Principles of Data Visualization 2

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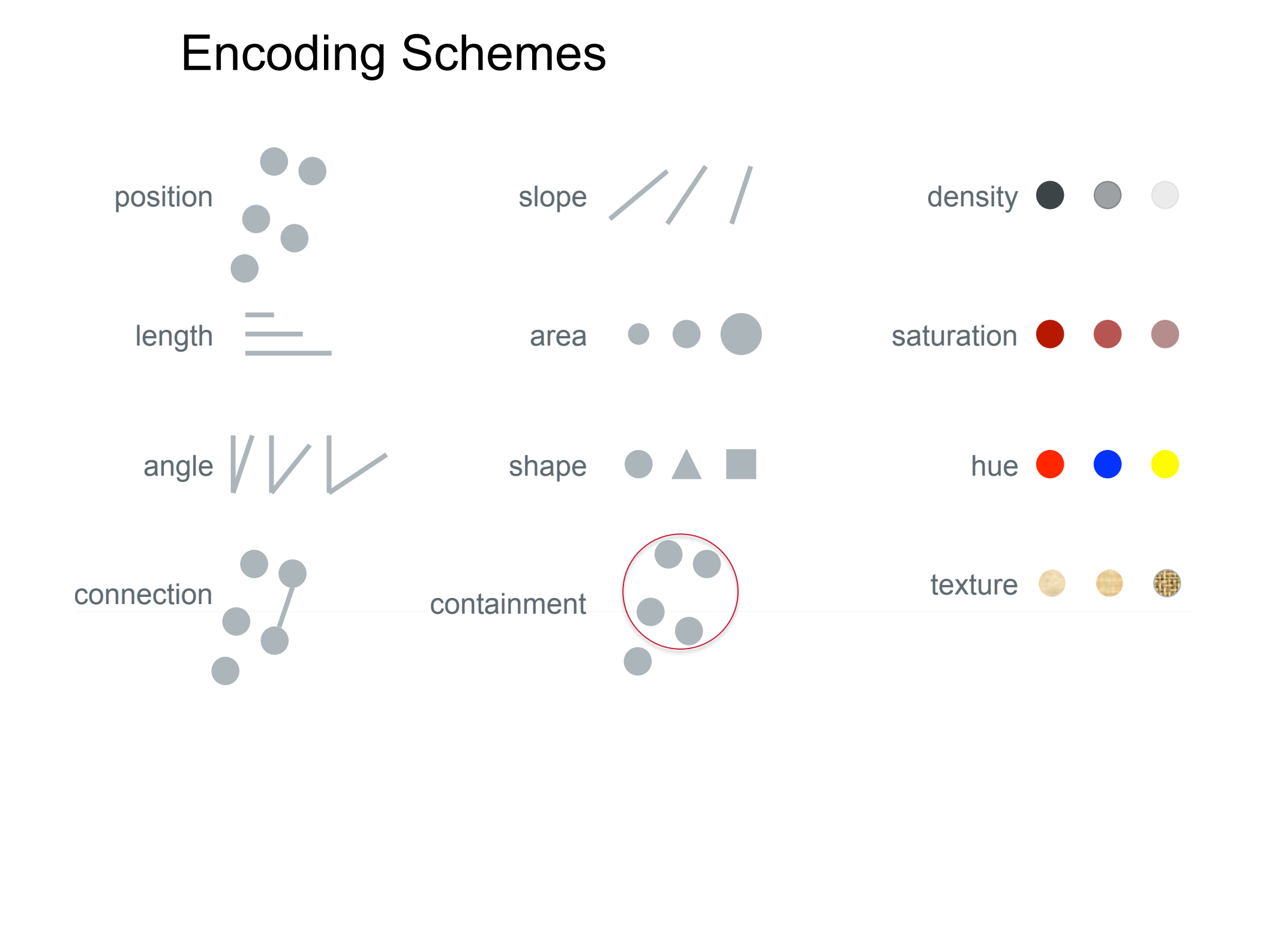
URPP Evolution in Action

Outline

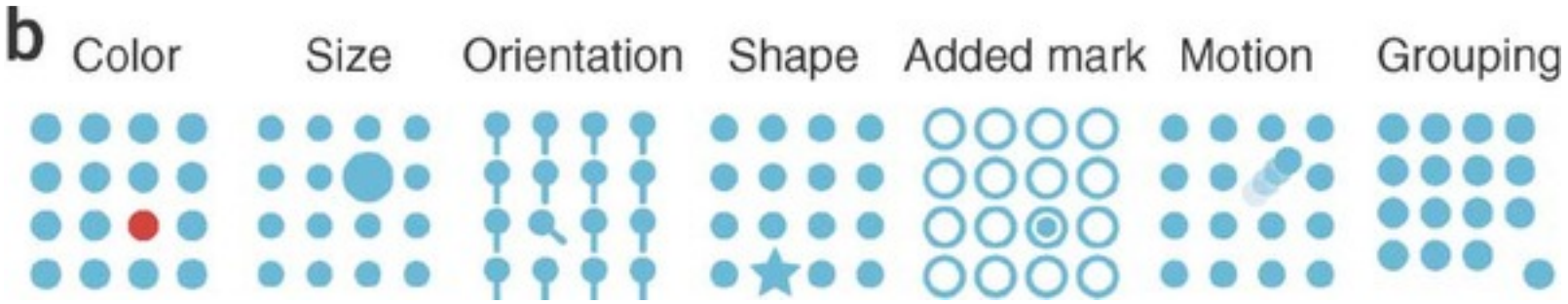
1. The properties of the data or information (HTL)
2. Use of salience, colors, consistency and layout (HTL)
3. The rules mapping data to images (SW)
4. Examples of effective visualizations in biology (SW)
5. Presentation and discussion of “good” and “bad” graphics (HTL & SW)

Encoding Schemes



Salience ("Pop out")

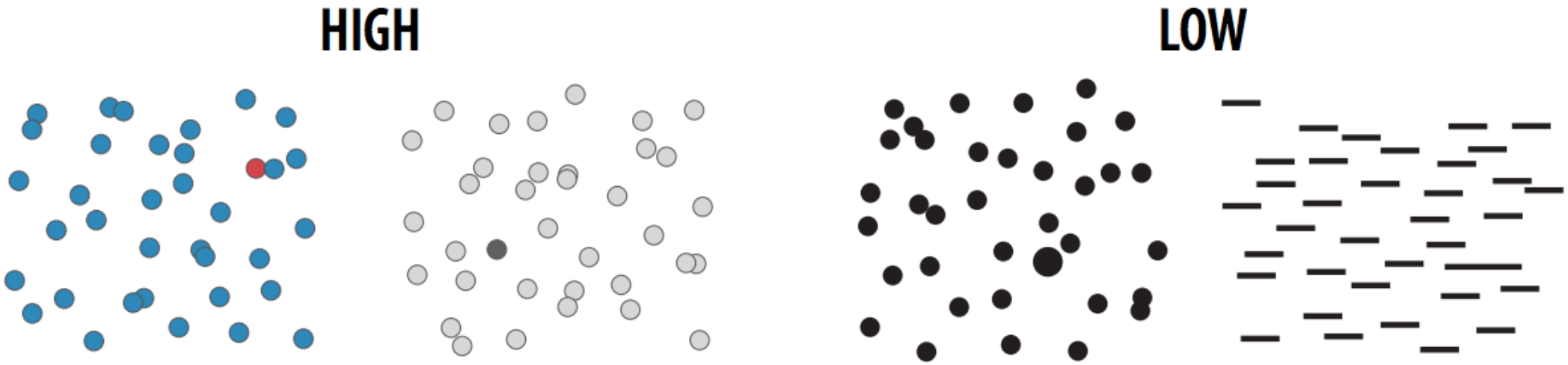
- Distinct features have high salience
- Choose salient encodings for primary navigation



- Focus attention by increasing salience of interesting patterns
  The reader will use salience to suggest what is important
- Context affects salience
- Color is good for categories - salience decreases with more hues/colors

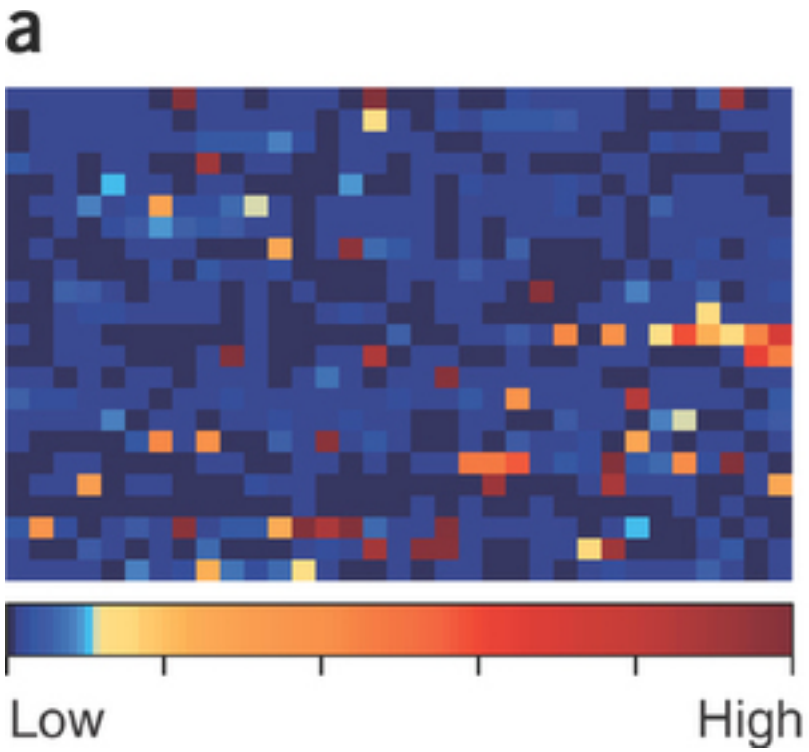
http://www.nature.com/nmeth/journal/v7/n10/full/nmeth1010-773.html

Salience



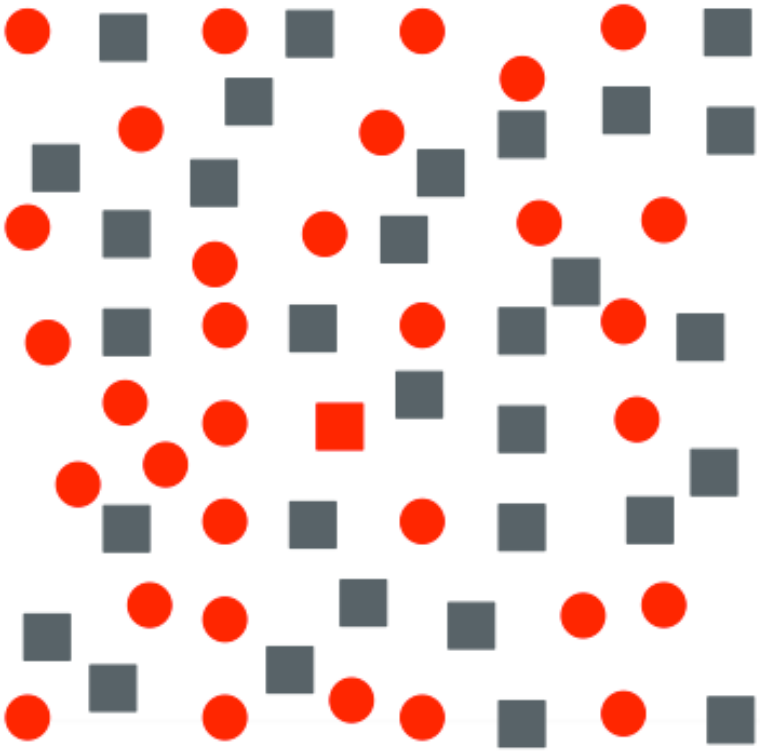
Fecteau JH, Munoz DP (2006) Salience, relevance, and firing: a priority map for target selection. Trends Cogn Sci 10: 382-390.
Yantis S (2005) How visual salience wins the battle for awareness. Nat Neurosci 8: 975-977.

