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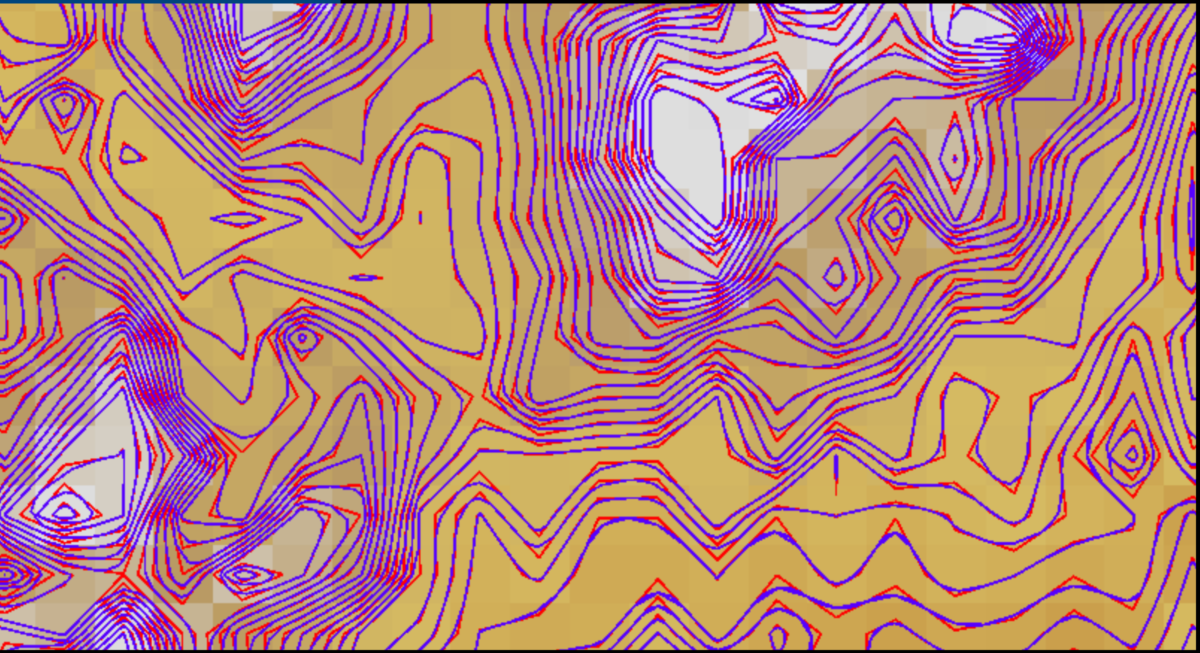


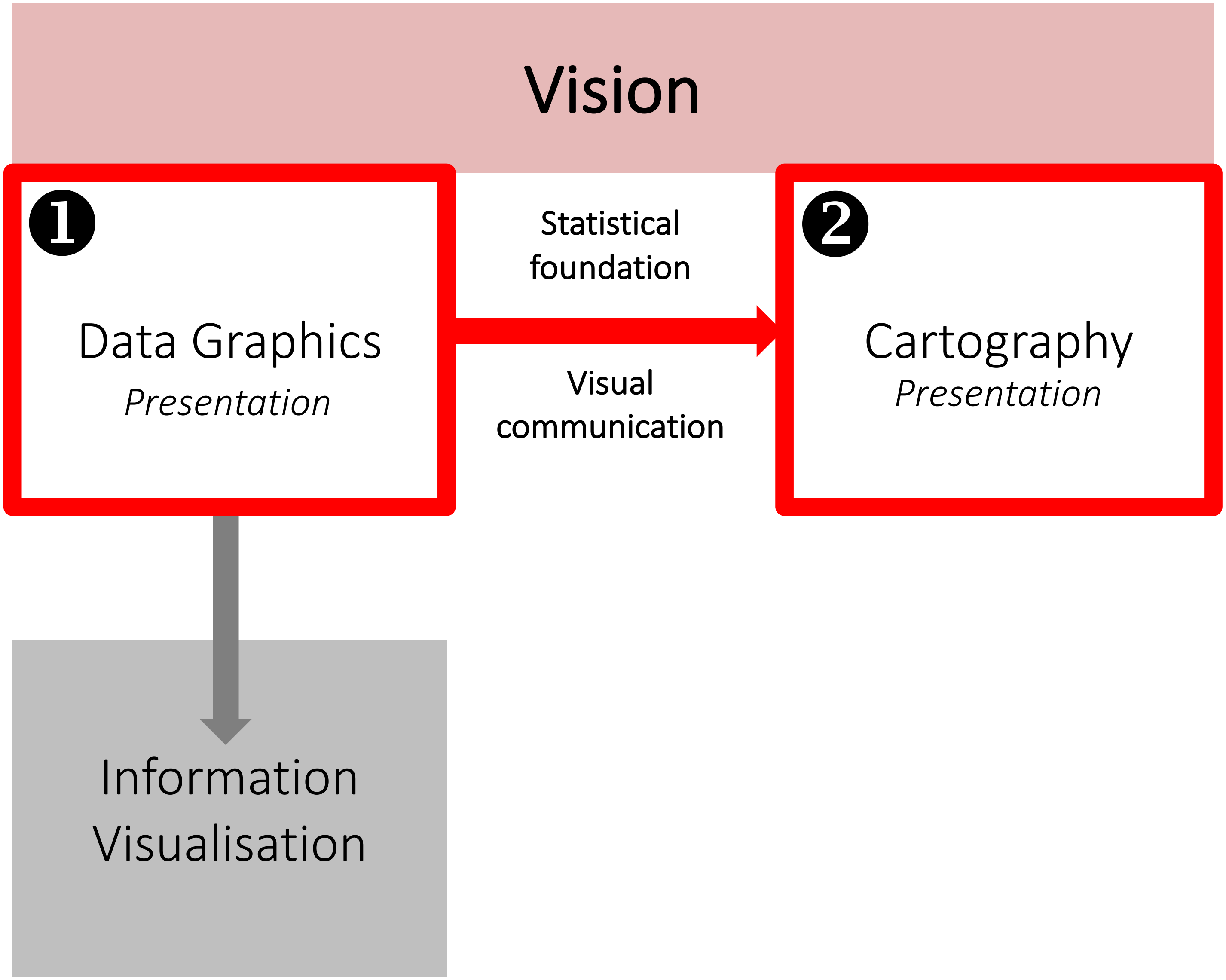
Image: GRASS Toolbox example, QGIS

GEOM90007

SPATIAL VISUALISATION

Week 6:

CARTOGRAPHY 1


Vision
❶
Data Graphics
Presentation
Statistical
foundation
Visual
communication
❷
Cartography
Presentation
Information
Visualisation

REVISION: SENSING

Stimuli provide data about the physical world

Sensors

- Human biological
- Electronic

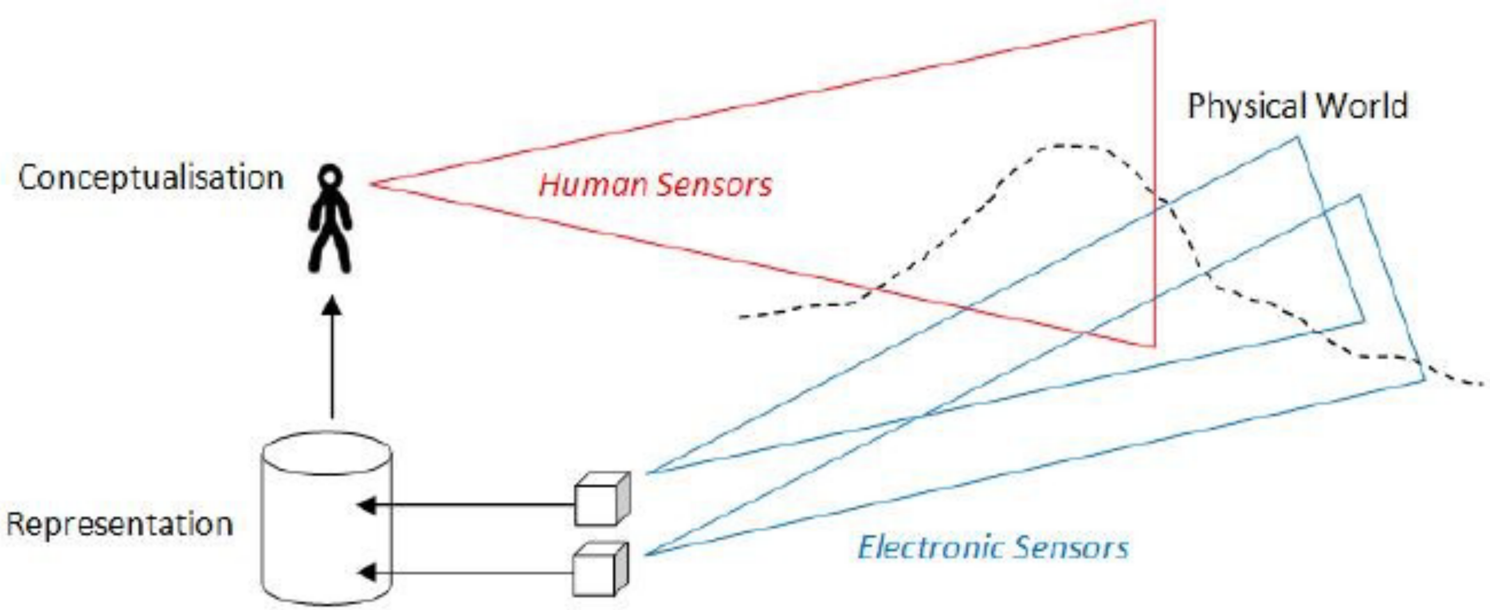
Signal transmission

- Direct
- Indirect

PERCEPTION

Sensed data is translated into an internal conceptualisation to construct a **mental image**

This may not be the same for all persons! ∞*
e.g. physiological differences such as colour deficiency



CARTOGRAPHY

A very long history

A cartographic map is a **representation**
- Visual language (marks and visual variables)
- Abstract, symbolic representation of the real world*

