CSC2537 / STA2555 - INFORMATION VISUALIZATION

DATA MODELS

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DATA TYPES

Taxonomies of **data types** stem from Steven's scale of measurement

- **Nominal** (identity)
- **Ordinal** (comparison)
- **Quantitative** (differences, ratios)

S.S. Stevens, On the theory of scales of measurements, 1946

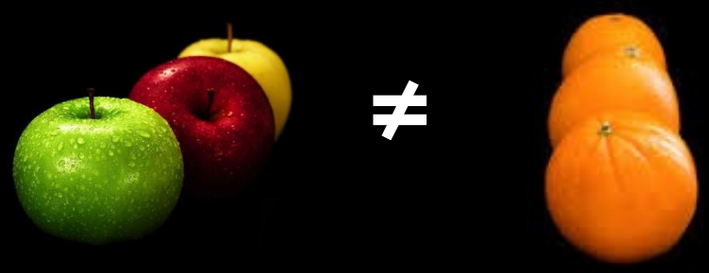
See also:
S. Card and J. Mackinlay. The Structure of the Information Visualization Design Space. In proc. InfoVis'97, 92–99, 1997.

DATA TYPES

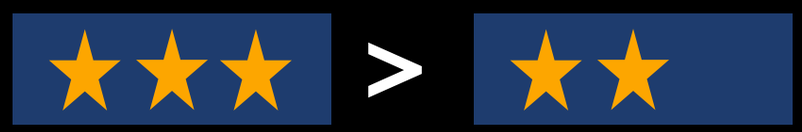
- **Nominal** (labels)
  - Fruits: apples, oranges
- **Ordinal**
  - Energy class: A, B, C, D, E
  - Meat quality: grade A, AA, AAA
  - Can be counted and compared, but not measured
- **Quantitative** : Interval
  - No absolute zero (or arbitrary)
  - E.g., dates, longitude, latitude
- **Quantitative** : Ratio
  - Meaningful origin
  - Physical measures (temperature, mass, length)
  - Accounts

DATA TYPES

- **Nominal** (labels)
  - Operations: =, ≠



- **Ordinal**
  - Operations: =, ≠, <, >



- **Quantitative** : Interval
  - Operations: =, ≠, <, >, -, +
  - Distance measure possible

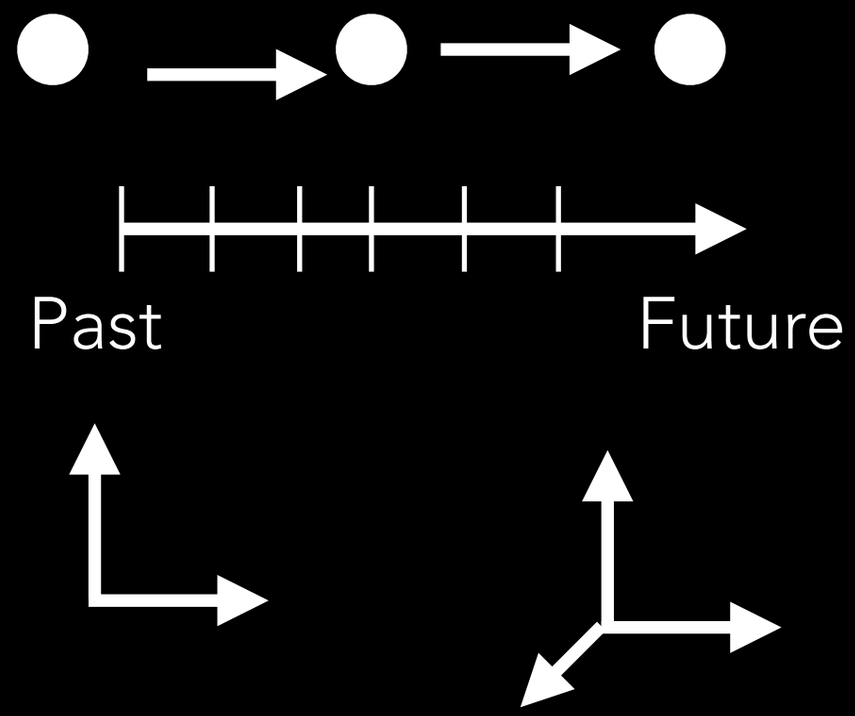
[1989 - 1999] **+** [2002 - 2012]

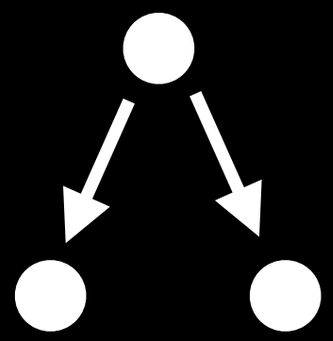
- **Quantitative** : Ratio
  - Operations : =, ≠, <, >, -, +, x, /
  - Ratio or proportion measure possible

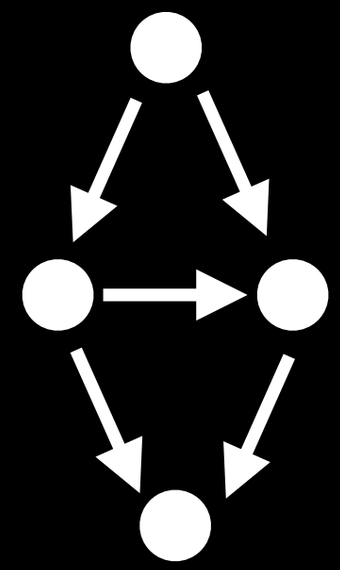
10kg **/** 5kg

DATA TYPES

- **1D** (linear)
- **Temporal**
- **2D** (map)
- **3D**
- **nD** (relational)
- **Tree** (hierarchical)
- **Network** (graphs)







Why is it important?

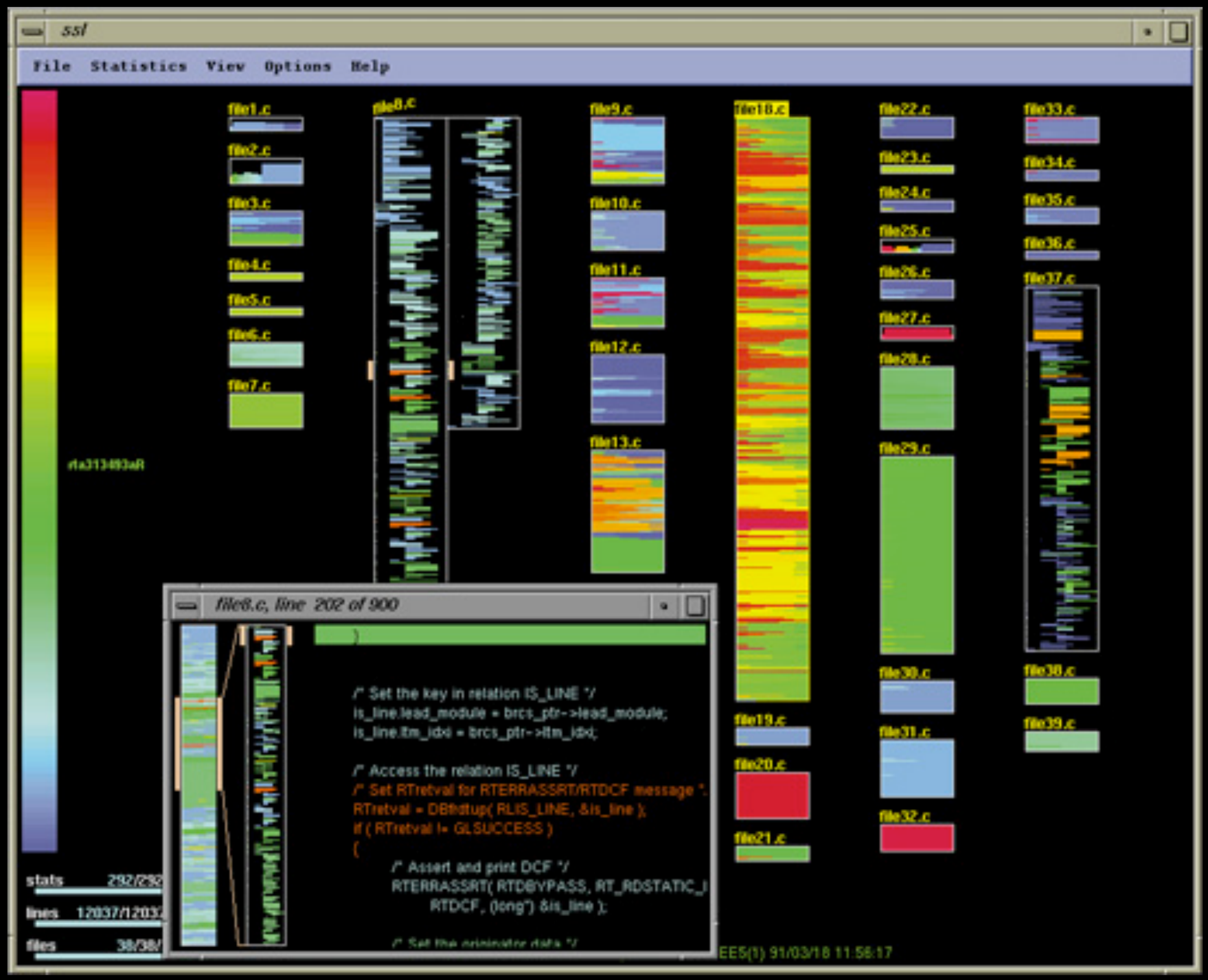
- The most appropriate visual representation for different data types (ordinal, nominal, quantitative) are different

- Different data types are often tied to specific tasks
    - temporal data: compare events
    - hierarchical data: understand parent-child relationships

But :

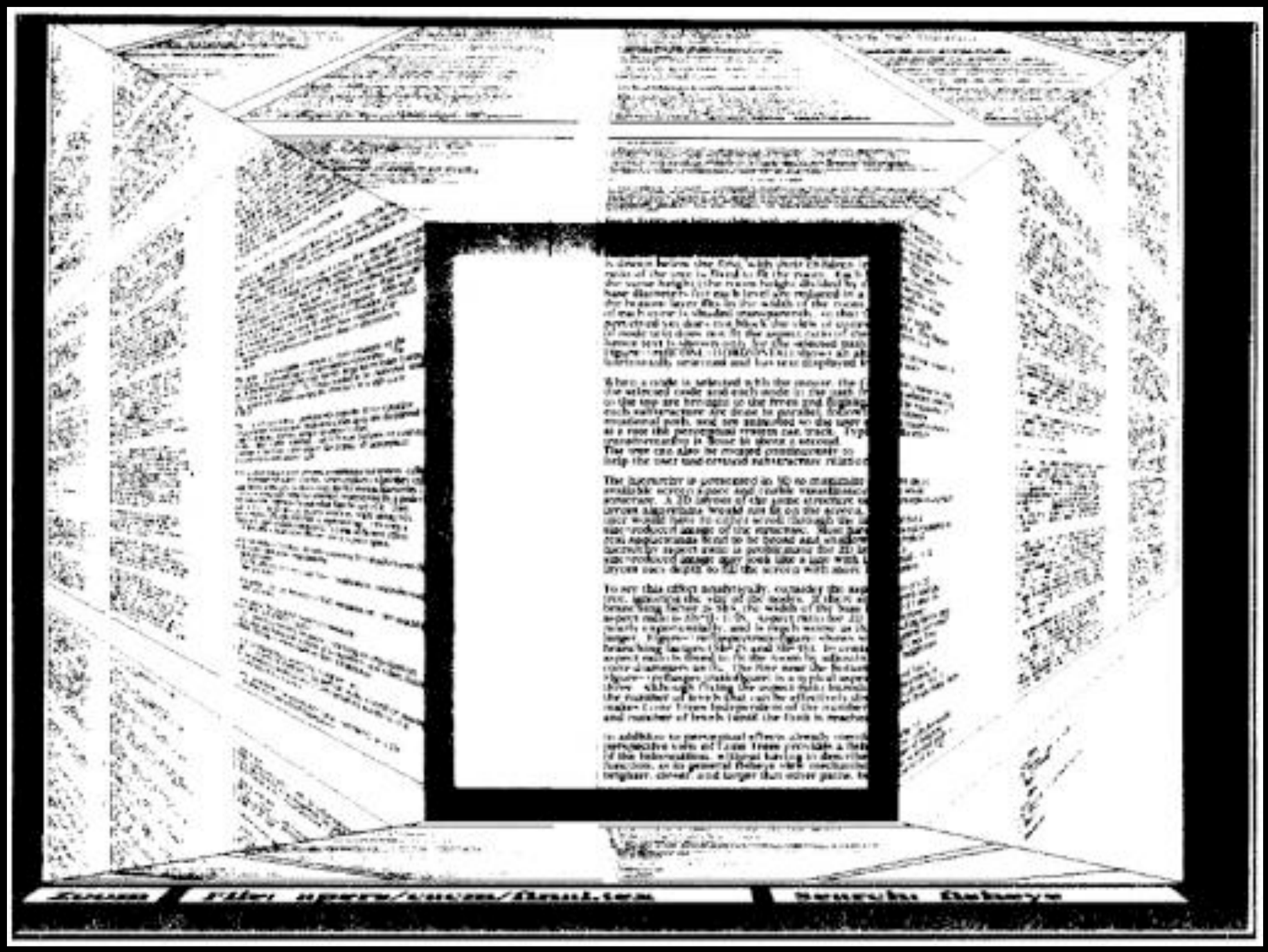
Each data type (1D, 2D, …) can be represented in multiple ways