Discordances between salience and relevance



- a color scale that makes common sense
- lower values are actually more salient than higher ones because deep red is hard to see against the deep blue background of the lowest values

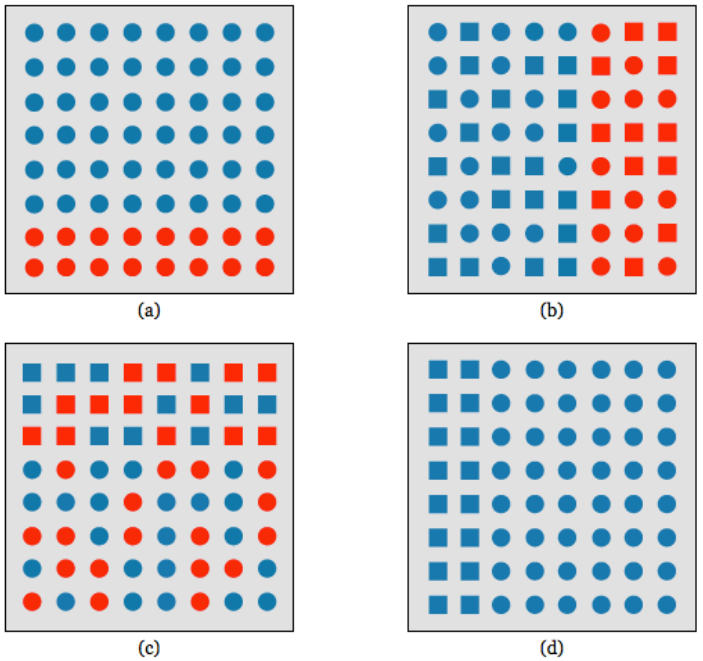
Visual interference



- Spot the red square
- difficult to detect
- serial search required

Katy Borner

Feature Hierarchy in the visual system



b) random variations in shape have no effect on a viewer's ability to see colour patterns
c) random variations in color have a strong effect on a viewer's ability to see shape patterns

- Color > Shape
- Interactions between different visual features hide or mask information in a display
- We want to choose a data-feature mapping that does not produce visual interference

https://www.csc.ncsu.edu/faculty/healey/PP/

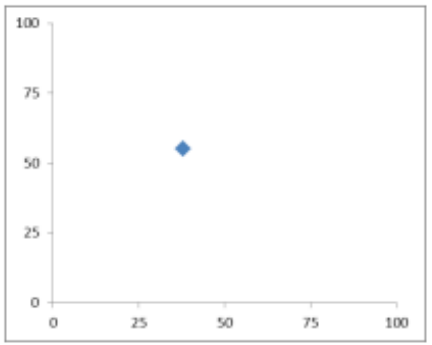
Bertin's Image Theory

- We can only perceive 3 variables (2 planar and 1 retinal) "efficiently" (preattentive, without additional attention)

PLANAR

Spatial dimension 1

Spatial dimension 2



RETINAL

Texture

Color

Shape

Orientation

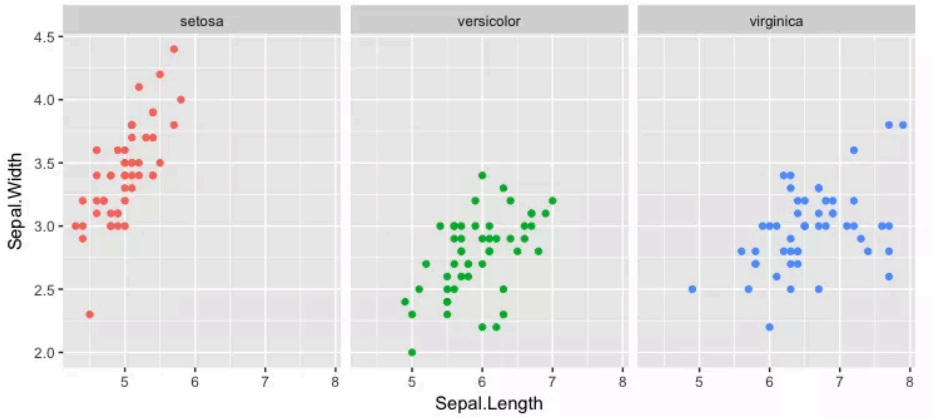
Size

Brightness

- We can not effectively visualize 4 or more dimensions on a 2-d display

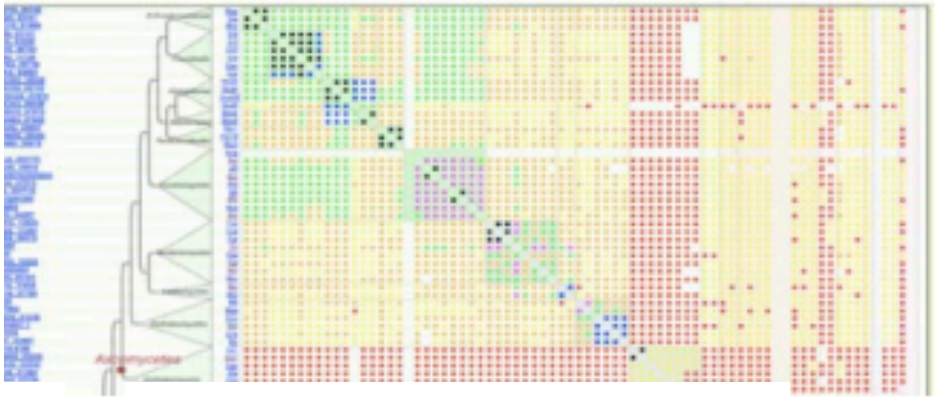
Solution 1

Small Multiples (Facets)



each view uses the same
visual encodings
but shows a different data set

Multiple (coupled) windows



Katy Borner

Solution 2: Interaction / Operations on the data

Overview first, zoom and filter, then details on demand

Search, filter, select

Zoom, Pan

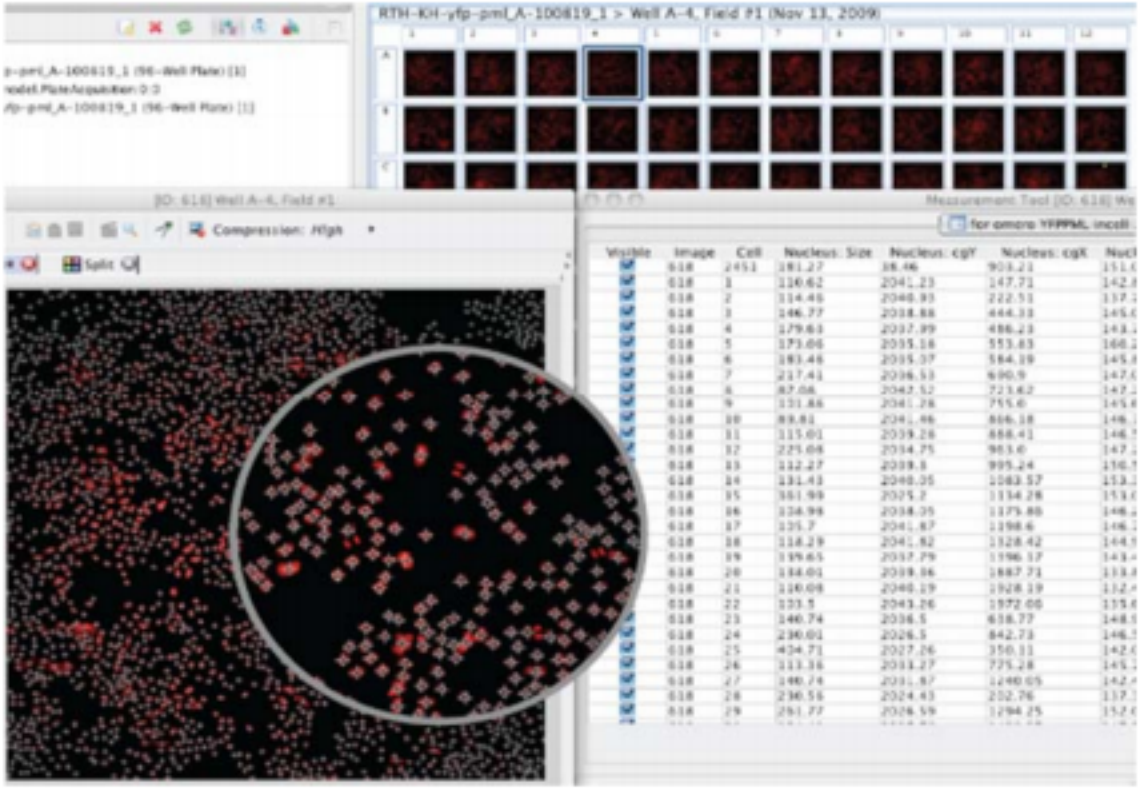
Pruning

Brushing

Details on demand

Focus & context

User status



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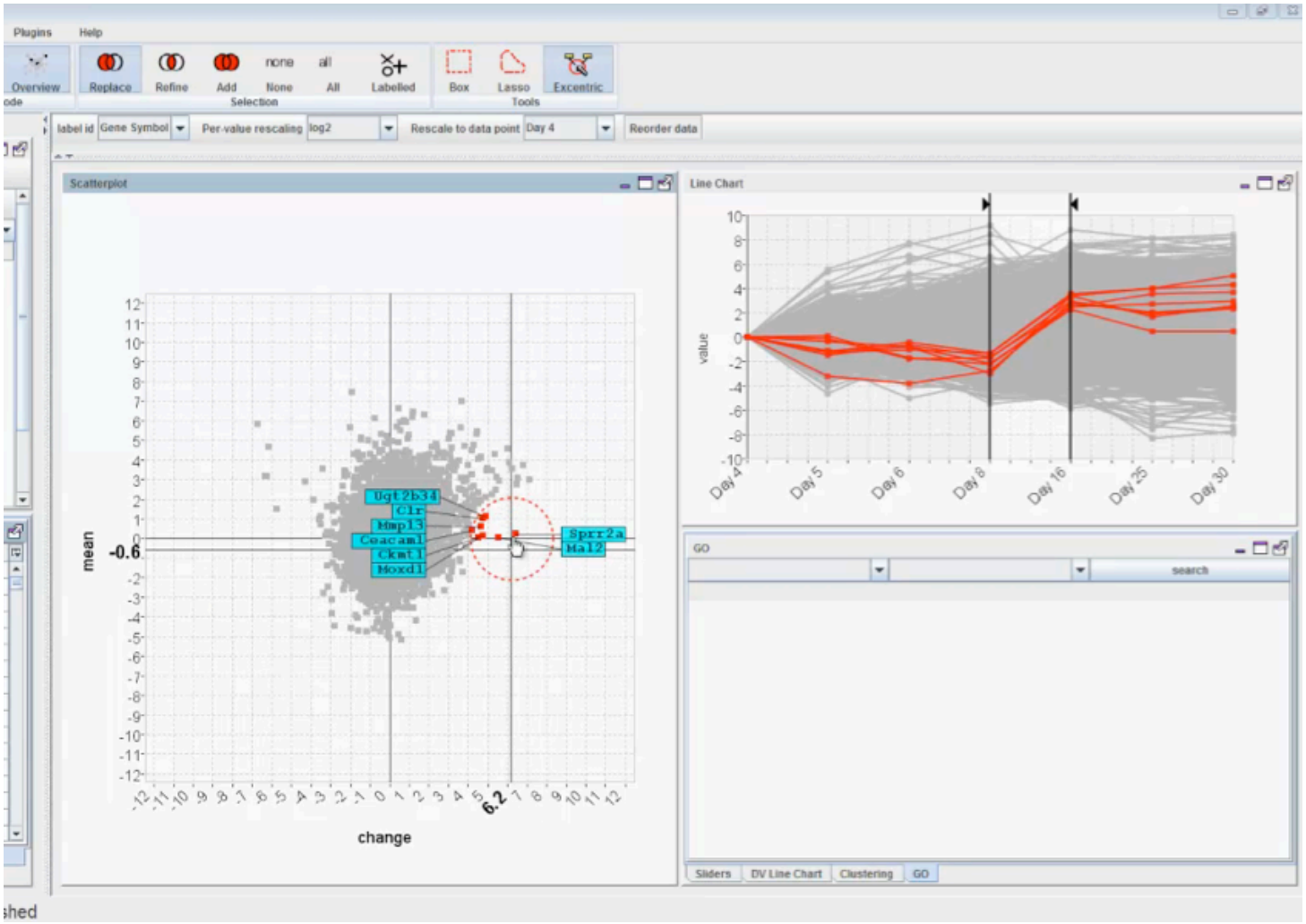
Solution 3: Interaction / Linked views

allow the user to have a dialog with the data

Time-series expression data



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Examples of effective visualizations in biology

Is a graphical representation really necessary?

