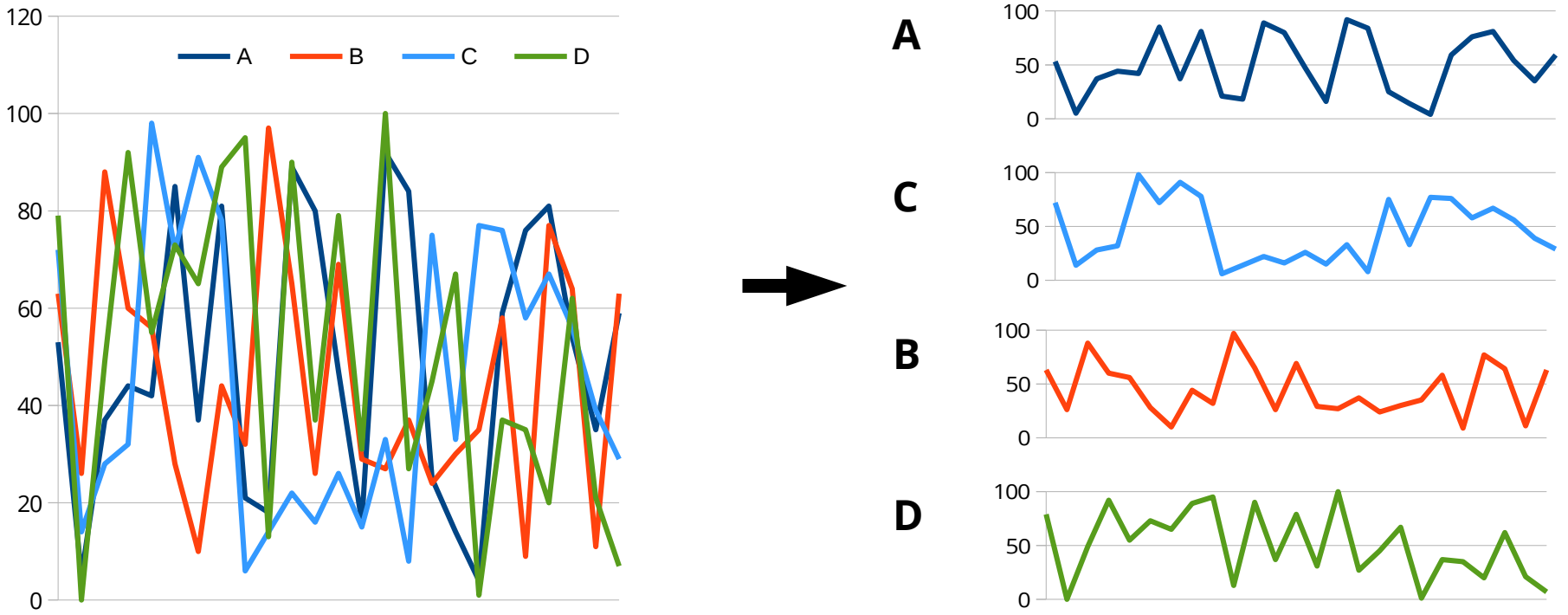


McInerny & Krzywinski 2015

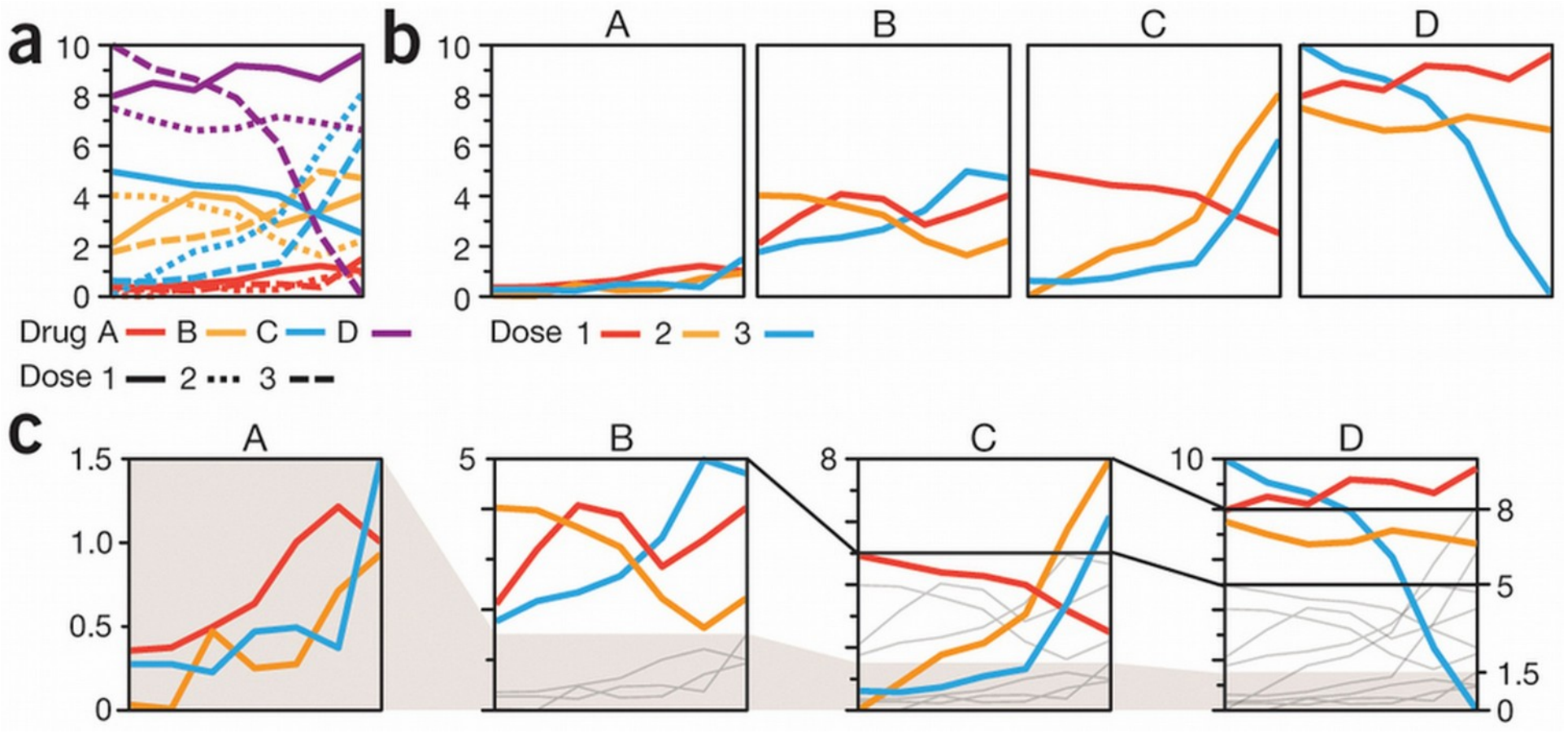
Small multiples



Small multiples



Small multiples



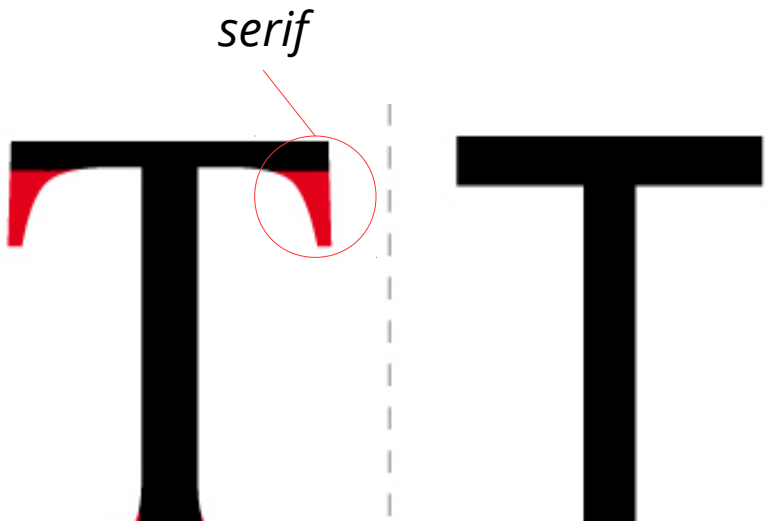
McInerny & Krzywinski 2015

Typography (fonts)

- All the elements need to be labelled
- The essential criteria for choosing fonts is **readability:**
  - **Scalability** (readable at small sizes)
  - **Contrast** with the background
- Fonts convey a personality, mood or attitude (some more than others)

Typography

- **Serif** for large blocks of text, **sans-serif** for titles, labels and annotating figures
  - Sans-serif is easier to read at smaller sizes
- **Sizing**: the size of fonts is given in points, and it's the size of an imaginary block of metal that is used in printing.
  - In practice, the only way to know exactly how well your font will be read is to print it.



with **serif**

sans serif *(without)*

Typography

- **Monospace** is good for code, or for text intended to be aligned from line to line (e.g. pseudo-tables)
  e.g. **m** vs `m` ; **i** vs `i`
- **Casing**:
  - UPPERCASE,
  - lowercase,
  - Sentence case,
  - Title Case.
- Check the journal guidelines for font types

```
Monospace font keeps
the alignments tidy.
(this is monospace!)
```

Monospace font keeps
the alignments tidy.
(not monospace font)

Each of the lines above has 20 characters.