LINEAR DATA



Seesoft [Eick, IEEE TVCG 1992]

LINEAR DATA



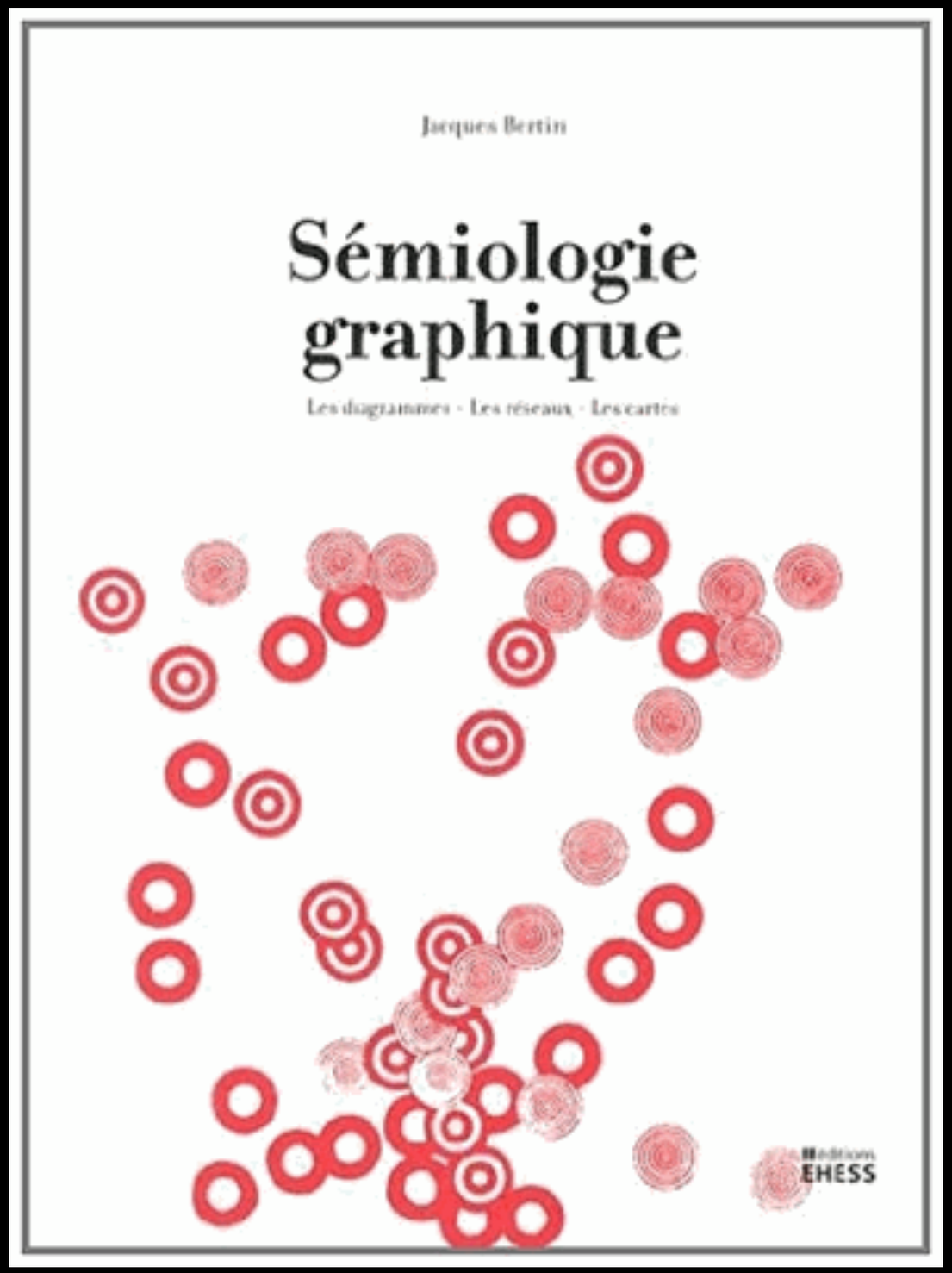
The Document Lens [Robertson & Mackinlay, UIST'93]

LINEAR DATA

See also: http://www.bewitched.com/song.html

Arc Diagrams [Wattenberg, Infovis 2002]

GRAPHIC SEMIOLOGY

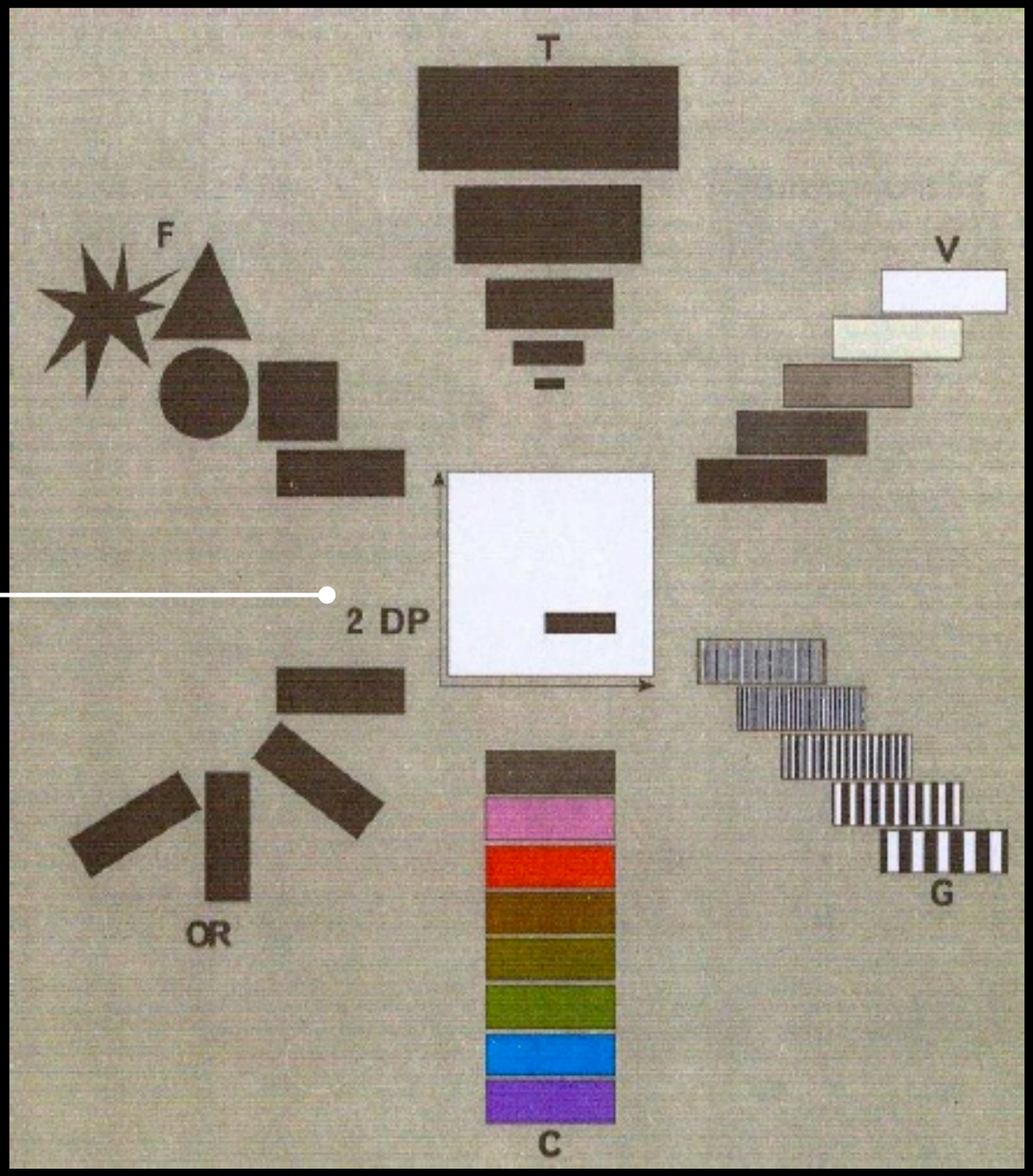


Jacques Bertin (1918-2010)

VISUAL VARIABLES (aka Retinal variables)

Size

Shape



Value

2D position

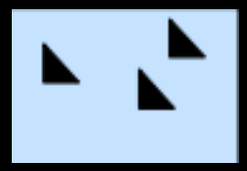
Orientation

Texture

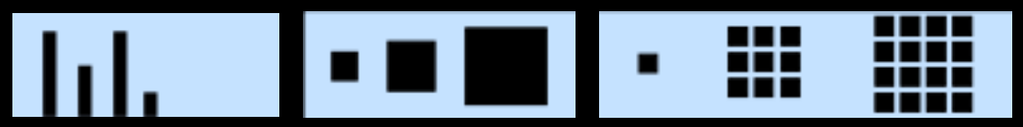
Color (Hue)

VISUAL VARIABLES: ATTRIBUTES

- **position**
  changes in the x, y (z) location

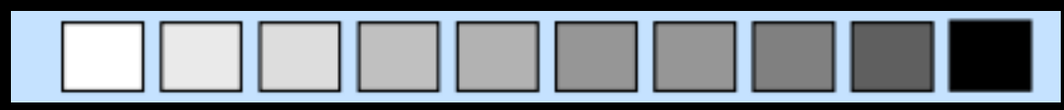


- **size**
  changes in length, area or repetition



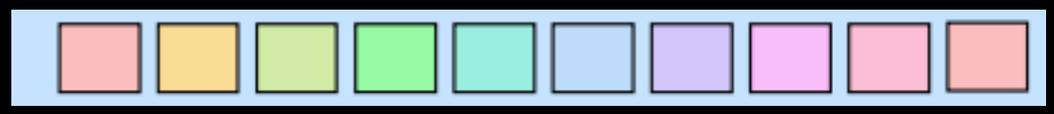
- **shape**
  infinite number of shapes

- **value**
  changes from light to dark

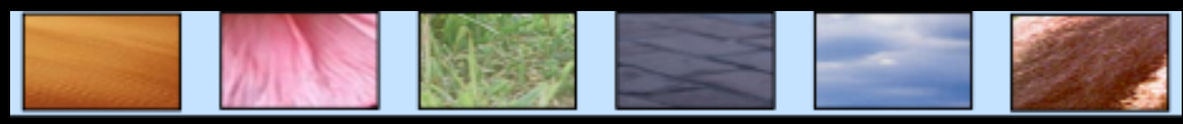


- **orientation**
  changes in alignment

- **colour**
  changes in hue at a given value



- **texture**
  variation in pattern



- **(motion)**

VISUAL VARIABLES : CHARACTERISTICS

- **selective**
  is a change in this variable enough to allow us to select it from a group?

- **associative**
  is a change in this variable enough to allow us to perceive them as a group?

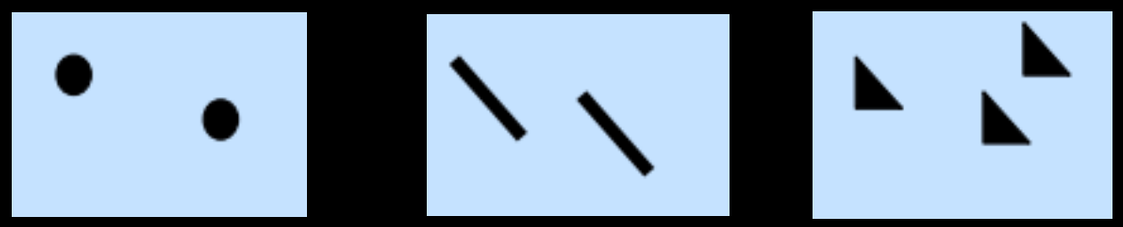
- **quantitative**
  is there a numerical reading obtainable from changes in this variable?

- **order**
  are changes in this variable perceived as ordered?

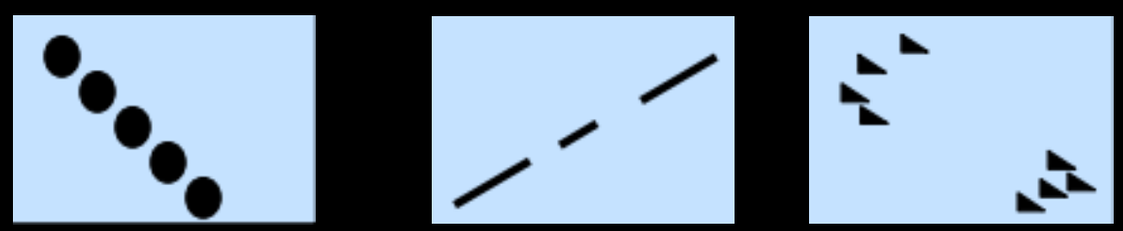
- **length**
  across how many changes in this variable are distinctions perceptible?