Is the legend enough?

What is my message?

Does my figure communicate it clearly?

Are there extraneous or ornamental elements?

What can I remove without changing the overall story?

modified from M. Krzynwiski

The reader does not know what they need to know.

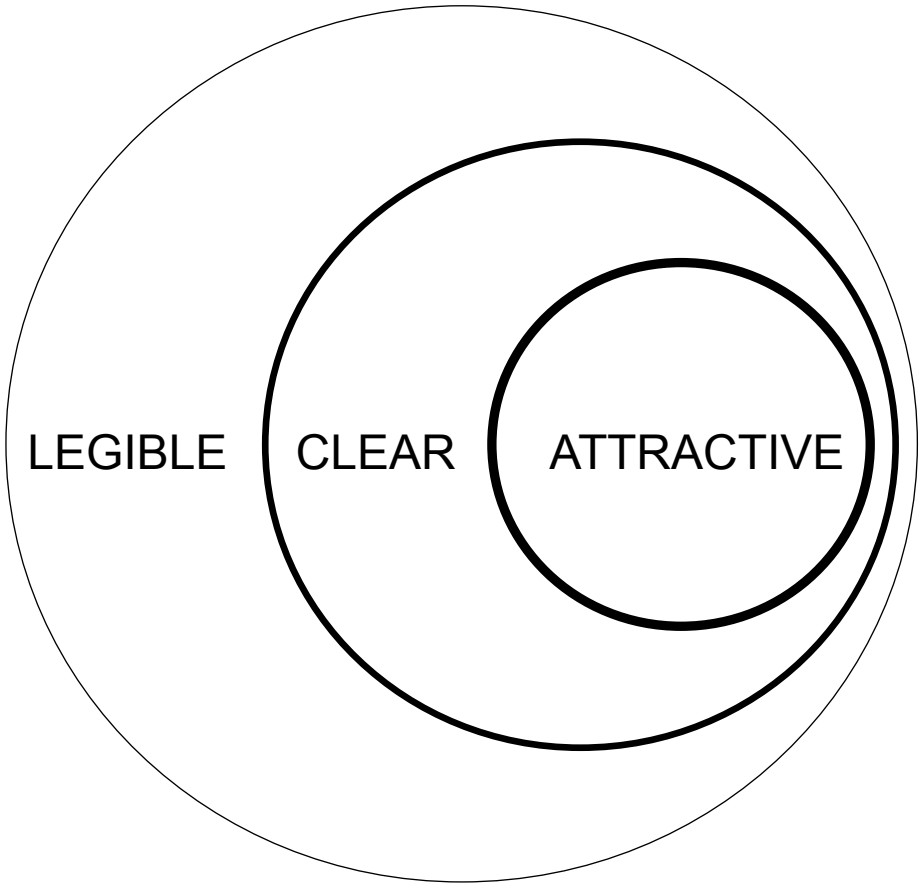
You must tell them.

The reader does not know what is important.

You must show them.

The reader's cognitive and visual acuity are limited.

modified from M. Krzywinski



quality of communication

GOOD

BETTER

BEST

M. Krzywinski

LEGIBLE

are all elements discernable?

does text contrast well with background?

is there simultaneous contrast?

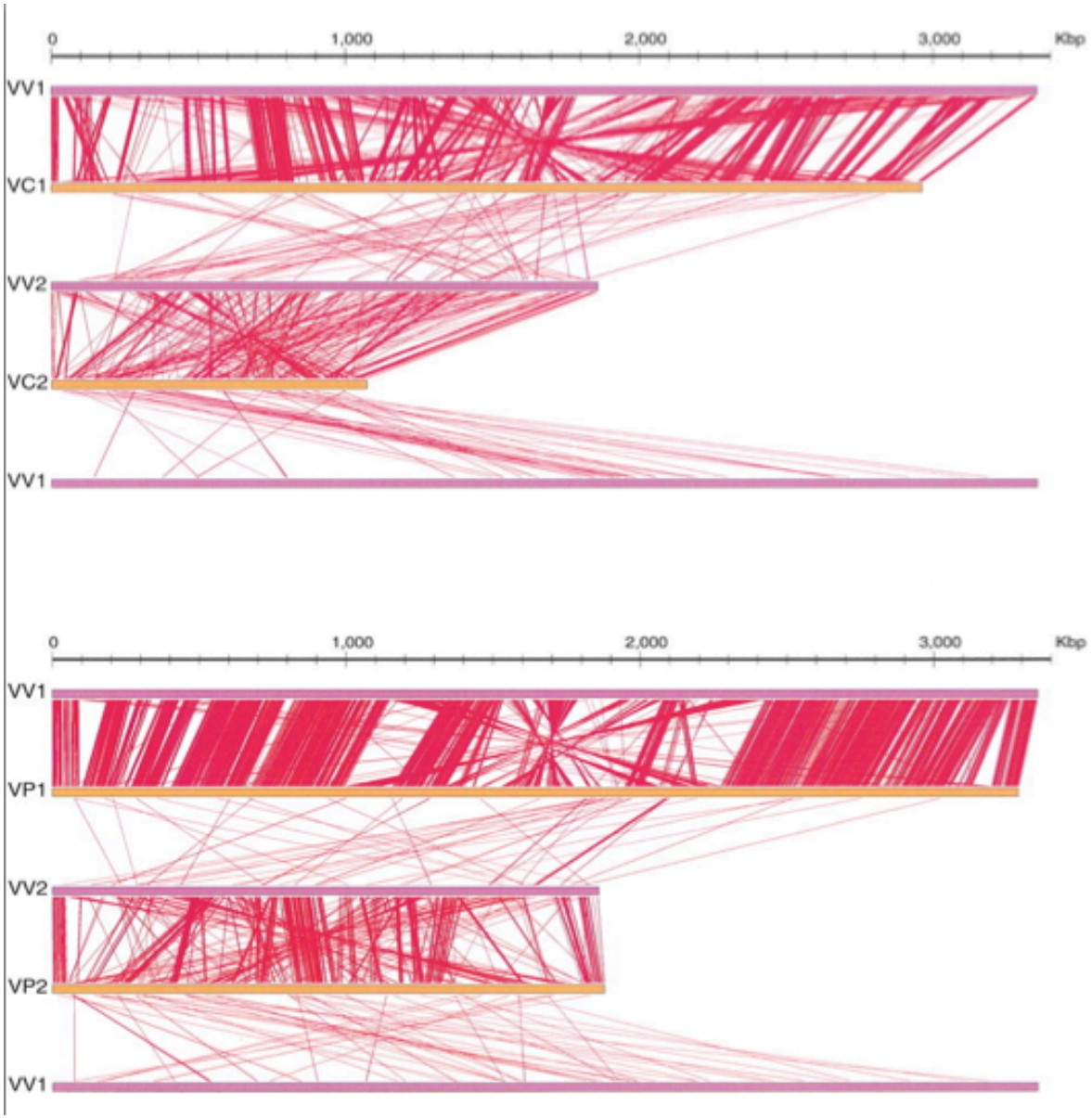
RESOLUTION

PARSABILITY

COLOR

M. Krzywinski

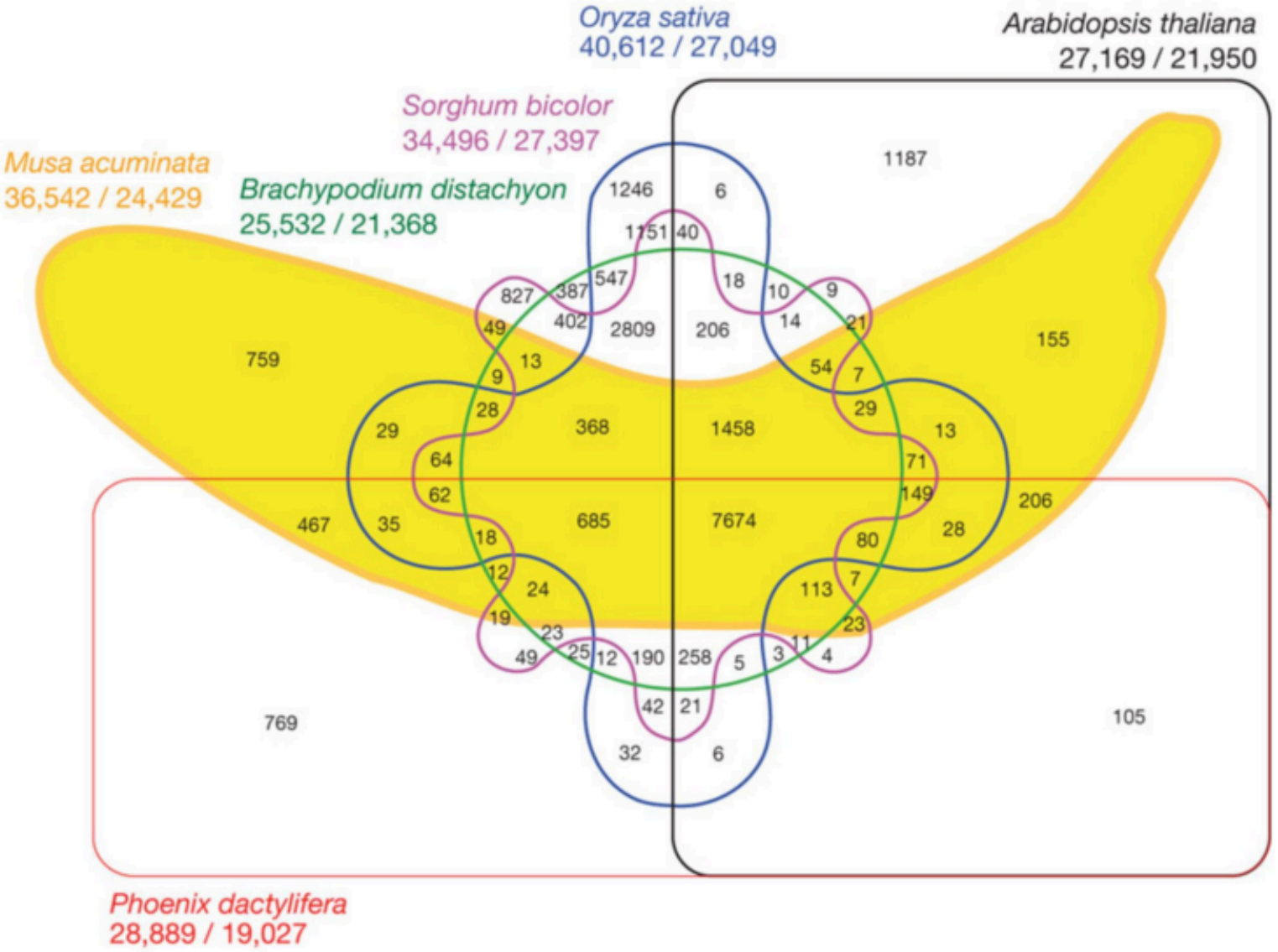
Help the reader identify meaningful patterns