Typography: **Guidelines**

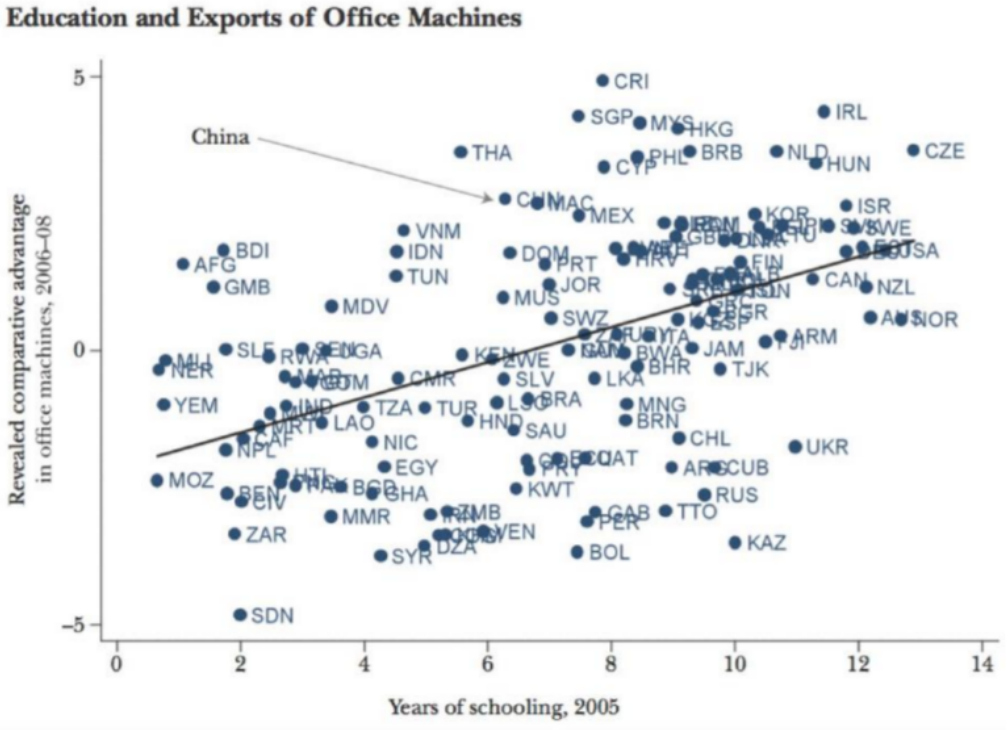
✔

✘

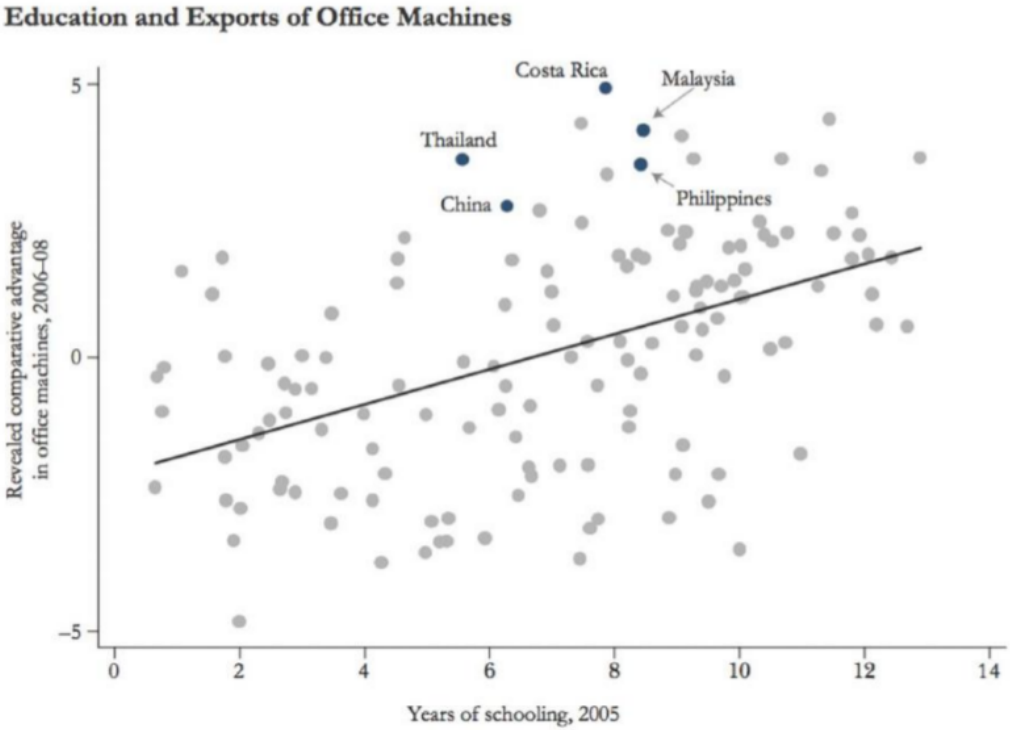
Avoid **aspect-ratio distortions**: changing font height or size.

- The same applies to images and circular objects
- Scale axes using comparable units

Typography: **Guidelines**



Minimise text; keep it simple



Typography: **Typesetting**

- Is the arrangement (spacing) of characters in words, lines or paragraphs
  - **Tracking:** space between characters
  - **Leading:** line height
  - **Paragraph alignment:** left, justified, etc.
- Important considerations where figures have many annotations, and in axis and figure titles.

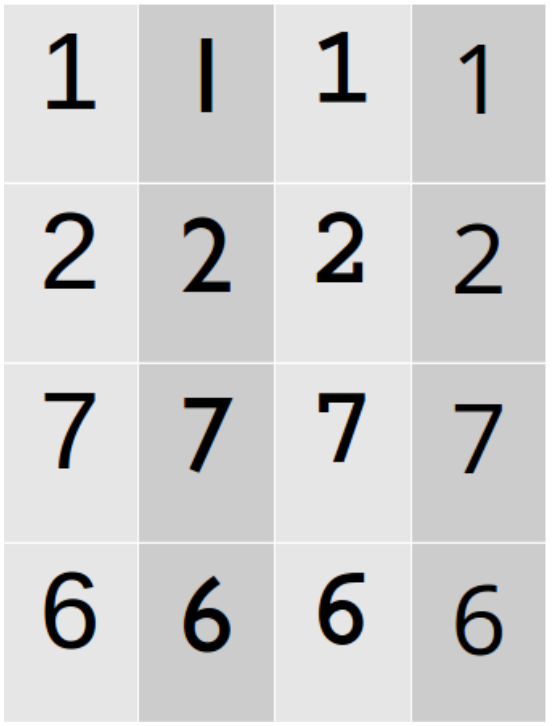
Typography: **Guidelines**

- **Avoid colour** in text, particularly in figures (to maximise contrast)
- **Do not tilt** text, always horizontal (or vertical)
- Check **scalability**: text should be readable after resizing

✔ Typeset in blocks of text that are **solid shapes**

✘ Avoid typeset in blocks of text that are not **solid shapes**

Typography:
Heed the numbers in your font



- Each font has different styles of numbers
- Make sure that the font you choose distinguishes them well (e.g. I in *Gill Sans*) and is legible at small sizes

