Lecture 2

Foundation in Human Visual Perception

How it relates to creating effective information visualizations

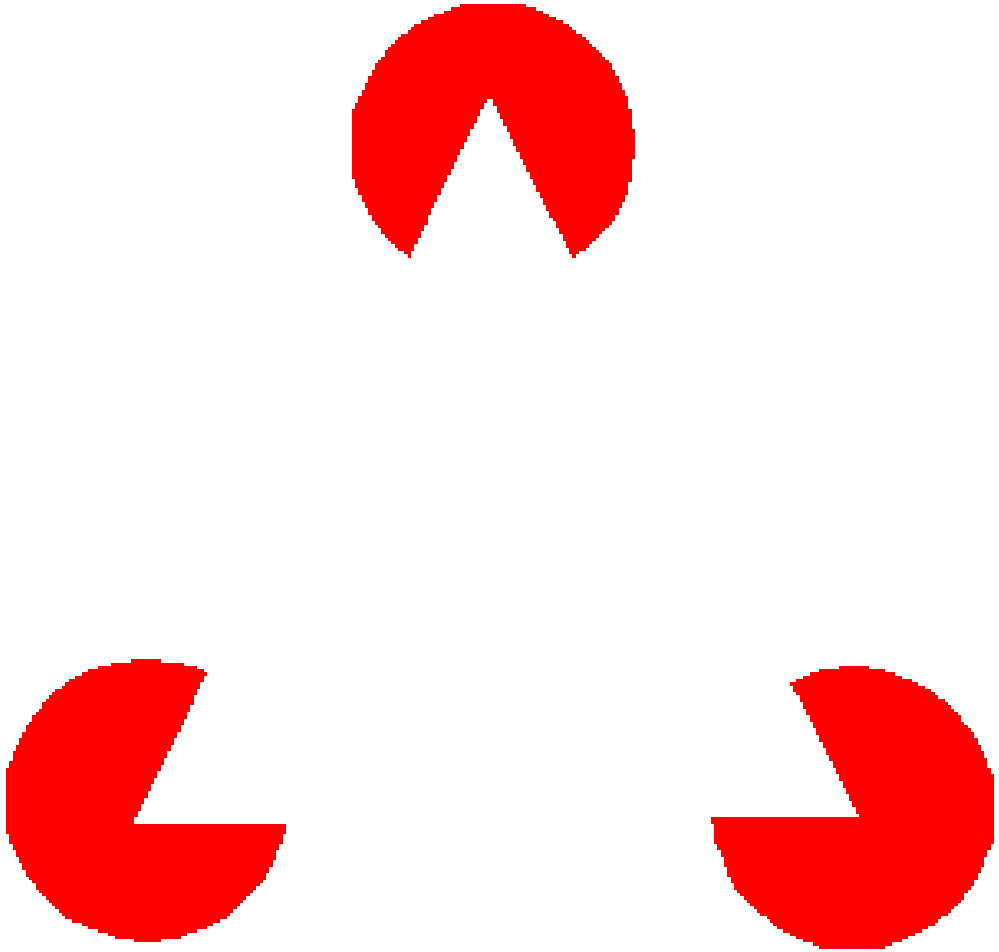
- Attention: Searchlight Model
- Stages of Visual Processing
- Luminance & Color Channels
- Pre-Attentive Processing
- Motion Perception
- Structure from X and Depth Cues

➔Building Foundation for Guiding The Eye

Tufte – Envisioning Information

- Tufte's Measures and Design Principles

What do you see?



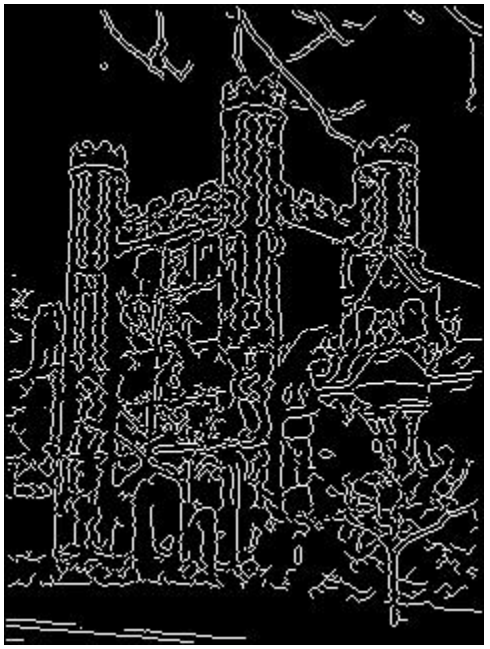
Subjective Contours

What do you see?

What do you see?

Scale Matters

Edge Detection



Physical World Structured

Well-Defined Surfaces

Objects have mostly **smooth** surfaces

Temporal Persistence

Objects don’t randomly appear/vanish

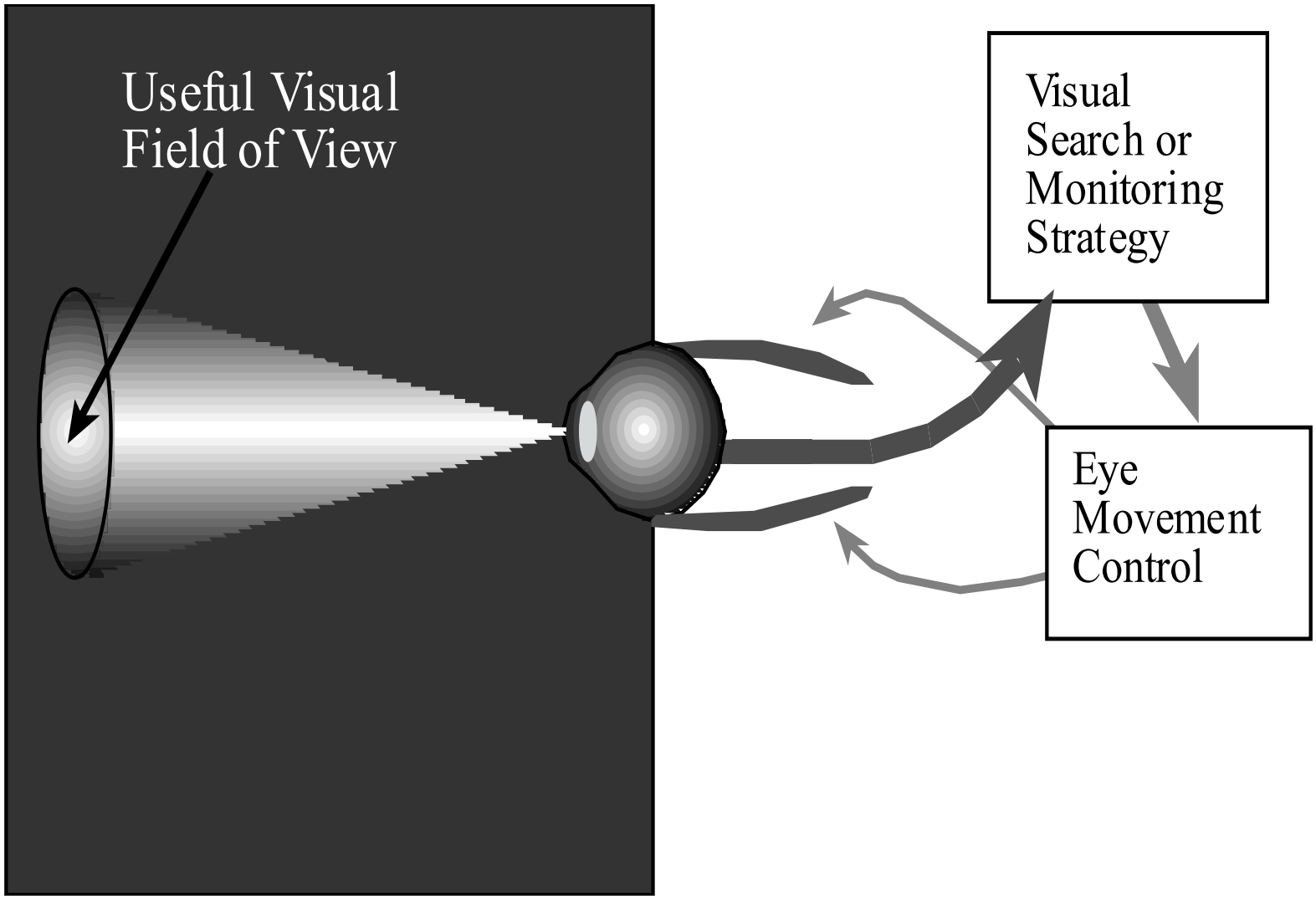
Light travels in Straight Lines

reflects off surfaces in certain ways

Law of Gravity

➔ **Human Visual System** Detects **Changes + Patterns**

Attention – Searchlight Model



Attention – Searchlight Properties

Searchlight Size varies with

- Data density
- Stress level

Attention Operators work within searchlight beam

Attention = Tunable Filter

Eye movements 3/sec – series of saccades

Popout Effects (general attention)

Segmentation Effects (dividing up the visual field)

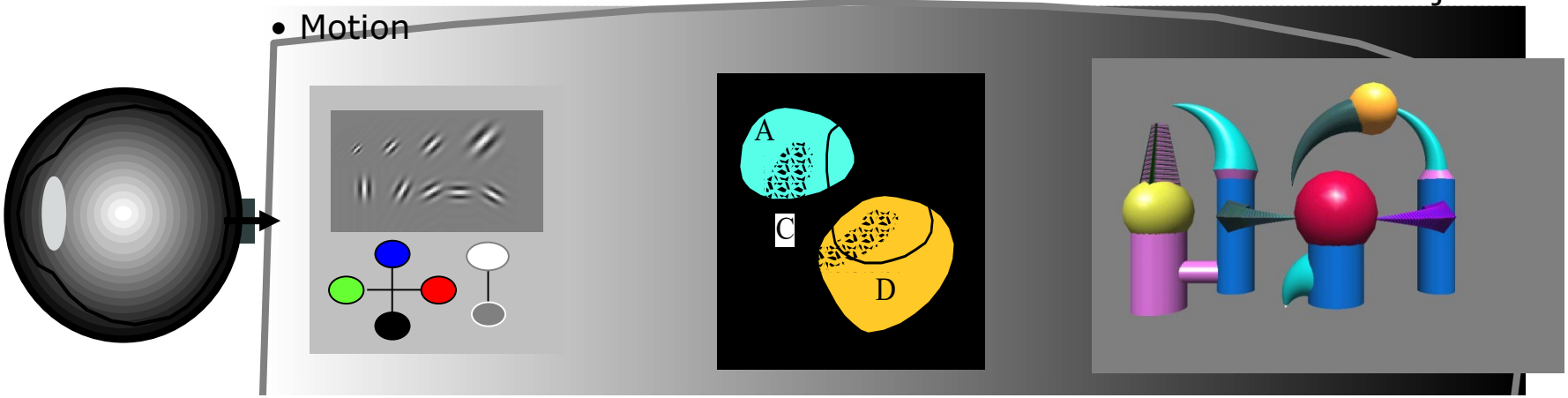
➔ Guide Attention

Parallel Processes ➔ Serial Processes

Parallel Processing
- Orientation
- Texture
- Color
- Motion

Detection
- Edges
- Regions
- 2D Patterns

Serial Processing
- Object Identification
- Short Term Memory
  5 ± 2 = 3 to 7 Objects



Stages of Visual Processing

1 Rapid Parallel Processing

- **Feature Extraction**: edges, orientation, color, texture, motion
- Transitory: briefly held in an iconic store
- **Bottom-up**, data-driven processing

2 Serial Goal-Directed Processing

- Object recognition: visual attention & memory important.
- Slow and serial processing
- Uses both short-term memory and long-term memory
- More emphasis on arbitrary aspects of symbols
- Different pathways for object recognition & visually guided motion
- **Top-down** processing

Luminance vs. Color

Luminance Channel

- Detail
- Form
- Shading
- Motion
- Stereo

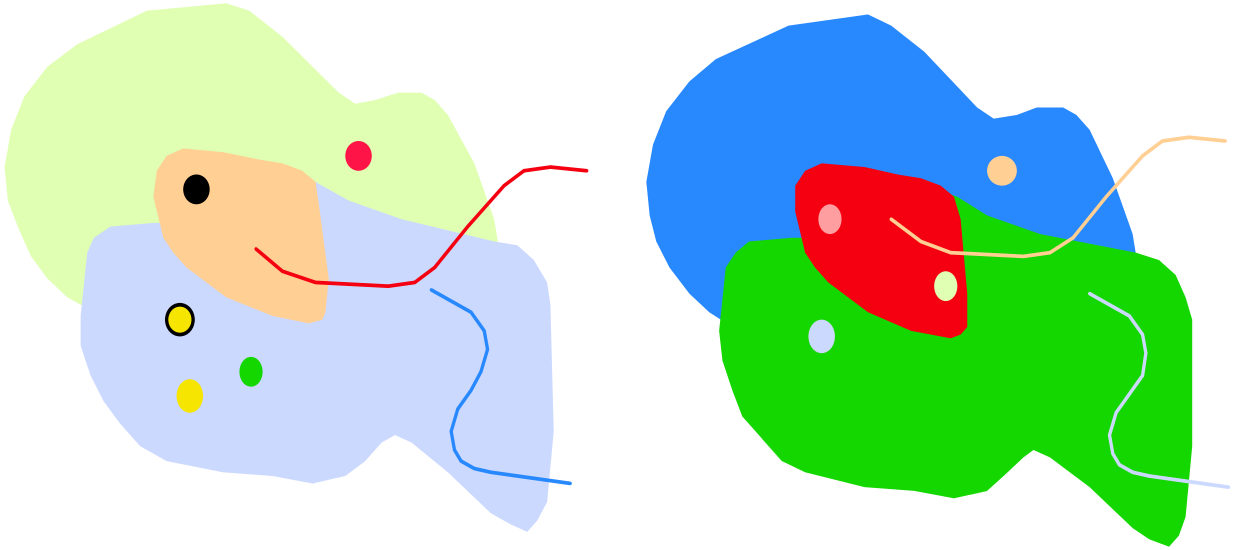
Color Channels

- Surfaces of Things
  - Sensitive to Small Differences
- Rapid Segmentation

- Categories (about 6-10)
  - Not Sensitive to Absolute Values
- Unique Hues: Red, Green, Yellow, Blue
- Small areas = high saturation
- Large areas = low saturation

