

**Cancer Research UK**

# **Designing more effective scientific figures**

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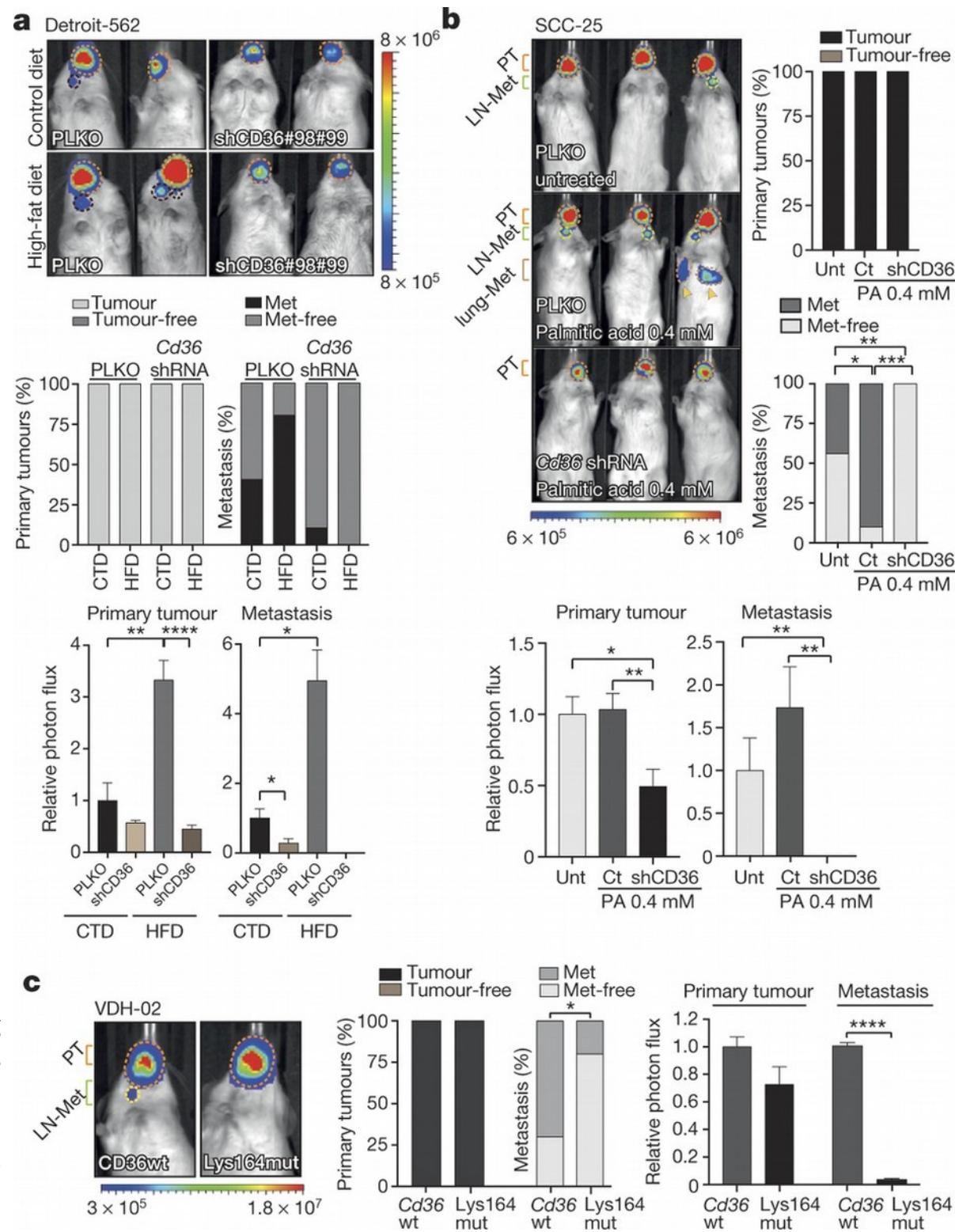
## Cancer spread is increased by a high fat diet, groundbreaking evidence shows

Researchers discover new cancer spreading protein

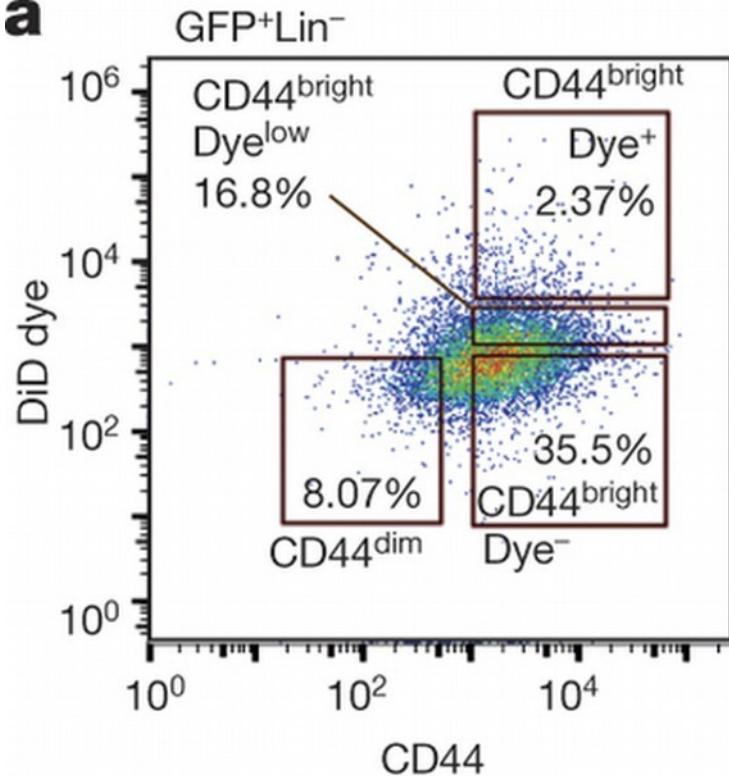
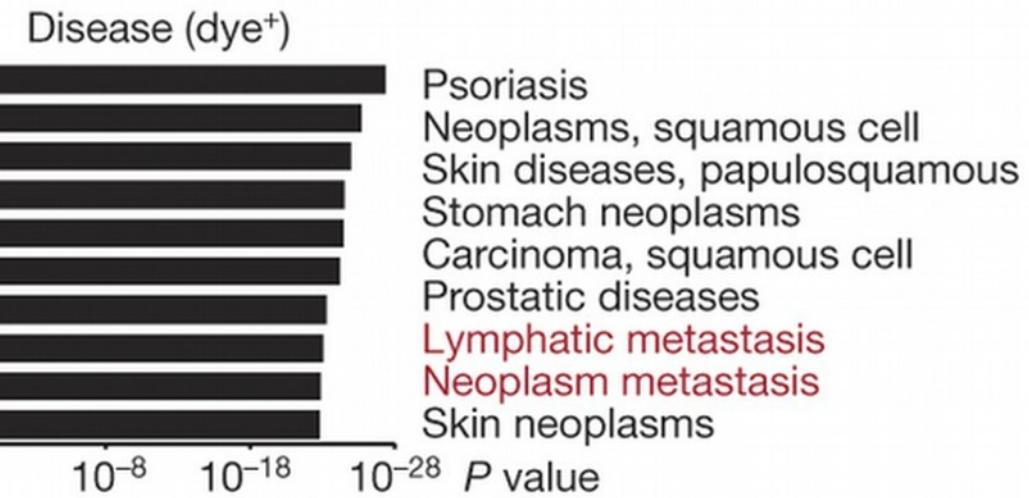
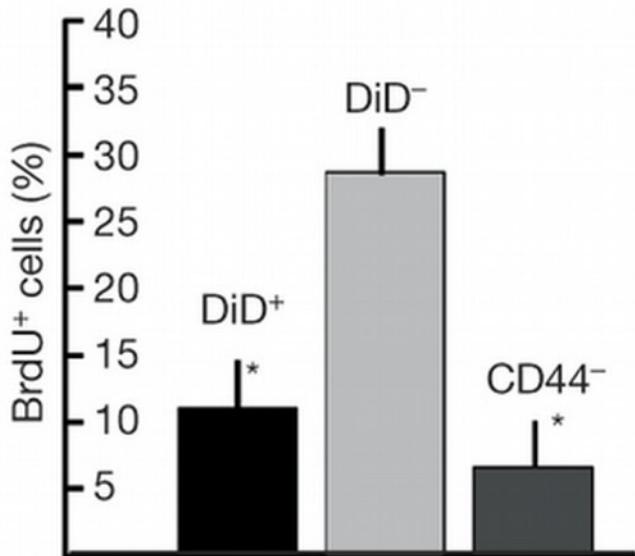
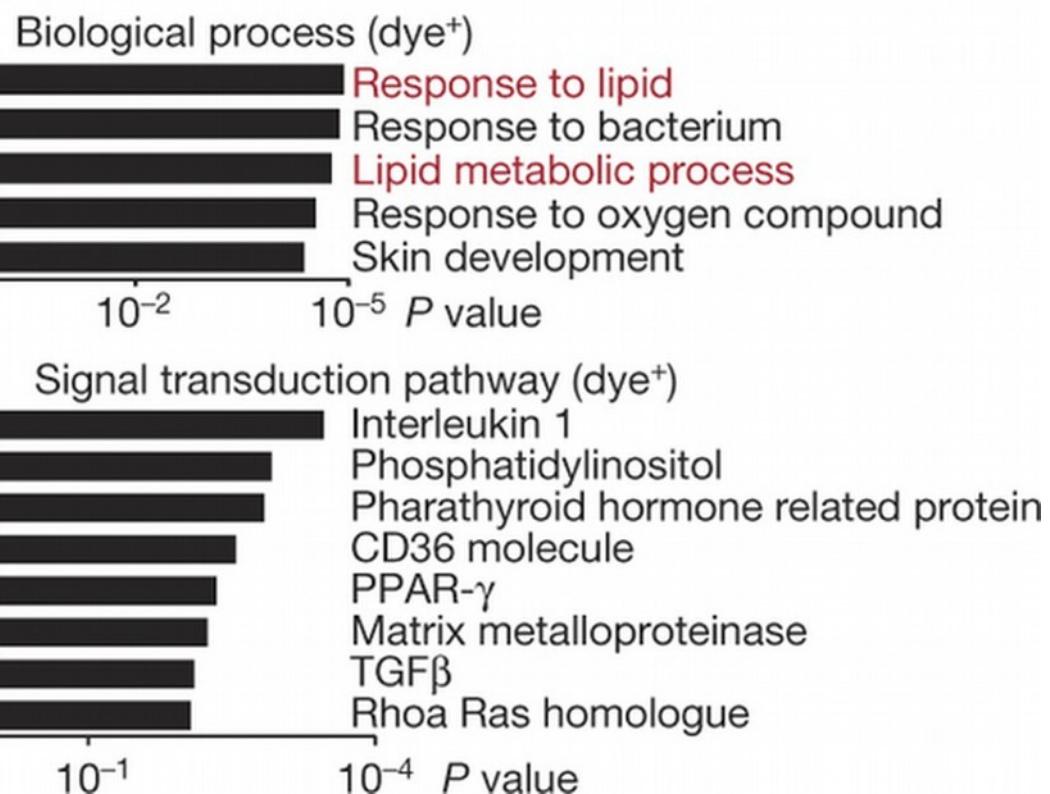
*Date:* December 7, 2016

*Source:* Worldwide Cancer Research

*Summary:* New research shows that the metastatic process (cancer spread) is enhanced by fat intake. Mice given a high fat diet, including palmitic acid (a major component of palm oil which is found in lots of household products) developed the most aggressive cancer spread. The study identifies for the first time a protein called CD36 which has an essential role in cancer spreading.



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

**a****c****b****d**

# What is figure design? Why design?

'is not to take bad scientific content and disguise it as great [...] the goal is to **communicate great content in a clear, succinct [efficient], and inspiring way** [...] in the best possible light'

'is not decoration [...] is not adding anything meaningless that lacks information or **purpose**'

Carter

'Design should never say, '*Look at me.*'

It should always say, '**Look at this.**'

Craig

# 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

# Goals of this session

## Theory

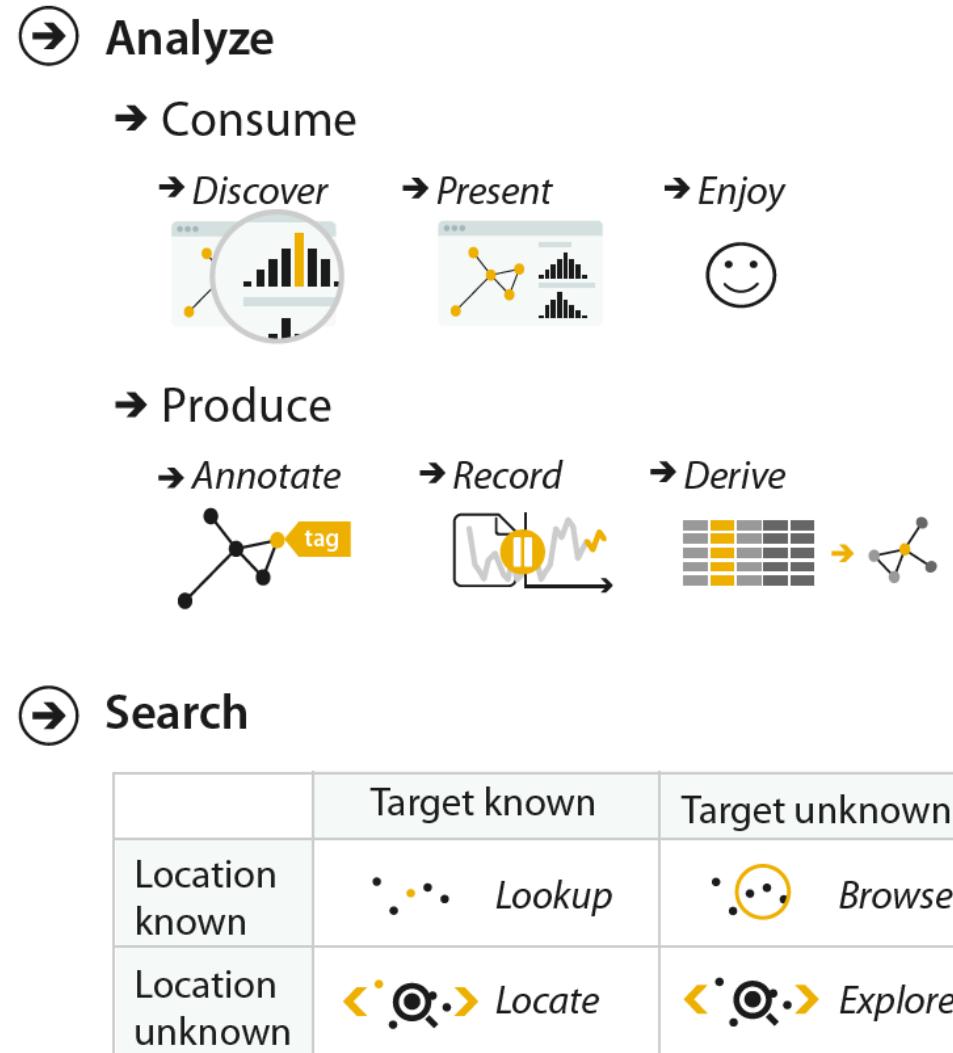
- Explain the key ingredients for sci-figure design
- Discuss what works, what doesn't and what's unethical
- How to choose a type of figure that is appropriate for the data

## Practical

- An introduction to two (free) programmes to edit images for professional results:
  - *Gimp*: for bitmap images (equiv. to *Ad. Photoshop*)
  - *Inkscape*: for vectorial images (equiv. to *Adobe Illustrator*)
- Produce a journal-ready figure using standard analysis software and Inkscape