Typography:
Think your words carefully

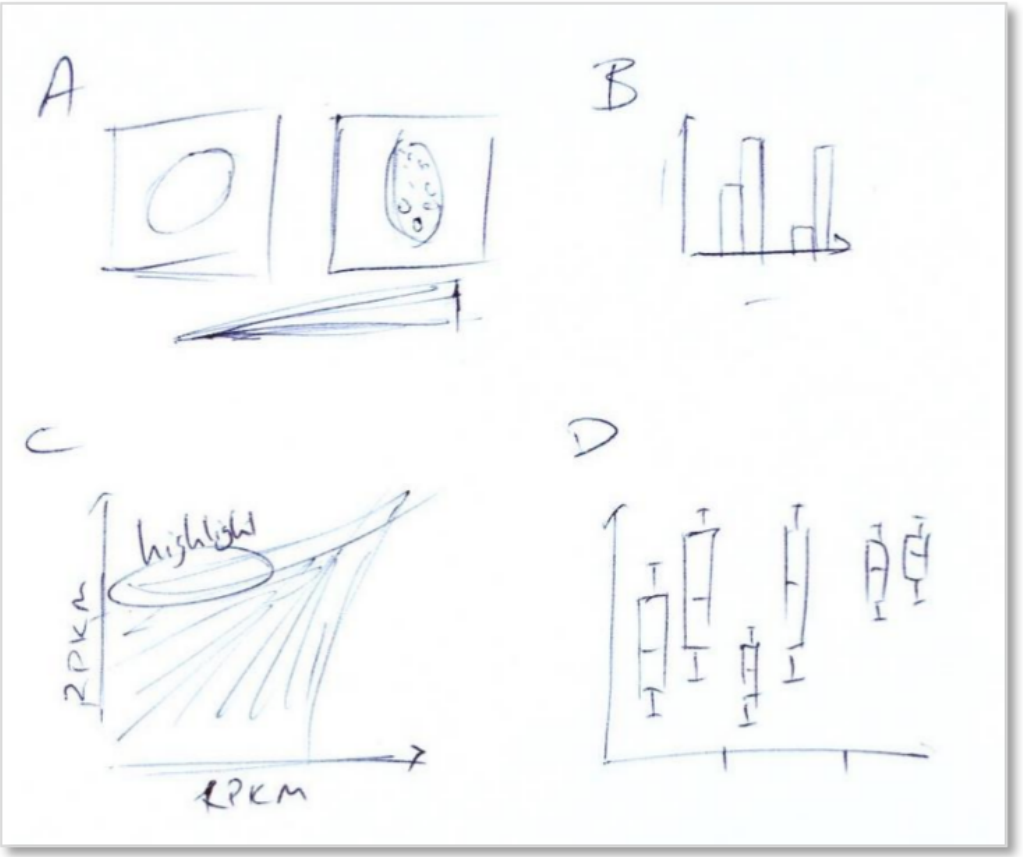
- Avoid wordiness… it’s a figure!
- Choose words that “precisely convey what you mean”
- Avoid contractions and spell out whenever possible

Composition and layout

- Draft
- Grid and alignments
- Balance and hierarchy

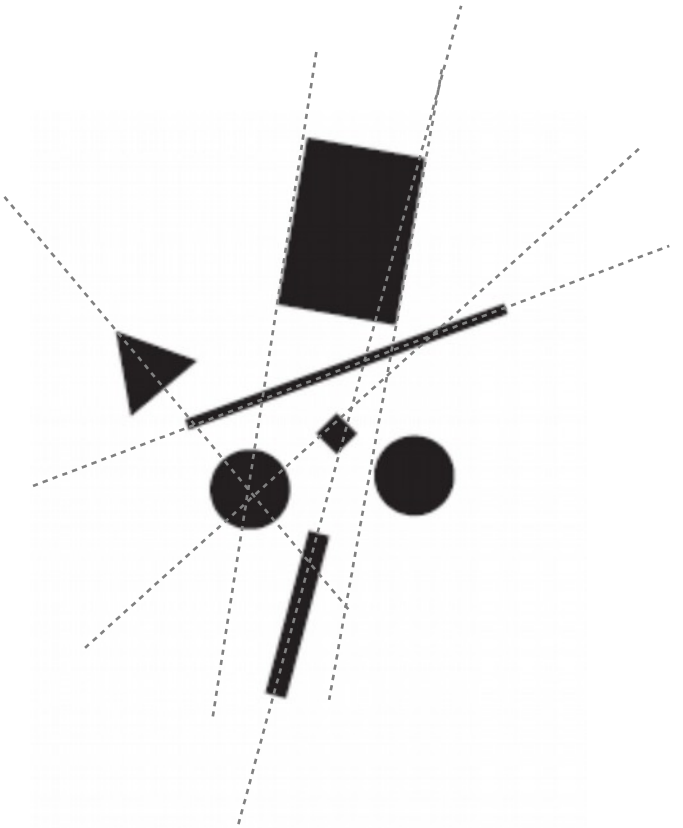
Composition and layout

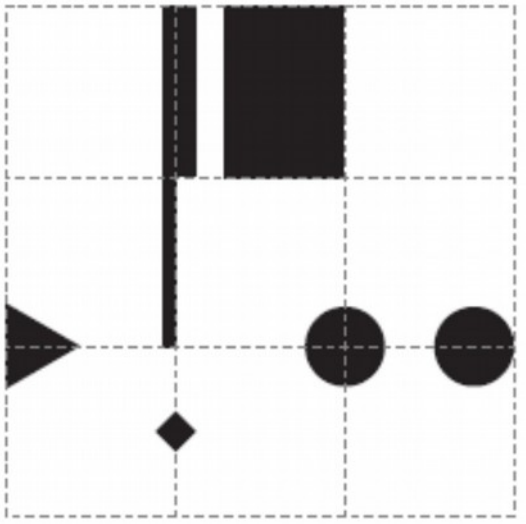
- Have an idea of what your final figure will look like
  - What message are you trying to convey?
  - How does each figure contribute to that message?
  - Identify what is essential (Supporting Information)
- Outlines can reduce time spent moving or resizing images



Grids

- Grids are the invisible structure behind a composition that makes it look balanced
- Every alignment (of a box, column, text line and text margin) creates a **visual line** in the grid
- Conversely, a composition where elements are aligned to a grid creates a sense of balance





Grids can help to organize the spaces around and in-between elements. *Rolandi et al 2011*