Cartography is a special case of data graphics

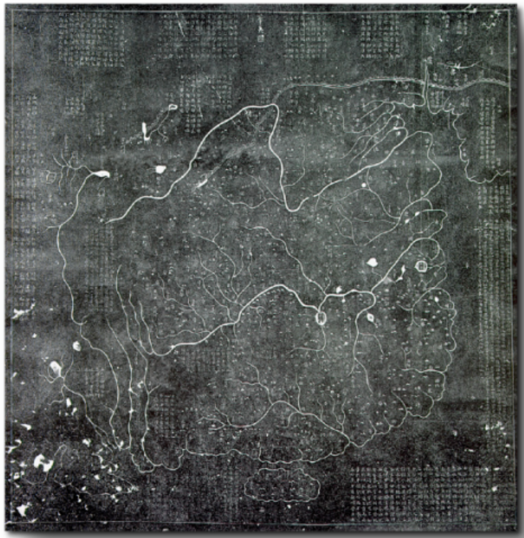


Image: Yu Ji Tu (c. 1137),

Library of Congress, Geography and Map Division

CARTOGRAPHIC PROCESS

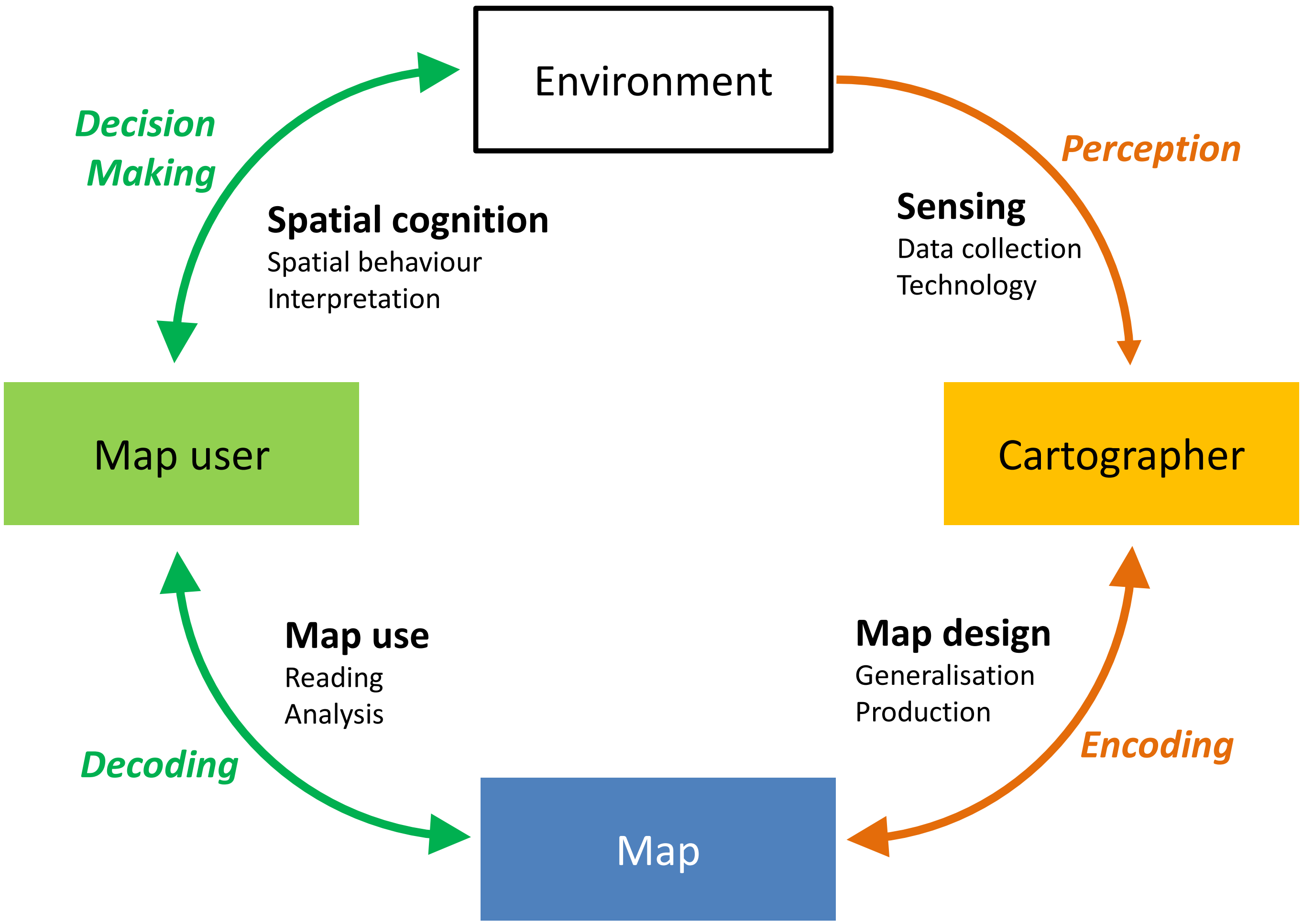


Image: Original, Muehrcke and Muehrecke (1992), redrawn from PSU Geography 160

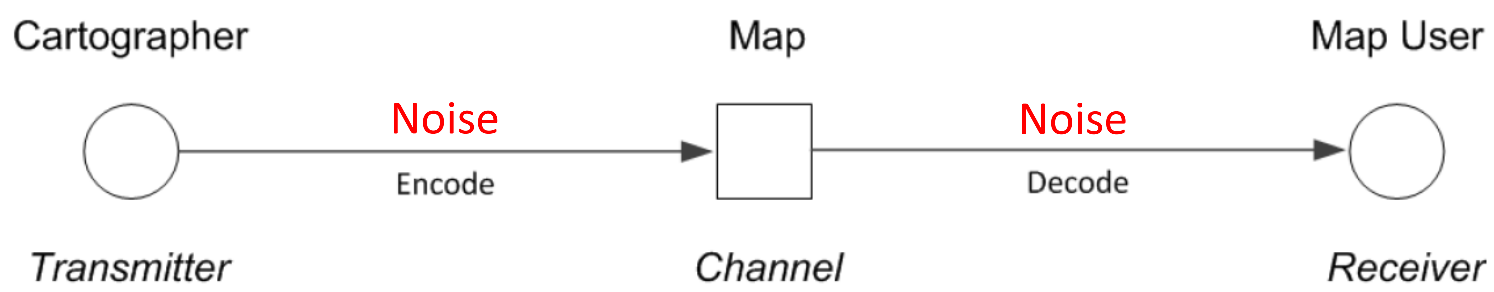
COMMUNICATION MODEL

Mathematical theory of communication (Shannon, 1948)

- Model describes transmission of a signal through a channel

Adopted by Keates (1996) for cartography

- Sensed data is captured, processed and perceived
- Signals communicated through noisy channels
- The concept of "transmitted information" is contentious!



GENERALISATION

It is possible to create a 3D map of the entire world in an area measuring 22 x 11μm!
(1000 maps could fit on a single grain of salt)
http://nationalgeographic.org/photo/worlds-smallest-map/

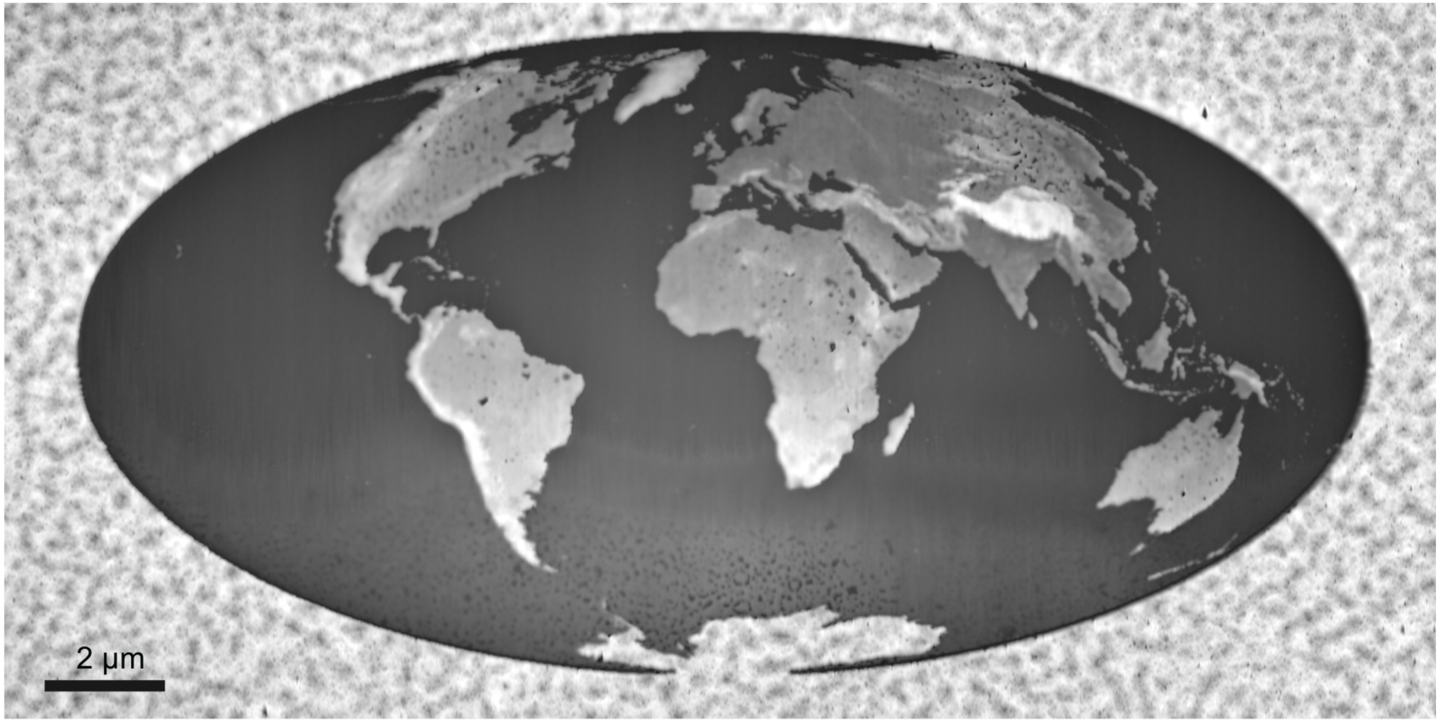


Image: IBM Research Zurich

What information do you include or leave out?

GENERALISATION PROCESS

Maps are useful because they **suppress irrelevant data** (ruler metaphor)

Recall memory issues from Lecture 3

- Pre-attentive processing
- Short term memory
- Long term memory

Two key dimensions (Mustière et a., 1999)

1. **Abstraction**
2. **Representation**

1. ABSTRACTION – Spatial and attribute transformation

To go from a detailed… to a more abstract description
(Mustière et al., 1999)

Reasons: Scale change, map purpose, map user, technical constraints

i. *Data selection*
Where? When? What? Why? (Muehrcke, 1992)

ii. Generalisation and Classification
Two processes with which to reduce details on maps

a) Generalisation operators (McMaster and Shea, 1989)

Simplification:

Retaining the least number of data points necessary to represent a phenomenon

Exaggeration:

Deliberately amplify a portion of a feature to increase it's overall visibility

… many more

b) Classification operators

How to decide the best classification method

More information: http://mapcontext.com/autocarto/proceedings/auto-carto-9/pdf/pages76-109.pdf