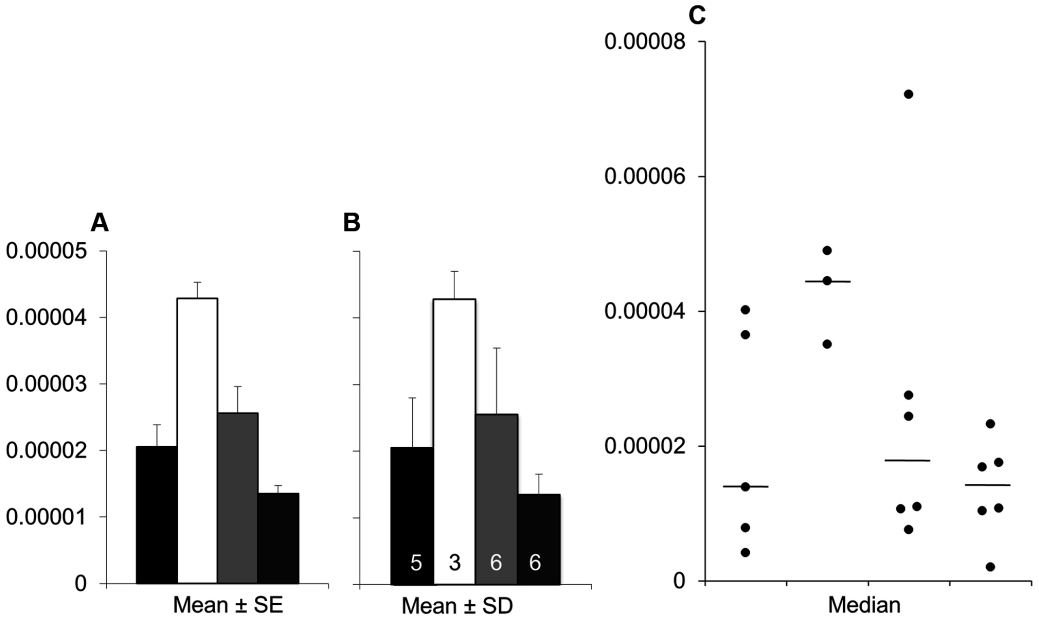
Intra- and interchromosomal shuffling of Vibrio genes

M. Krzywinski

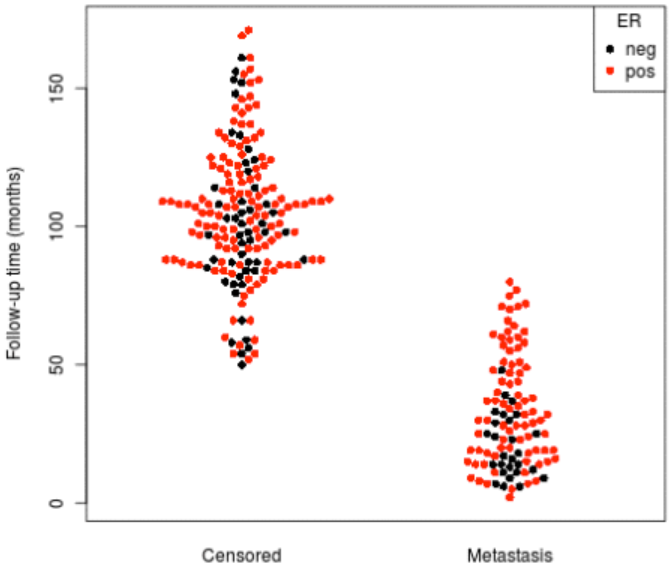
What is my message?



Show the raw data (<100 points)

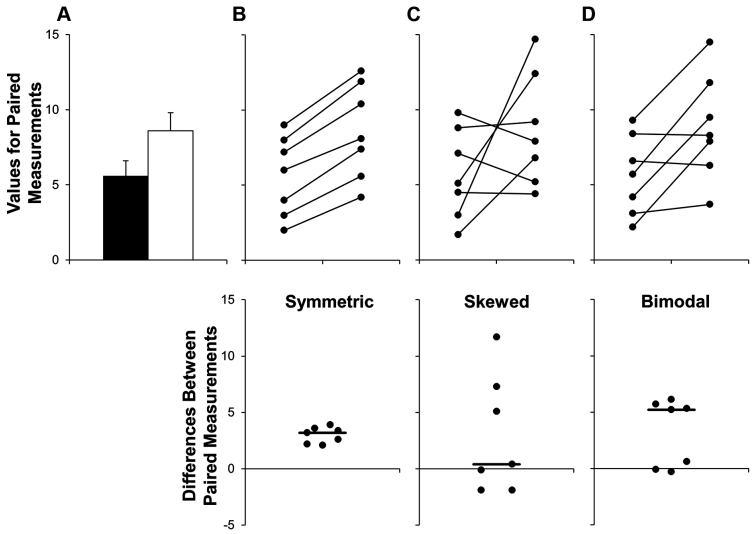


or
Boxplots



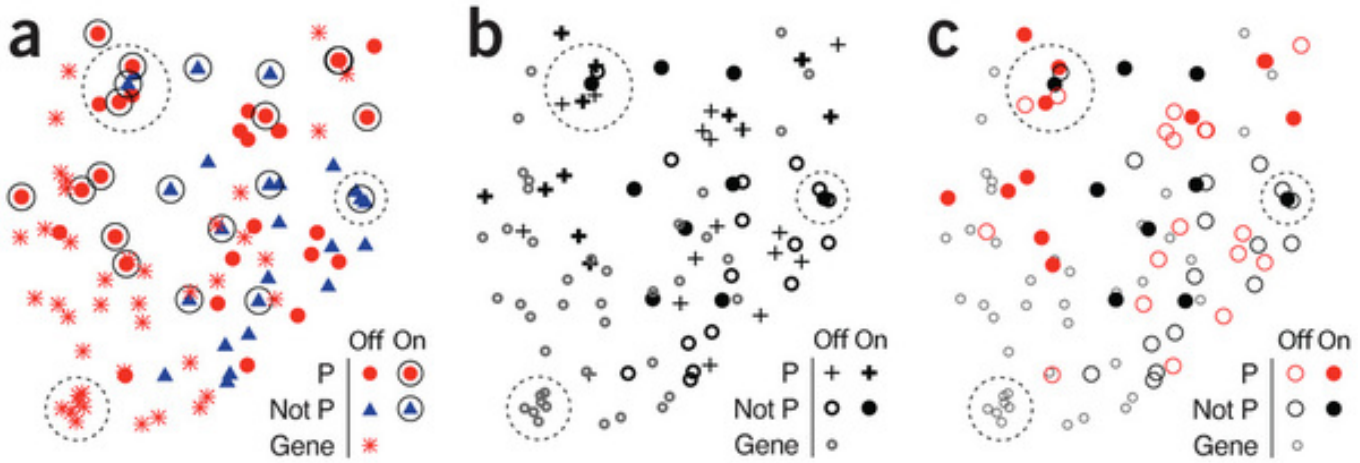
http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002128

Paired Measurements



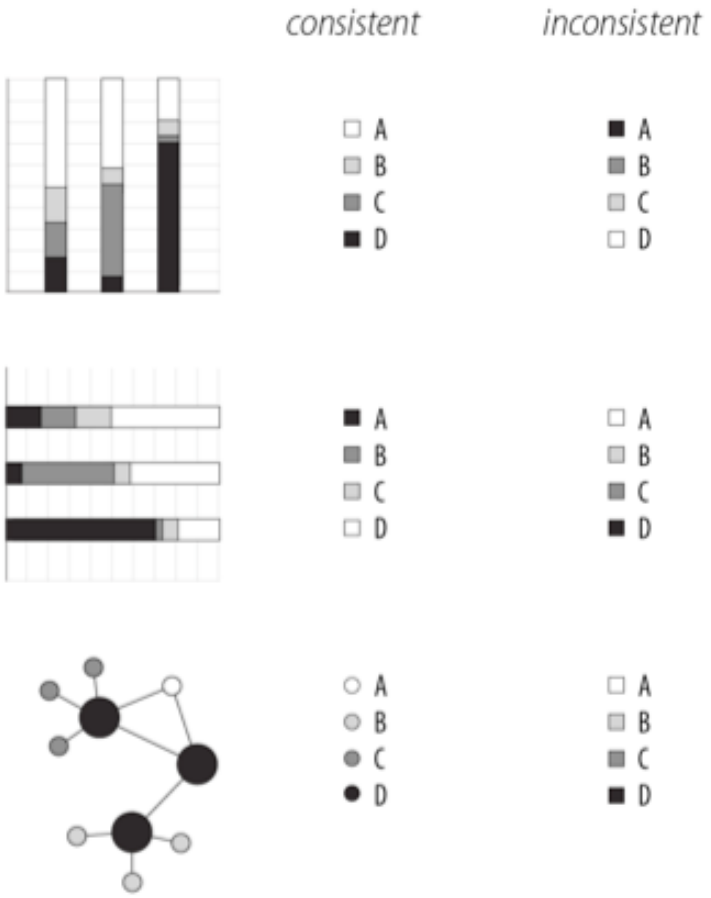
Good legends

Natural hierarchy. By varying shape and color meaningfully, the encoding becomes more memorable



http://www.nature.com/nmeth/journal/v10/n6/full/nmeth.2490.html

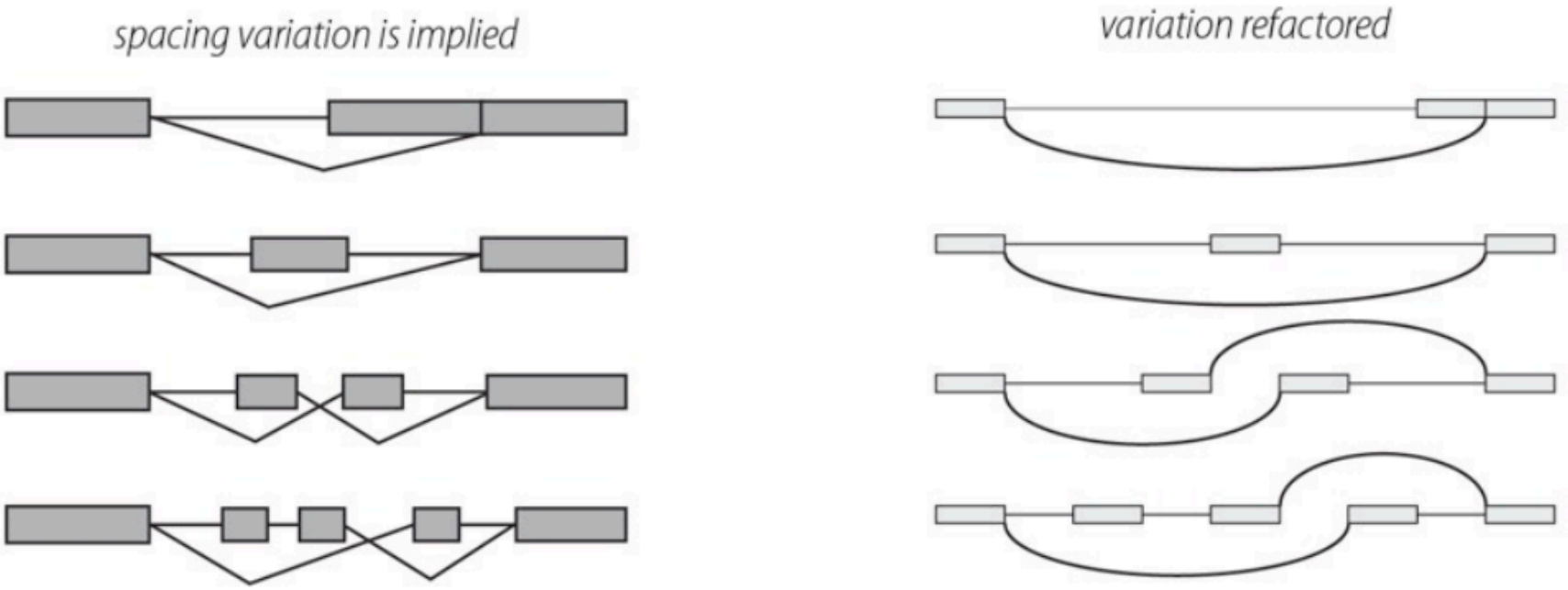
Legend order



- Order elements in the legend consistently with their appearance in the figure
- more visually balanced when darker tones are at the bottom