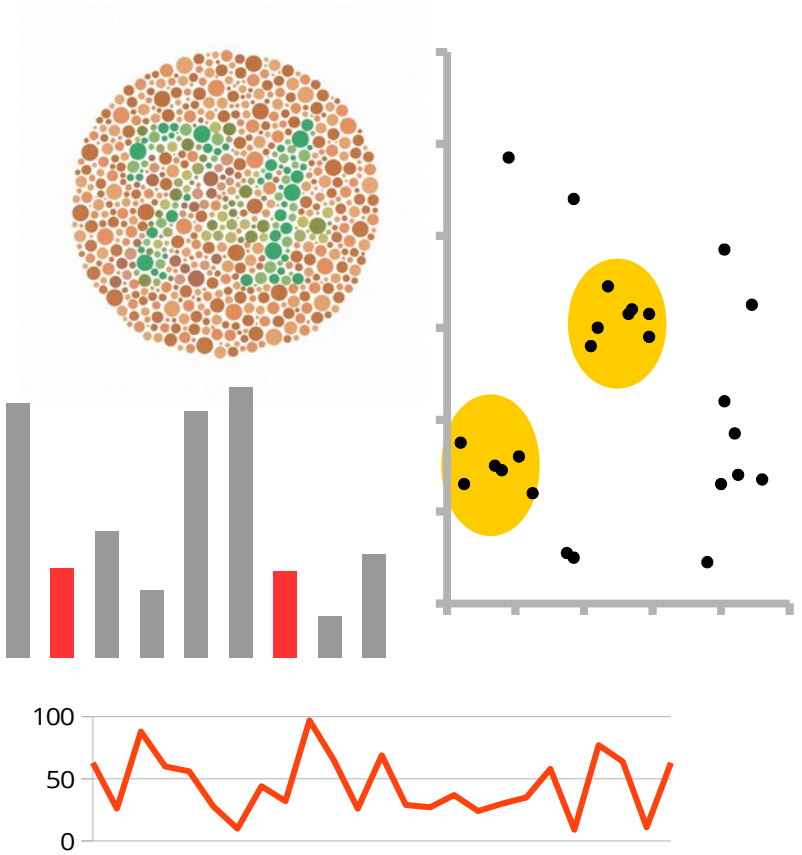
Alignments

Alignments

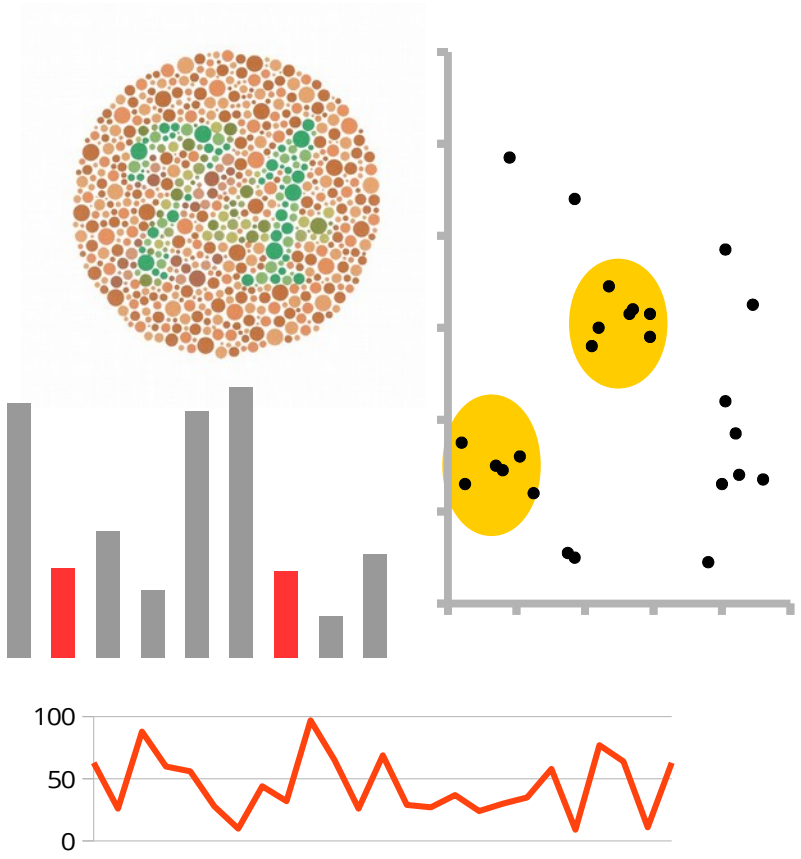
Use tools to align objects, don’t do it by eye!

Most programmes have tools for automatic alignment and to distribute objects with equal space.