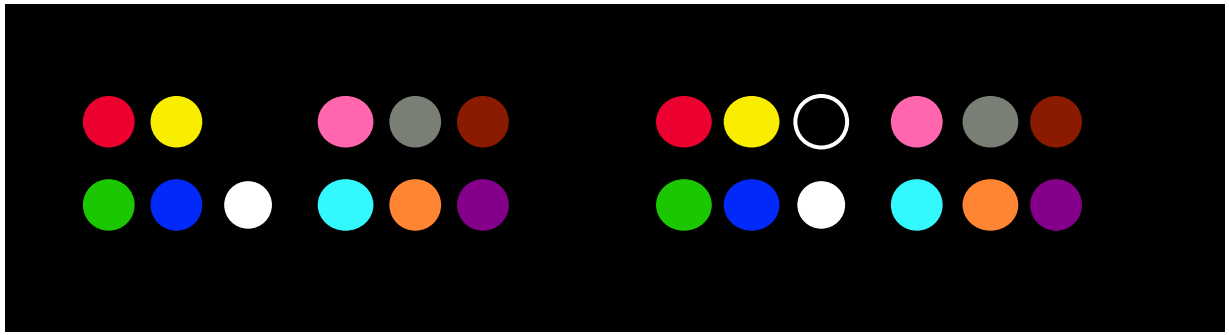
➔ **Luminance** More Important than Color

Color Coding



Large areas = low saturation

Small areas = high saturation



12 Colors
for labeling

Color – Take Home Messages

Use **Luminance for Detail, Shape and Form**

Use **Color for Categorization** - few colors

Strong Colors for Small Areas

Contrast in luminance with background

Subtle Colors for Large Areas

Pre-Attentive Processing

Some Visual Properties Processed Pre-Attentively

- No need to focus attention

Pre-Attentive Properties Important for Design of Visualizations

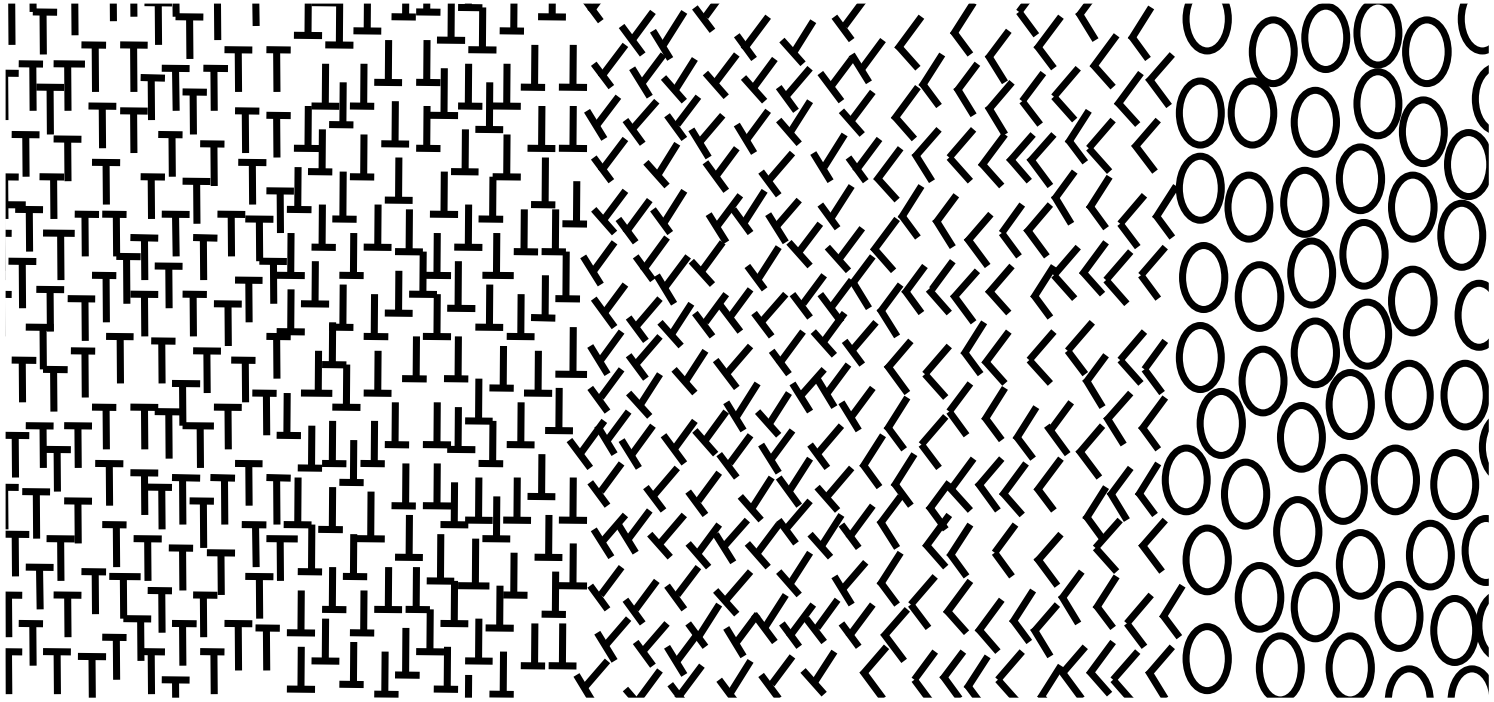
- Can be perceived immediately
- Can mislead viewer

< 200 - 250ms

- Eye movements = at least 200ms
- Some processing can be done very quickly
  ➔ Implies low-level processing in parallel

Segmentation by Primitive Features

How many areas ?



Pre-Attentive Processing

How many 3s ?

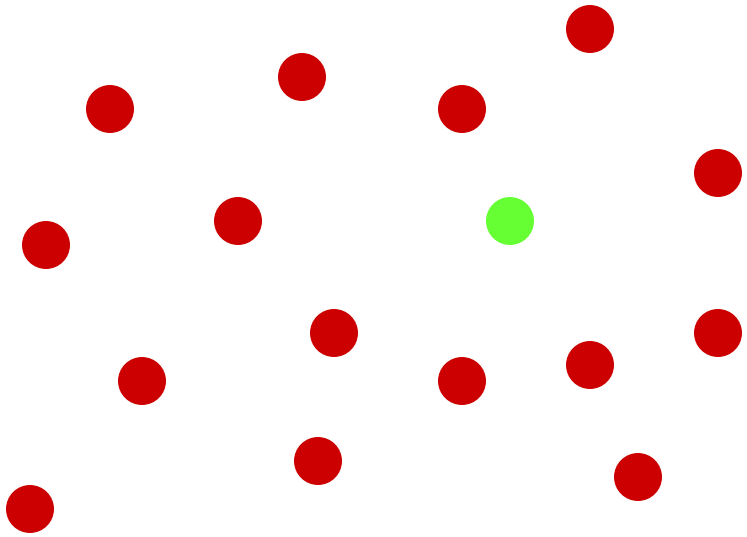
0802808508083080280985O–802808
56784729887Zty458202094757720O
2178984389Or455790456099272188
897594797902855892594573979209

Color ➔ Pre-Attentive (Pops out)

How many 3s ?

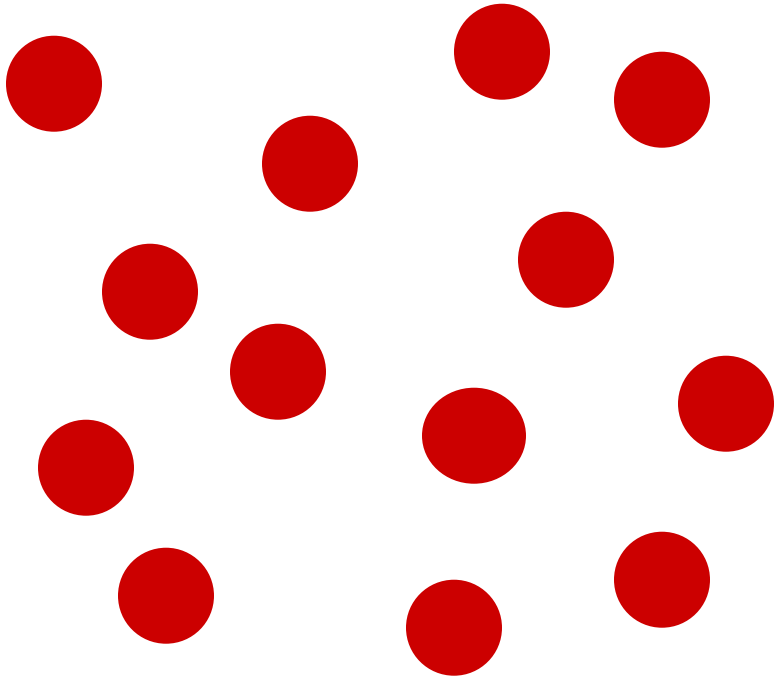
0802808508083080280985O–802808
56784729887Zty458202094757720O
2178984389Or4557904560992721 88
897594797902855892594573979209