# What is data visualisation?

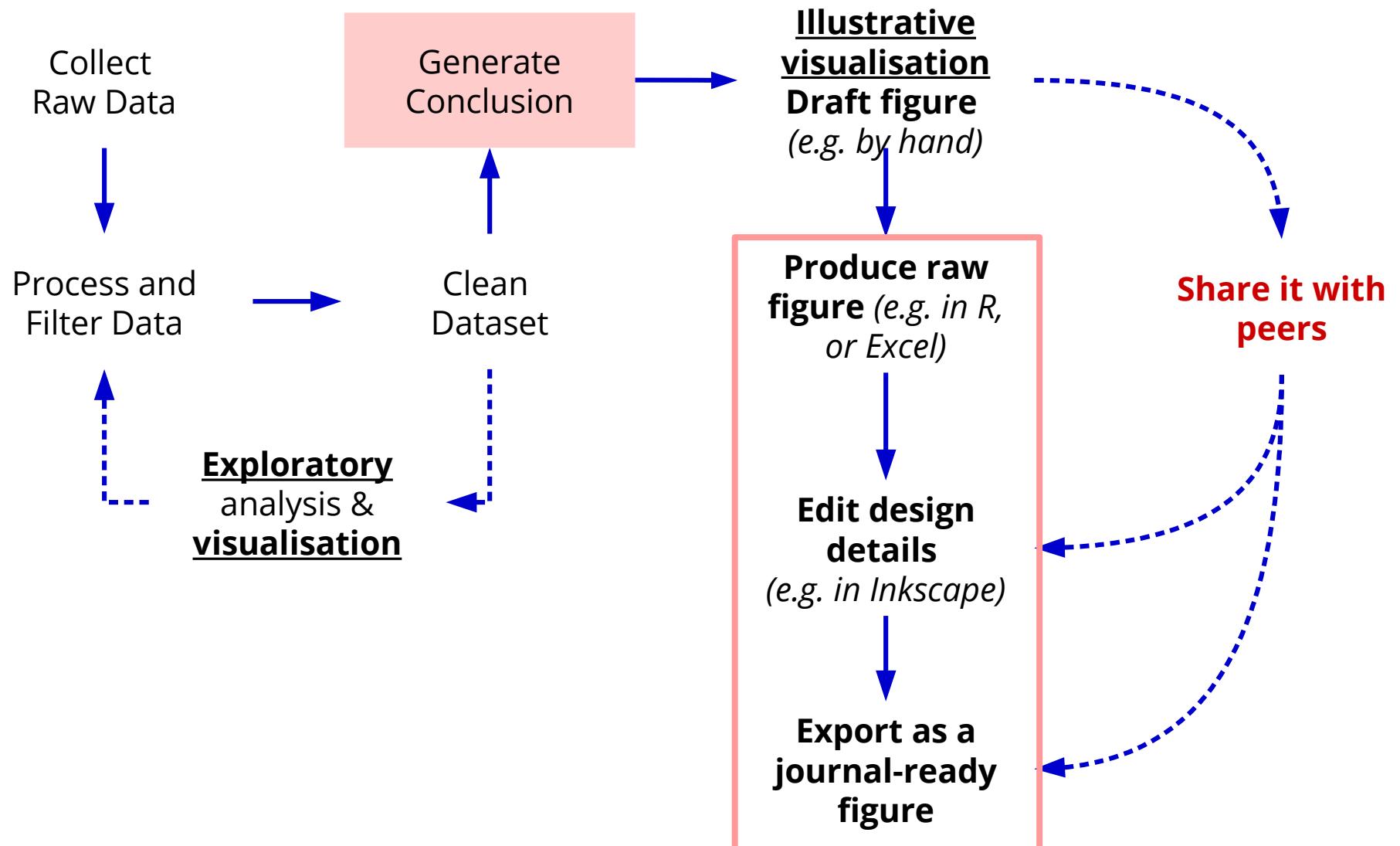
Visual representation of data to communicate information clearly and “help people carry out tasks more effectively”



# Exploratory visualisation

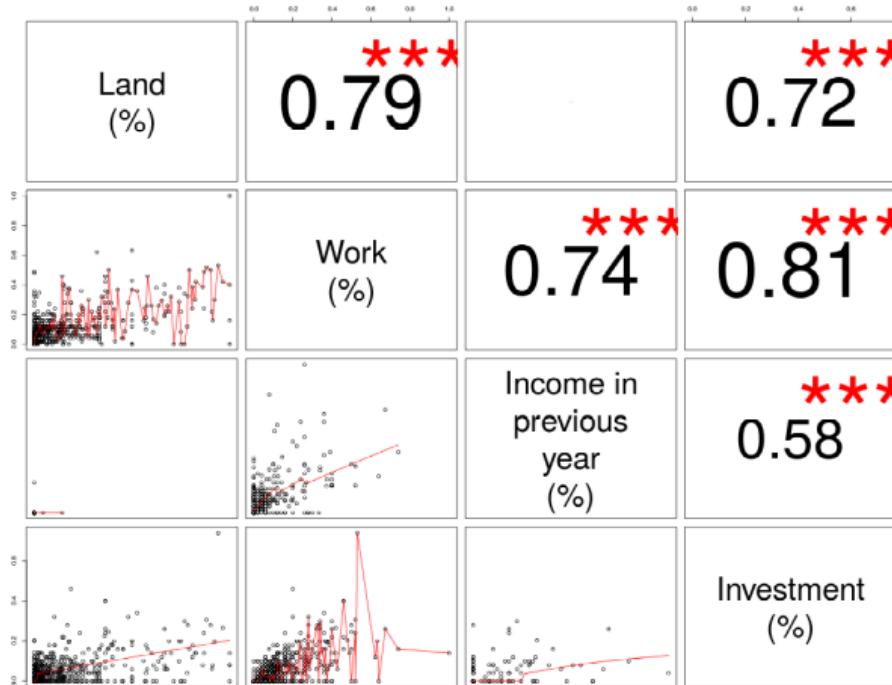
- Understand your data
- Multiple ways to present and summarise
- Crude representations
- Interactive
- Not intended for final publication
  - Can be adapted for publication

# Data Visualisation Process

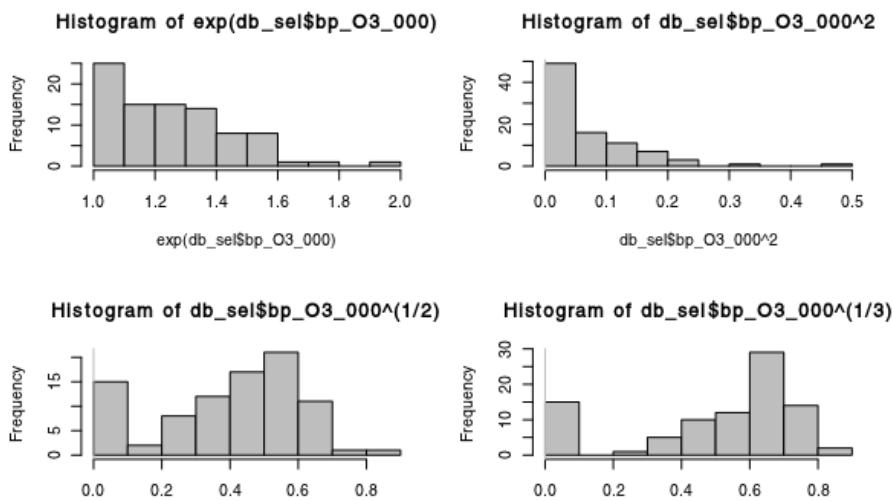


# Exploratory visualisation

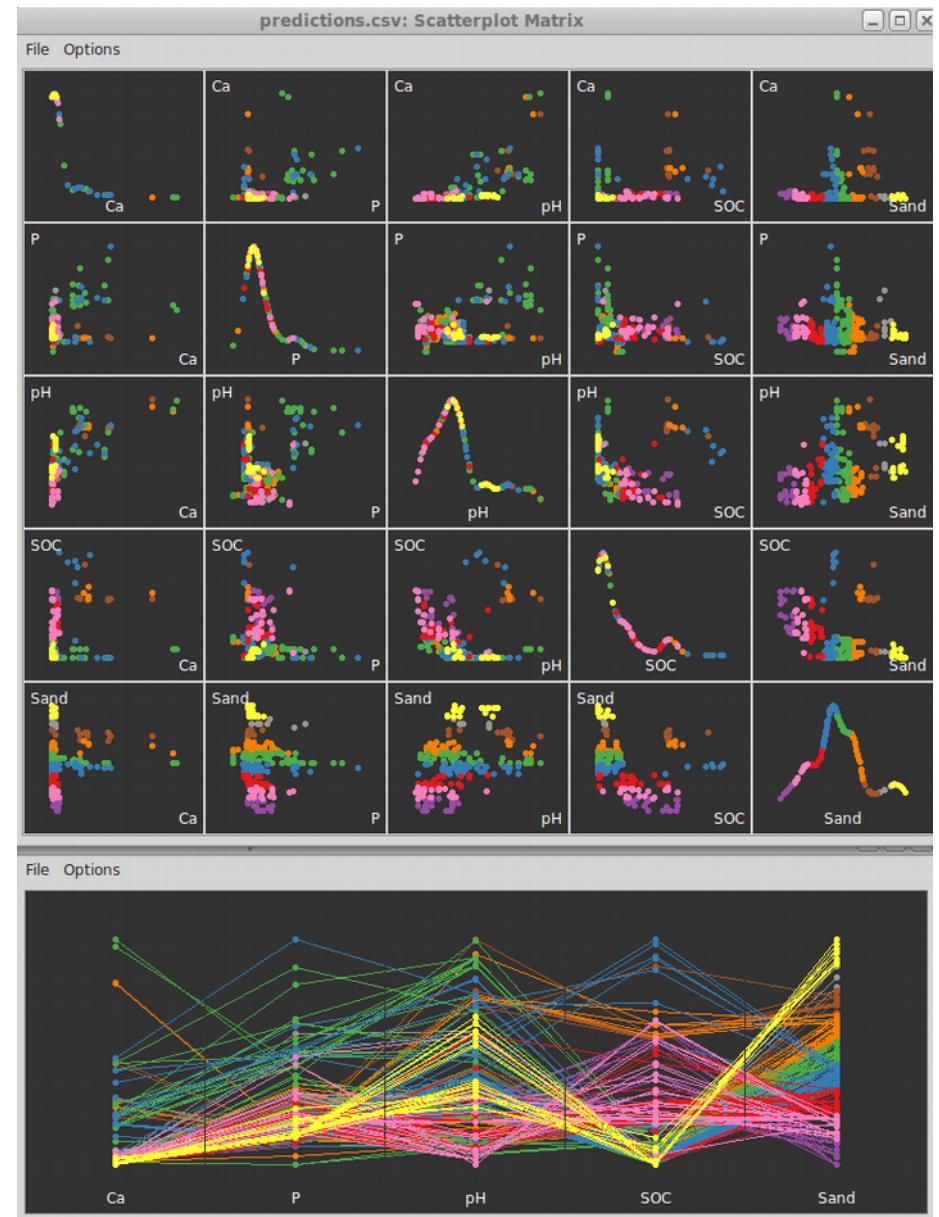
- Understand your data
- Multiple ways to present and summarise
- Crude representations
- Interactive
- Not intended for final publication
  - Can be adapted for publication



## Correlogram to see bivariate relations



Histograms to see the **distribution** of variables



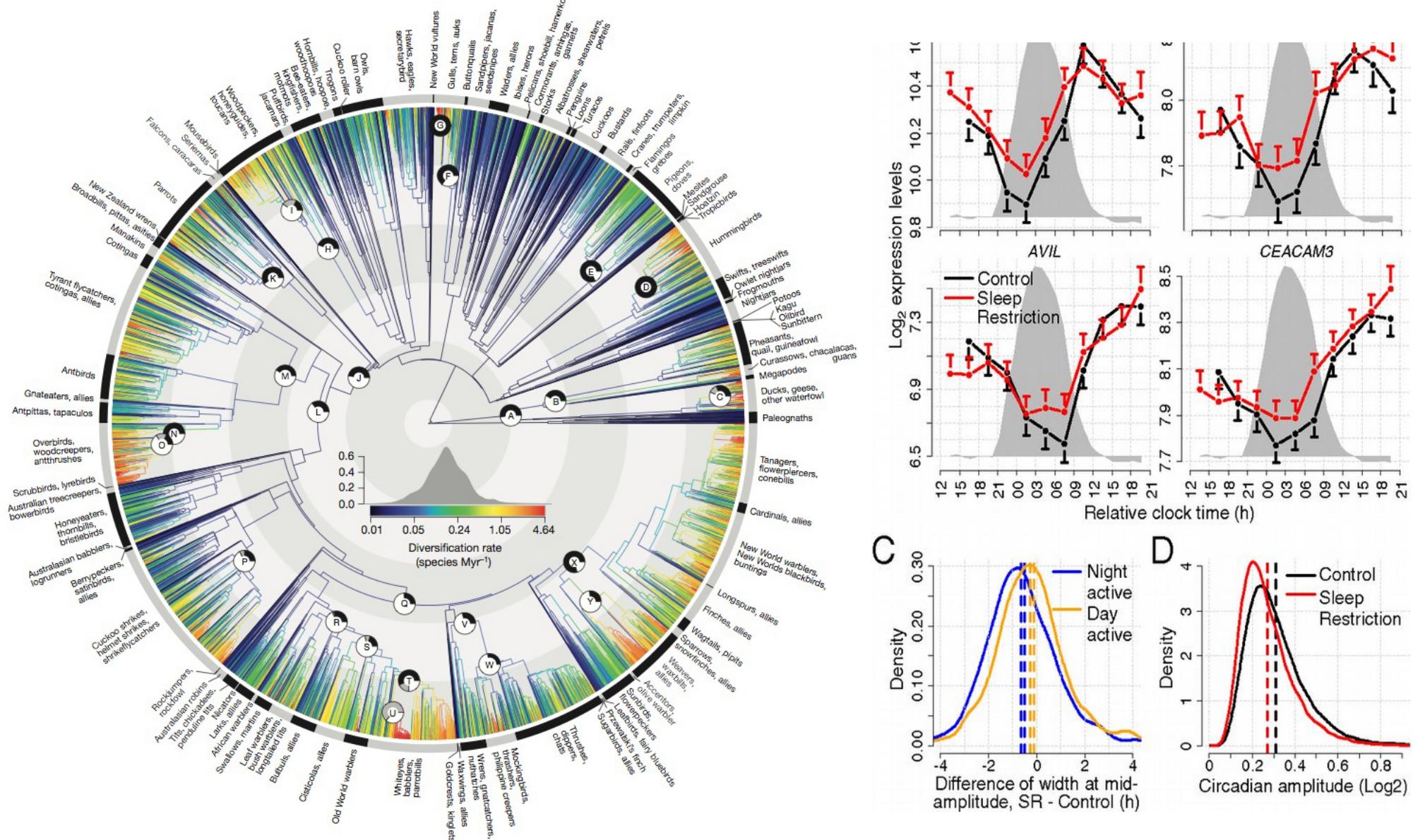
Interactive data exploration with the R package **ggobi**

# **Reference** visualisation

- Using your data as a resource
- Allows users to look up data of interest
- Tabular / Configurable
- Interactive

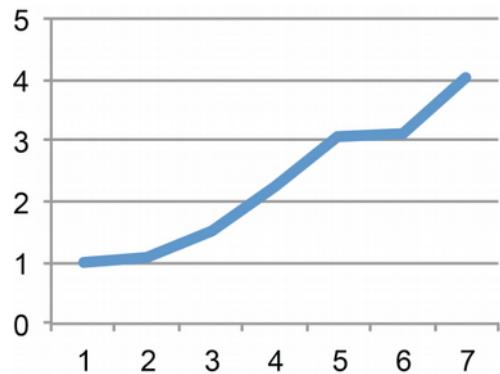
# **Illustrative** visualisation

- Intended to convey a specific point
- Carefully chosen subset of data
- Optimised presentation
- Good design
- Used for figures in papers

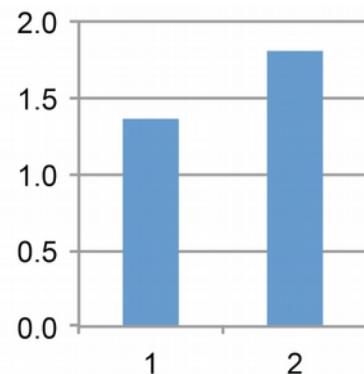


Figures: Avian phylogenetic tree, Jetz et al 2012. Sleep deprivation and genetic expression Möller-Levet et al 2013

