

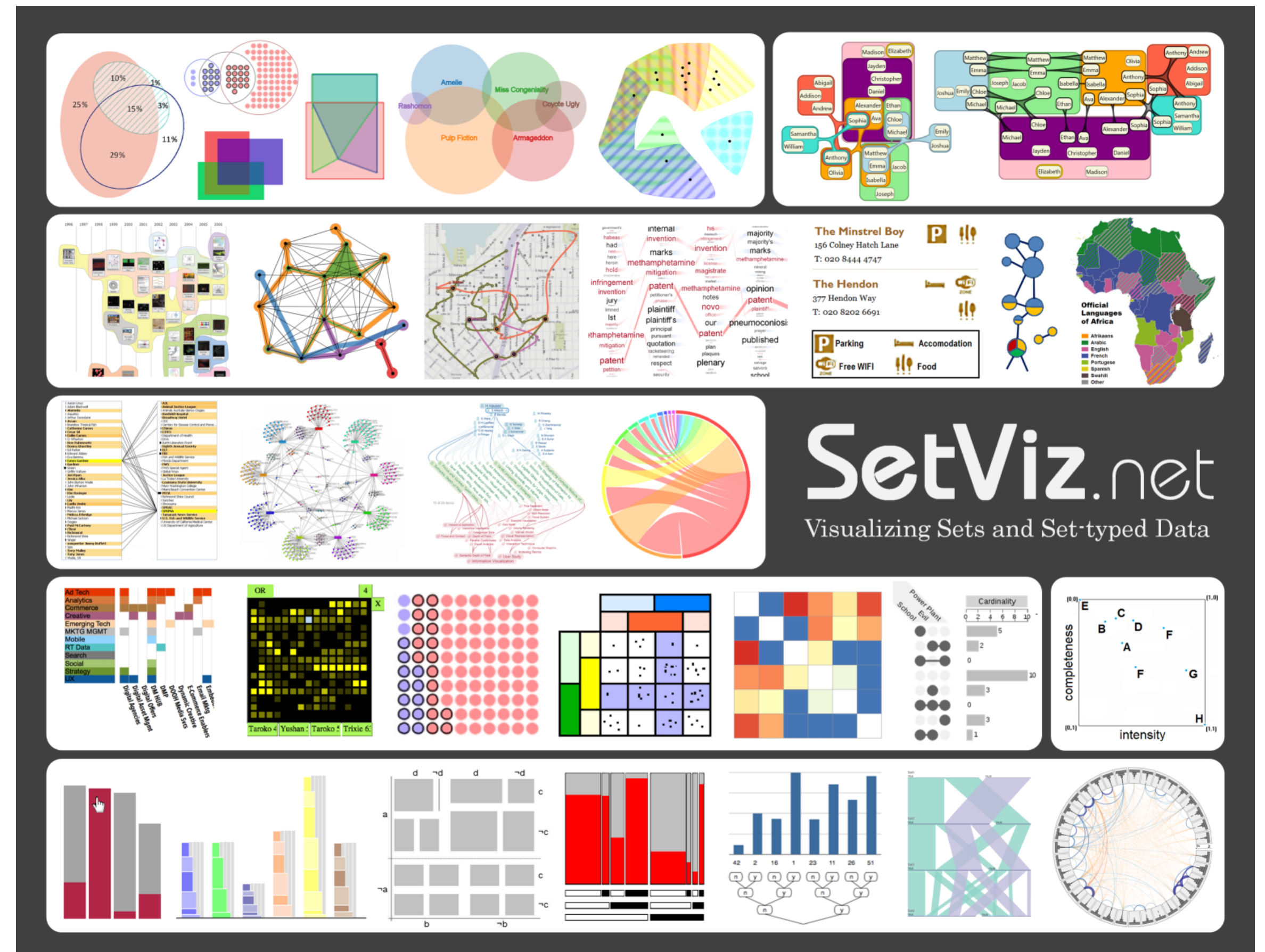
Data Visualization (CSCI 490/680)

Design

Dr. David Koop

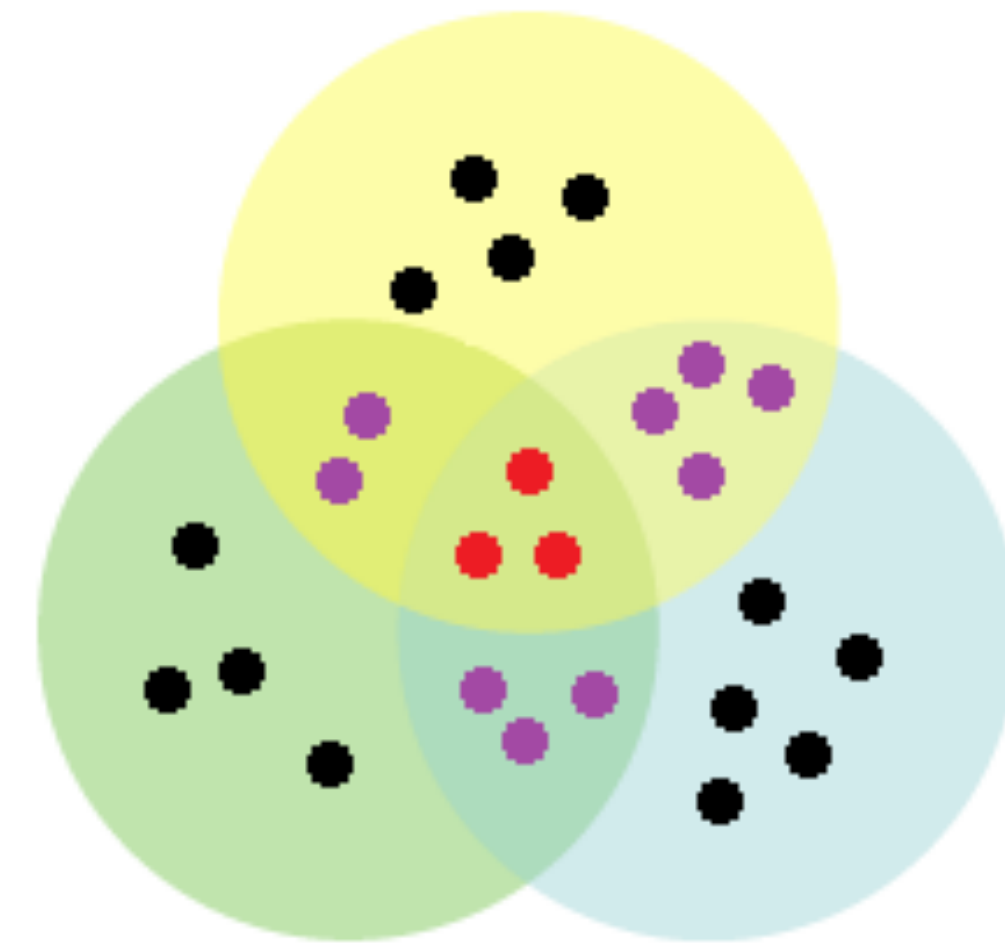
Set and Cluster Visualization

- Set and cluster visualization not covered in depth in the textbook
- Nice summary of set visualization in the following paper:
 - Visualizing Sets and Set-typed Data, B. Alsallakh et al., 2014
 - Also: Web Resources

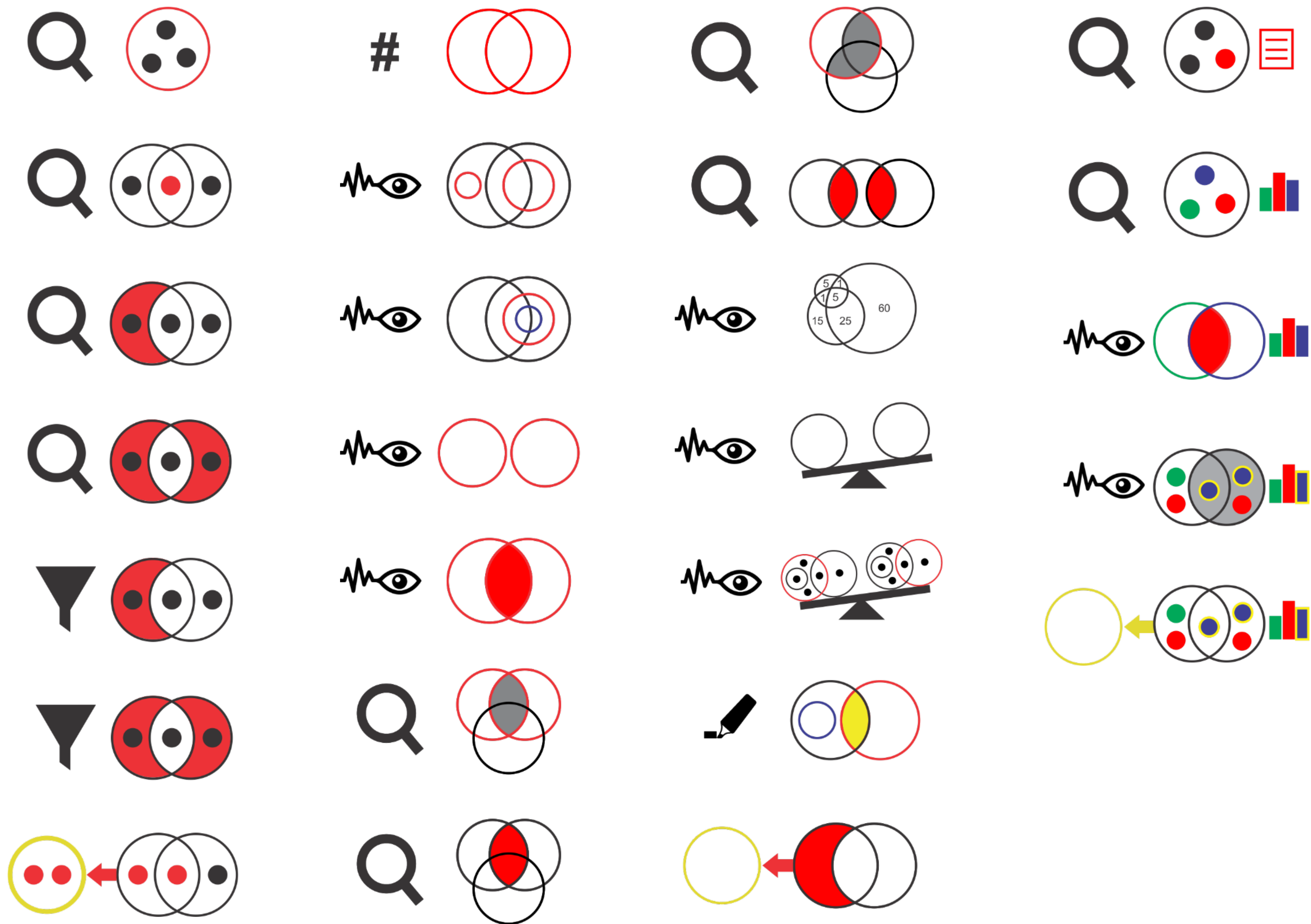


Set-typed Data - Characteristics

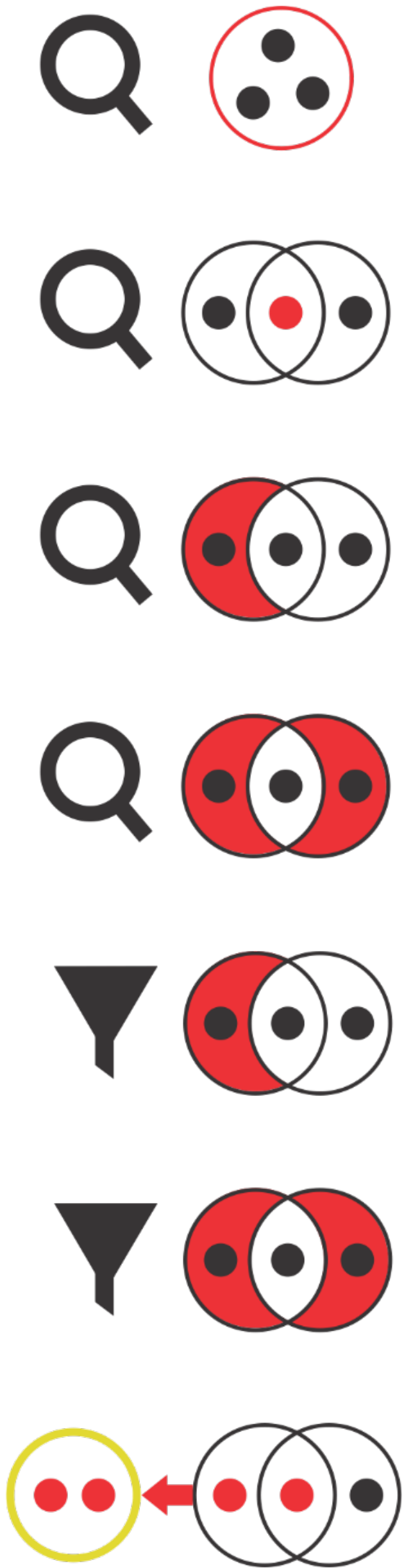
- **Set Algebra**
 - Set operations, Cartesian product, power set, ...
- **Set similarities**
 - Similarity measures (Jaccard, Tversky, etc.)
- **Element degree**
 - exclusive set membership
- **Dimensionality**
 - 2^n possible combinations
 - $2^{(2^n)}$ possible queries



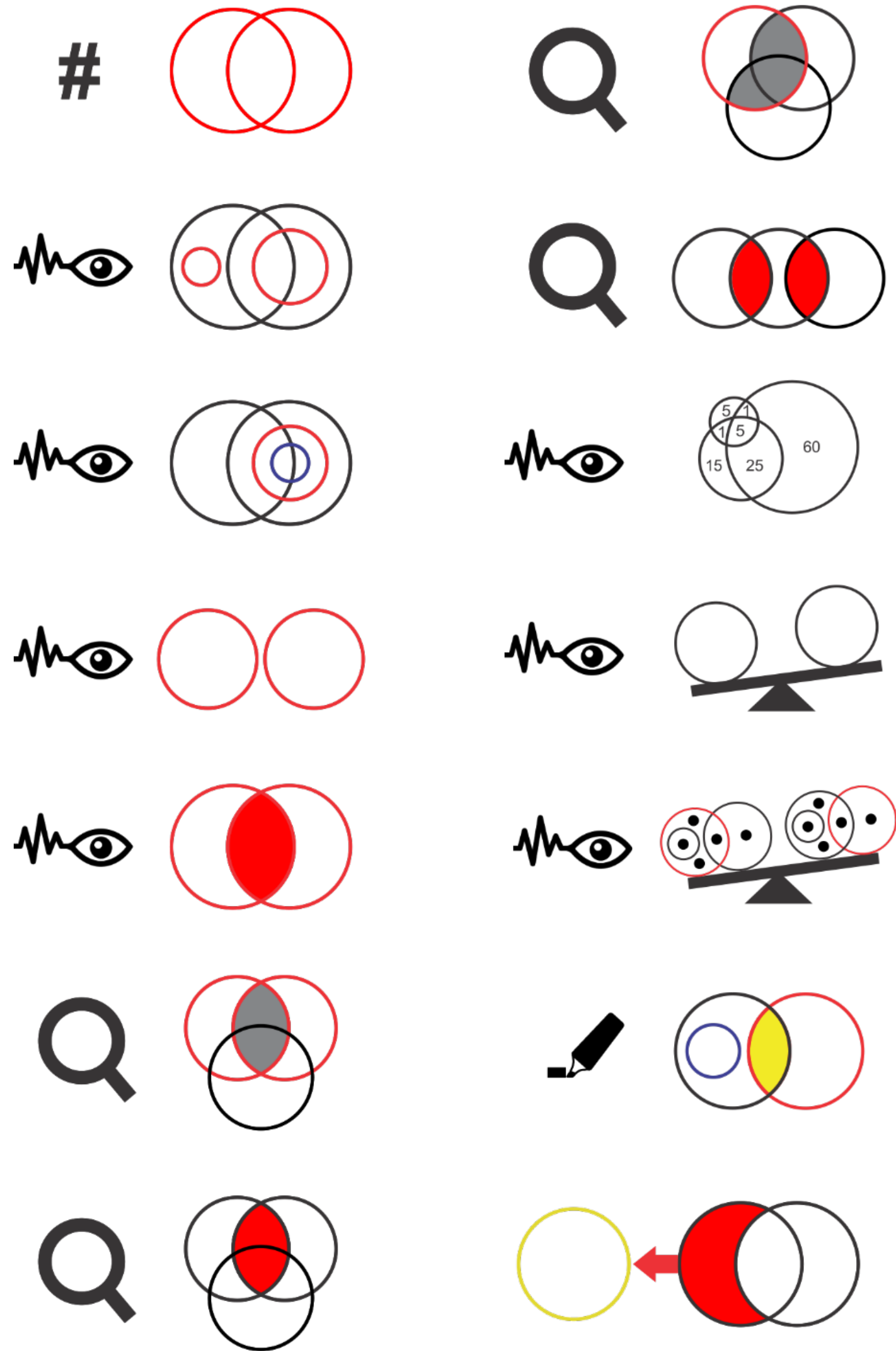
[B. Alsallakh et al., 2014]



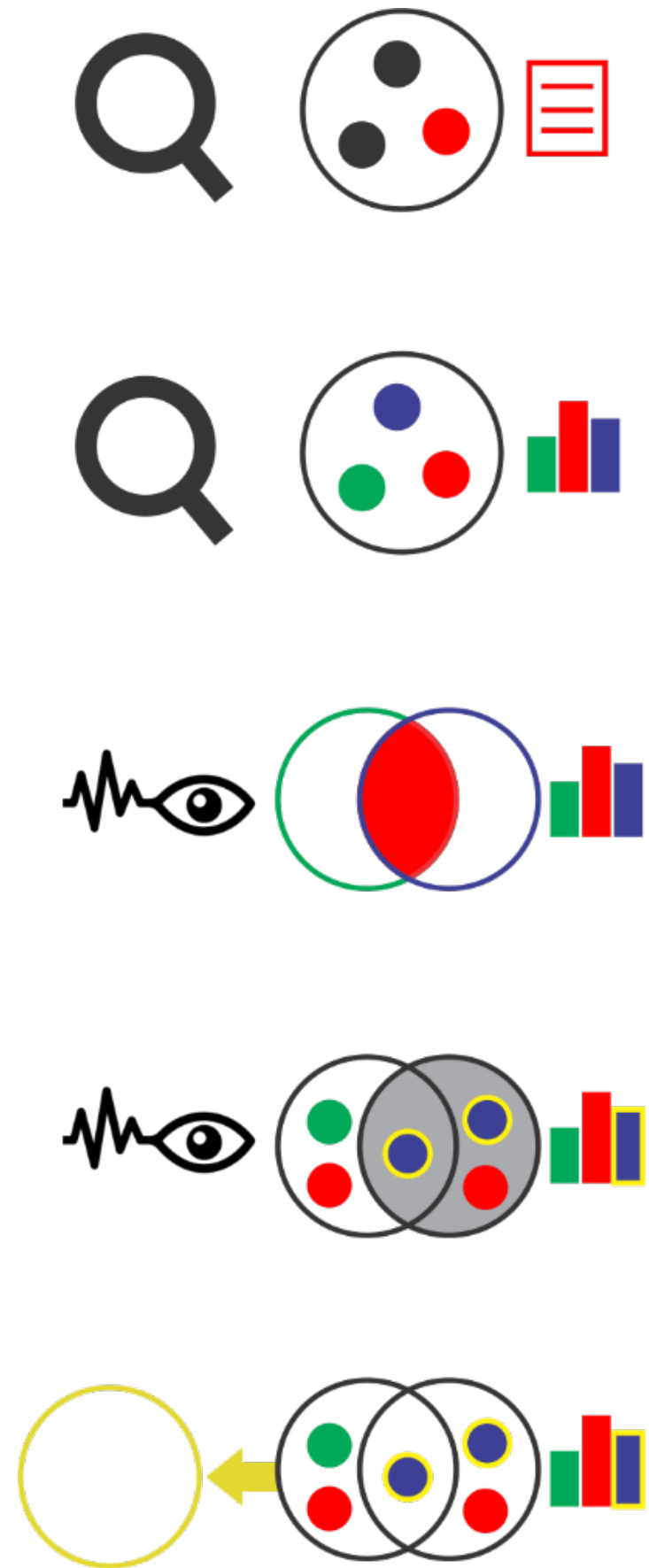
Elements



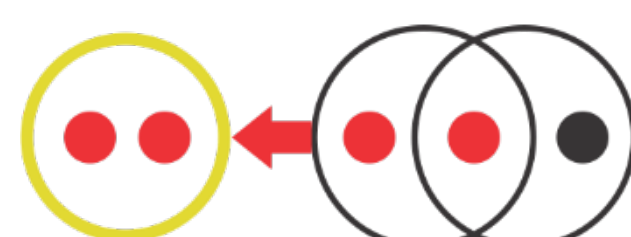
Sets and Set Relations



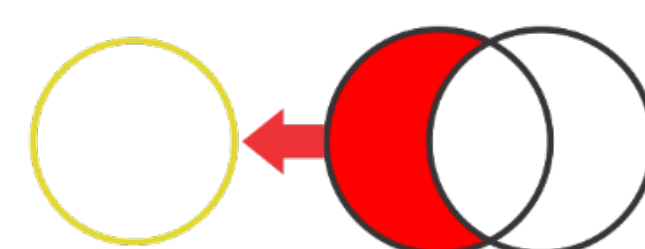
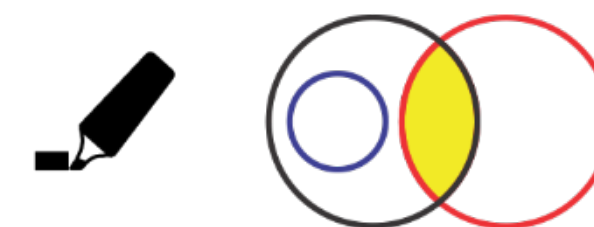
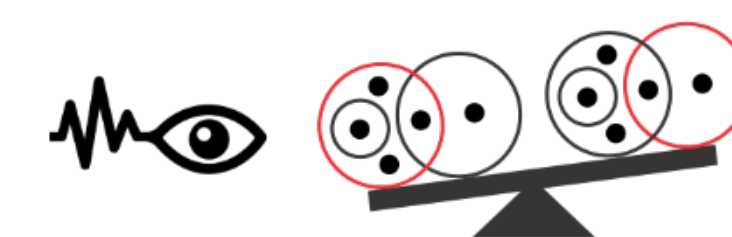
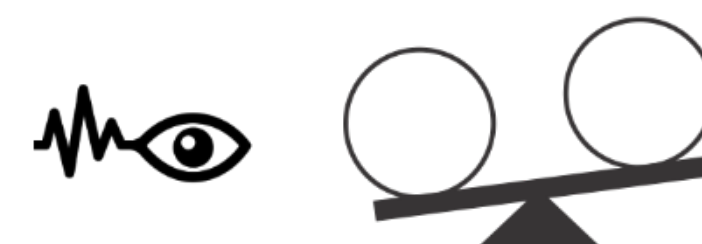
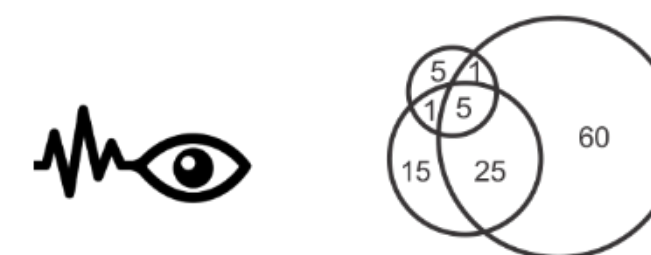
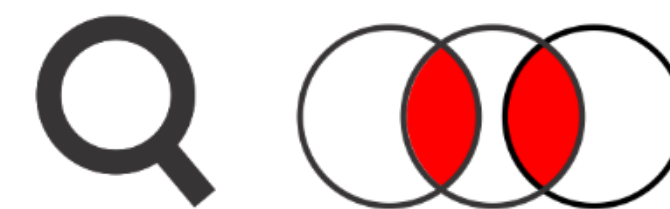
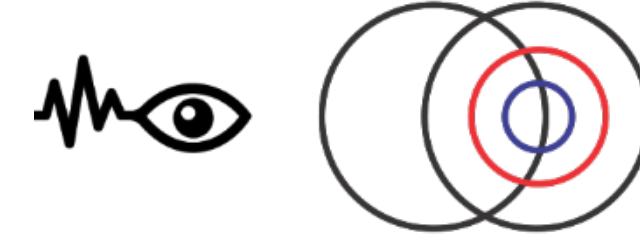
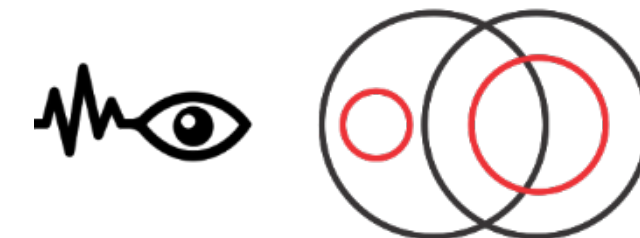
Element Attributes