Pre-Attentive Processing - **Color**

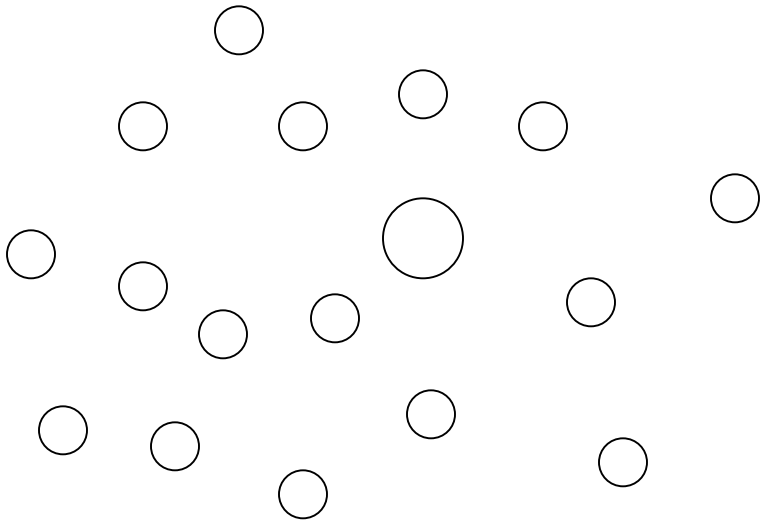


Pre-Attentive Processing - **Orientation**

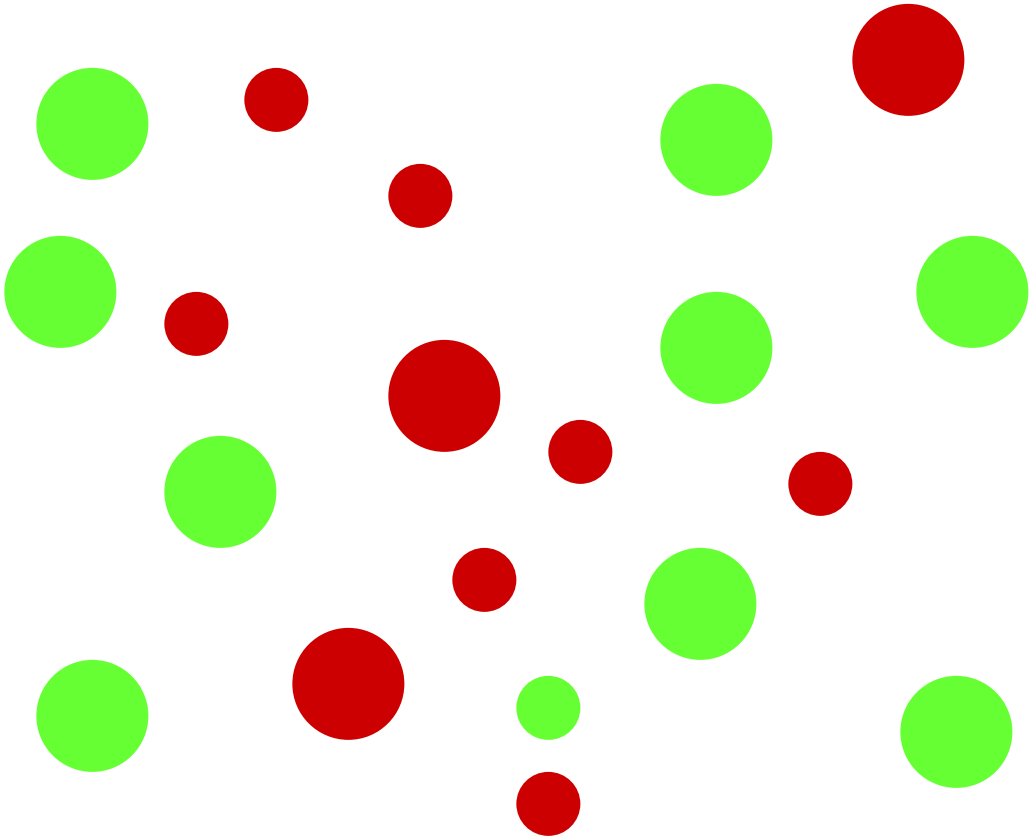
Pre-Attentive Processing - **Motion**



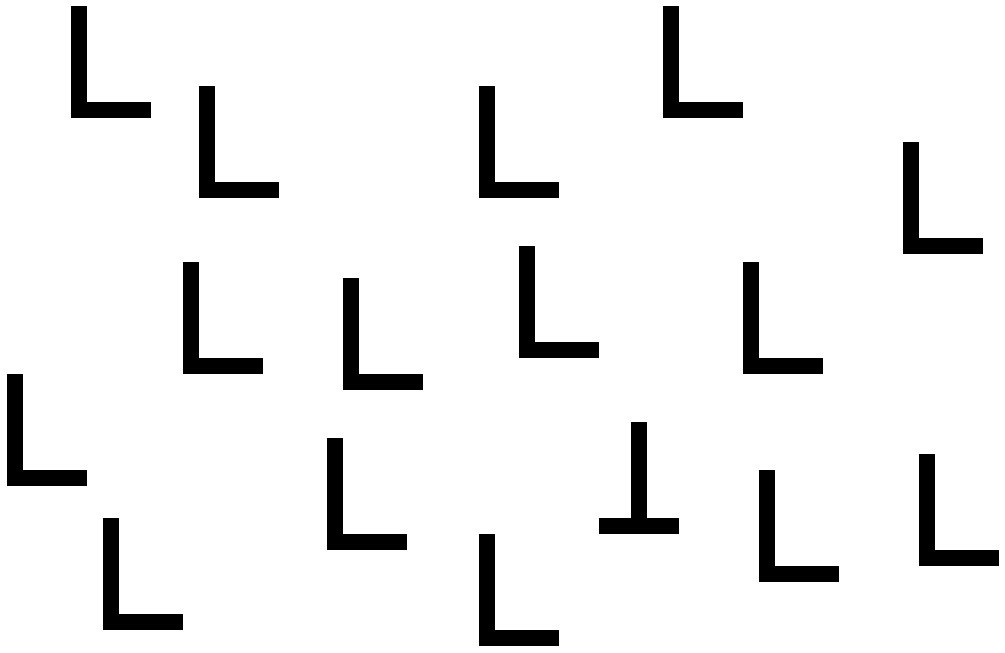
Pre-Attentive Processing - **Size**



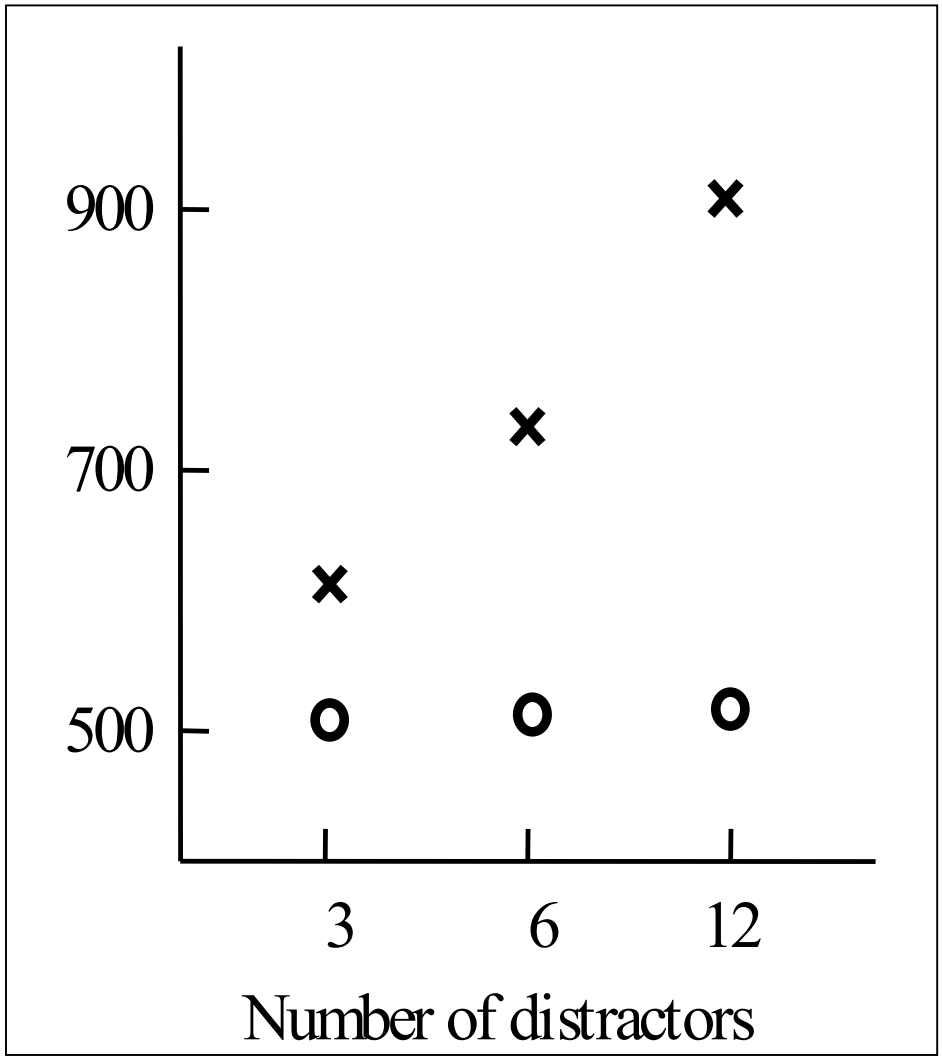
Conjunction (does not pop out)



Compound features (do not pop out)



Pre-Attentive Experiment



Decision = Fixed Time
regardless of the number of distractors
➔ **Preattentive**

Pre-Attentive Demo by Christopher Healey

Target = **Red Circle** 

Distractors

- blue circles (colour search)
- red squares (shape search)
- blue circles and red squares (conjunction search)

Laws of Pre-Attentive Display

Must **Stand Out** in **Simple Dimension**

- **Color**
- **Simple Shape** = orientation, size
- **Motion**
- **Depth**

Gestalt Laws

Max Westheimer, Kurt Koffka and Wolfgang Kohler (1912)