SPATIAL VISUALISATION

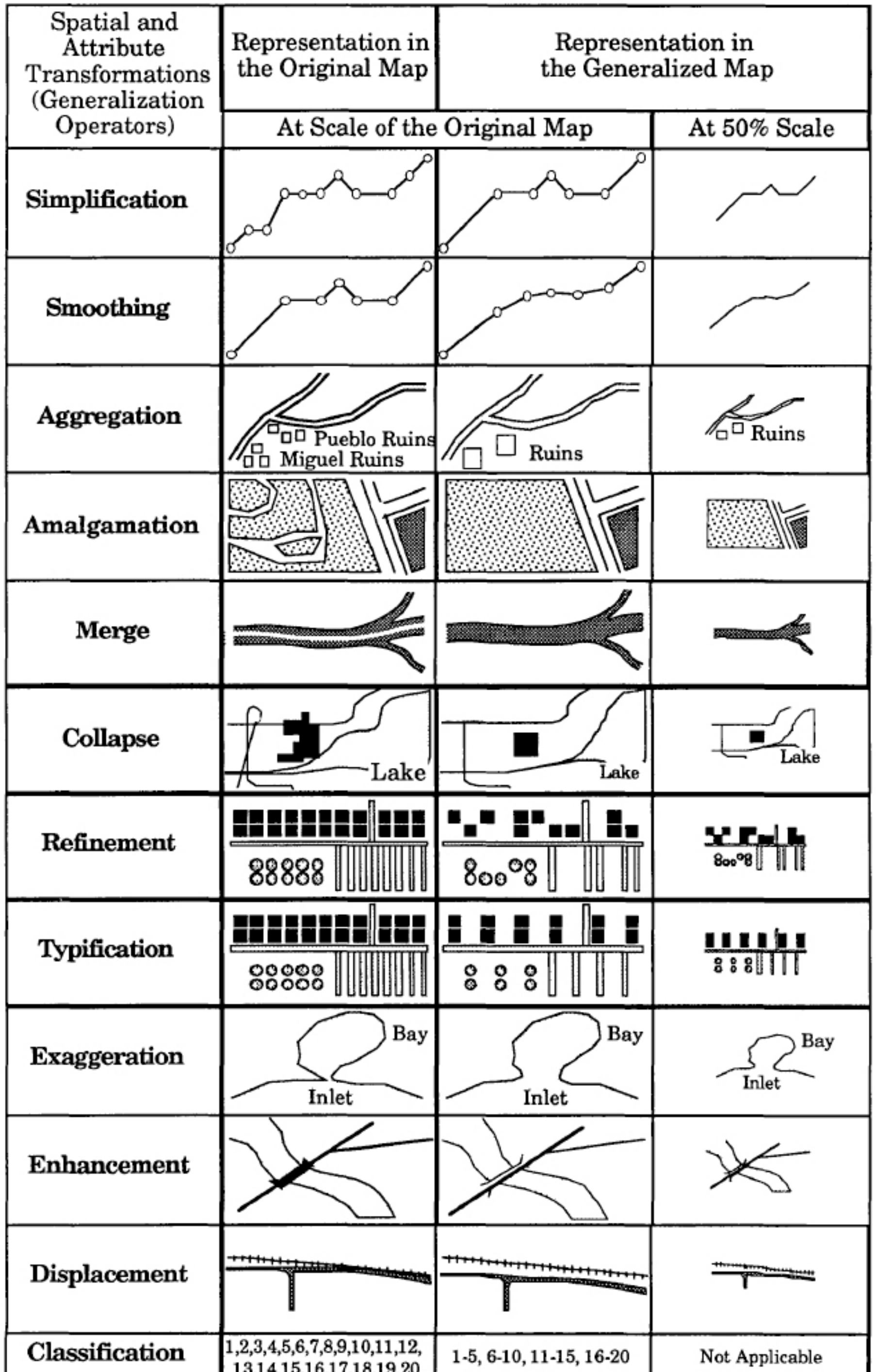


Image: McMaster and Shea (1989) Descriptions: Slocum et al. (2009)

- Reducing angles between line segments
- Grouping points and representing using areal features
- Grouping areal features and representing using areal features
- Grouping line features
- Selecting portions of an object to represent the whole
- Separating objects

BASIC CARTOGRAPHIC TERMINOLOGY

Ratio of map units to Earth units

- **Large** scale (1:25,000)
- **Small** scale (1:250,000)

Differentiating between phenomena and data in visualisation

- **Phenomena** are physical objects or processes
- **Data** is simply that, the results of measuring phenomena

Data resolution

- The granularity of the data captured
  - Low resolution = **coarse grain**
    - Suburbs
  - High resolution = **fine grain**
    - Parcels/lots

2. REPRESENTATION

Geometric primitives

1. Point
2. Line
3. Area
4. Surface
5. Volume

Focused data

Data variable

Map →

Graphic representation

Visual variables

1. Position
2. Shape
3. Size
4. Brightness
5. Colour
6. Orientation
7. Pattern
8. Motion

2. REPRESENTATION – SPATIAL DIMENSION

1. Point
   - Zero-dimensional (no spatial extent)
   - 2D (x,y) or 3D (x,y,z) space
2. Line
   - One-dimensional (length only, no width)
   - Series of points (e.g. linestring*)
3. Area
   - Two-dimensional (length and width)
   - Series of points that enclose a region (e.g., closed linestring*)

*Spatial databases, e.g., http://revenant.ca/www/postgis/workshop/geometries.html

2. REPRESENTATION – SPATIAL DIMENSION

4. Surface
   - 2.5 dimensional
   - Areal object (x,y) projected by a certain value (z)

5. Volume
   - Three-dimensional
   - Areal object with points of unique value (x,y,z)

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VISUAL VARIABLES IN CARTOGRAPHY

Some different labels, but remain similar to the **8 standard variables of Data Graphics** (Lecture 4)

New labels have evolved with technology

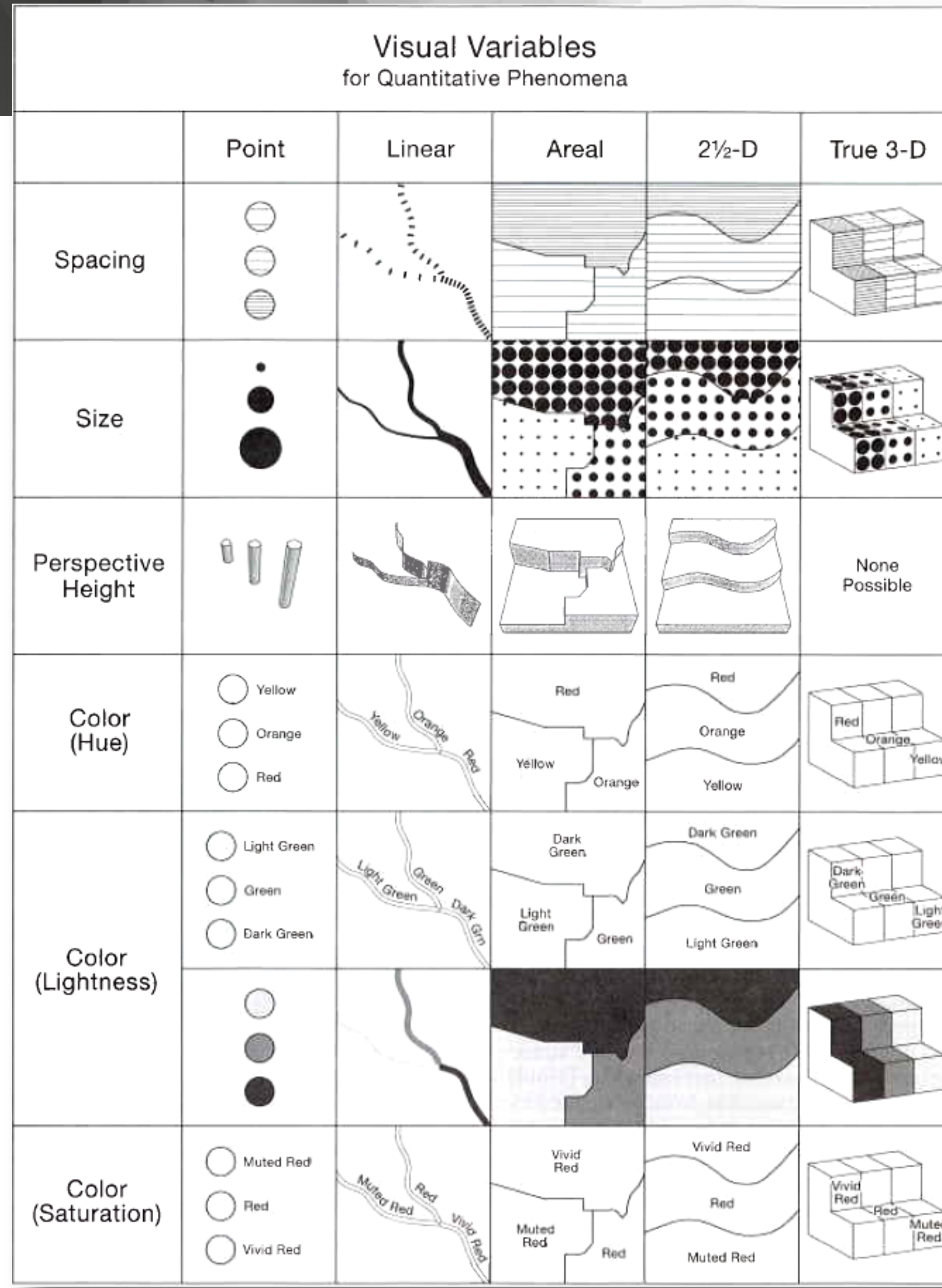


Image: slocum et al. (2009), page 82

VISUAL VARIABLES IN CARTOGRAPHY

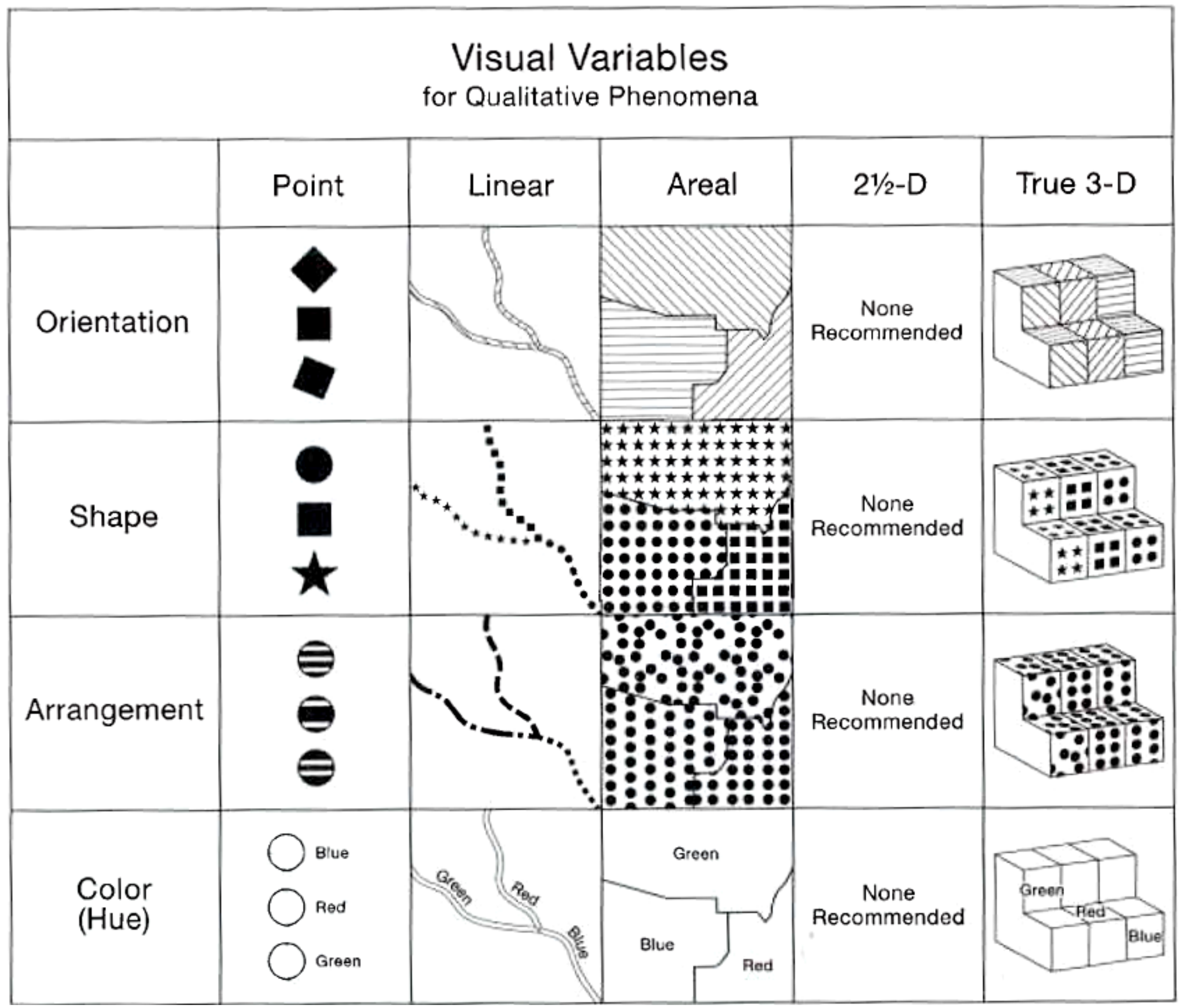


Image: Slocum et al. (2009), page 83

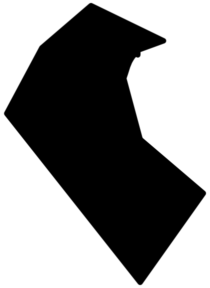
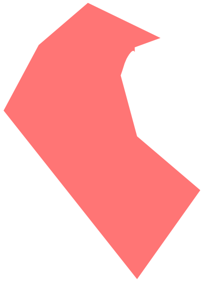
TERMINOLOGY