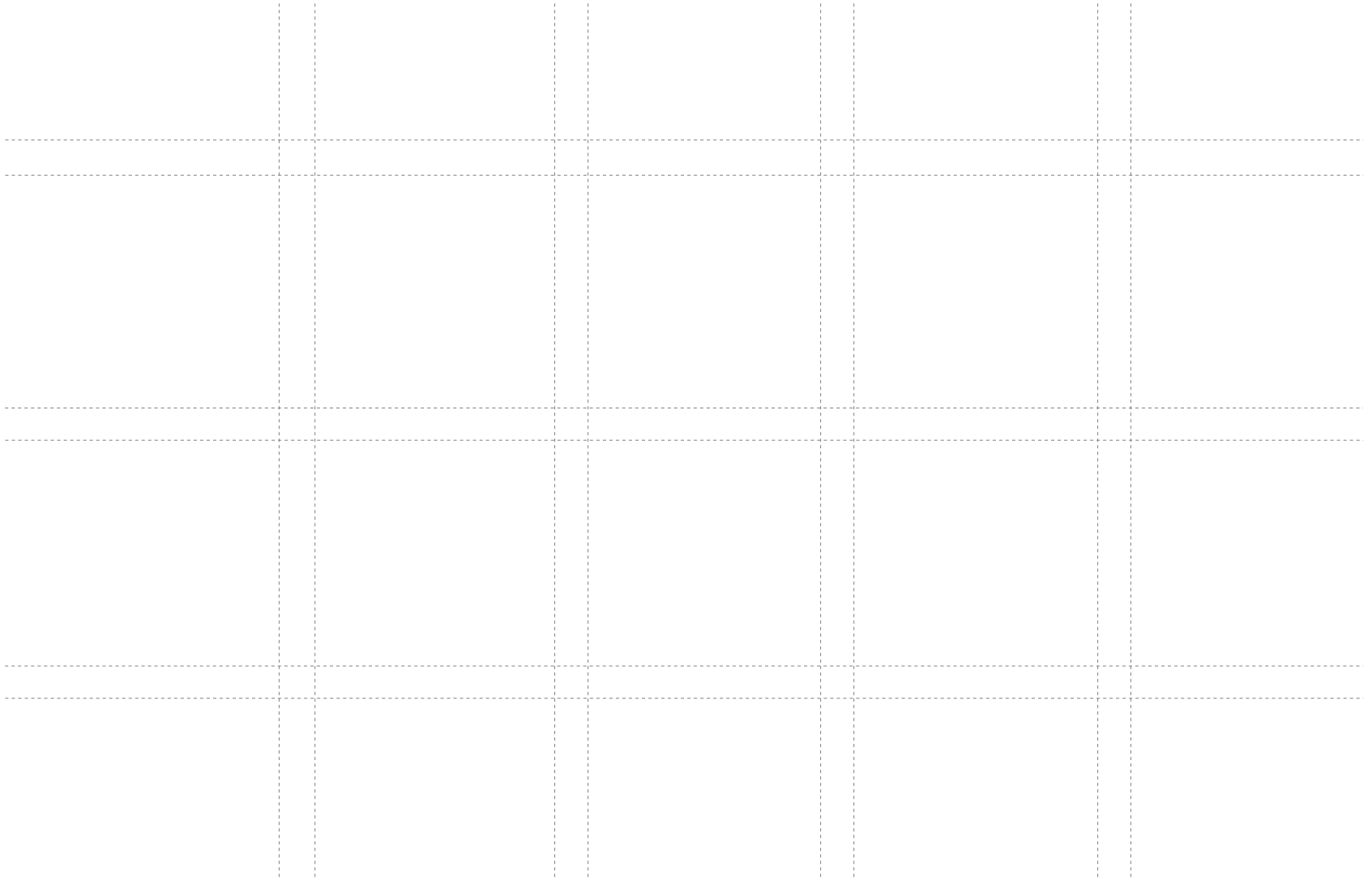
Using grids



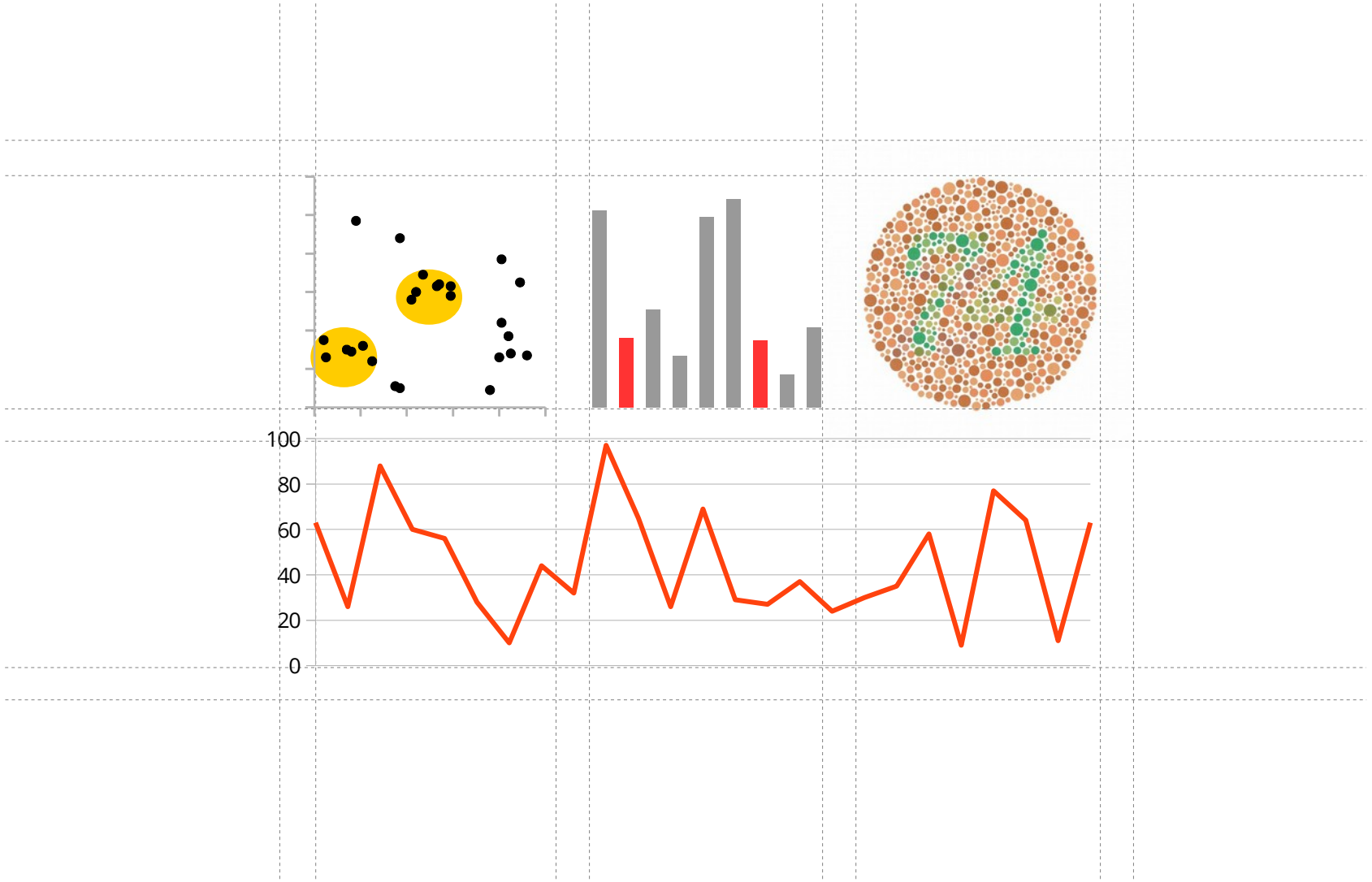
Using grids



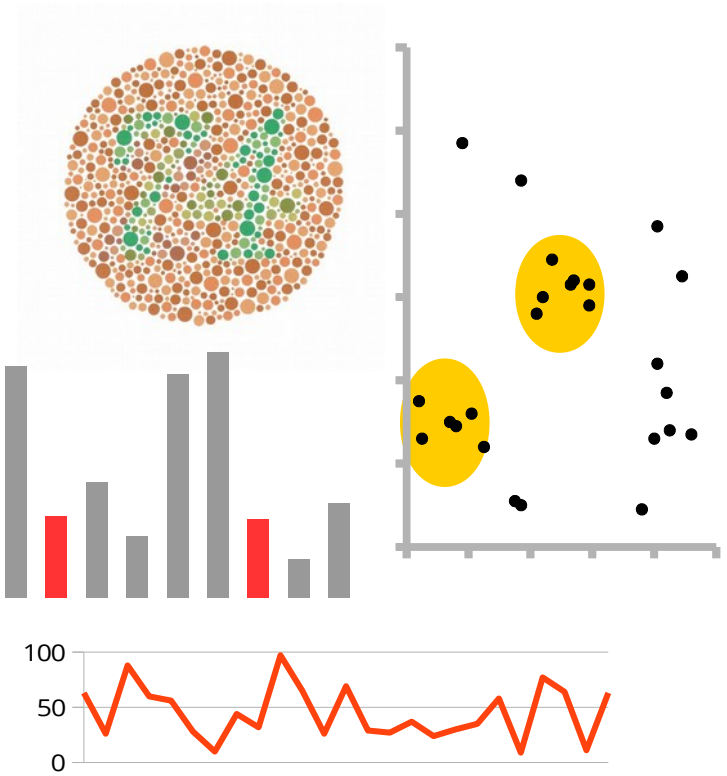
Using grids

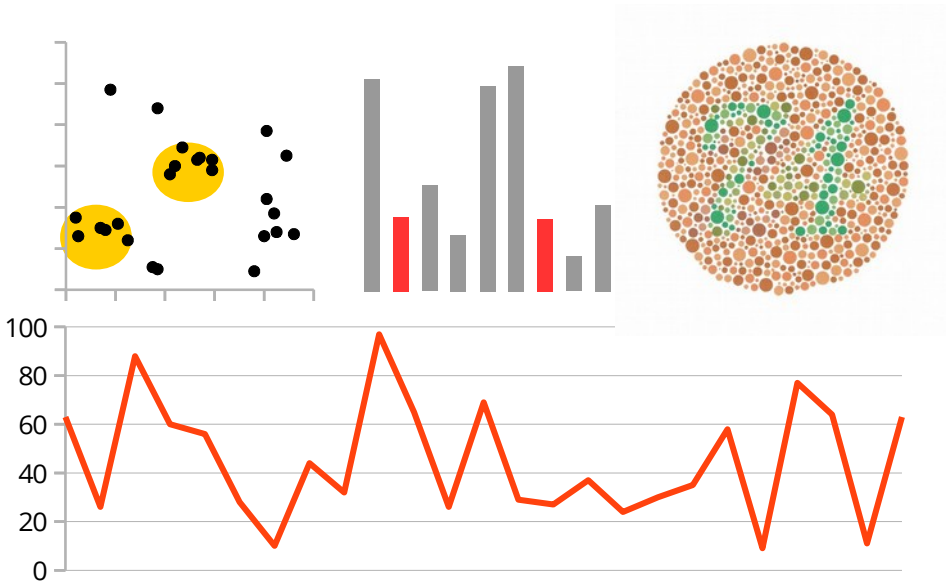


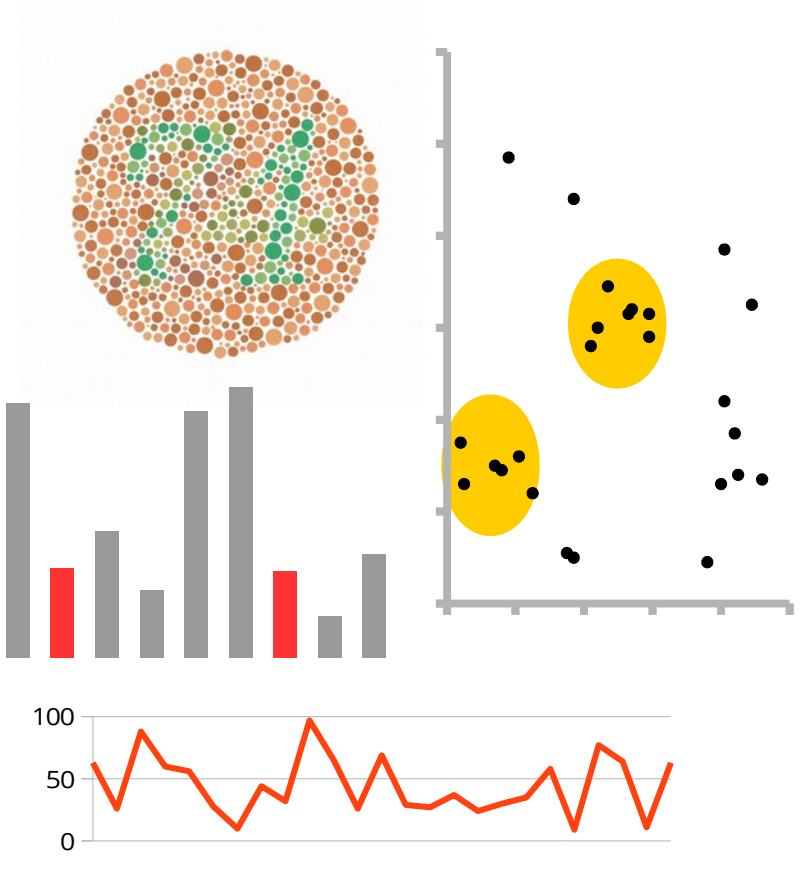
Using grids



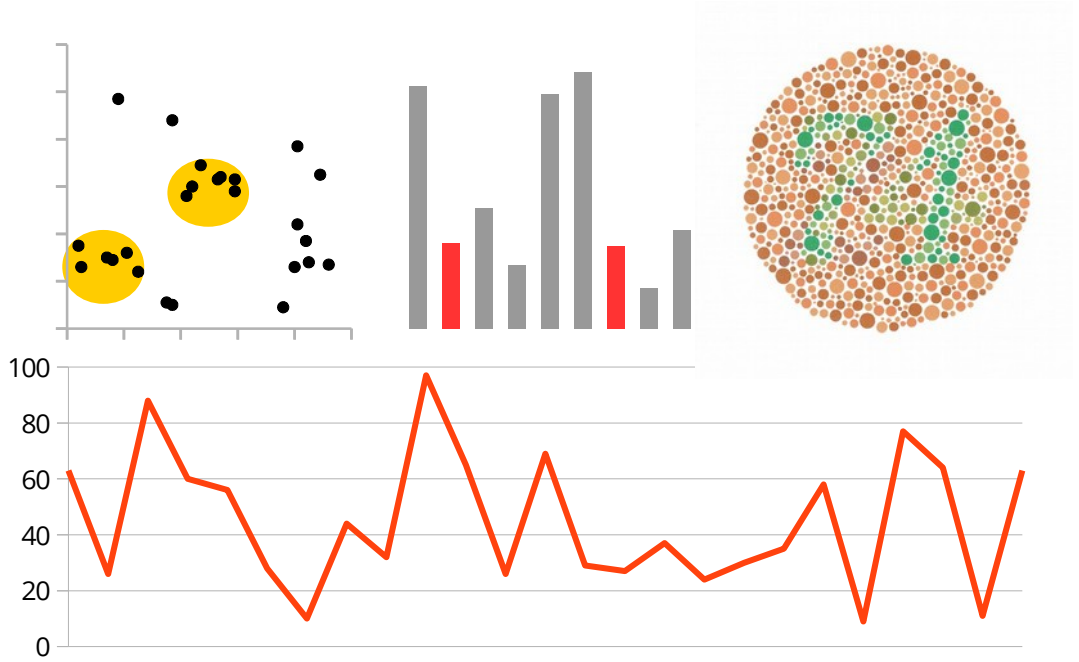
Using grids






100
50
0

Using grids



Visual balance and hierarchy

The composition of a graphic object and the **emphasis** on each element will determine what is the **hierarchy between elements**, and how the eye will **flow** and where it will **focus**