Proximity

Similarity

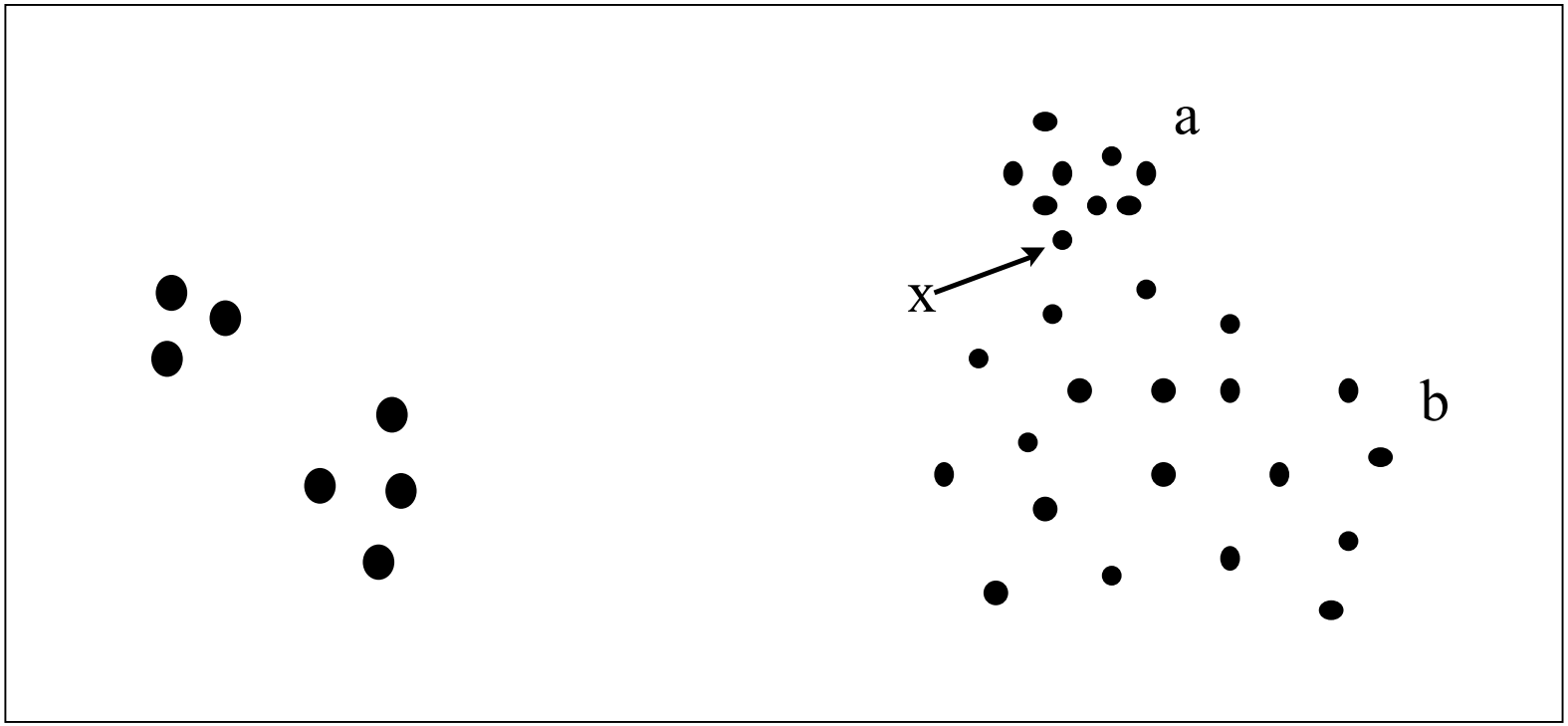
Continuity

Symmetry

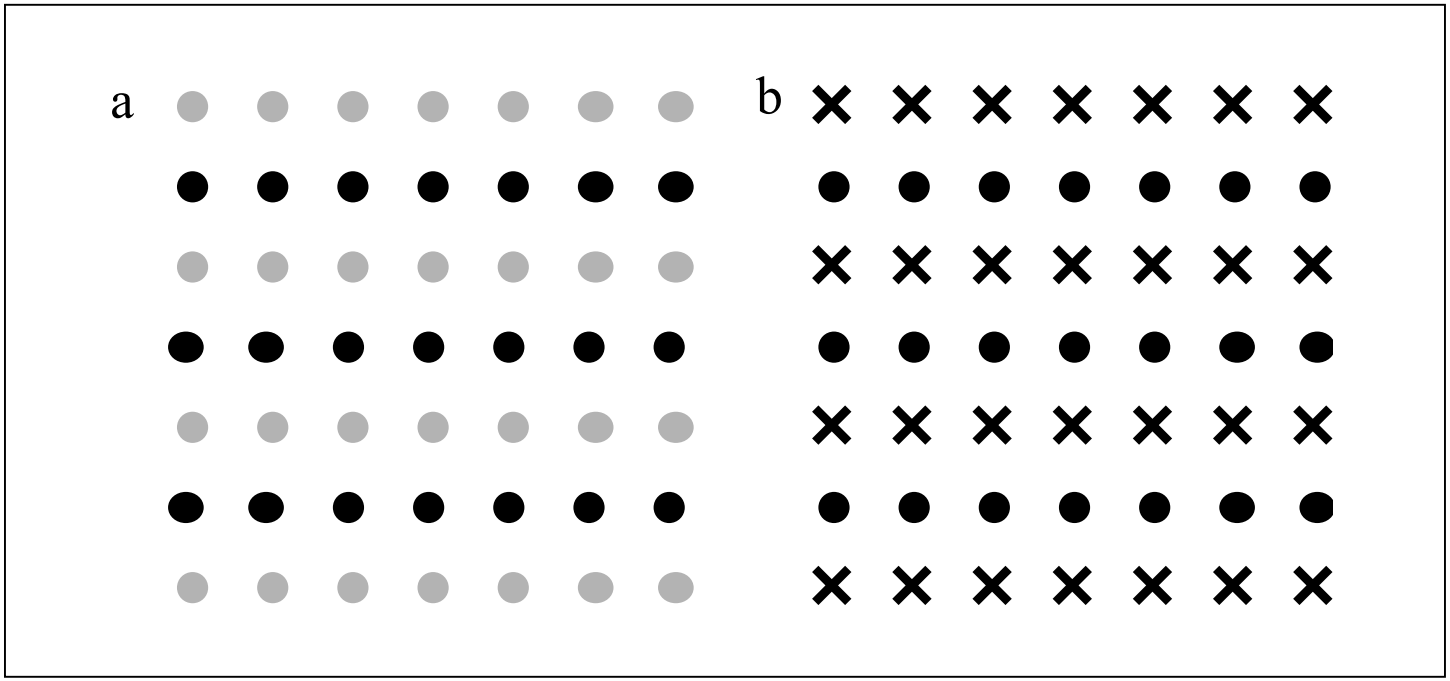
Closure

Figure and Ground

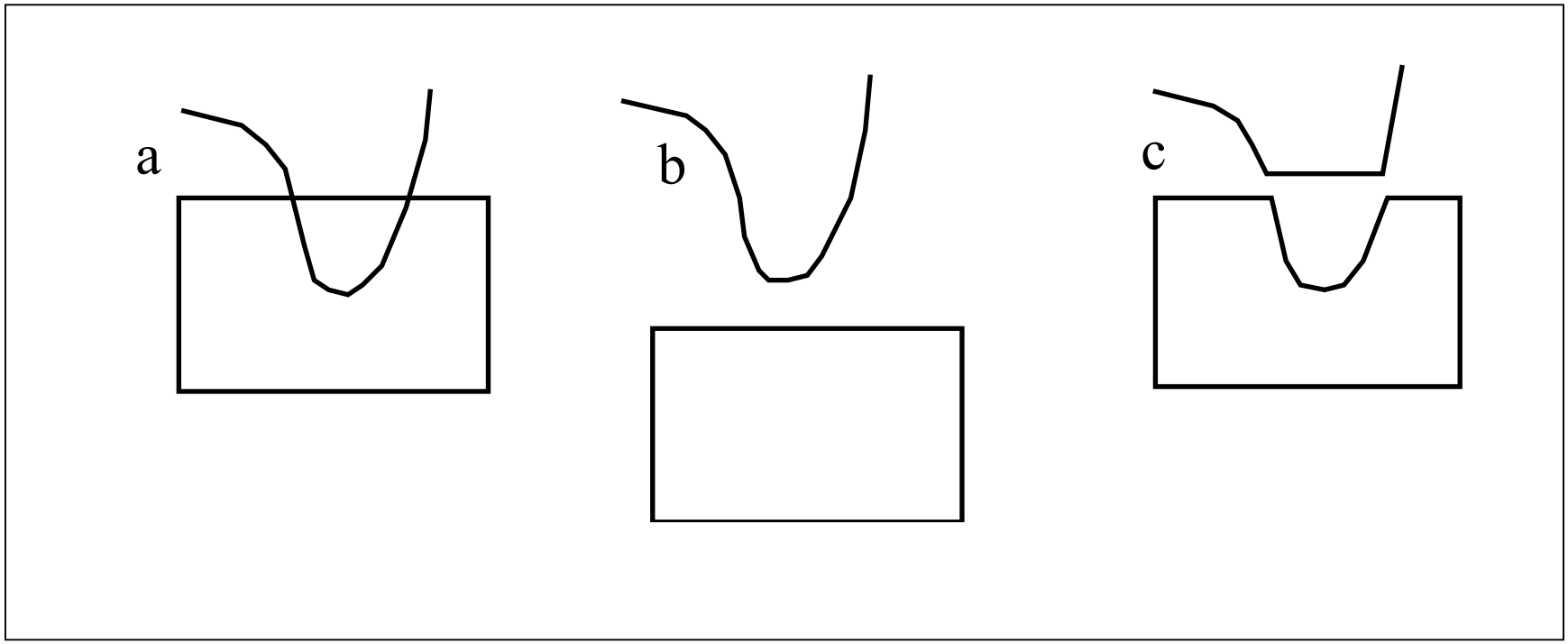
Gestalt Laws – Proximity



Gestalt Laws – Similarity

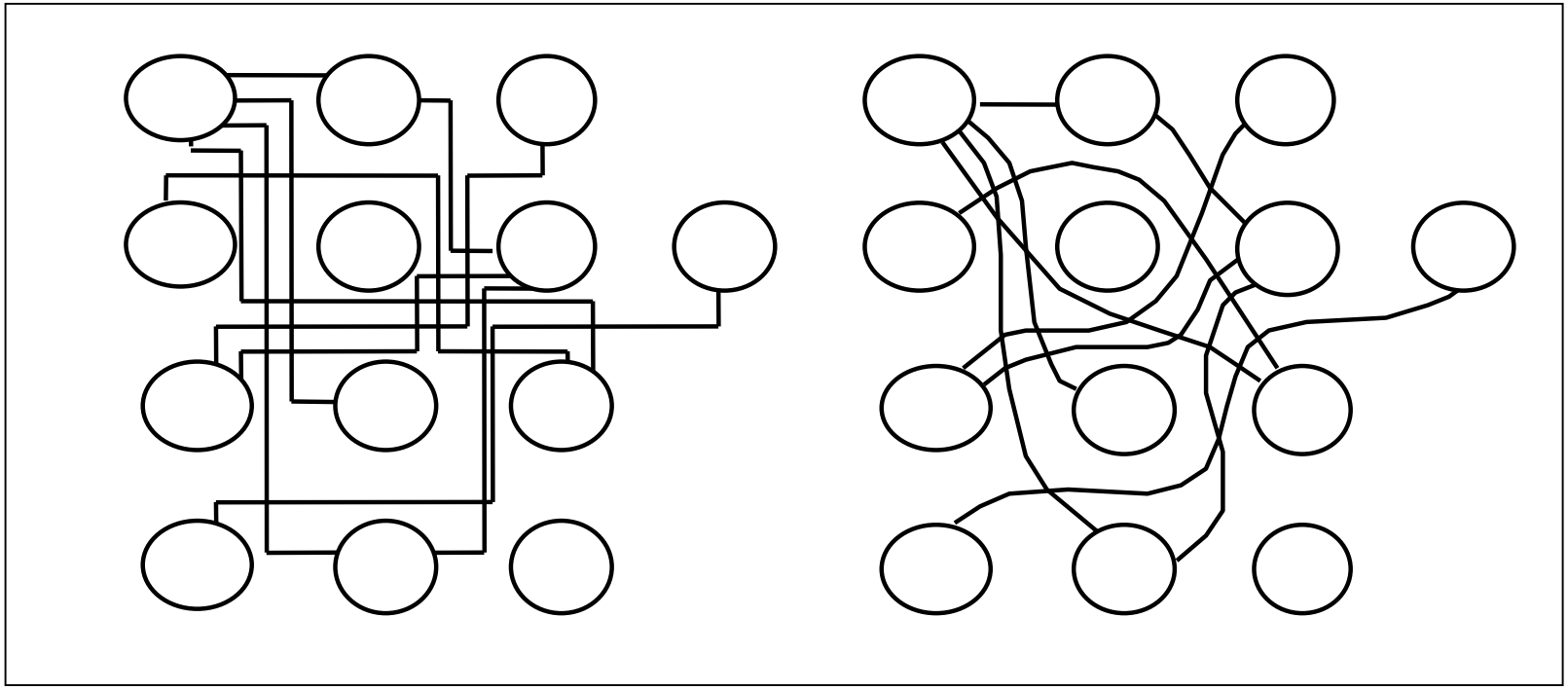


Gestalt Laws – Continuity



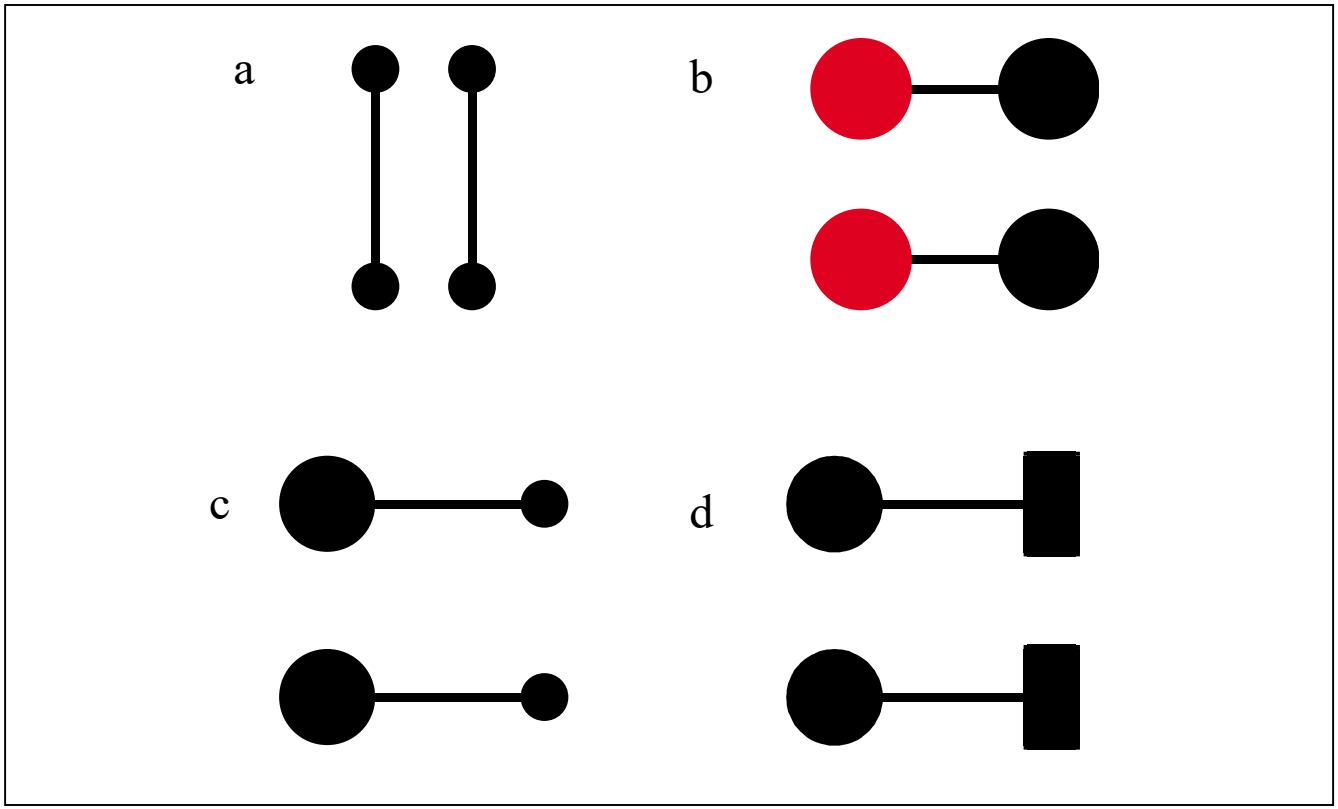
Visual objects tend to be smooth and continuous