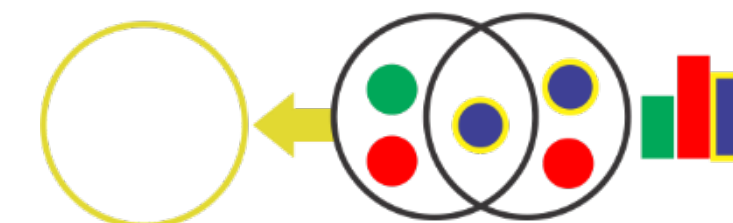
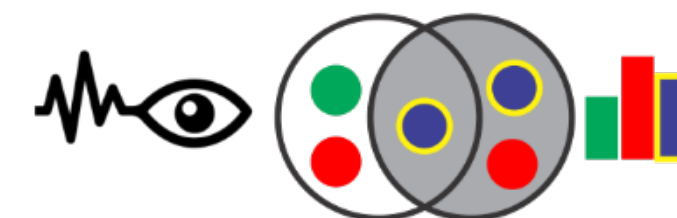
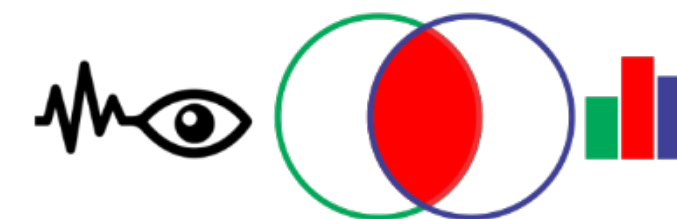
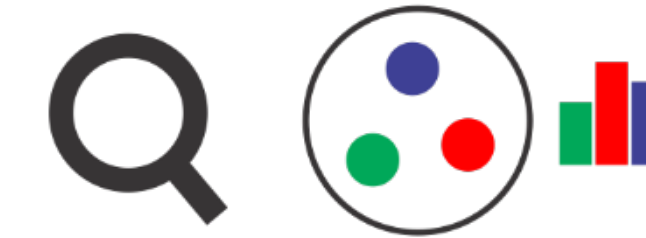
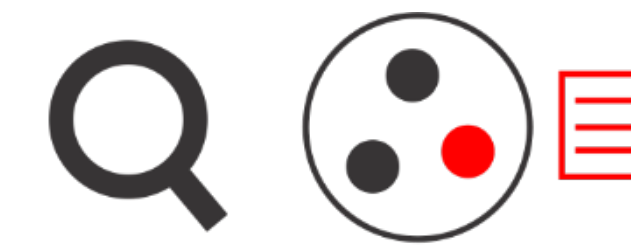
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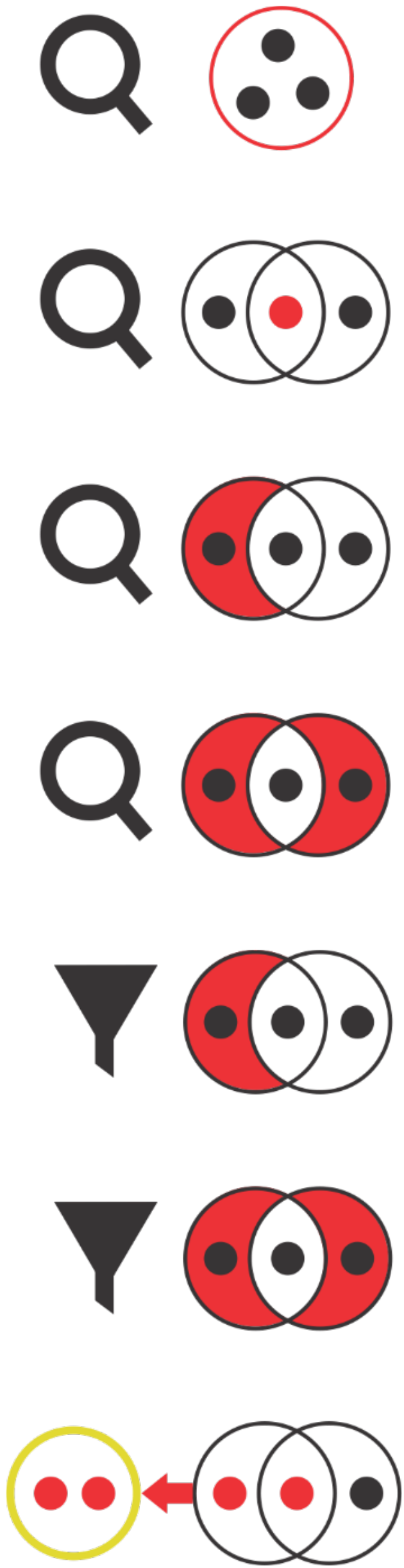
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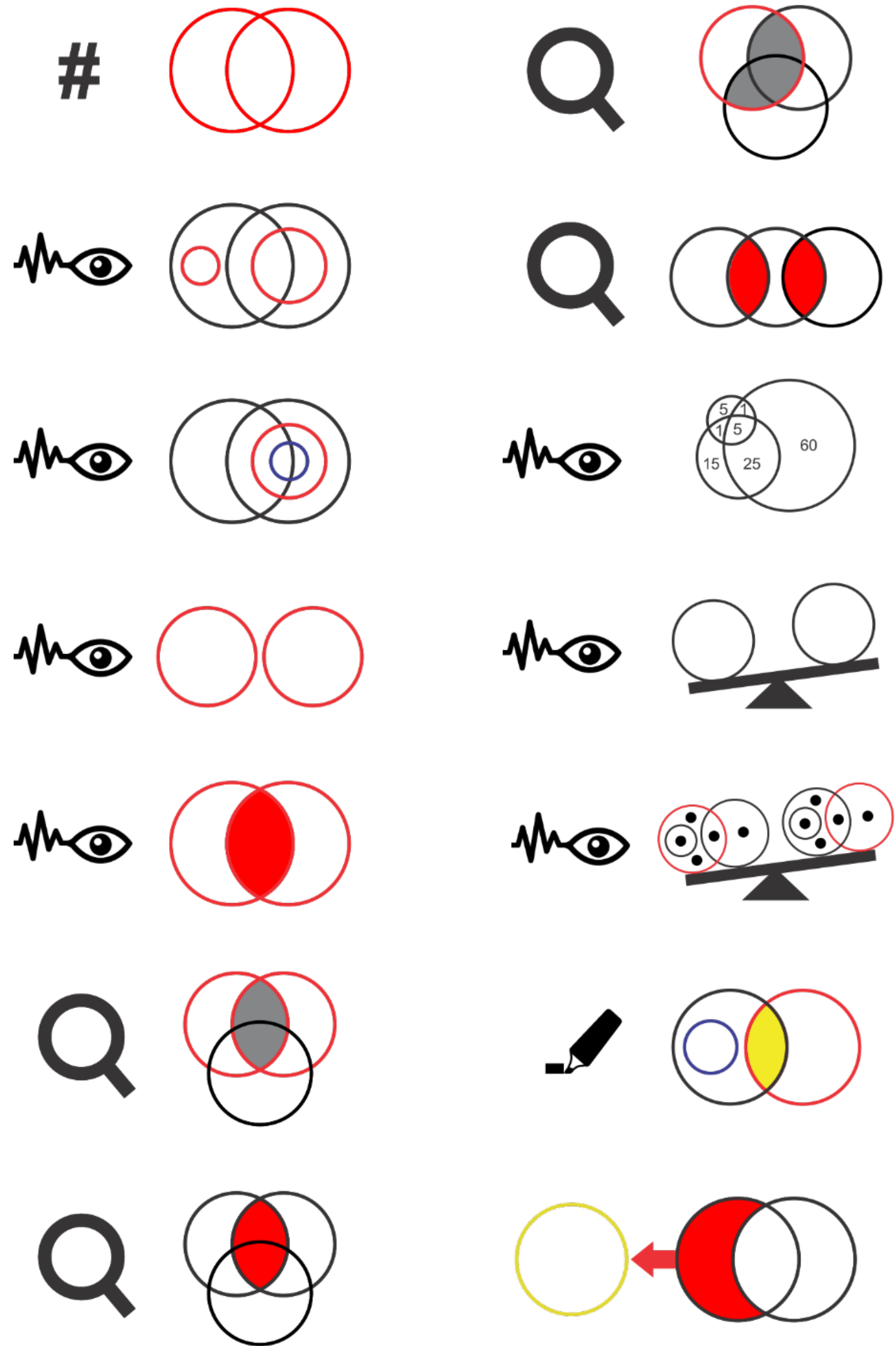
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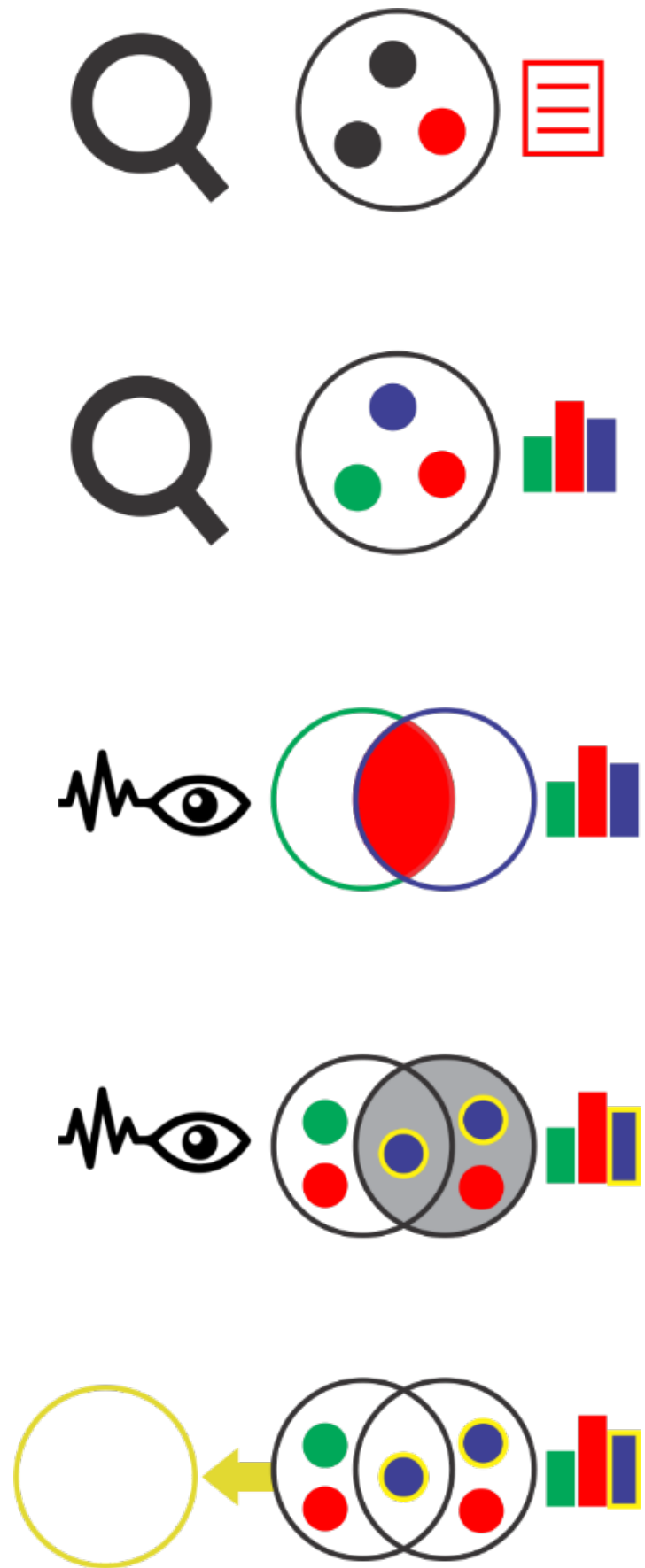
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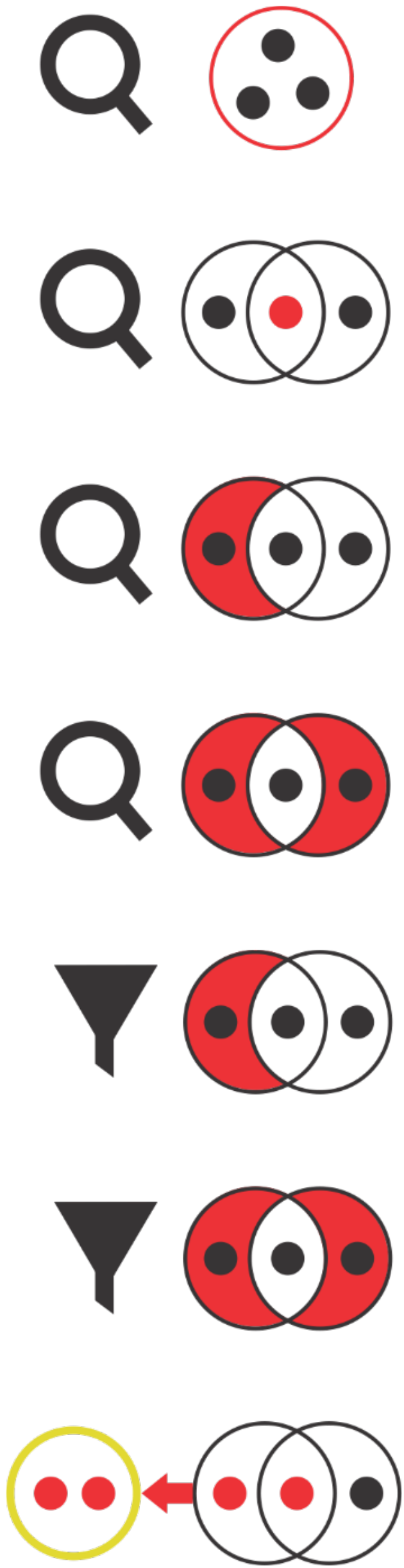
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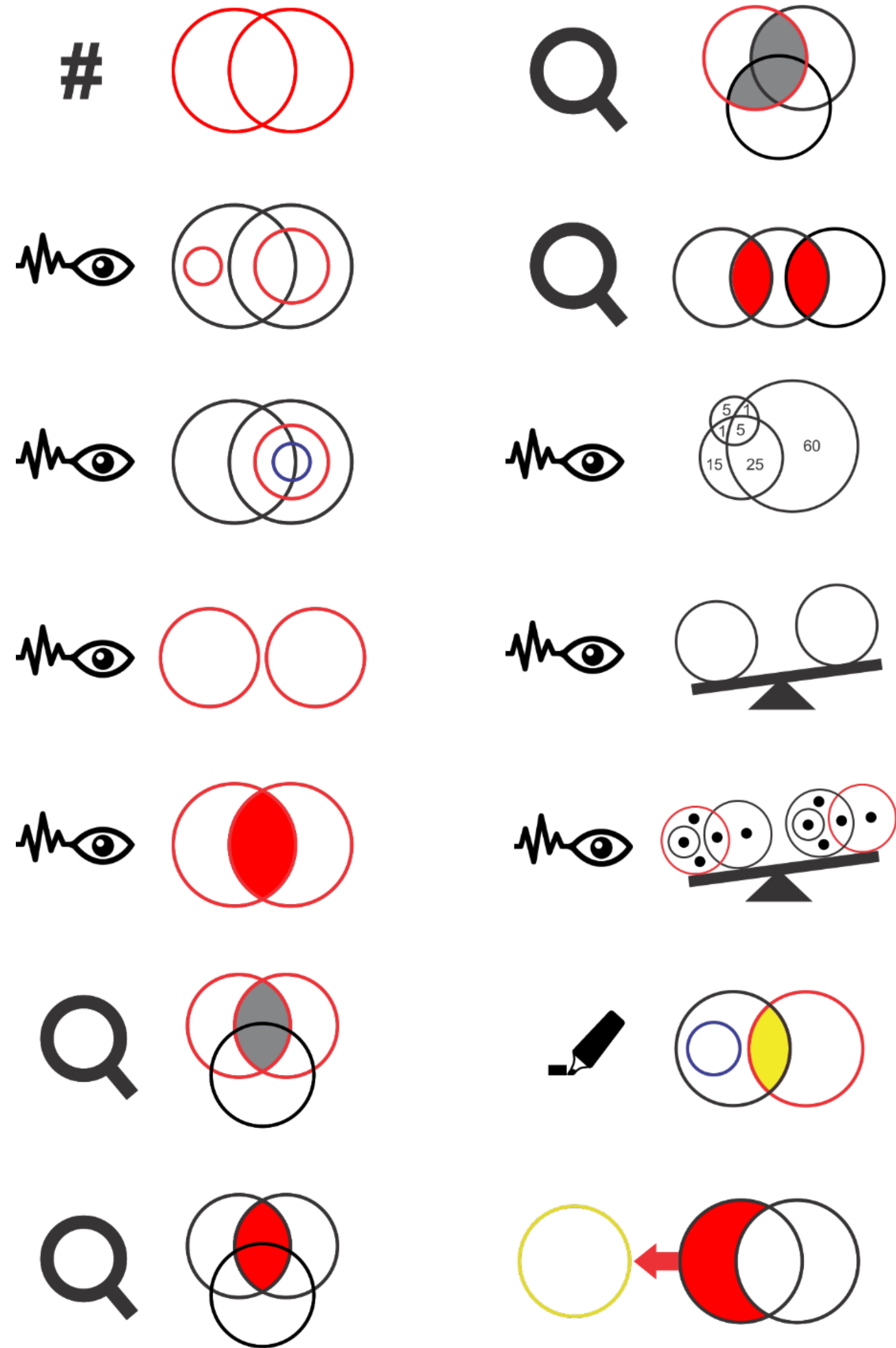
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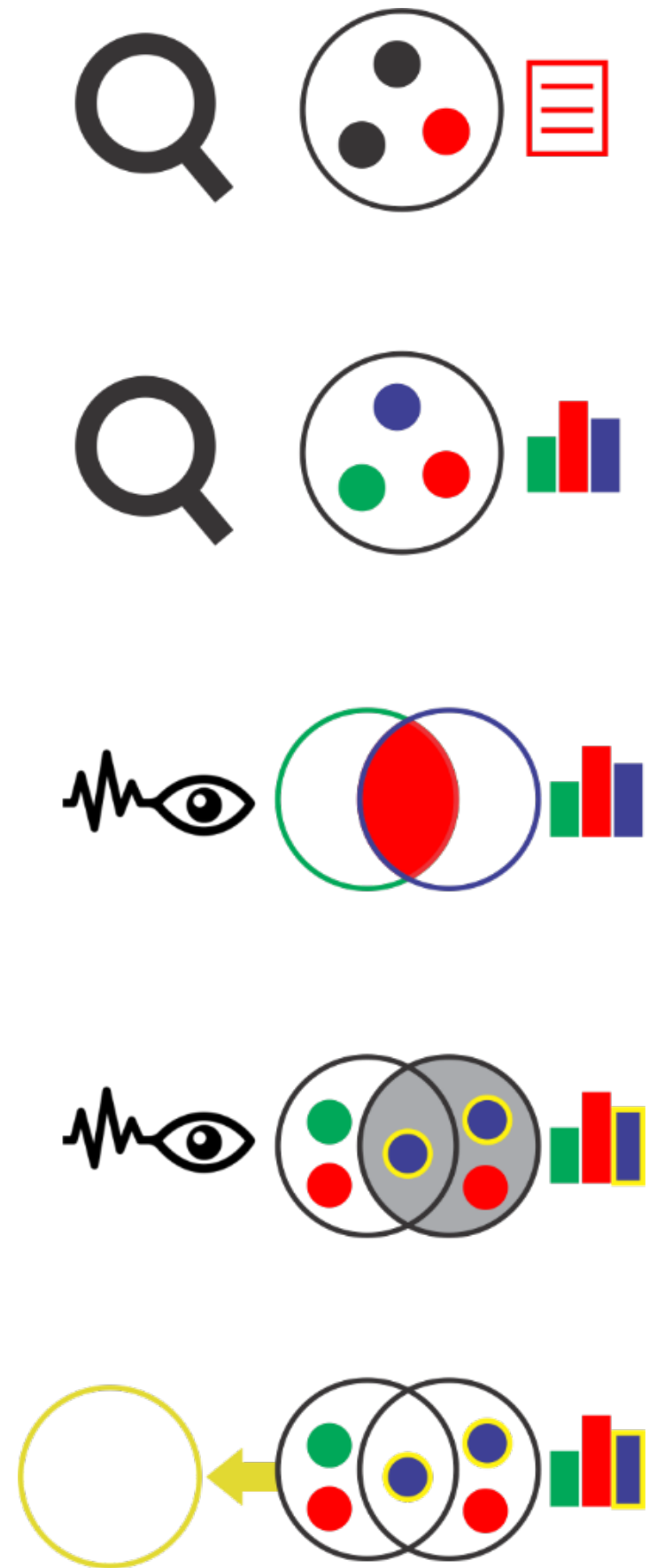
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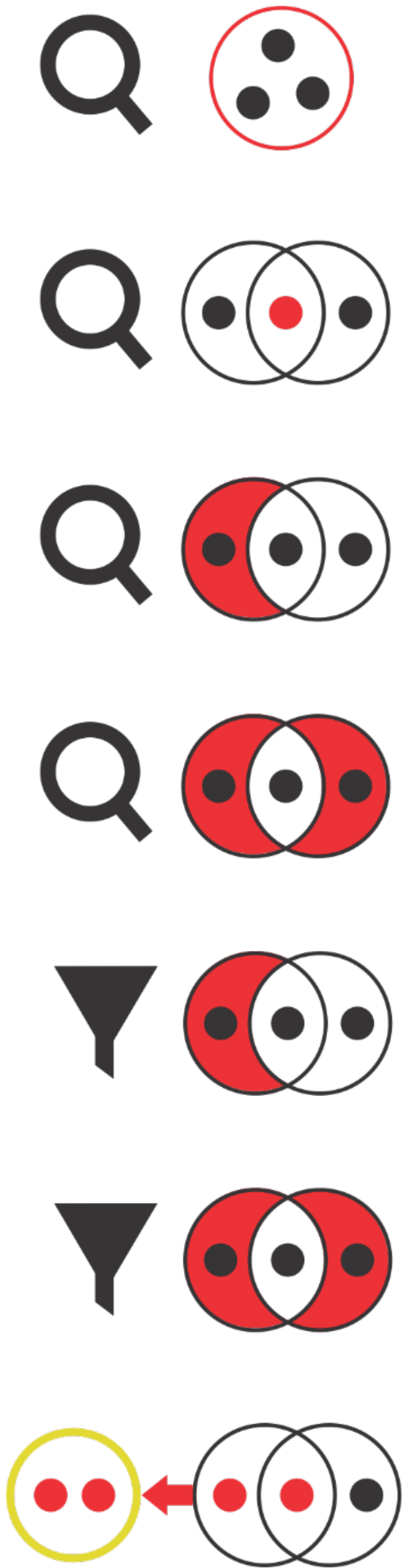
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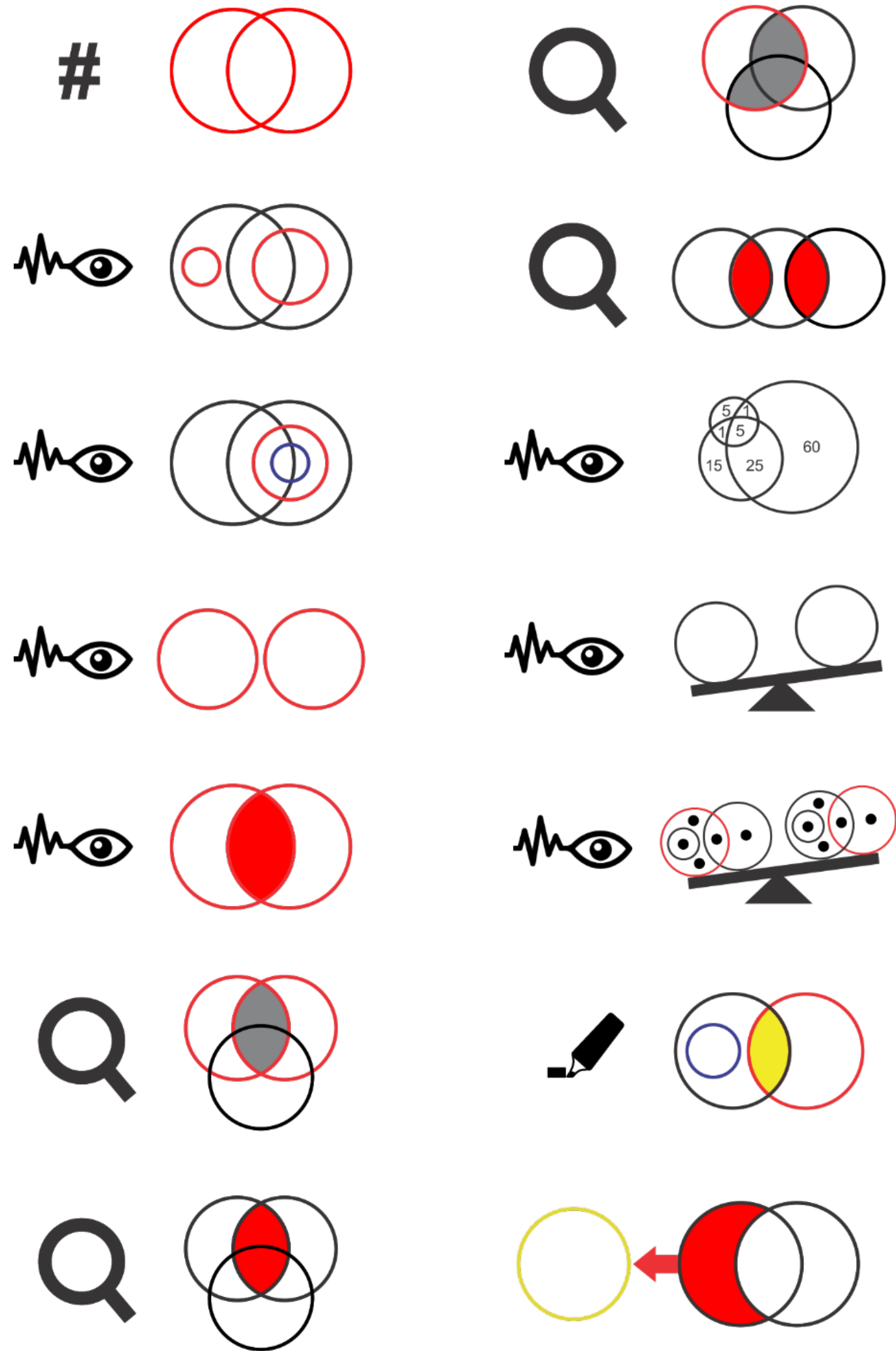
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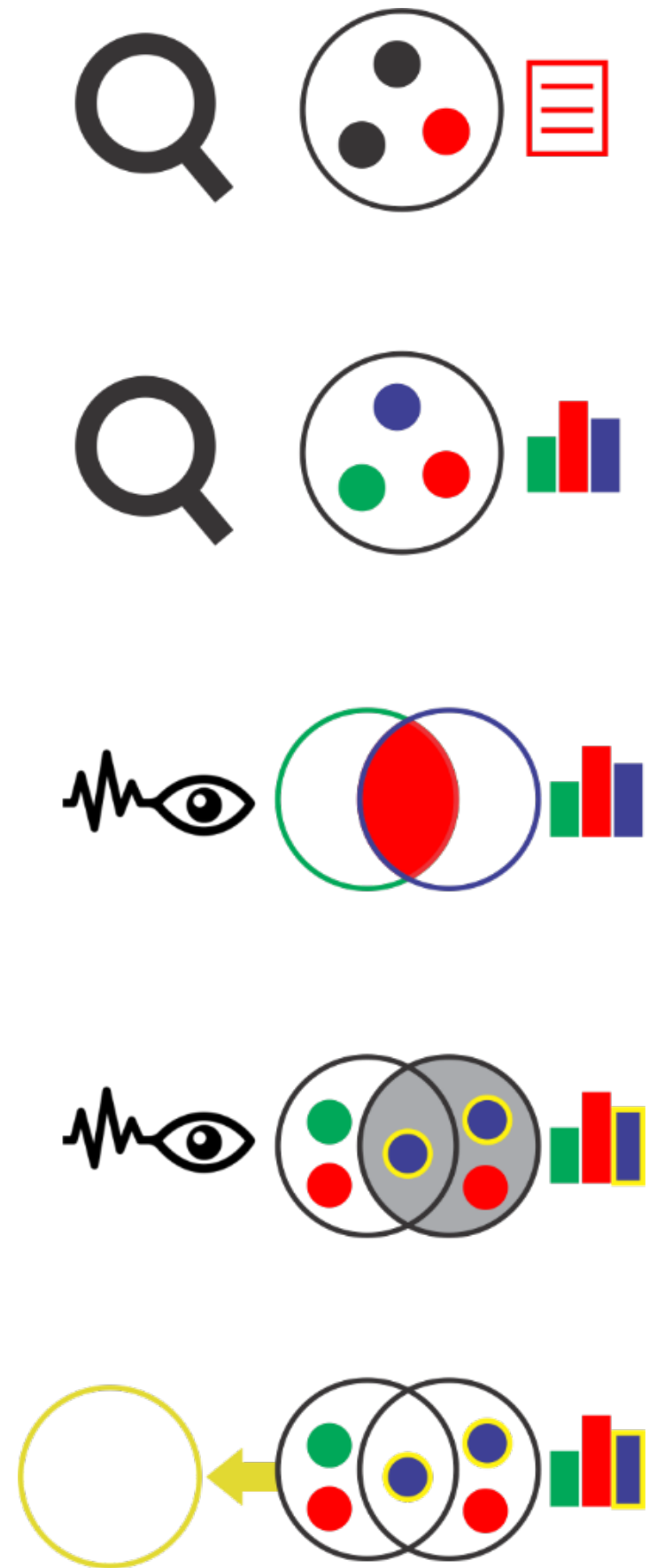
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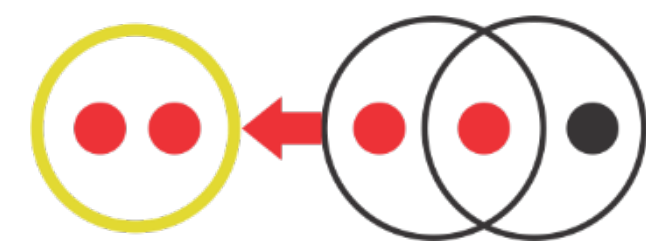
Sets and Set Relations



Element Attributes



Elements



Elements



Find elements belonging to **a specific set**



Find sets containing **a specific element**



Find elements based on their **set memberships**



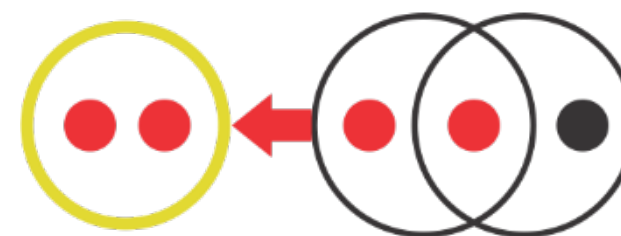
Find elements with **a specific set membership degree**



Filter out elements based on their **set memberships**



Filter out elements based on their **set membership degrees**

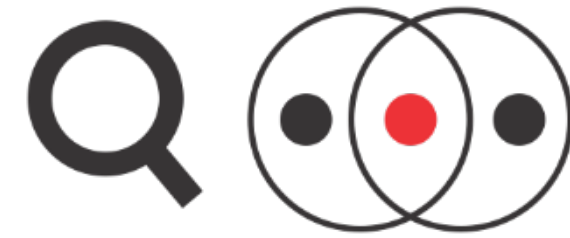


Create **a new set** that contains **certain elements**

Elements



Find elements belonging to **a specific set**



Find sets containing **a specific element**



Find elements based on their **set memberships**



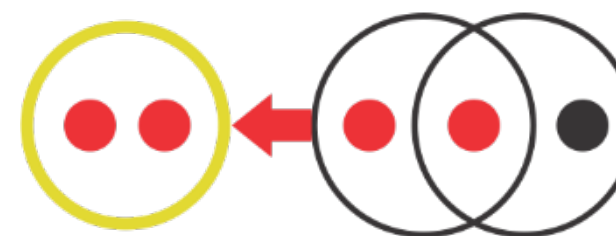
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Filter out elements based on their **set membership degrees**

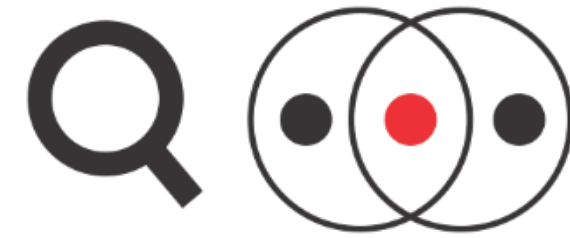


Create **a new set** that contains **certain elements**

Elements



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Find elements based on their **set memberships**



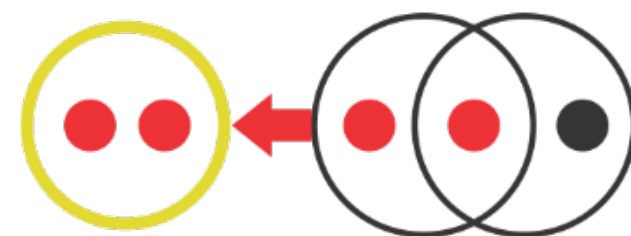
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Elements



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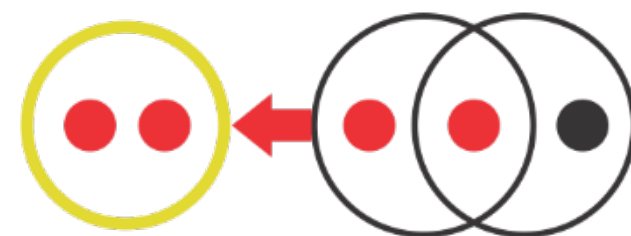
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Elements



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Find sets containing **a specific element**



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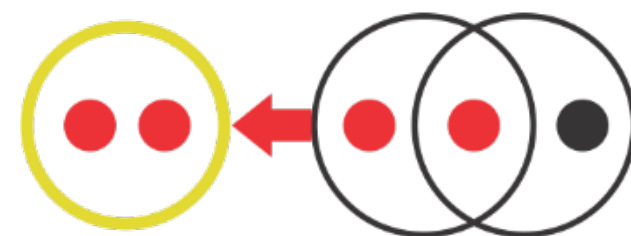
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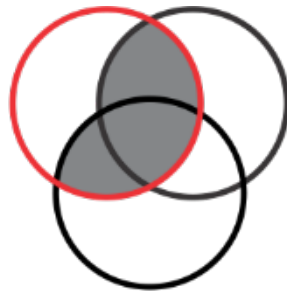
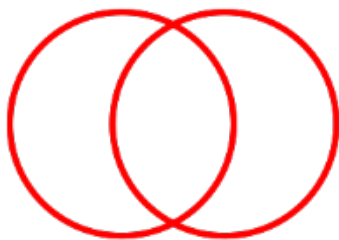
Filter out elements based on their **set membership degrees**



Create **a new set** that contains **certain elements**

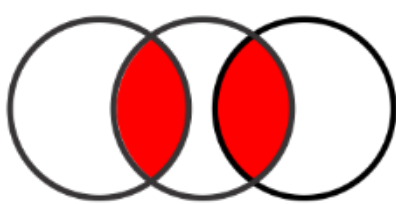
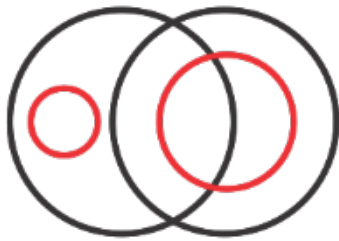
Sets and Set Relations

Find the # of sets
in the set family



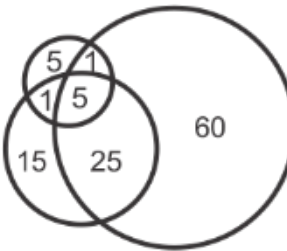
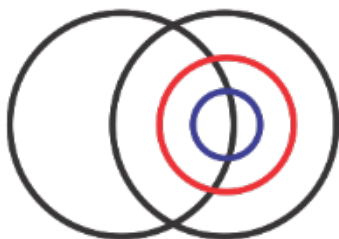
Find set intersections
of a specific set

Analyze
inclusion relations



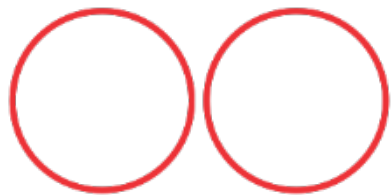
Find the set with largest
pairwise set intersections

Analyze
inclusion hierarchies



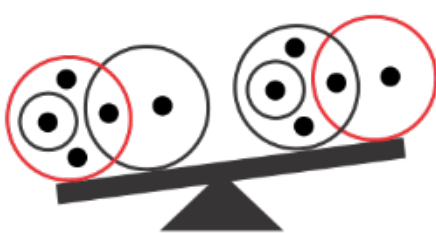
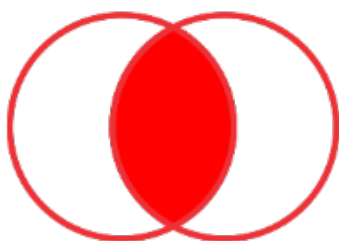
Analyze set & set
intersection cardinalities

Analyze
exclusion relations



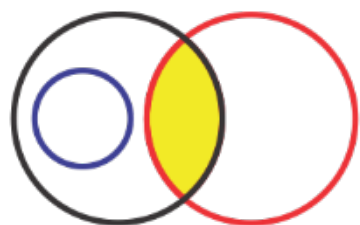
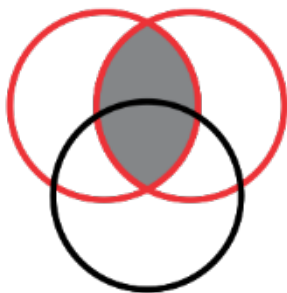
Analyze and compare
set similarities

Analyze
intersection relations



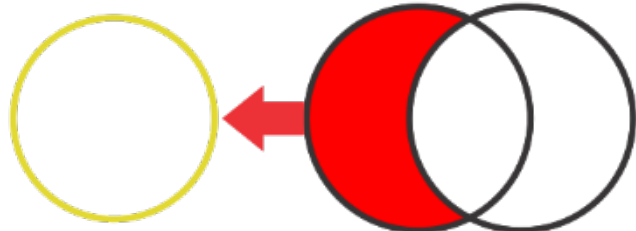
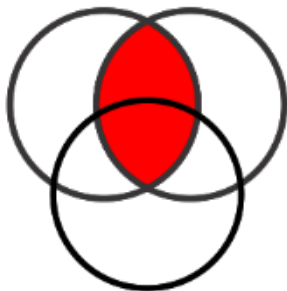
Analyze and compare
set exclusiveness

Find intersections
between k sets



Highlight specific sets,
subsets, or set relations

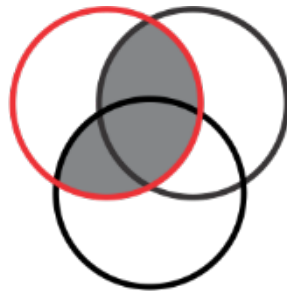
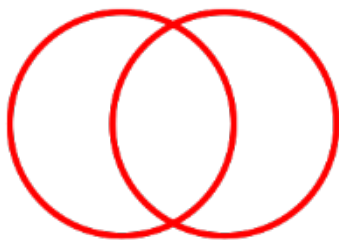
Find sets involved in
certain intersection



Create a new set using
set-theoretical operations

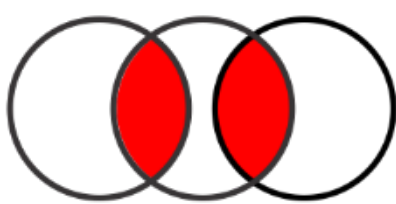
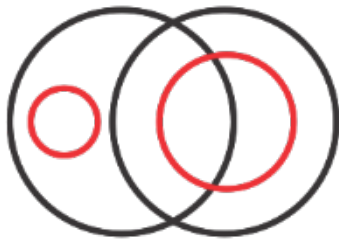
Sets and Set Relations

Find the # of sets
in the set family



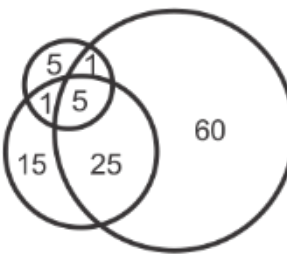
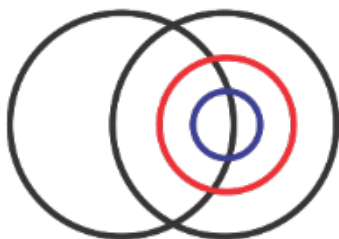
Find set intersections
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Analyze
inclusion relations



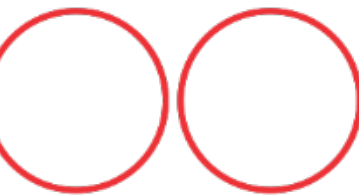
Find the set with largest
pairwise set intersections

Analyze
inclusion hierarchies



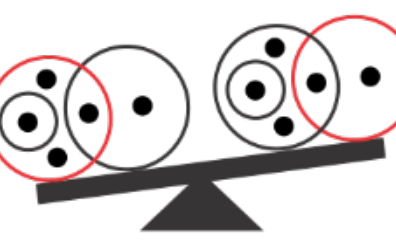
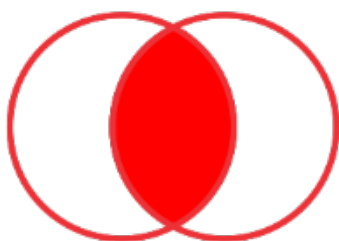
Analyze set & set
intersection cardinalities

Analyze
exclusion relations



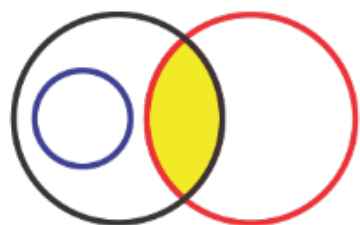
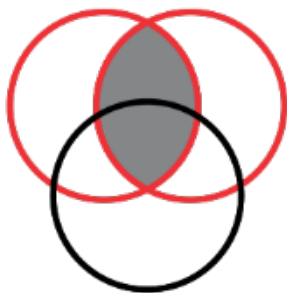
Analyze and compare
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Analyze
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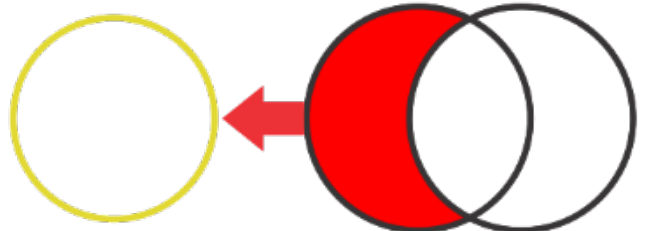
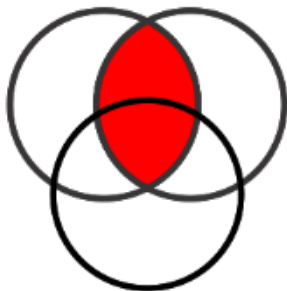
Analyze and compare
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Find intersections
between k sets



Highlight specific sets,
subsets, or set relations

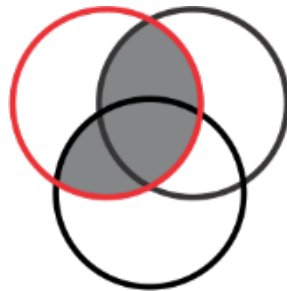
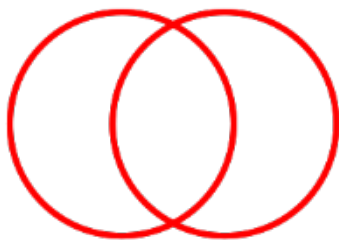
Find sets involved in
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Create a new set using
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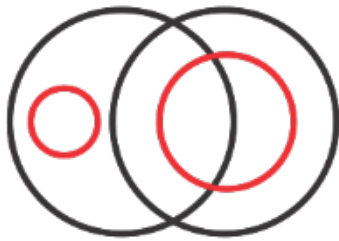
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Find the # of sets
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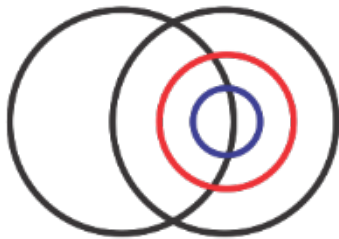


Find set intersections
of a specific set

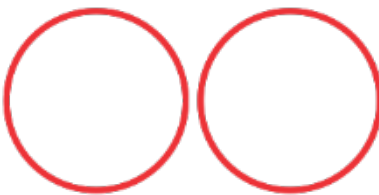
Analyze
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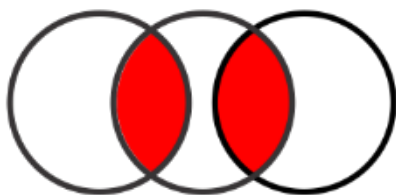
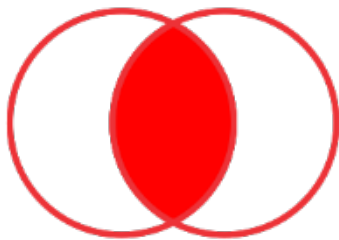
Analyze
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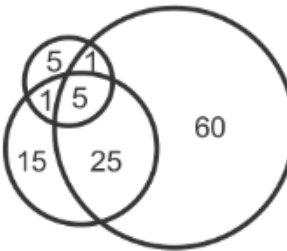
Analyze
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Analyze
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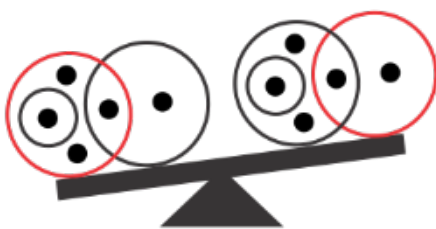
Find the set with largest
pairwise set intersections



Analyze set & set
intersection cardinalities

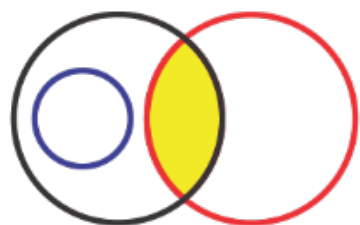
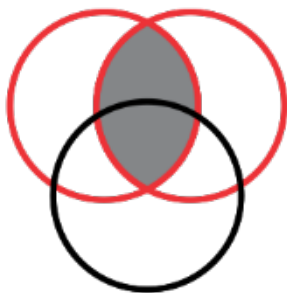