M. Krzywinski

Uniform spacing and sizing

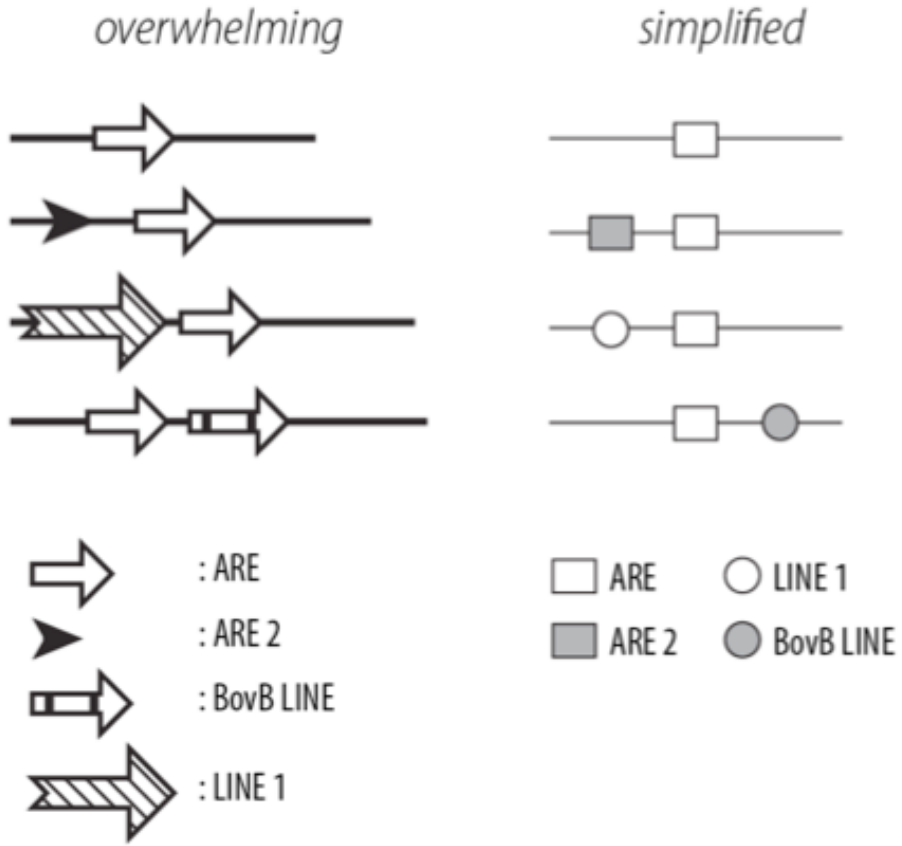


Sharov et al. (2005)

- Keep the size, spacing and alignment fixed of as many elements as possible
- Any variation in the figure will be interpreted as important to its message

M. Krzywinski

Remove redundancies

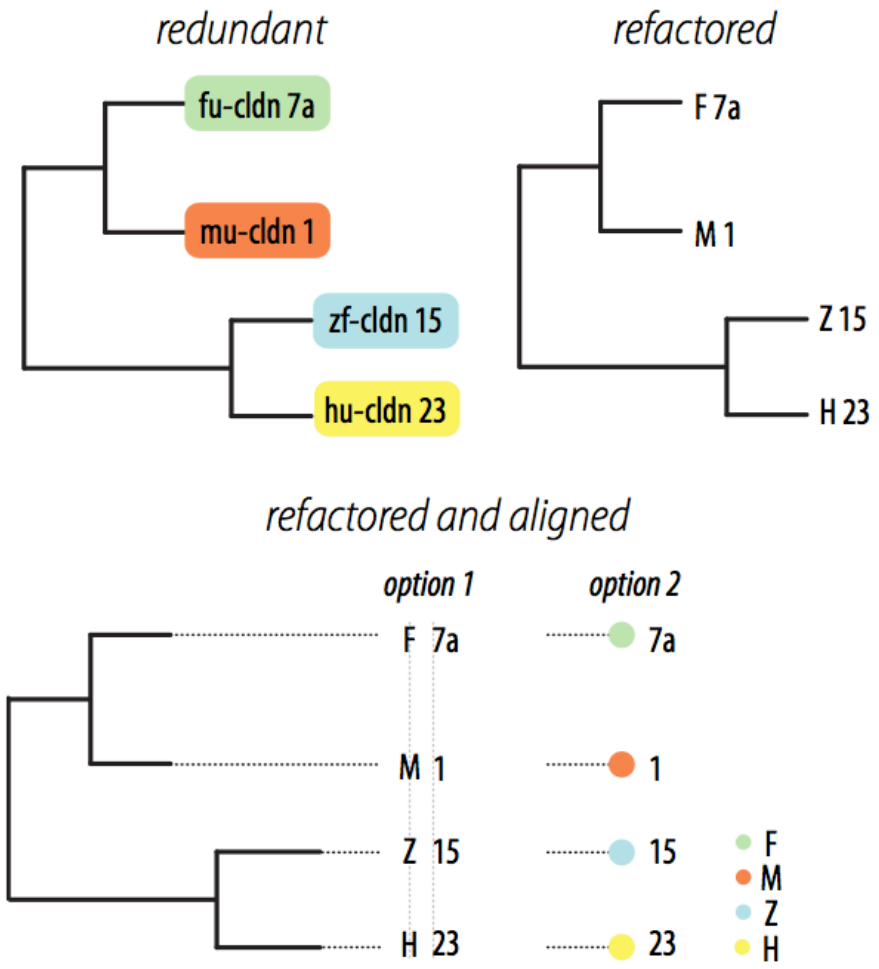


Nikaido et al. (1999)

- unclear whether the arrows' size and distance is meaningful
- All arrows point in the same direction
- Any variation in the figure will be interpreted as important to its message

M. Krzywinski

Remove redundancies



Loh et al. (2004)

- remove repetitions
- aligned is easier to read

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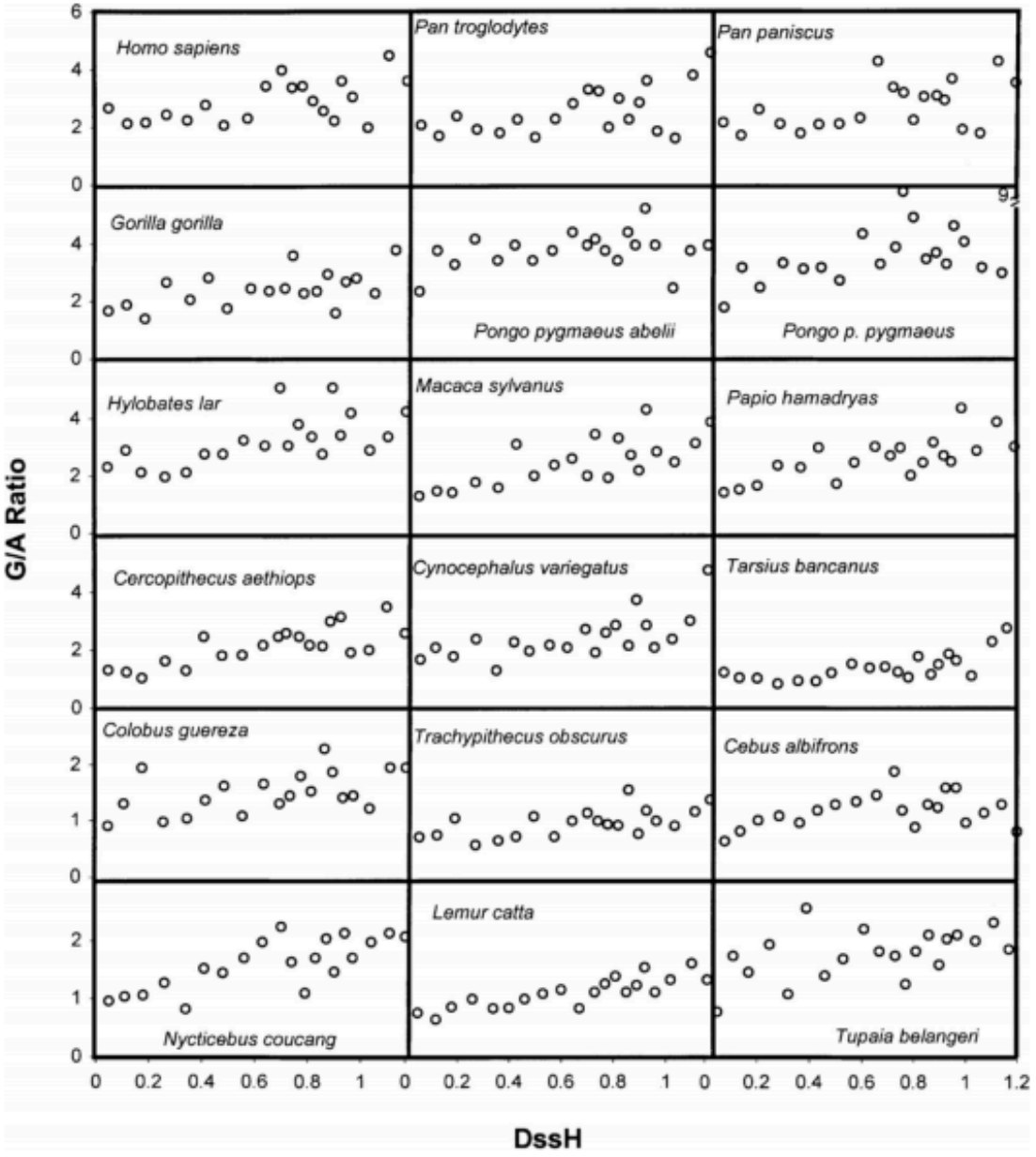
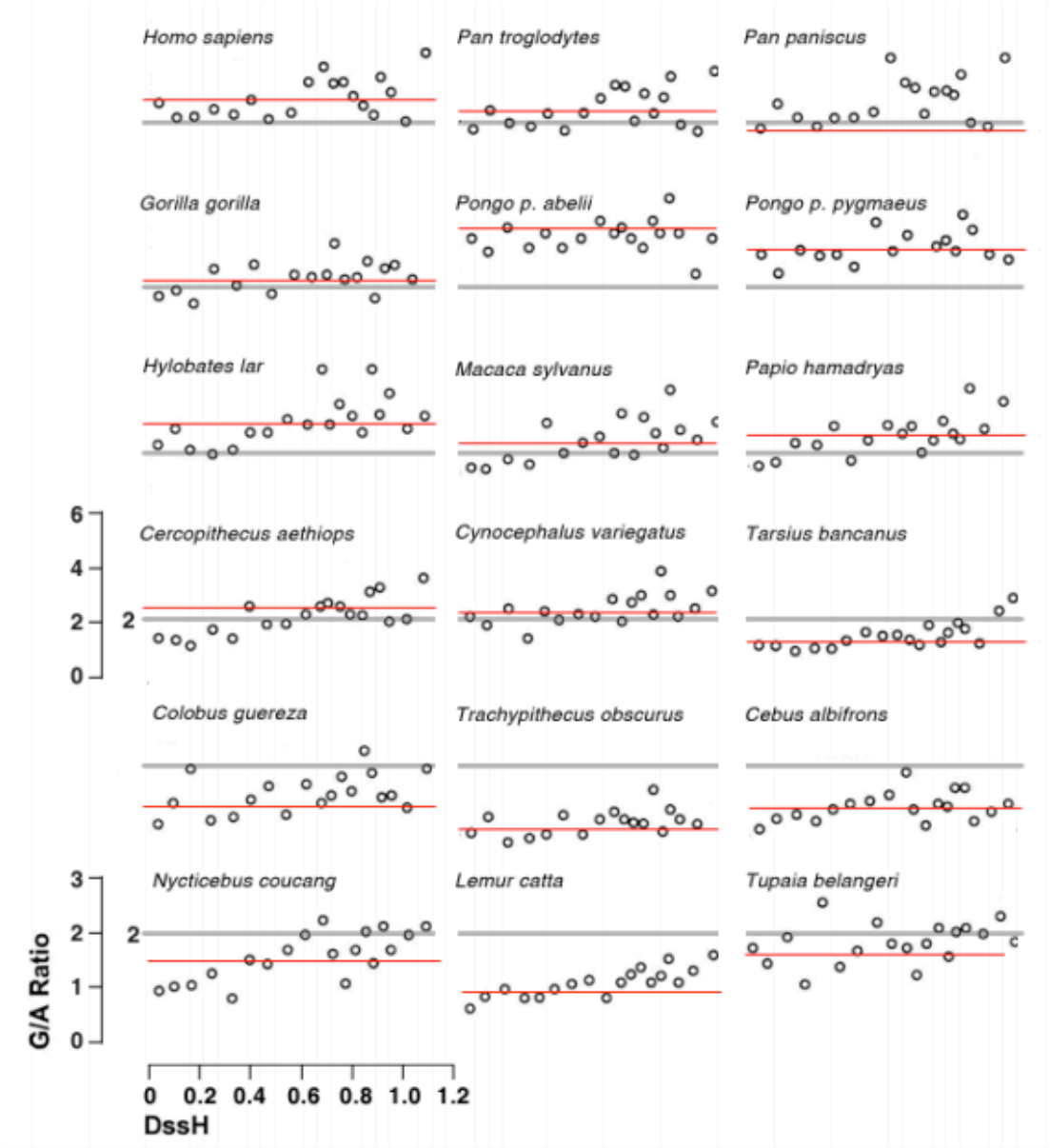
Focus on data