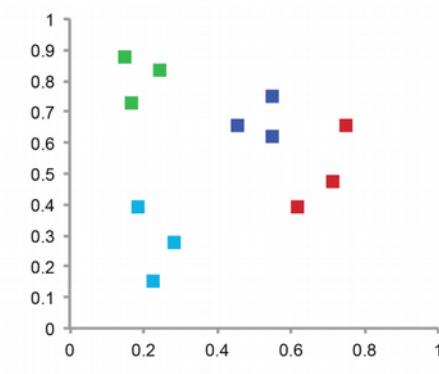
# Things you can illustrate



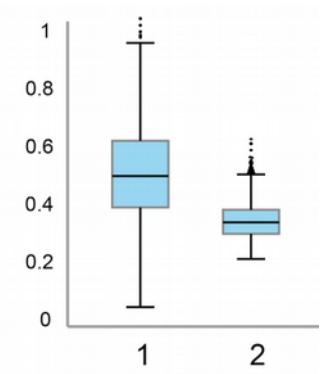
Relationship



Comparison

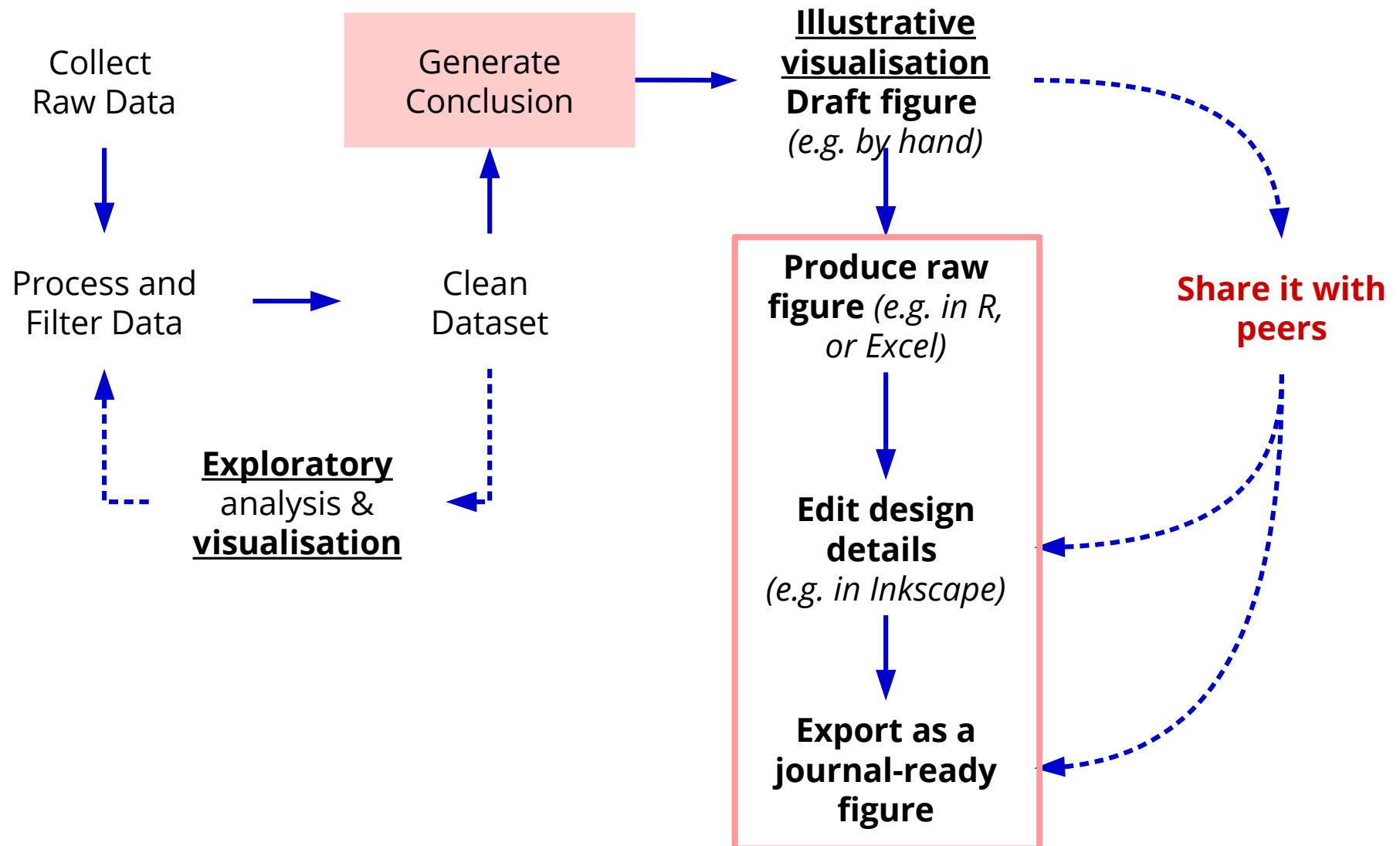


Composition



Distribution

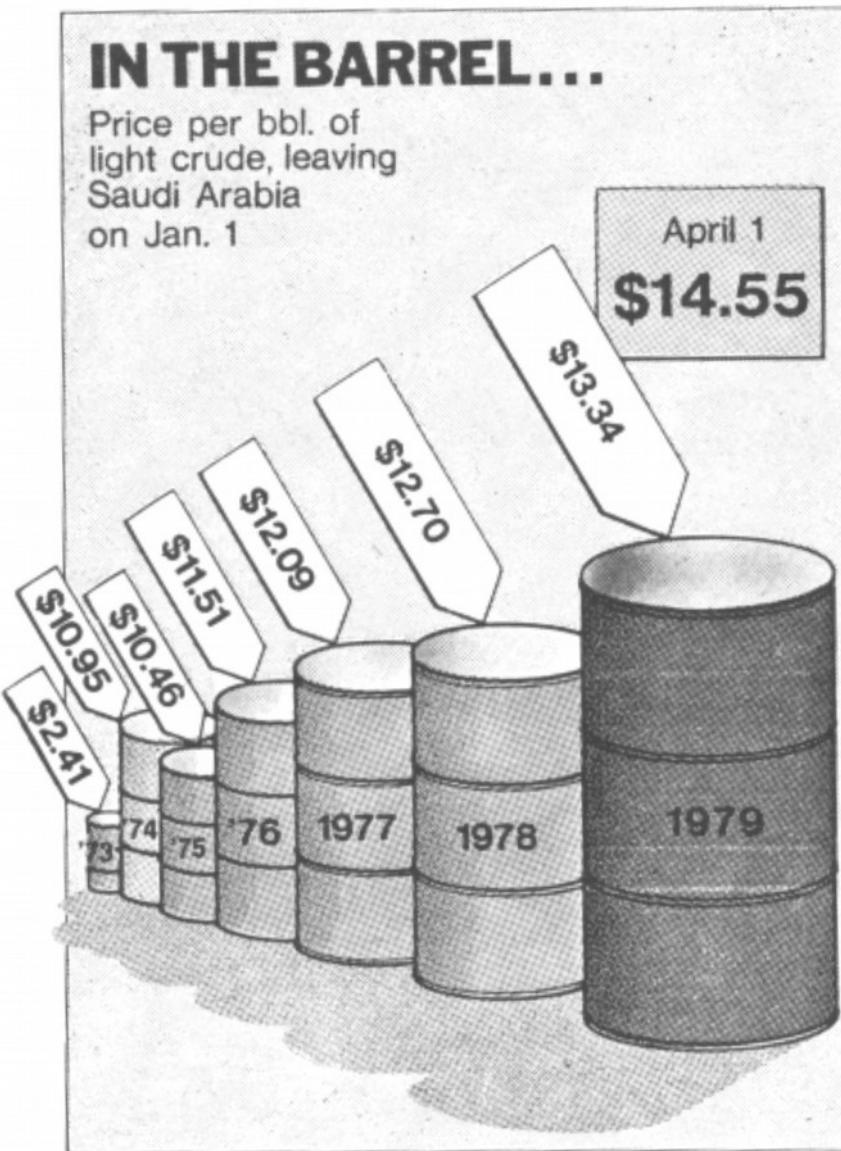
# Data Visualisation Process



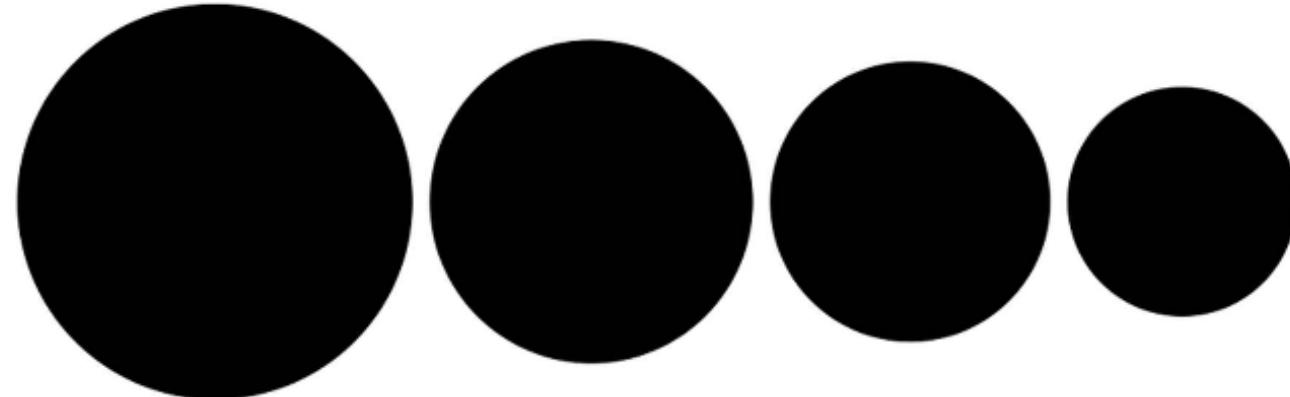
# Key ingredients: principles

- **Simplicity**
- **Continuous** process
- *Rules* in graphic design are, as in many other disciplines, rather guidelines: you can break them to allow for creativity and when there is a good reason to break them, but you need to know how to use them.

# What makes a good figure?



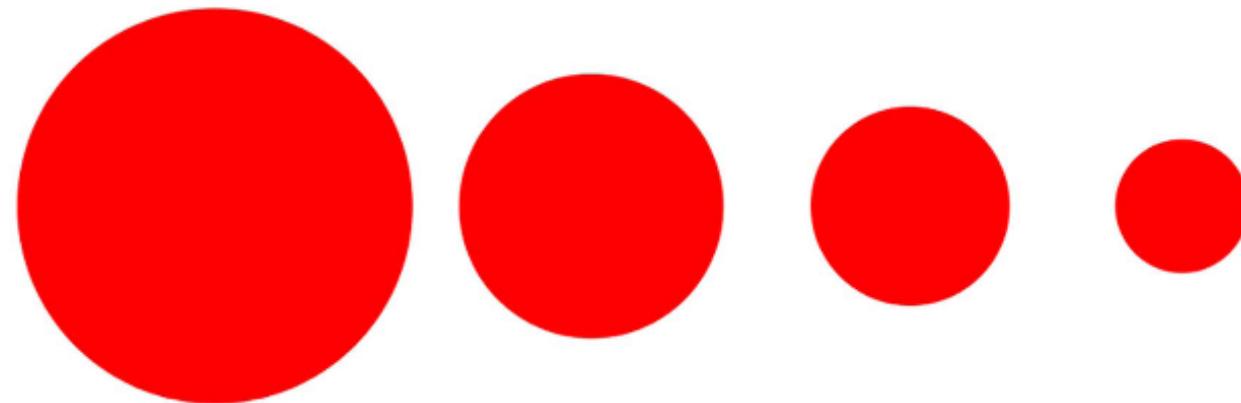
# Areas and 3D can be misleading



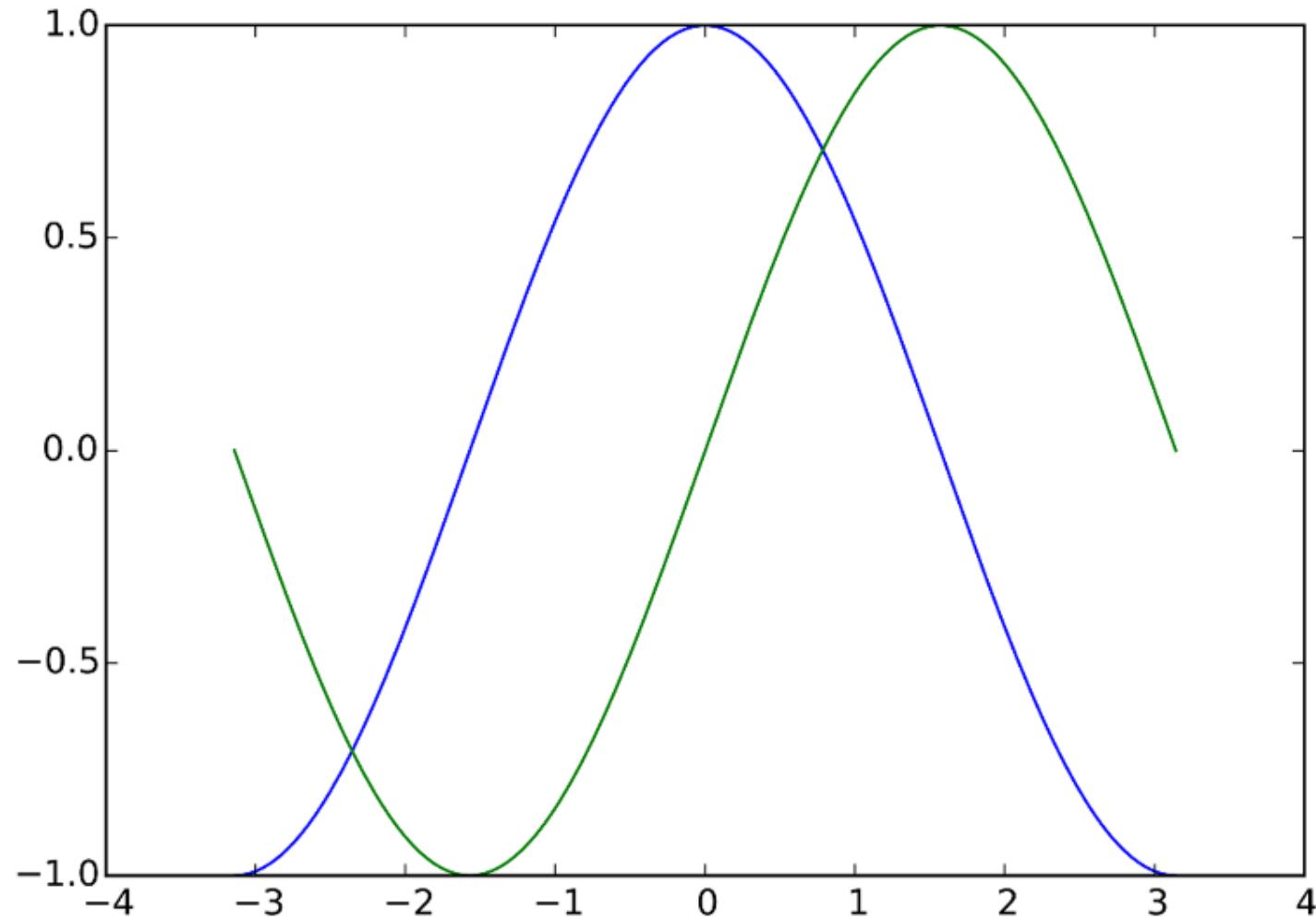
Relative size using disc area

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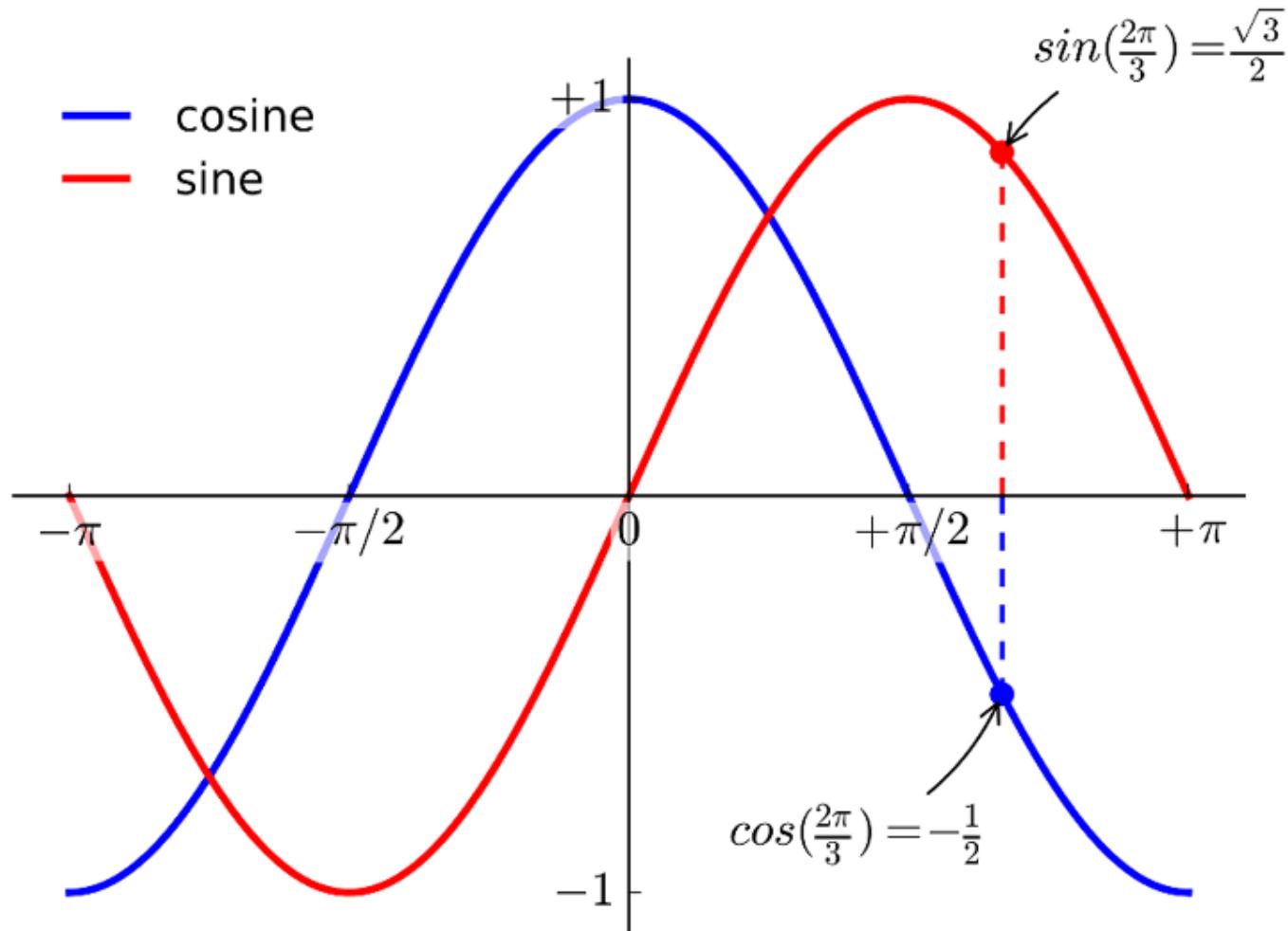
Relative size using disc radius



# What makes a good figure?



# What makes a good figure?



# What makes a good figure?

- Has a clear message
  - Helps to tell a story
  - Adds and relates to the text
- Is focused
  - Don't confuse one message with another
- Is easy to interpret correctly
  - Good data visualisation
  - Good design
- Is a honest and true reflection of the data

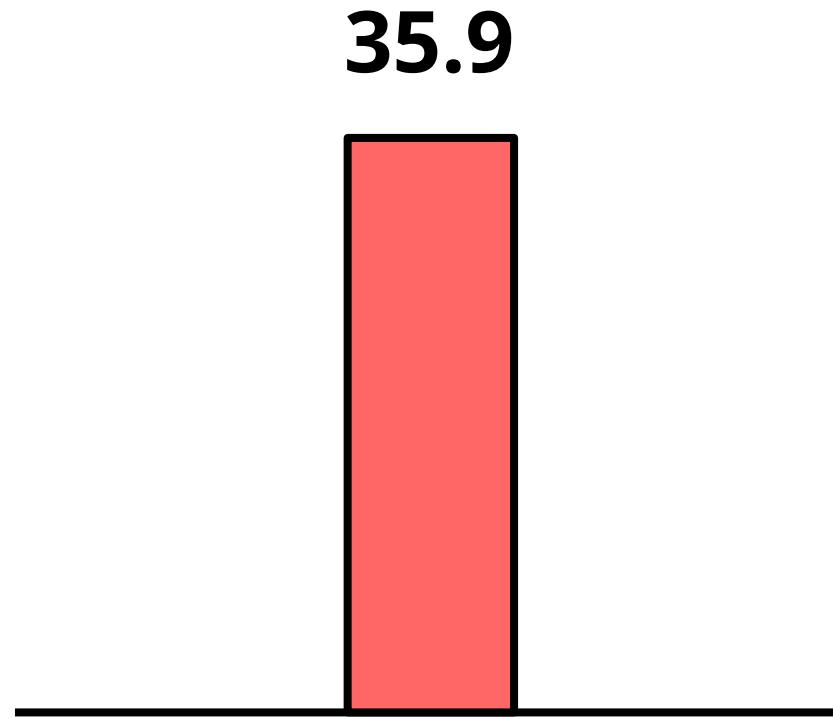
## **A *data visualisation* should:**

- Show the data
- Link to the accompanying text and statistics
- Summarise to make things clearer
- Serve a clear purpose
- Not distort the data

# Simplicity

- Every single element has to be there for a reason, 'distinguish between what is **meaningful** and what is **unnecessary** [...] avoid the latter'
- Simplicity is not boredom, but effectiveness in communicating a message and leaving aside anything unnecessary
- Avoid confounding decorations, e.g. excessive background grids or frames

# Simplicity



This figure indicates altitude in **six separate ways**.  
Can you find them?