Gestalt Laws – Continuity

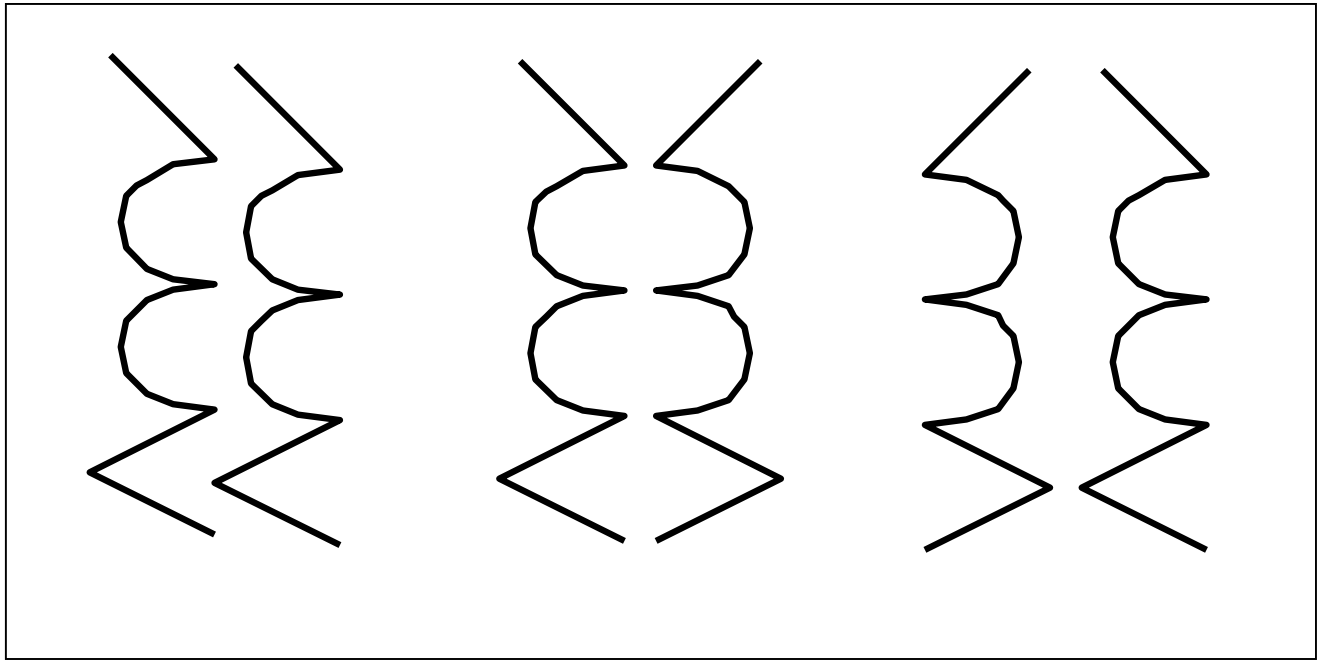


Connections using smooth lines

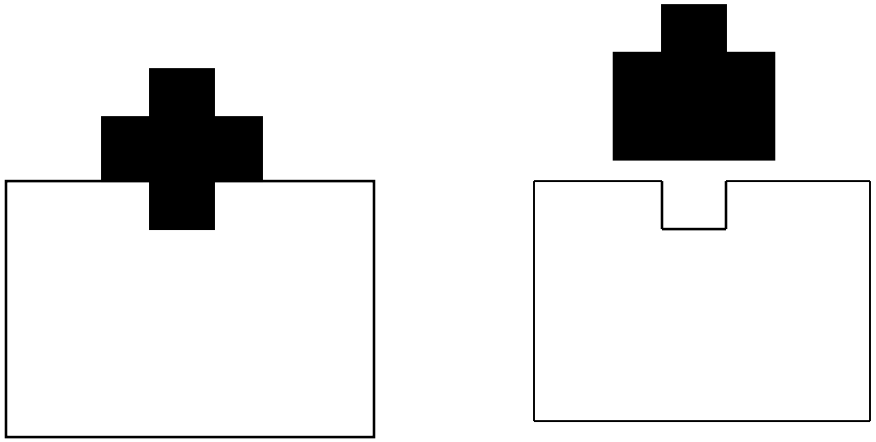
Gestalt Laws – Continuity & Connectness



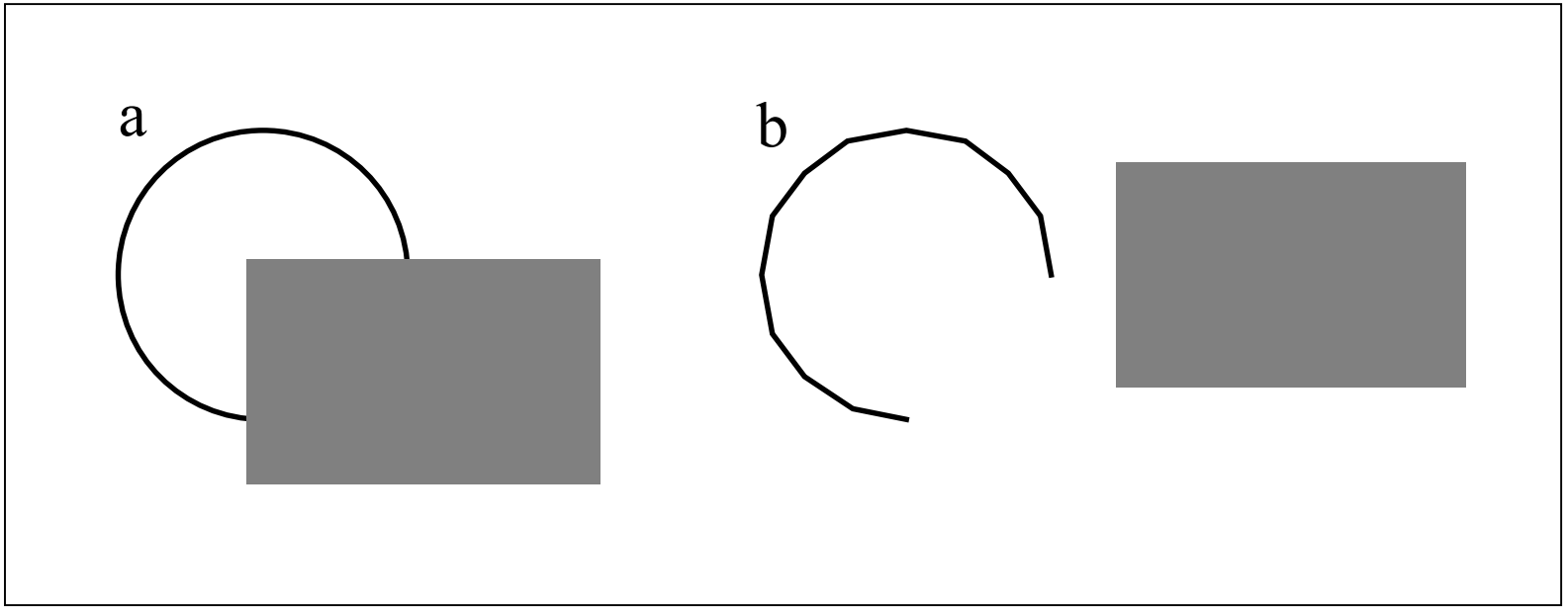
Gestalt Laws – Symmetry



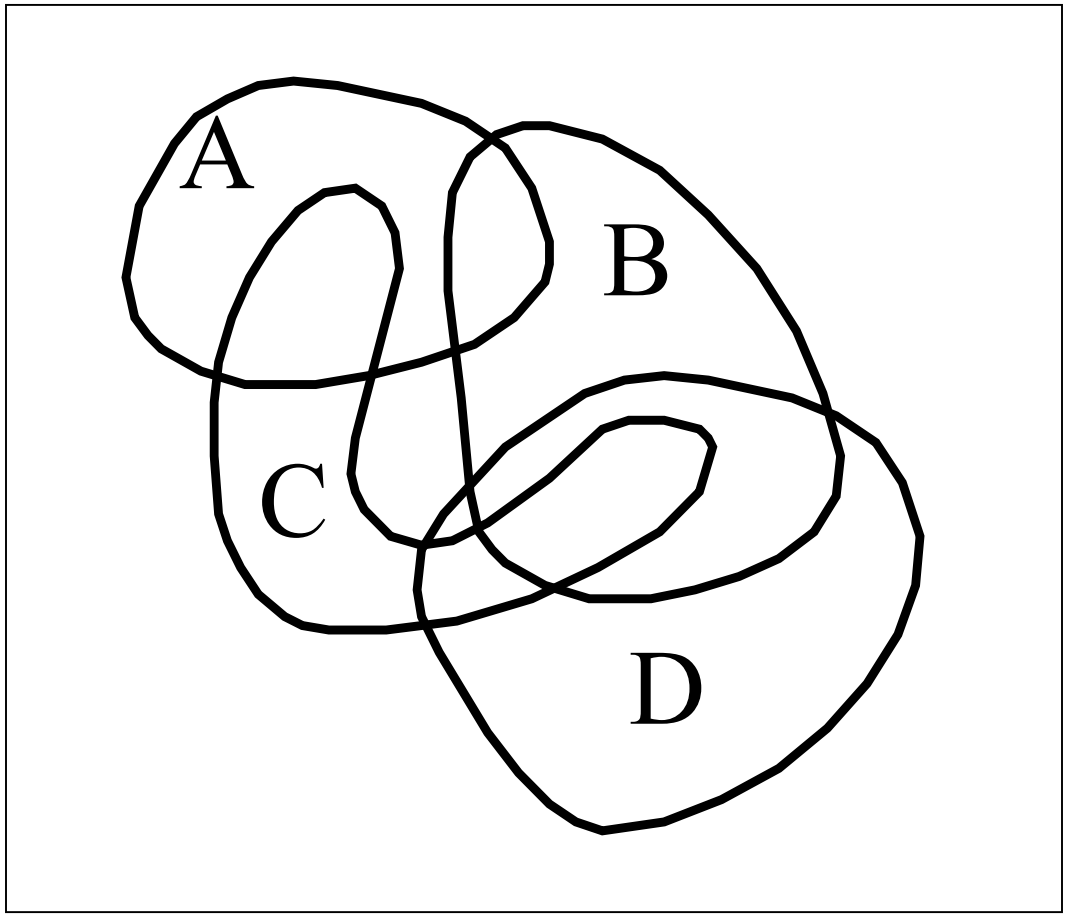
Gestalt Laws – Symmetry



Gestalt Laws – Closure



Gestalt Laws – Closure

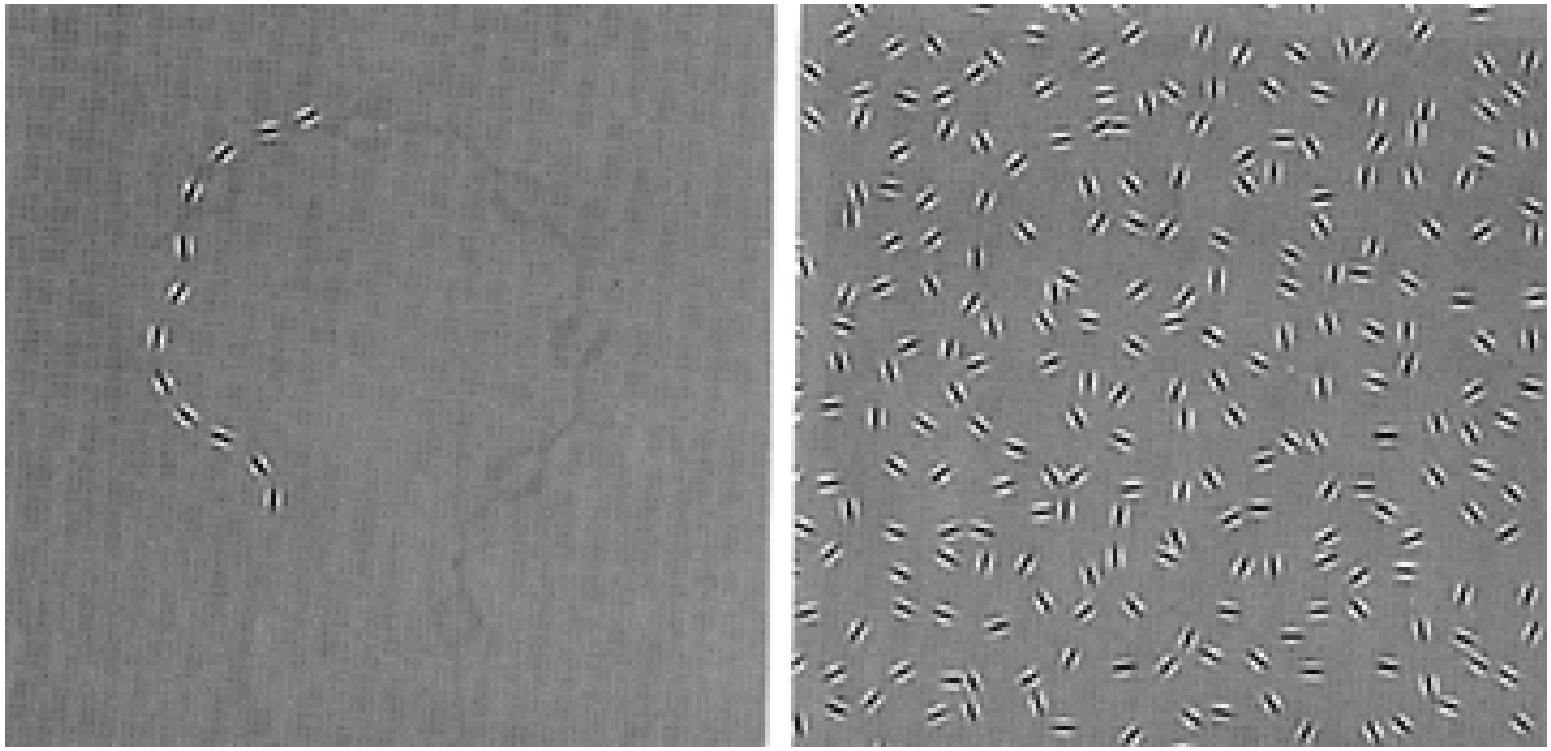


Gestalt Laws – Figure and Ground

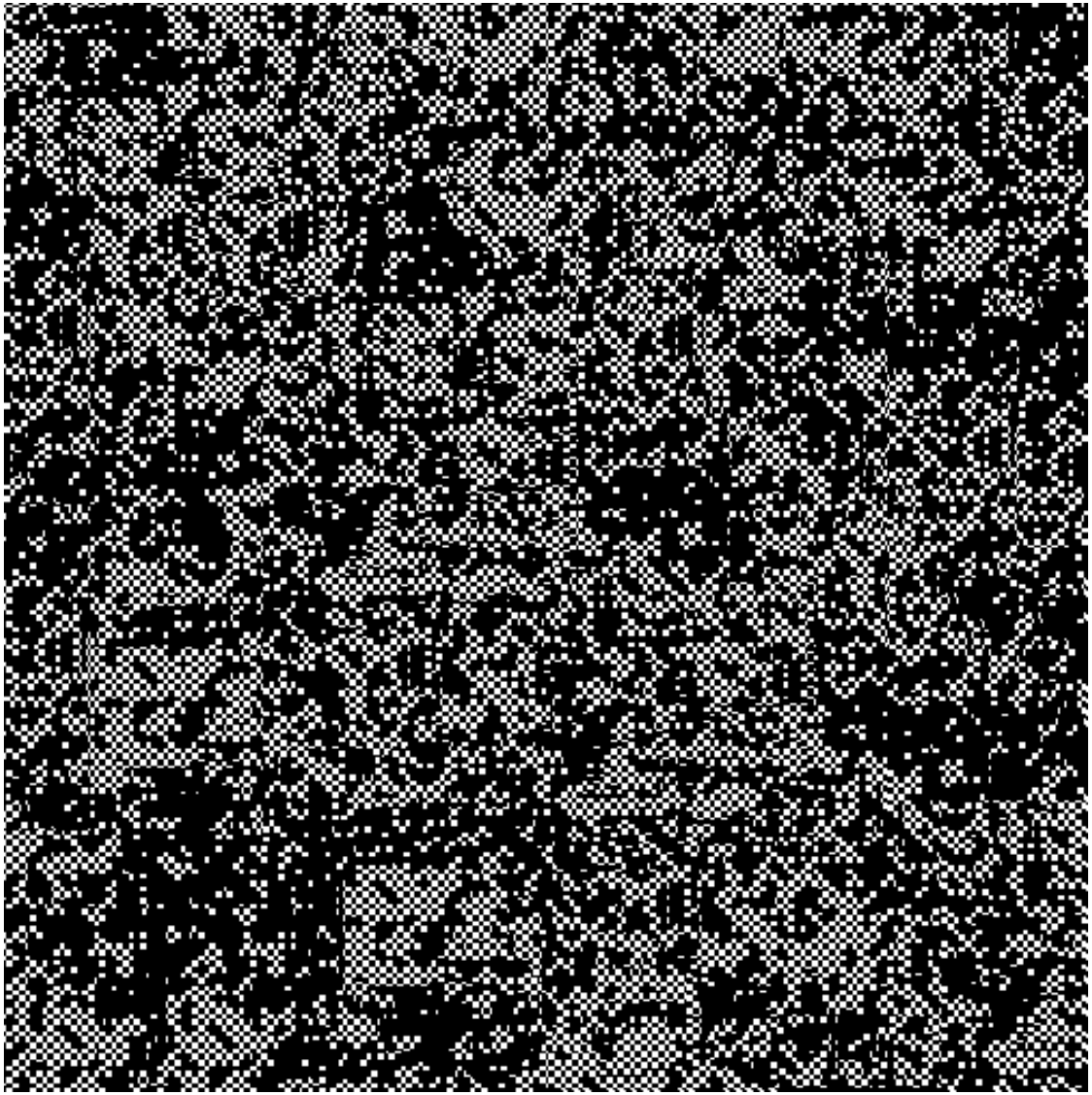
Rubin's Vase

- Competing recognition processes

Contour Finding



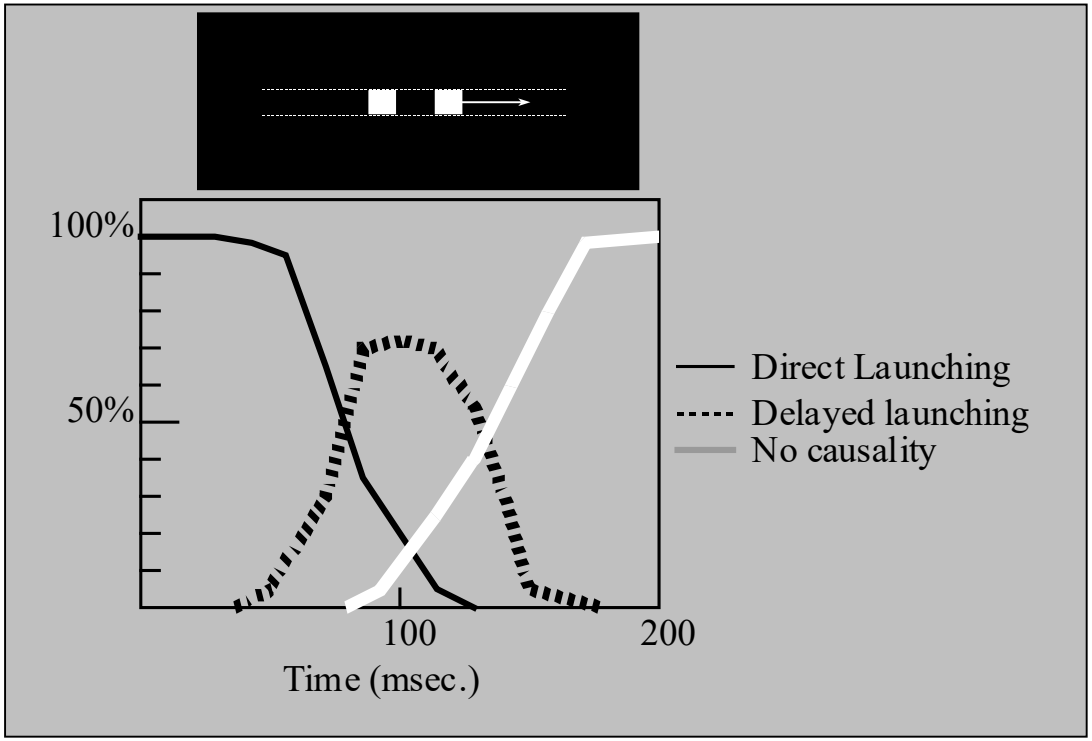
Motion



Motion Phenomena

- Kinetic Depth demo
- Anthropomorphic Form from Motion demo

Perception of Causality



Motion Perception

Which Human Visual Capabilities are exploited in iPod ads?

http://www.youtube.com/watch?v=TE4EEwQAfxo

http://www.youtube.com/watch?v=nljs4kzpebU

http://www.youtube.com/watch?v=znYzUW_XNOs

➔ **Structure from Silhouettes and Motion**

➔ **Perception of Causality**

Space Perception

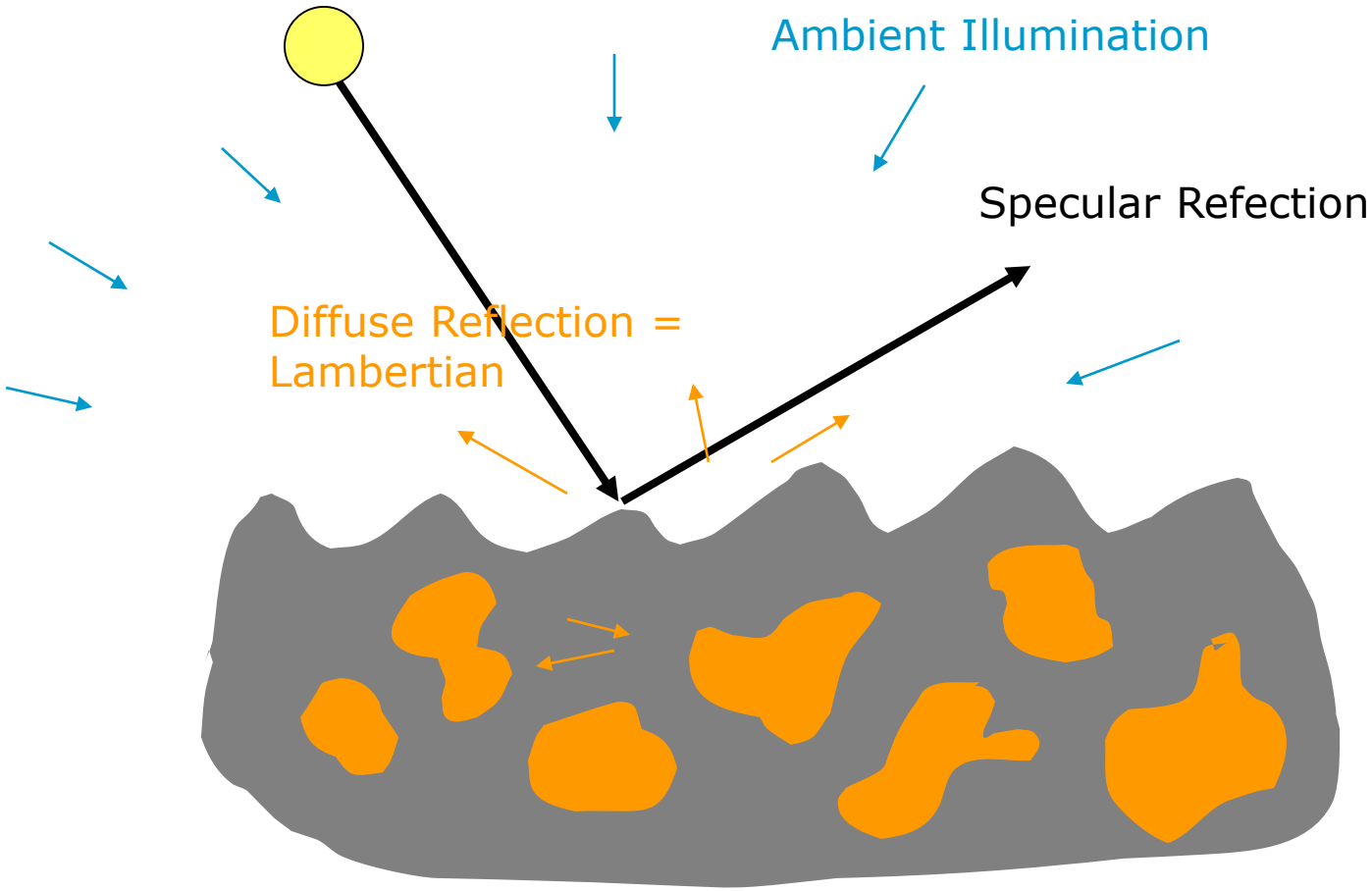
Shape-from-Motion

Shape-from-Shading

Shape-from-Texture

Depth Cues

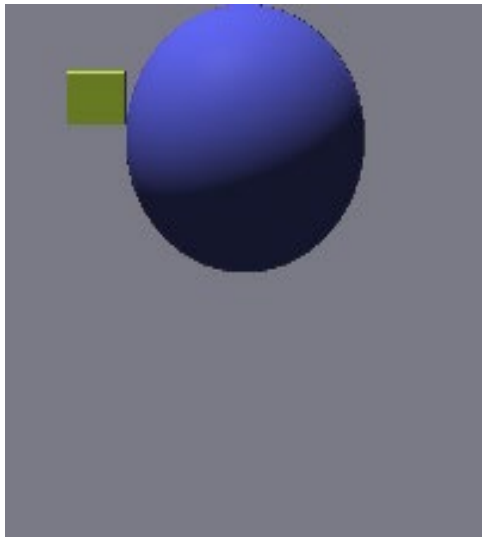
Perception of Surface Shape – Standard Lighting Model