Analyze and compare
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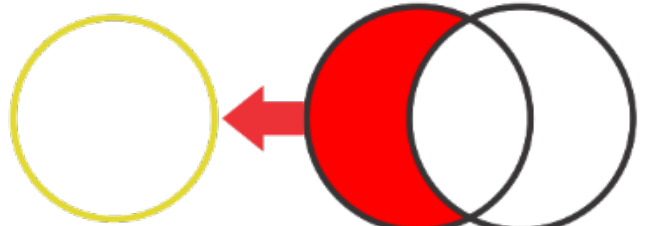
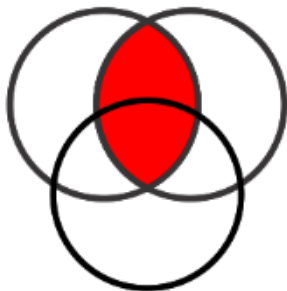
Analyze and compare
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Find intersections
between k sets



Highlight specific sets,
subsets, or set relations

Find sets involved in
certain intersection



Create a new set using
set-theoretical operations

Sets and Set Relations

Find the # of sets
in the set family

#

Analyze
inclusion relations

Analyze
inclusion hierarchies

Analyze
exclusion relations

Analyze
intersection relations

Find intersections
between k sets

Find sets involved in
certain intersection

Find set intersections
of a specific set

Find the set with largest
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Analyze and compare
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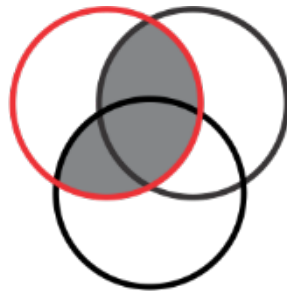
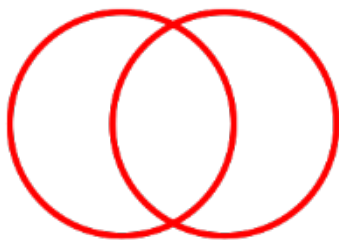
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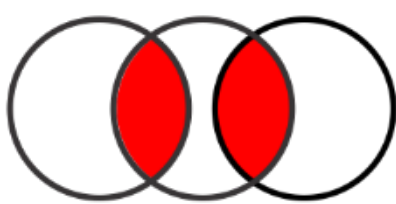
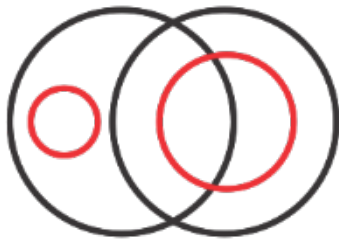
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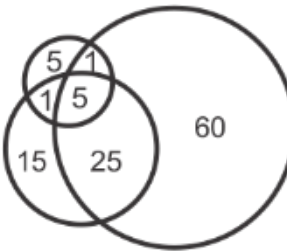
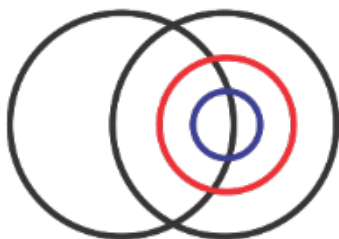
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inclusion relations



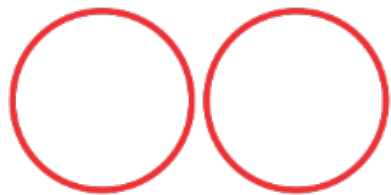
Find the set with largest
pairwise set intersections

Analyze
inclusion hierarchies



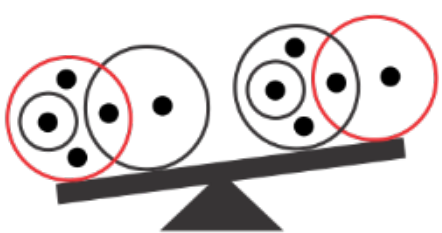
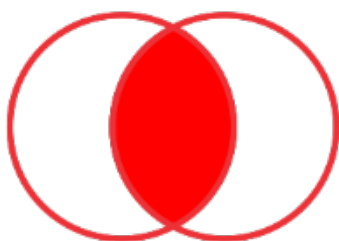
Analyze set & set
intersection cardinalities

Analyze
exclusion relations



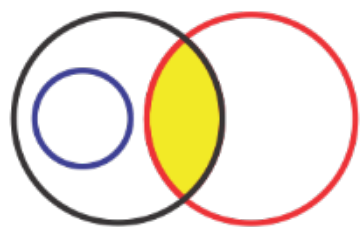
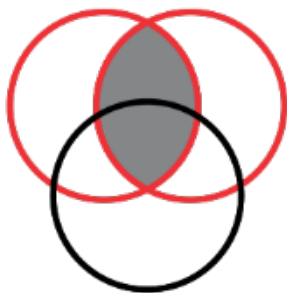
Analyze and compare
set similarities

Analyze
intersection relations



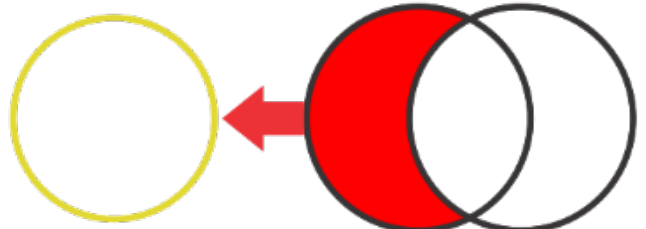
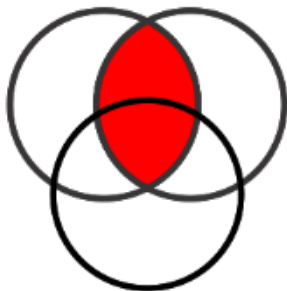
Analyze and compare
set exclusiveness

Find intersections
between k sets



Highlight specific sets,
subsets, or set relations

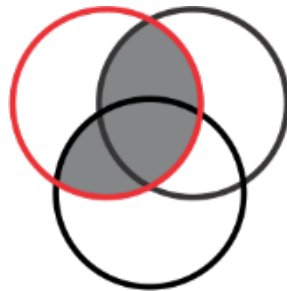
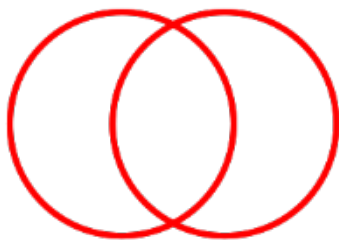
Find sets involved in
certain intersection



Create a new set using
set-theoretical operations

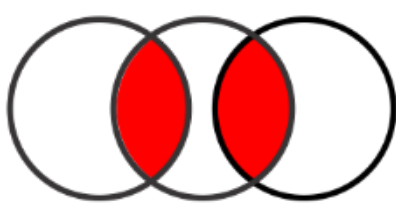
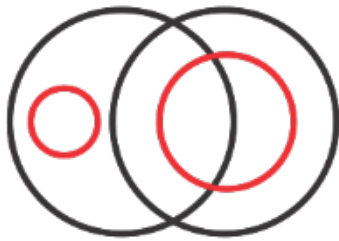
Sets and Set Relations

Find the # of sets
in the set family



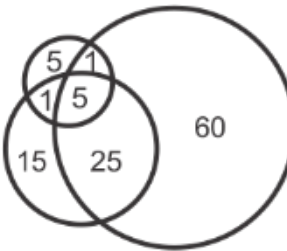
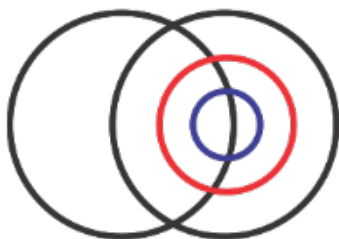
Find set intersections
of a specific set

Analyze
inclusion relations



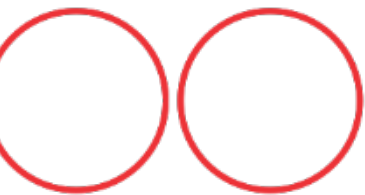
Find the set with largest
pairwise set intersections

Analyze
inclusion hierarchies



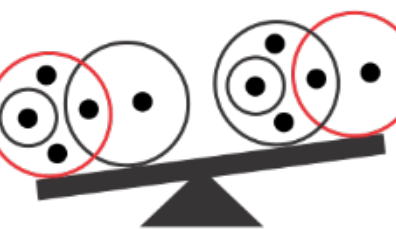
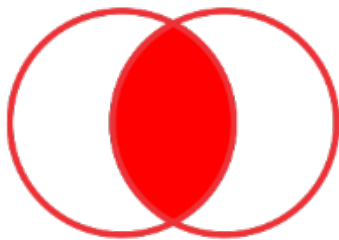
Analyze set & set
intersection cardinalities

Analyze
exclusion relations



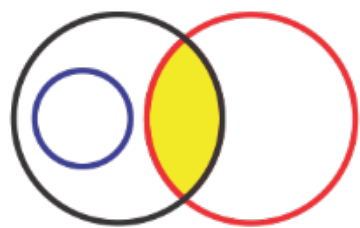
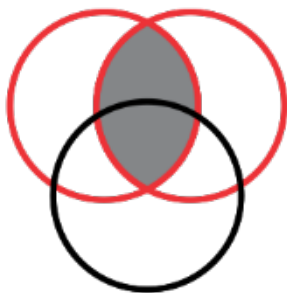
Analyze and compare
set similarities

Analyze
intersection relations



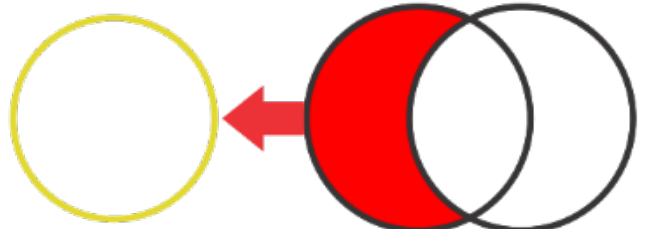
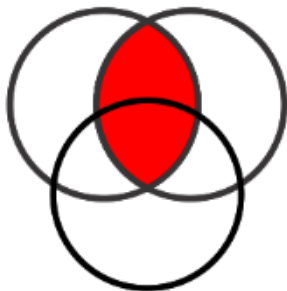
Analyze and compare
set exclusiveness

Find intersections
between k sets



Highlight specific sets,
subsets, or set relations

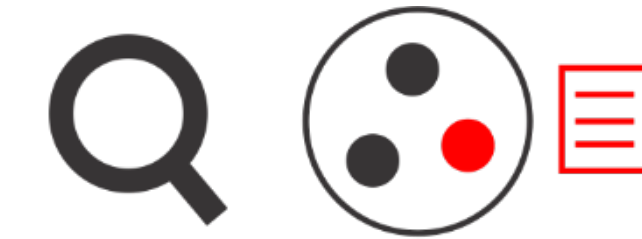
Find sets involved in
certain intersection



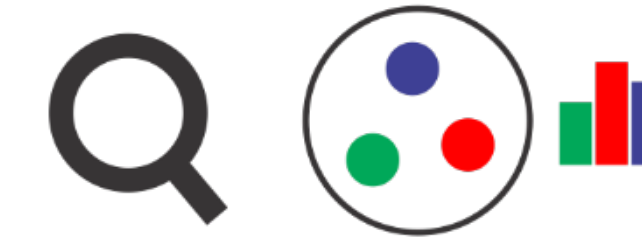
Create a new set using
set-theoretical operations

Element Attributes

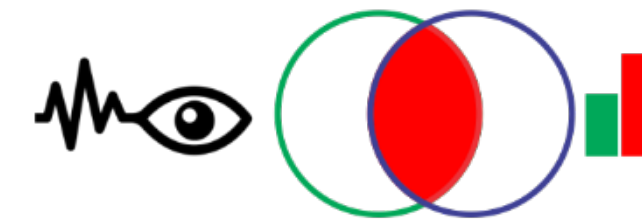
Find the **attribute value** of a certain element



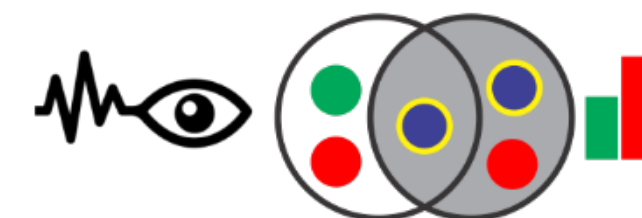
Find the **distribution** of an attribute in a certain set or subset



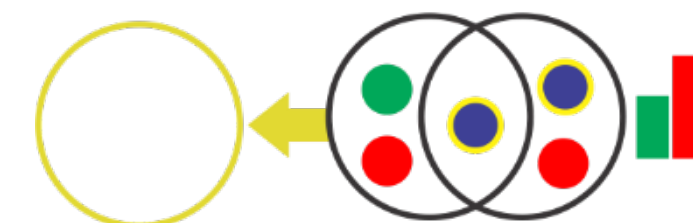
Compare the **attribute values** of sets or set intersections



Analyze the set memberships for elements having
certain attribute values

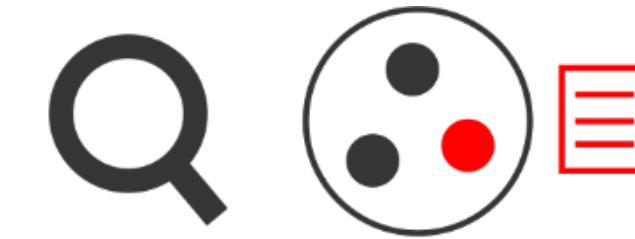


Create **a new set** out of elements having
certain attribute values

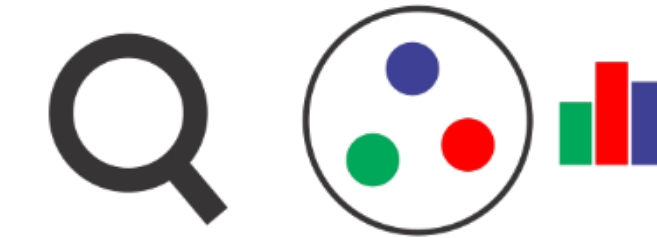


Element Attributes

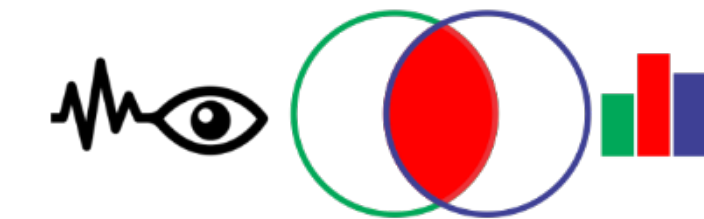
Find the **attribute value** of a certain element



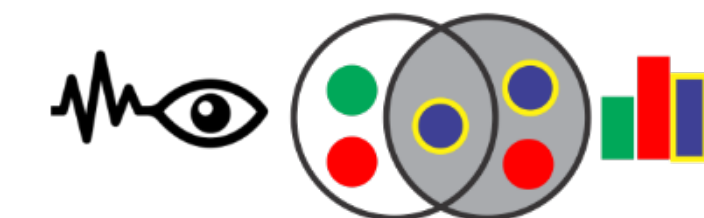
Find the **distribution** of an attribute in a certain set or subset



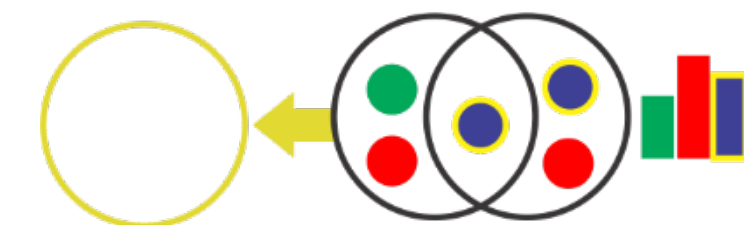
Compare the **attribute values** of sets or set intersections



Analyze the set memberships for elements having
certain attribute values

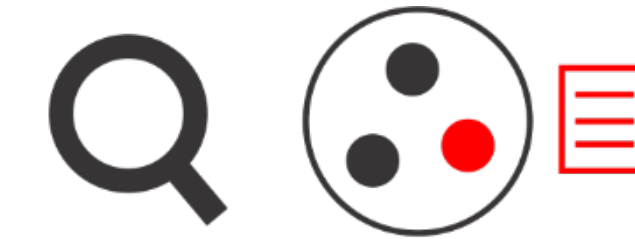


Create **a new set** out of elements having
certain attribute values

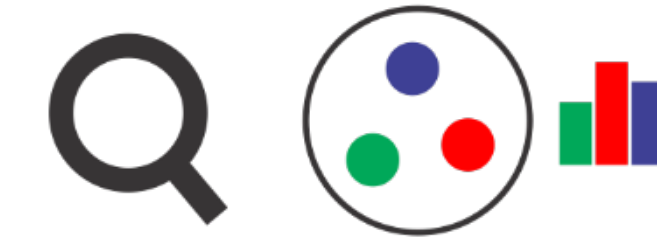


Element Attributes

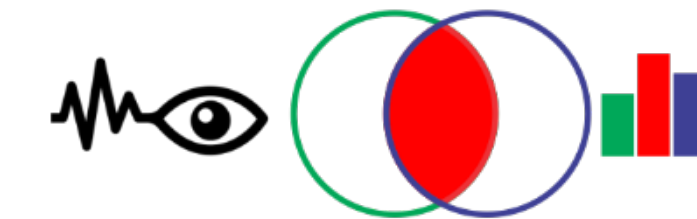
Find the **attribute value** of a certain element



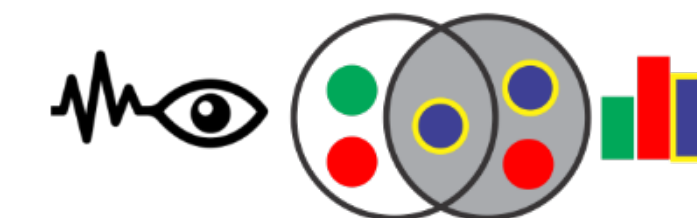
Find the **distribution** of an attribute in a certain set or subset



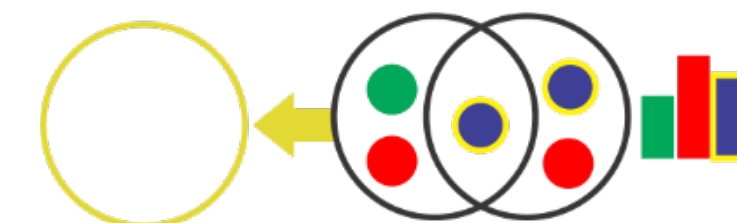
Compare the **attribute values** of sets or set intersections



Analyze the set memberships for elements having
certain attribute values



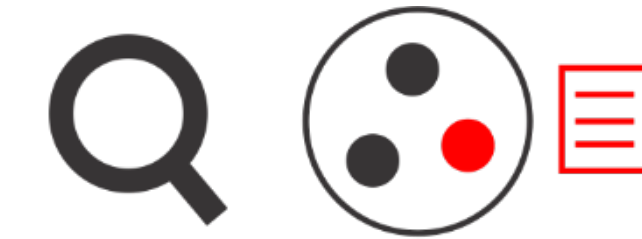
Create **a new set** out of elements having
certain attribute values



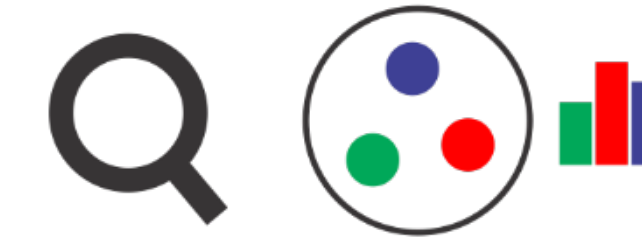
age

Element Attributes

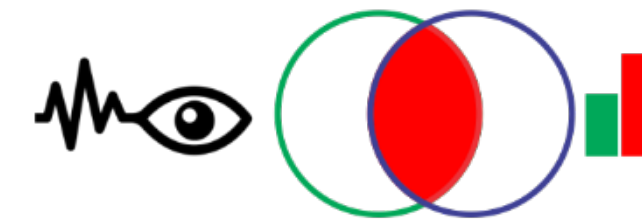
Find the **attribute value** of a certain element



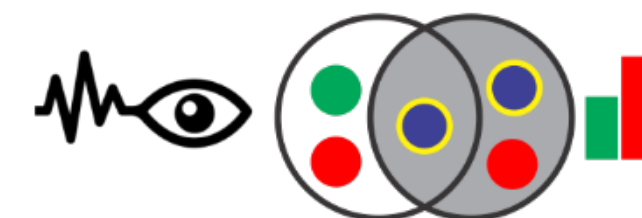
Find the **distribution** of an attribute in a certain set or subset



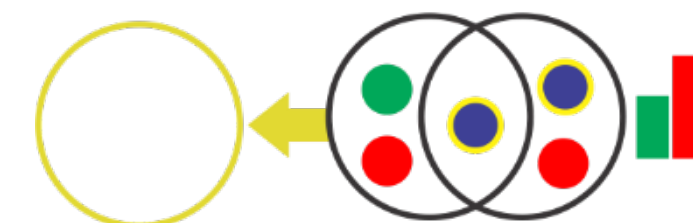
Compare the **attribute values** of sets or set intersections



Analyze the set memberships for elements having **certain attribute values**



Create **a new set** out of elements having **certain attribute values**

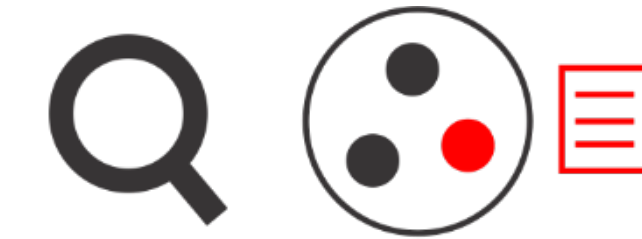


age

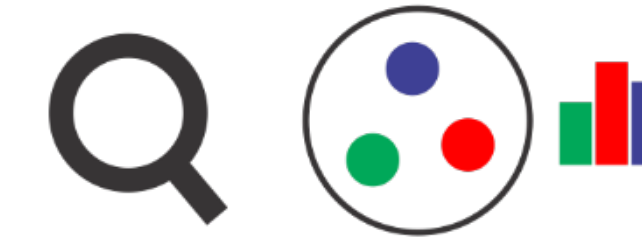


Element Attributes

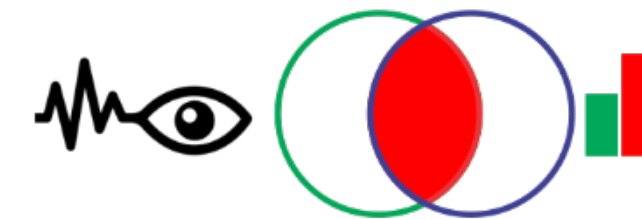
Find the **attribute value** of a certain element



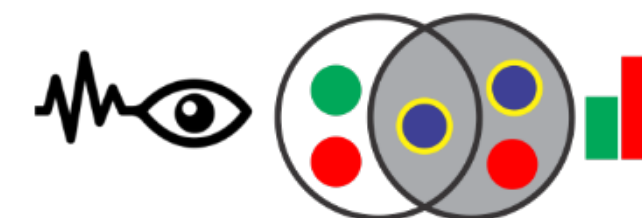
Find the **distribution** of an attribute in a certain set or subset



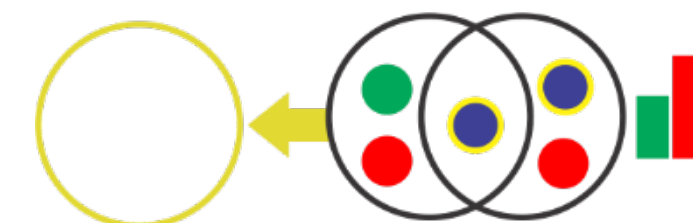
Compare the **attribute values** of sets or set intersections



Analyze the set memberships for elements having **certain attribute values**



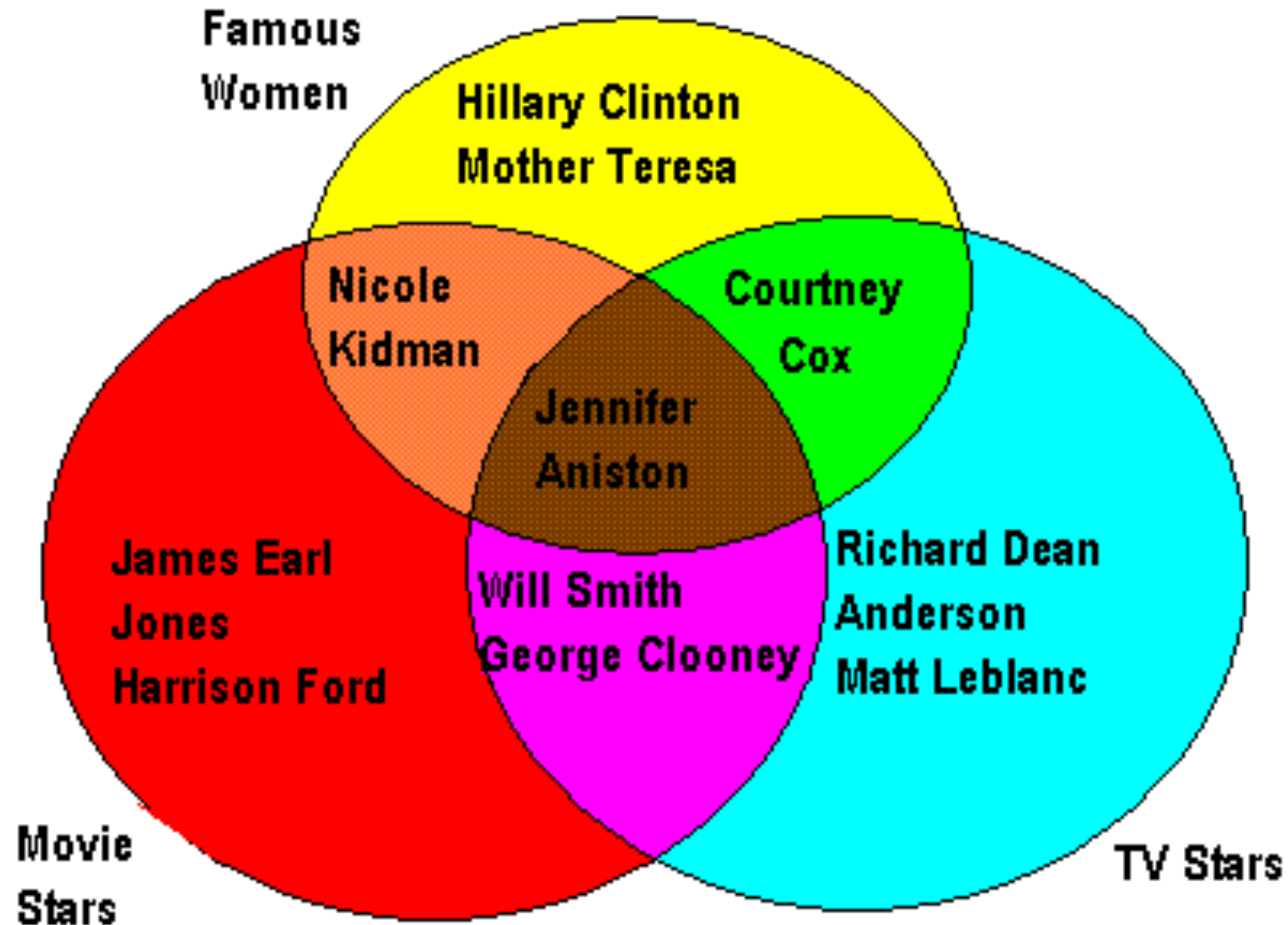
Create **a new set** out of elements having **certain attribute values**



age



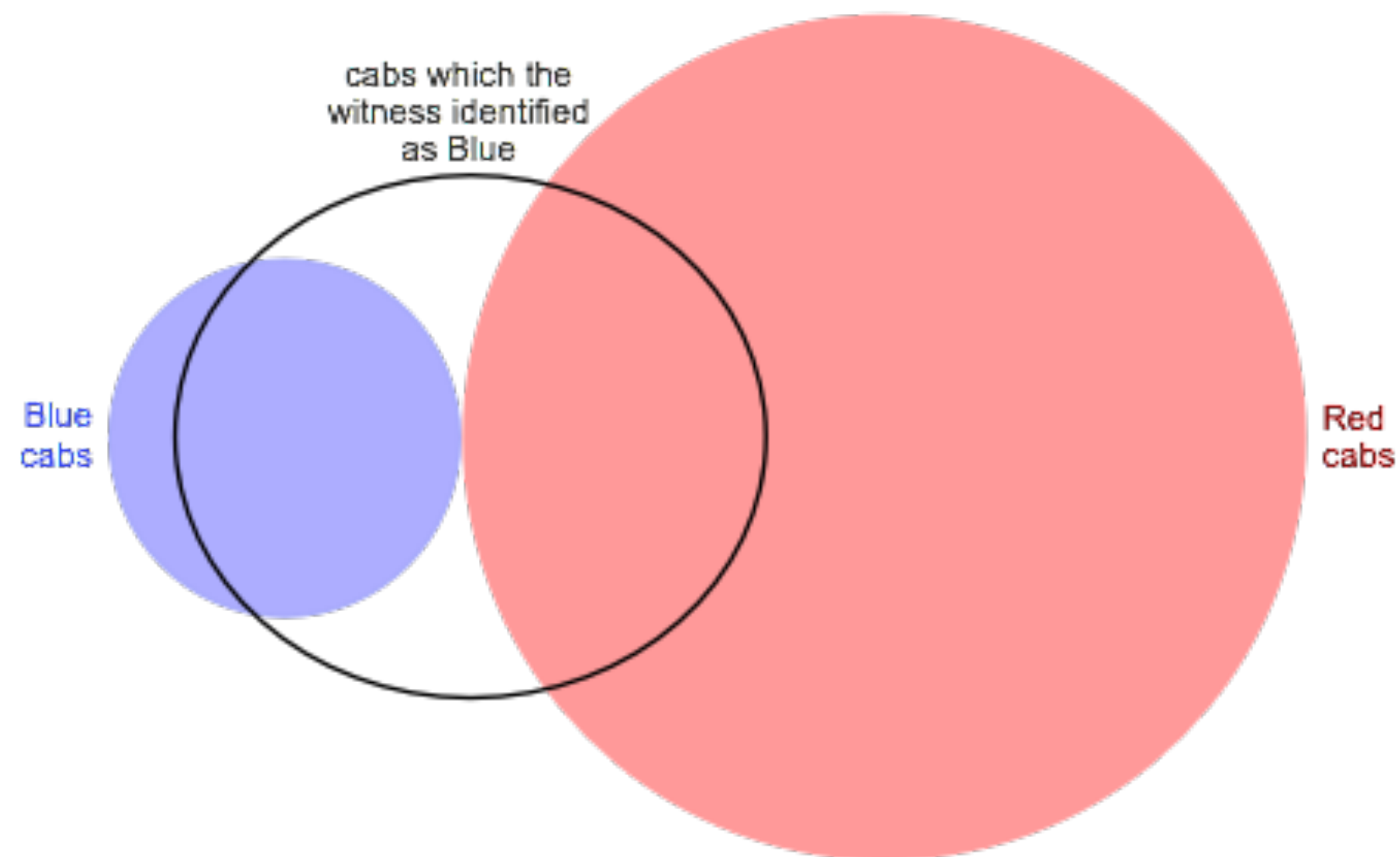
Venn Diagram



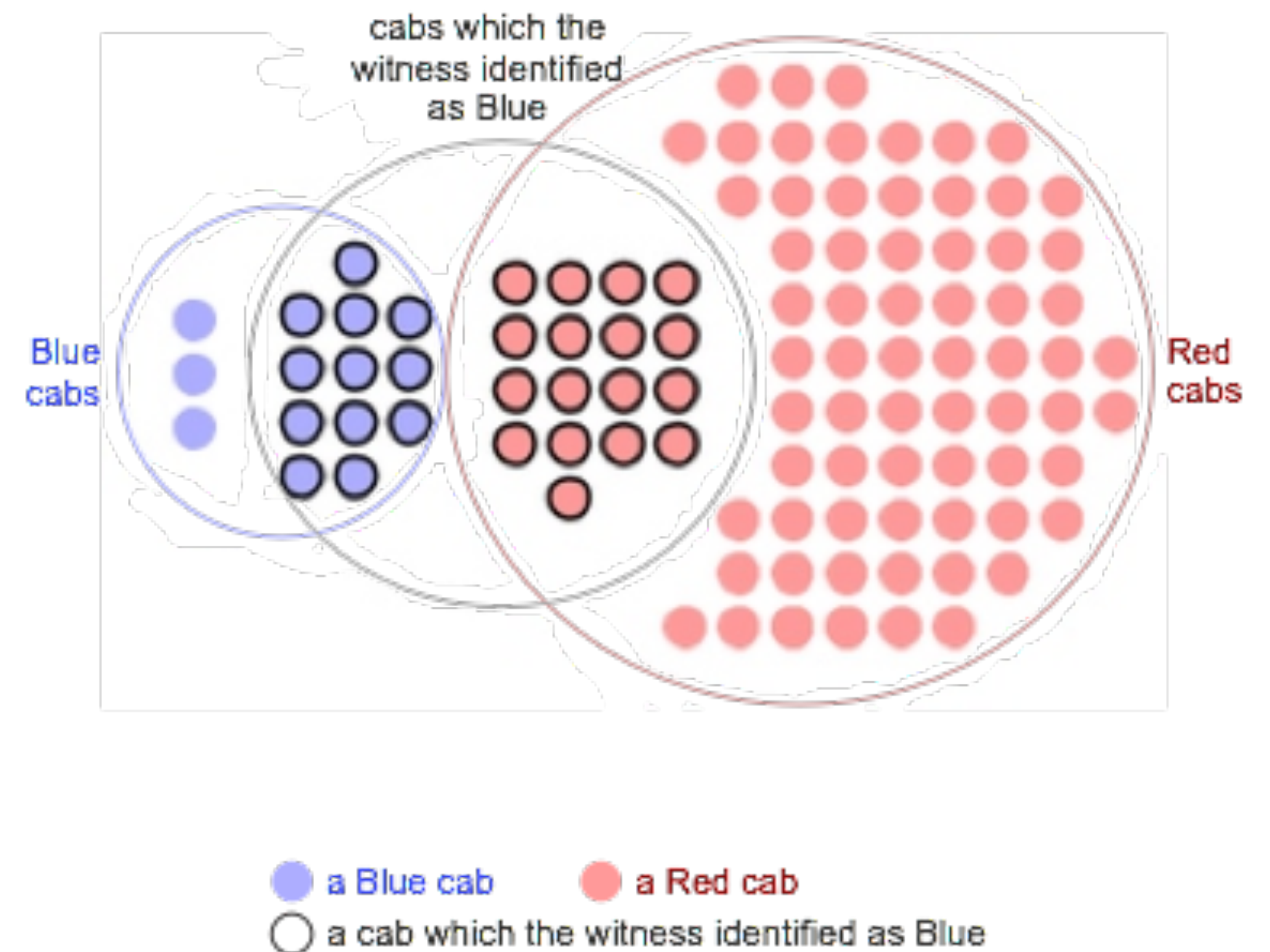
[<http://askville.amazon.com/idea-Venn-diagram/AnswerViewer.do?requestId=8420613>]

What about cardinality?