# Consistency

- Make the figures uniform to help viewers understand the figure
- Try not to use more than two types of these
  - Font styles and sizes
  - Line weights (thickness)
- When combining more than one chart
  - Use the same colours and shapes for the same groups
  - Use same sizes and scales for comparable charts
  - Position of axis titles and labels
  - Stick to your own rules, e.g. if presented 'Sample A' and then 'Sample B', maintain this throughout

# Some useful concepts

- **Data-ink ratio** (and non-data ink)
- **Data density** of a display:  
high-info graphics and  
the shrink principle



Edward Tufte

# Graphical Representations

- Basic questions:
  - How are you going to **turn the data into a graphical form** (weight becomes length etc.)
  - How are you going to **arrange things in space**
  - How are you going to use **colours, shapes** etc. to clarify the point you want to make
- Think about the **audience**:
  - Specialised journal or broader readership?
  - Be aware of disciplinary conventions

# Key ingredients: the tools

## Elements: marks and channels

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

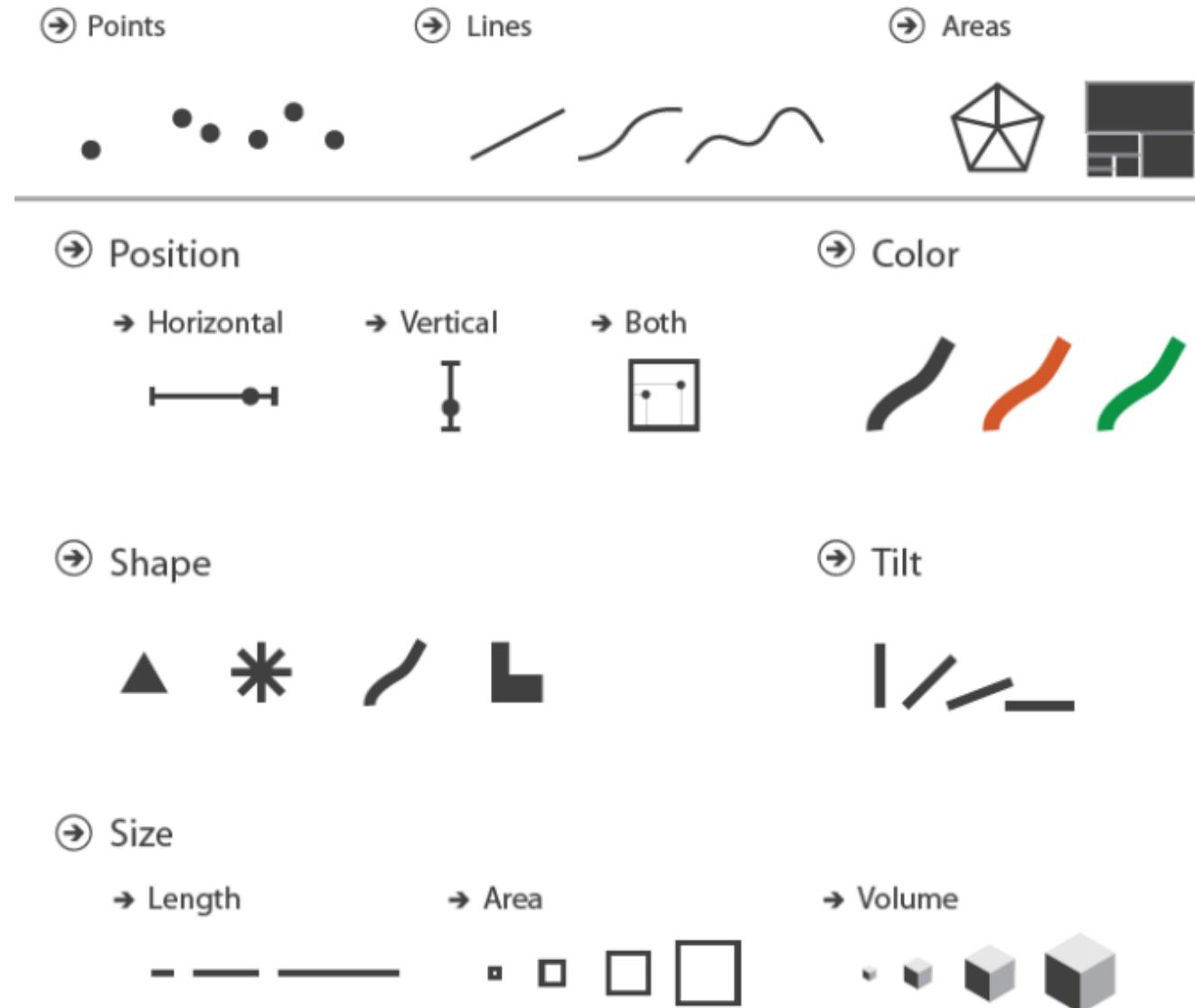
## Composition

- Grid and alignments
- Balance
- Hierarchy and focus

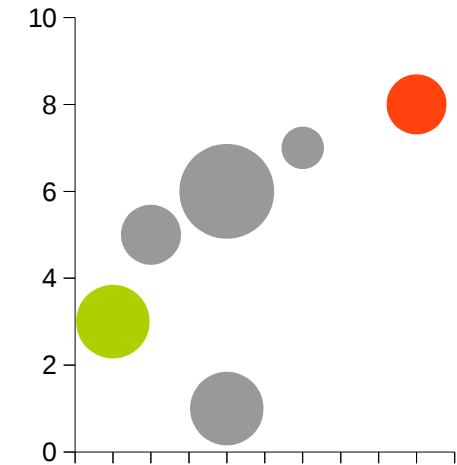
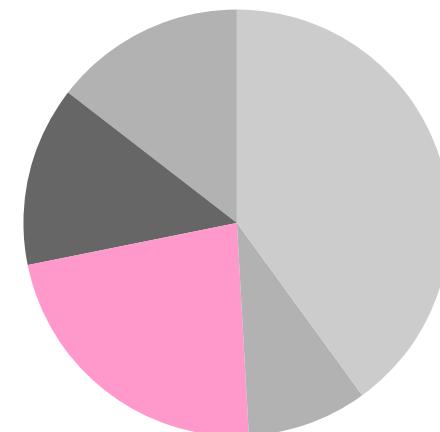
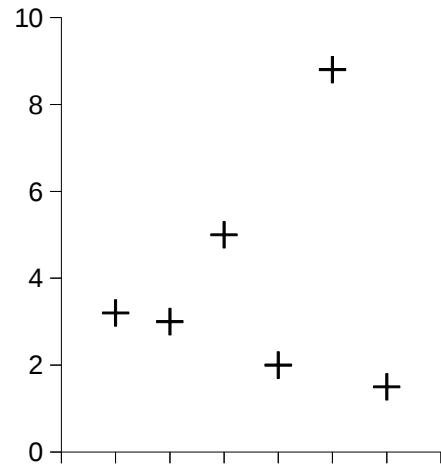
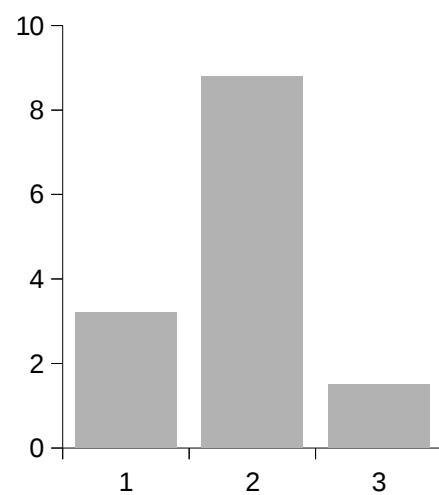
# Elements: Marks and channels

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

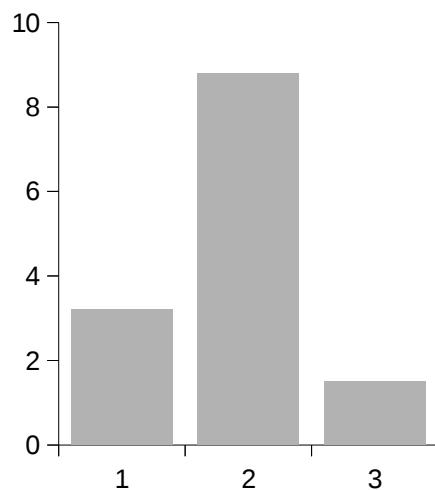
**Channels** control the graphical appearance of marks: used to **encode** data, can be combined



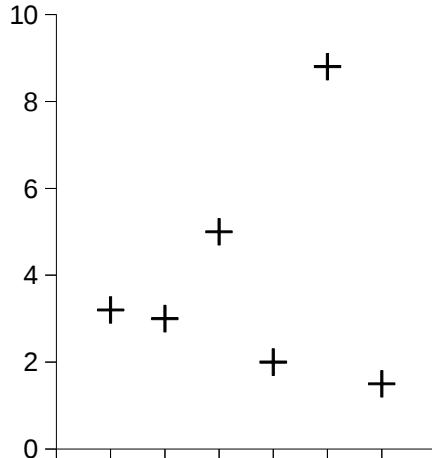
# Figures are a combination of marks and channels



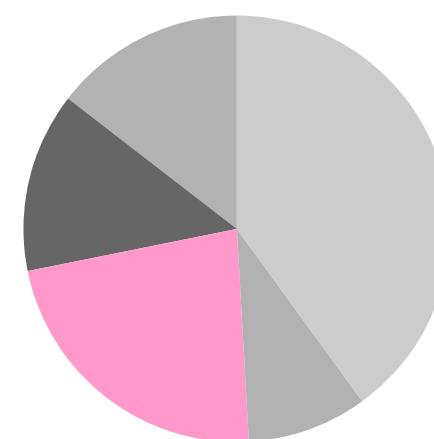
# Figures are a combination of marks and channels



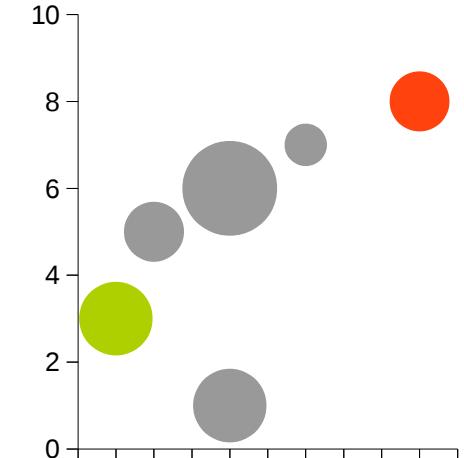
**1 Mark =**  
Rectangle  
**1 Channel =**  
Length of  
longest side



**1 Mark =**  
Cross shape  
**2 Channels =**  
X position  
Y position



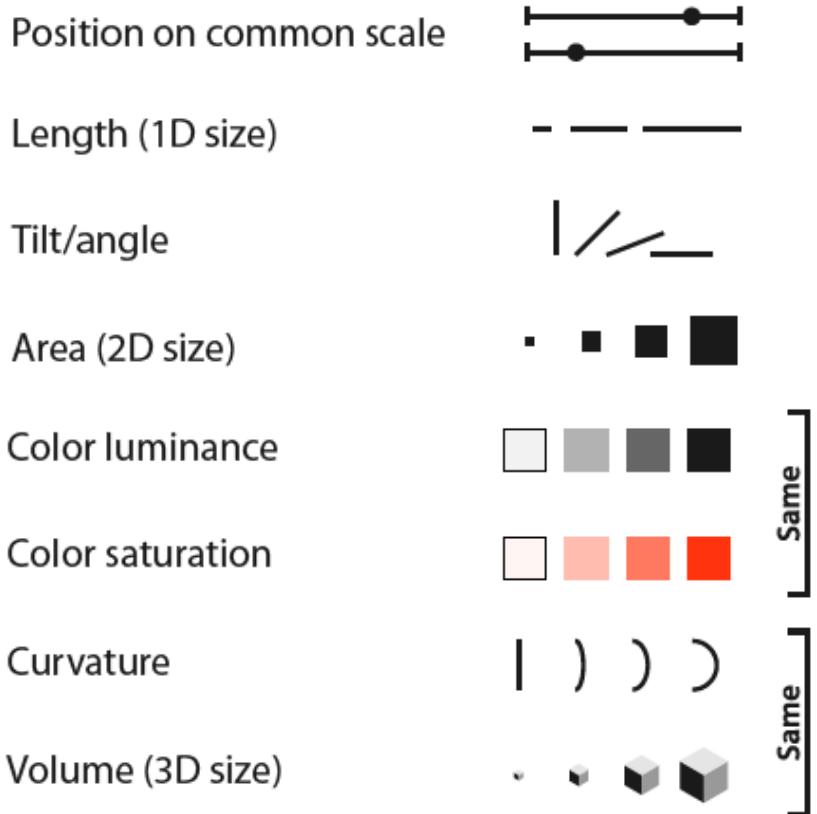
**1 Mark =**  
Circle segment  
**2 Channel =**  
Angle  
Colour



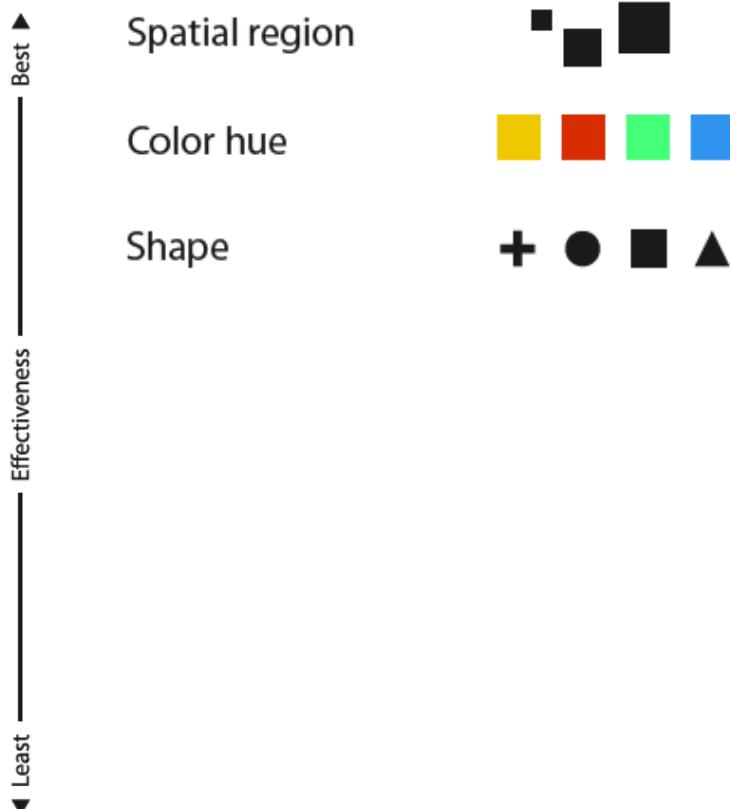
**1 Mark =**  
Circle  
**4 Channels:**  
X position  
Y position  
Area  
Colour