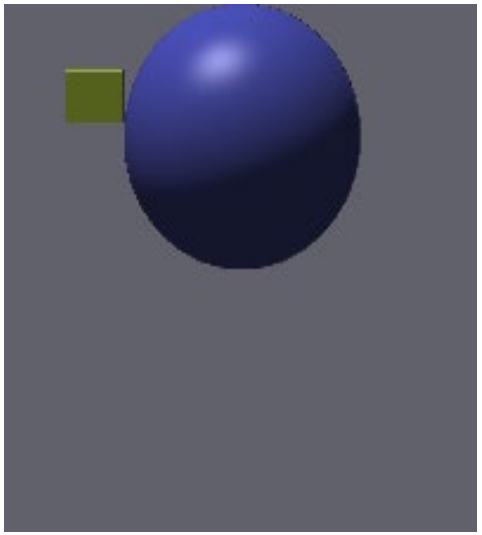
Standard Lighting Model (cont.)

Light from above and at infinity

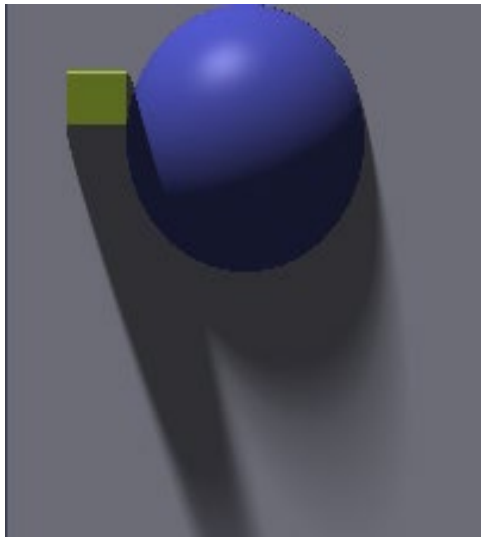
Diffuse, Specular and Ambient Reflection Depth Cues



Diffuse
Lambertian

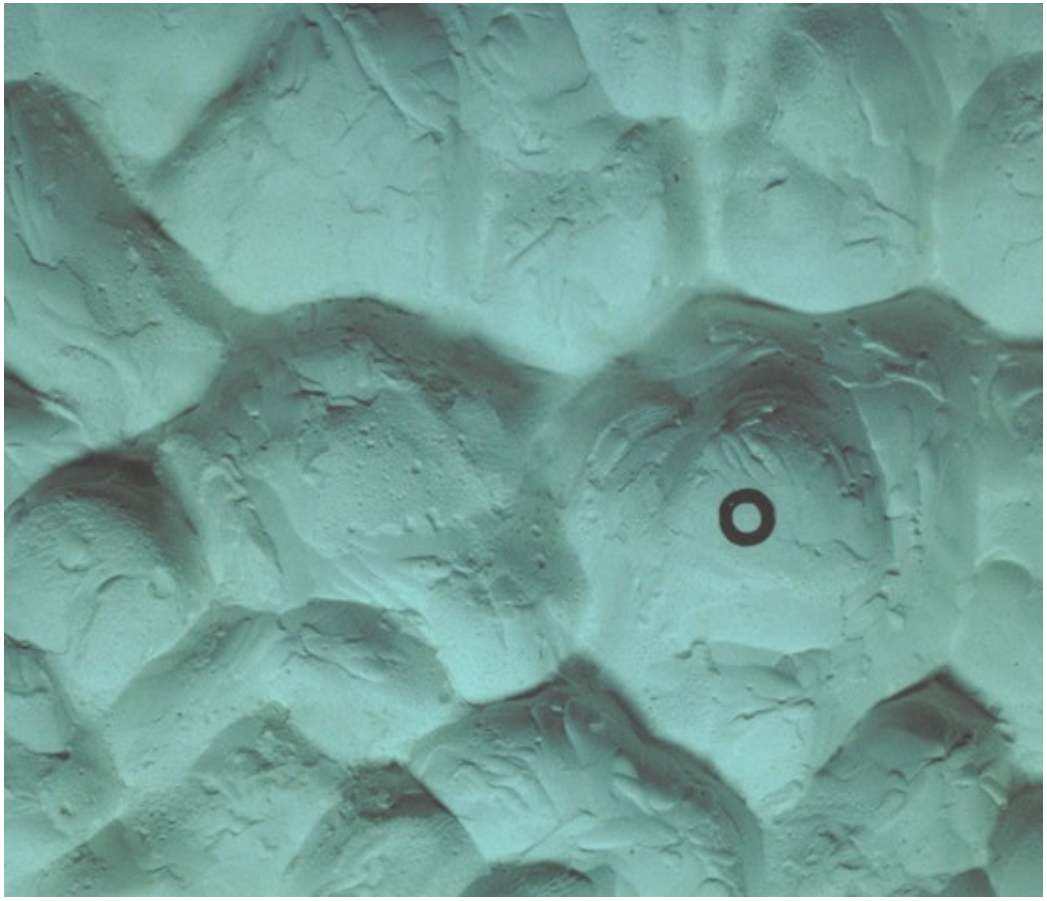


Specular



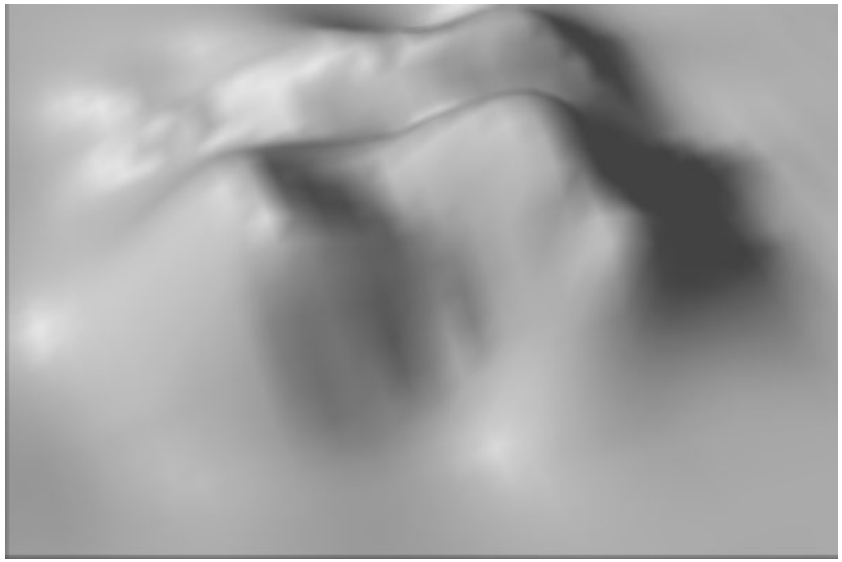
Ambient
Shadows

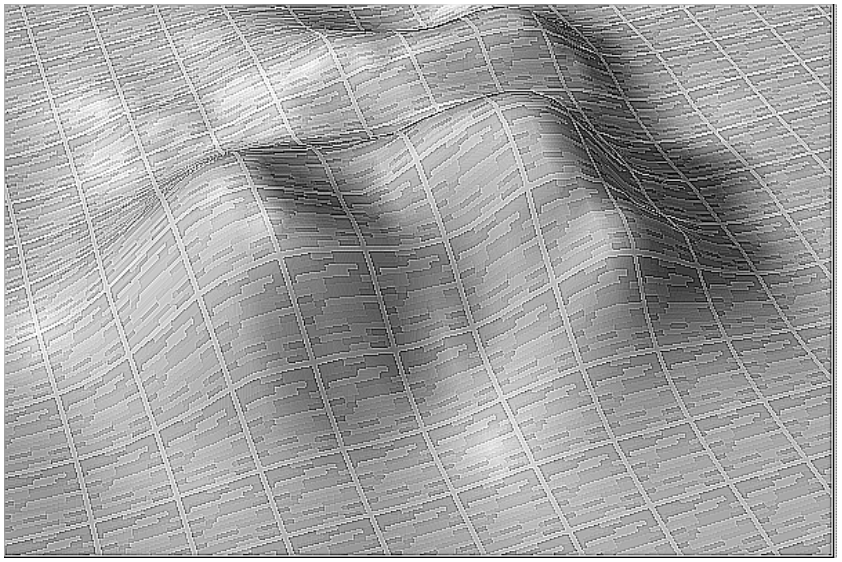
Examples



Examples

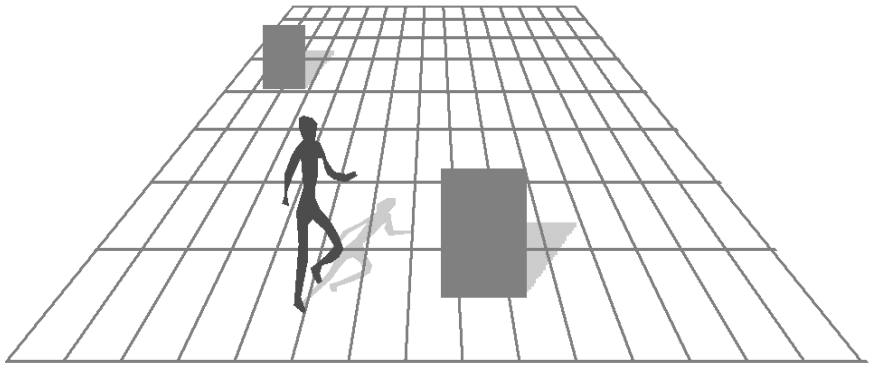
Textures for Surface Orientation

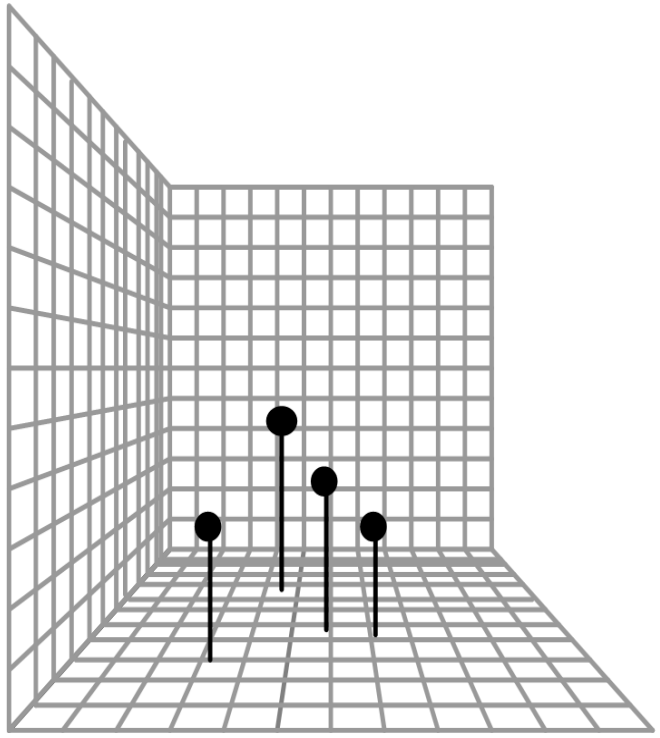




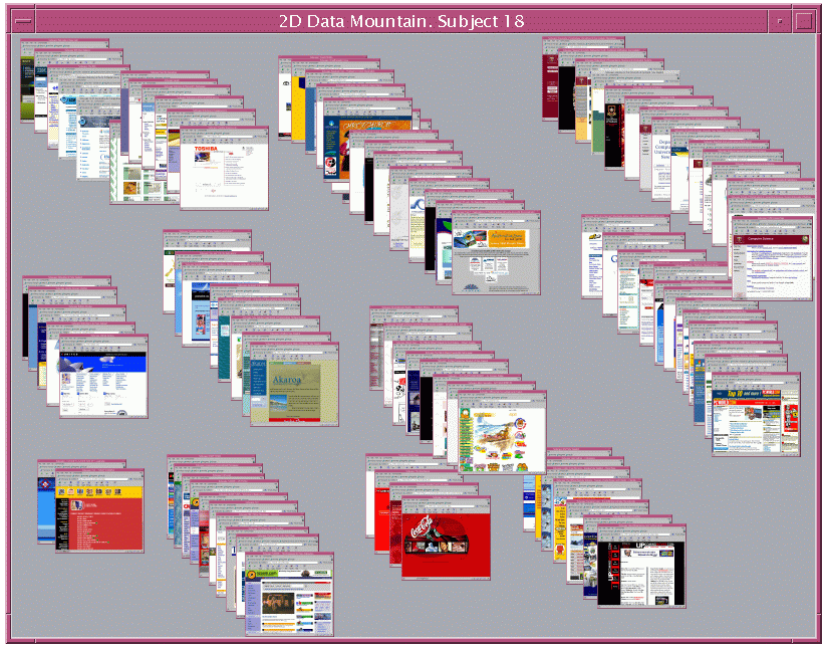
Depth Cues – Occlusion ➔ strongest depth cue