Area encoding



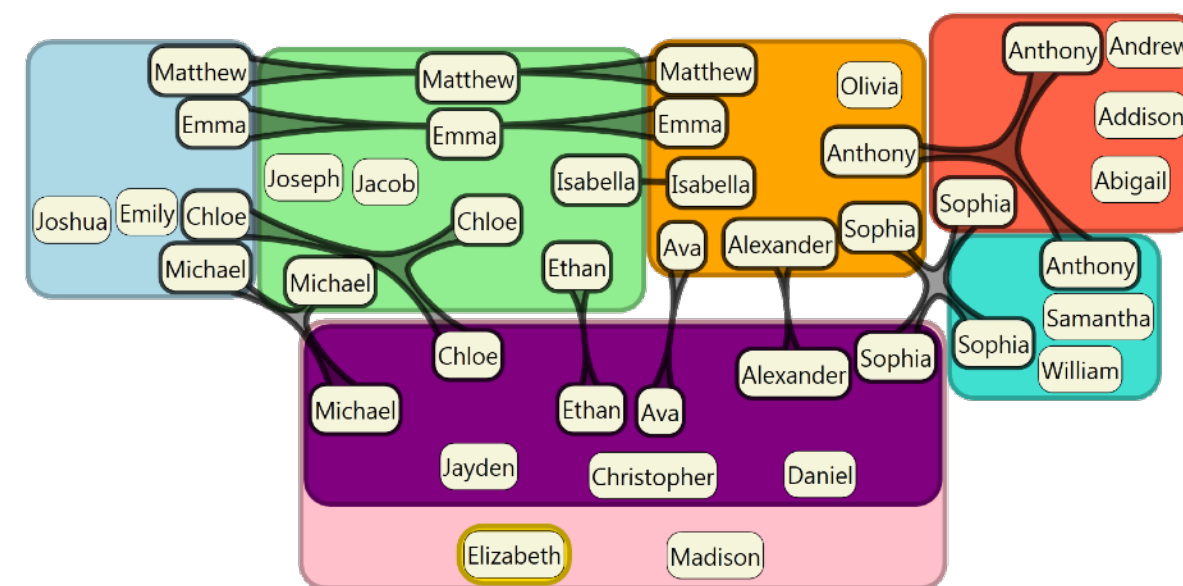
Using glyphs



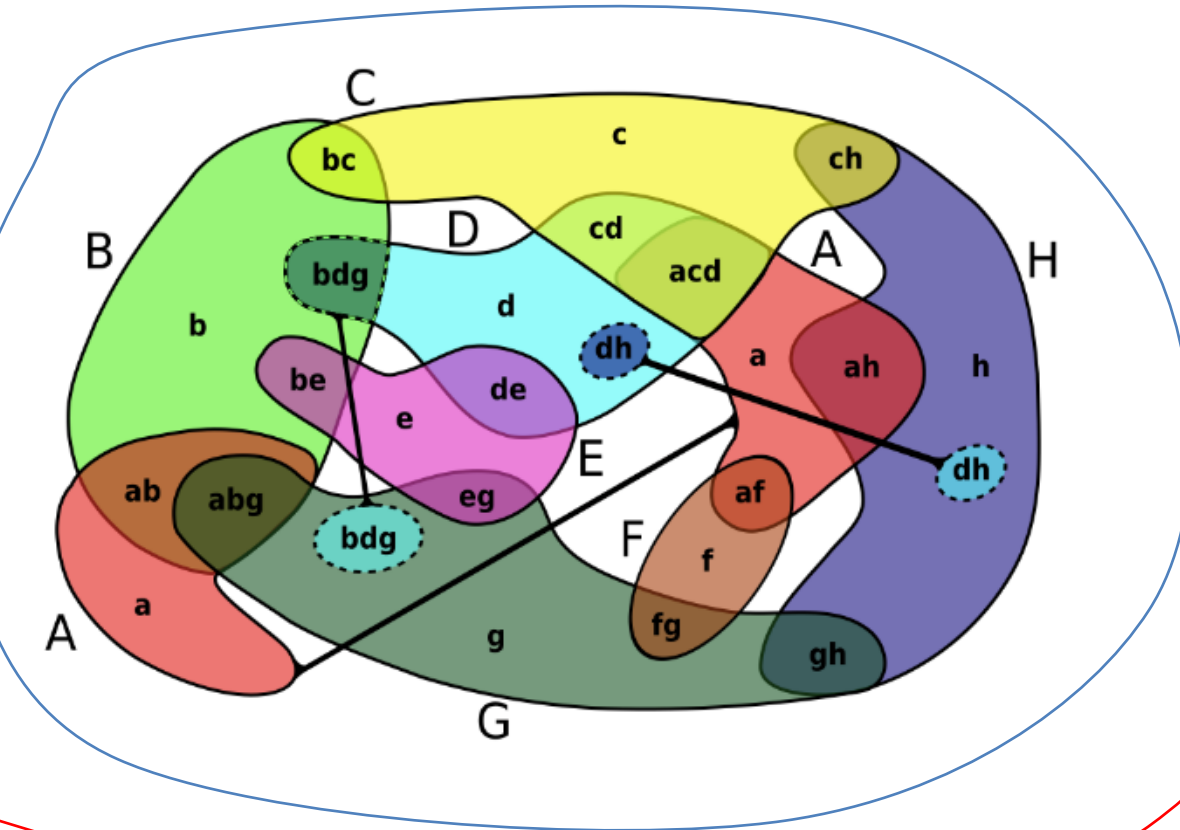
[B. Alsallakh et al., 2014]

Euler Diagram Variants

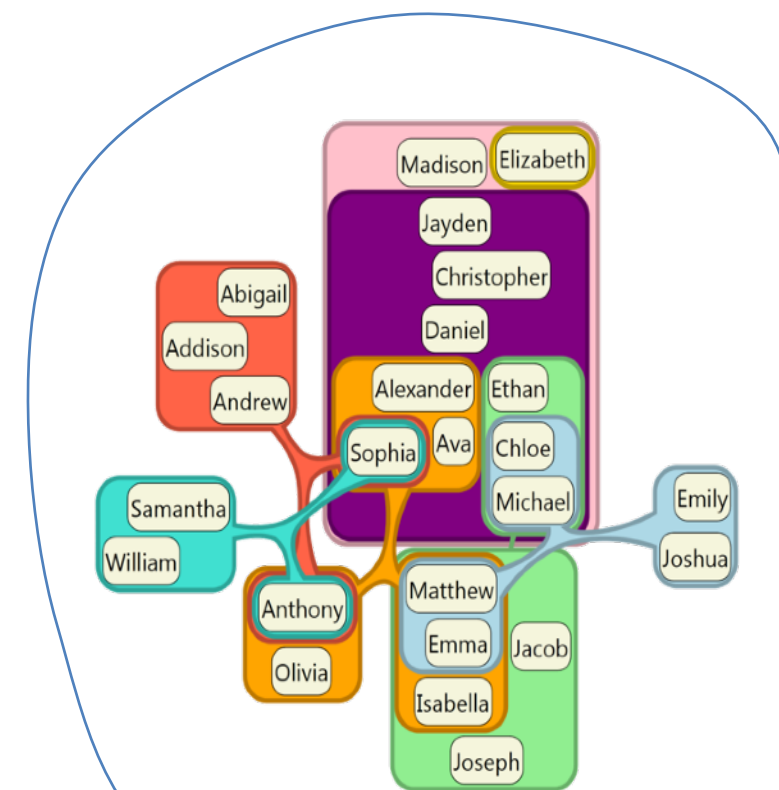
use edges



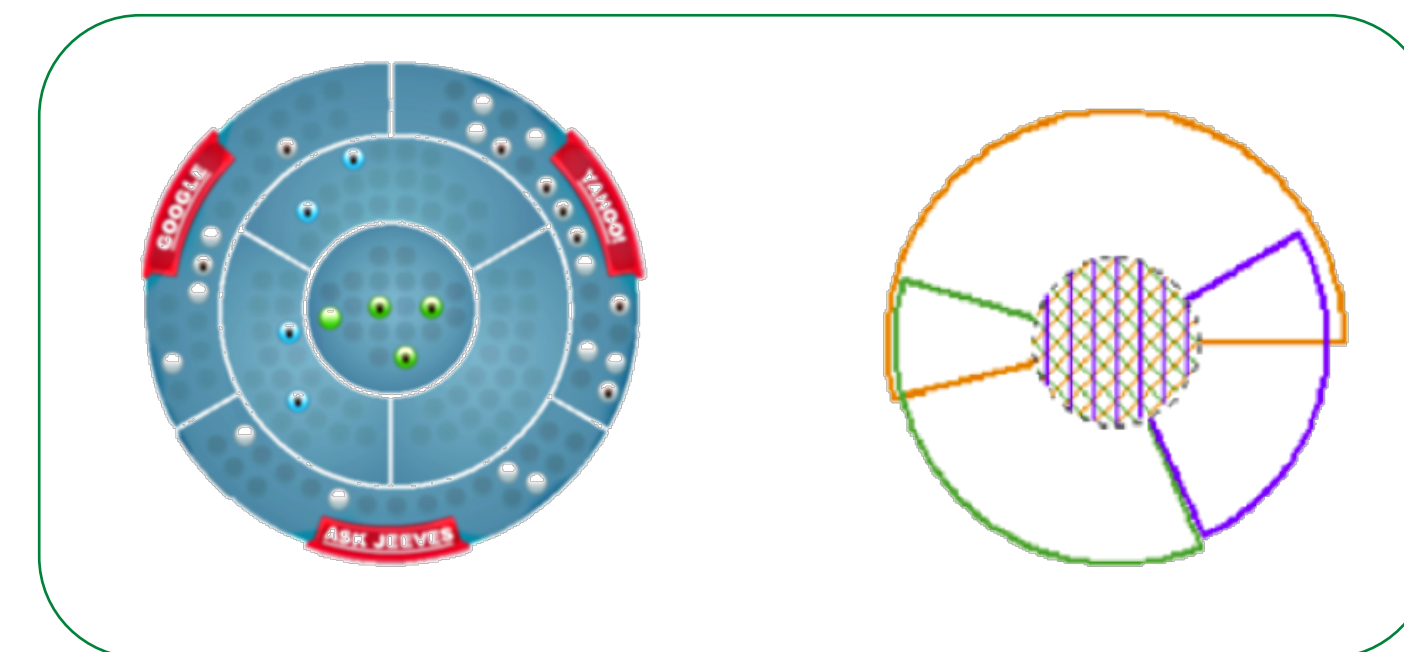
split set into components



split set into components

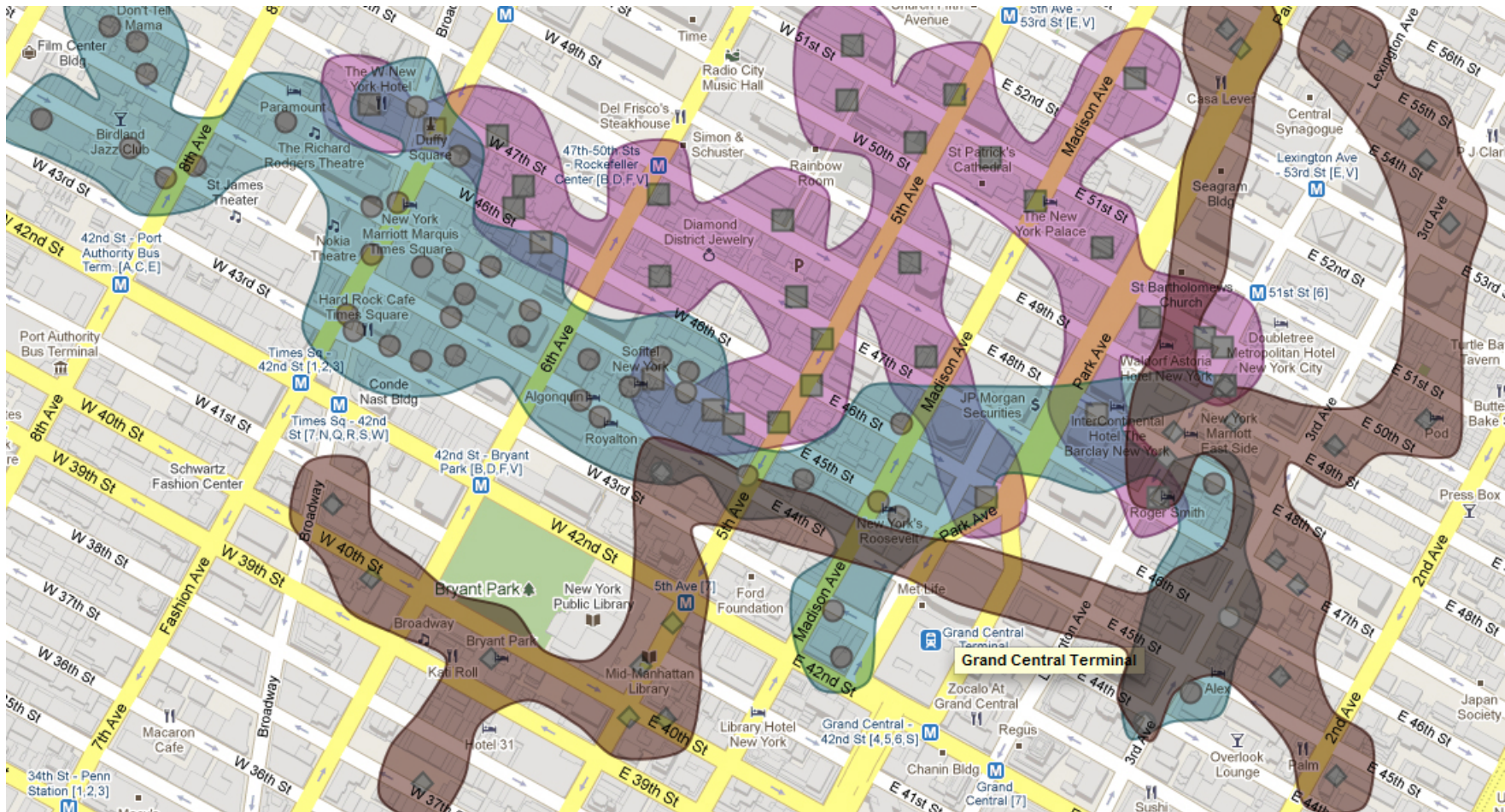


use a concentric layout



[B. Alsallakh et al., 2014]

KelpFusion



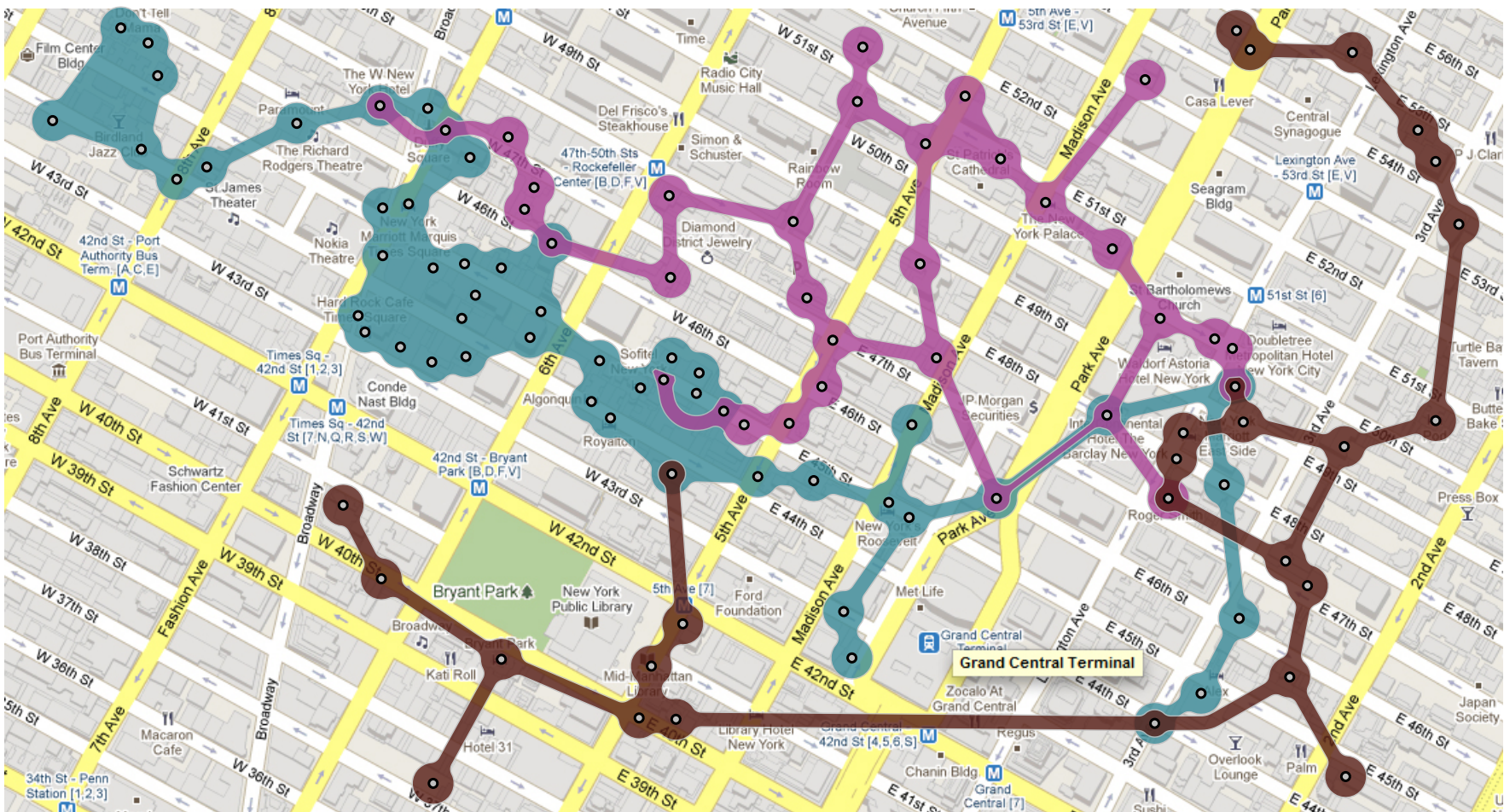
(a) Bubble Sets



(c) LineSets



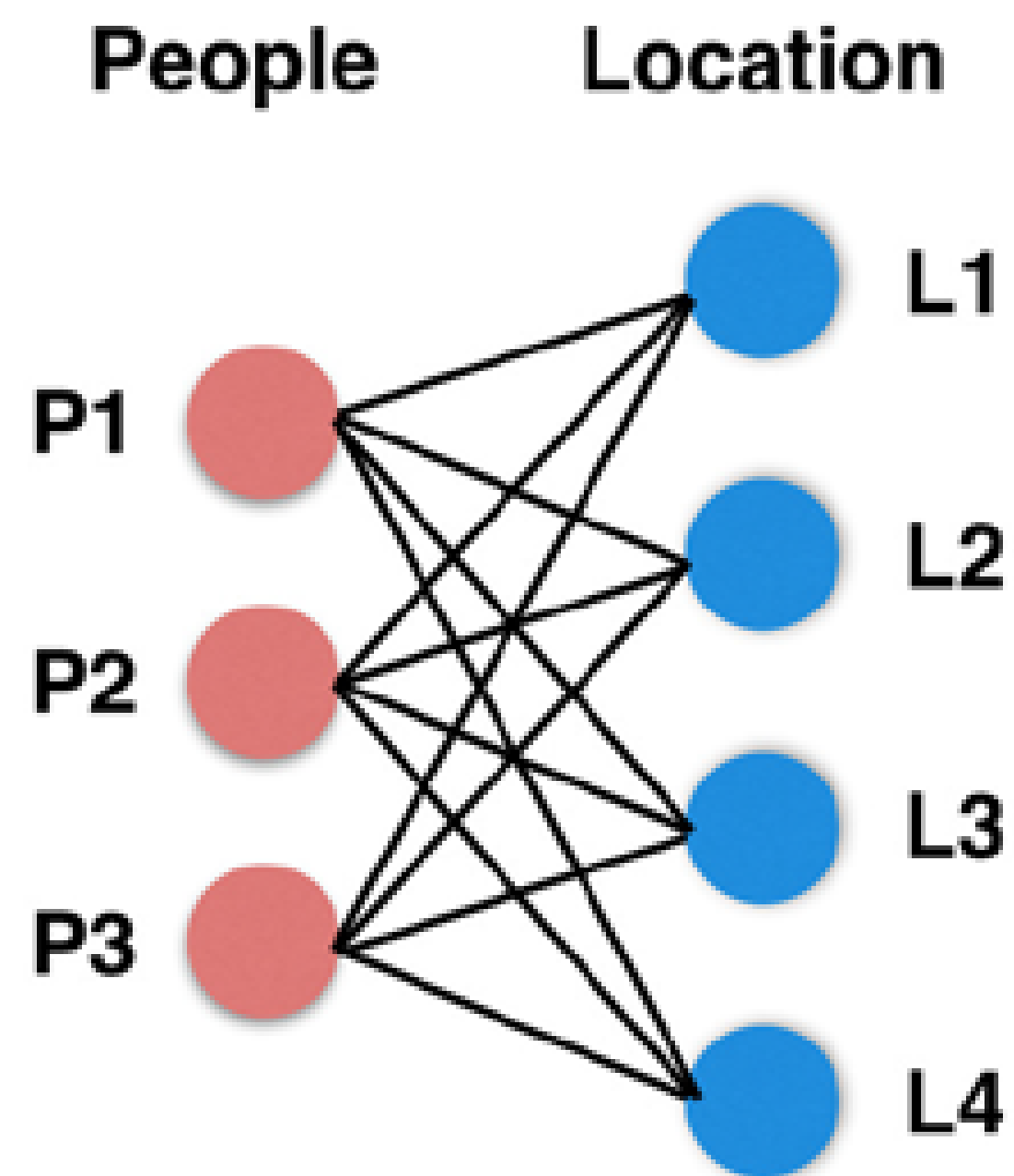
(b) Kelp Diagrams



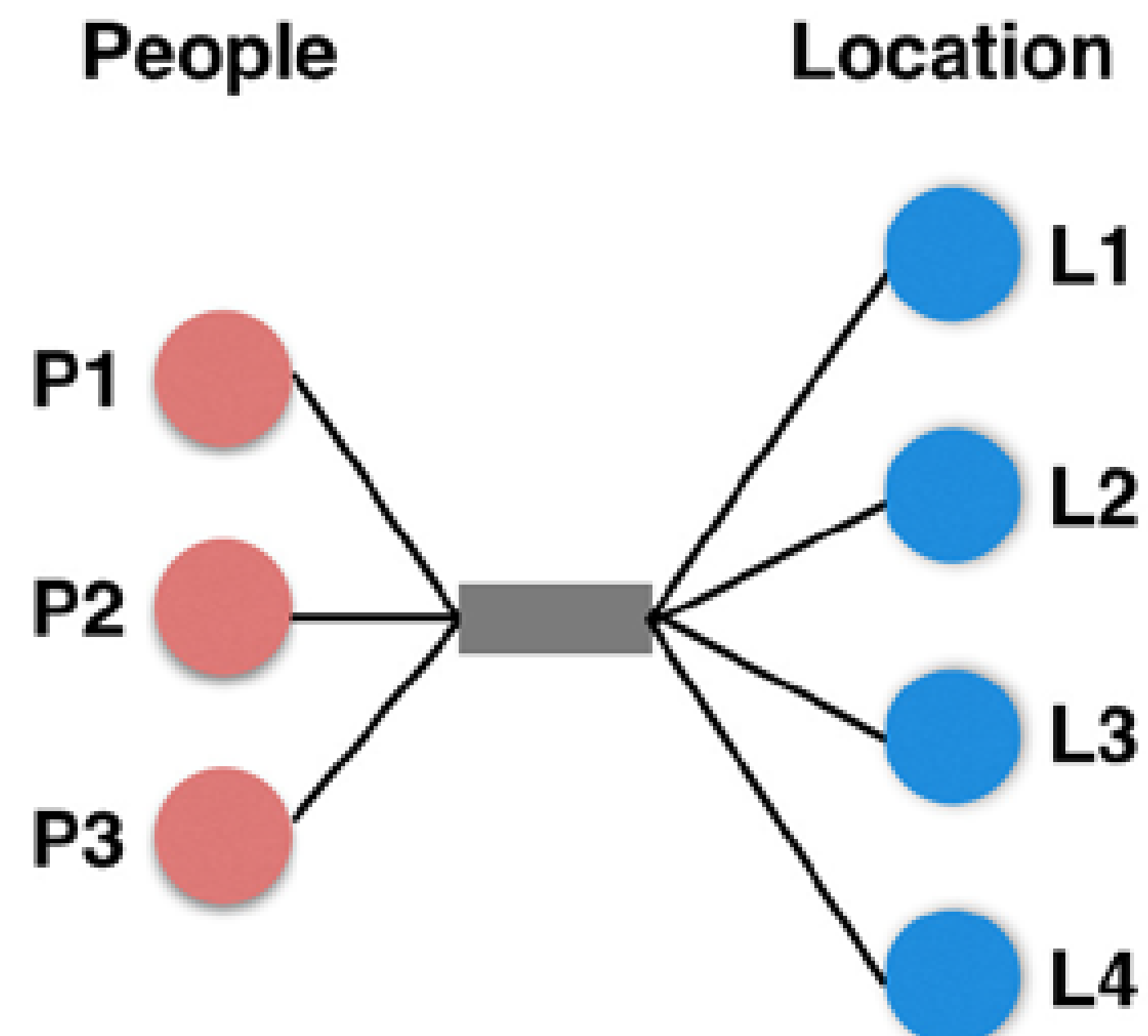
(e) KelpFusion (medium)

[Meulemans et al., 2013]

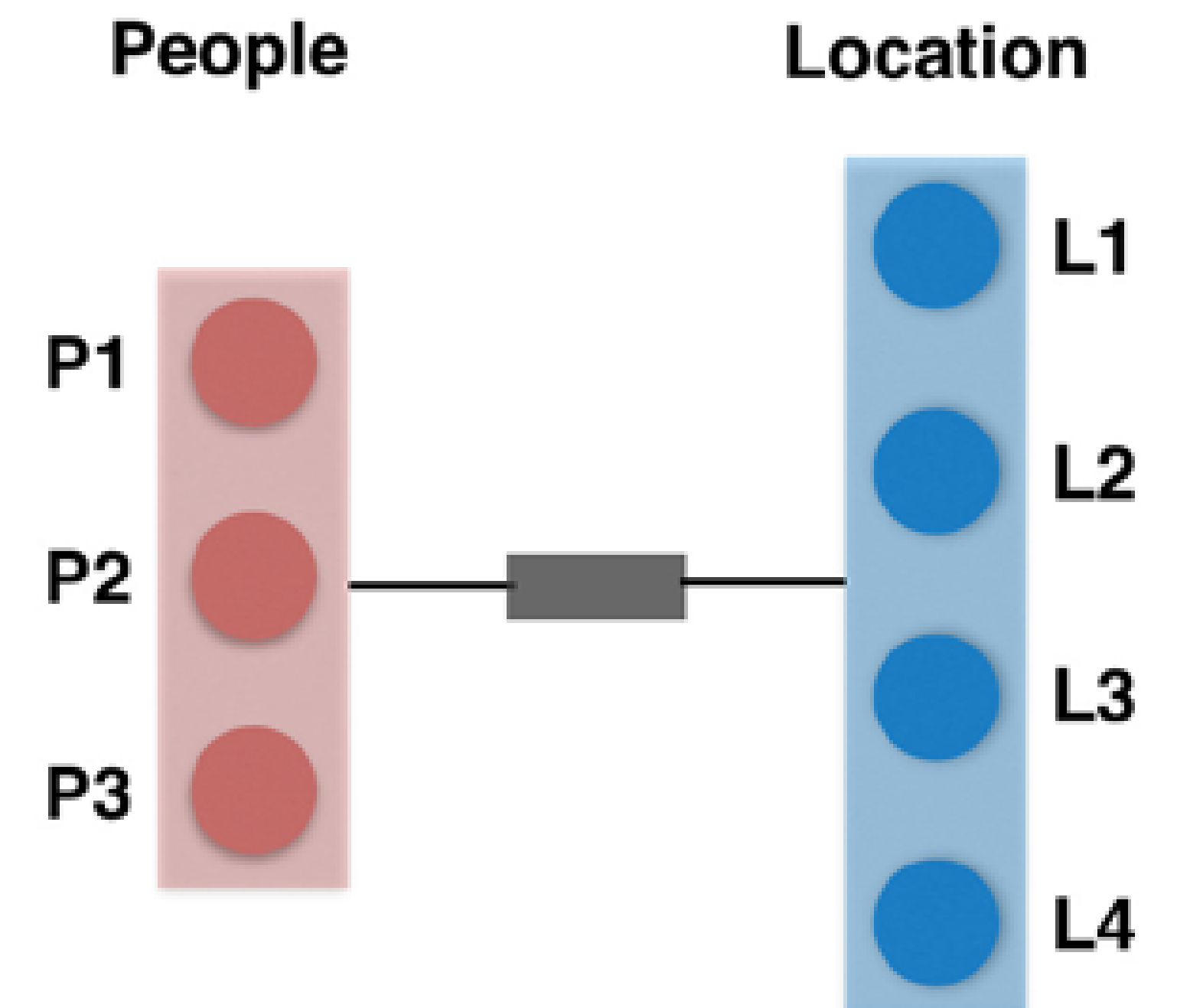
Biset edge bundling (and grouping)



(A)



(B)



(C)

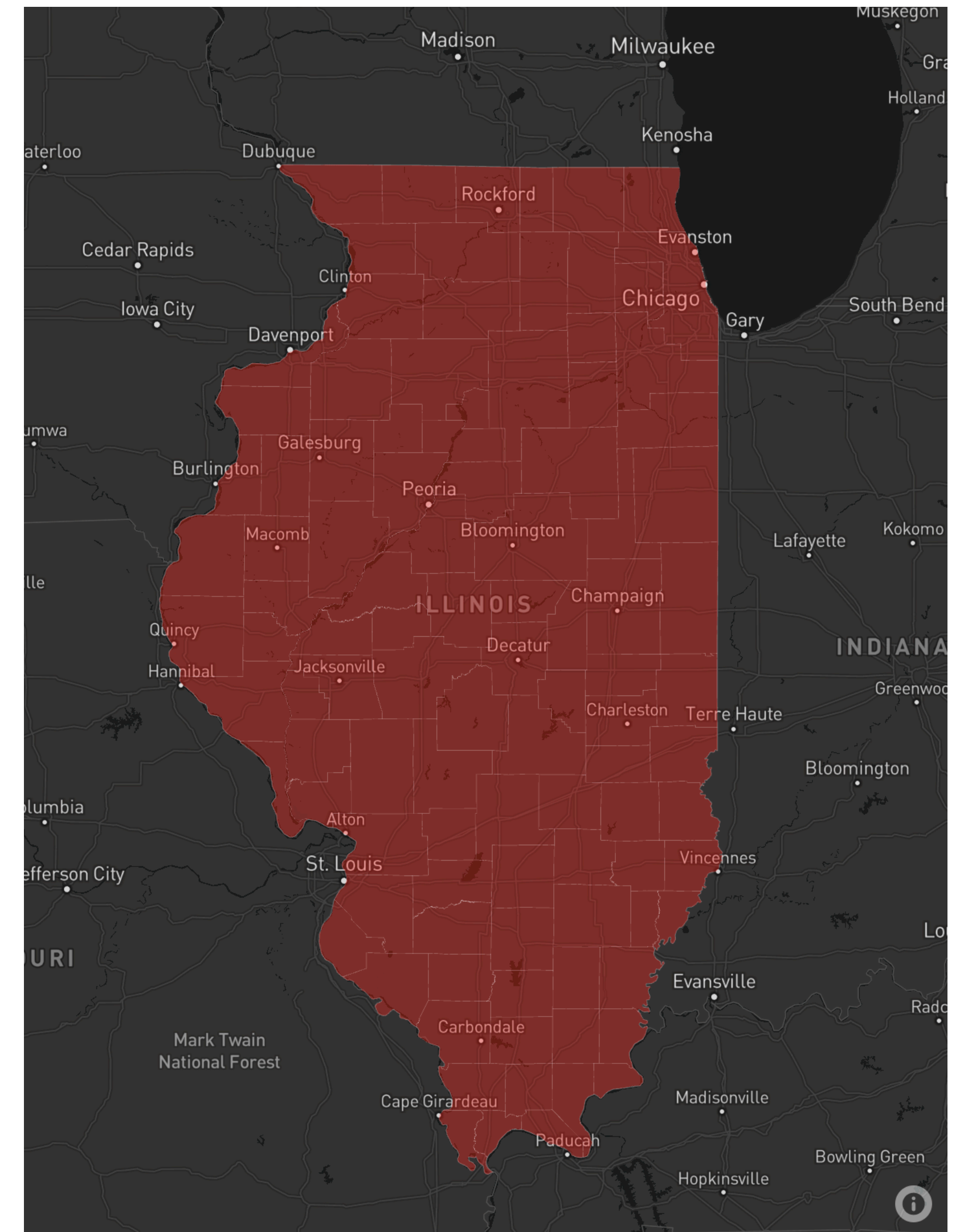
[M. Sun et al., 2016]

Project Design

- Start working on turning your visualization ideas into designs
- Feedback to Blackboard today
- Sketch (talk about today)
- Options:
 - Try vastly different options
 - Refine an initial idea

Assignment 4

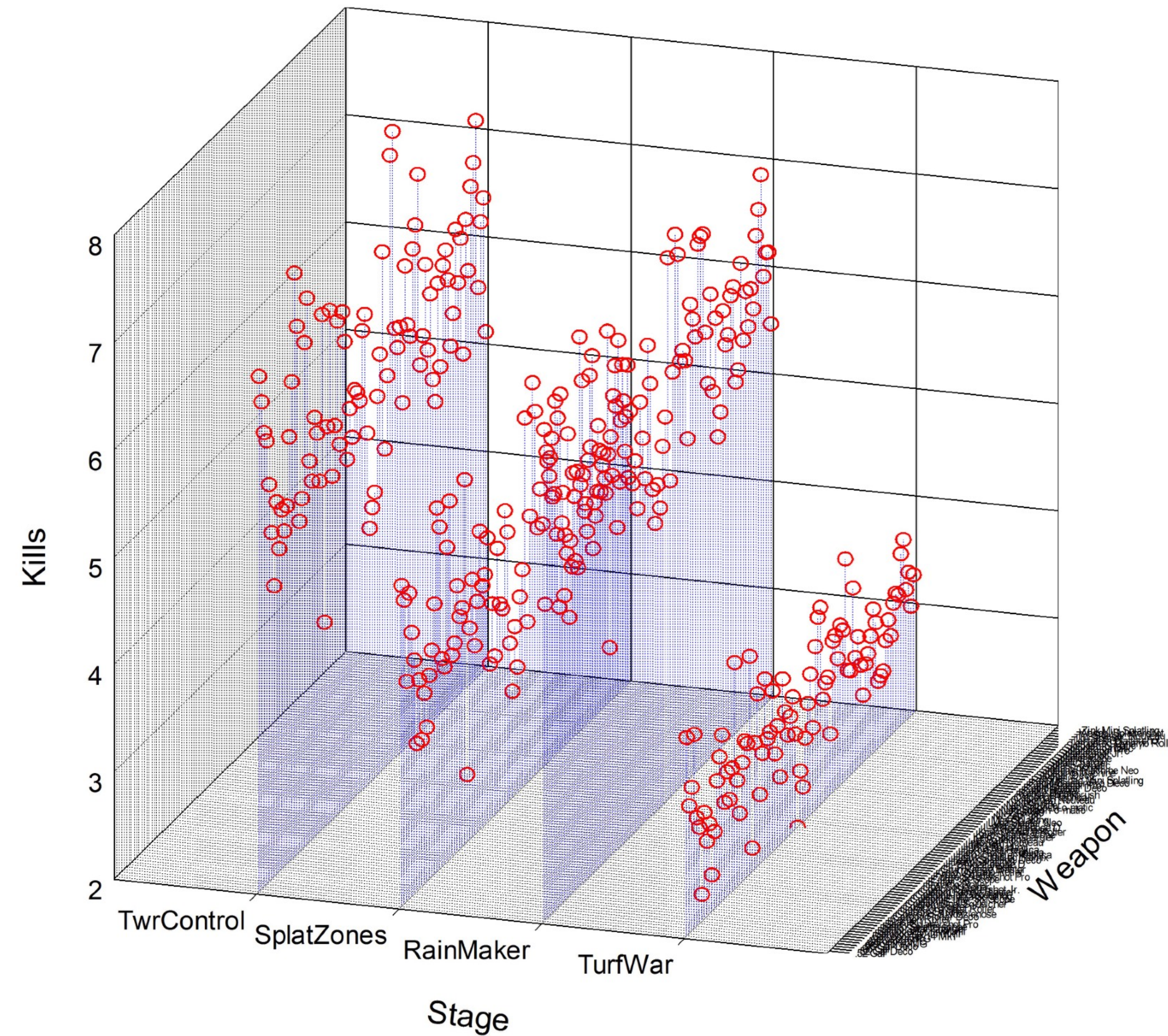
- Create Choropleth Maps
 - Deal with projections and GeoJSON Data
 - Select appropriate colormaps
- [CS 680 Only] Part 3 is using other libraries, you only need to do **one** option
- Example image at the right is **not** a solution to Part 3, needs proper colormapping!