Visualising spatial objects

Geometry type X + Graphic Element E = Visualisation Y

$E = \{v_1, v_2, v_3 \ldots\}$, where each v_i is the visual variable mapped to your dataset

Zero-dimensional point  + graphic element (lightness) = 

Two-dimensional polygon  + graphic element (saturation) = 

LEVELS OF MEASUREMENT

When a phenomenon is observed and measured to create a dataset, geographers consider four **levels of measurement**

1. Nominal
   - Categorisation only (no ordering or ranking)
     - Example: different states, or land use categories

QUALITATIVE

2. Ordinal
   - Categorisation + ordering (or ranking)
     - Example: low-medium-high density
     - Example: least-most likes

QUANTITATIVE

LEVELS OF MEASUREMENT

3. **Interval**
   - Ordering (or ranking) + numerical differences between two categories
     - Arbitrary zero point
     - Ratio of two scales is meaningless
       - Example: Celsius vs Fahrenheit temperature scales

QUANTITATIVE

4. **Ratio**
   - Characteristics of interval + non-arbitrary zero point
     - More common than interval datasets

QUANTITATIVE

THREE MAIN TYPES OF MAP

- Topographic
- Thematic
- Schematic

1. Topographic

A representation of the major physical (natural and man-made) features within a spatial extent

Key features:

- Human settlements
- Contour lines
- ...

More information: http://www.icsm.gov.au/mapping/maps_topographic.html

Various mark types:

- Point
- Line
- Area

What else?

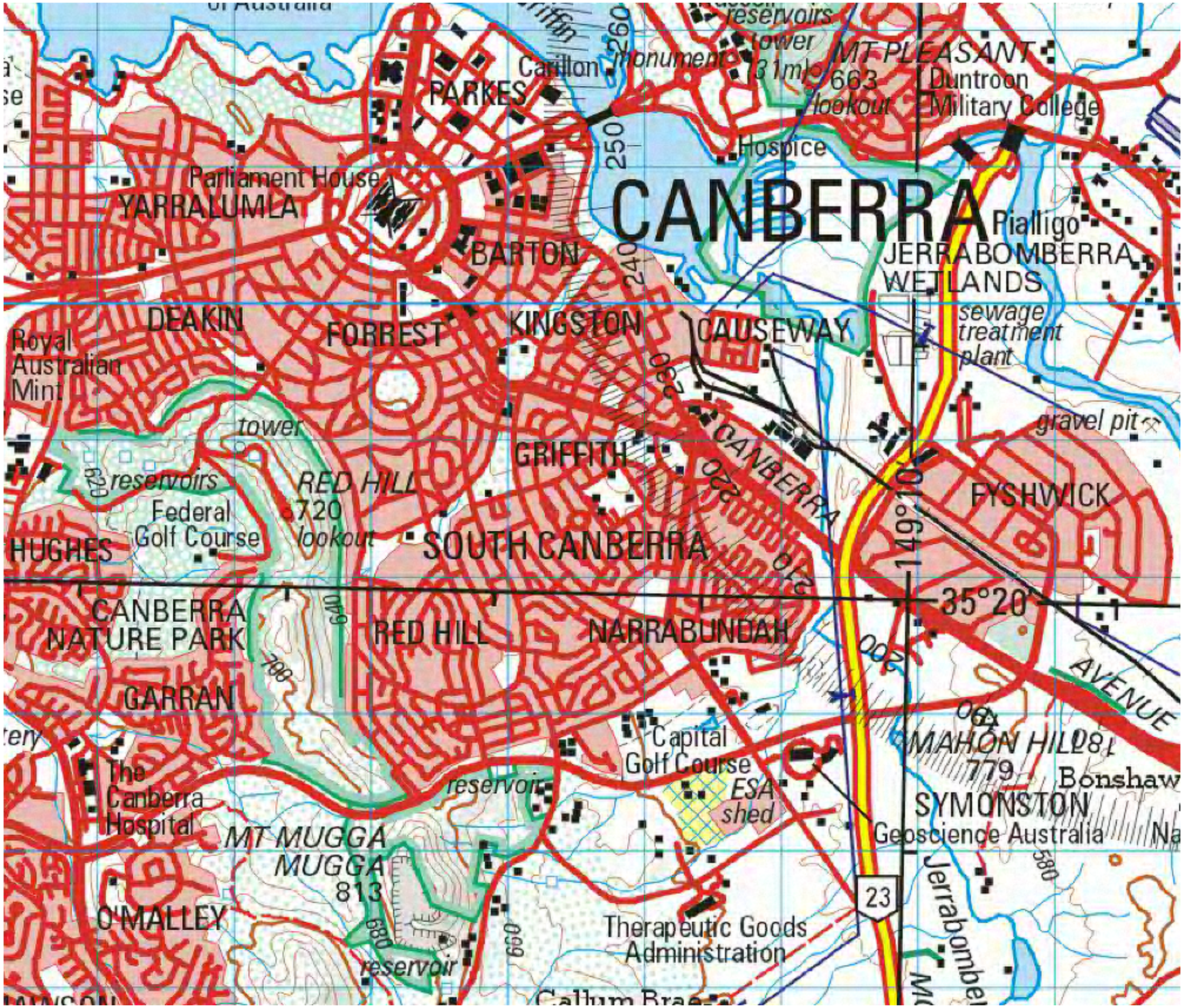


Image: Geoscience Australia (2016) http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_64002

2. Thematic Map

- ‘Statistical maps’ that emphasize the spatial pattern of one or more attributes (or variables)
  - e.g.: population density or income

- Various examples:
  - Choropleth map
  - Proportional symbol maps
  - Dot map
  - Flow map
  - Isarithmic (or contour) map

SPA ATION

Choropleth

Image: AURIN (2016)

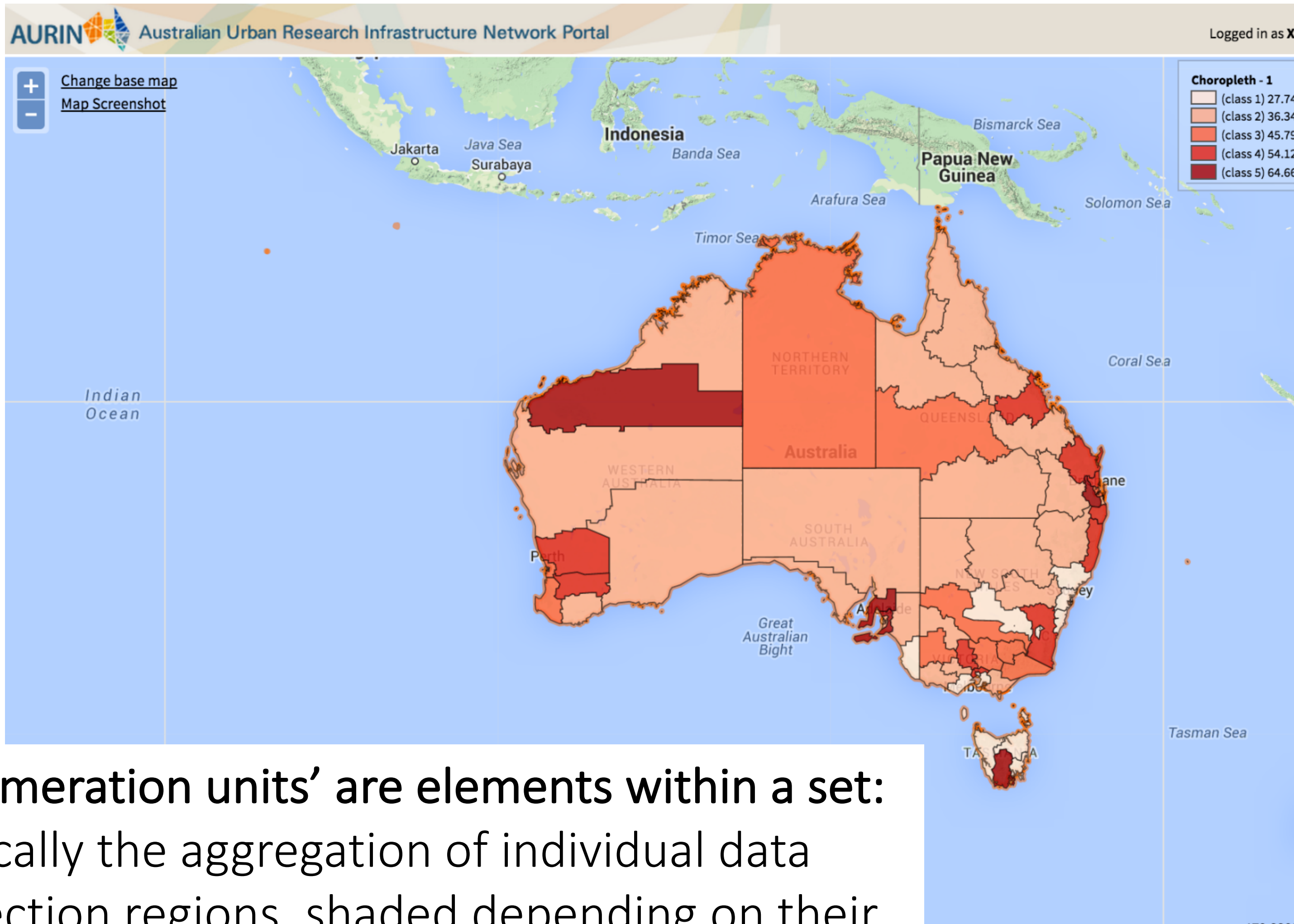


Image: ASGS Main Structure, Australian Bureau of Statistics, (2016)

'Enumeration units' are elements within a set:
Typically the aggregation of individual data collection regions, shaded depending on their magnitude