POSITION

✓ **selective**



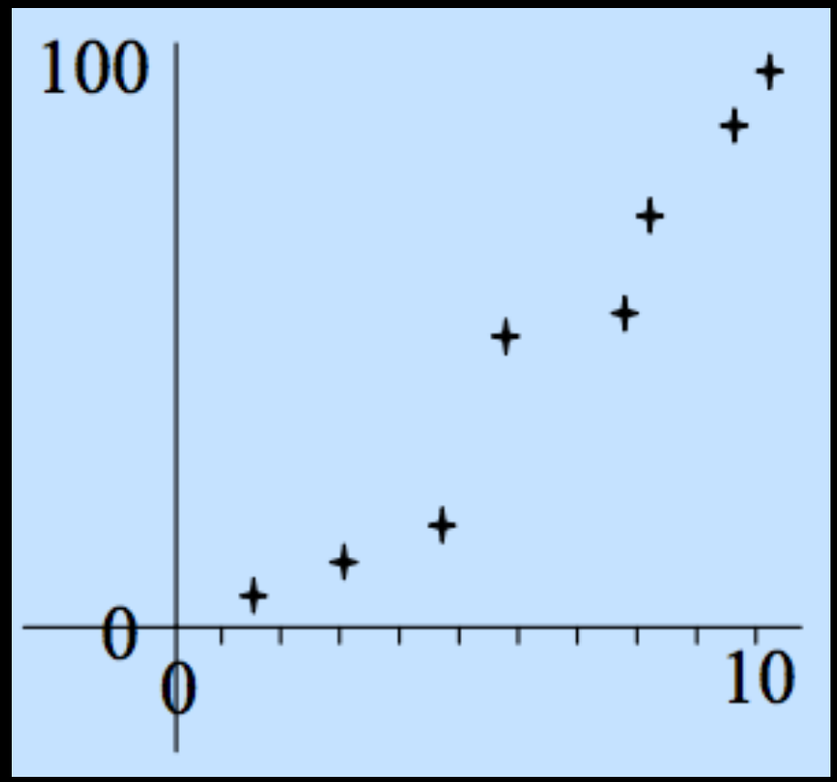
✓ **associative**



✓ **quantitative**

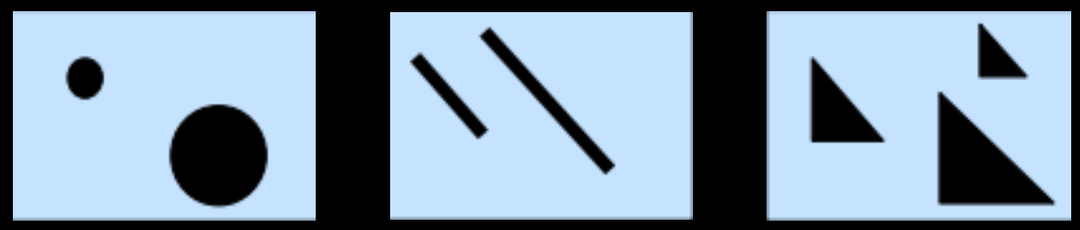
✓ **order**

✓ **length**

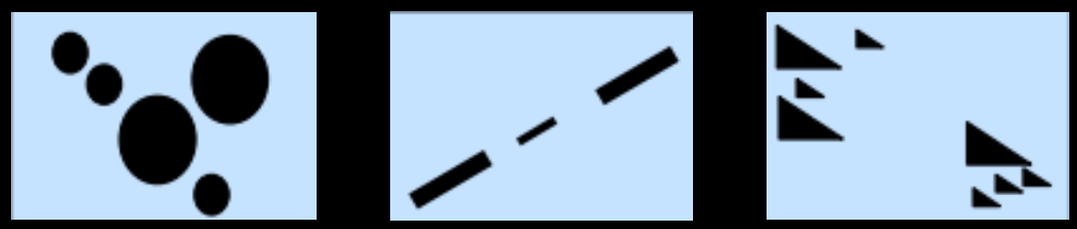


SIZE

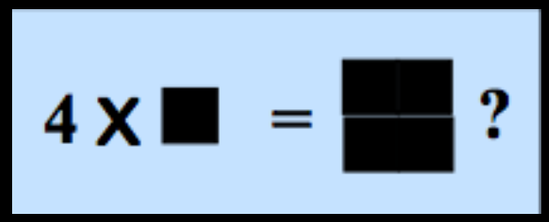
✓ **selective**



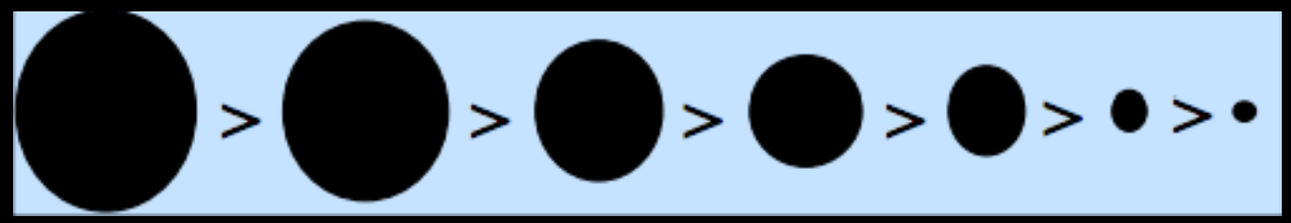
✓ **associative**



≈ **quantitative**



✓ **order**

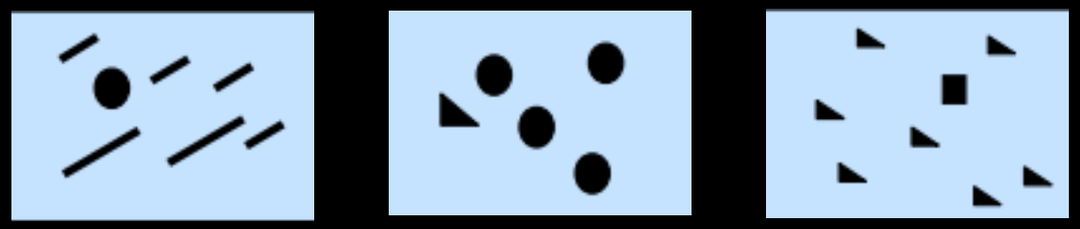


length

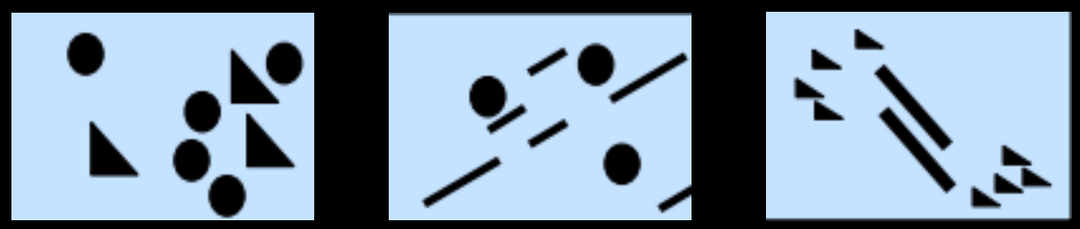
✓
- theoretically infinite but practically limited
- association and selection ~5 and distinction ~ 20