Keep a balance between **white space**, text and figures

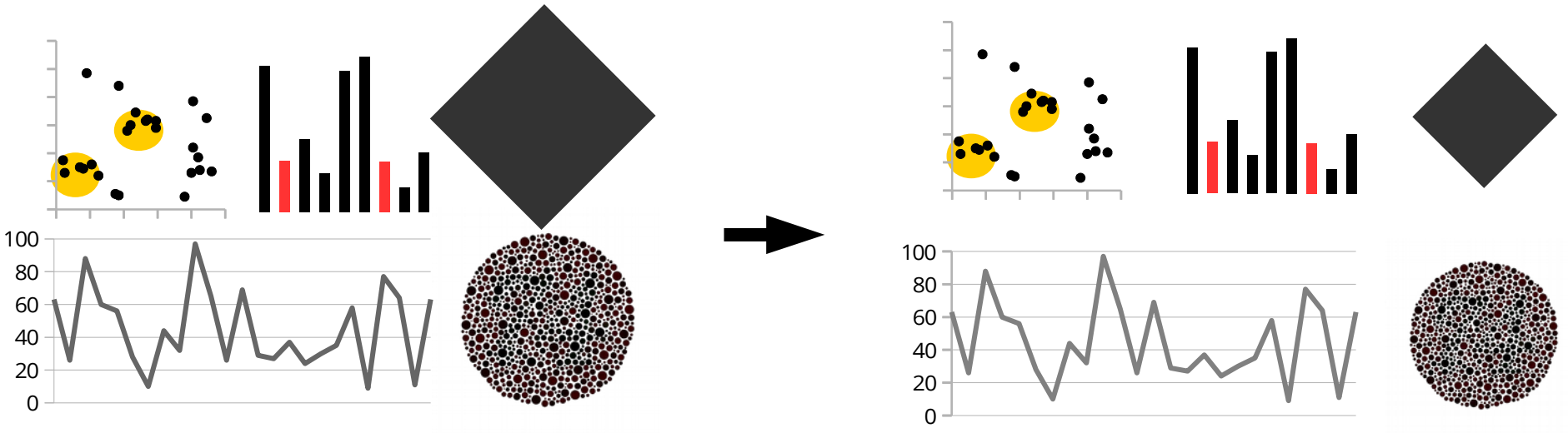
Visual weight/ emphasis:

- How much an object on the page attracts and retains the attention of your viewer
- Depends on size, colour, position, etc.
- Should match the relevance of the information

These are some questions you can make to assess visual balance and flow: *Is there a clear (and justified) hierarchy or arrangement between elements? Can adjustments be made to make more relevant connections? Does the place feel cluttered/ scattered?* (Krause, 2004)

Visual weight and balance

Visual weight: A measure of how much an object on the page attracts and retains the attention of your viewer



In the left figure, the black diamond and, to a lesser extent, the circle stand out (*is this our intention?*).

There is also little separation between the charts, which makes the figure look cluttered.

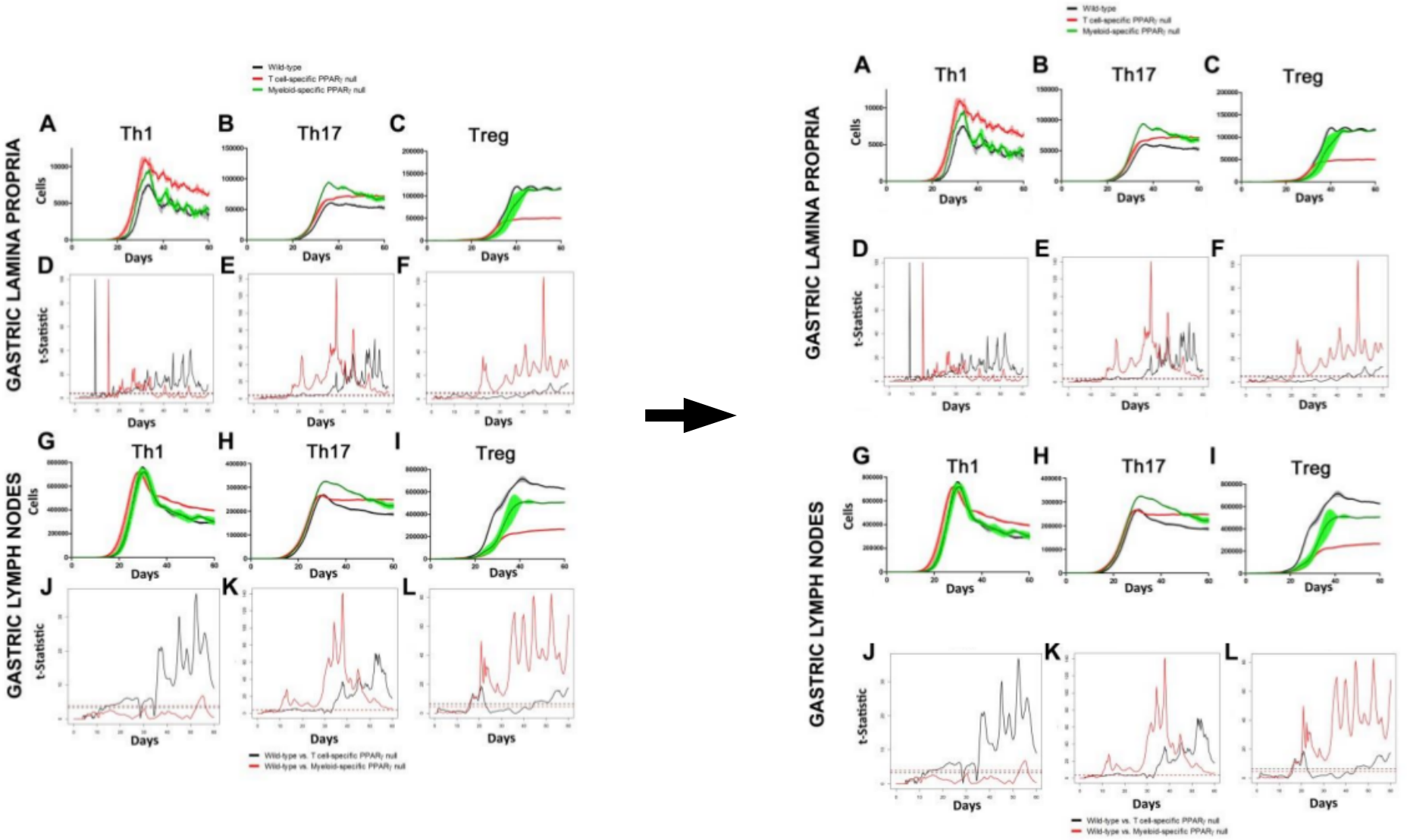

YOU FOCUSED ON THIS FIRST
YOU FOCUSED ON THIS SECOND

Visual weight and balance

Visual weight: A measure of how much an object on the page attracts and retains the attention of your viewer