# Types of channel

Identity channels: categorical/  
**qualitative** attributes

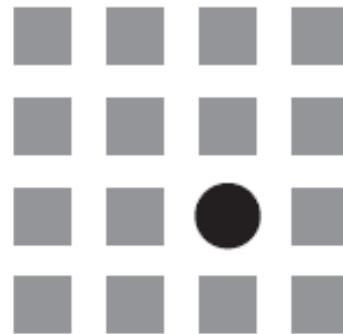


Magnitude channels: ordered/  
**quantitative** attributes



# Types of channel (continued)

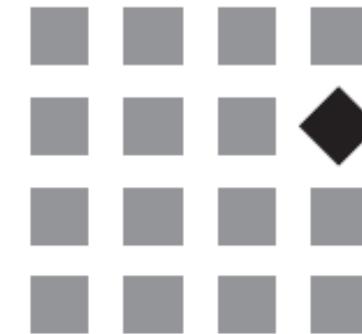
SHAPE



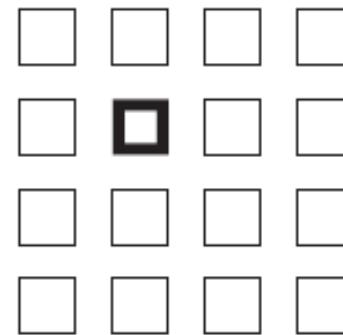
SIZE



ORIENTATION



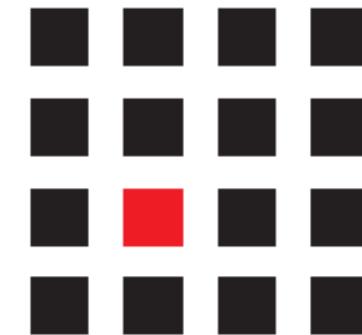
WEIGHT



POSITION



COLOR



# More principles

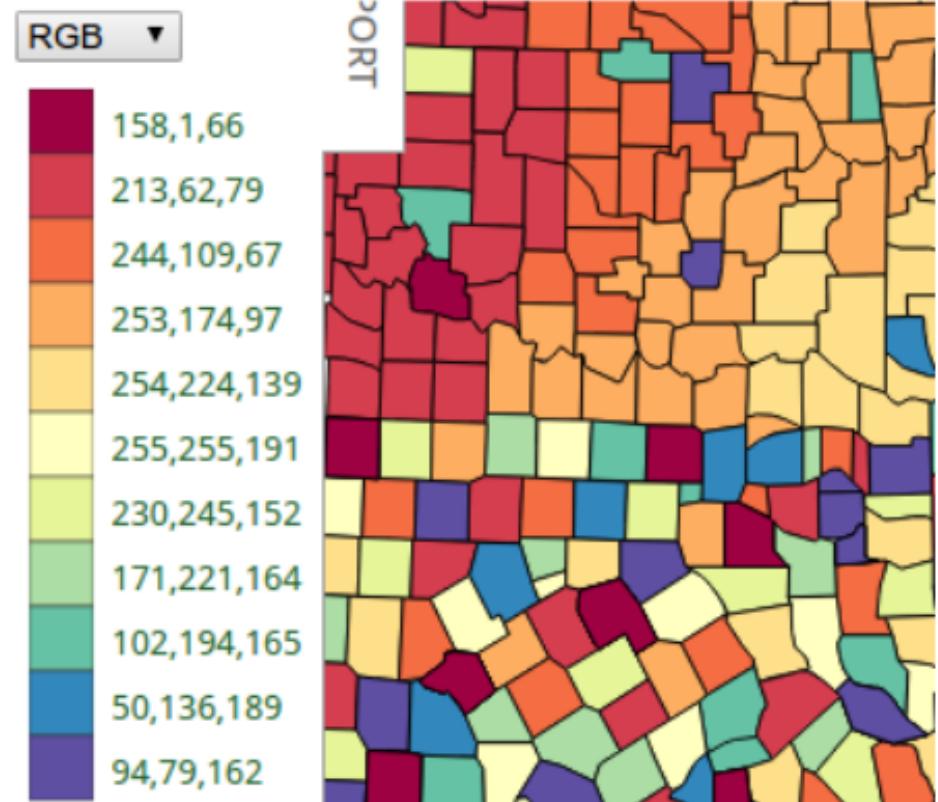
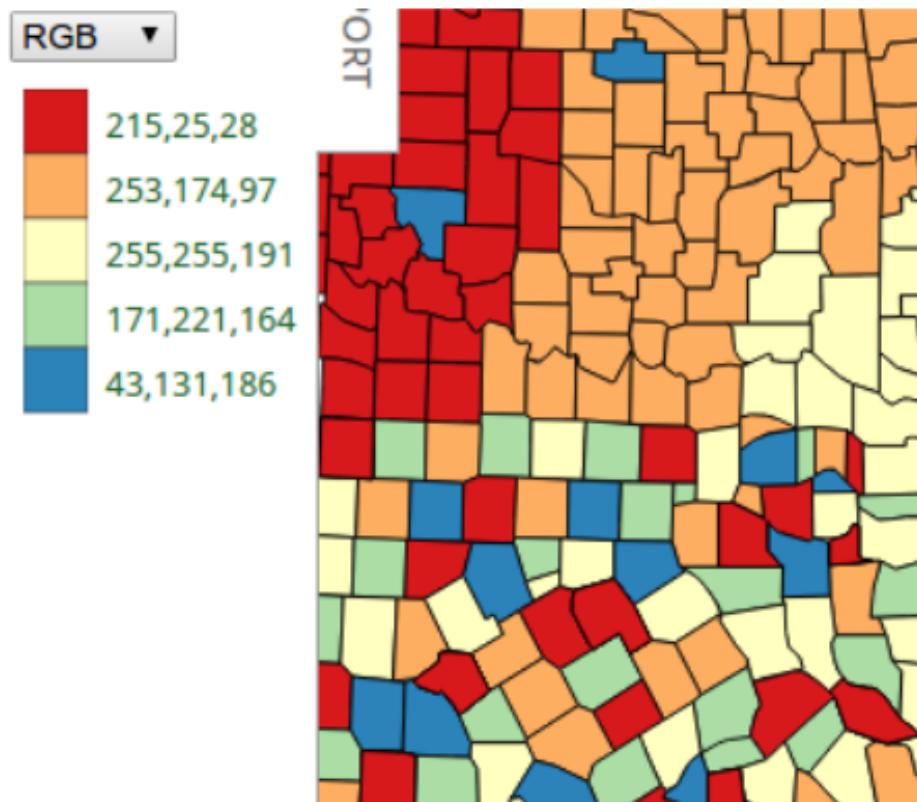
- **Effectiveness:** encode the most important information with the most effective channel
- **Expressiveness:** match the properties of the data and channel
  - i.e. heed whether the data are **quantitative**, **ordered** or **categorical**, and choose accordingly

# More principles

## Discriminability and separability

How many different types can you distinguish?

How easy is it to distinguish them?



# Qualitative discrimination

Fillable **shapes**: can be combined with colour, but the fillable area needs to be similar,



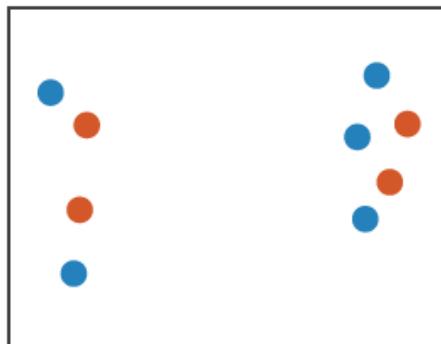
and they have to be distinguishable at small sizes

□○△◊+◊○△◊

■●▲◆+◆■●▲◆

# Separability

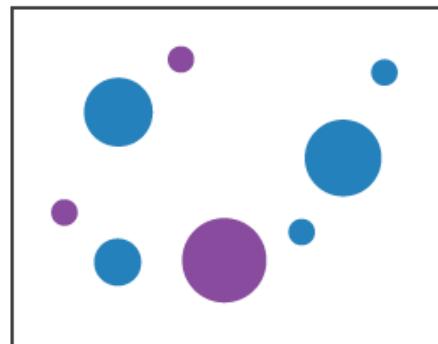
Position  
+ Hue (Color)



Fully separable

2 groups each

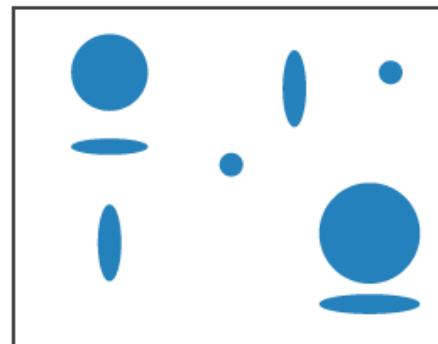
Size  
+ Hue (Color)



Some interference

2 groups each

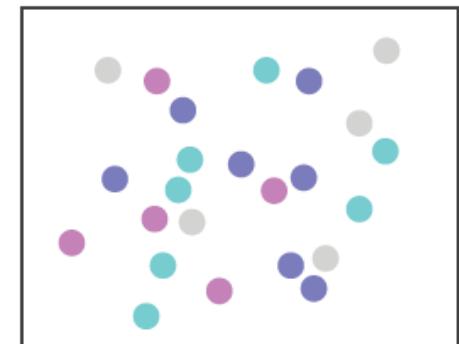
Width  
+ Height



Some/significant  
interference

3 groups total:  
integral area

Red  
+ Green



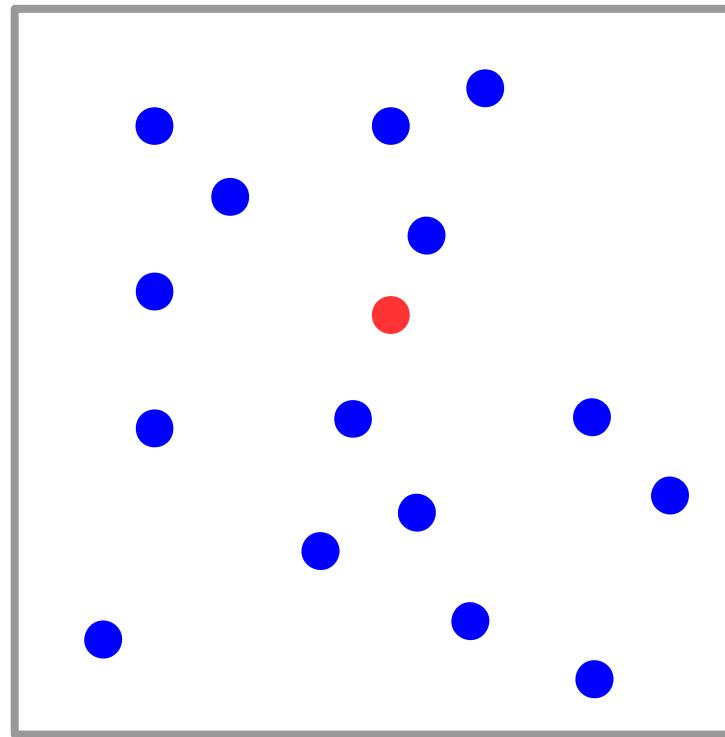
Major interference

4 groups total:  
integral hue

# Separability

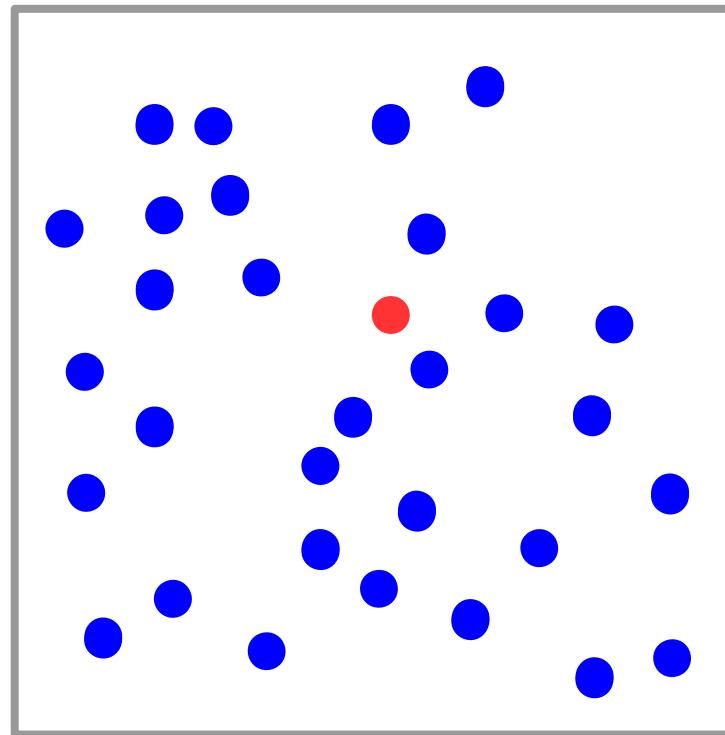
- The effectiveness of a channel does not always survive being combined with a second channel
- There are large variations in how much two different channels interfere with each other
- Trying to put too much information on a figure can erode the impact of the main point you're trying to make

# Popout



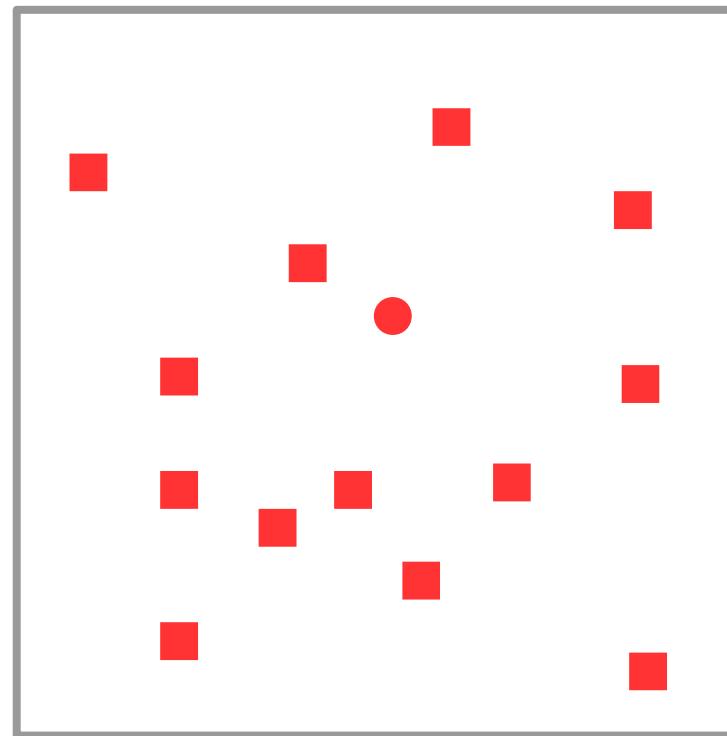
Find the red dot: how long does it take?

# Popout



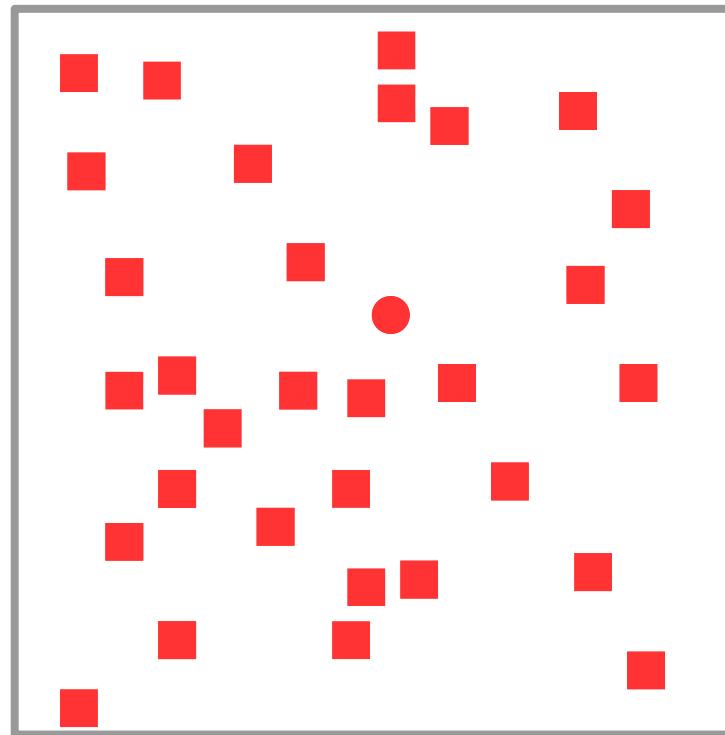
**The speed of identification is independent  
of the count of distractors**