SHAPE

≈ **selective**

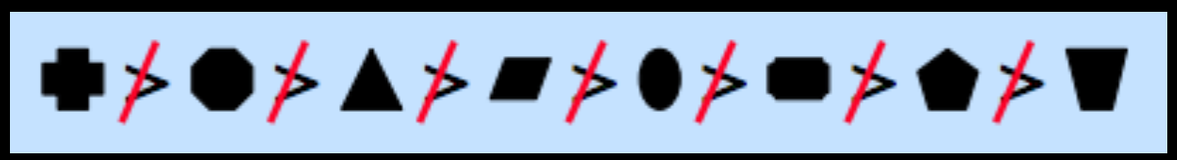


≈ **associative**



✗ **quantitative**

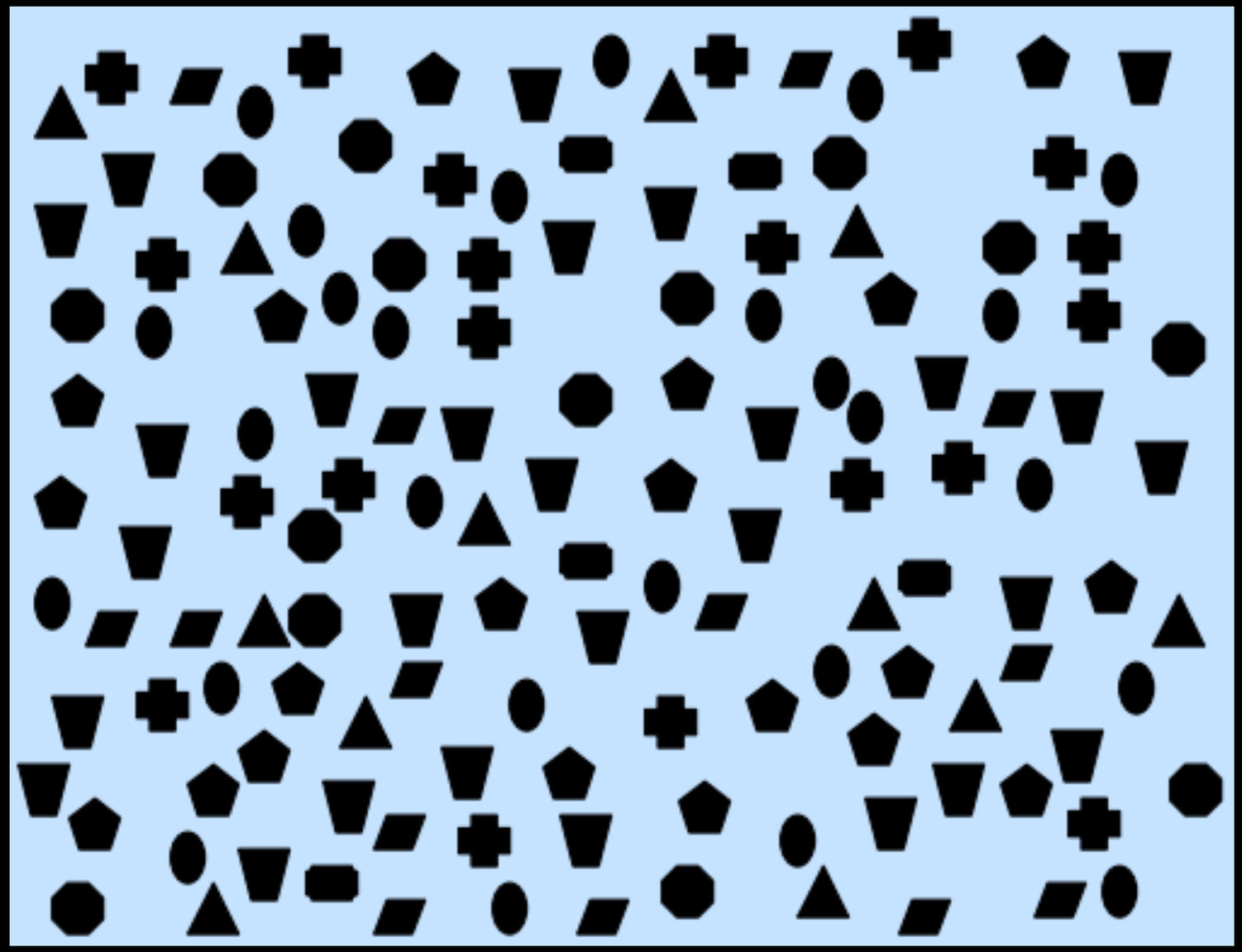
✗ **order**



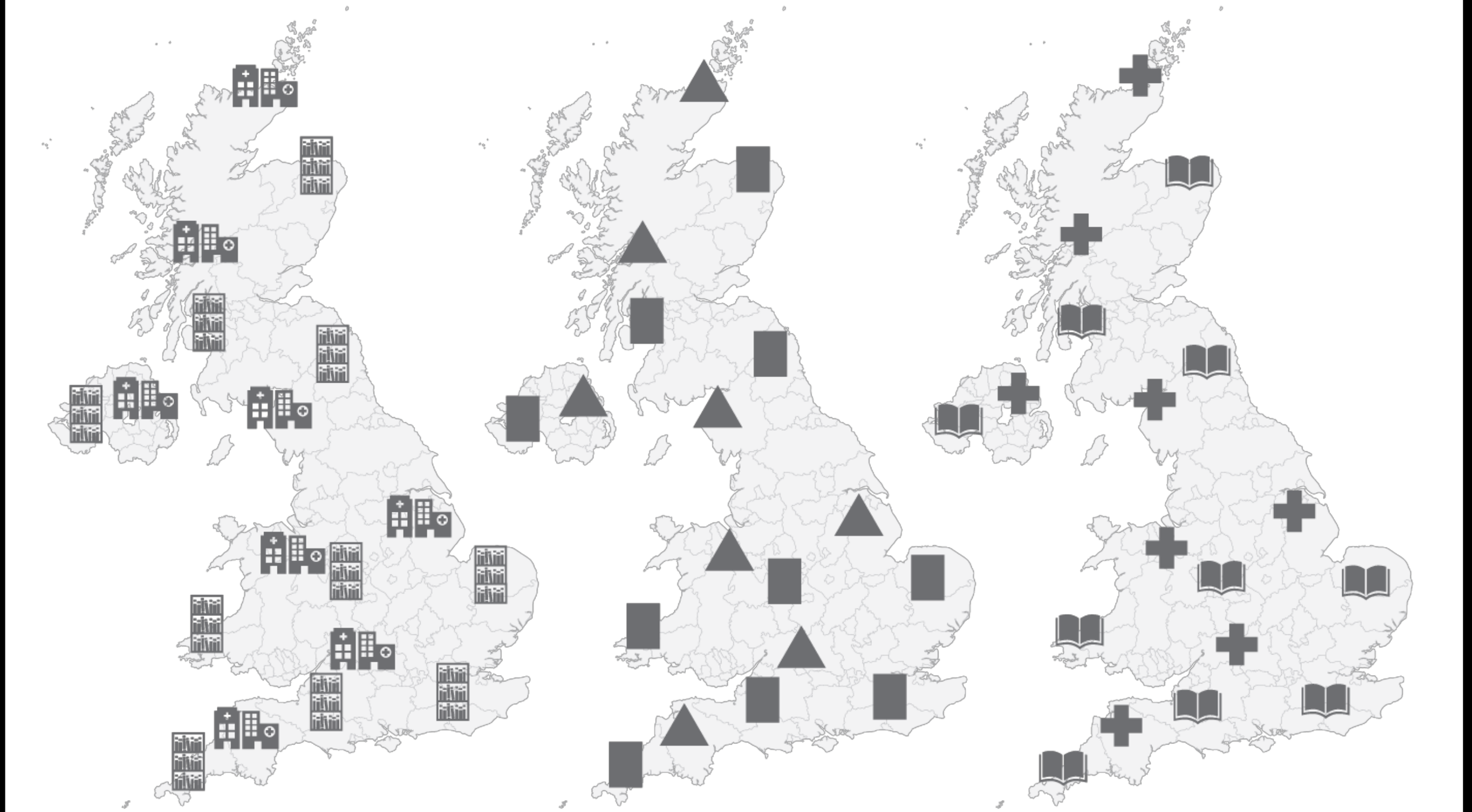
✓ **length**

- infinite variations

SHAPE

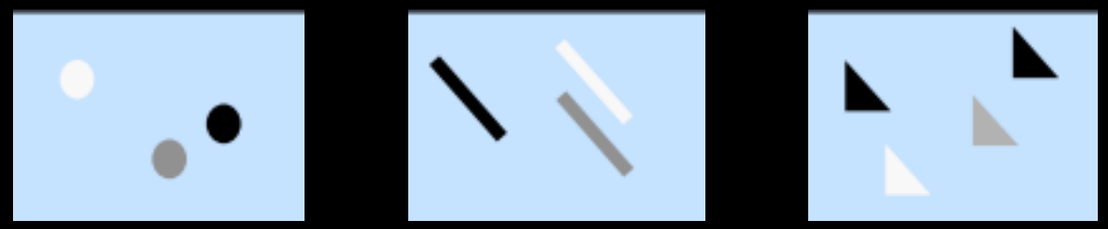


SHAPE

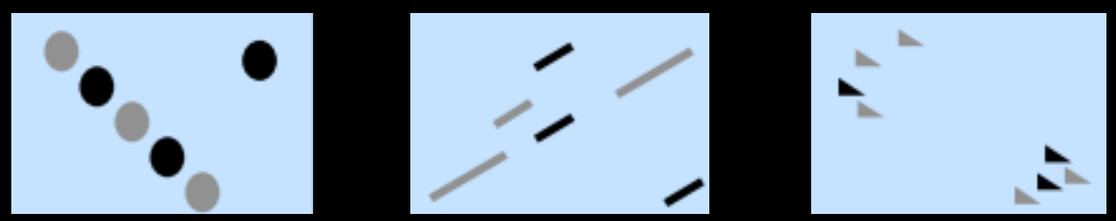


VALUE

✓ **selective**

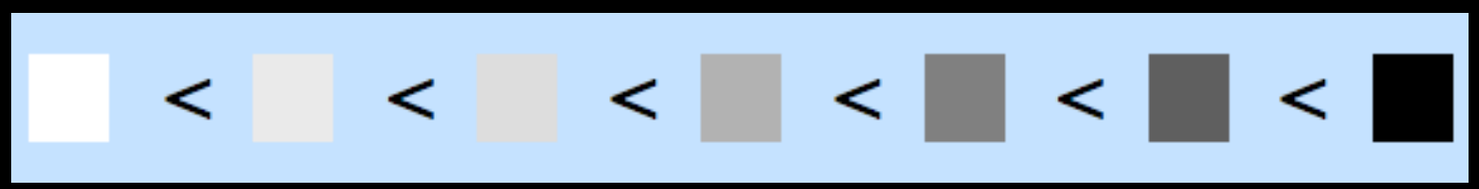


✓ **associative**



✗ **quantitative**

✓ **order**

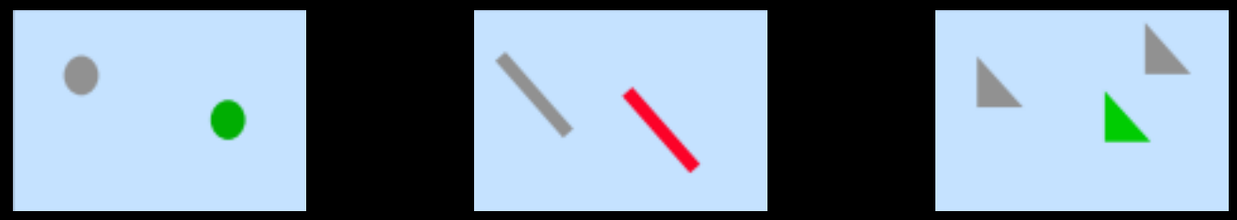


✓ **length**

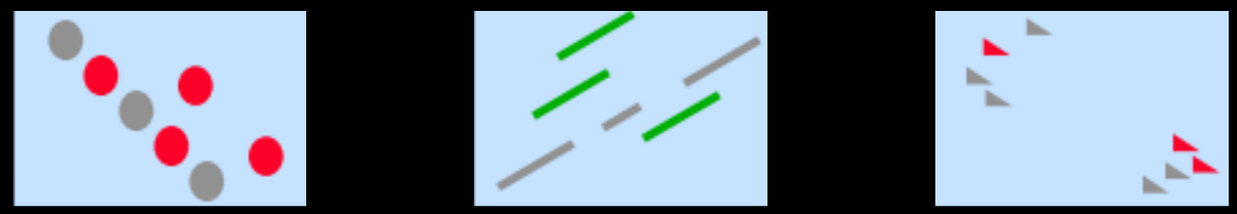
- theoretically infinite but practically limited
- association and selection < ~7 and distinction ~10

COLOUR

✓ **selective**



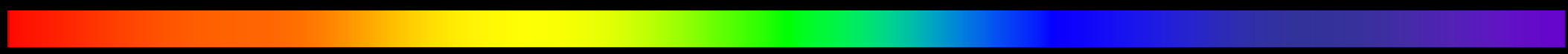
✓ **associative**



✗ **quantitative**

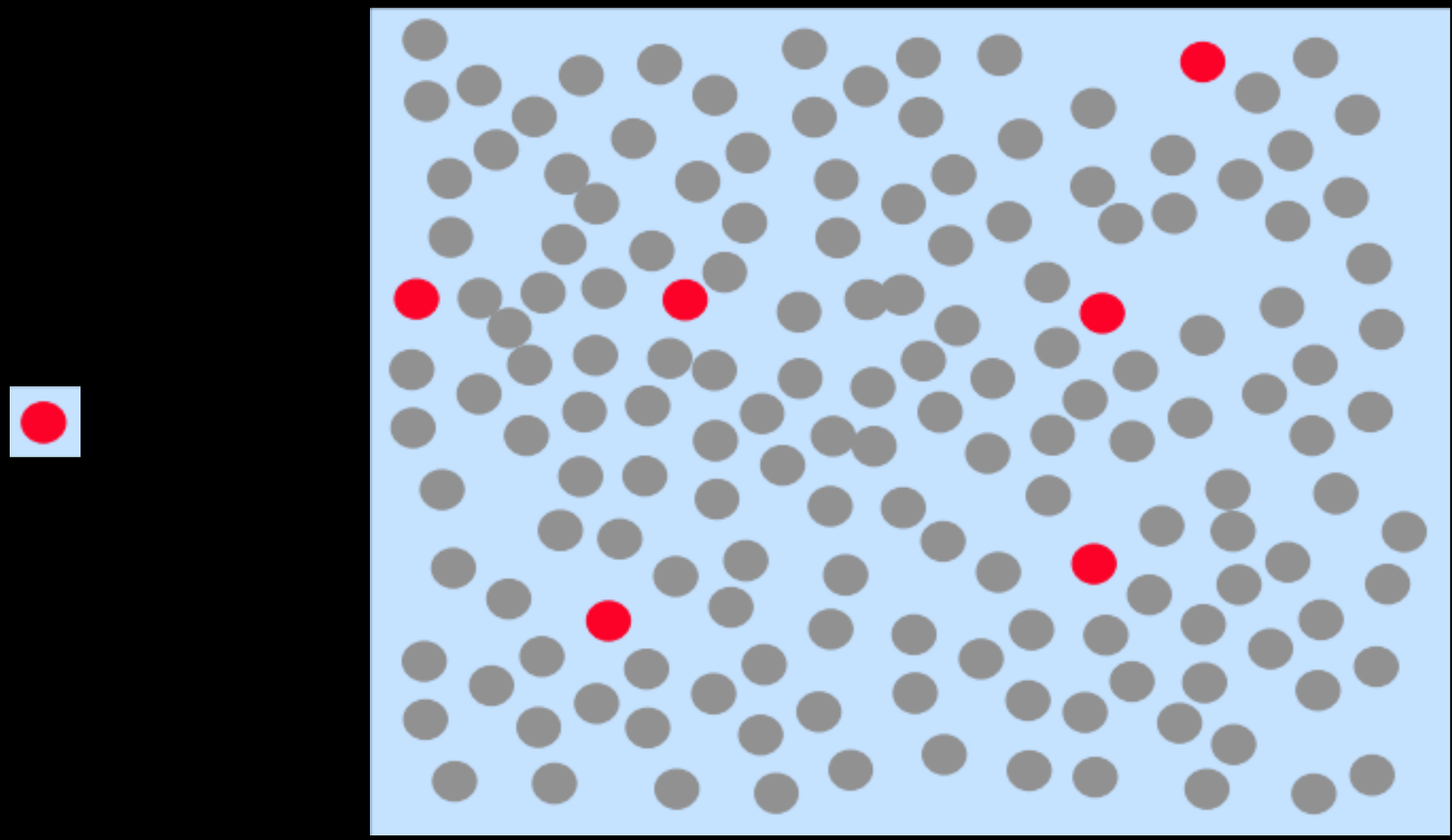
✗ **order**

✓ **length**



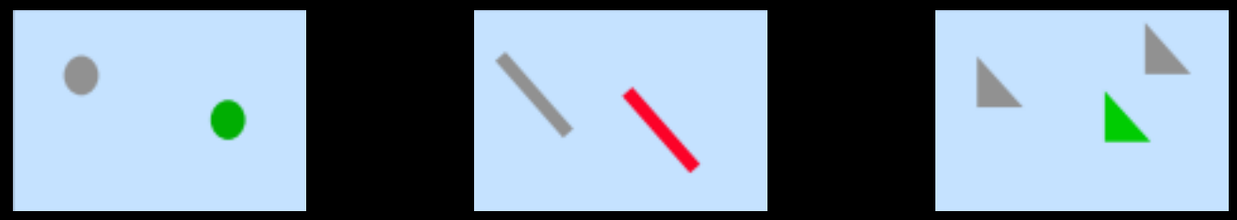
- theoretically infinite but practically limited
- association and selection < ~7 and distinction ~10