Guidelines for Visualization Design

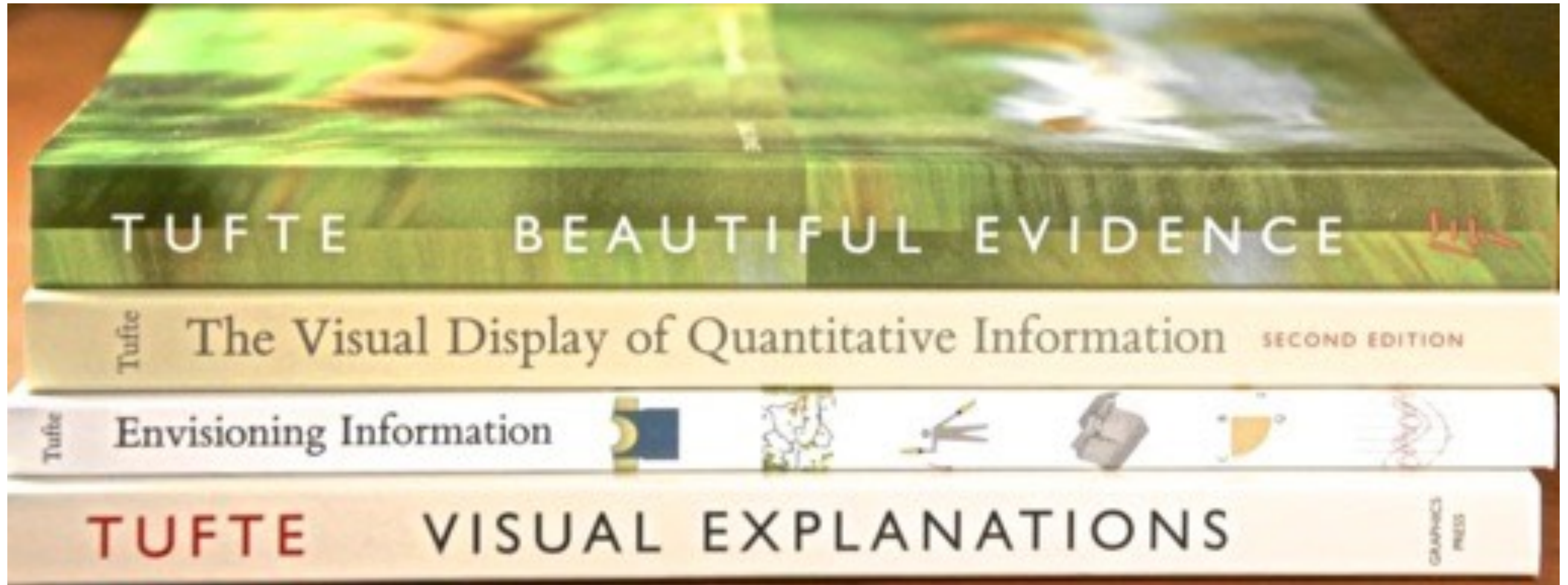
WTF Visualizations (wtfviz.net)

3D Category Scatter



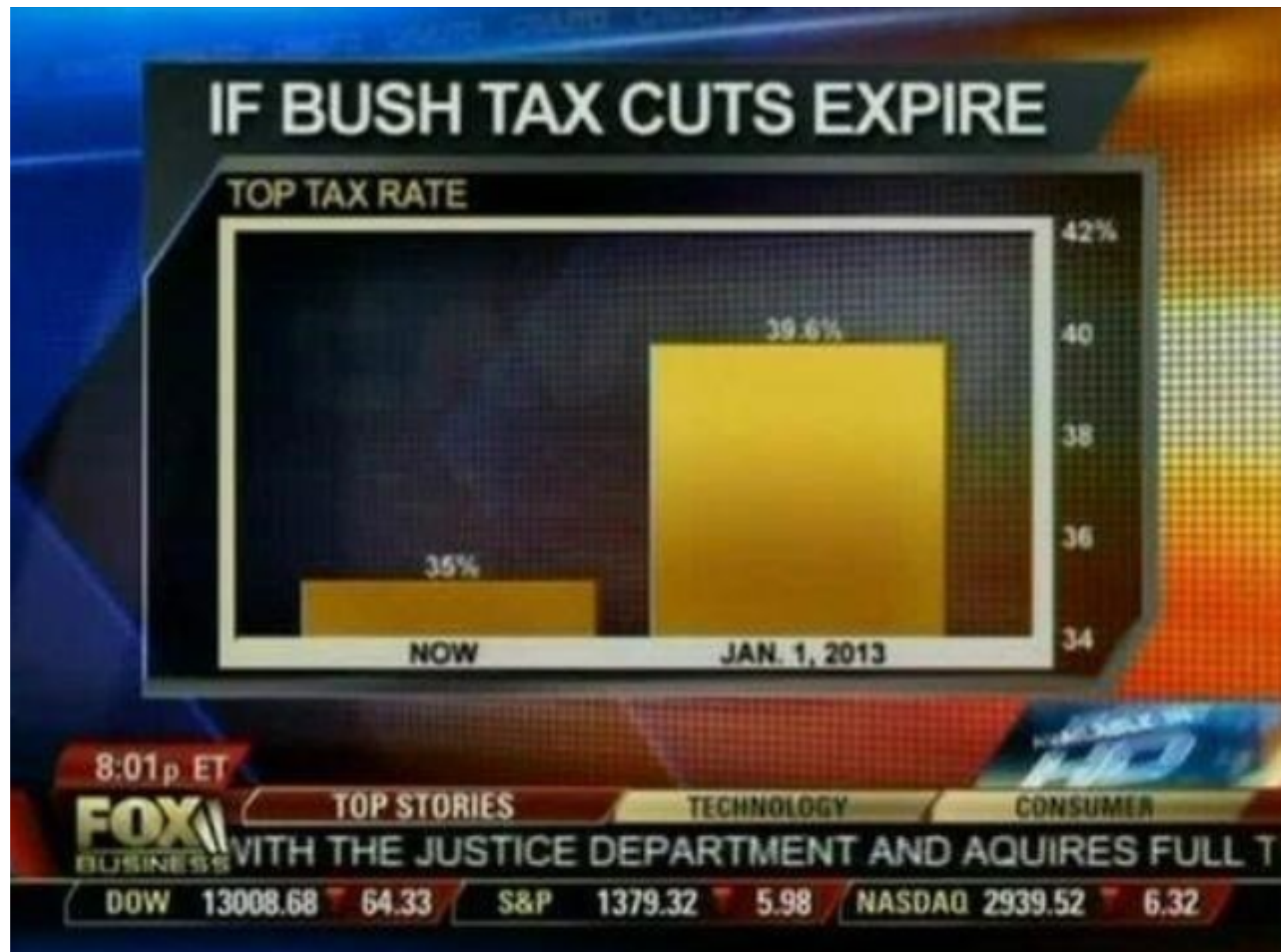
[WTF Visualizations, 2017]

Tufte: "The da Vinci of Data" — NYTimes



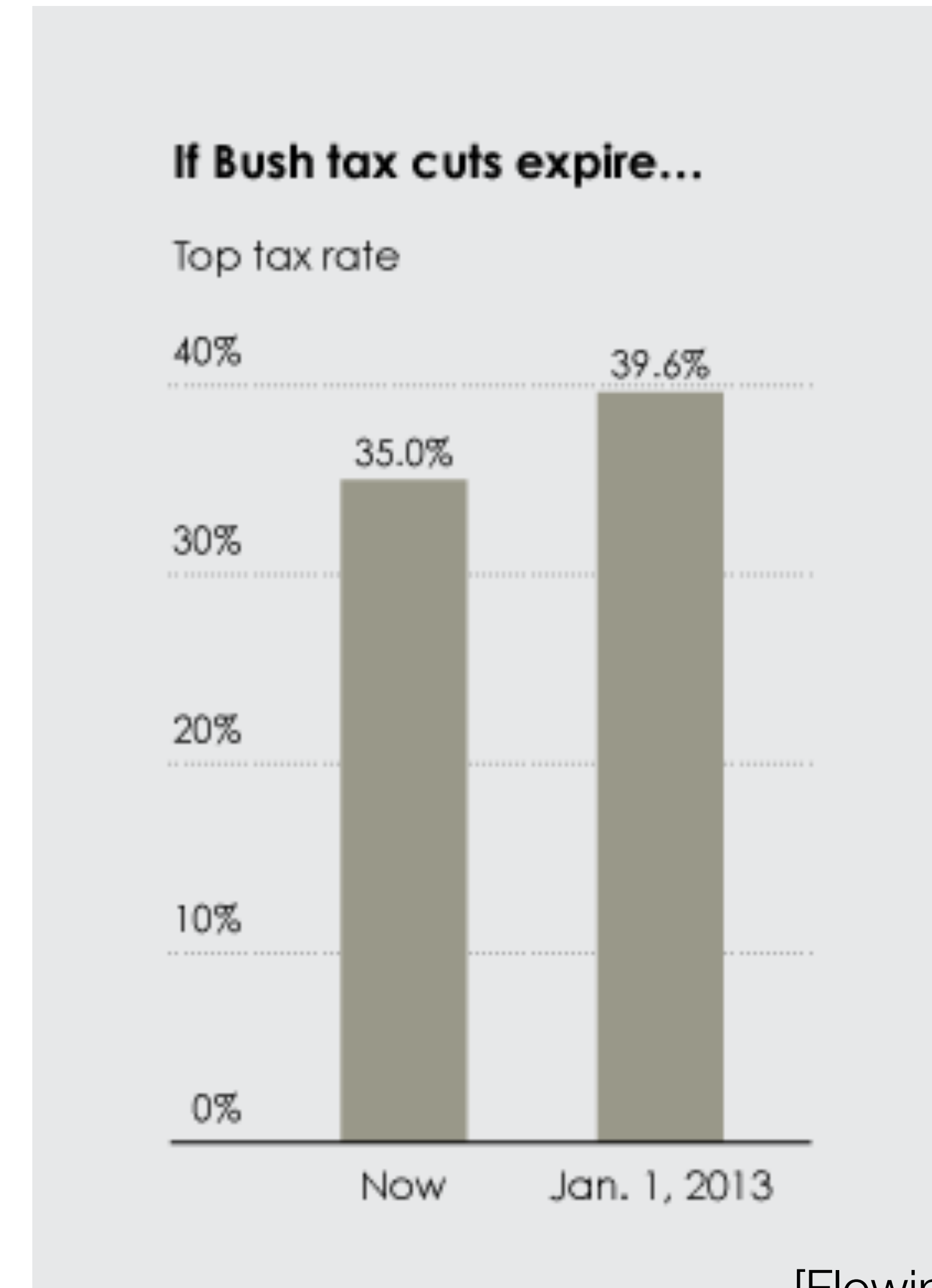
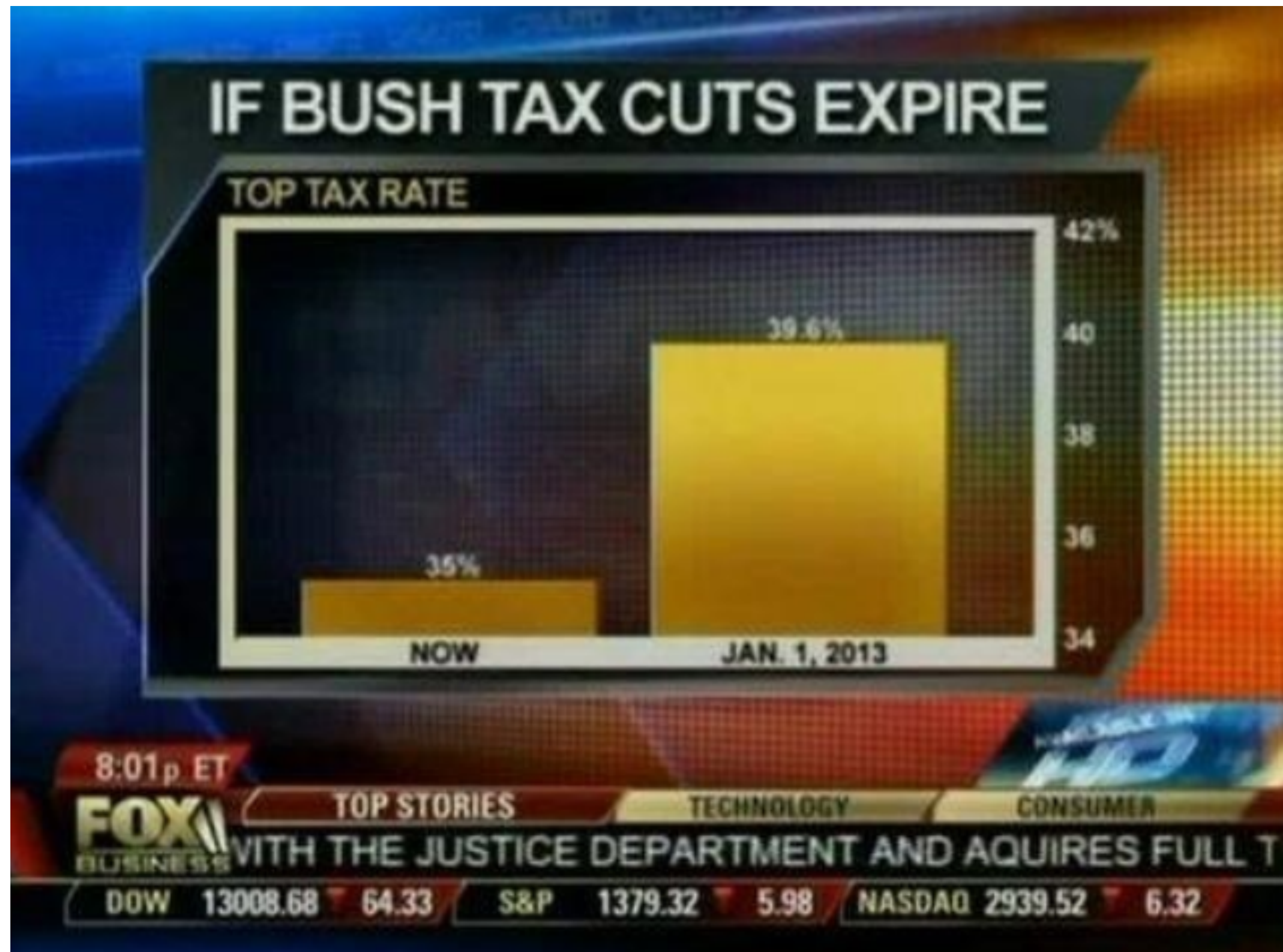
[<https://www.edwardtufte.com/tufte/>, 2017]

Bad: Data magnitude $\neq$ Mark magnitude



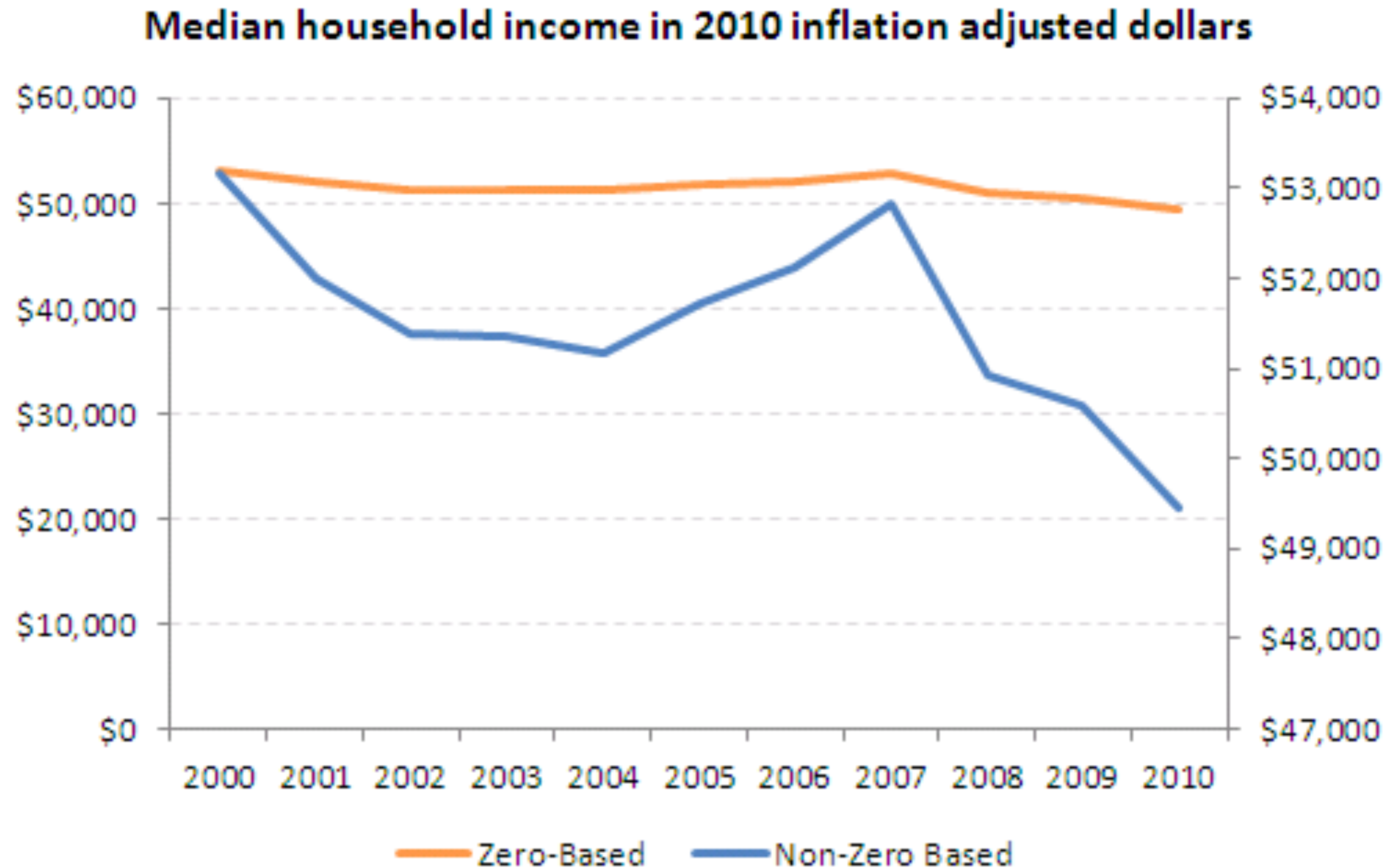
[Flowing Data, 2012]

Good: Data magnitude $\Leftarrow \Rightarrow$ Mark magnitude



[Flowing Data, 2012]

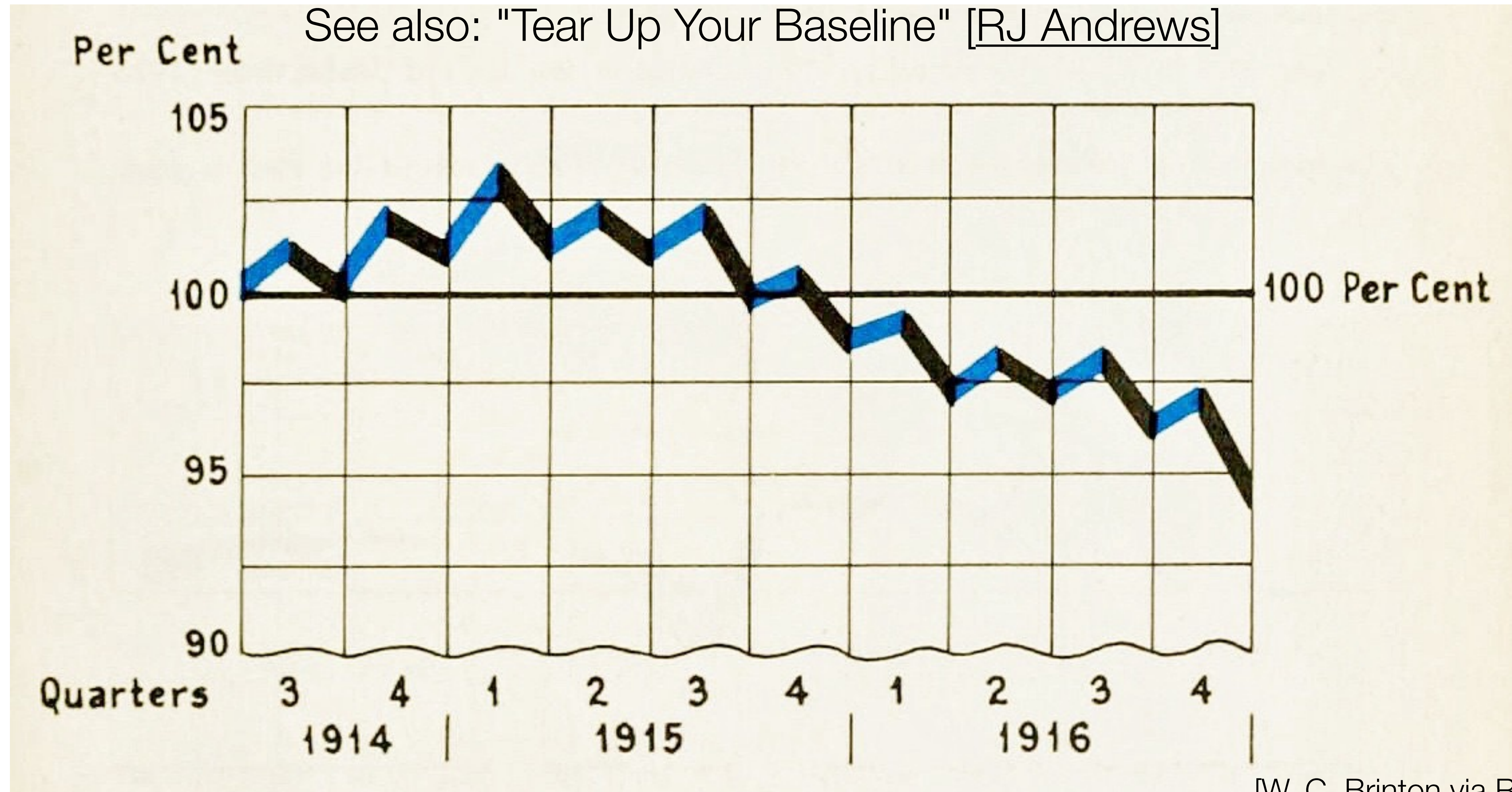
Starting Scales at Zero?



[A. Kirebel, VizWiz]

Wavy baselines for non-zero starts

See also: "Tear Up Your Baseline" [[RJ Andrews](#)]



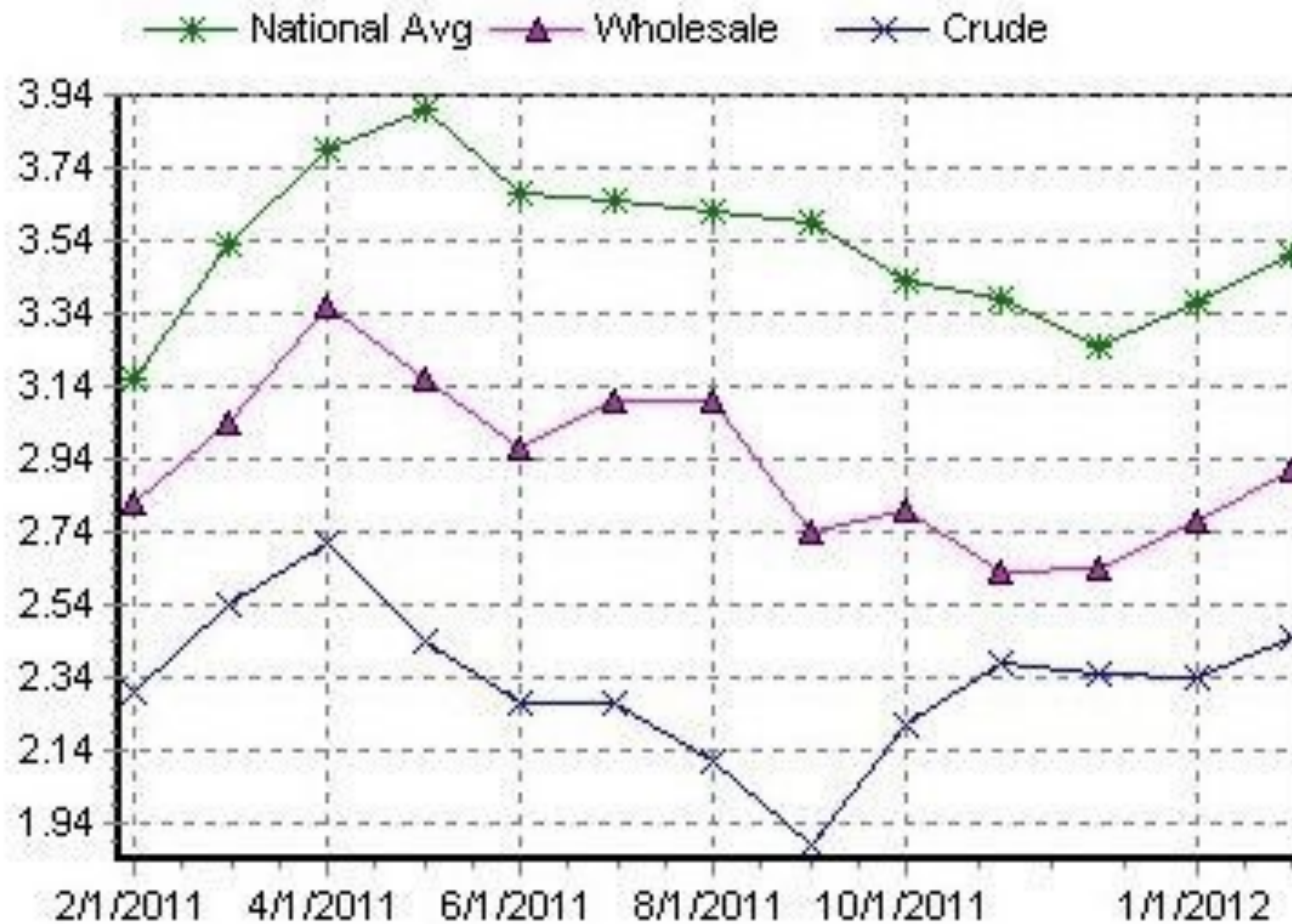
[W. C. Brinton via [RJ Andrews](#)]

Cherry-picking data



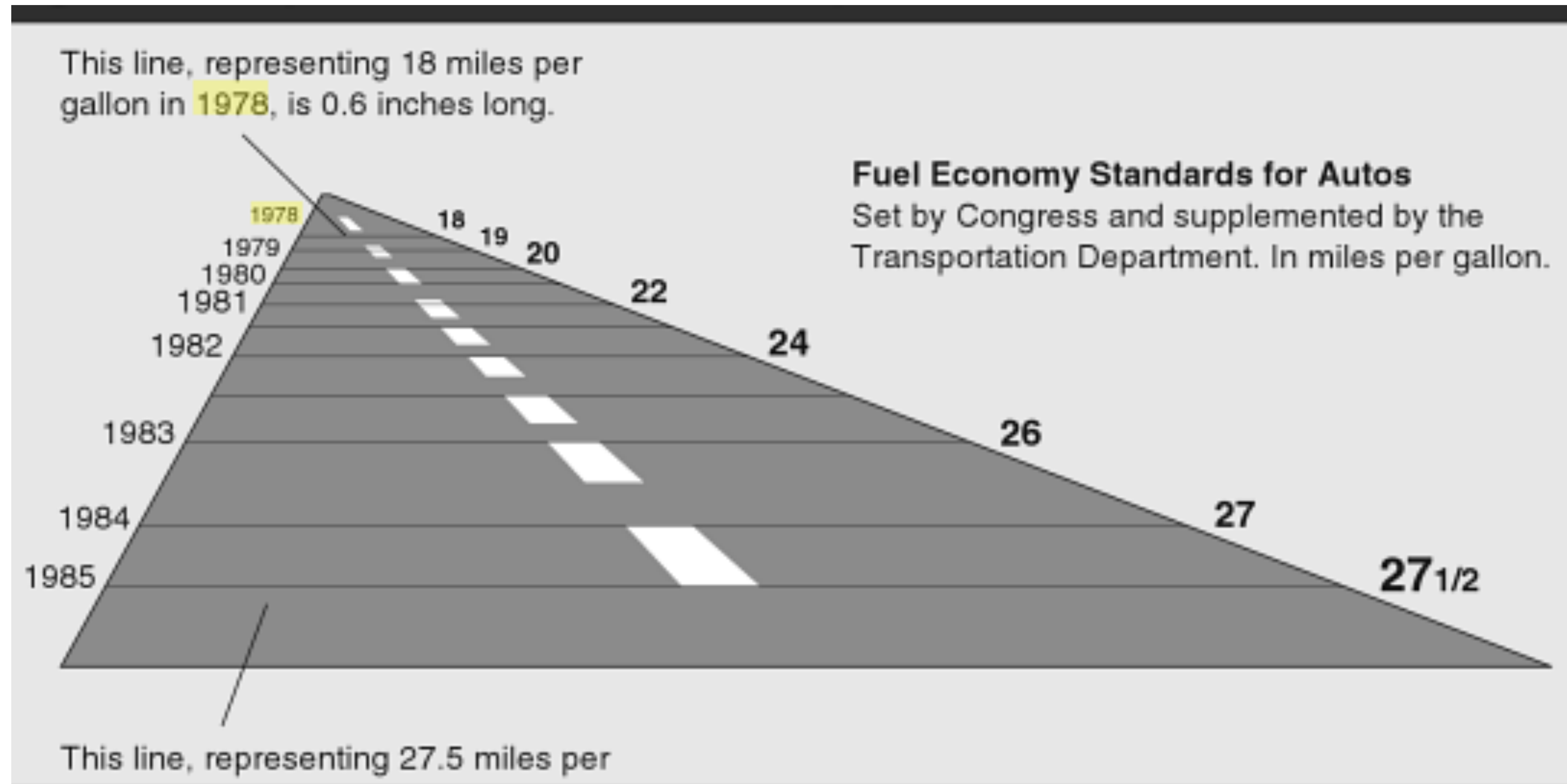
[Fox News via [Media Matters](#), 2012]

Show **all** the data



[AAA via [Media Matters](#), 2012]

Tufte's Lie Factor

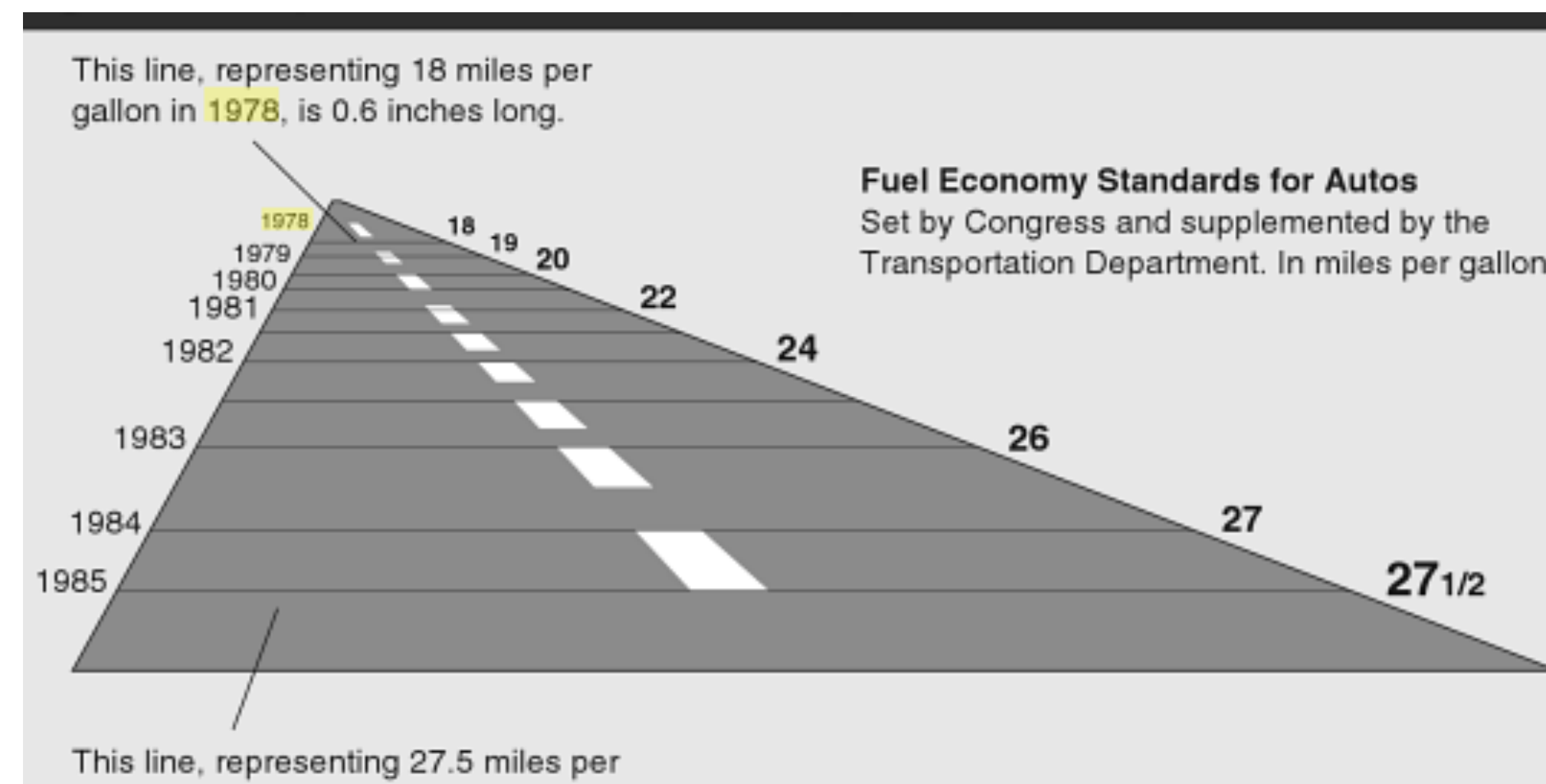


[NYTimes via Tufte, 1991]

Tufte's Lie Factor

- Size of effect = (2nd value - 1st value) / (1st value)
- Lie factor = (size of effect in graphic) / (size of effect in data)
- In the graphic:

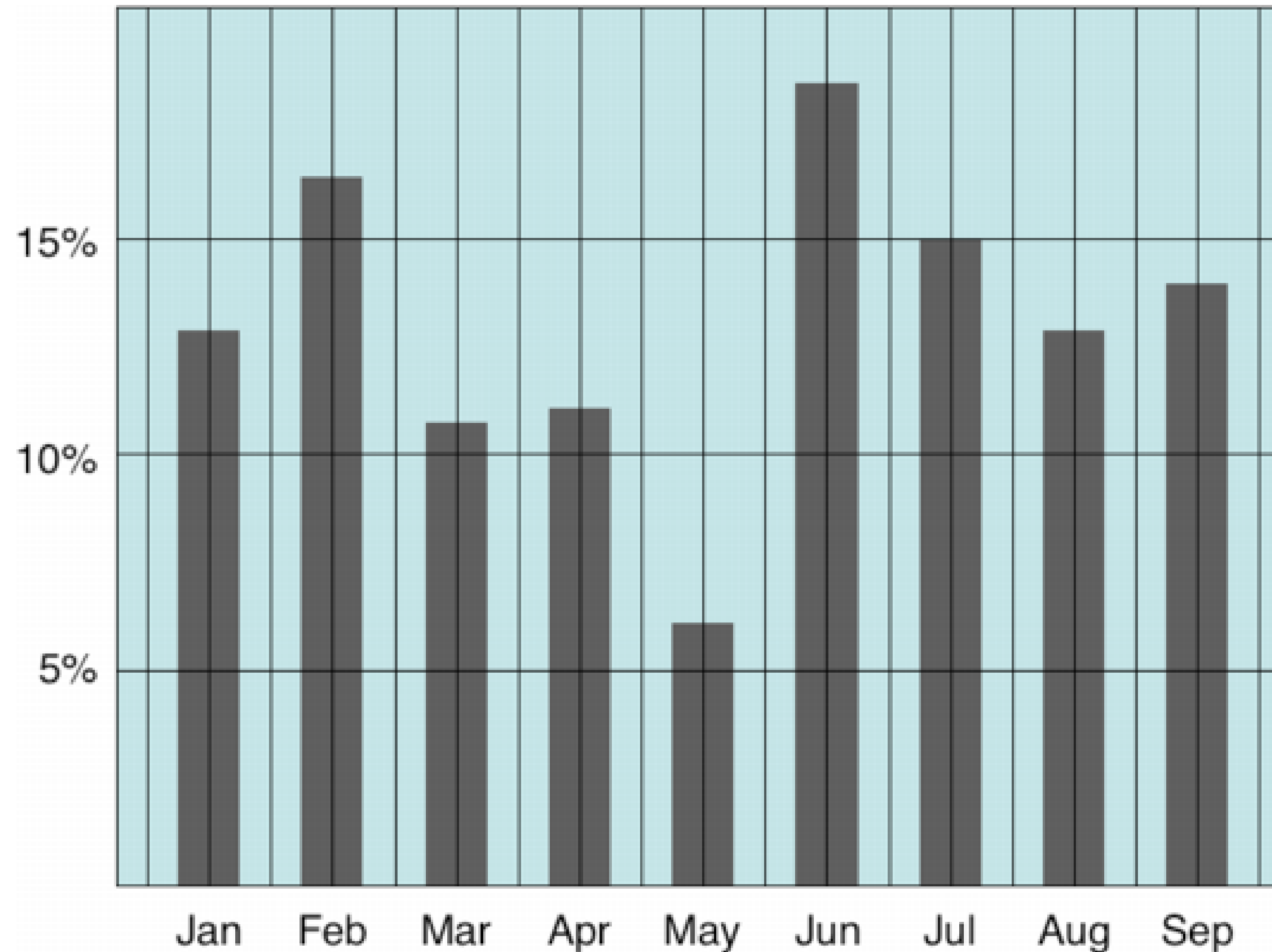
$$\text{Lie Factor} = \frac{\frac{5.3 - 0.6}{0.6}}{\frac{27.5 - 18}{18}} = 14.8$$



(Some of) Tufte's Integrity Principles

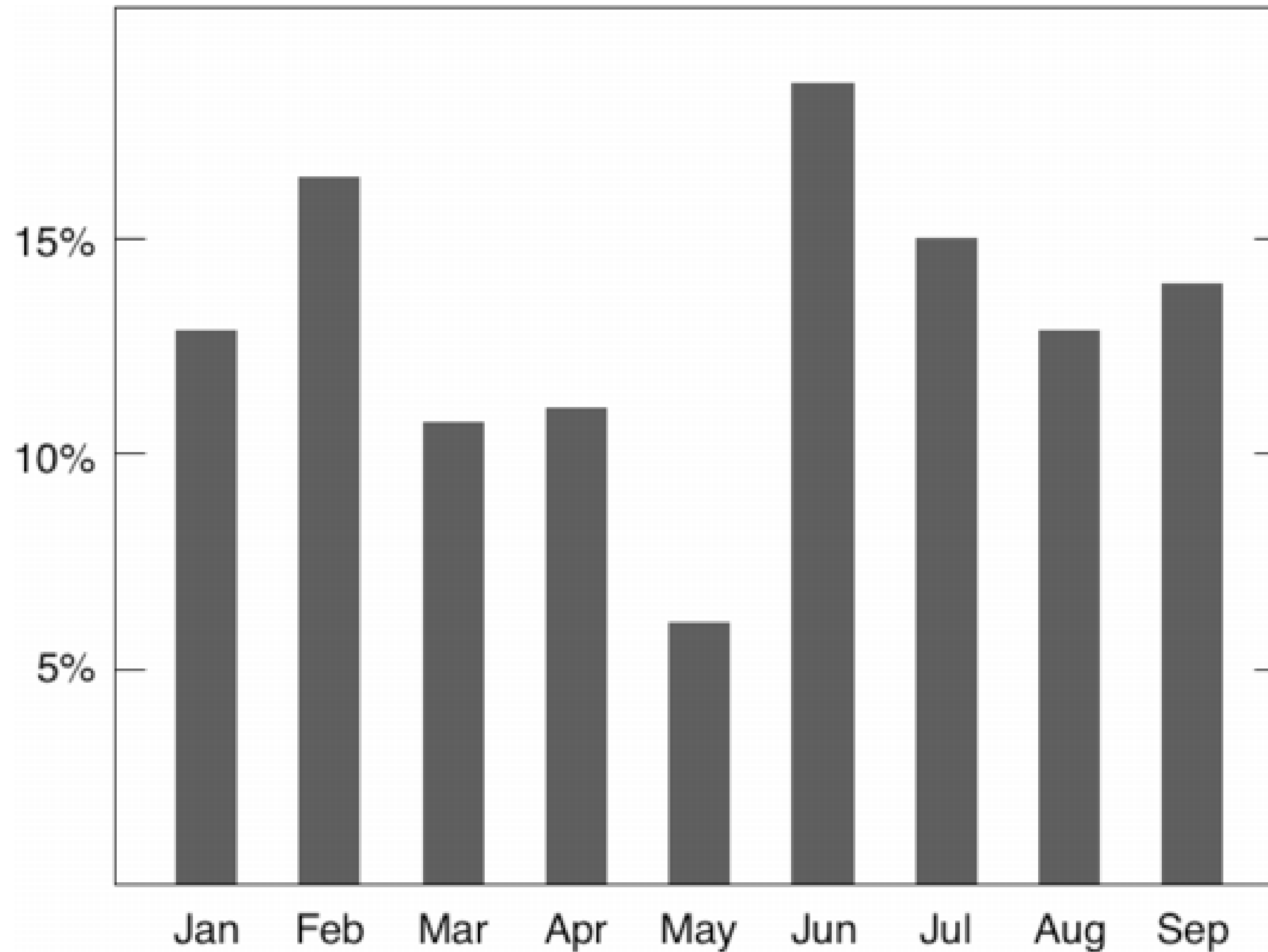
- Show data variation, not design variation
- Clear, detailed, and thorough labeling and appropriate scales
- Size of the graphic effect should be directly proportional to the numerical quantities ("lie factor")

Avoid Chartjunk



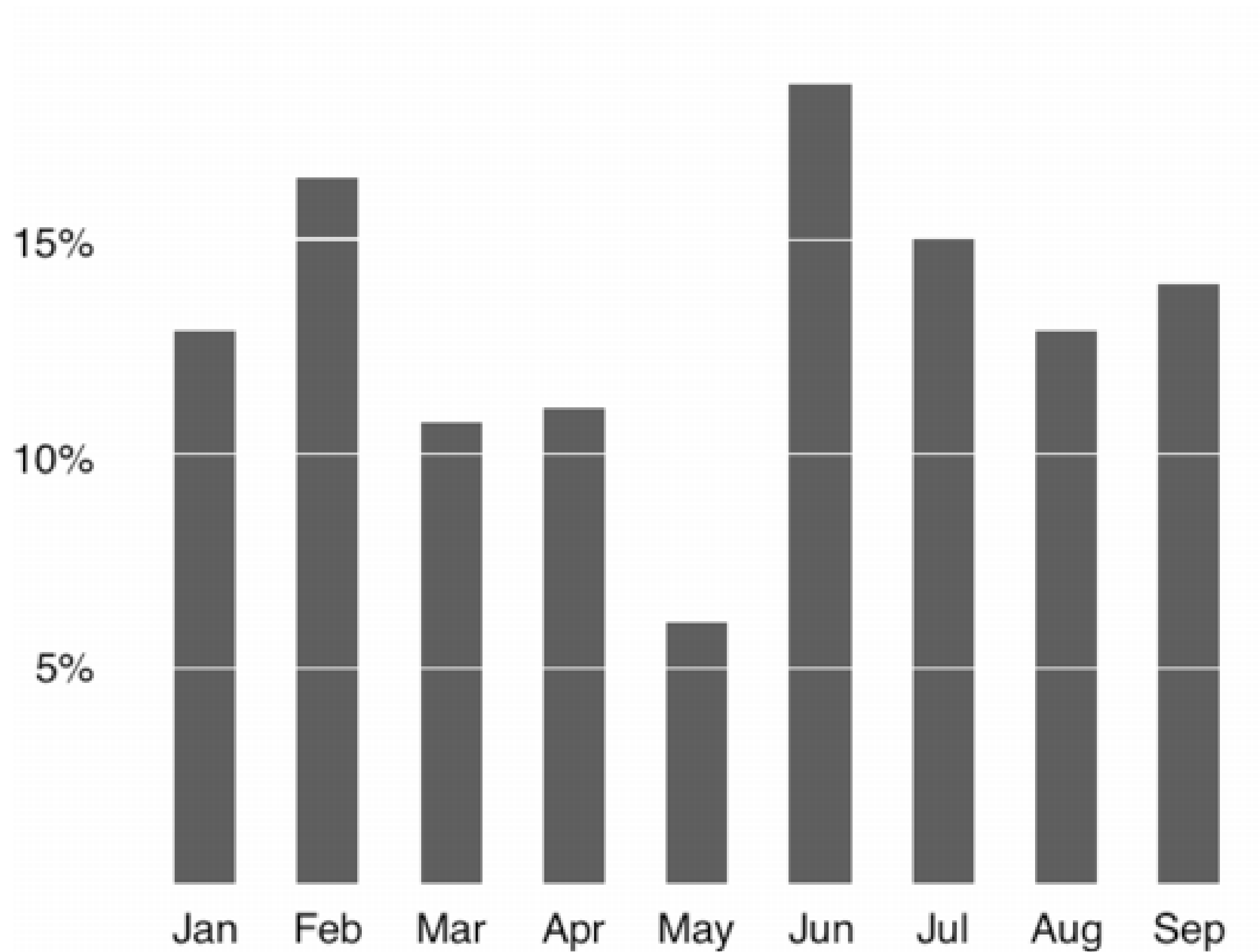
[T. Brey via [A. Lex](#)]

Avoid Chartjunk



[T. Brey via [A. Lex](#)]

Avoid Chartjunk



[T. Brey via [A. Lex](#)]

Avoid Chartjunk?

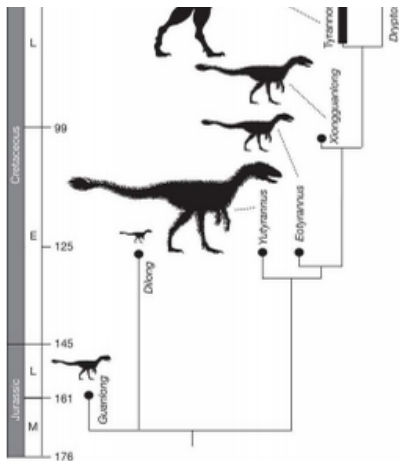
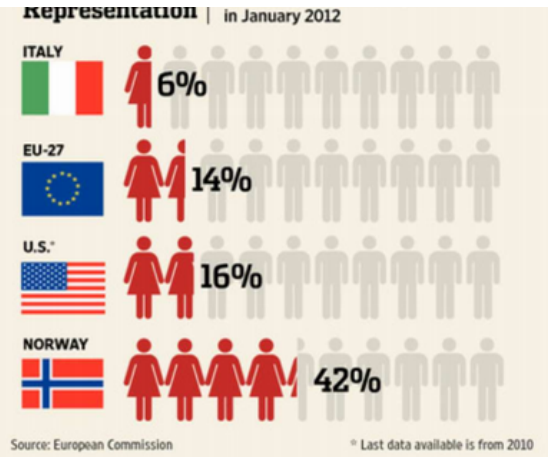
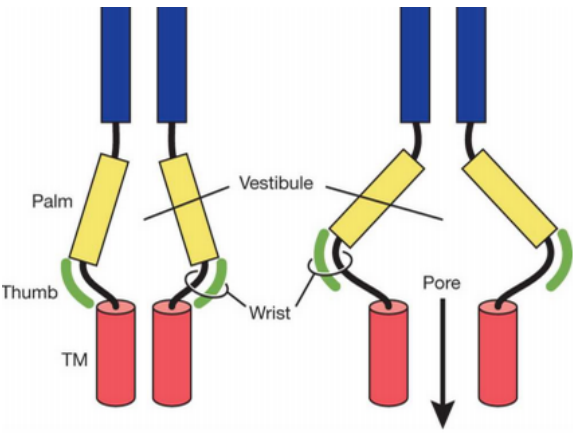
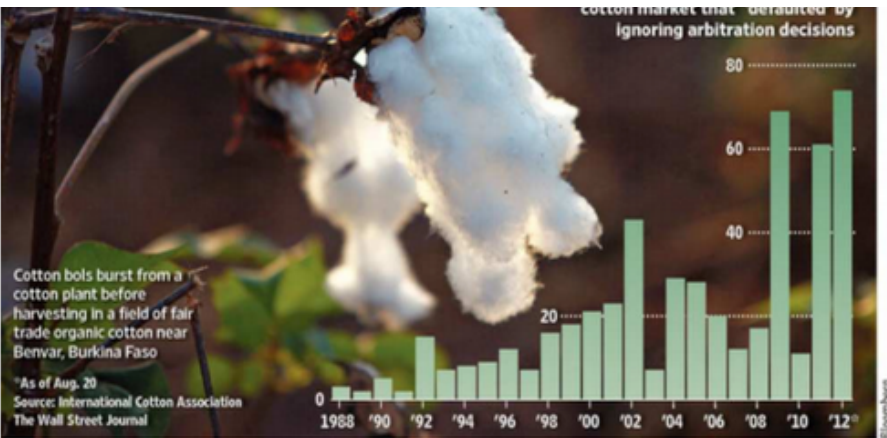
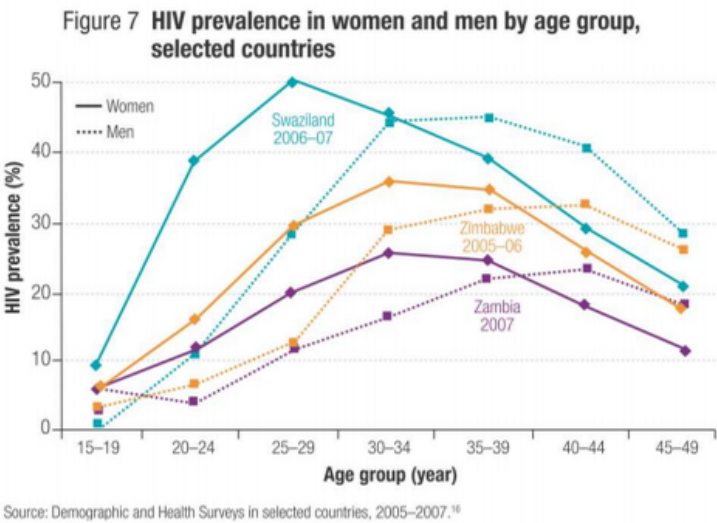
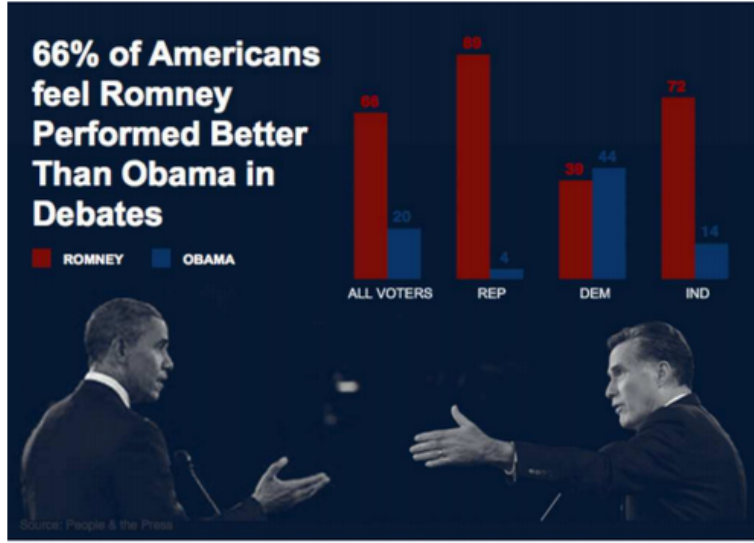
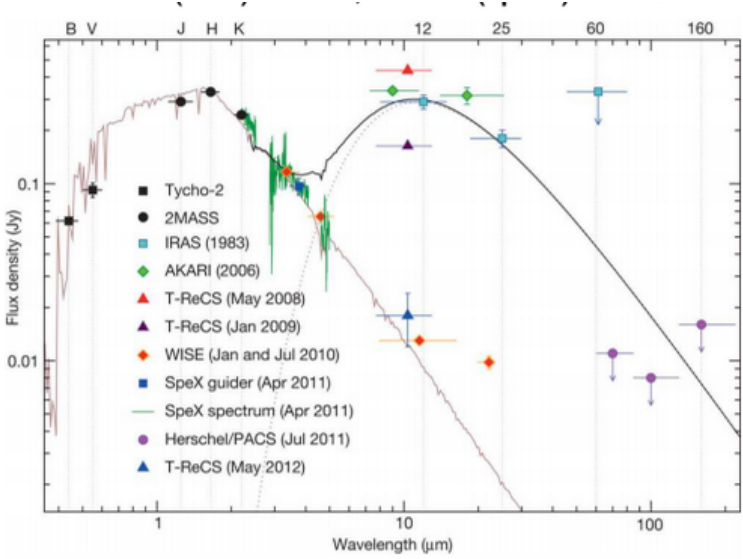
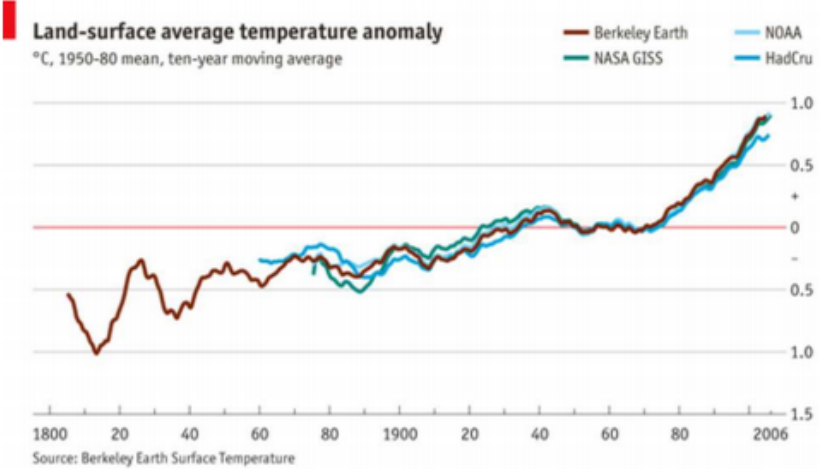


Figure 6.2: Policy shifts and interventions to enable wetland practices to accommodate notions of ecosystem services and human health

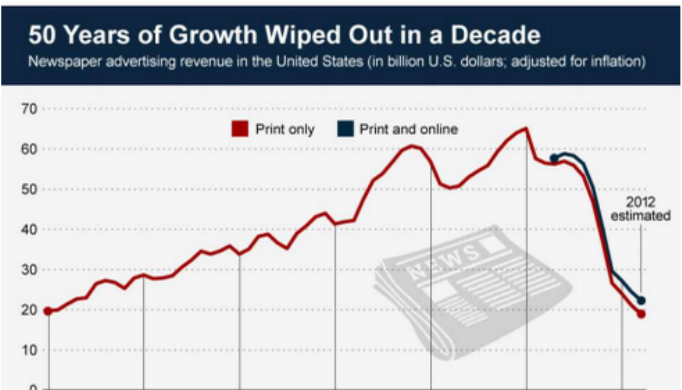
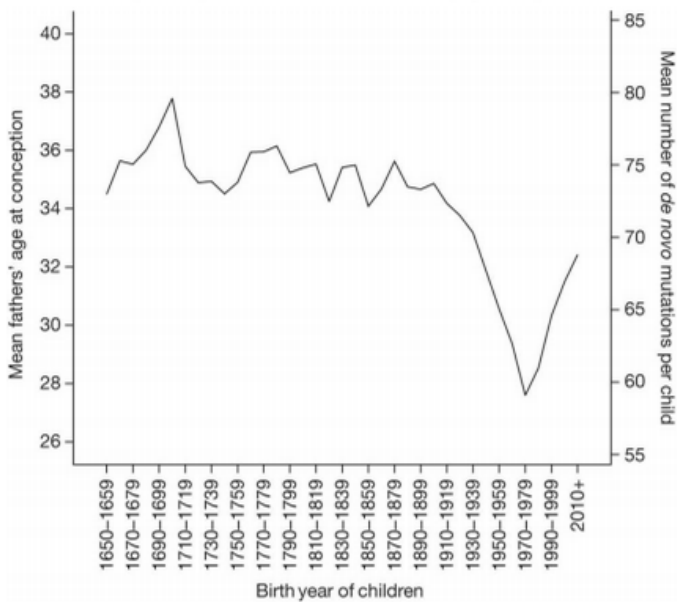


LOW
QUALITY
DESCRIPTION

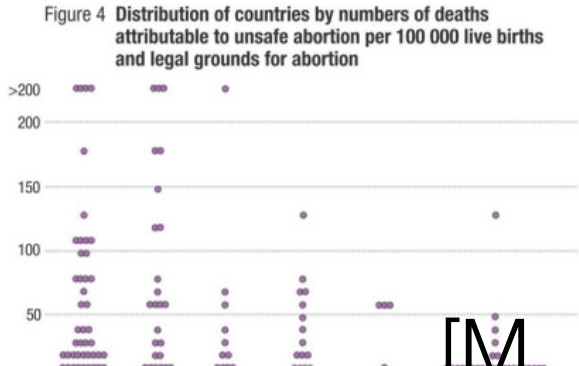
HIGH
QUALITY
DESCRIPTION



News Corp. Results, by Segment		
Revenue for the nine months ended March 31		
\$6.66 billion	Cable network programming	\$2.50 billion
6.22	Publishing	\$458 million
5.56	Filmed entertainment	\$1.01 billion
3.65	Television	\$493 million
2.79	Direct broadcast satellite television	\$165 million
0.45	Other	~\$437 million

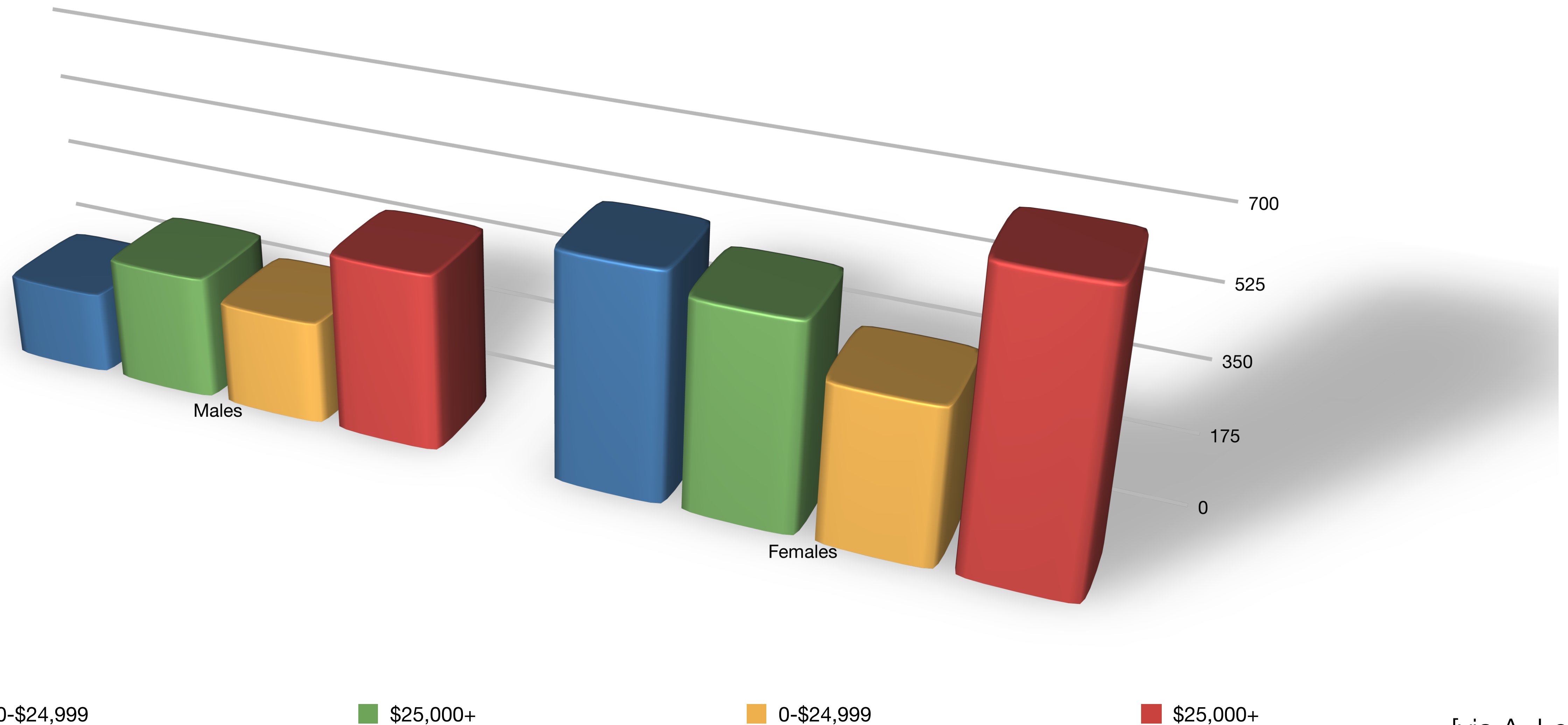


Country	Percentage of students who drink at least one drink containing alcohol on one or more of the past 30 days, by country or WHO region (based on the data from GSSIP)
Algeria	10.1
Argentina	10.4
Australia	10.4
Brazil	10.4
Canada	10.4
Chile	10.4
China	10.4
Colombia	10.4
Costa Rica	10.4
Czechia	10.4
Denmark	10.4
Egypt	10.4
France	10.4
Germany	10.4
Greece	10.4
India	10.4
Indonesia	10.4
Italy	10.4
Japan	10.4
Kenya	10.4
Malaysia	10.4
Mexico	10.4
Netherlands	10.4
Norway	10.4
Poland	10.4
Portugal	10.4
Romania	10.4
Russia	10.4
South Africa	10.4
Spain	10.4
Sweden	10.4
Switzerland	10.4
Taiwan	10.4
Thailand	10.4
Turkey	10.4
Ukraine	10.4
United Kingdom	10.4
United States	10.4
USA	10.4



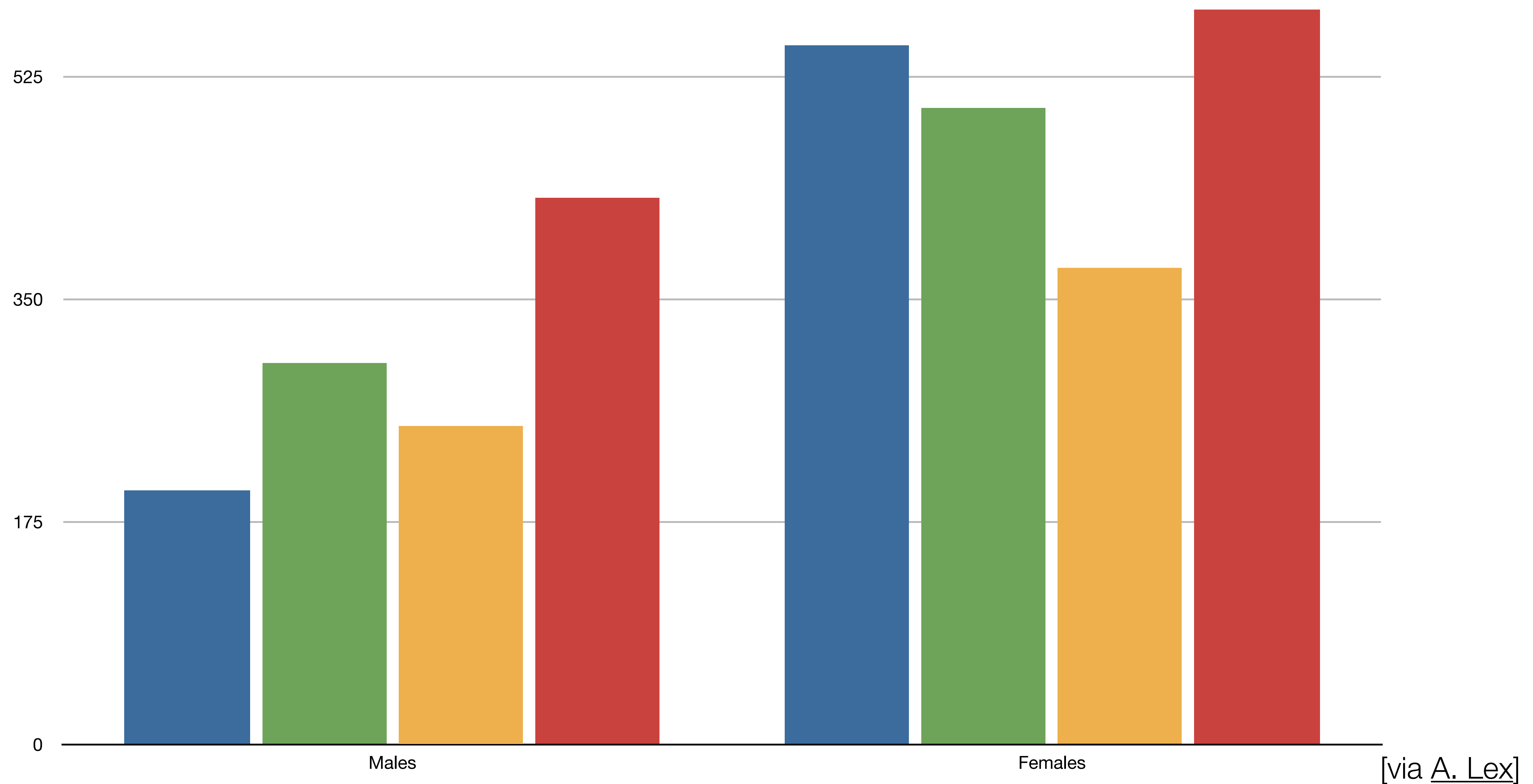
[M. Borkin et al., InfoVis 2015]

Data-to-Ink Ratio (Also Unjustified 3D)

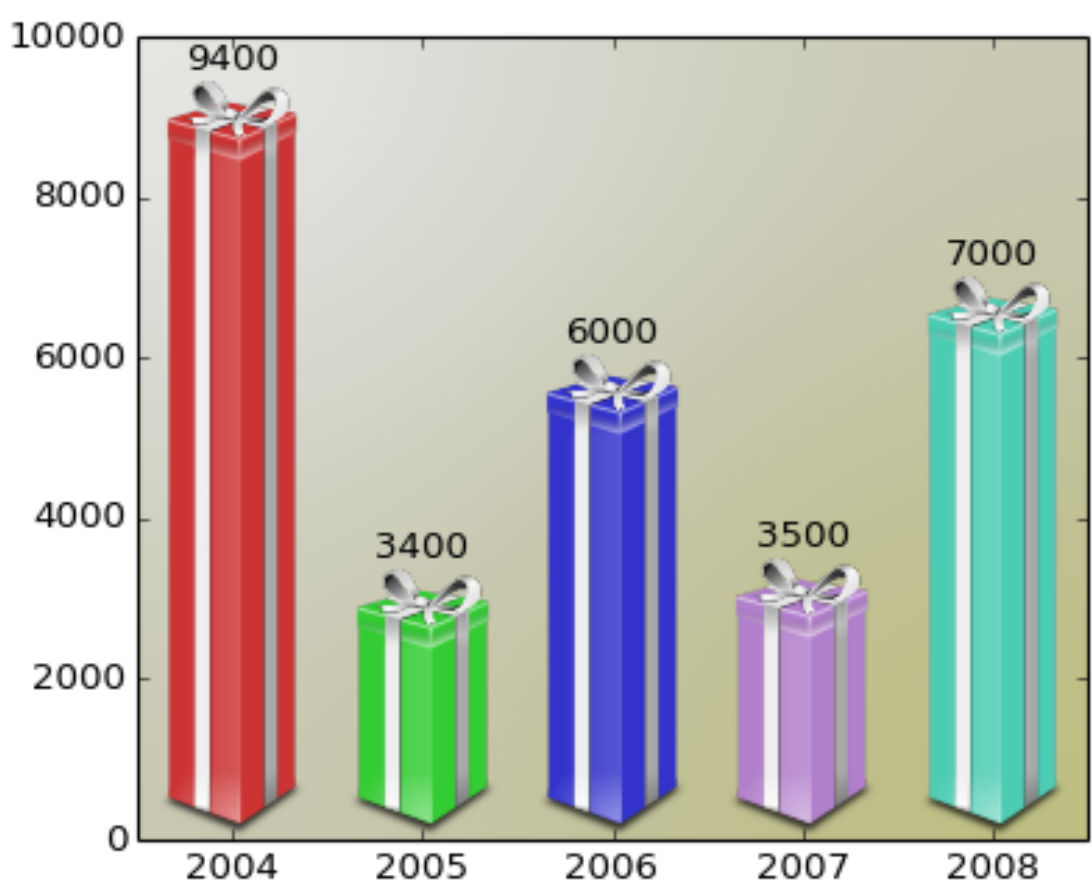
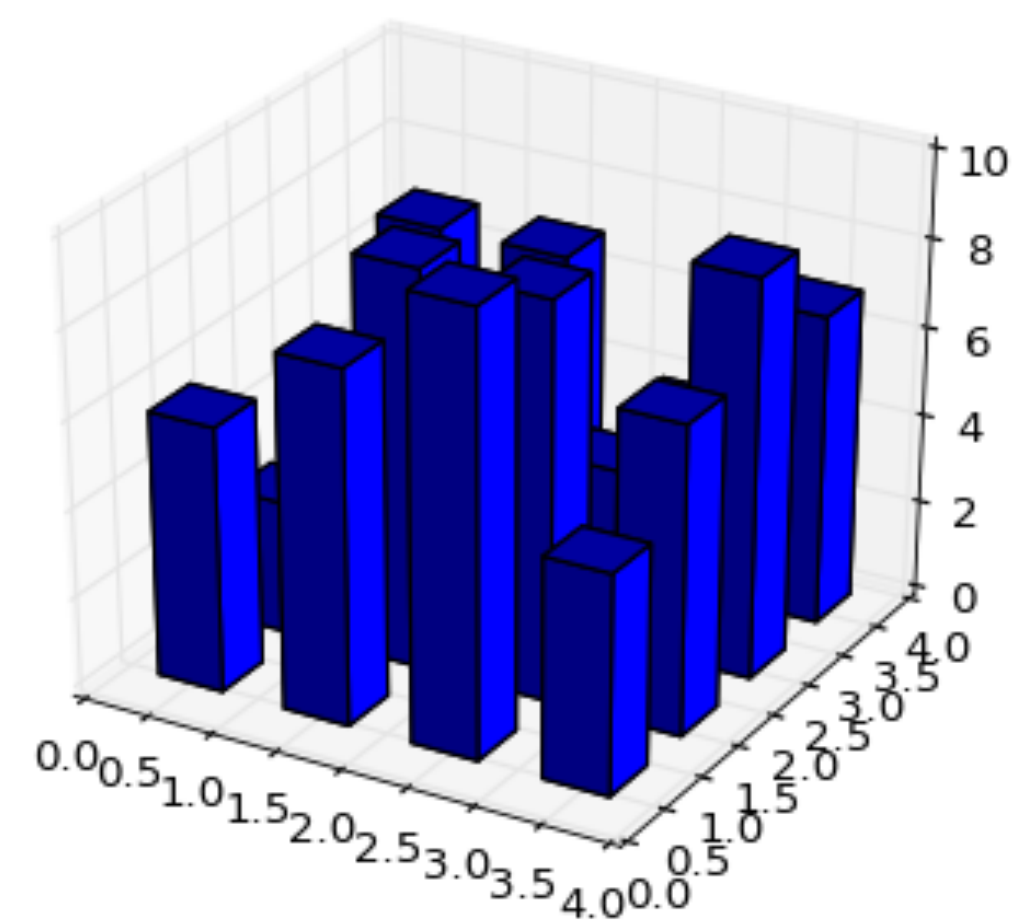