Proportional symbols

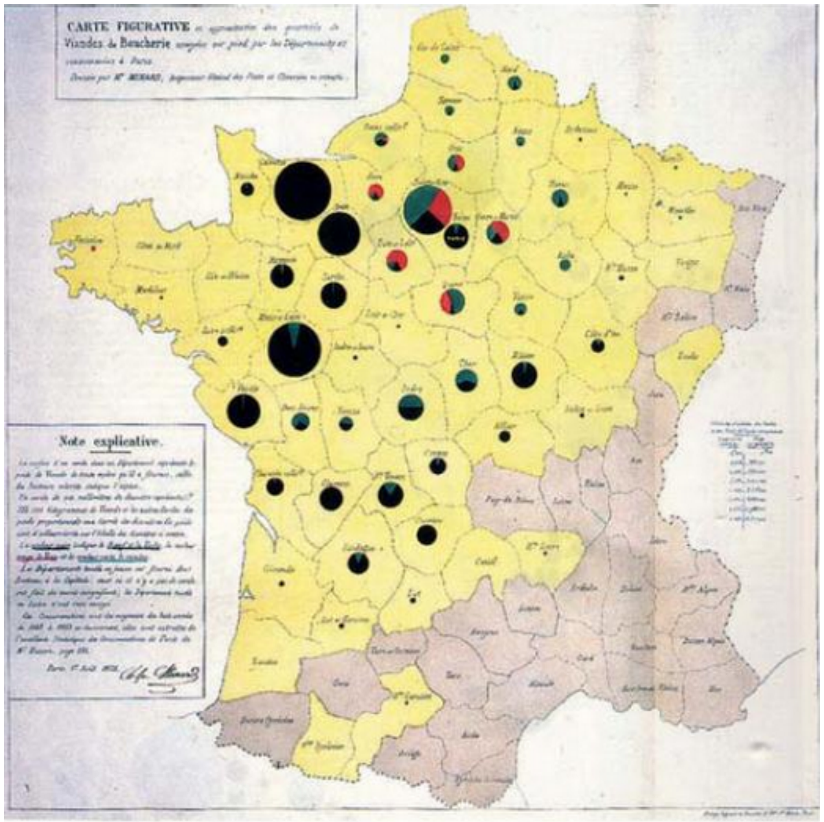


Image: Minard (1958)

Image: Slocum et al. (2009)

Classic map:
Proportion of meat type sent to butchers

Pictographic symbols:
Difficult to estimate area and overlapping areas are difficult to read

Dot map

Mapping

1:1 (e.g. deaths)
or
1:Many (e.g. wheat yield)

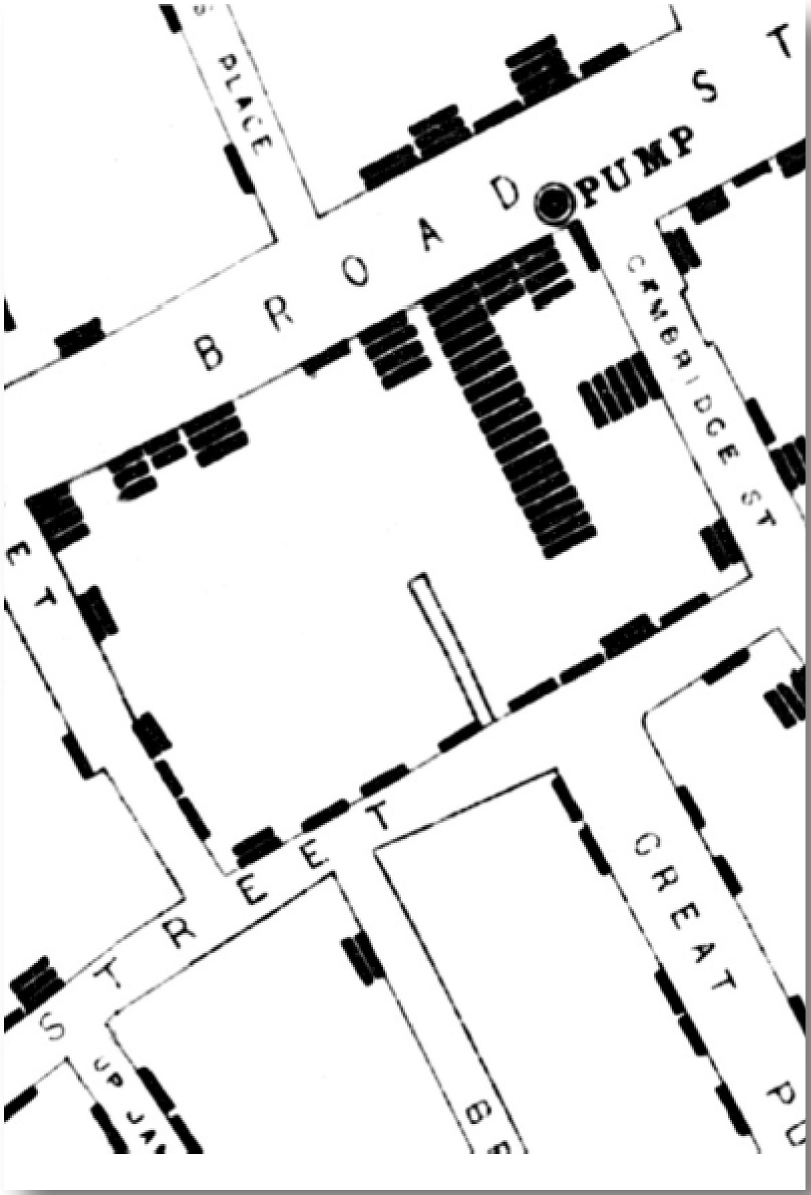


Image: Snow (1854)

Isarithmic (contour)

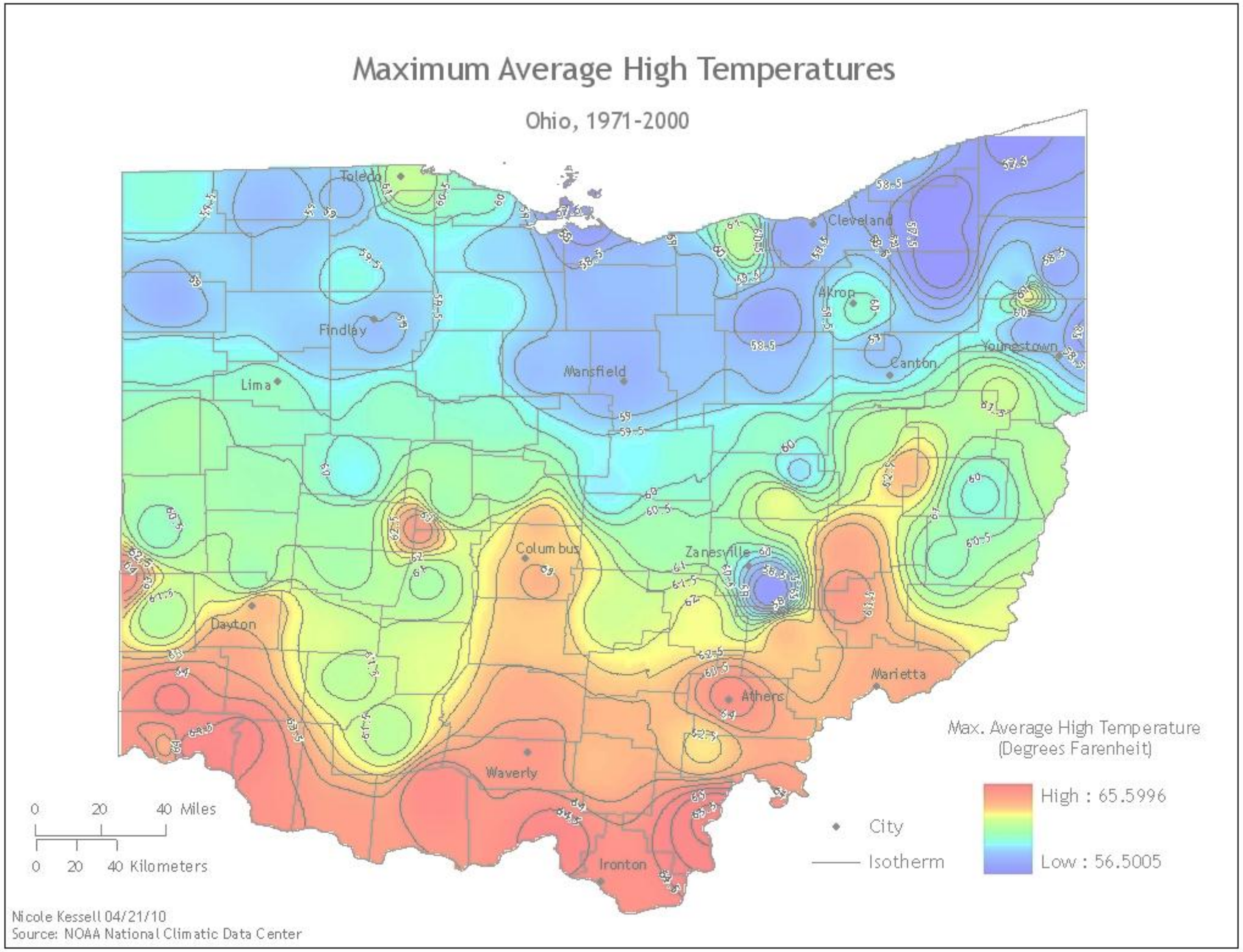
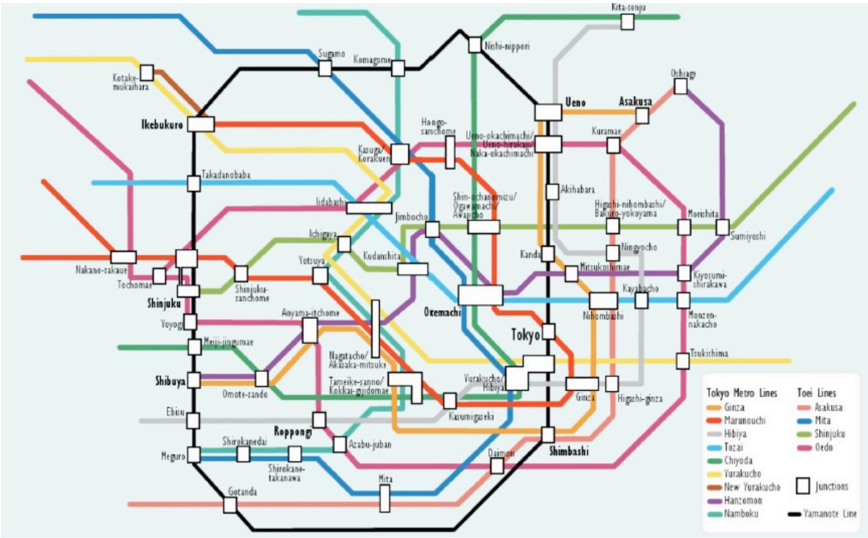


Image: wiki.gis.com

3. Schematic

An abstract representation of a system’s elements

e.g., “The geometry is deliberately distorted to improve readability and facilitate way finding in the network” (Jenny, 2006)



Tokyo Underground

Image: Wikimedia commons

THEMATIC MAPPING TO CREATE A CHOROPLETH MAP

GETTING STARTED

Choropleth is ideal for communicating phenomena uniformly distributed within the enumeration unit

- e.g., population density or wheat yield in a state (ACT, VIC, WA…)

Visualisation pipeline:

1. Data modelling
2. Data selection

DATA MODELLING AND SELECTION

Ensure that the raw data is adjusted for the scale of the enumeration unit(s) using **standardisation** for comparison

*Can I add each state's wheat yield (y) over ten years and display their ratios on the same map?

$$\frac{\sum(y_1, y_2, \ldots, y_{10})}{10\ years} + \frac{\sum(y_1, y_2, \ldots, y_{10})}{10\ years} + \ldots$$

Choice of standardisation method impacts the map of the phenomena!