COLOUR

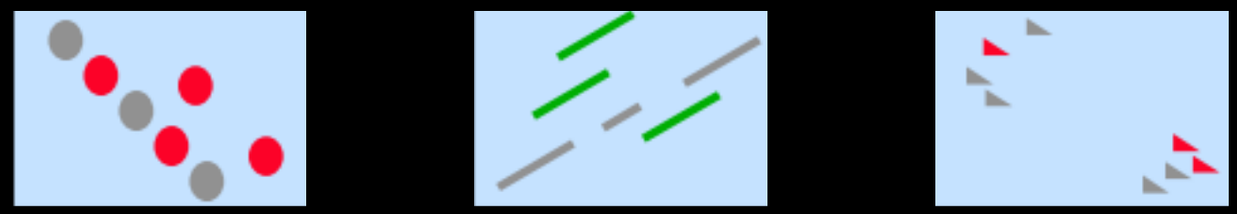


COLOUR

✓ **selective**



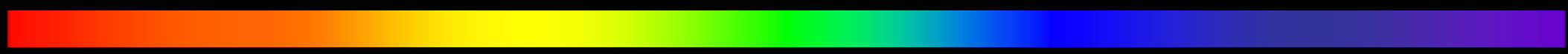
✓ **associative**



✗ **quantitative**

✗ **order**

✓ **length**

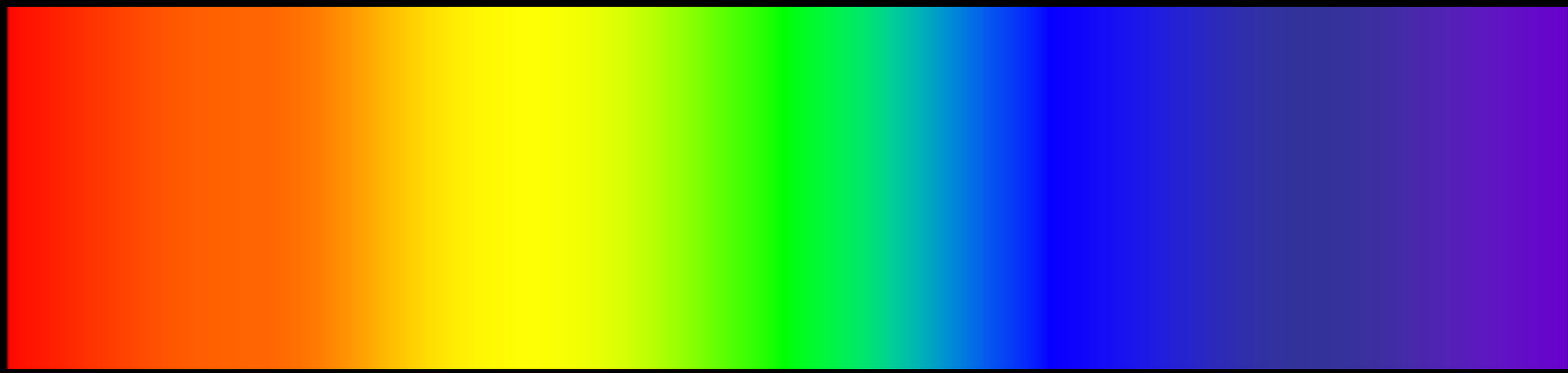


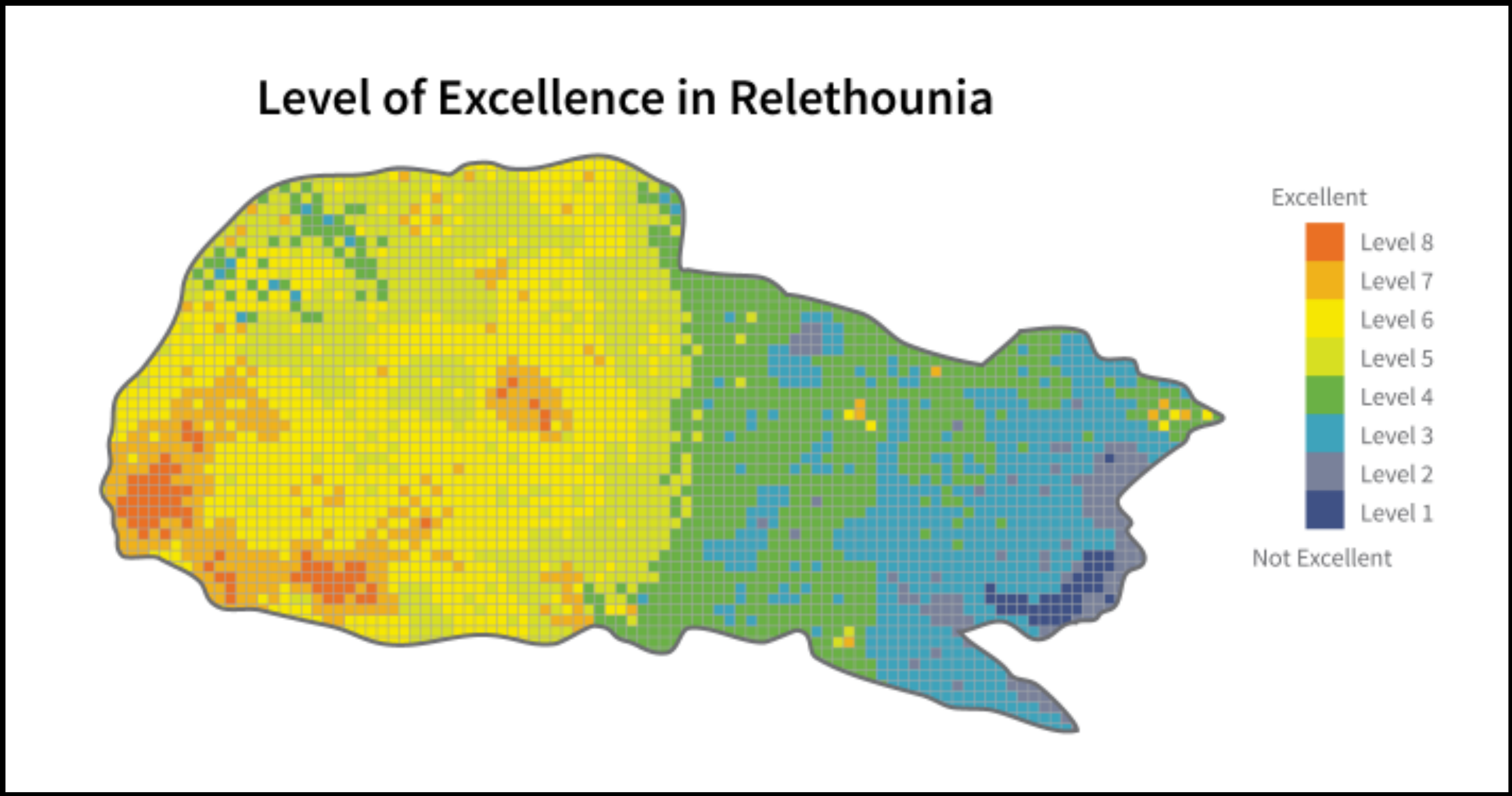
- theoretically infinite but practically limited
- association and selection < ~7 and distinction ~10

ENCODING

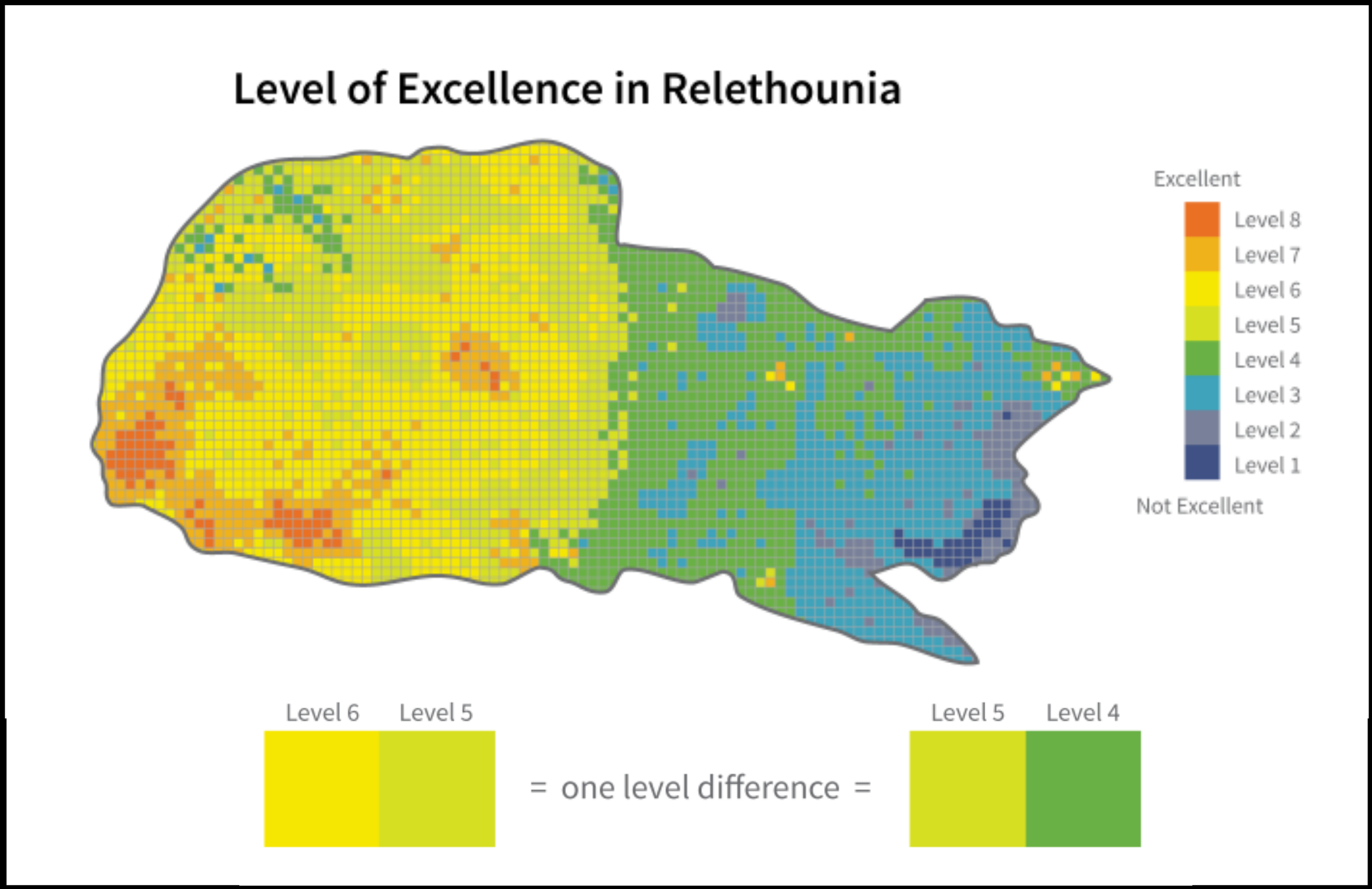
Common advice says use a rainbow scale

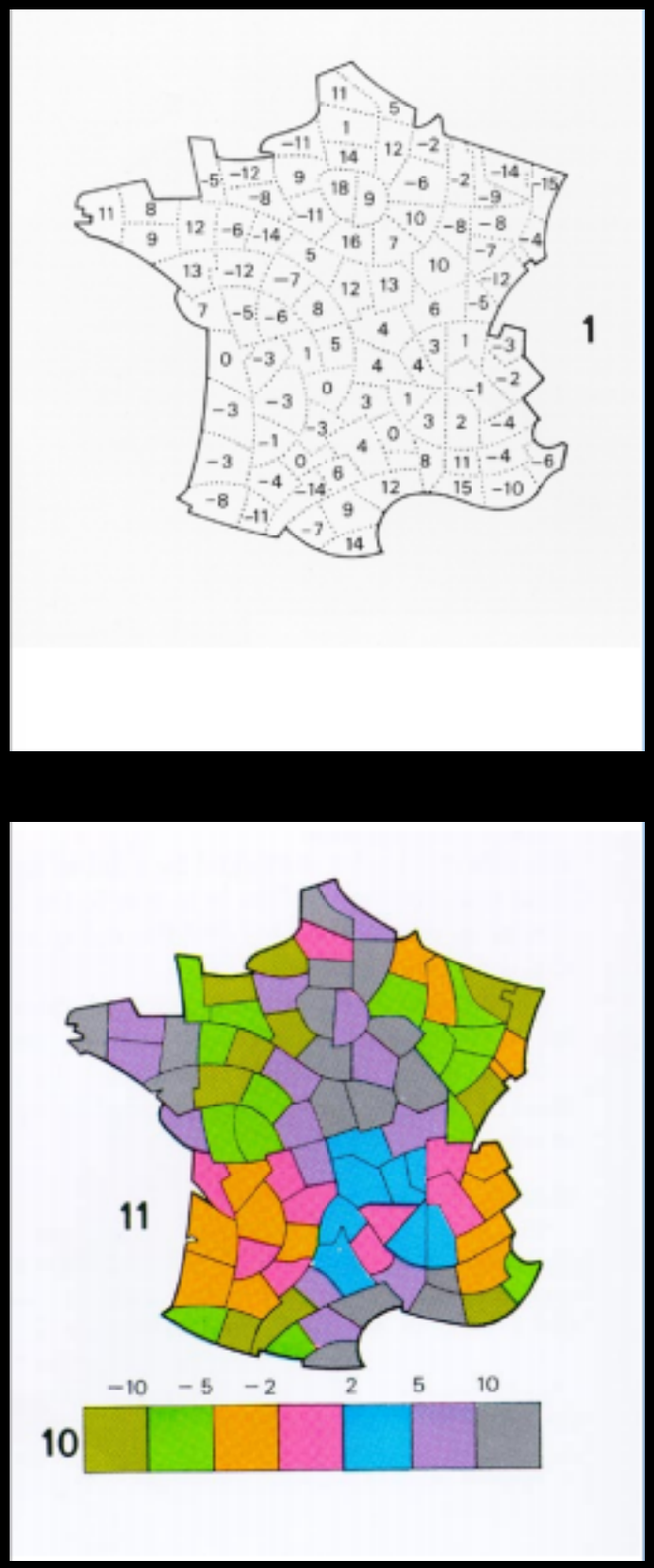
- Marcus, Murch, Healey
- strong problems with rainbows