# Popout



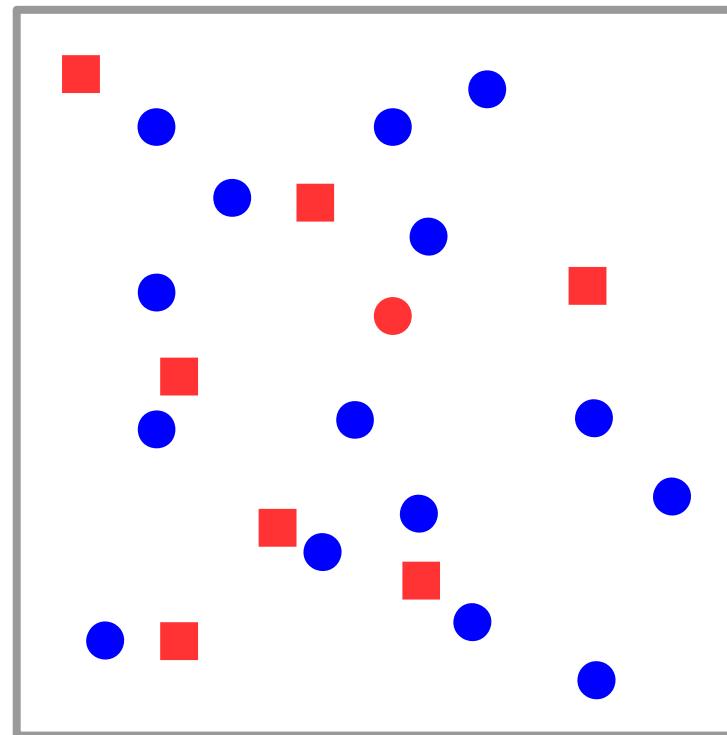
Find the circle

# Popout



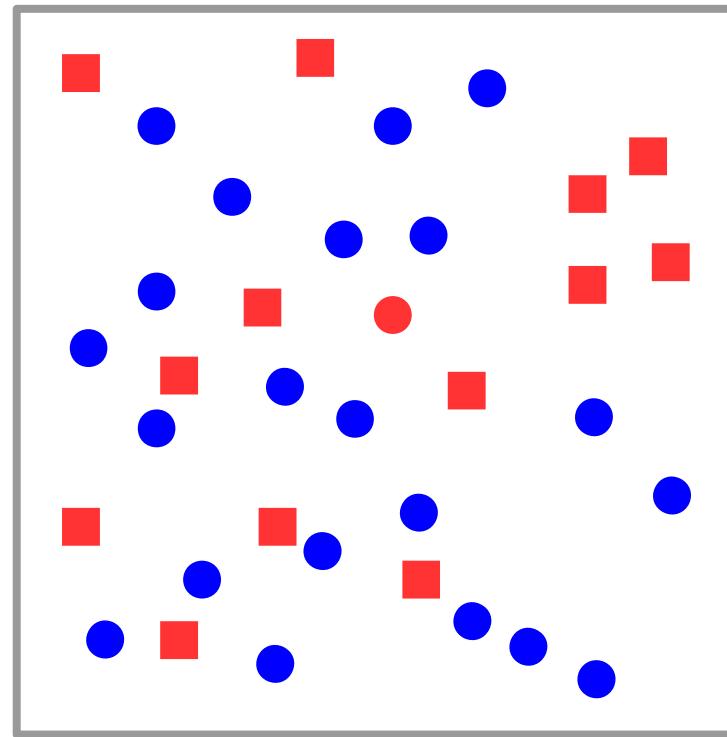
**Colour stands out more than shape**

# Popout



Find the red dot

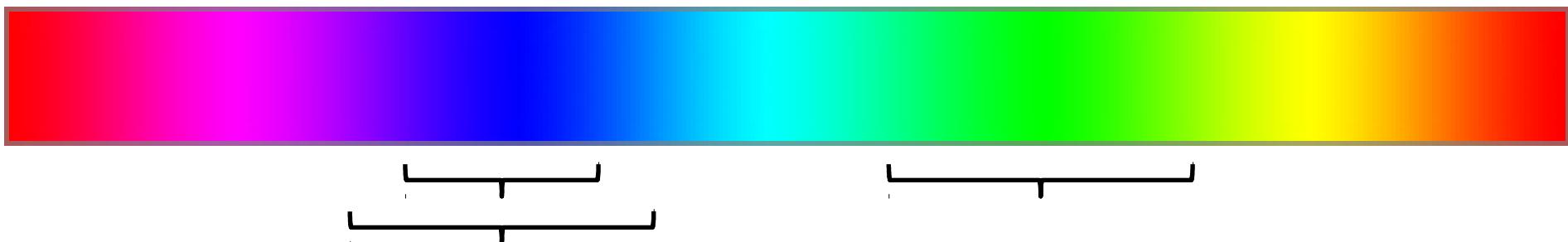
# Popout



**Mixing channels removes the effect**

# Colour

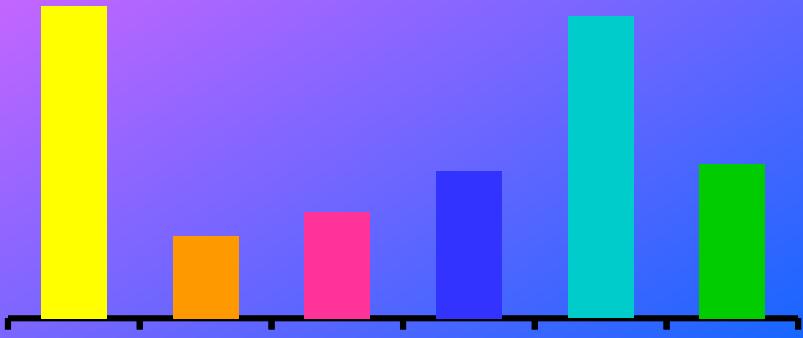
- Colour can be used to:
  - Highlight specific data
  - Group categories of data
  - Encode quantitative values
- Colours: primary, secondary, intermediate
- Our perception of hue is not linear



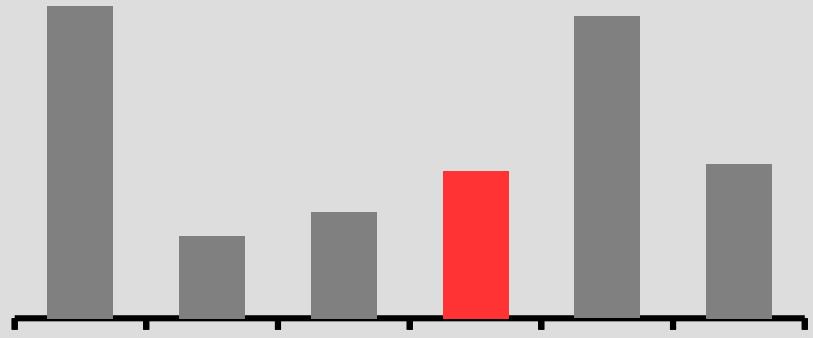
Don't let your  
**colours**  
distract from your  
message...

Instead, use colour  
to communicate

Don't let your colours  
overwhelm your data



Instead, use colour to  
emphasise your data



*Example based on Carter*

# Characteristics of a colour

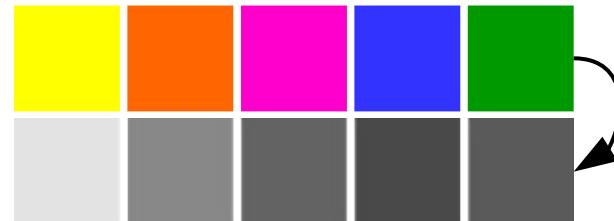
- **Hue:** the *actual* colour (qualitative)



- **Saturation:** the intensity of the hue (quantitative)



- **Value:** the lightness/ darkness of a colour (quantitative; useful to know how a colour will behave when transformed to grayscale)



Convert to  
grayscale

- **Lightness**

- **Shade:** the amount of black
  - **Tint:** the amount of white



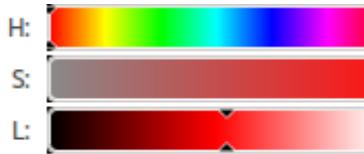
# Colour: How computers identify colours



**CMYK:** percentage of Cyan + Magenta + Yellow + Black



**RGB:** intensity of Red + Green + Blue



**HSL:** Hue + Saturation + Lightness

**Hexvalue:** 0 to F values of Red, Green, Blue. 0: no intensity. F: maximum, *what colour is this?* #FF 00 00

	#ff00ff	rgb(255, 0, 255)	hsl(300, 100%, 50%)
	#ff0000	rgb(255, 0, 0)	hsl(0, 100%, 50%)

Colour in screen and in print usually differ slightly (especially greens). To match them, the screen has to be calibrated (a cumbersome process!).

Playing with colours: [http://www.w3schools.com/colors/colors\\_picker.asp](http://www.w3schools.com/colors/colors_picker.asp)

# Three ways to name colours in R

1. By **name**, see available colours using **colors()**, and the list with the actual colours:

<http://www.stat.columbia.edu/~tzheng/files/Rcolor.pdf>

2. Using **hexadecimal**, e.g. “#**00FF00**”, or “#**00FF0055**”  
(the 7<sup>th</sup> and 8<sup>th</sup> digits, if any, correspond to opacity)

3. Converting **RGB** to hexadecimal, using the function  
**rgb**, e.g. **rgb(1, 1, 1)**

# Colour palettes



**Sequential:** between two values or colours.  
For quantitative distinctions.



**Divergent:** colours diverge in opposite directions from a central value.  
Quantitative and qualitative.



**Categorical:** no order in the colours.  
Qualitative.

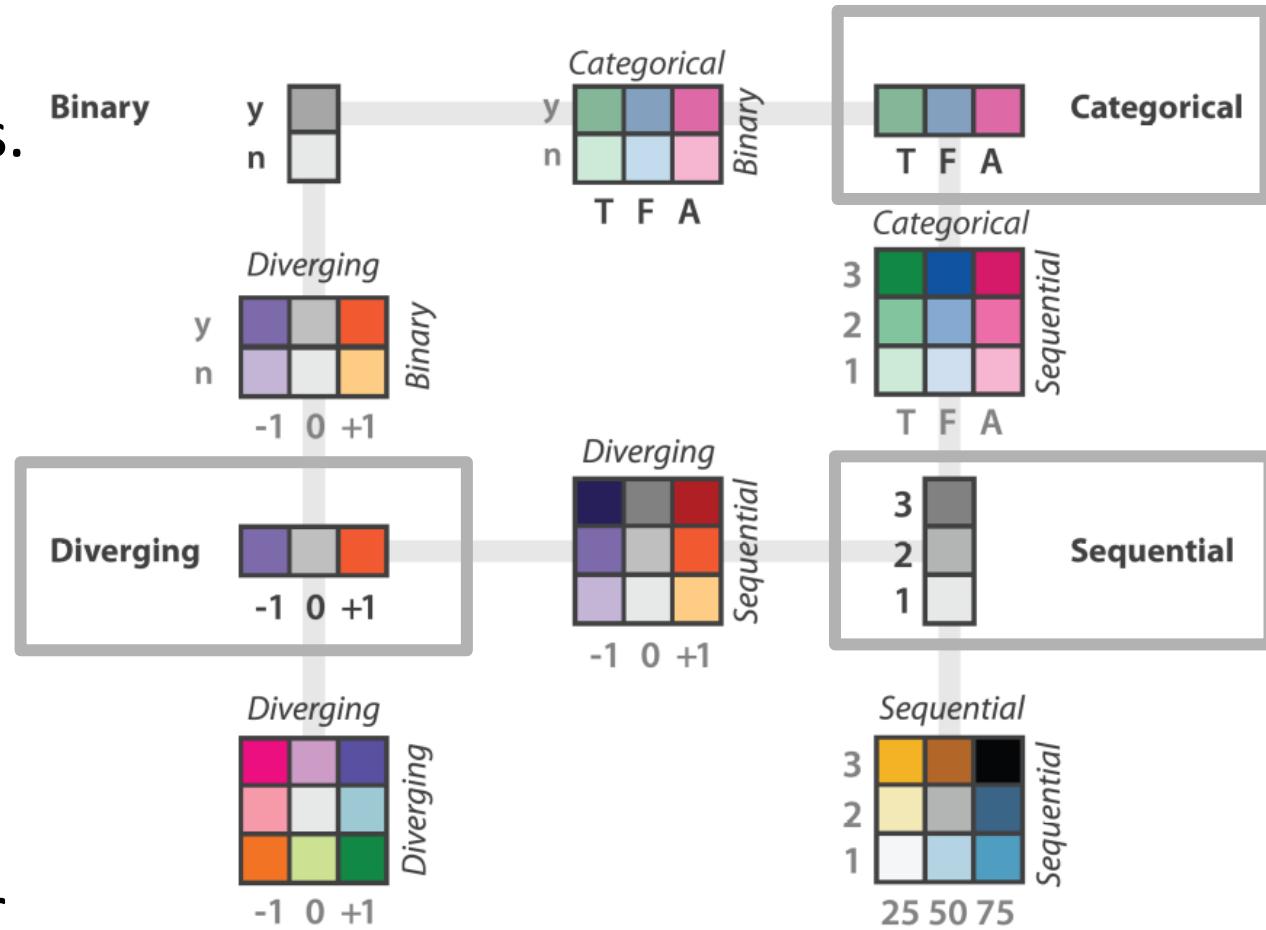
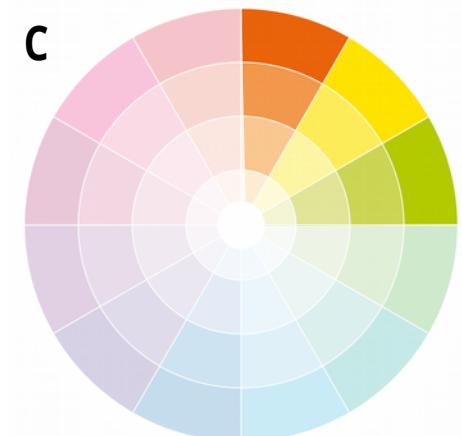
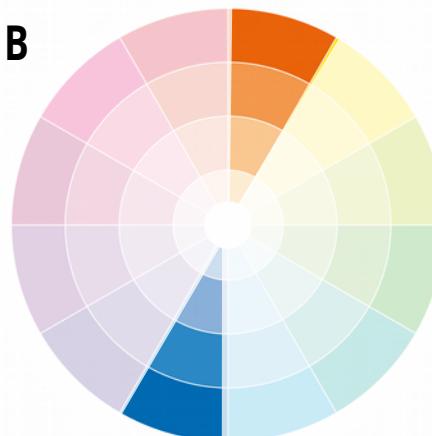
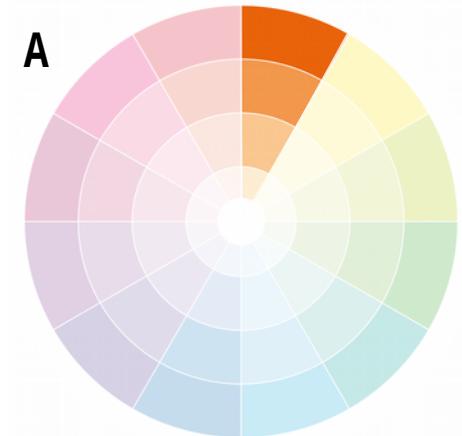


Image from Munzner after "Color use guidelines for mapping and visualization. Brewer 1994"

# Colour: Choosing palettes

- The **colour wheel**. Choose combinations that are:
  - Monochromatic**: for a uniform look
  - Complementary**: to highlight differences between categories
  - Analogous**: for both
- Online colour pickers  
e.g. <http://colorbrewer2.org/>



# Colour: Choosing palettes

- Principles for choosing colours:
  - **Contrast**
  - Colour **blindness**
  - Black and white/ **grayscale** printing
  - How many **separable** colours in a legend?
- “*Black and white are colours, too*”

# Contrast

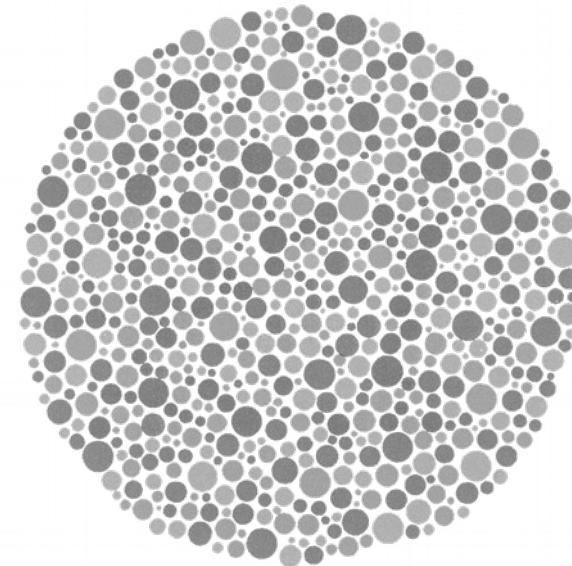
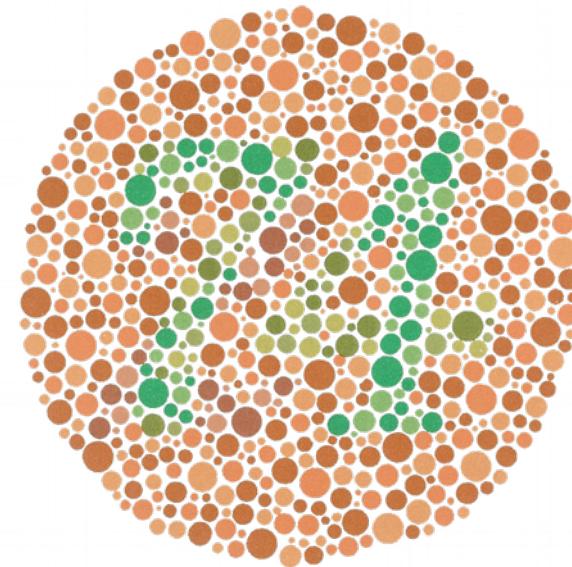
Fine detail (e.g. text) needs good contrast to be visible

Beware of patterned backgrounds



# Colour Blindness

- Affects 1:12 men and 1:200 women worldwide
- *“If a submitted manuscript happens to go to three male reviewers of Northern European descent, the chance that at least one will be colour blind is 22 percent.”*