Can help to guide the viewers eye through the figure

Use of white space



General tips

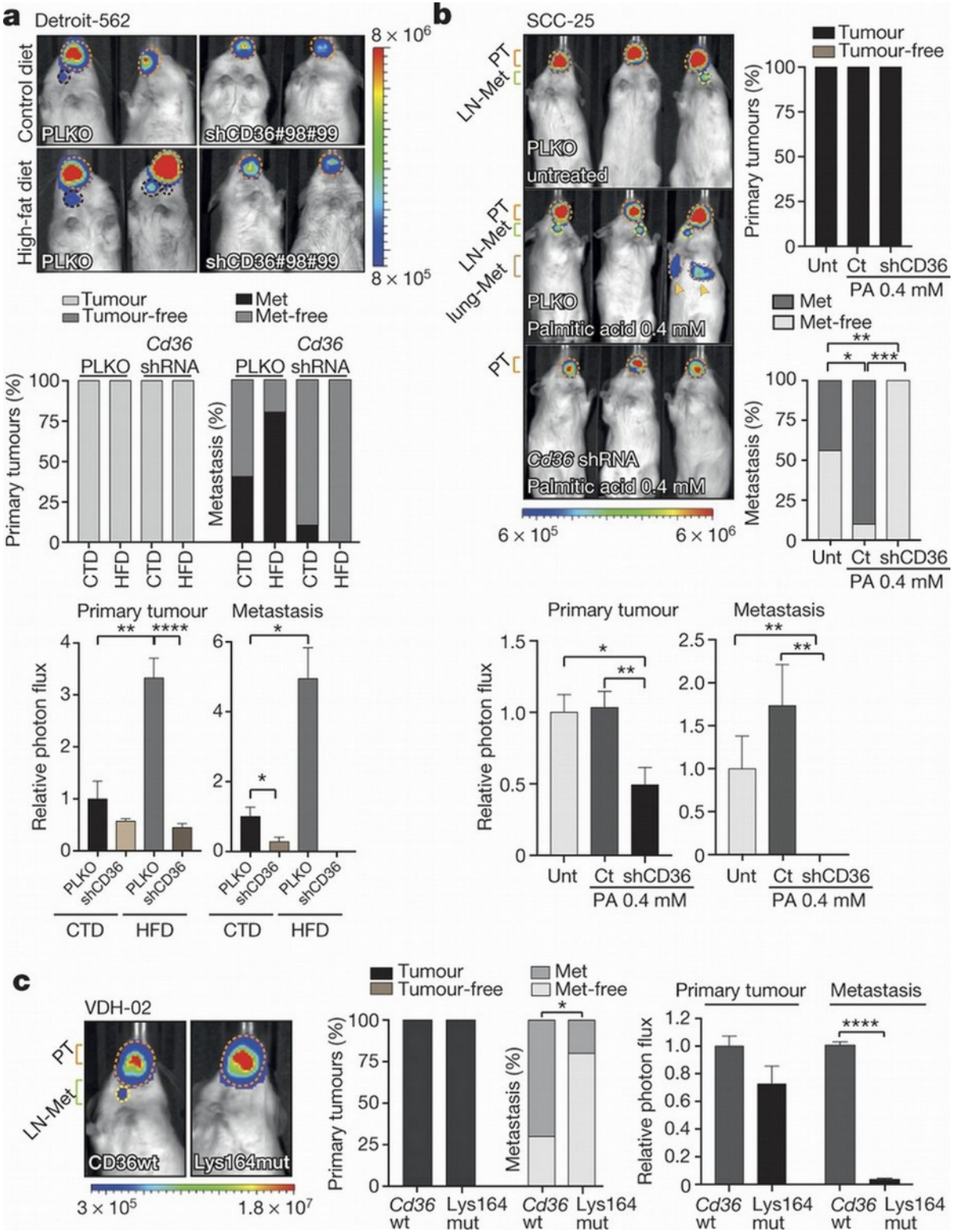
Don’t-s:

- Don’t distort the data
- No unnecessary figures or elements: *do we really need a figure? or a table would suffice?*
- Don’t rely absolutely on colour
- No 3D: in most cases it distorts perception

Do-s:

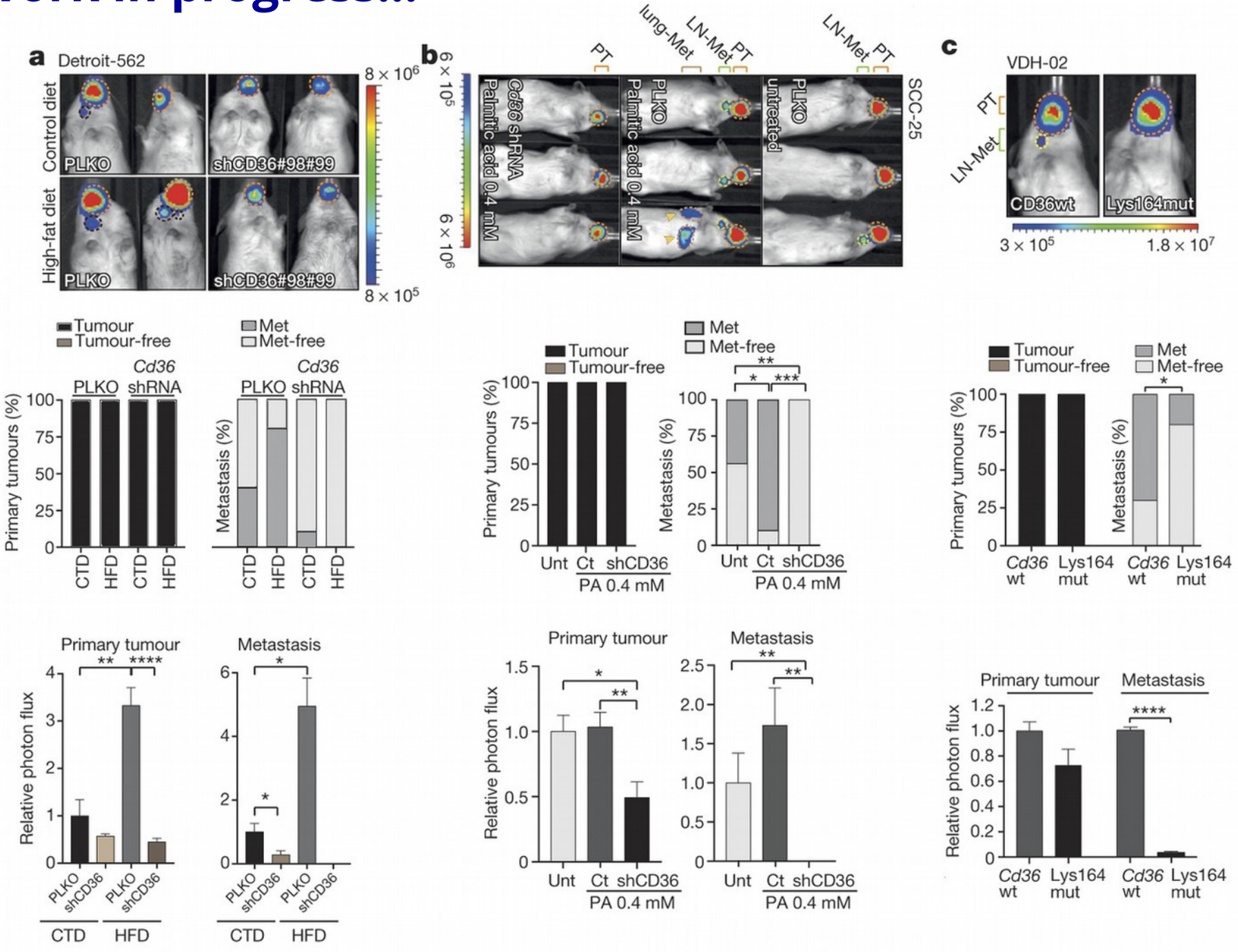
- One point per figure
- Summarise to clarify
- Have a clear purpose/ message
- Link to accompanying text and statistics

Can you find ten ways to improve this figure?