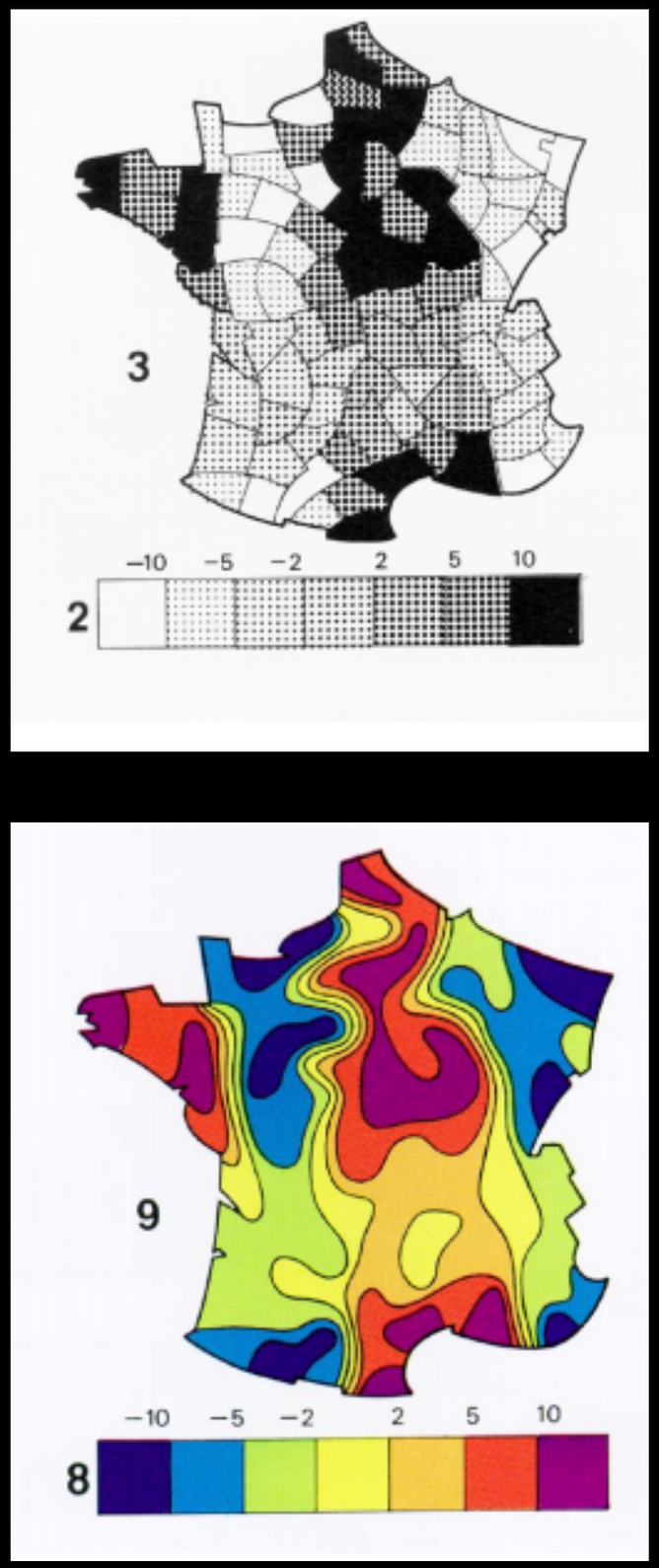


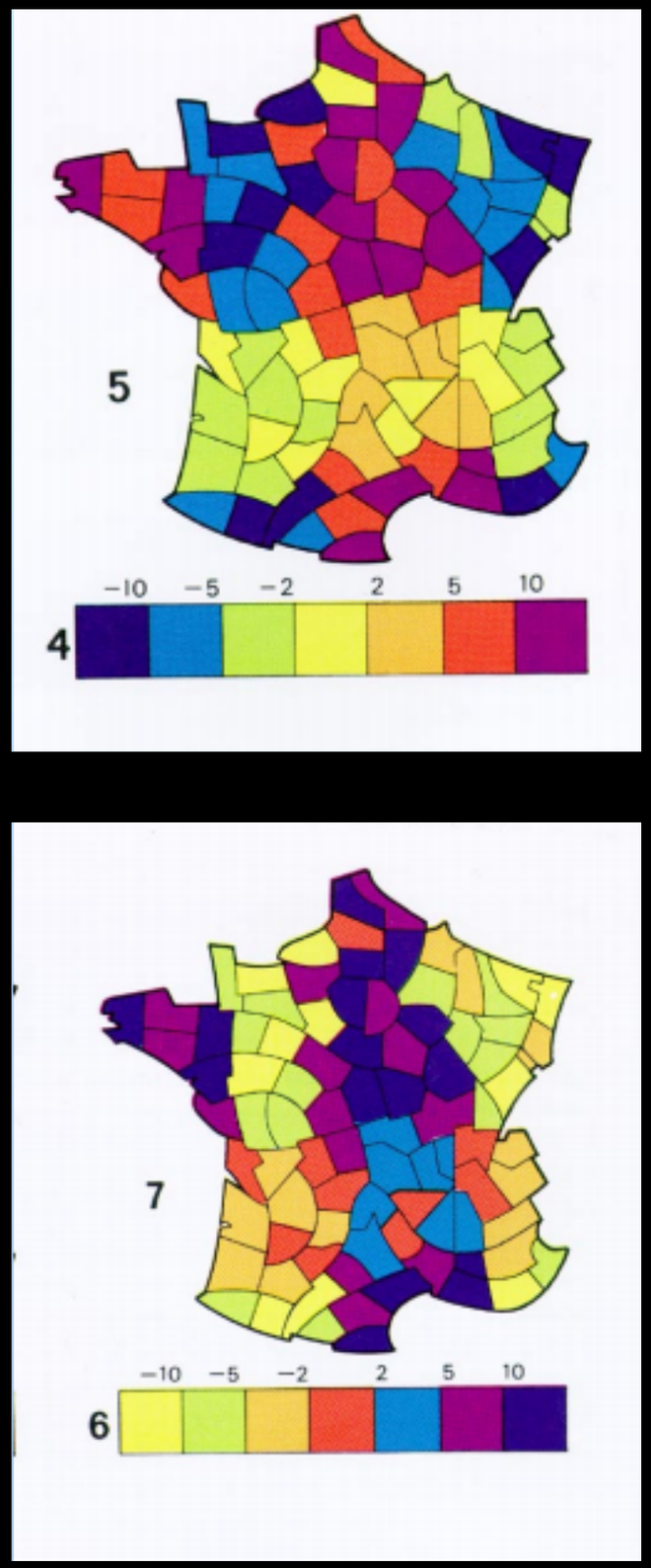


Which stands out to you? Do you see a division?


Level of Excellence in Relethounia
Excellent
Level 8
Level 7
Level 6
Level 5
Level 4
Level 3
Level 2
Level 1
Not Excellent
Level 6
Level 5
= one level difference =
Level 5
Level 4