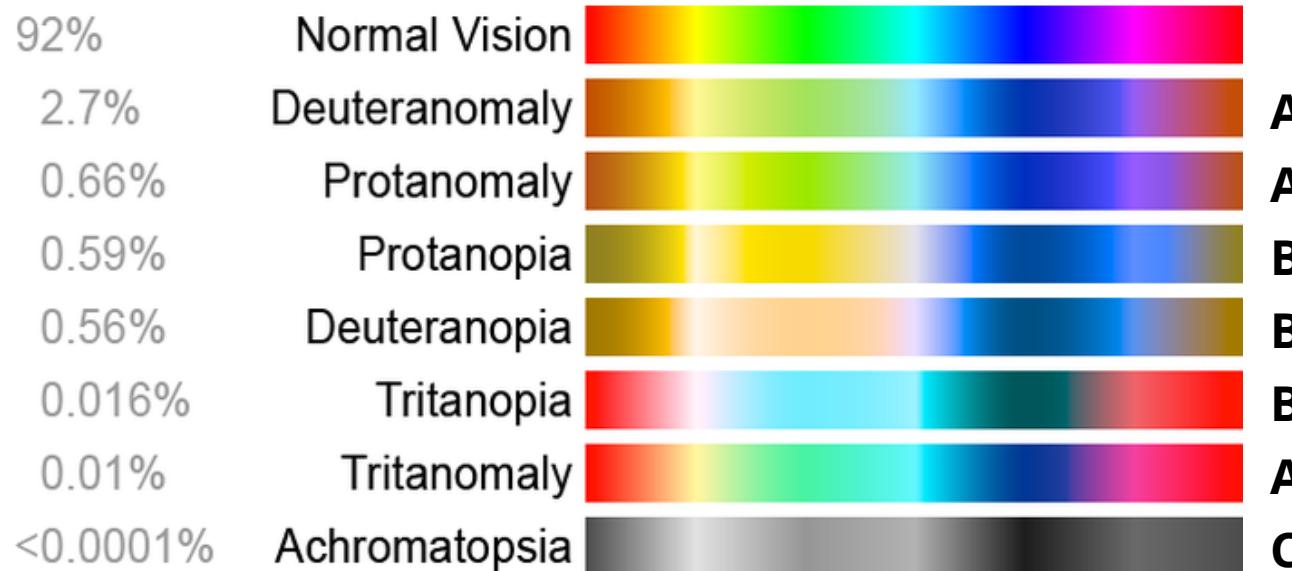


# Types of colour blindness

Normal vision: trichromacy (all 3 primary colours)

Colour deficient vision:

- A. **Anomalous Trichromacy**: unusual 3 colour vision
- B. **Dichromacy**: 2 colour vision
- C. **Monochromacy**: black and white vision



# Colour: Choosing palettes

- Principles for choosing colours:
  - **Contrast**
  - Colour **blindness**
  - Black and white/ **grayscale** printing
  - How many **separable** colours in a legend?
- “*Black and white are colours, too*”

# Colour tools in R

## Colour ramps:

```
# rainbow, heat.colors, topo.colors, terrain.colors,  
cm.colors  
plot(1:5, col=palette(terrain.colors(7))), pch=15, cex=3)
```

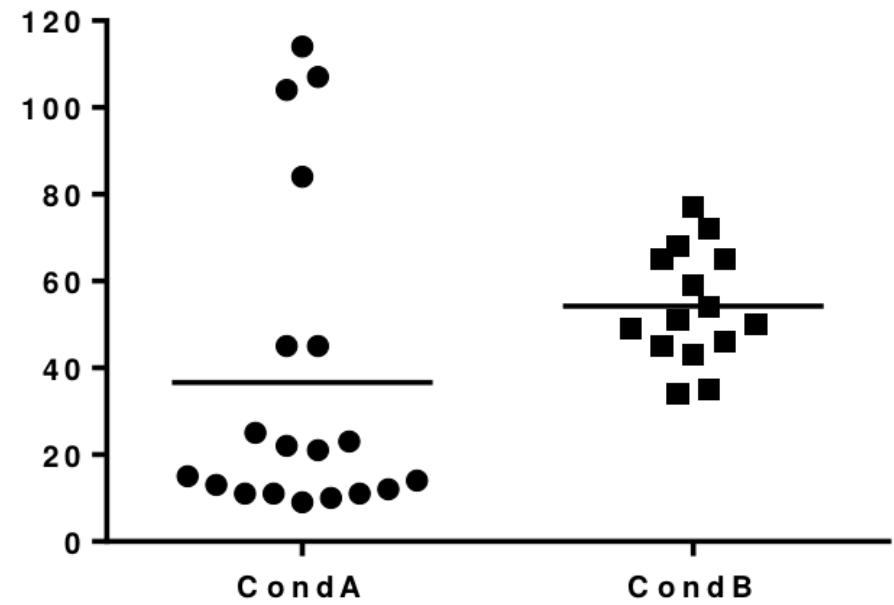
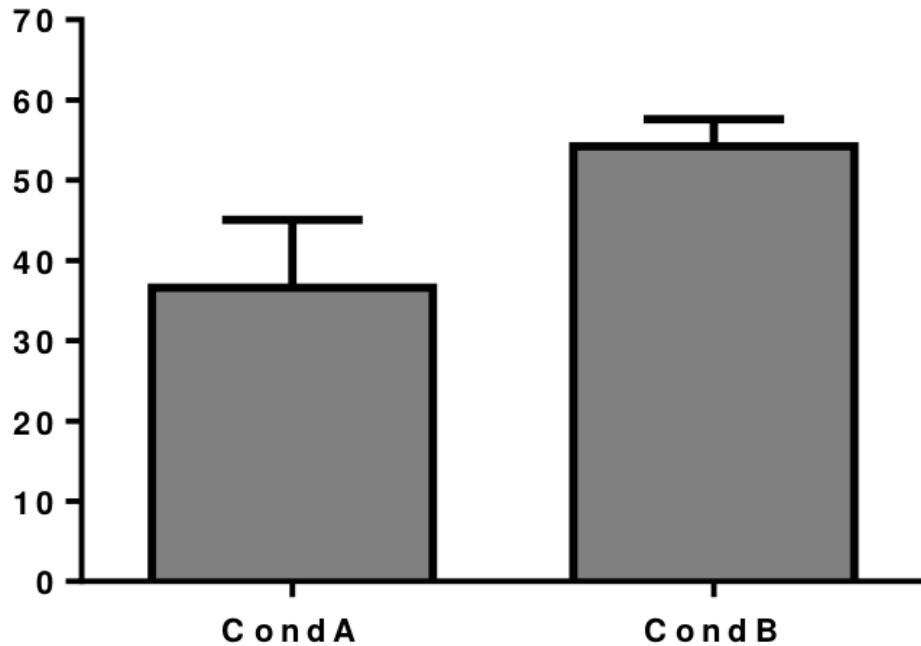
## RcolorBrewer:

```
# install.packages("RColorBrewer")  
library(RColorBrewer)  
# check out the available palettes  
display.brewer.all(n=NULL, type="all",  
                      select=NULL, exact.n=TRUE)  
brewer.pal(5, "Set1")
```

# Ethics of data representation

- The figure/graph/image should show **what is actually happening** and **not what you want to happen**
- Different ways of being unethical:
  - Not exploring/getting to know the data well enough
  - Misusing your chosen graphical representation
  - Deliberately showing the data in a misleading manner
  - Choosing the ‘most representative’ image/experiment

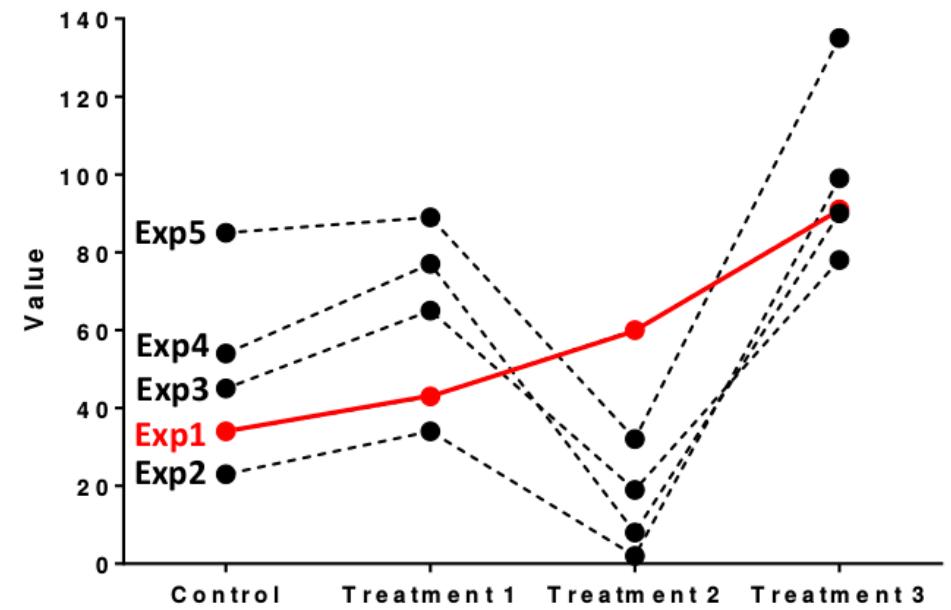
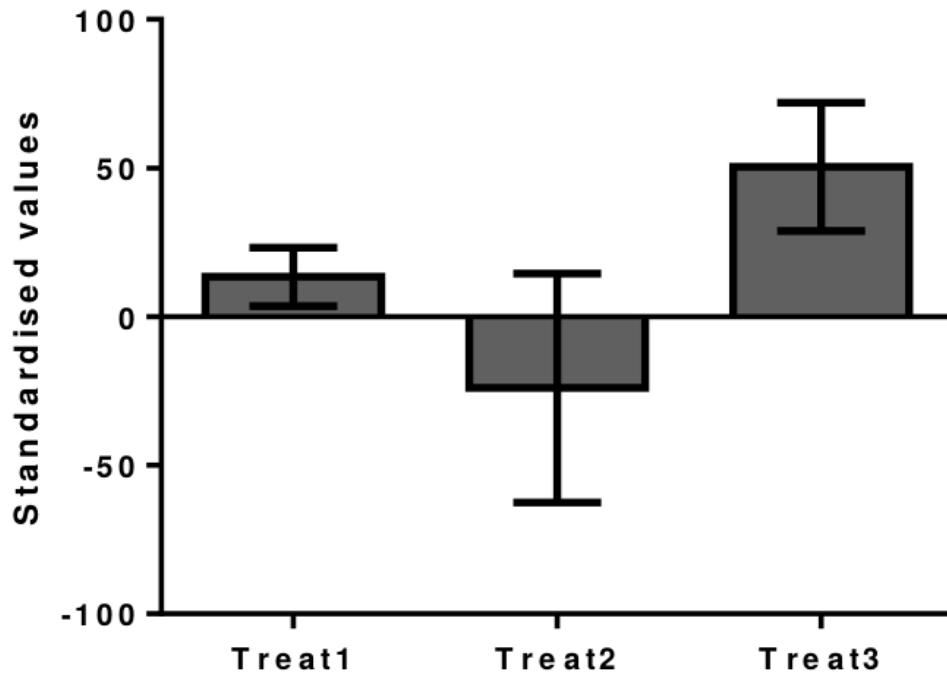
# Not exploring/getting to know the data well enough - Example 1



**One experiment:** change in the variable of interest between CondA to CondB.

✗ Data plotted as a bar chart.

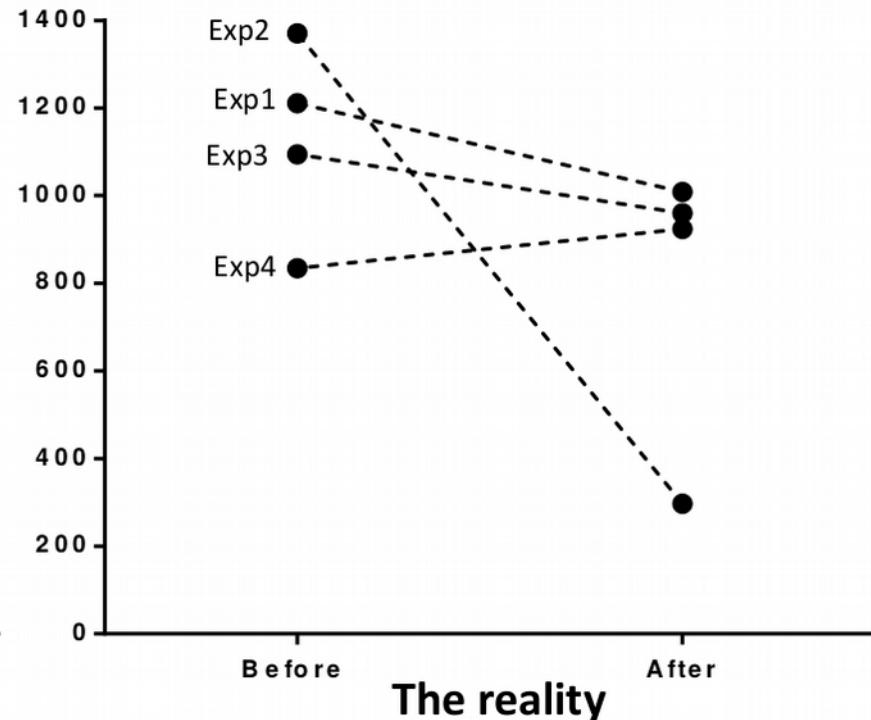
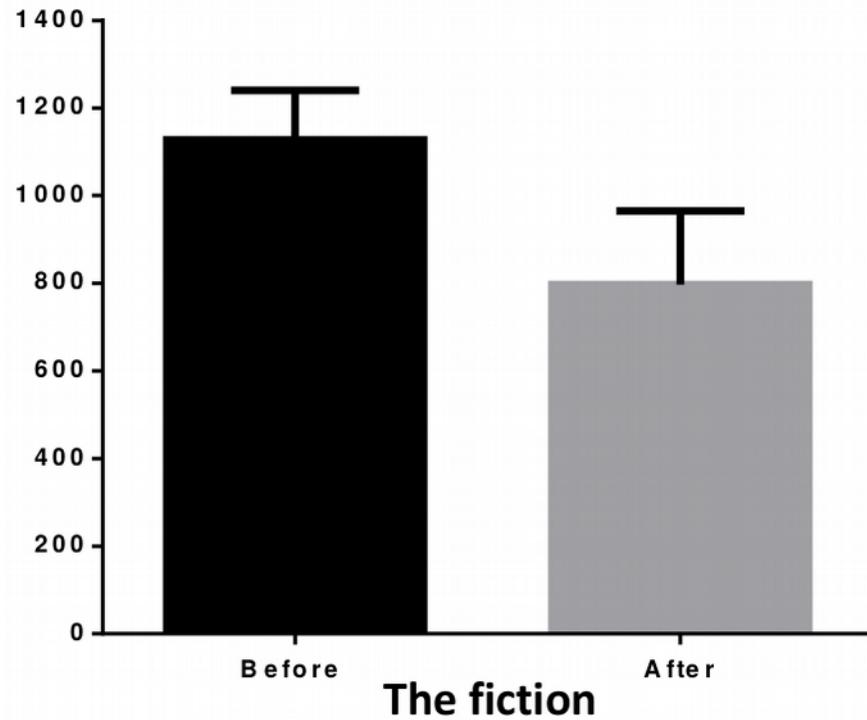
# Not exploring/getting to know the data well enough - Example 2



**Five experiments:** change in the variable of interest between 3 treatments and a control.

✗ Data plotted as a bar chart.