[via A. Lex]

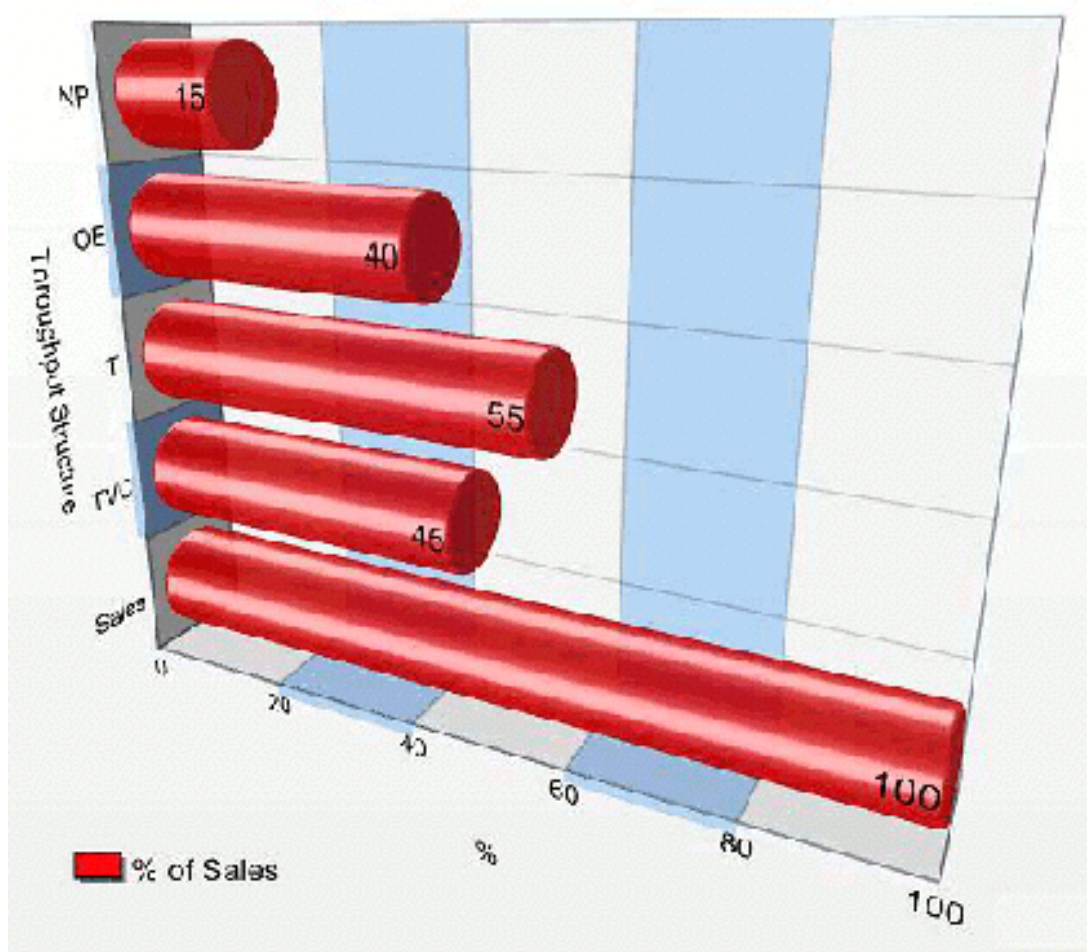
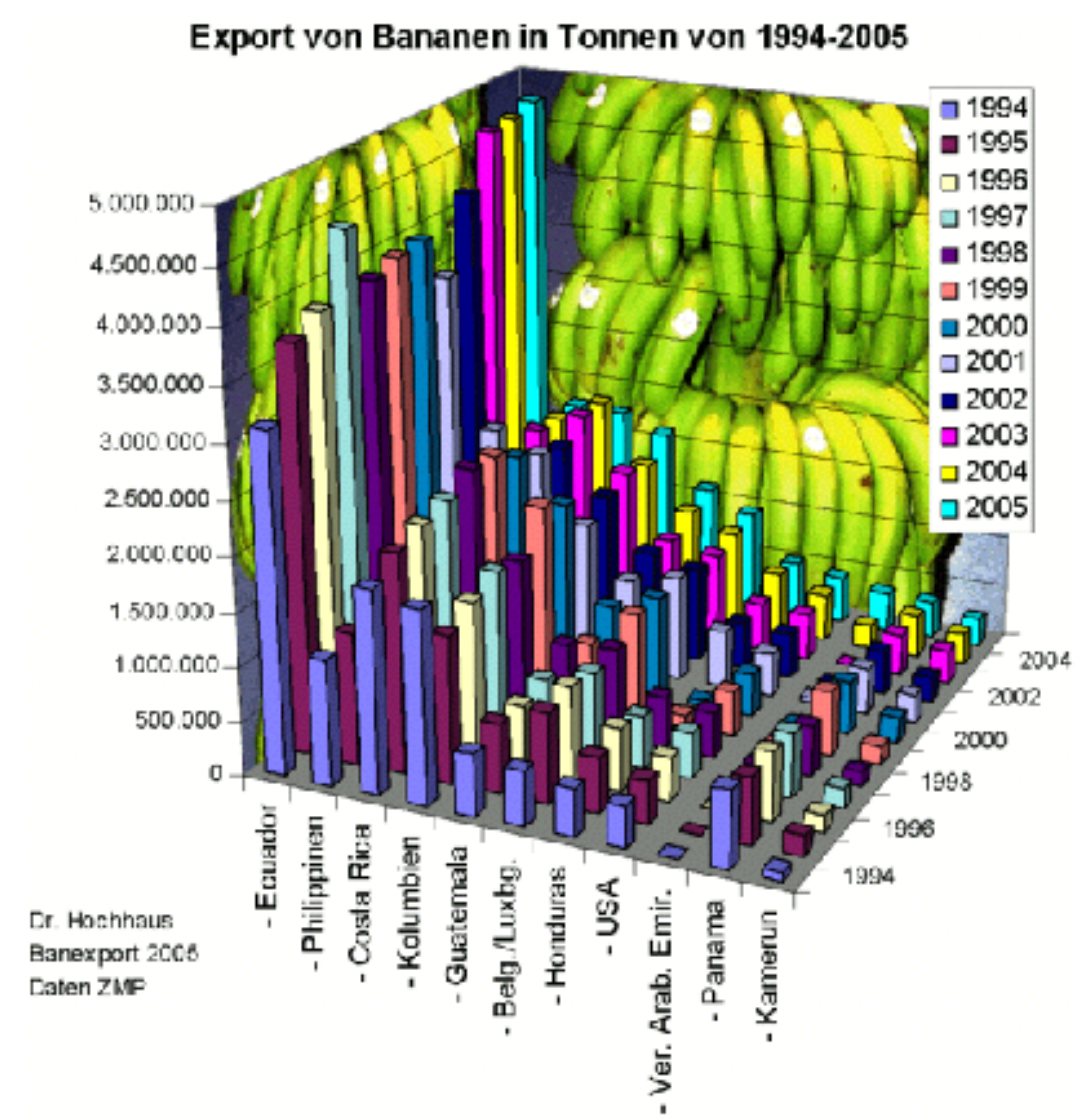
Maximize Data-to-Ink Ratio



No Unjustified 3D



matplotlib gallery

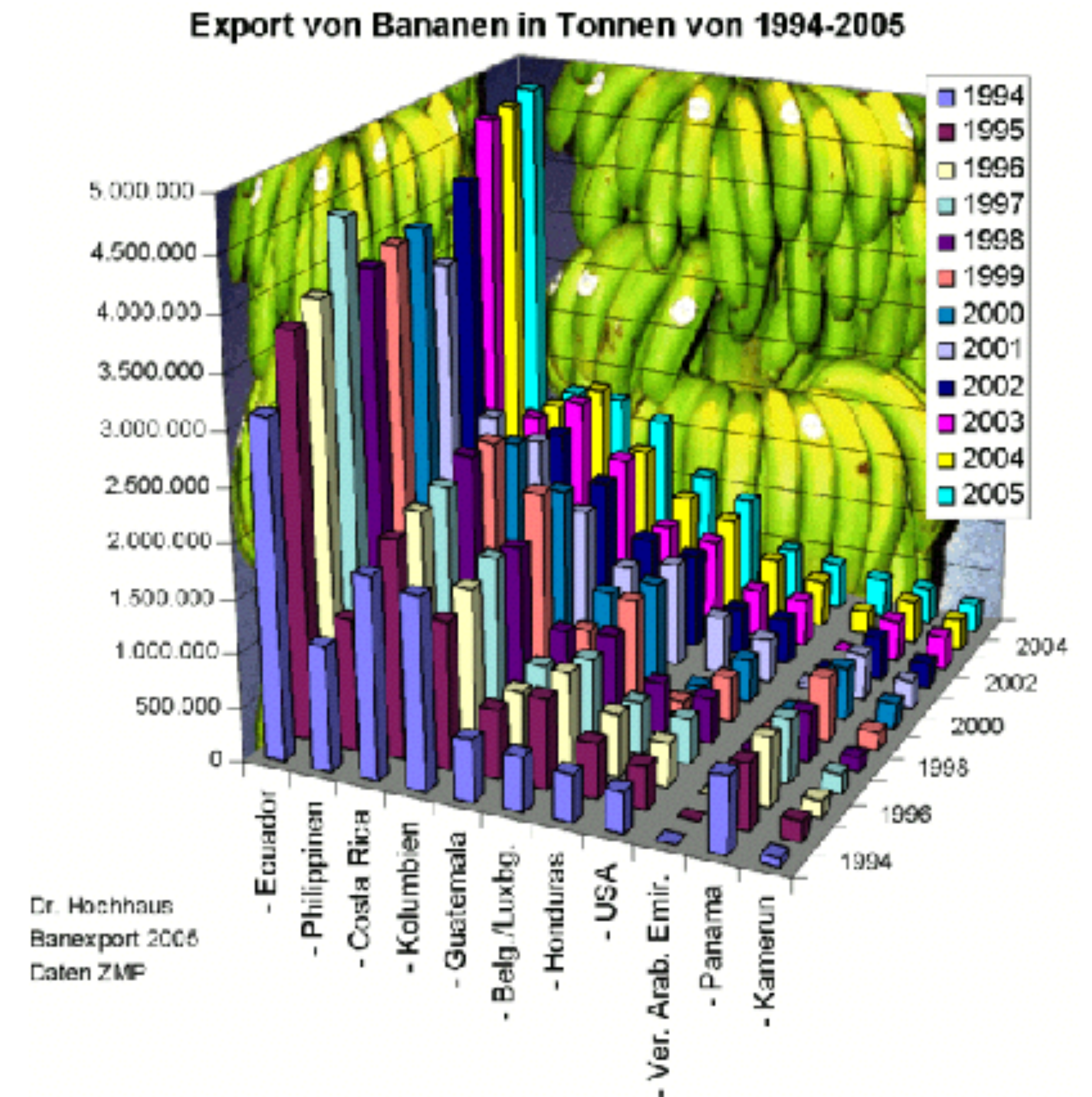


Excel Charts Blog

[via A. Lex]

No Unjustified 3D

- Occlusion hides information
- Perspective distortion dangers
- Tilted text isn't legible
- Can **help** with shape perception



[via A. Lex]

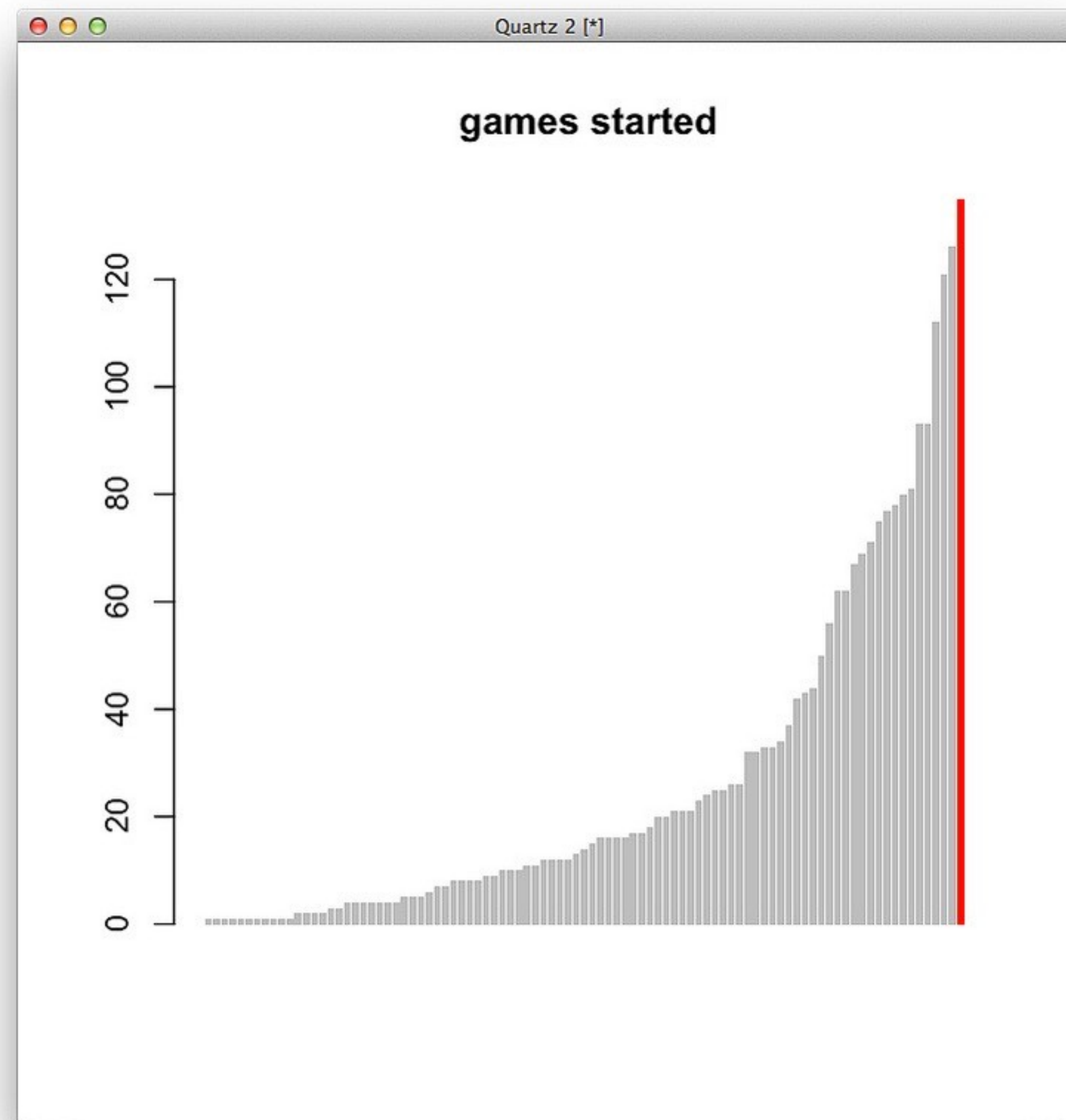
Eyes Beat Memory

- Reduce cognitive load (using up working memory)
- Animation versus side-by-side views
- Change blindness

“Computer-based visualization systems provide visual representations of datasets **designed** to help people carry out tasks more effectively.”

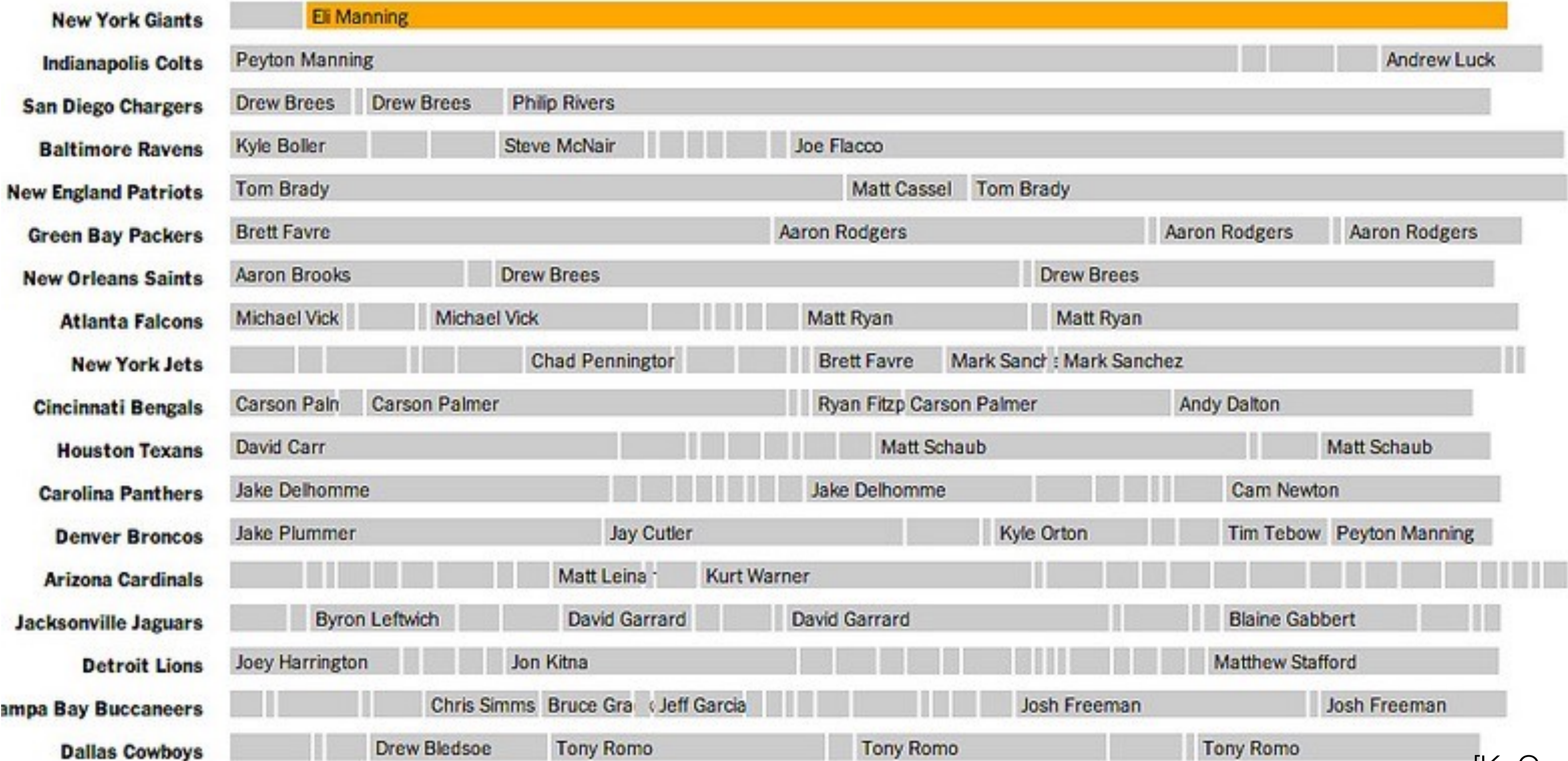
— T. Munzner

Design Iteration



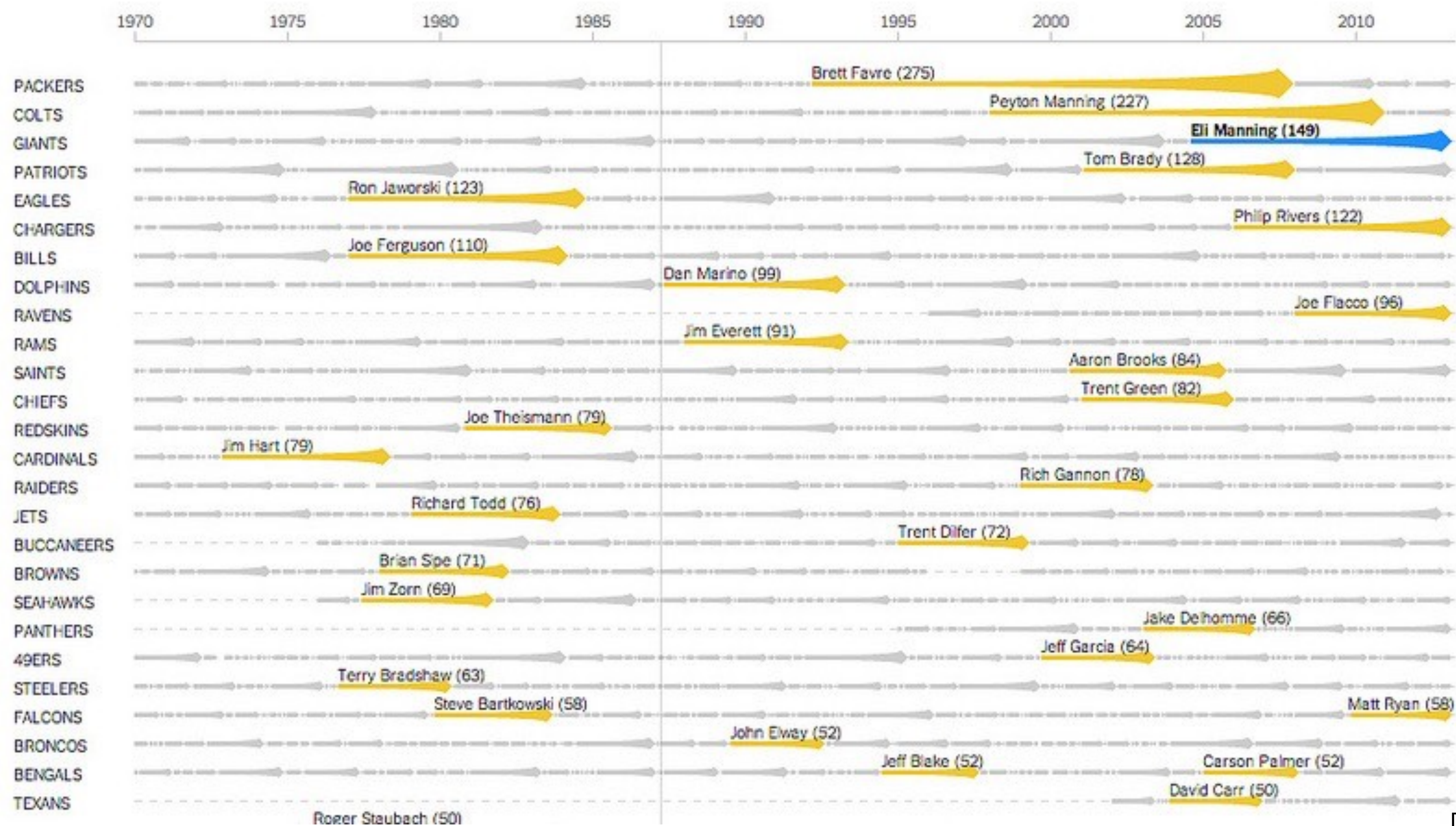
[K. Quealy, 2013]

Design Iteration



[K. Quealy, 2013]

Design Iteration

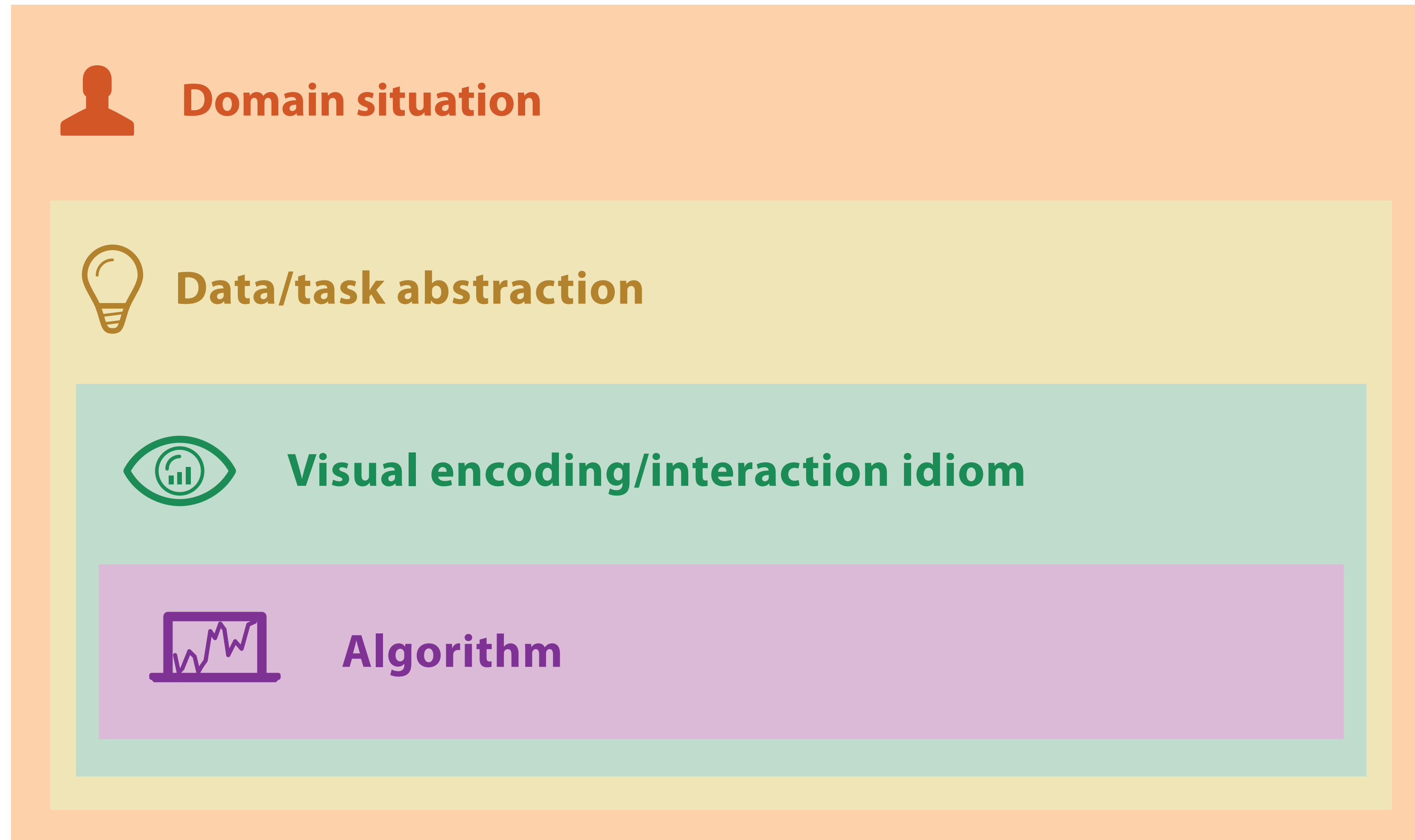


[K. Quealy, 2013]

Design

- Unlike a math problem, there are many different approaches for the visualization of some data
- Need to have some way to discuss how to determine whether a visualization is doing what we want
- Validation: Understand why a design is effective
 - What problems can be effective
 - Do this at different levels

Four Nested Levels of Design



[Munzner, 2014]

Potential problems at each level

Domain situation

You misunderstood their needs

Data/task abstraction

You're showing them the wrong thing

Visual encoding/interaction idiom

The way you show it doesn't work

Algorithm

Your code is too slow

[Munzner, 2014]

Validation at each level

❗ **Threat** Wrong problem

☑ **Validate** Observe and interview target users

❗ **Threat** Wrong task/data abstraction

❗ **Threat** Ineffective encoding/interaction idiom

☑ **Validate** Justify encoding/interaction design

❗ **Threat** Slow algorithm

☑ **Validate** Analyze computational complexity

Implement system

☑ **Validate** Measure system time/memory

☑ **Validate** Qualitative/quantitative result image analysis

Test on any users, informal usability study

☑ **Validate** Lab study, measure human time/errors for task

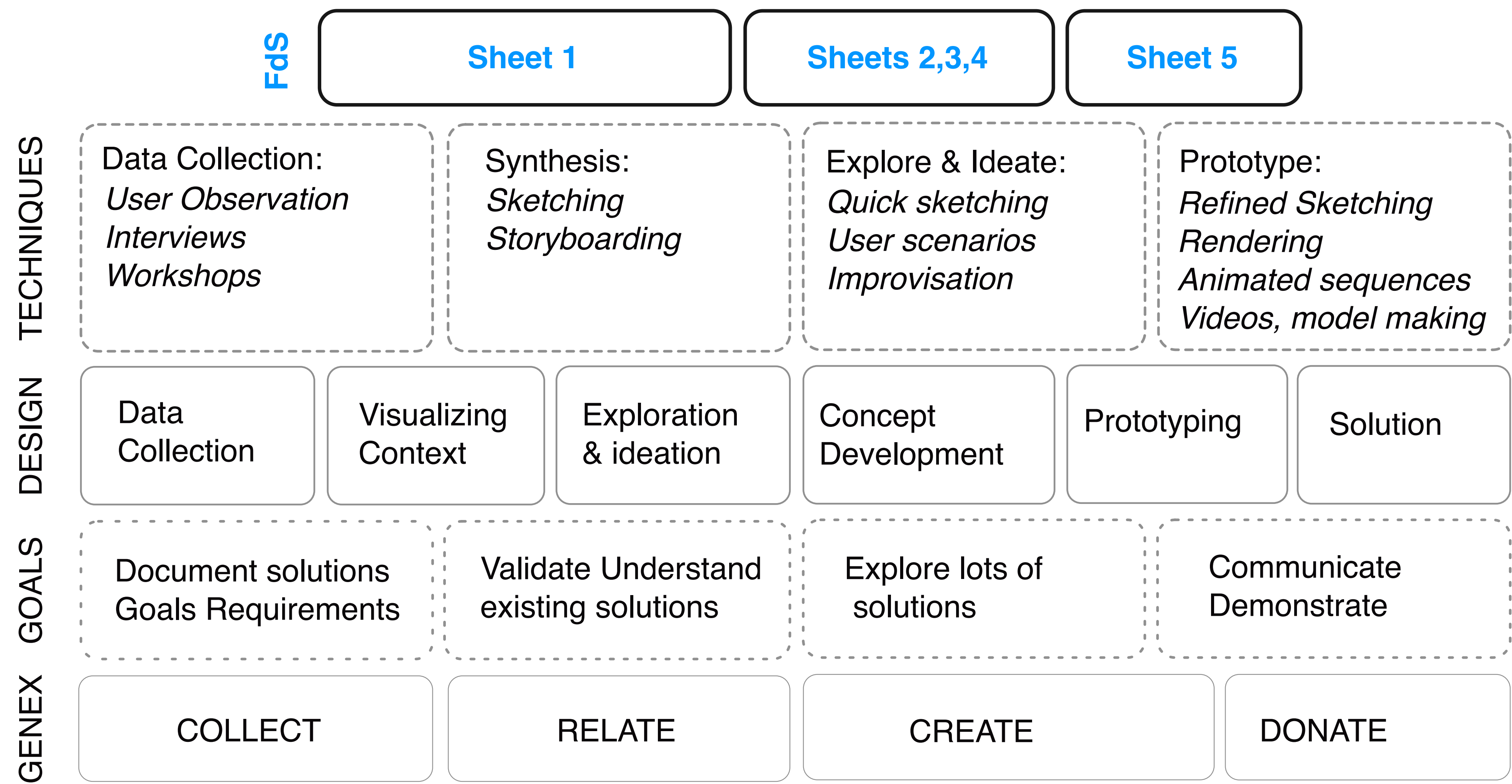
☑ **Validate** Test on target users, collect anecdotal evidence of utility

☑ **Validate** Field study, document human usage of deployed system

☑ **Validate** Observe adoption rates

[Munzner, 2014]

Five Design-Sheet Methodology



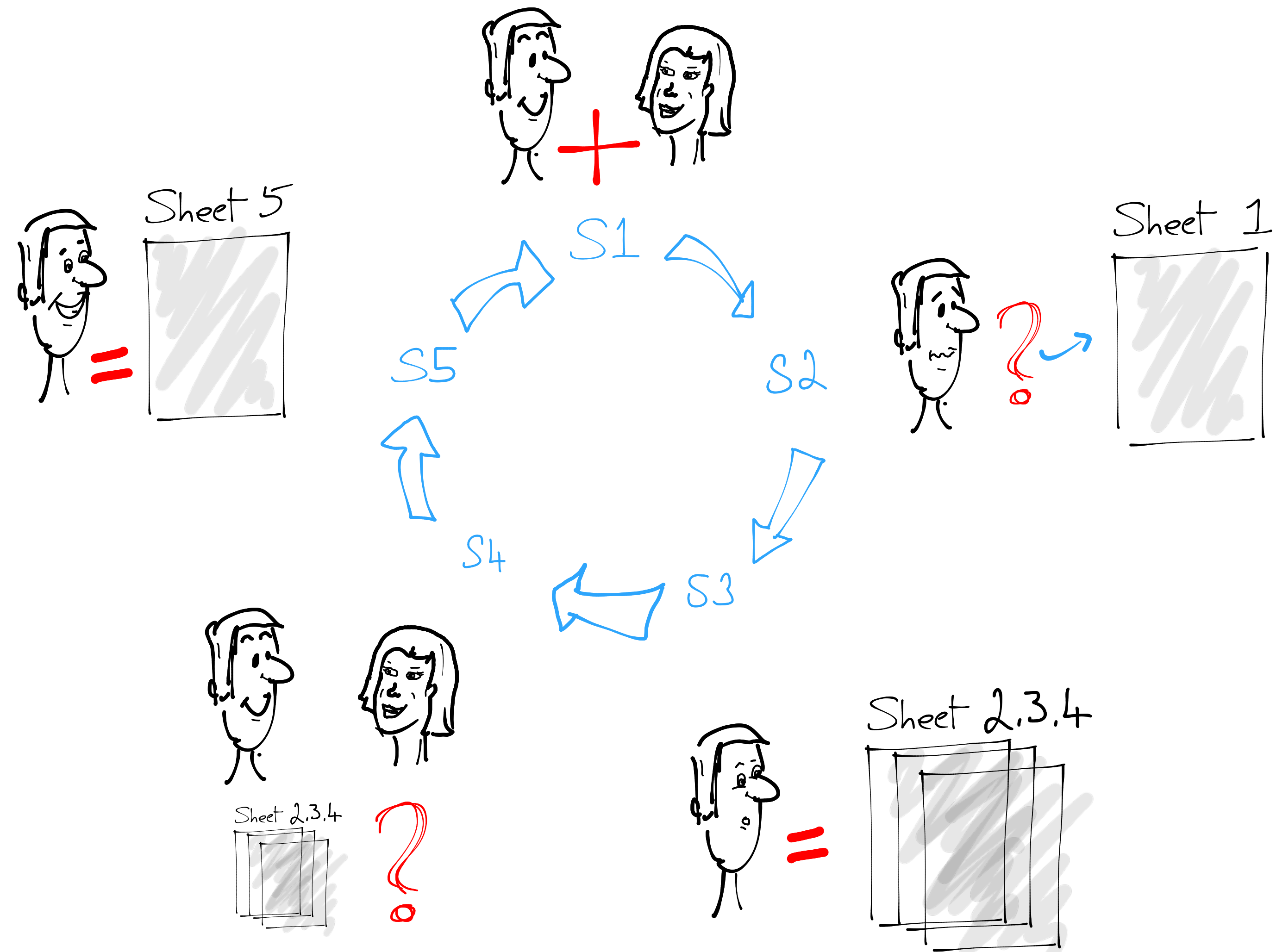
[J. Roberts et al., 2016]

Five Stages

1. Meet with client and consider task; or contemplate task on own.
2. Ideate and sketch small ideas.
3. Sketch and plan three alternative designs.
4. Consider solutions with client; or deliberate on own.
5. Generate realization sheet, and implement prototype. Discuss with client and re-iterate if necessary.