1

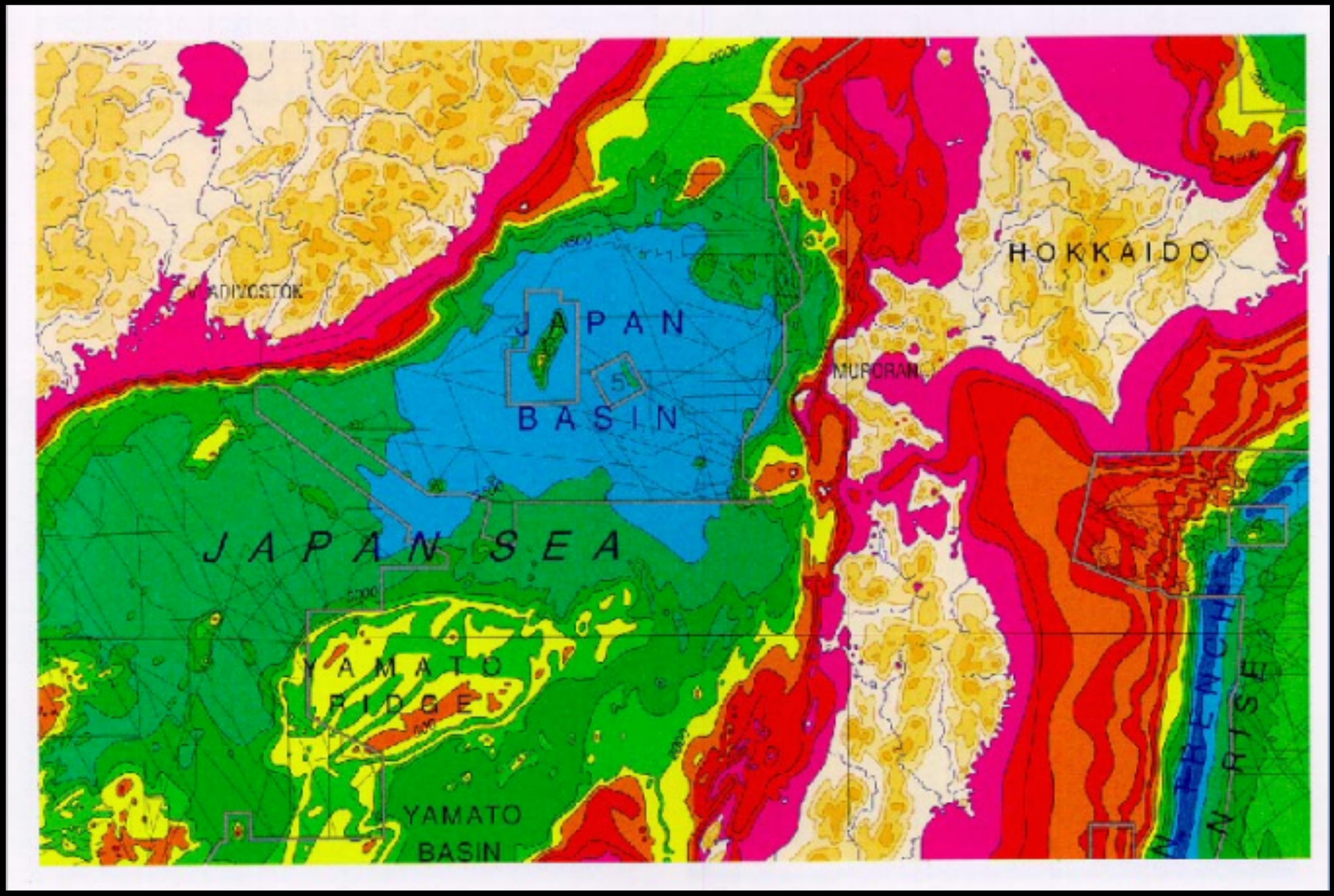

3
2
−10 −5 −2 2 5 10

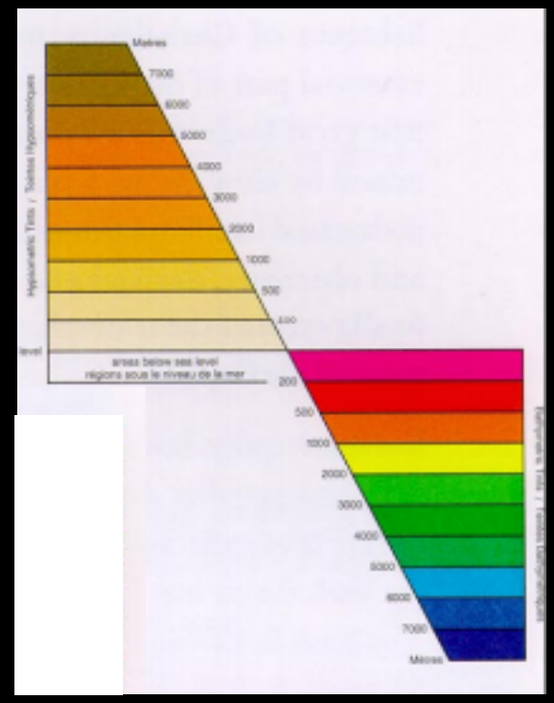

5
4
−10 −5 −2 2 5 10

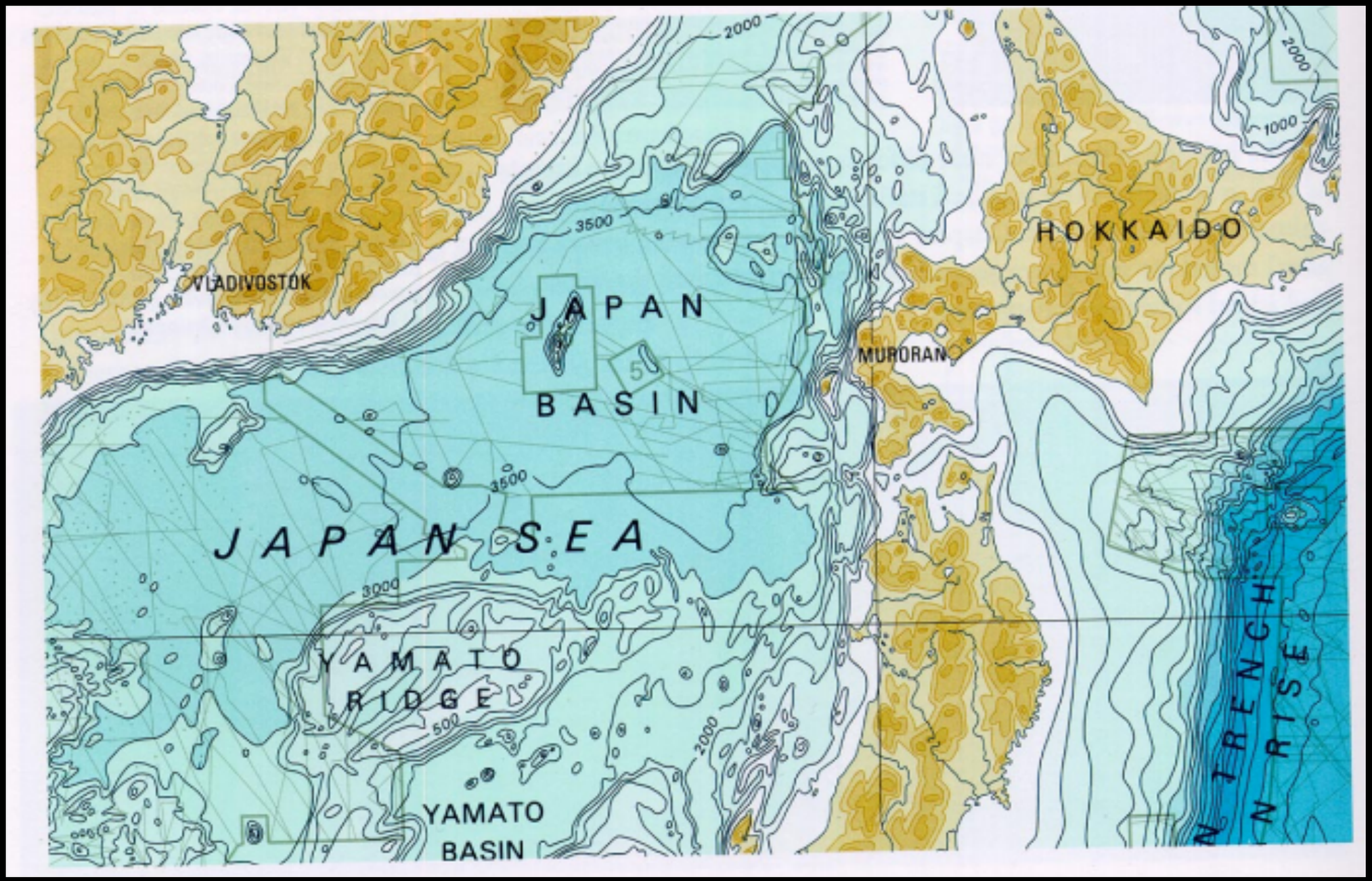
11
10
−10 −5 −2 2 5 10

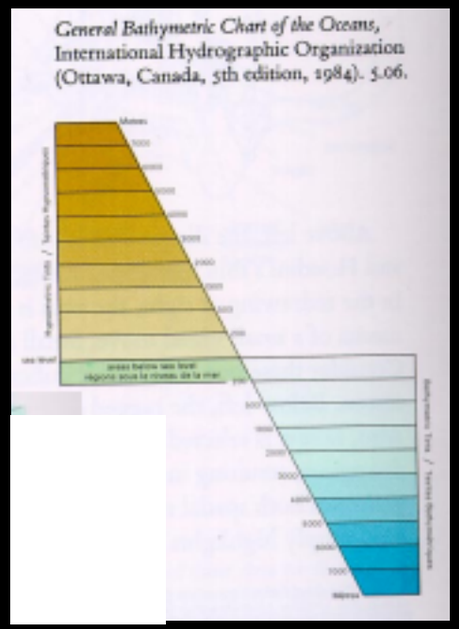
9
8
−10 −5 −2 2 5 10

7
6
−10 −5 −2 2 5 10


HOKKAIDO
VLADIVOSTOK
JAPAN
BASIN
MURORAN
JAPAN SEA
YAMATO
RIDGE
YAMATO
BASIN
NORTH HONSHU RIDGE


Metres
7000
6000
5000
4000
3000
2000
1000
500
400
200
500
1000
2000
3000
4000
5000
6000
7000
Metres
areas below sea level
régions sous le niveau de la mer


2000
3500
1000
VLADIVOSTOK
JAPAN
BASIN
HOKKAIDO
MURORAN
JAPAN SEA
3000
YAMATO
RIDGE
500
2000
YAMATO
BASIN
TRENCH
RISE


General Bathymetric Chart of the Oceans,
International Hydrographic Organization
(Ottawa, Canada, 5th edition, 1984). 5.06.

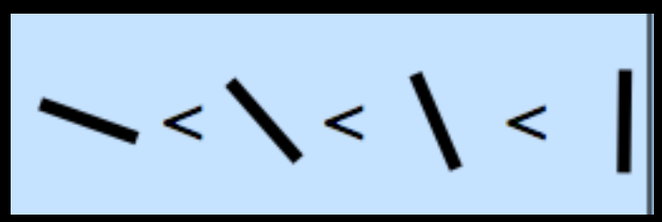
ORIENTATION

✓ **selective**

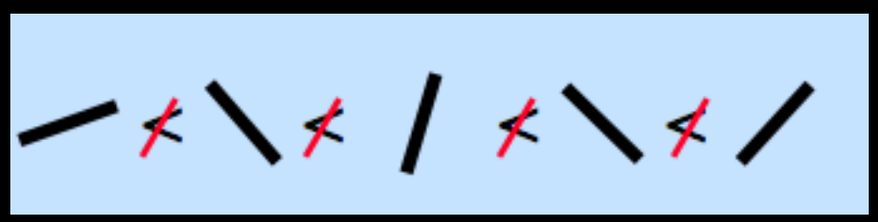
✓ **associative**

✗ **quantitative**

✗ **order**



?