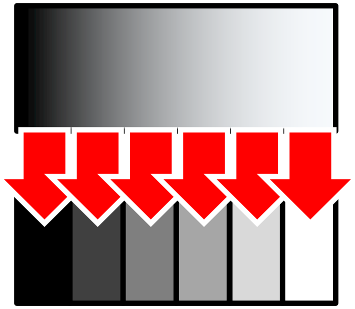
CLASSIFICATION

Data classification is the process of combining raw data into classes (groups) and representing each with a **unique symbol**

To classify or not to classify?

Unclassed: More accurately represent the data

Classed: Groupings provide easier reading (visual processing)



Classification tips from Brewer

Fewer classes = oversimplified (increased generalisation)
More classes = more “information rich” (decreased generalisation)

However too many classes may overwhelm the map user and may hide patterns

In addition “more classes require more colours that become increasingly difficult to tell apart” (Brewer, 2002)

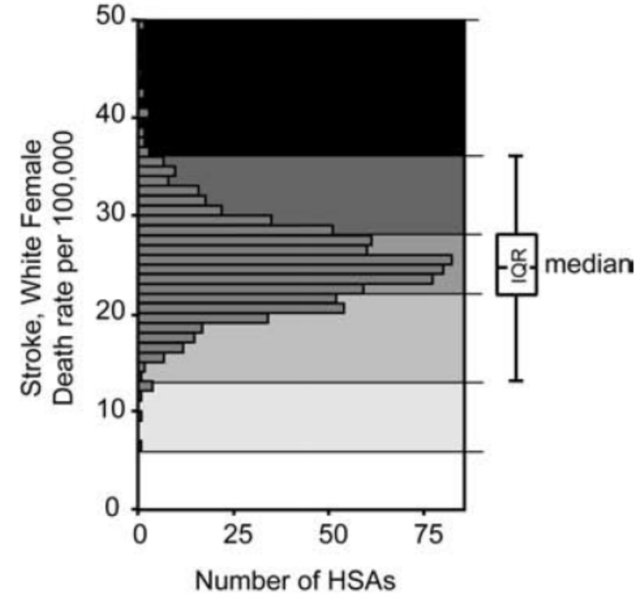


Image: Brewer and Pickle (2002)

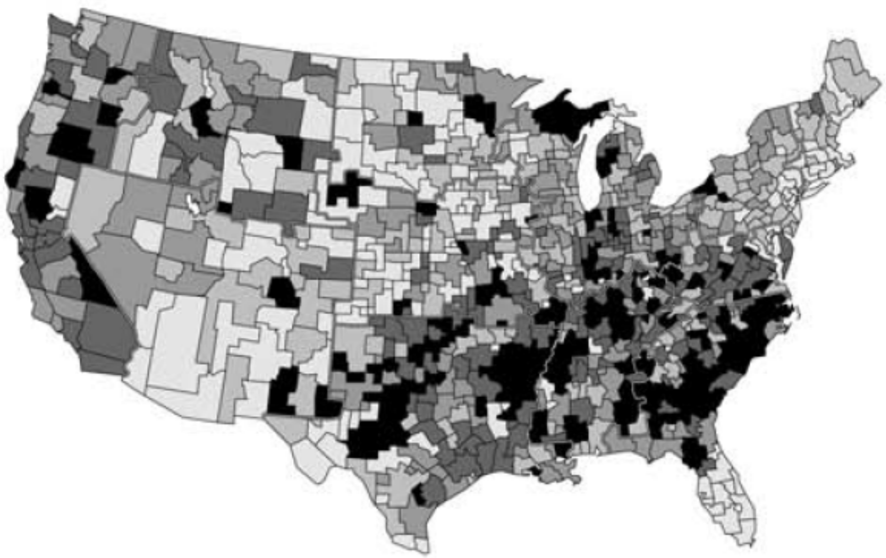
So how many do researchers think?*
Static: 7 ± 2 Dynamic: 5 ± 2 (Al-Ghamdi, 2014)

CLASSIFICATION

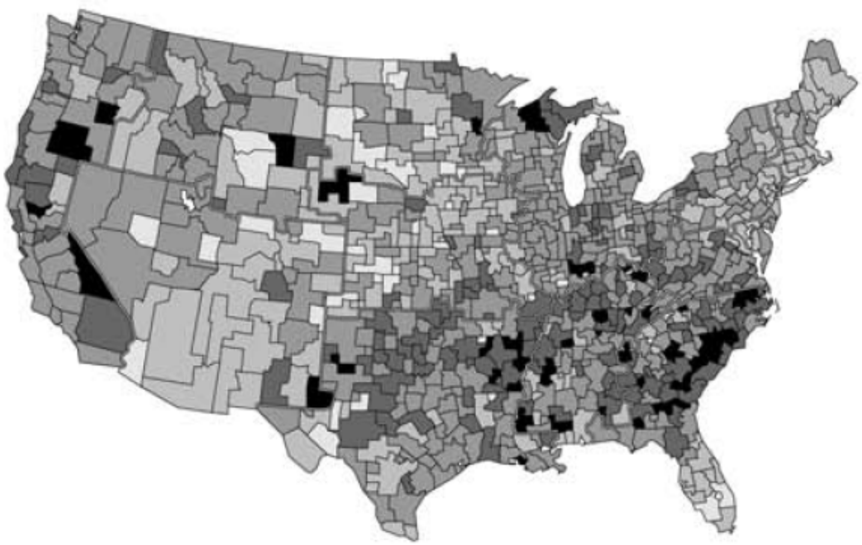
Various classification techniques

1. ***Equal interval*** *(or equal steps)*
2. ***Quantiles*** *(e.g., 20%)*
3. ***Standard deviation***
4. ***Maximum breaks, natural breaks***
5. ***Optimal*** *(e.g., Jenks-Capsall)*

THEMATIC MAP – Classification techniques



2. Quantiles
Classes formed from the total number of observations



3. Standard deviation
Assumes normal distribution. Classes formed around the standard deviation from the mean (+1, +2)

Image: Brewer and Pickle (2002)

THEMATIC MAP – Classification techniques (towards clustering)

4a. Maximum breaks:
Data ordered low or high, differences computed between observations, largest form the class breaks

4b. Natural breaks (manual):
Minimise standard deviation between values in the same class, while maximise differences between classes

5. Optimal (automated):
Similar data values are placed in a class by minimising an objective function.

Jenks-Caspall algorithm
Fisher-Jenks algorithm

Advantage:

- Best consideration of dataset distribution
- Help determine number of classes

Disadvantage:

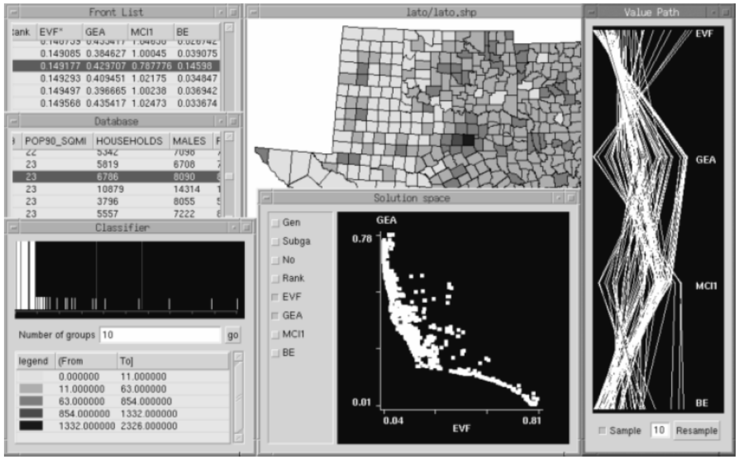
- Difficulty understanding the concept
- Communicating gaps in the legend

	1	2	3	4a	4b	5
	Equal interval	Quantile	Mean SD	Max. breaks	Natural Breaks	Optimal
Considers distribution along a number line	Poor	Poor	Moderate	Moderate	Good	Good
Ease of cartographer understanding	Good	Good	Good	Good	Moderate	Moderate
Ease of computation	Good	Good	Good	Good	Good	Good
Ease of understanding the legend	Good	Poor	Moderate	Poor	Poor	Poor
Legend values match range of data in classes	Poor	Good	Poor	Good	Good	Good
Use with ordinal Data	-	OK	-	-	-	-
Assists selecting number of classes	Poor	Poor	Poor	Poor	Moderate	**Good**

Redrawn from Slocum et al. (2009), page 68

THEMATIC MAP – Advanced classification techniques

Image: Armstrong et al. (2003)



Multi-criteria to determine classes

- Genetic algorithm

  e.g. Armstrong et al. (2003)

Other spatial statistic approaches:

- Sum of Squares Clustering Model (SSCM)
- Spatial Lag Cluster Model (SLCM)

  e.g., Murray and Grubesic (2013)

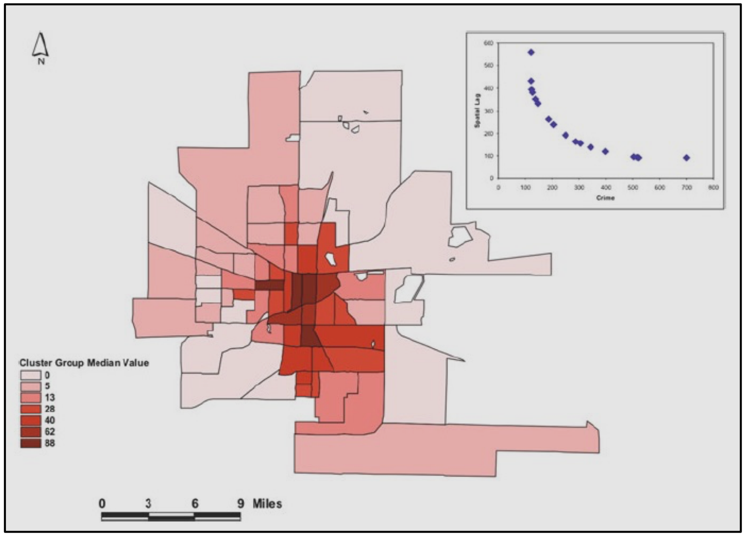
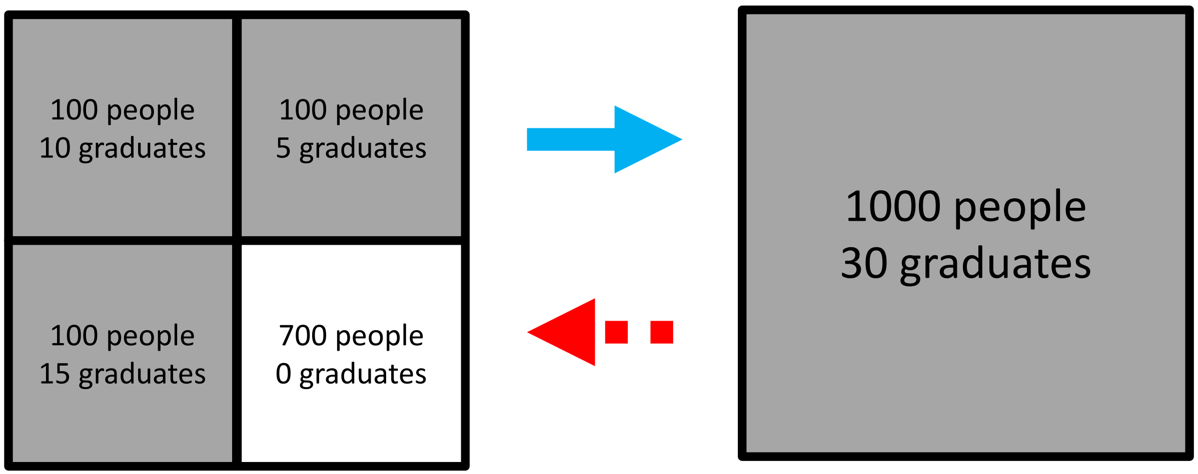


Image: Murray and Grubesic (2013)

ALWAYS REMEMBER THE SCALE (AGGREGATION) PROBLEM

Average of the four regions: 7.5%



Average of region: 3%

- Scaling up: data may be lost
- Scaling down: **ecological fallacy** (Anselin et al., 2000)

↘ Can not assign the properties of an aggregate region to its sub-units!