Raina et al. (2005)

Focus on data 2



Better data-to-ink-ratio removal of unnecessary elements

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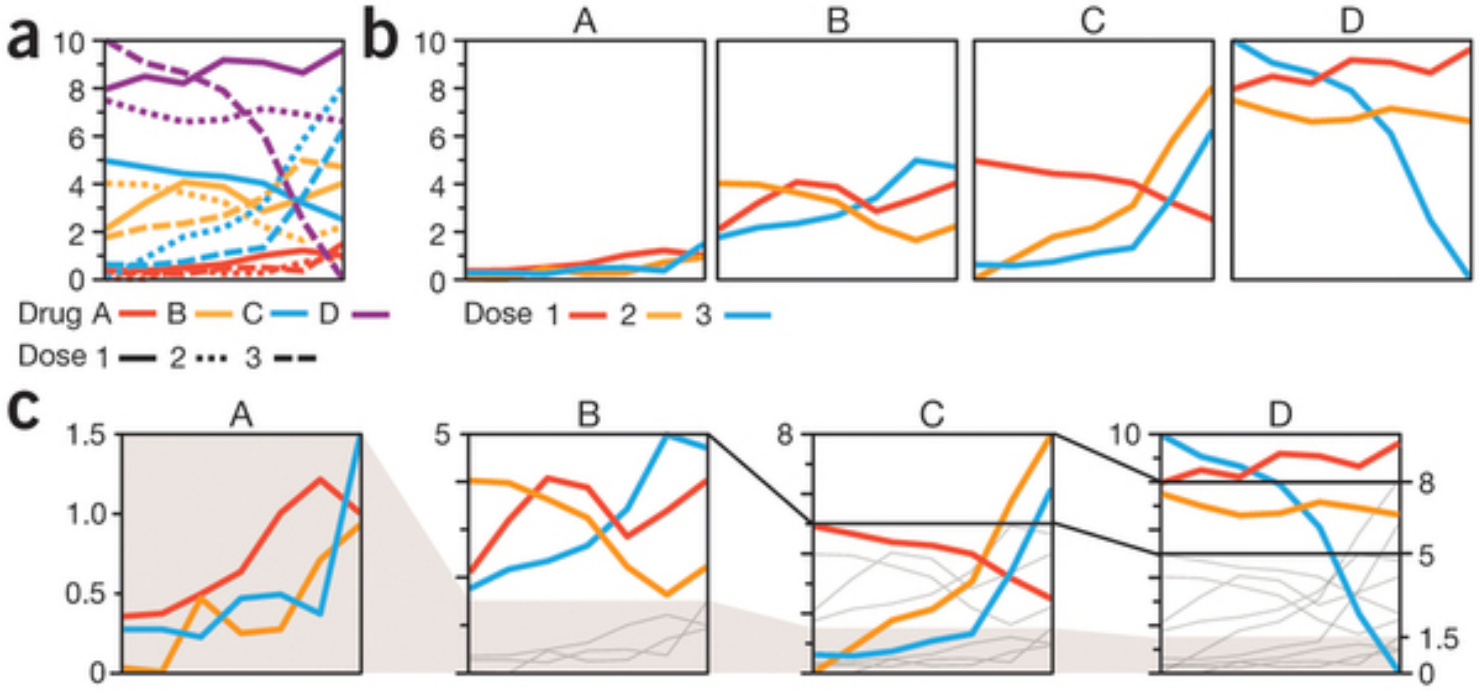
Variation in data range

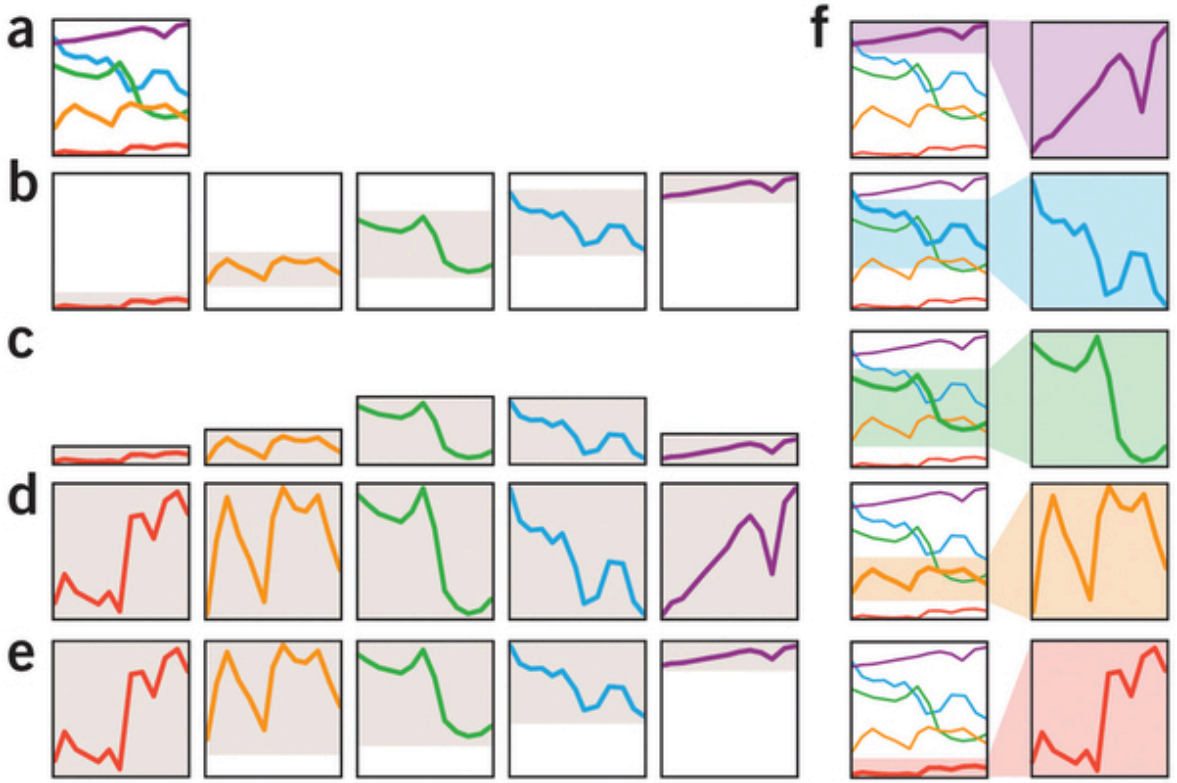


Small multiples / Subplots of time-series data

a) Small-multiple plots isolate and untangle the categories but lose context as categories are separated
b) Subtle scale annotations provide context while maintaining clarity

http://www.nature.com/nmeth/journal/v12/n7/full/nmeth.3451.html

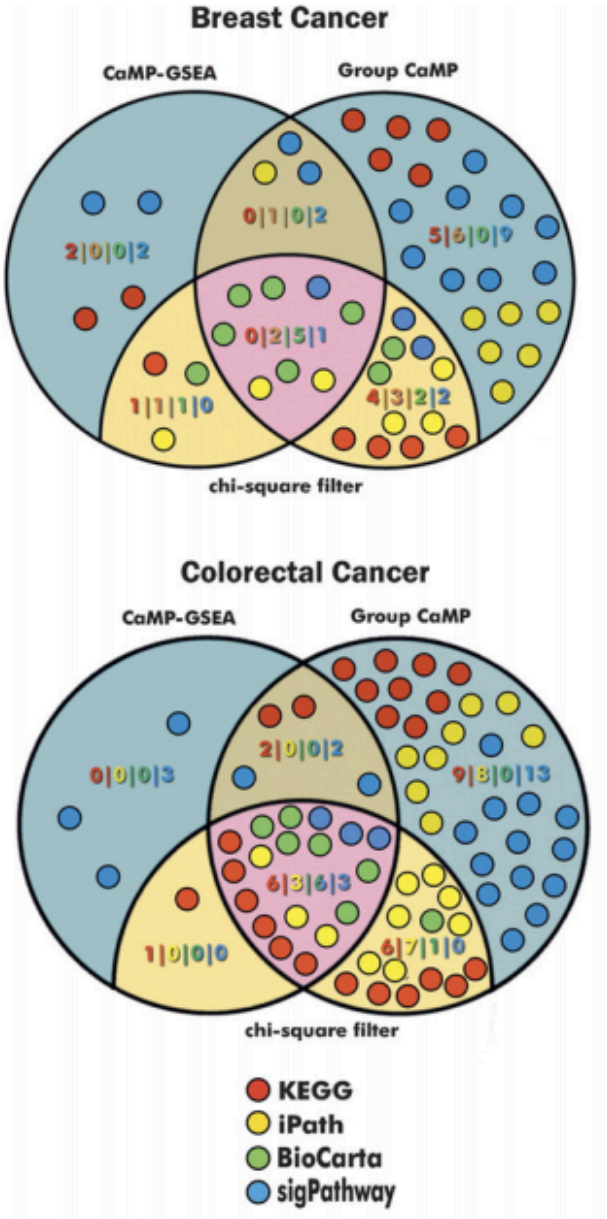
Variation in data range 2



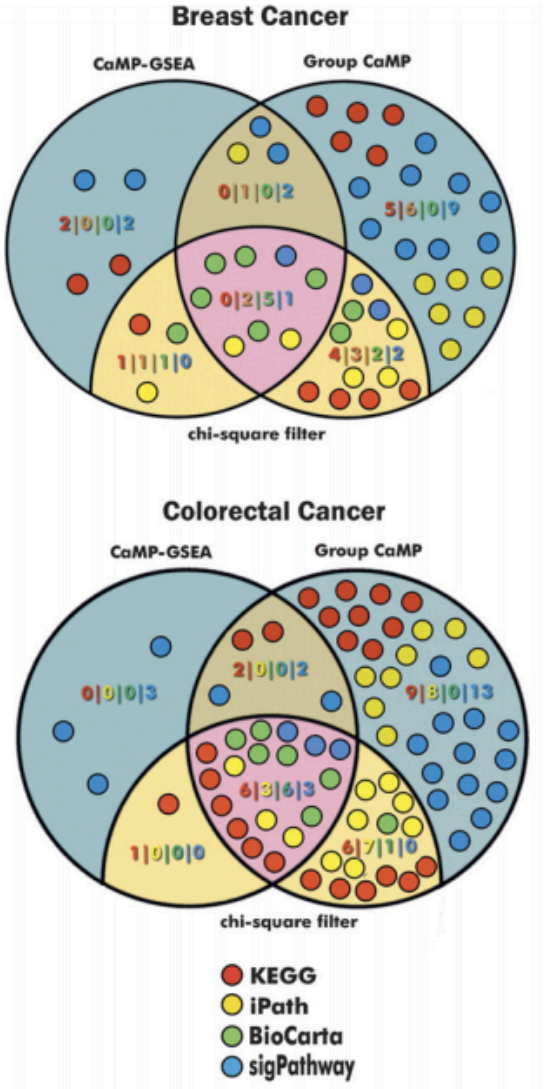
(f) Use an overview and scaled detail to contextualize, highlight and examine each category. Colored backgrounds emphasize differences in scale expansion