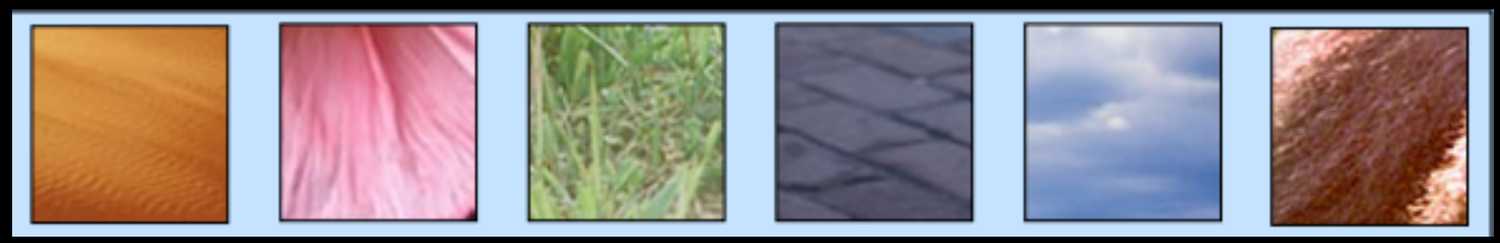


✓ **length**

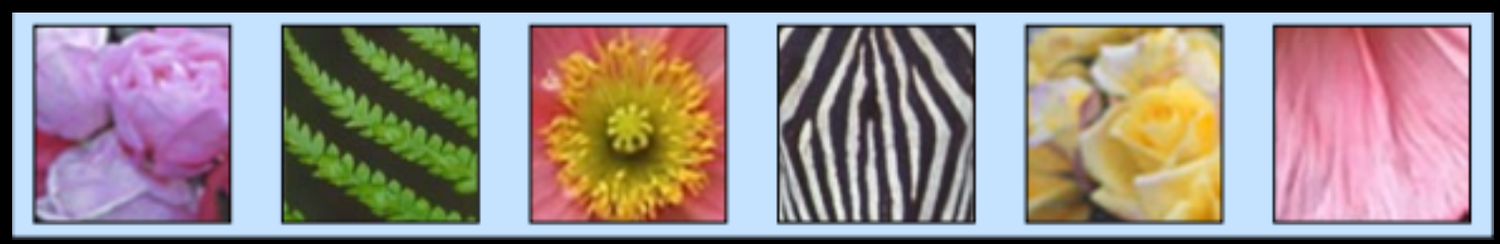
- ~5 in 2D; ? in 3D

TEXTURE

✓ **selective**

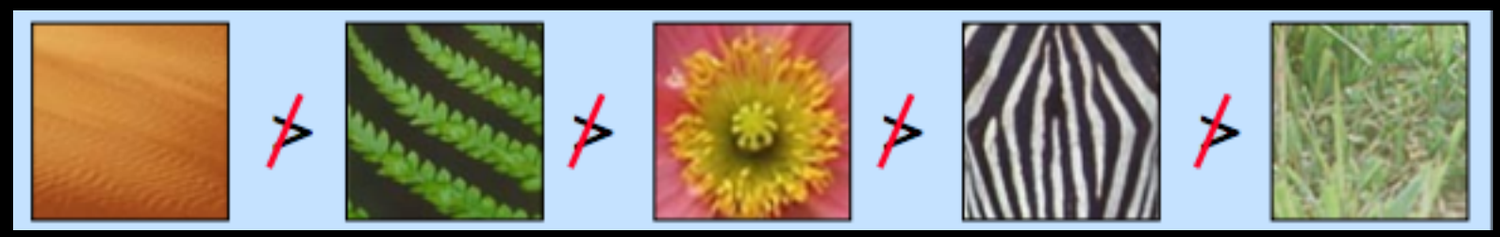


✓ **associative**



✗ **quantitative**

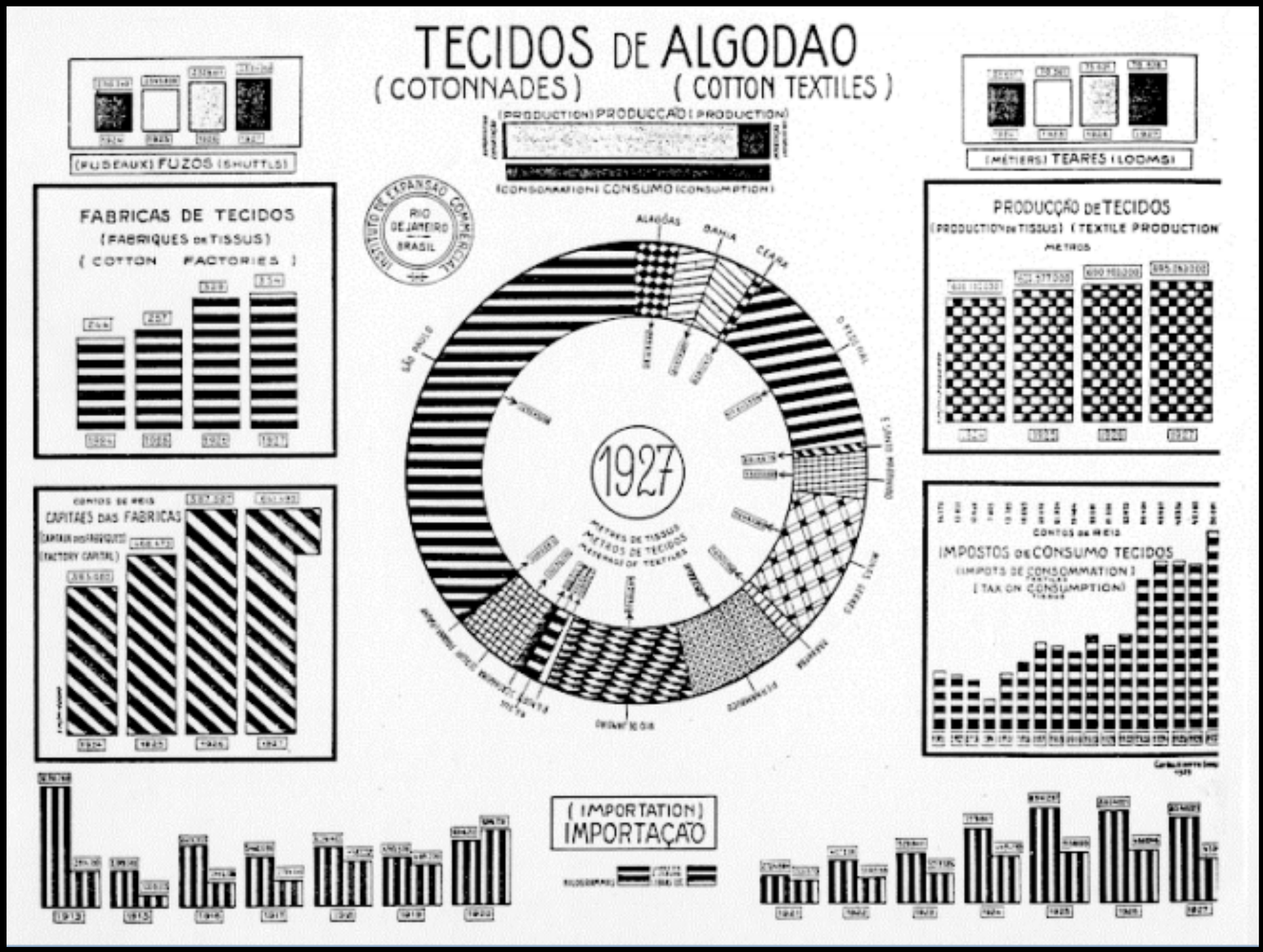
✗ **order**



✓ **length**

- ~5 in 2D; ? in 3D

TEXTURE



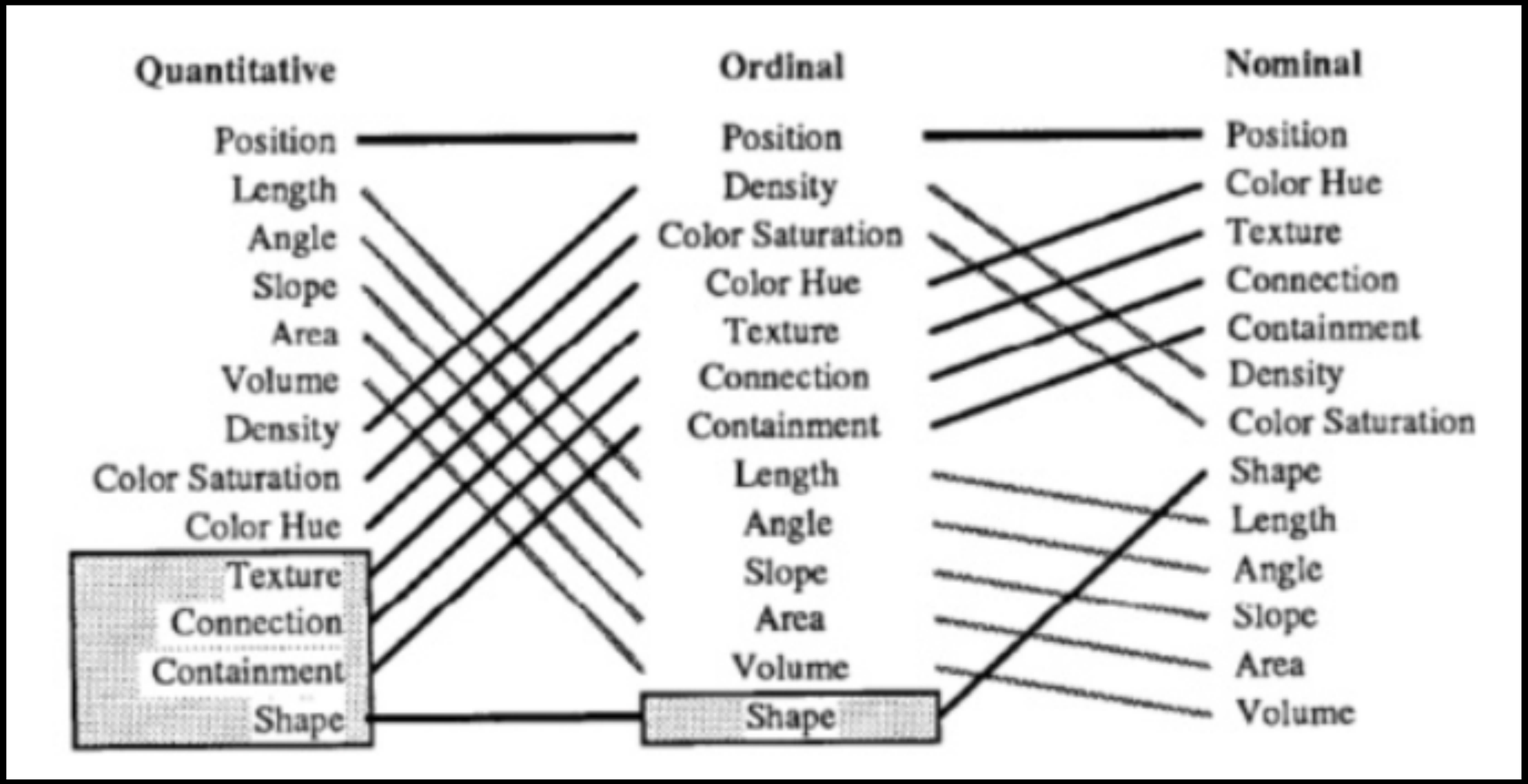
Cotton production in Brazil, 1927

LEVEL OF THE RETINAL VARIABLES

	ASSOCIATION	SELECTION	ORDER	QUANTITY
	≡	≠	O	Q
PLANAR DIMENSIONS	The marks can be perceived as SIMILAR	The marks are perceived as DIFFERENT, forming families	The marks are perceived as ORDERED	The marks are perceived as PROPORTIONAL to each other
SIZE	4 4 5			
VALUE	3 4 5			
TEXTURE	2 4 5			
COLOR	7 7 8			
ORIENTATION	4 2			
SHAPE				

Conventions leading to the
ELEMENTARY READING LEVEL

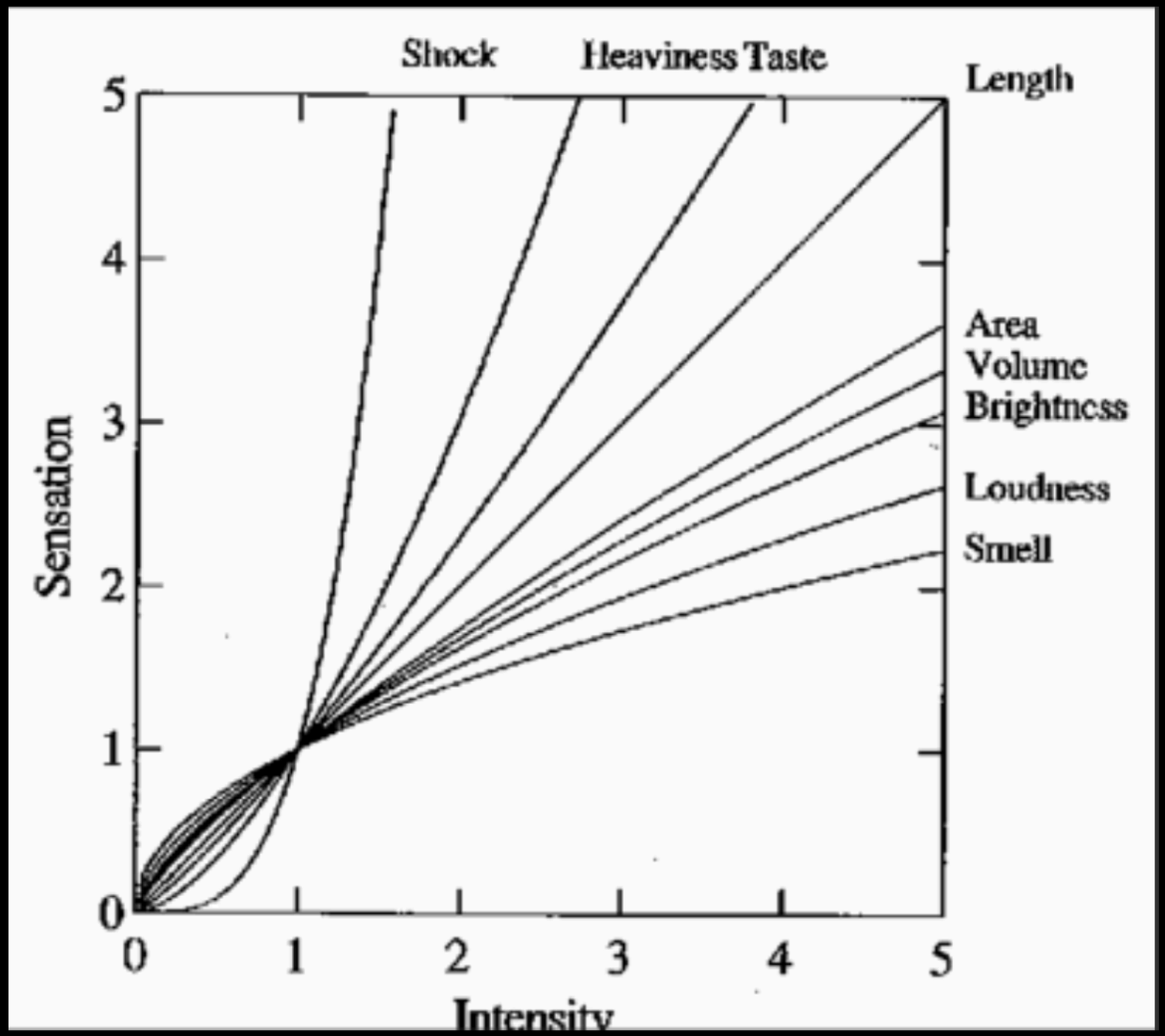
GUIDELINES FOR MAPPING



W. S. Cleveland and R. McGill. Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Journal of the American Statistical Association. 79(387). 1984

J. Mackinlay. Automating the Design of Graphical Presentations of Relational Information. ACM Trans. Graph. 5(2): 110–141, 1986.

PERCEPTION



The psychophysics of sensory function [Stevens 61]

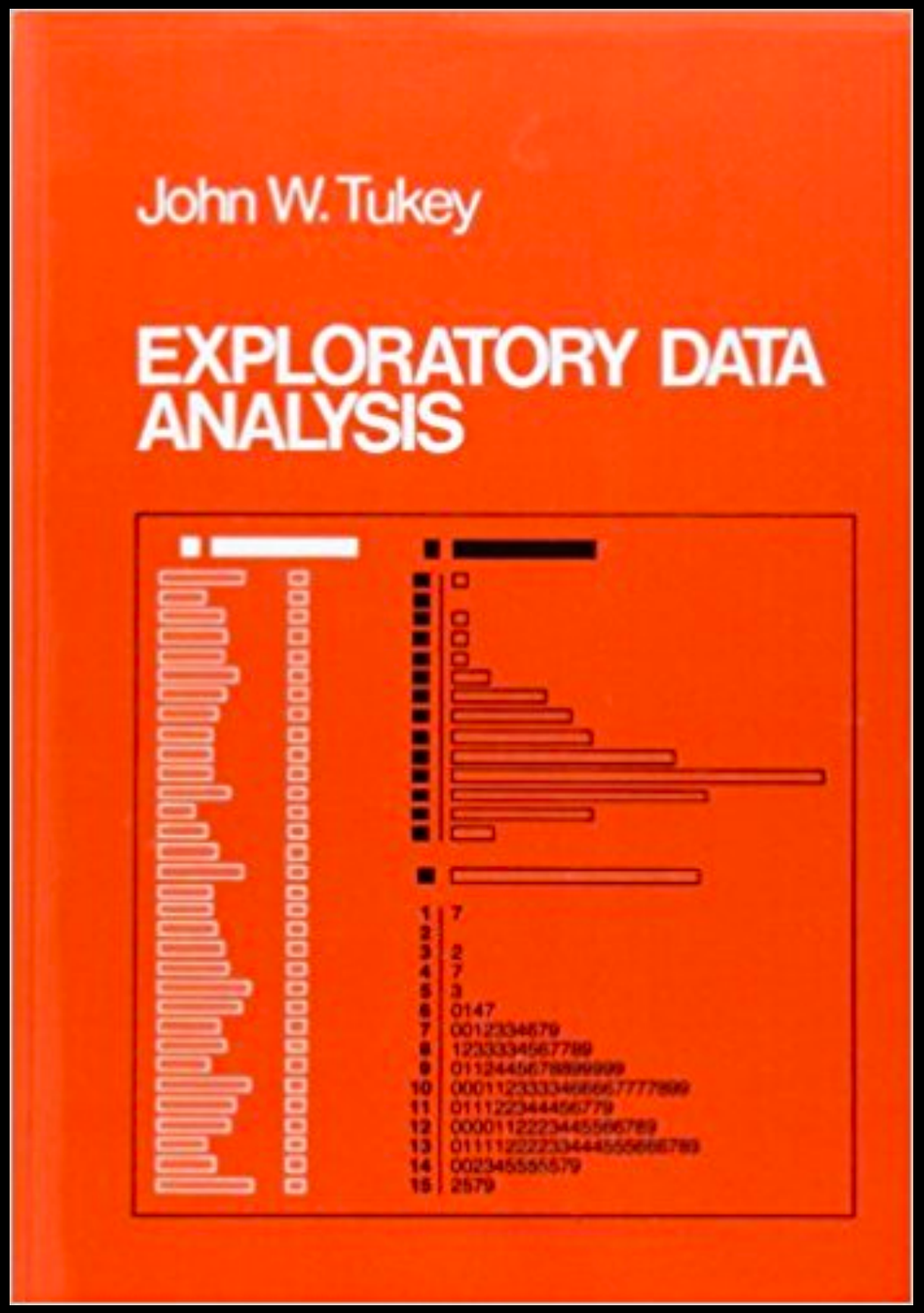
INFORMATION VISUALIZATION

Graphics should reveal the data

- show the data
- not get in the way of the message
- avoid distortion
- present many numbers in a small space
- make large data sets coherent
- encourage comparison between data
- supply both a broad overview and fine detail
- serve a clear purpose

E. Tufte
Visual Display of Quantitative Information

EXPLORATORY DATA ANALYSIS



- John Tukey coined the term "exploratory data analysis" (EDA)
- Scientists agree that serious time and effort should be devoted to exploring data to sanity-check its most basic properties, and to expose unexpected features.
- This type of "detective work" adds crucial insights to every data-driven endeavor.