Depth Cues – Perspective



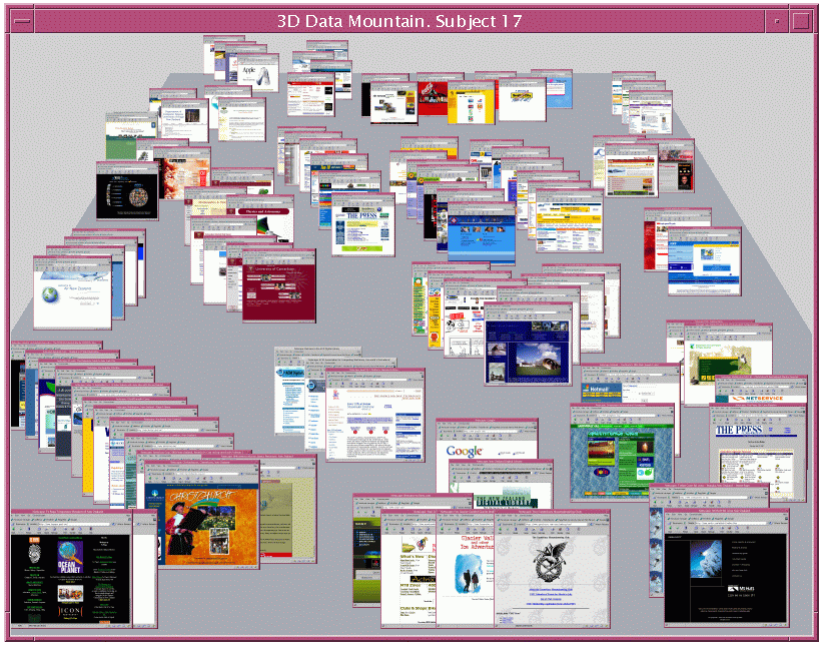


Perspective (Cockburn and McKenzie)