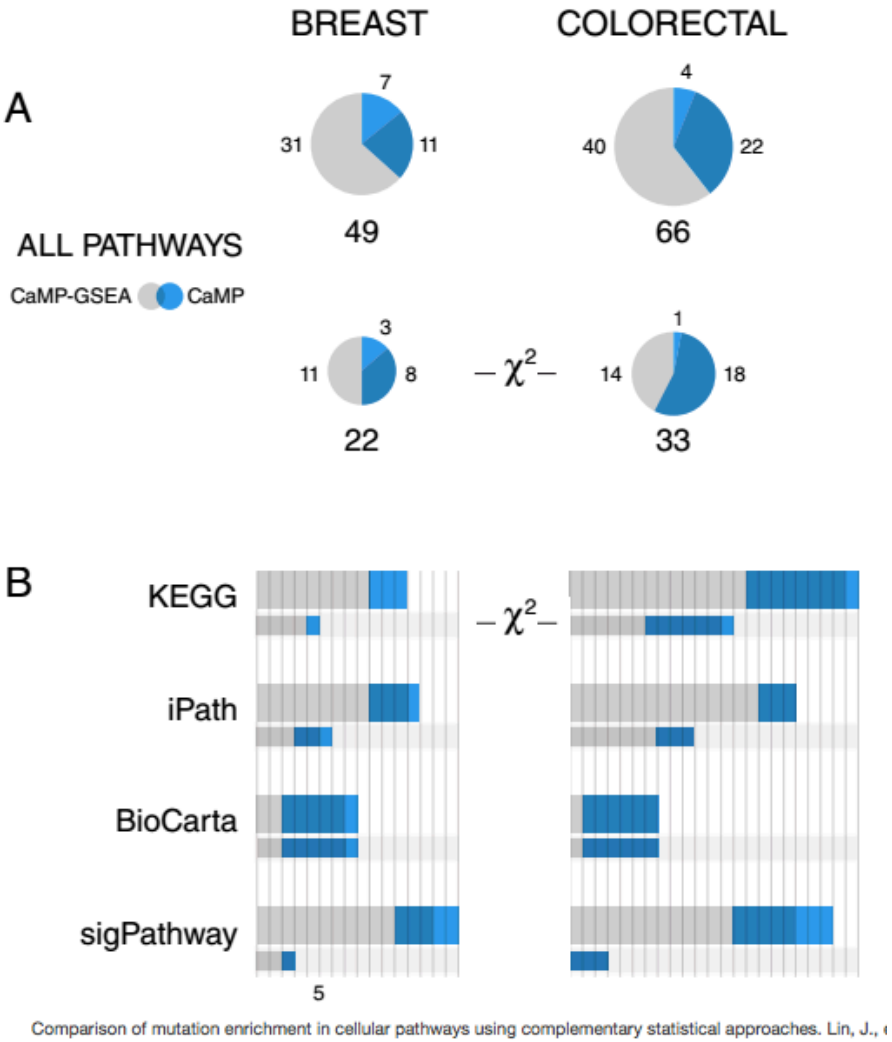
http://www.nature.com/nmeth/journal/v12/n7/full/nmeth.3451.html

Refactoring Complexity



Refactoring Complexity 2

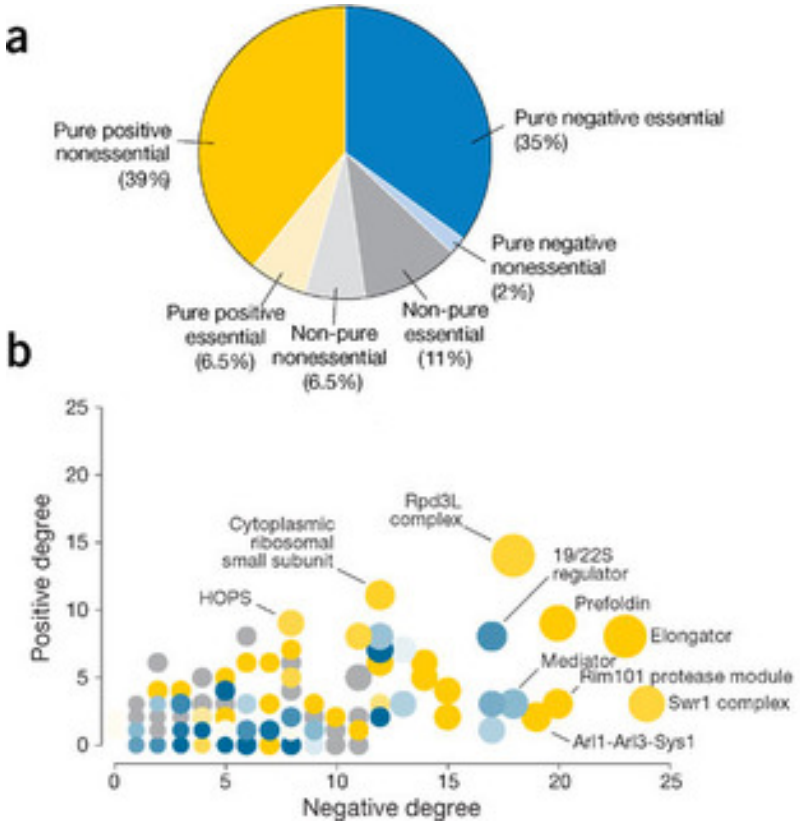




Message is clearer
(Breast > Colorectal, KEGG > sigPathway > iPath > BioCarta)

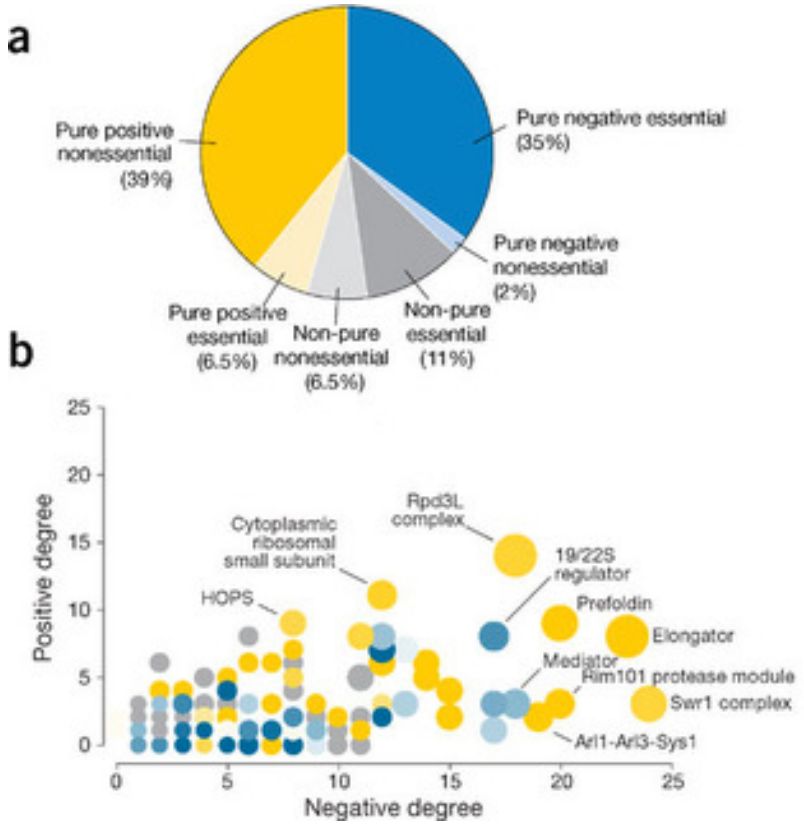
M. Krzywinski

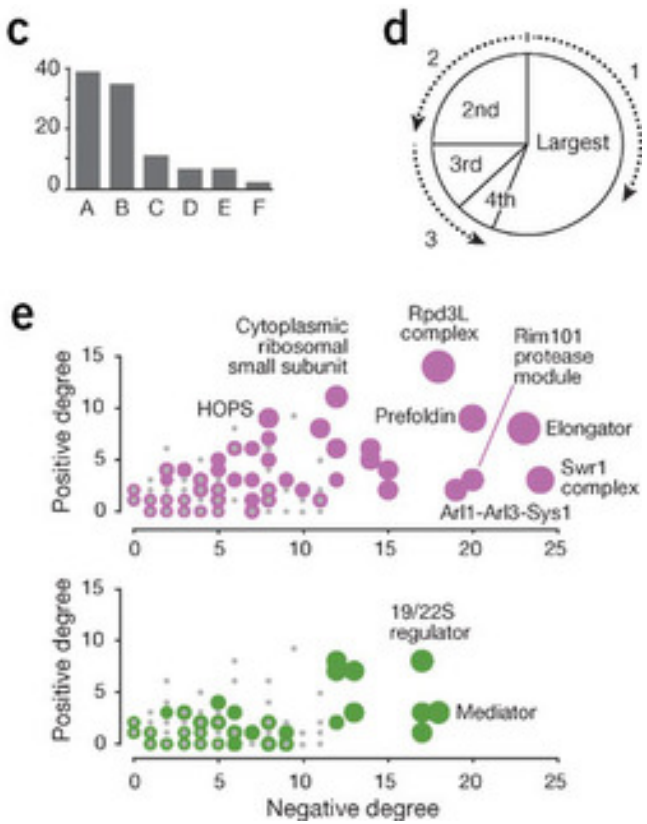
Refactoring Complexity 2



http://www.nature.com/nmeth/journal/v8/n3/full/nmeth0311-189.html

Refactoring Complexity 2



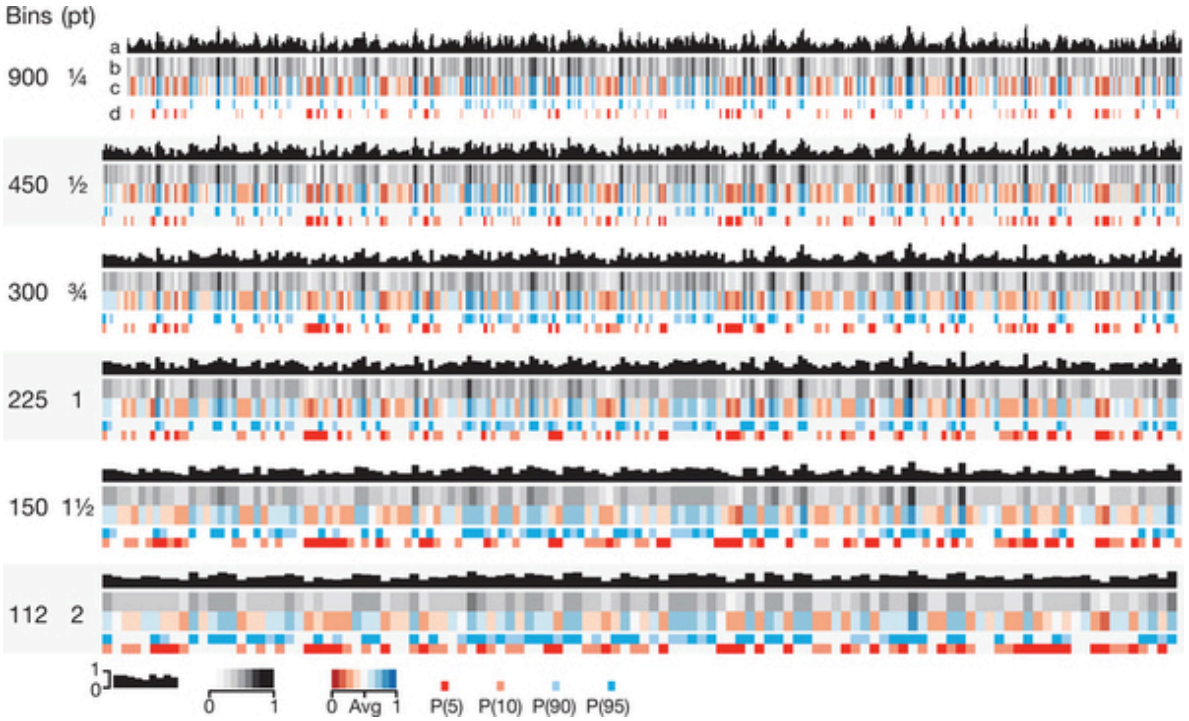


Busy / difficult to read graph
8 point sizes, 11 shades of yellow/ 13 blue

Reduce visual complexity
Limit the color value and size scales (0–3, 4–7 and others)