…AND THE MODIFIABLE AREAL UNIT PROBLEM (MAUP)

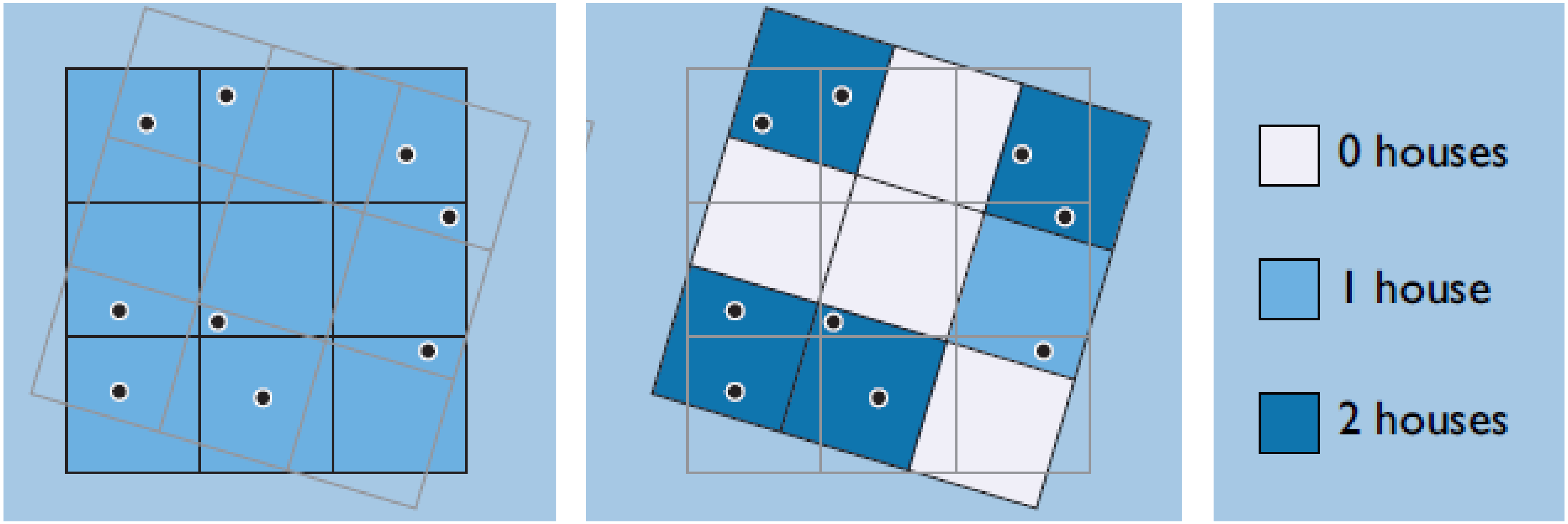


Image: Duckham (In press)

“the results of any analysis upon spatial data that has been aggregated using arbitrary (i.e., "modifiable") regions... is not guaranteed to be valid independent of those regions”

Worboys and Duckham (in press)

THEMATIC MAP – Selecting visual variables

Select a visual variable that appears to ‘conceptually match’ the level of measurement of the data

(Slocum et al., 2009)

Remember your **value message**! Can the map user decode your visualisation?

Example: A square with 2cm sides indicates 4 times as much stuff” as a square with 1cm sides

(Worboys and Duckham, 2004)

VISUALISING UNCERTAINTY

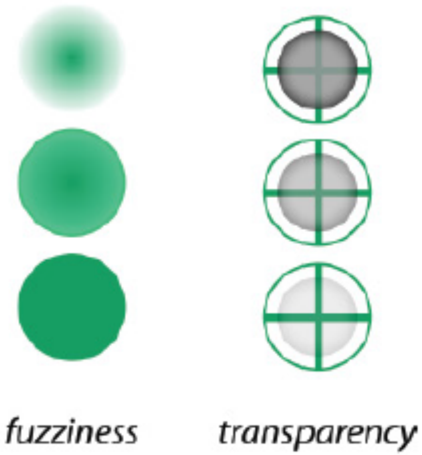
Two approaches

Intrinsic visual variables
Standard 8 visual variables from data graphics, e.g., size

Extrinsic visual variables
Additional objects added to the graphic, e.g., dials, arrows, grids

VISUALISING UNCERTAINTY

Image: MacEachren et al. (2012)



Intrinsic example

New visual variables (MacEachren et al., 2012)

- Fuzziness
- Transparency

Extrinsic example

Noise annotation lines (Kinkeldey, 2013)

- Vary from solid to diffuse
- Do not occlude underlying data

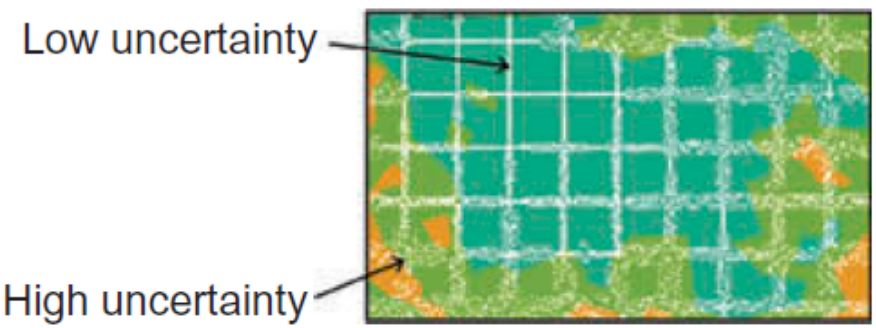


Image: Kinkeldey (2014)

CARTOGRAPHIC DESIGN PROCESS

Recall the 4 data graphic principles:

Data density, integrity, correspondence and aesthetics

DESIGN PROCESS

1. Determine how the map will be produced
   e.g. What medium (paper or digital)?

2. Select appropriate scale and map projection
   e.g. generalisation

3. Determine appropriate data classification and symbolisation

DESIGN PROCESS

4. Determine map elements

- Border
- Mapped area
- Inset (if applicable)
- Title and subtitle
- Legend
- Data source
- Scale
- Orientation

DESIGN PROCESS

5. Intellectual hierarchy

- "Scale of concepts" (Monmonier, 1993)
  - Ranking important symbols and map elements.

    e.g.

    1. Thematic symbols and labels
    2. Title, subtitle and legend
    3. Scale and north arrow
    4. Data source and notes
    5. Border and lines

6. Sketch the map

7. Construct the map

DESIGN PROCESS

Visual hierarchy

- Graphical representation of the intellectual hierarchy
  - Symbols are *emphasised*
  - Base information is *deemphasised*

- Degrees of salience
  - Eye needs to be drawn to the most important features first, less important later, with ease of correspondence and without confusion

DESIGN PRINCIPLES IN CARTOGRAPHY

Contrast (cartography definition)

- The visual differences between map features that allows the map user to understand your message

Balance

- Organisation of map elements and empty space for visual harmony (equilibrium)
  - Mapped area as large as possible and *looks* centred*

Basic Gestalt principles

- Grouping of graphic elements creating patterns
  - Marks on the map

1. Figure-ground

- Accentuating certain objects over others

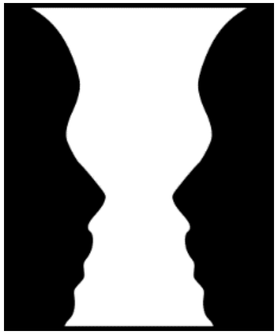
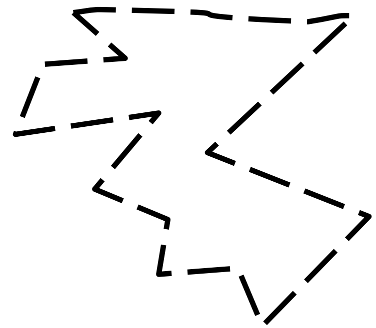