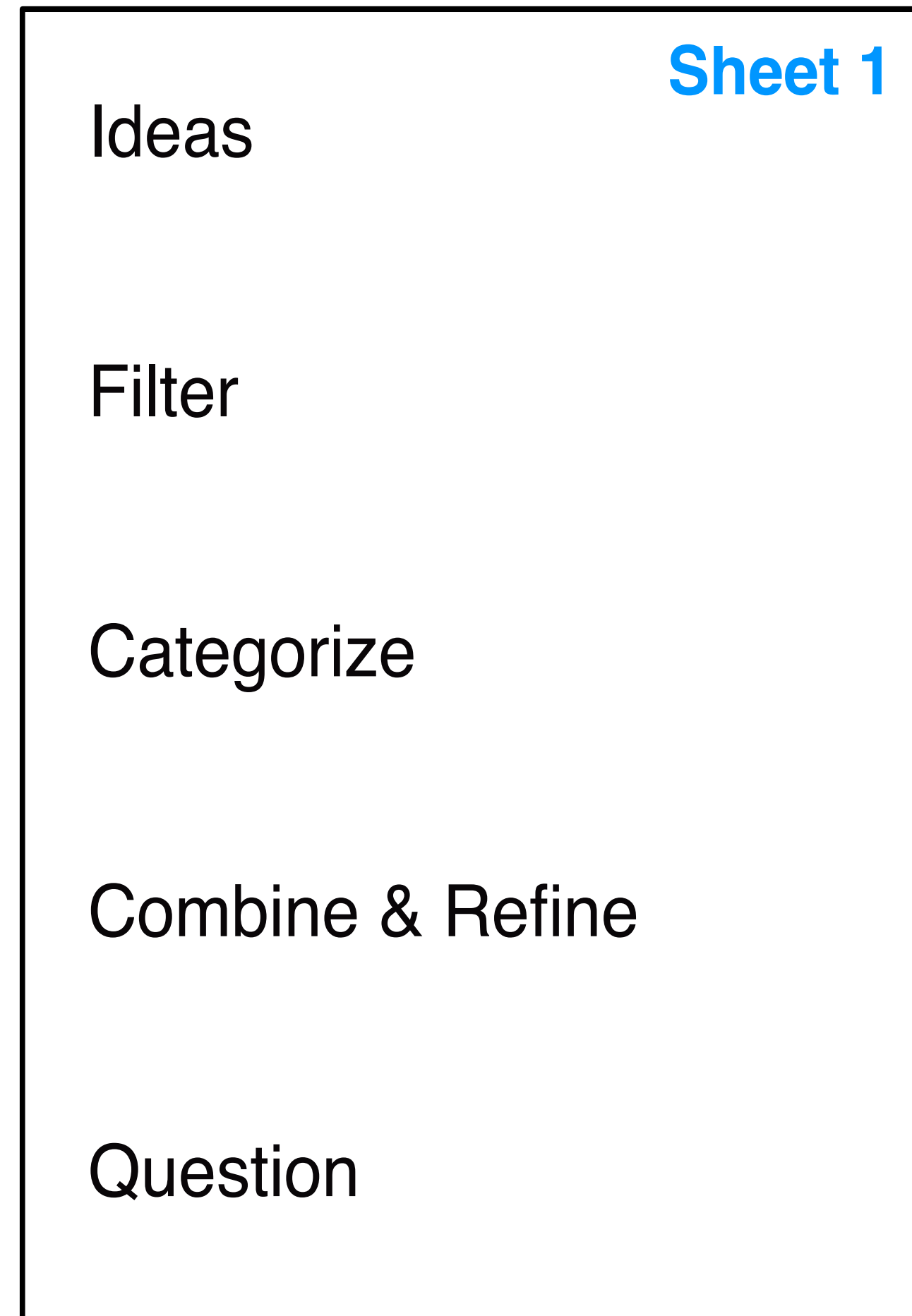
[J. Roberts et al., 2016]

Five Stages

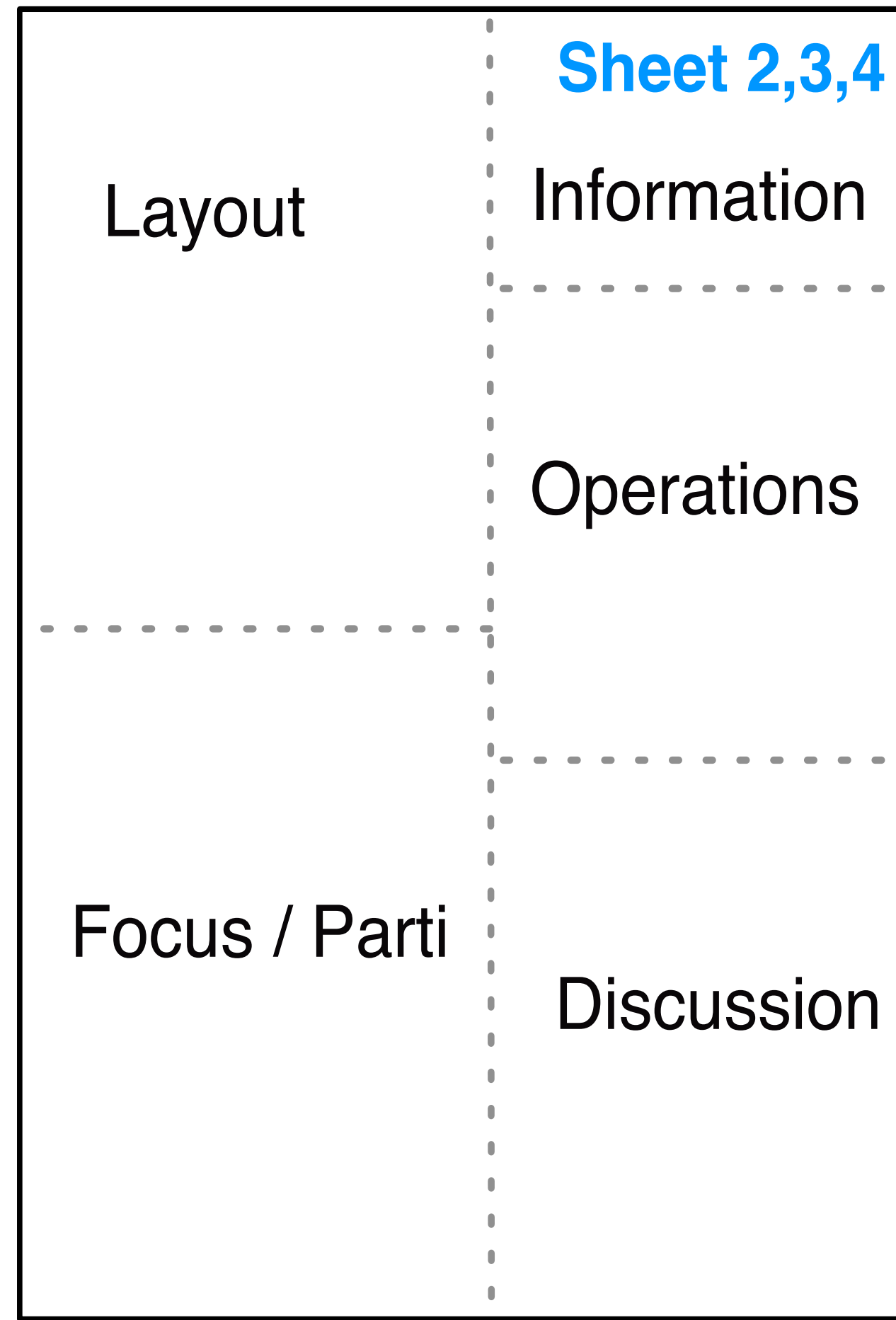


[J. Roberts et al., 2016]

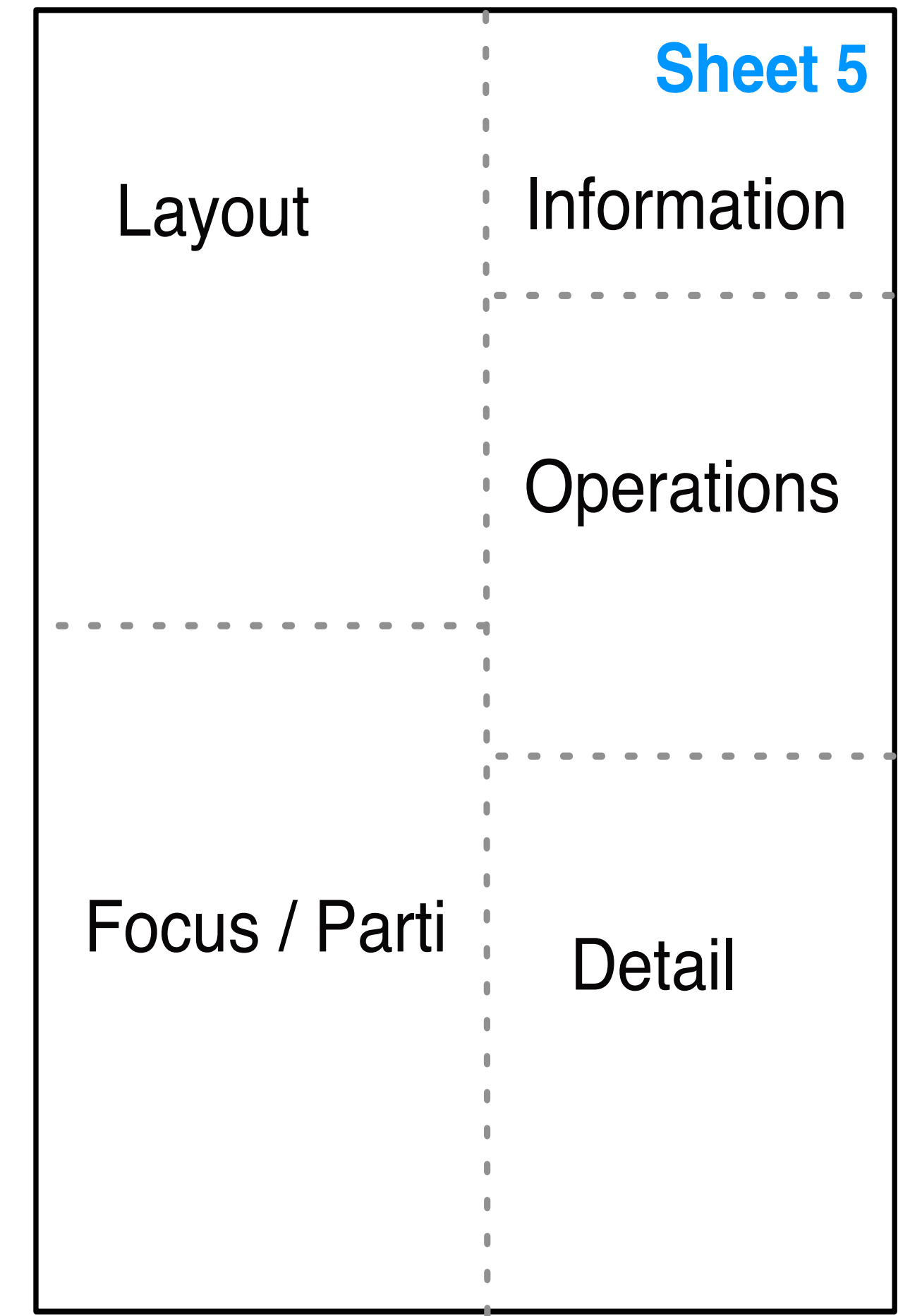
The Five Sheets



Ideation



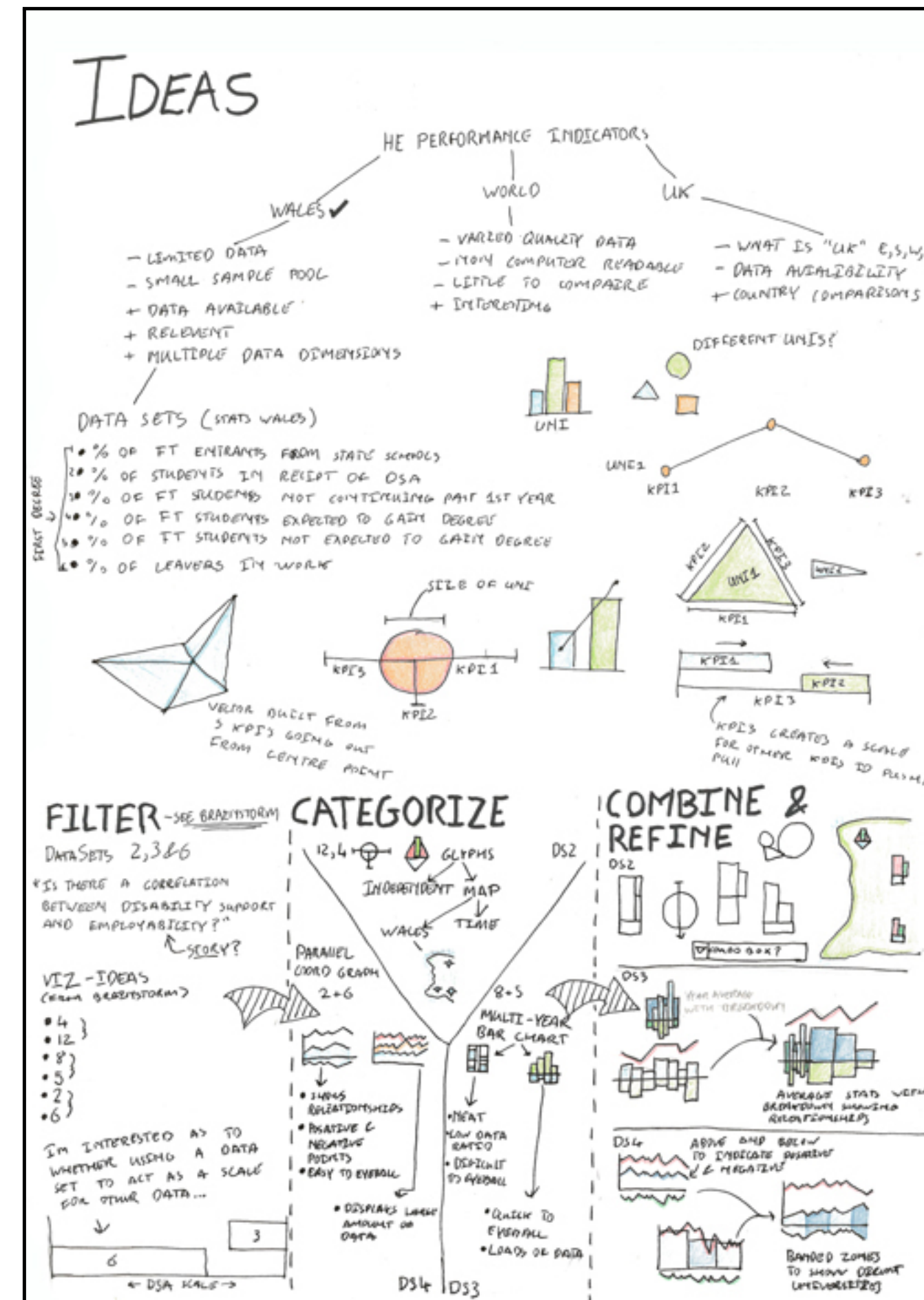
Alternative Designs



Realization

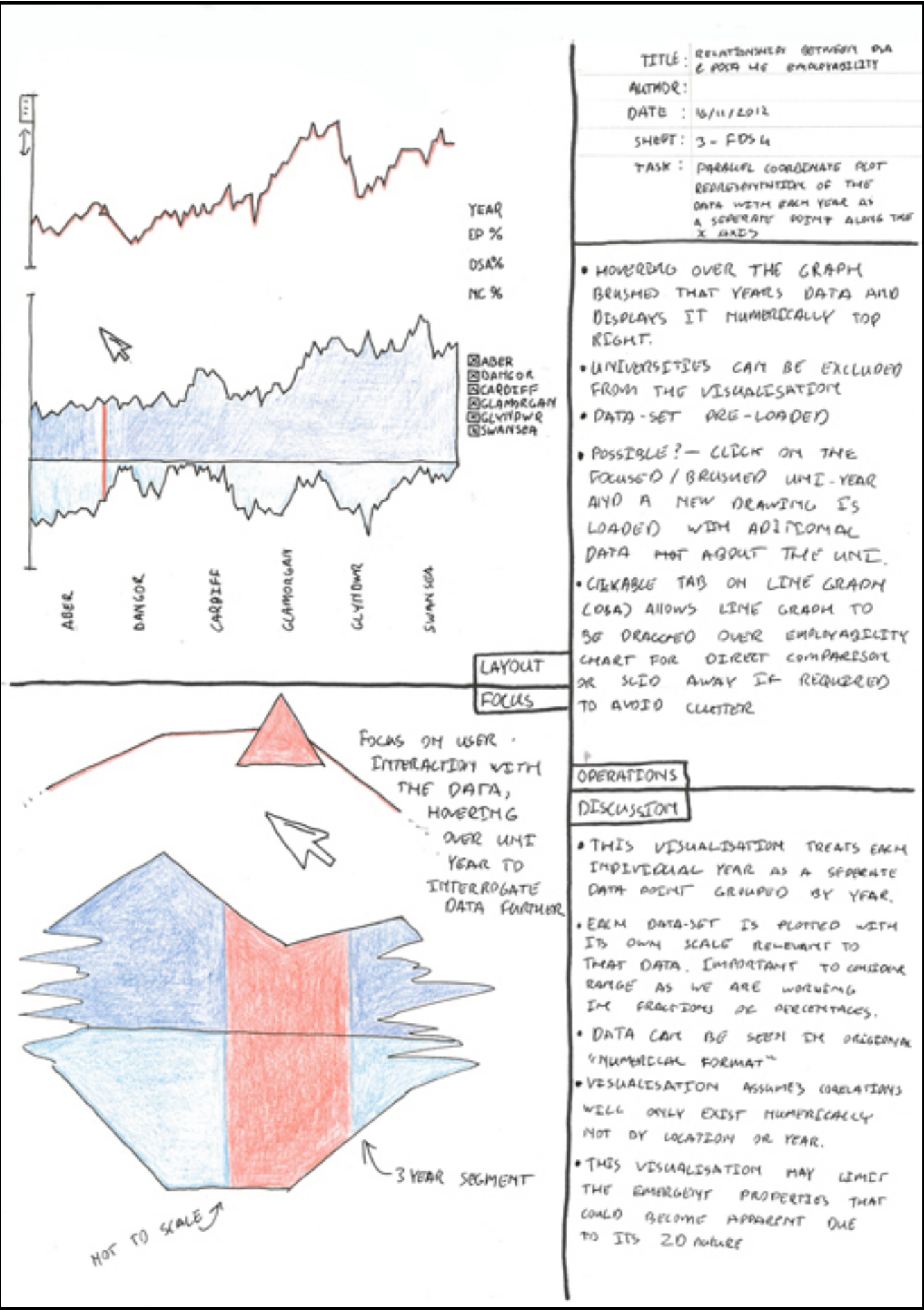
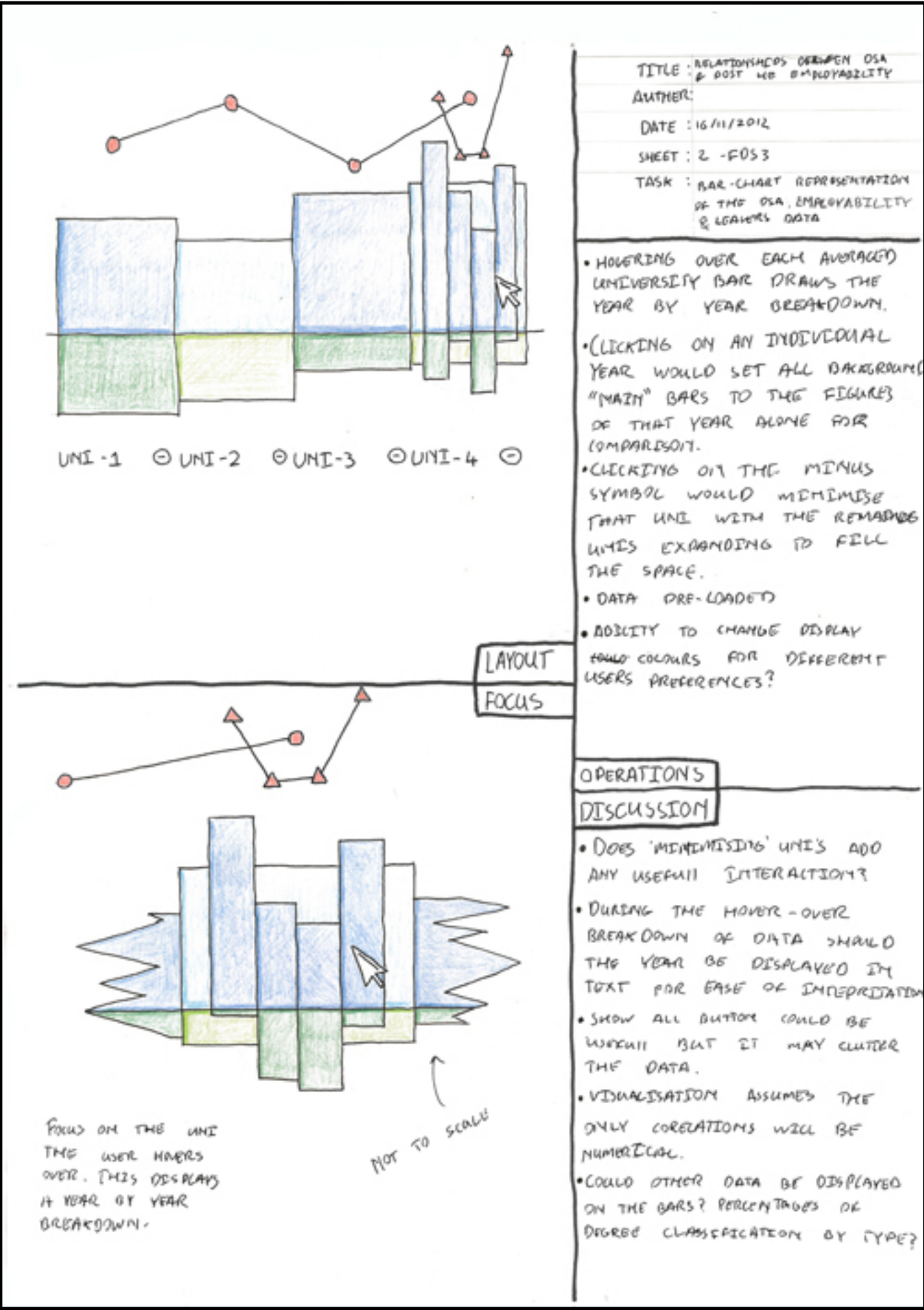
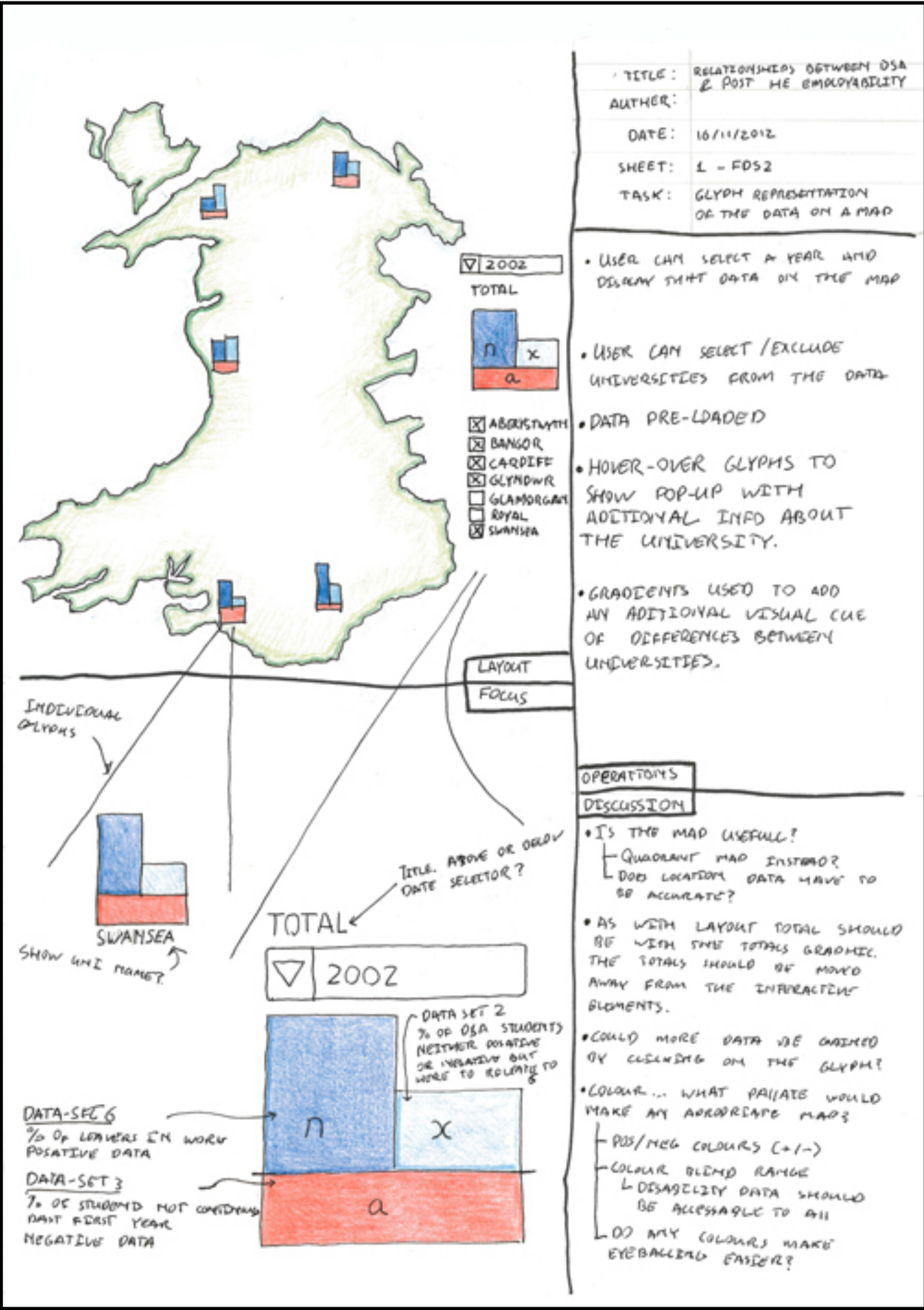
[J. Roberts et al., 2016]

Example: University Access for Disabled Students



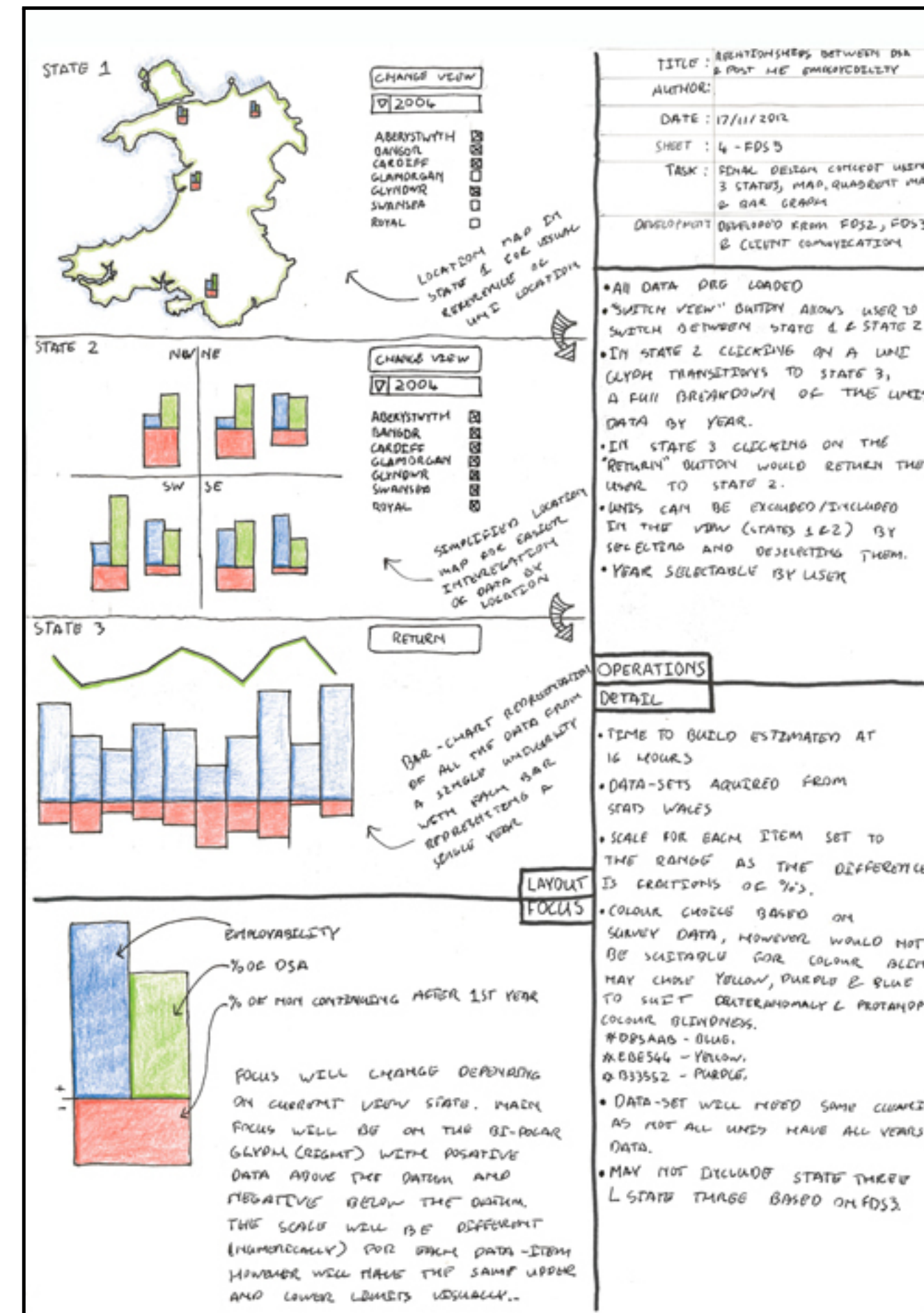
[J. Roberts et al., 2016]

Sheets 2-4



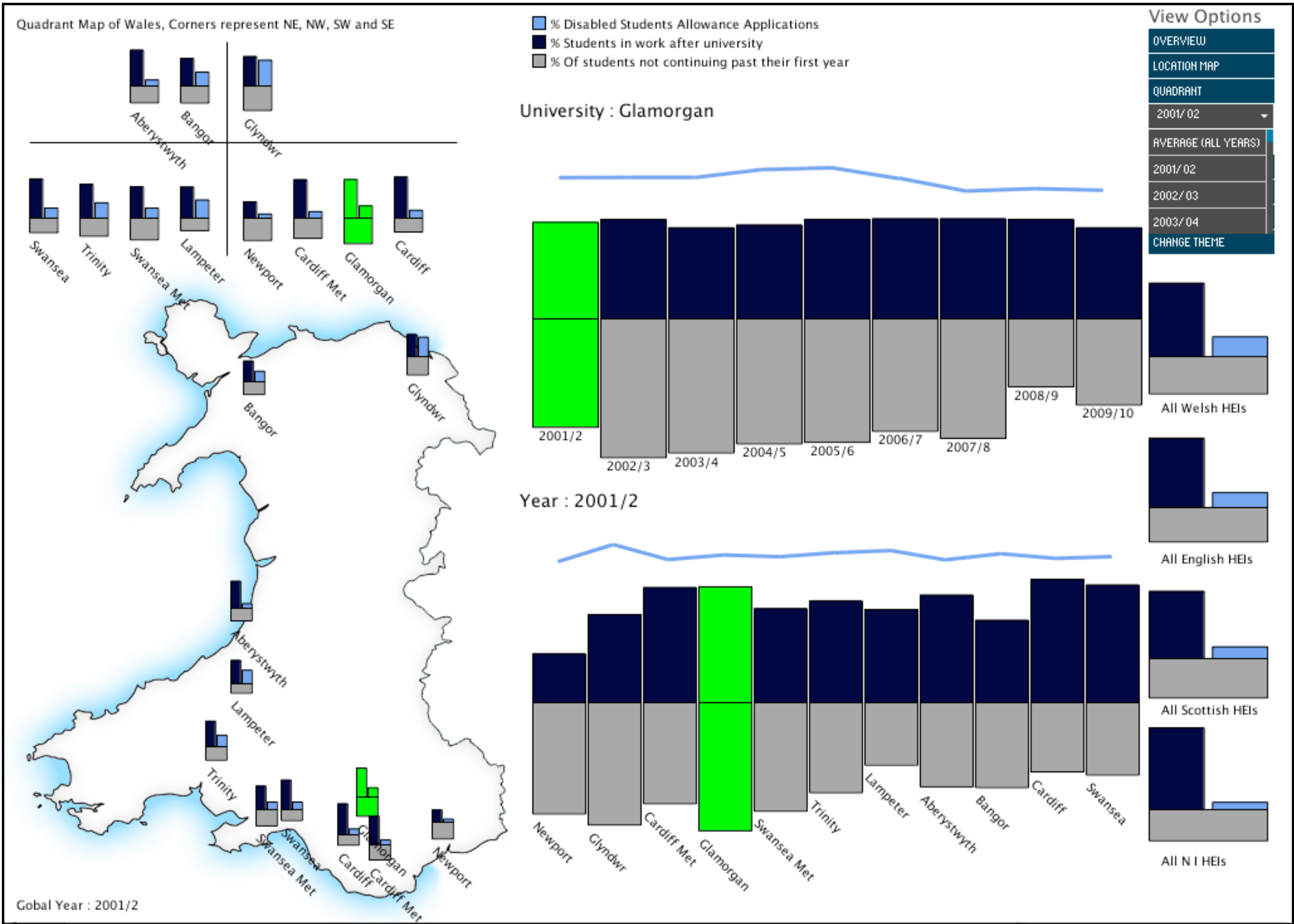
[J. Roberts et al., 2016]

Sheet 5



[J. Roberts et al., 2016]

Prototype



[J. Roberts et al., 2016]