http://www.nature.com/nmeth/journal/v8/n3/full/nmeth0311-189.html

Binning high-resolution data

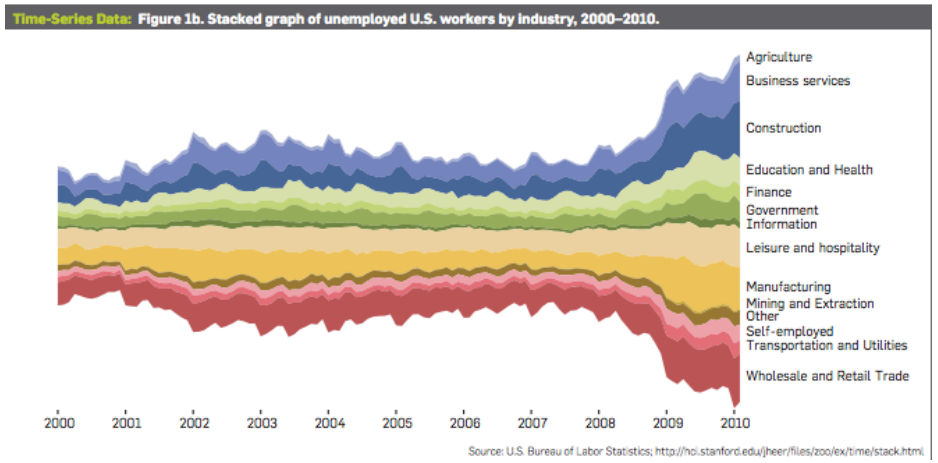


Read coverage of simulated sequencing
(a) histogram, (b) heatmap
(c) Coverage relative to the average
(d) Bins with values at least as extreme as the 5th, 10th, 90th or 95th percentile are marked

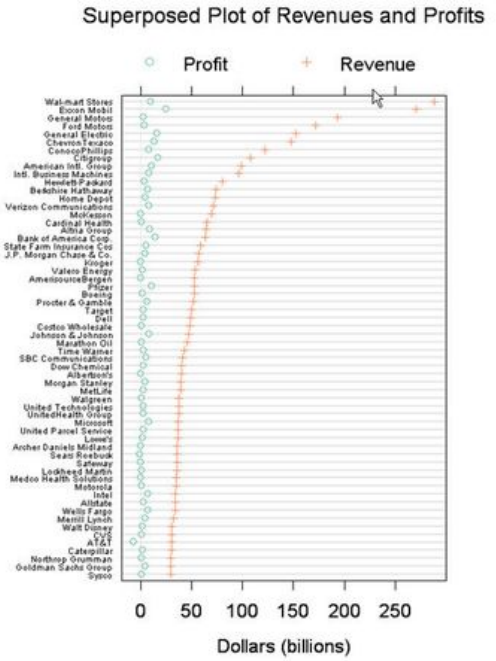
- Lines thinner than 1/2 pt cannot be comfortably resolved if less than 1/2 pt apart
- Finding local maxima is relatively easy even with 1/4-pt bins, but judging the average, assessing variability and discerning minima are difficult with bins smaller than 1 pt
- We suggest not binning data into more than ~250 intervals for one-column figures (3.5 inches wide) or ~500 intervals for two-column figures (7.2 inches)

http://www.nature.com/nmeth/journal/v13/n6/full/nmeth.3873.html

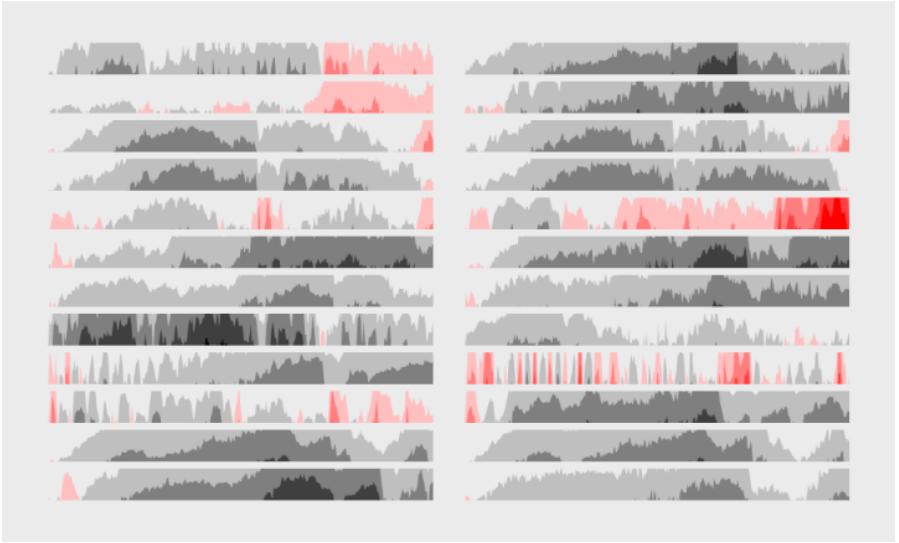
Many other types of charts exist



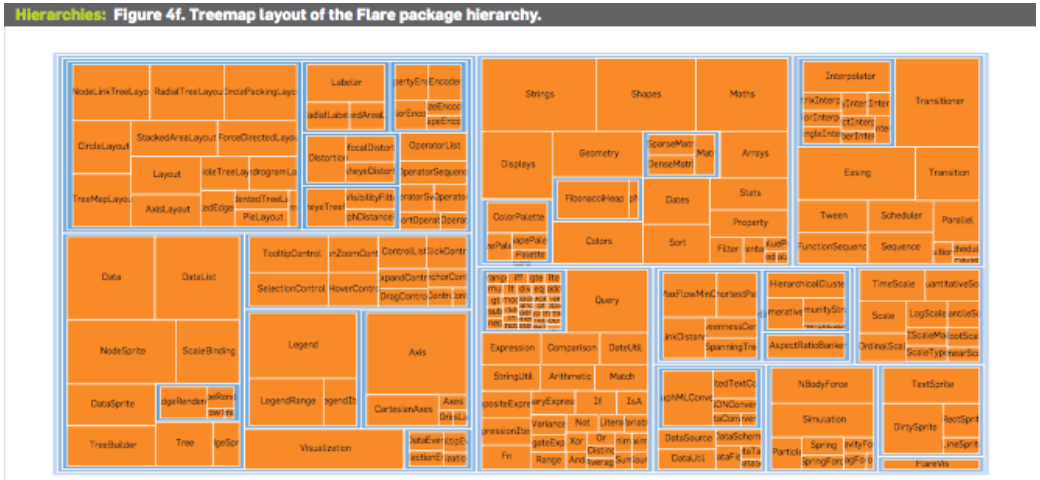
Stacked graph (controversial)



Dotplot



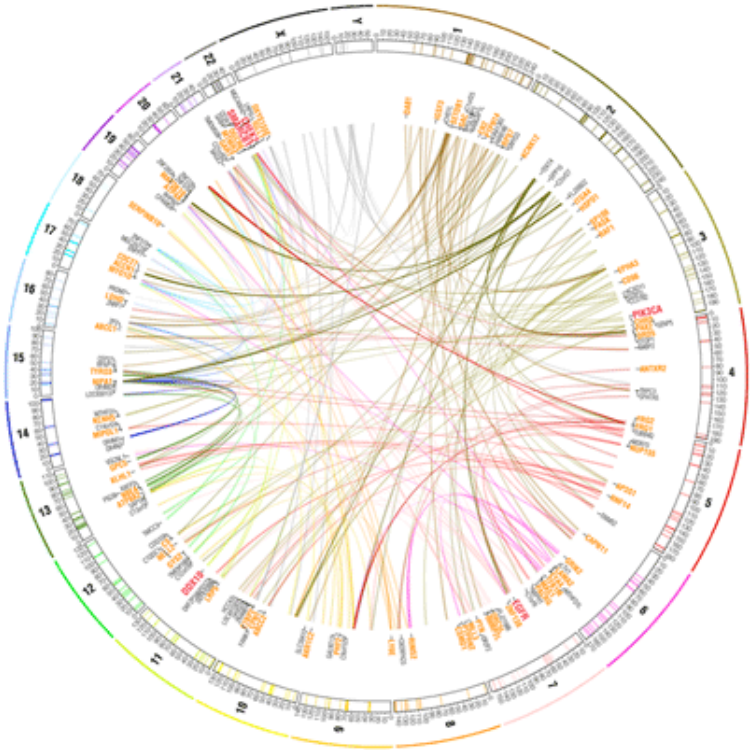
Horizon graph
(flowing data)

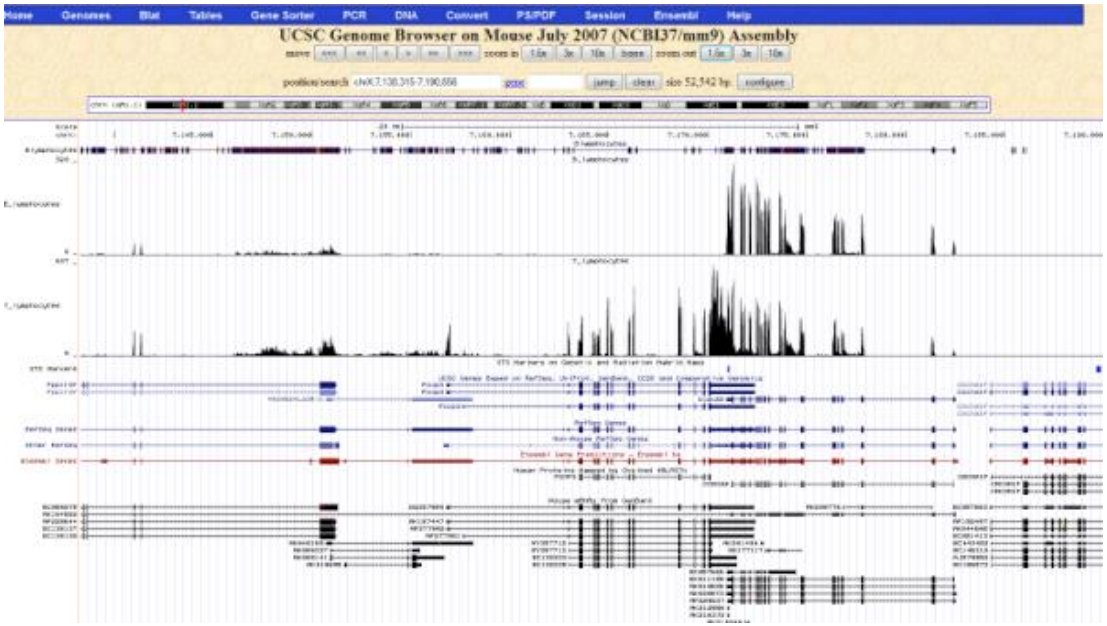


Treemap

Visualization zoo

Previous URPP tutorial





Some tools to visualize biological data (ensembl/UCSC genome browsers, IGV, circos) have been presented in a previous URPP tutorial https://github.com/mimolch/Genomic_Visualization

Tufte's design principles

- maximize the data-ink ratio
- avoid chart junk (sometimes)
- use multifunctioning elements
- separate layers
- maximize the data density
  shrink the graphics
  maximize the amount of data shown (sometimes)

- Show data variation, not design variation

Take home message (I try)

- Show the raw data - show individual data points if possible
- Reduce the complexity
  only 6-12 colors are visually discernable
  Use small multiples if more than 6-7 categories
- Remove unnecessary variation - Any variation in the figure will be interpreted as important to its message
- Display uncertainty (e.g. confidence intervals)
- Use transparency to improve clarity
- Do not trust the R defaults

Sources

- http://mkweb.bcgsc.ca/vizbi/2012/principles.pdf
- Points of view http://clearscience.info/wp/?p=546 column on data visualization in Nature method