Image: Wikimedia Commons

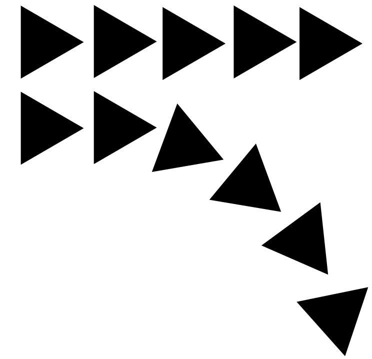
SOME GESTALT PRINCIPLES

2. Similarity

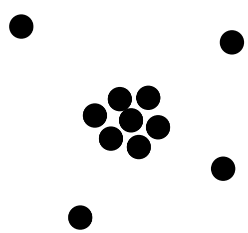
3. Closure



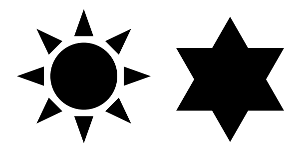
4. Common fate



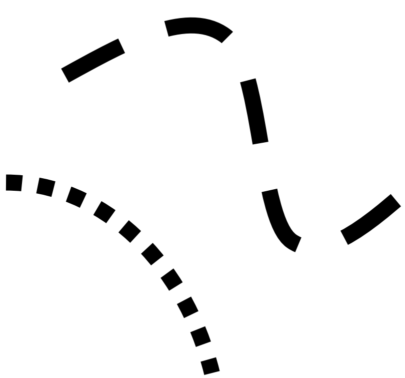
6. Proximity



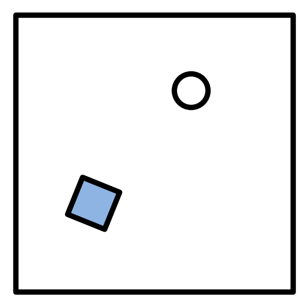
7. Symmetry



5. Continuity

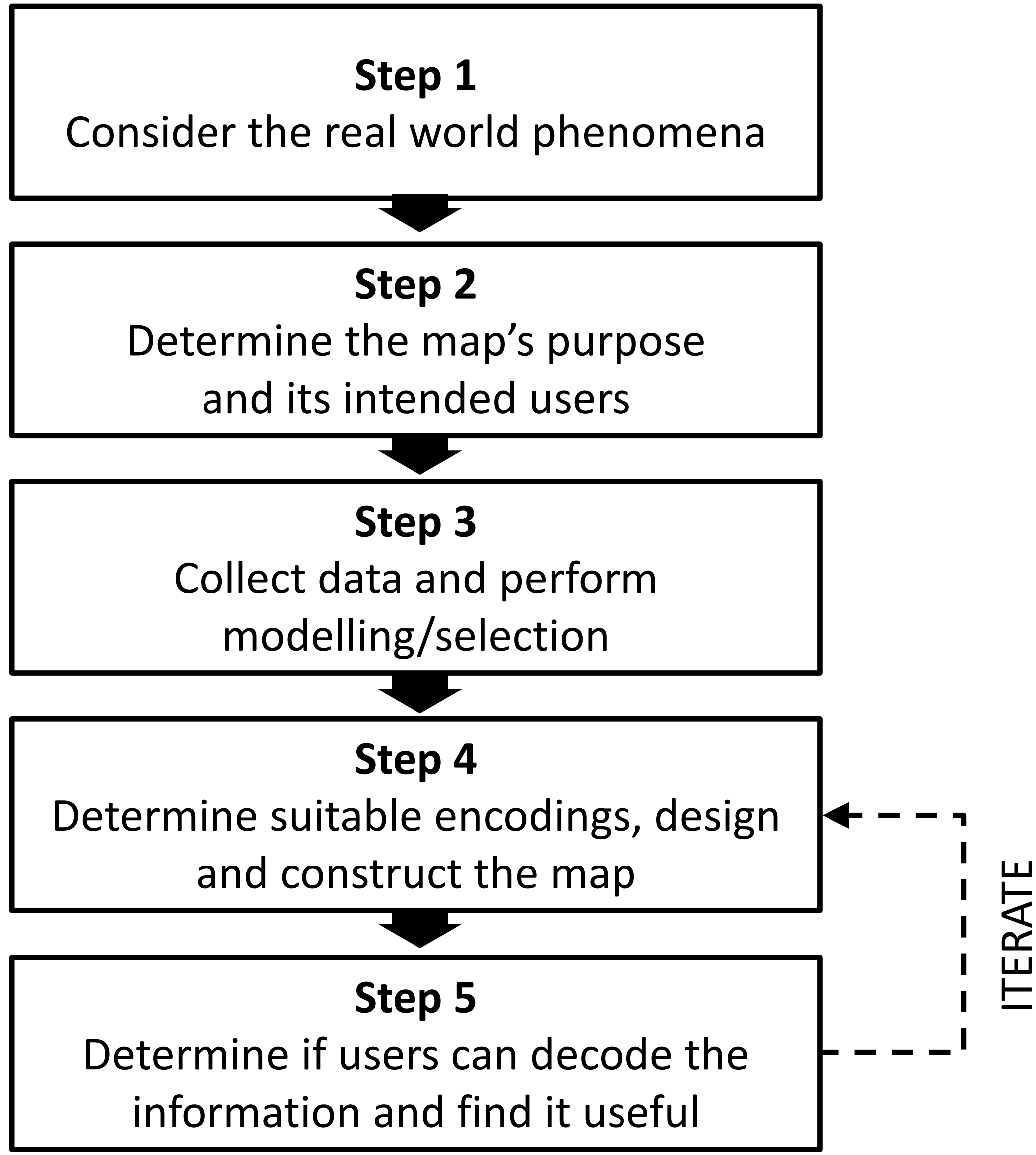


8. Smallness/area



Redrawn from Slocum et al. (2009)

THE CARTOGRAPHER'S COMMUNICATION



Redrawn from Slocum et al. (2009)

NEXT LECTURE

- Cartography 2

READING

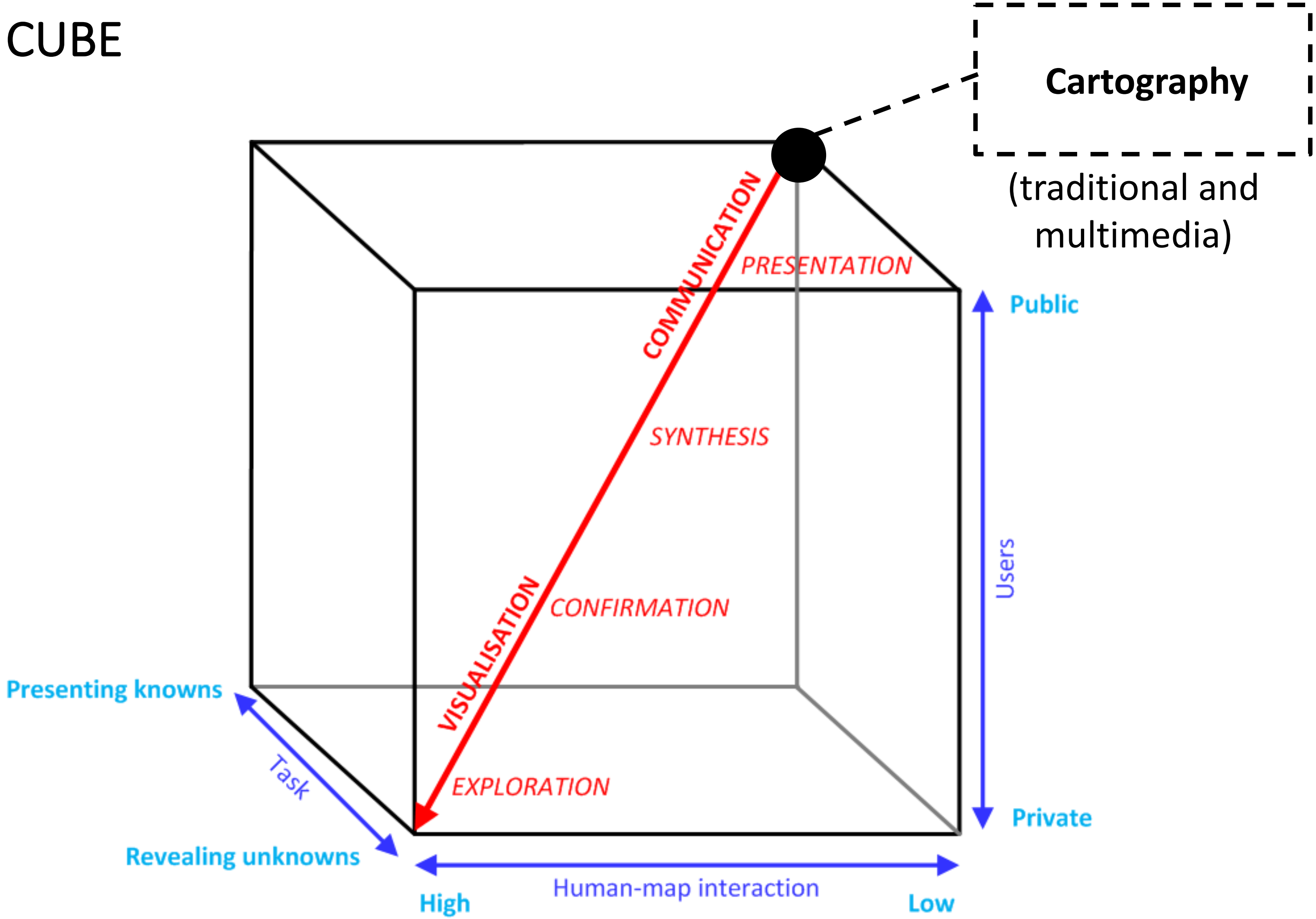
Ordance Survey – Design Principles

https://www.ordnancesurvey.co.uk/blog/tag/cartographic-design-principles/

ESRI ArcGIS – Design principles

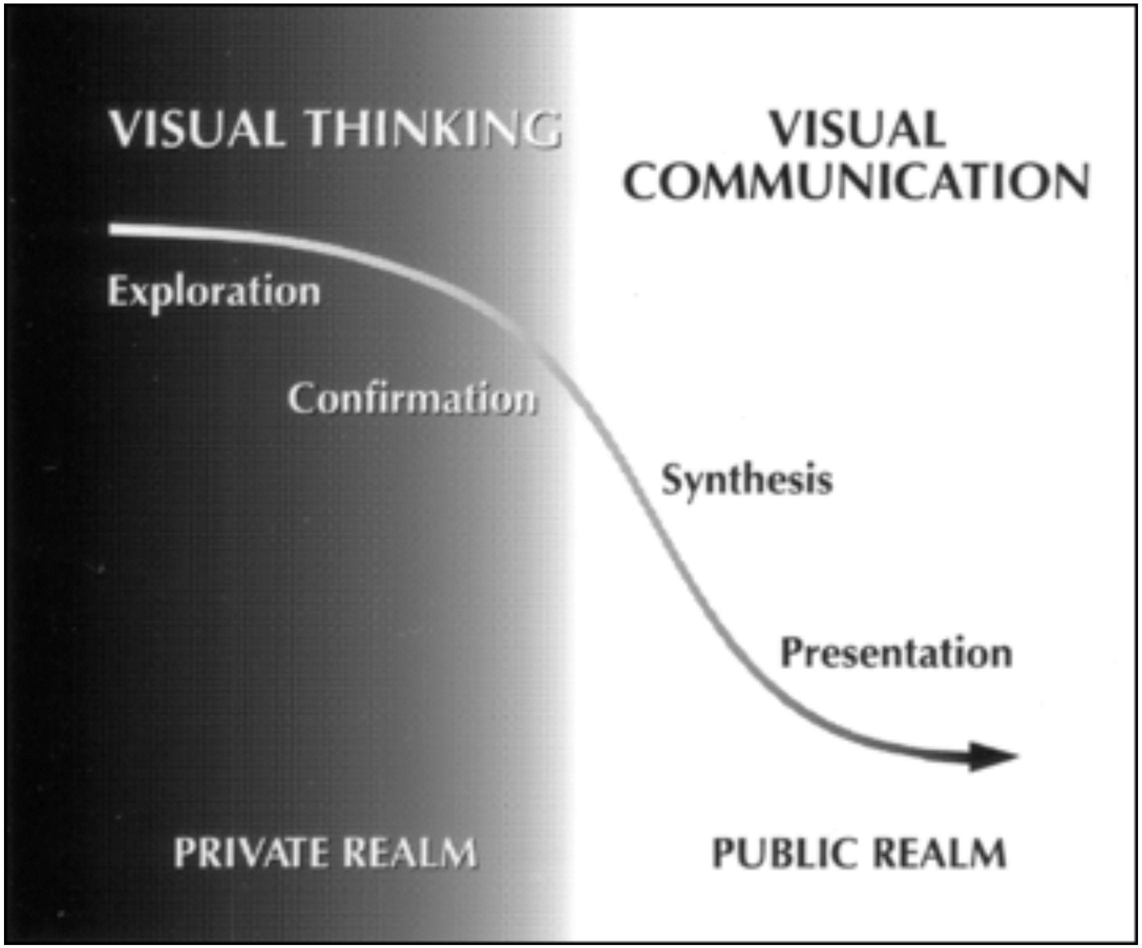
http://blogs.esri.com/esri/arcgis/2011/10/28/design-principles-for-cartography/

MAP USE CUBE



Redrawn from MacEachren (1995)

CARTOGRAPHY - VISUAL THINKING AND COMMUNICATION



The Original Swoopy Diagram

(Dibiase, 1990)