# Choosing the wrong graph to present

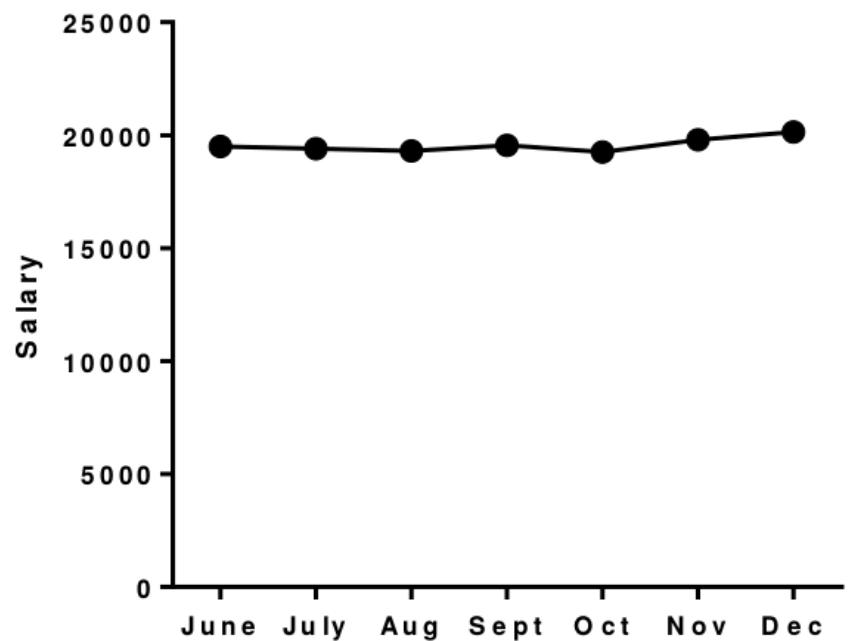
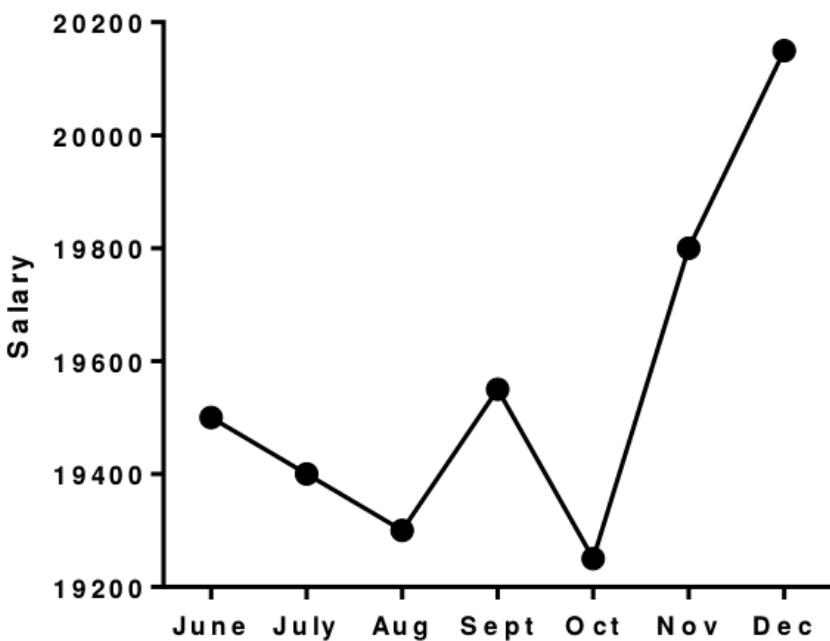


**Four experiments:** Before-After treatment effect on a variable of interest. **Hypothesis:** Applying a treatment will decrease the levels of the variable of interest.

✗ Data plotted as a bar chart.

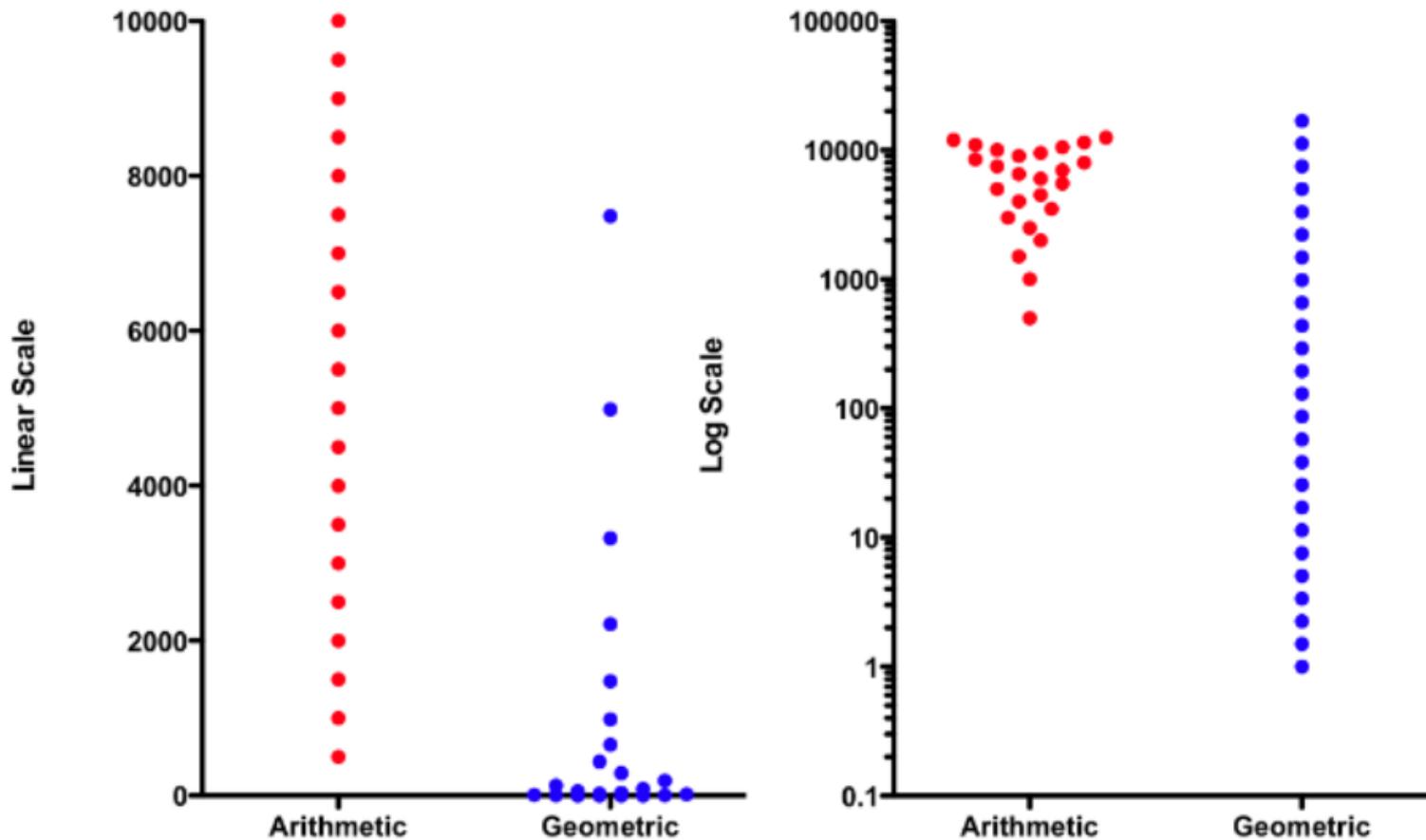
# Choosing the wrong axis/scale

Example: increase in salary in the last term



# Choosing the y-axis/scale

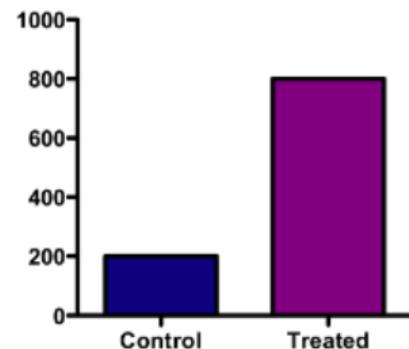
Be careful with Linear vs. logarithmic scale.



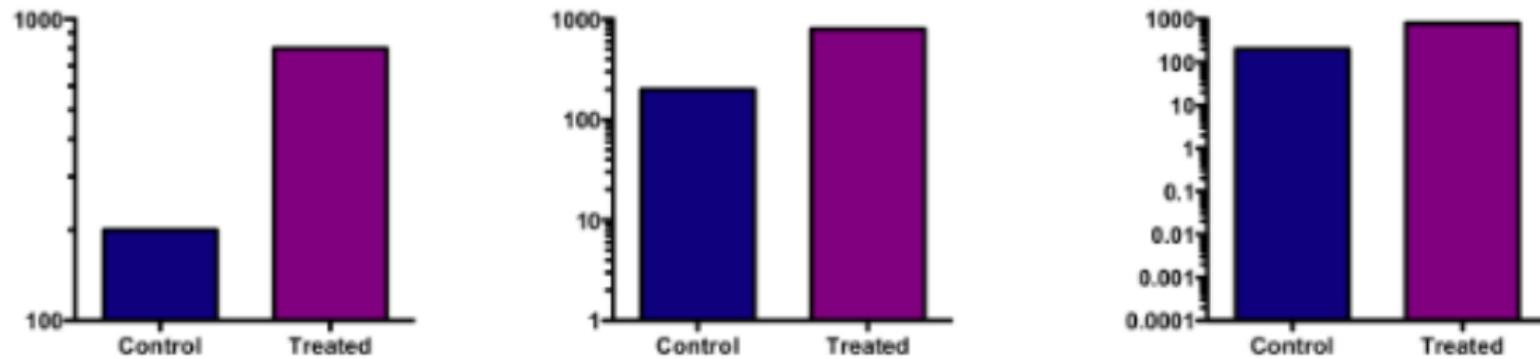
# Choosing the y-axis/scale

For cheating, a bar graph using a log axis is a great tool, as it lets you either exaggerate differences between groups or minimize them.

Linear

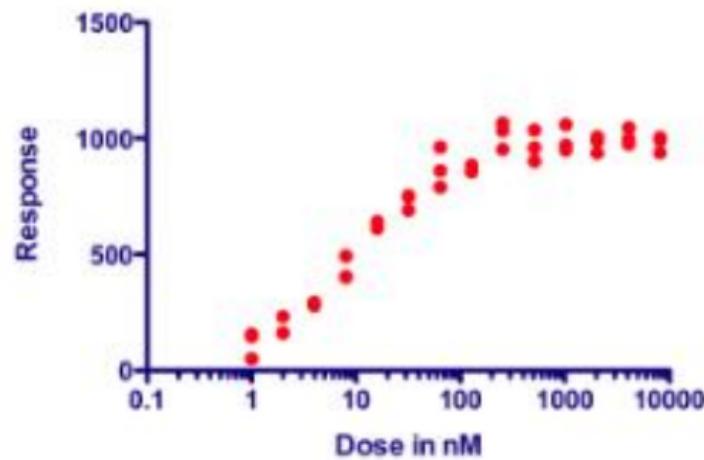
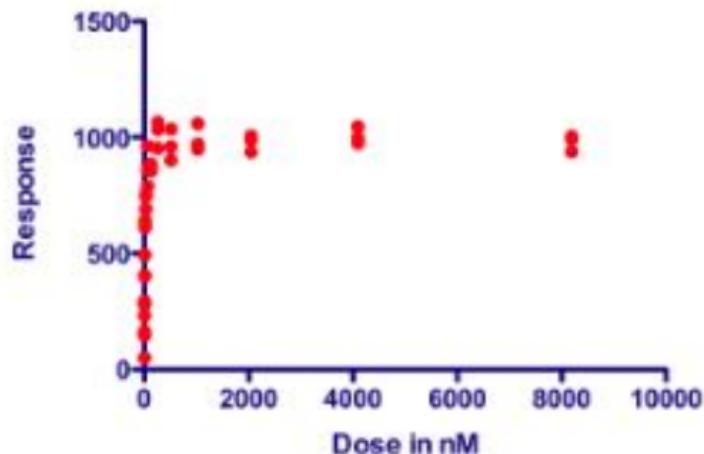


Logarithmic

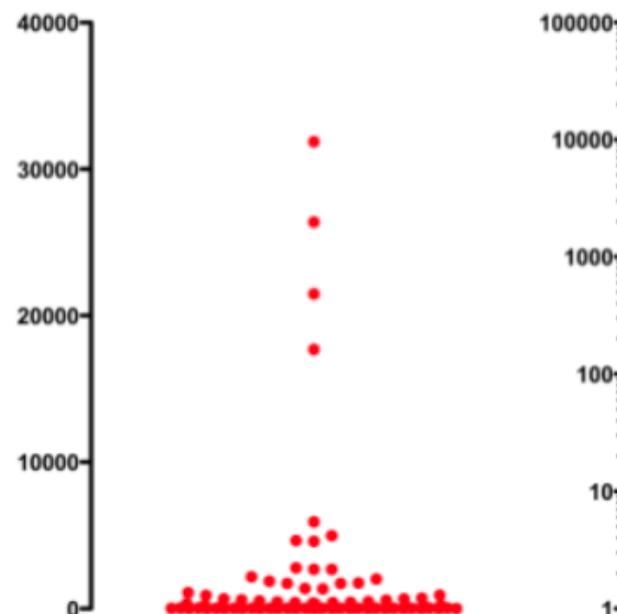


# Logarithmic axis should be used for:

Logarithmically  
spaced values



Lognormal data

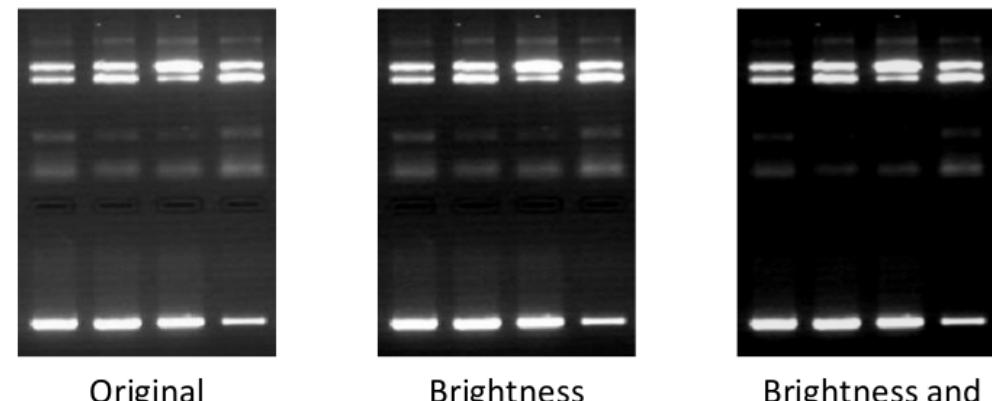
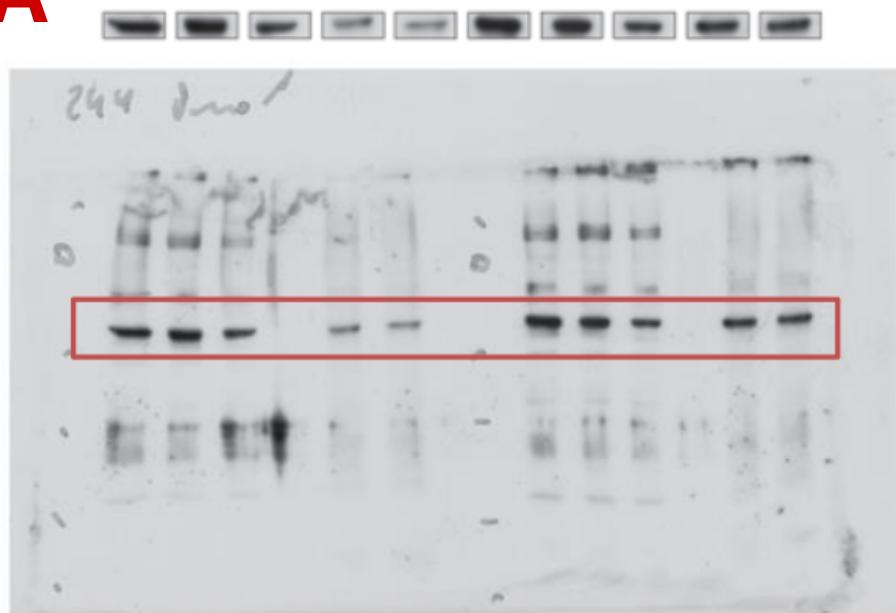


# Simply Cheating

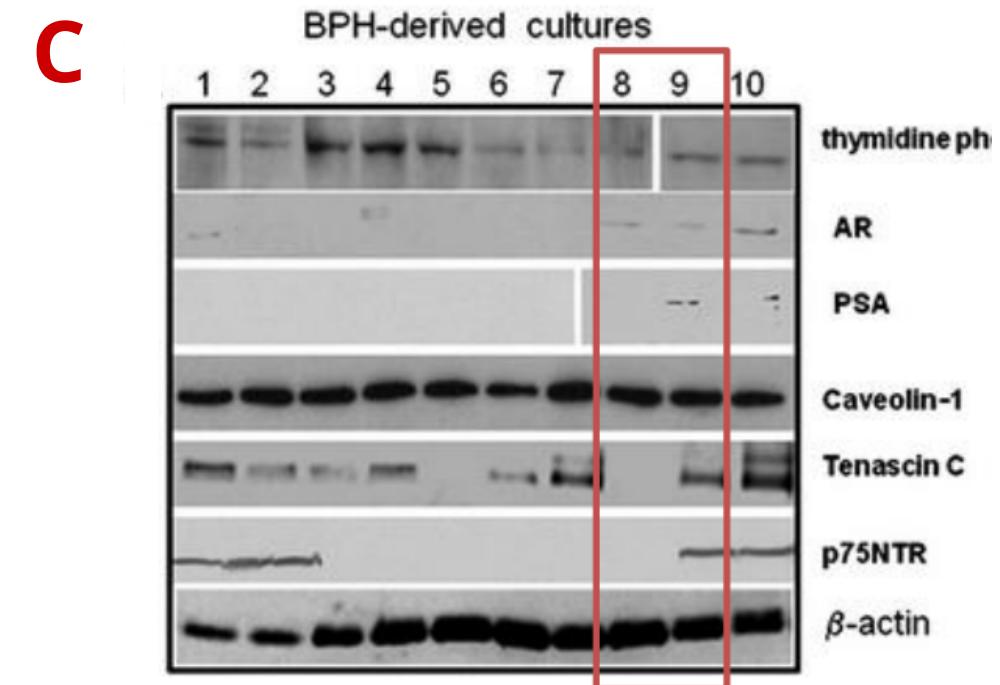
## Manipulating images: Western blot

- A) Presenting bands out of context
- B) 'Playing' too much with contrast
- C) 'Rebuilding' a Western blot from several cuts

A



B



C

# Is my plot ethical?

- Would a reader come to a different conclusion if they could see the details of the data which were omitted from the plot?

# Practical



**GIMP**  
For editing bitmap  
images (photos)