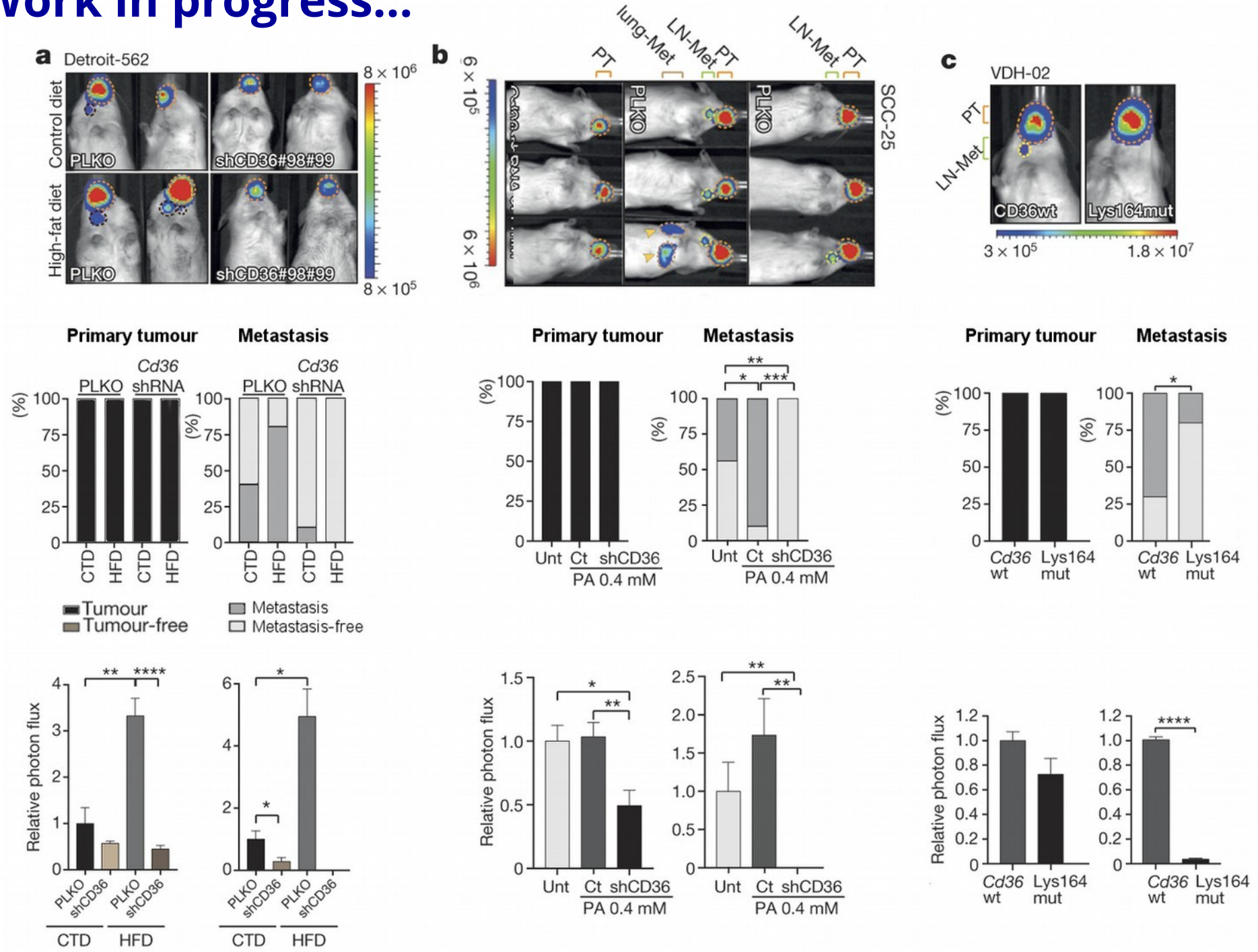


Pascual et al. Targeting metastasis-initiating cells through the fatty acid receptor CD36. *Nature.* 7 December 2016

Work in progress…



Work in progress…

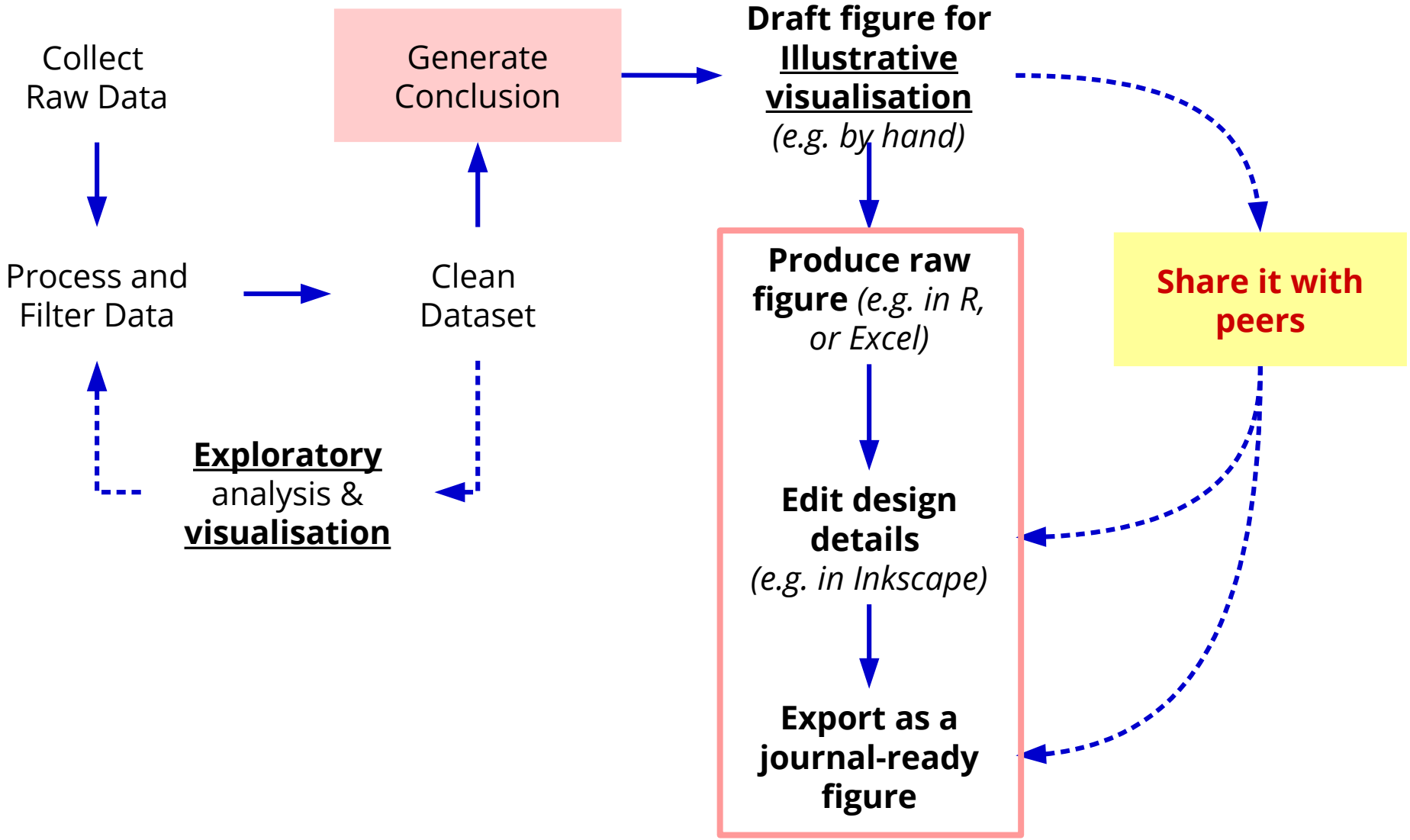


Checklist

Is your figure effective?

- ☐ The figure is **self contained**: understandable without additional information
- ☐ Every element is **labelled** or explained in the caption, including x and y units
- ☐ x and y axis: **scales** show appropriate variation of the data, or are comparable
- ☐ **Readability** and **contrast** are appropriate
- ☐ Every use of **colour** has a reason
- ☐ The figure works in **grayscale** (except for very complex figures)
- ☐ If there are **groupings**, they help understand the message without manipulating
- ☐ There are no channel **inconsistencies** within the figure
- ☐ It is as **simple** as possible: i.e. no decorations, every piece that could be eliminated without losing information has been eliminated
- ☐ Has been **validated** with other people...

Data Visualisation Process



Validation

- Always try to validate plots you create
- You have seen your data too often to get an unbiased view
- Show the plot to someone not familiar with the data
  - What does this plot tell you?
  - Is this the message you wanted to convey?
  - If they pick multiple points, do they choose the most important one first?

Babraham Bioinformatics

Not covered in this session

Diagrams

- Definition
- Workflow:
  - Clarify the purpose: essential elements to depict and their relation
  - Draft the structure of the diagram by hand and share and discuss it
- Use grids and think carefully about the label choice and position
- Types: Venn diagrams (composition of datasets), flowcharts (for decision making processes), tree diagrams, timelines, networks, pathways, procedural diagrams
- Remember: the key *"is not the quality of the diagram or drawing, but the clarity of the information"* Carter p128

Photos

- Avoid unethical manipulation (deleting noise, etc.), even if it doesn't change the results
- Crop to emphasize important bits
- Rule of thirds
- Use good quality images (sufficient resolution and colour/ brightness settings)
- Format differences: JPEG, TIFF, GIF, PNG
- Resolution
- Cropping and image composition
- Image size and proportions
- In context: contrast and relation with surrounding content
- Check license for use

Some useful resources

- Short papers:
  - **Rolandi** et al 2011. A Brief Guide to Designing Effective Figures for the Scientific Paper. *Advanced Materials* 23
  - **Rougier** et al 2014. Ten Simple Rules for Better Figures. *Plos Computational Biology* 10:9
- Design for scientists/ data:
  - **Carter**. 2013. Designing science presentations – *not just for figures, very clear*
  - **Munzner**. 2014. Visualization, analysis and design *– from a computer-graphics perspective*
  - **Tufte**. 2001. The visual display of quantitative information *– from a theory-of-design perspective*
  - **Meirelles**. 2013. Design for information *– advanced information visualizations (maps, time-space, flows)*
- Graphic design more generally:
  - **Krause**. 2004. Design basics index – *very concise and to the point*
  - **Samara**. 2014. Design elements: a graphic design manual – *reference book*
- *Nature* Points of View: http://blogs.nature.com/methagora/2013/07/data-visualization-points-of-view.html

If you need additional references, help or want to collaborate:
aiora.zabala@gmail.com, http://aiorazabala.net/portfolio/