Position

Occlusion

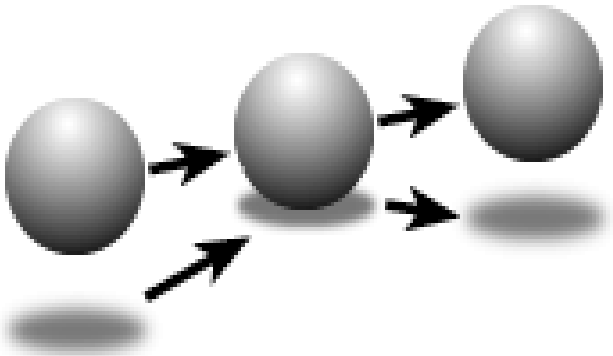


Position

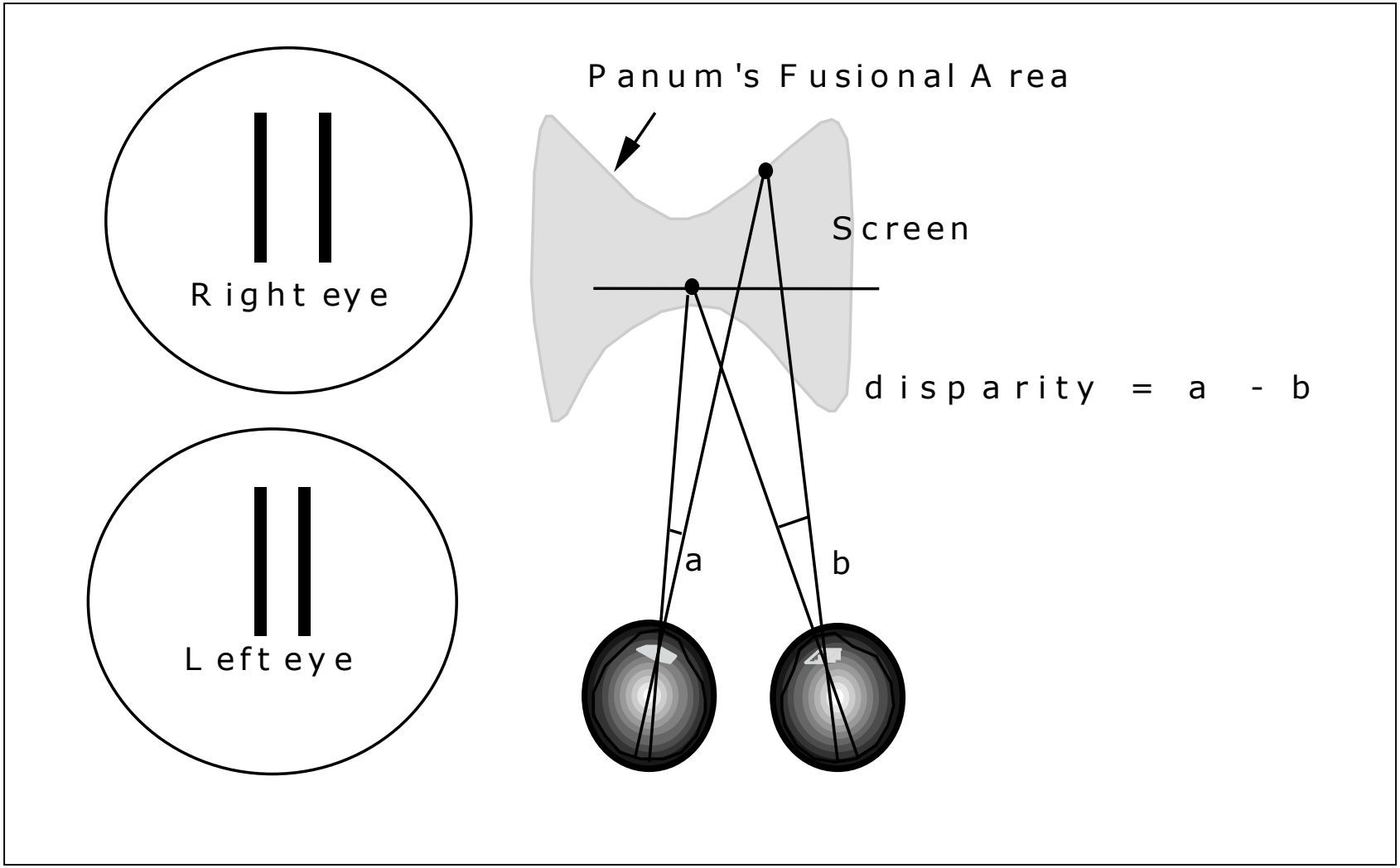
Occlusion

Perspective

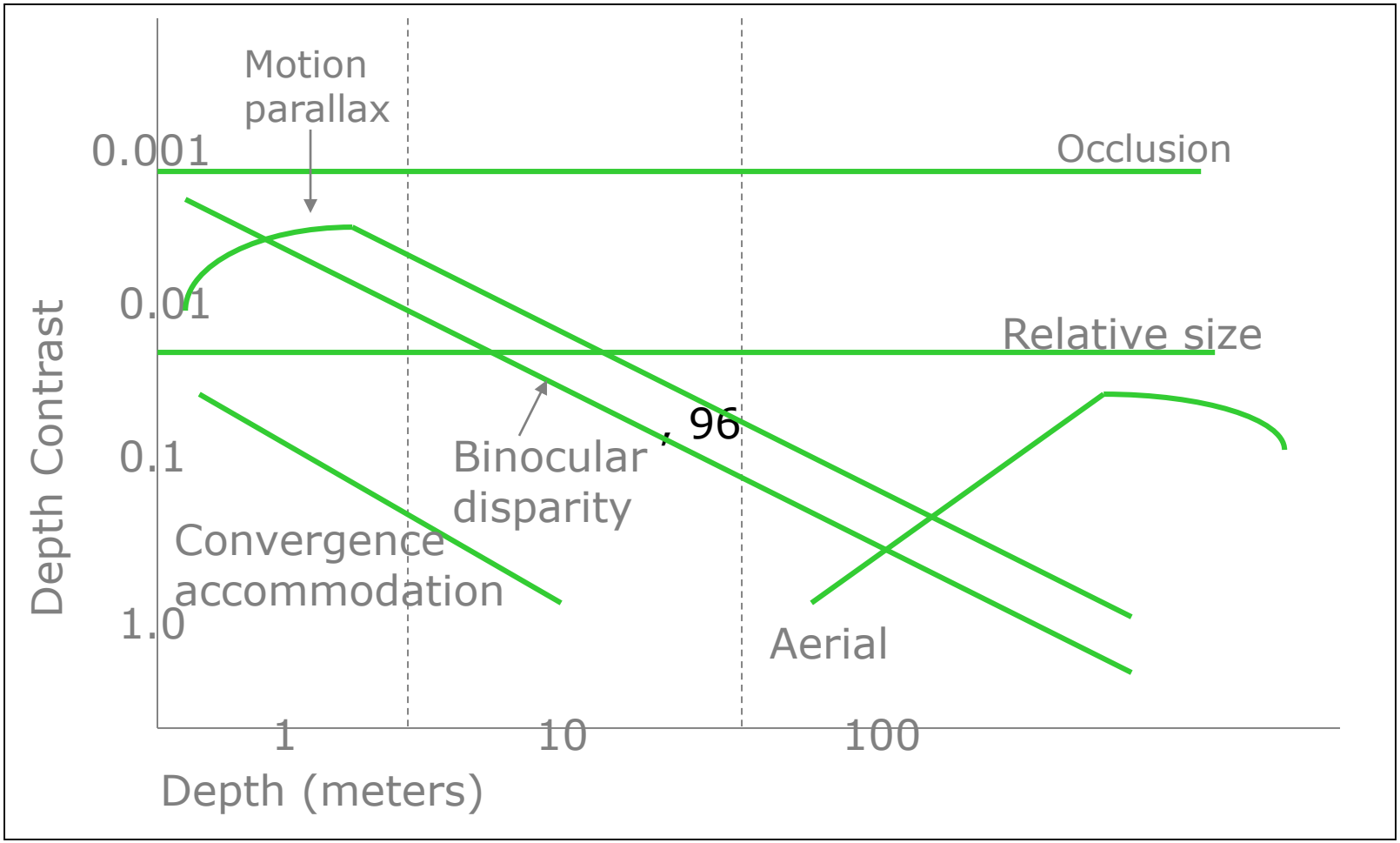
Depth Cues – Shadows



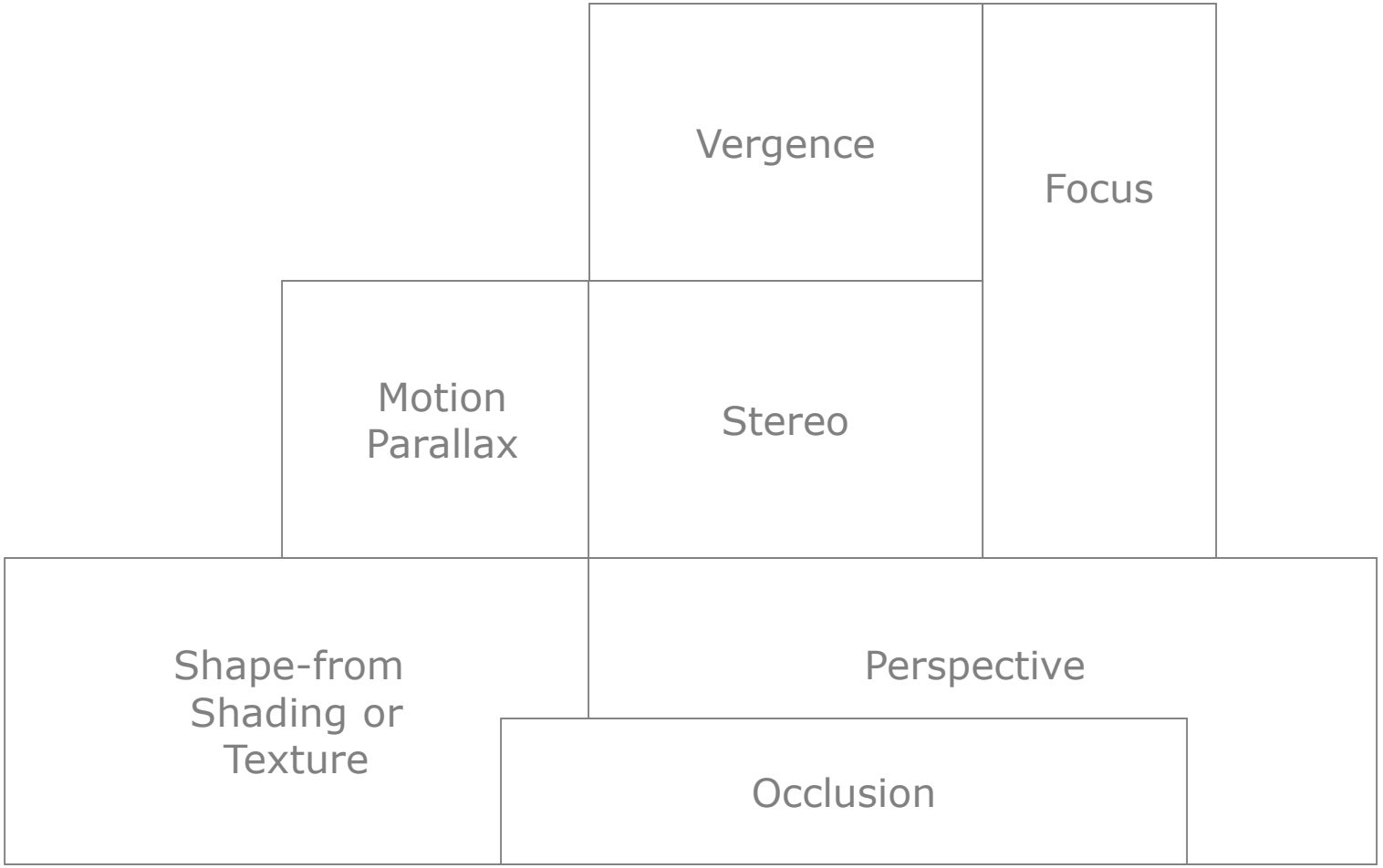
Stereo Vision Basics



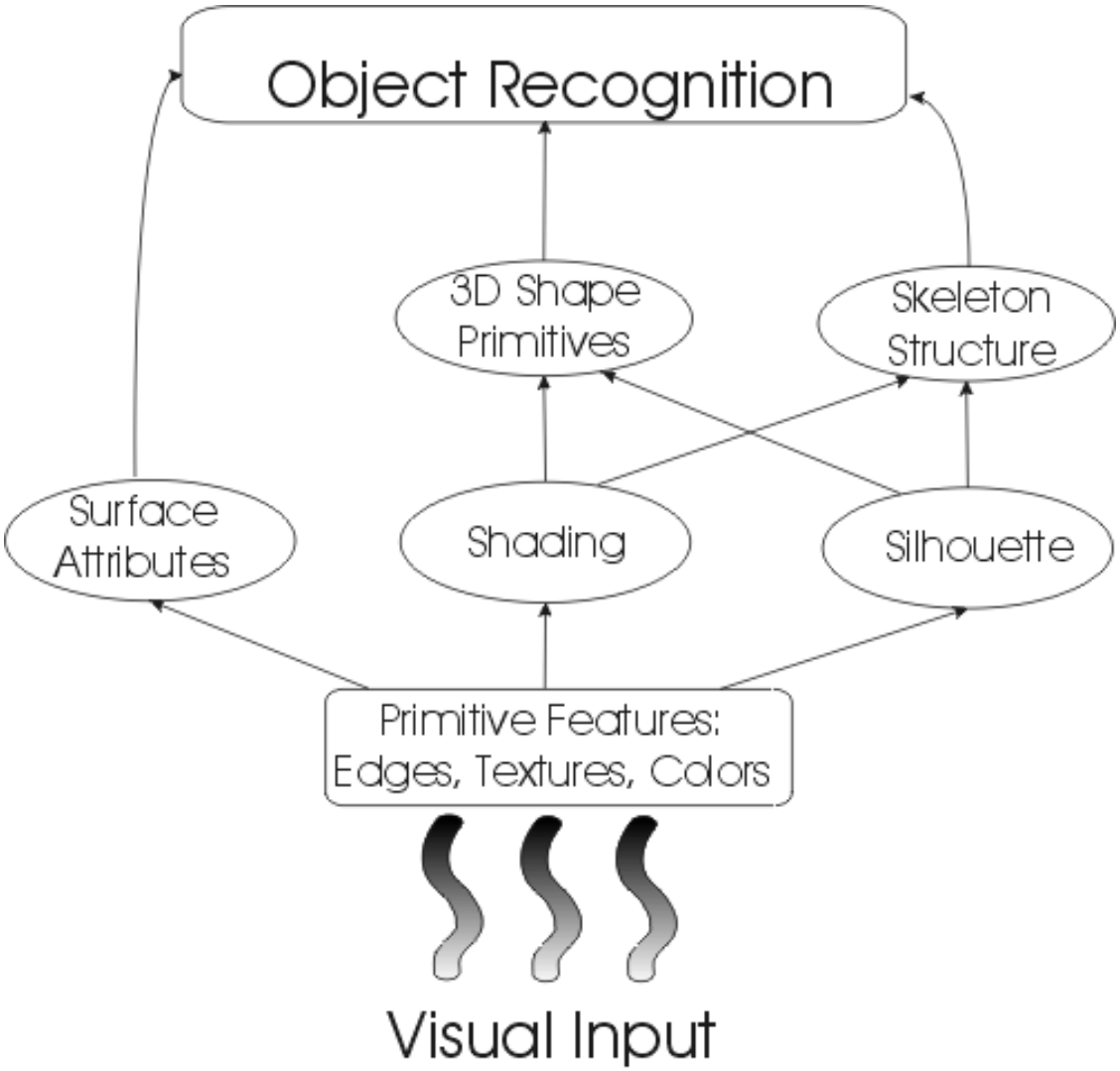
Depth Cues – Relative Importance



Depth Cues – 3D Options



Recognition – Processing Stages



Recap – Human Visual System

Physical World Structured

Stages of Visual Processing

1. **Rapid Parallel Processing**
   - Feature Extraction: Orientation, Color, Texture, Motion
   - Bottom-up processing
   - **Popout Effects**
   - Segmentation Effects: Edges & Regions
2. **Slow Serial Goal-Directed Processing**
   - Object Recognition: Visual attention & Memory important.
   - Top-down processing

Visual System Detects Changes + Patterns

Recap – Luminance versus Color

Luminance Channel

- Detail
- Form
- Shading
- Motion
- Stereo

Color Channels

- Surfaces of Things
  - Sensitive to Small Differences
- Rapid Segmentation

- Categories (about 6-10)
  - Not Sensitive to Absolute Values
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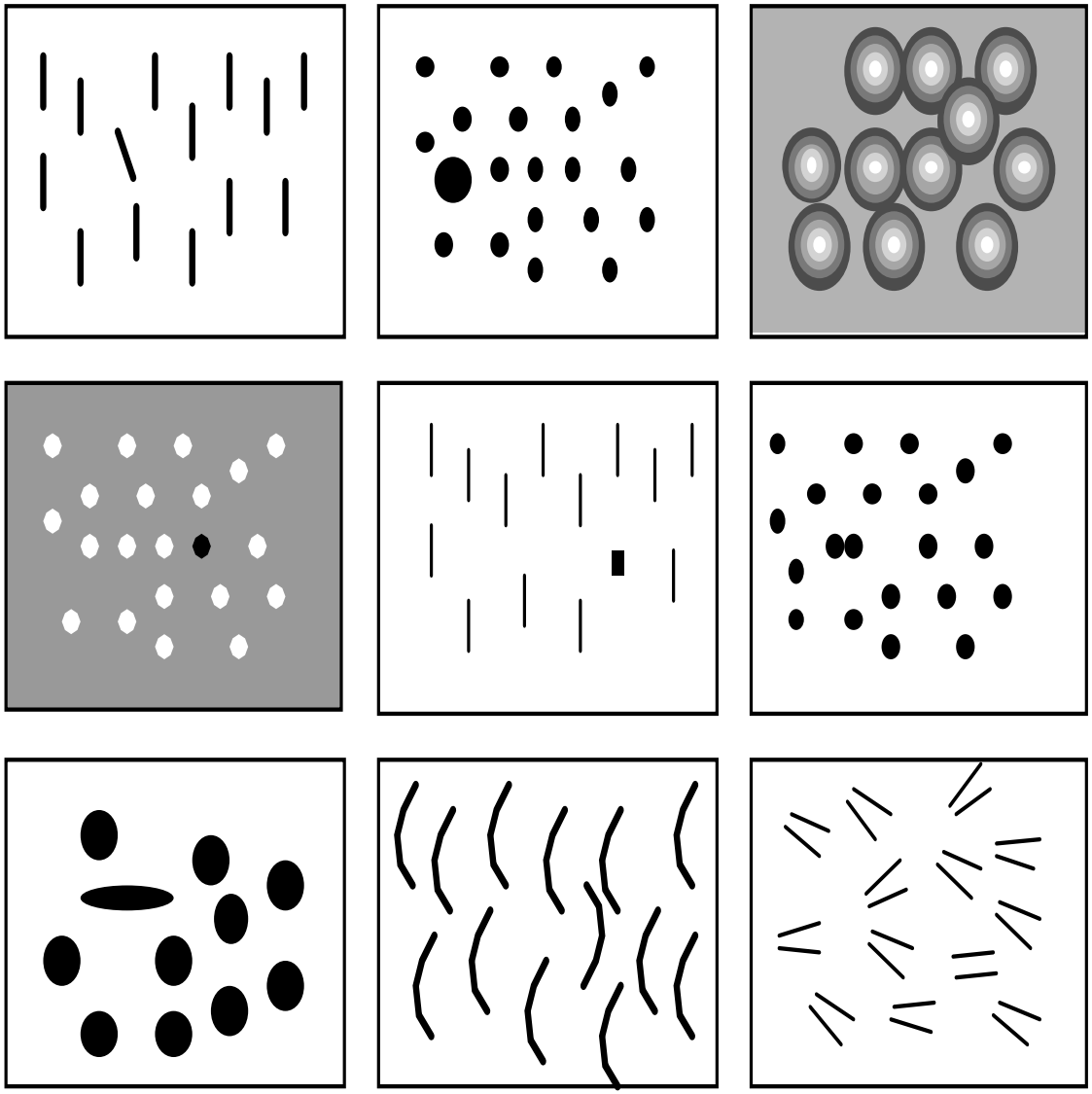
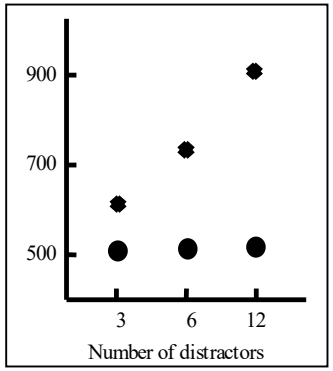
➔ **Luminance** More Important than Color

Recap – Pre-Attentive Visual Features



Recap – Pre-Attentive Visual Features



Pre-Attentive Processing

Important for Design of Visualizations

Pre-Attentive Properties can be **perceived immediately**

Laws of Pre-Attentive Display

Must Stand Out in Simple Dimension

- Position
- Color
- Simple Shape = orientation, size
- Motion
- Depth

Pre-Attentive Conjunctions

- Position + Color
- Position + Shape
- Position + Form
- Color + Stereo
- Color + Motion

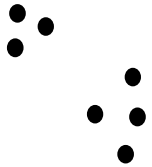
Design of Symbols

Simple Visual Attributes (or combination thereof)

Distinct – Use different visual channels for different types of information

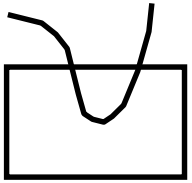
Recap – Gestalt Laws

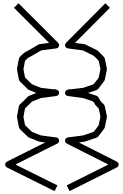
Proximity



Similarity

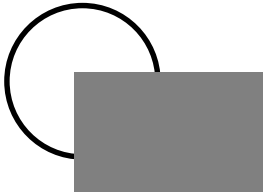
Continuity





Symmetry

Closure



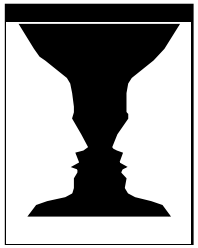


Figure / Ground

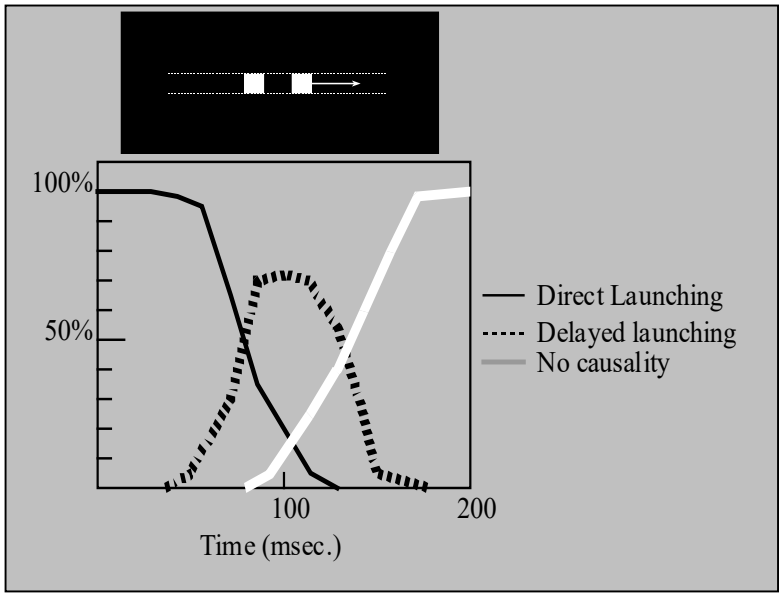
Recap – Motion

Motion Phenomena

- Kinetic Depth demo
- Anthropomorphic Form from Motion demo
- iPod ads

➔ **Structure** from **Silhouettes** and **Motion**

Perception of Causality



Important for Design of Visualizations

Use **Luminance for Detail, Shape and Form**

Make sure strong **Luminance Contrast**

Use **Color for Categorization** - few colors

Strong Colors for **Small Areas**

Subtle Colors for **Large Areas**

Leverage **Pre-Attentive Visual Properties**

Leverage **Gestalt Laws** and **Depth Cues**

Use Simple Motion Coding

- Causality
- Urgency

Edward Tufte

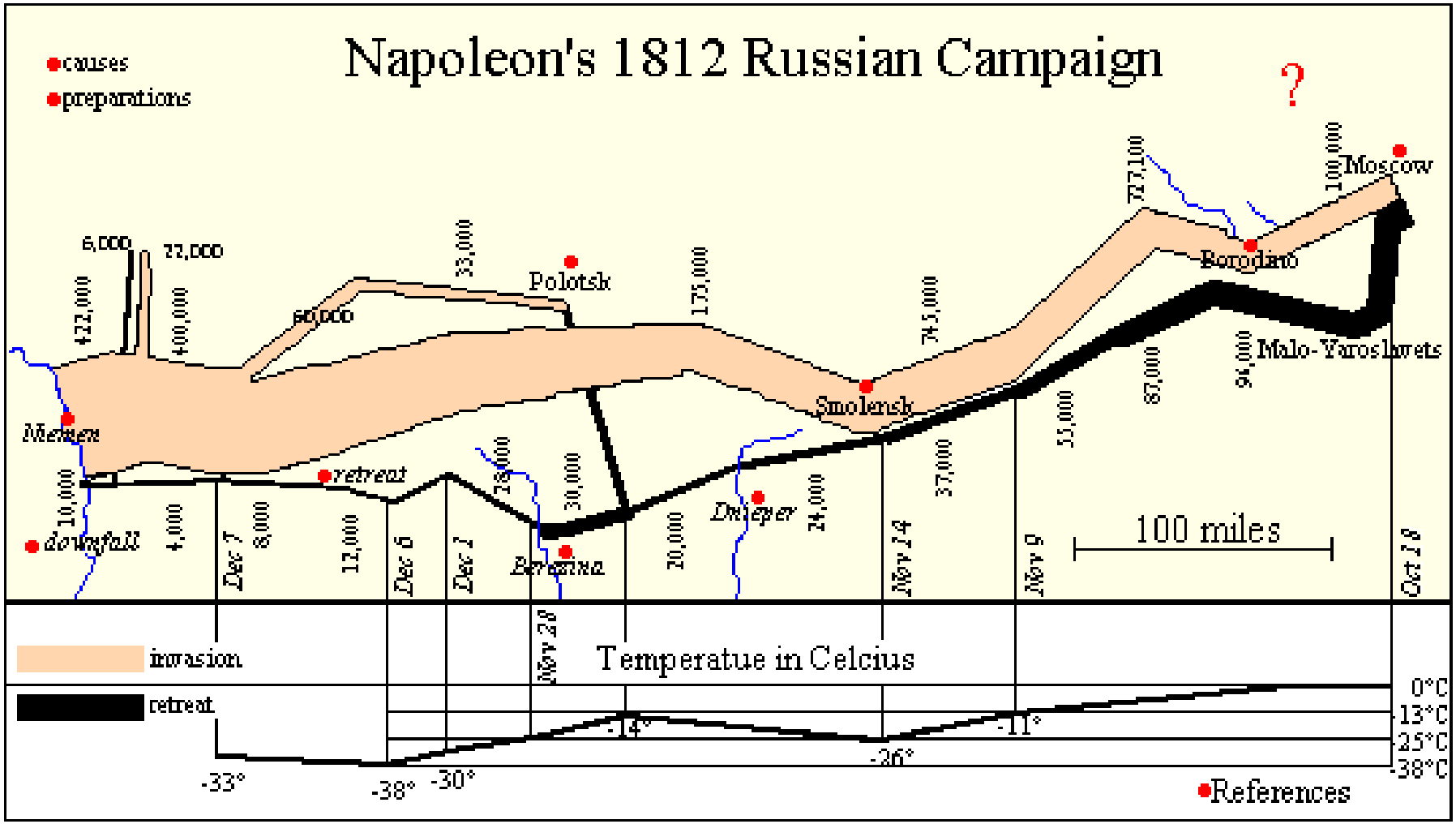
Books

The Visual Display of Quantitative Information

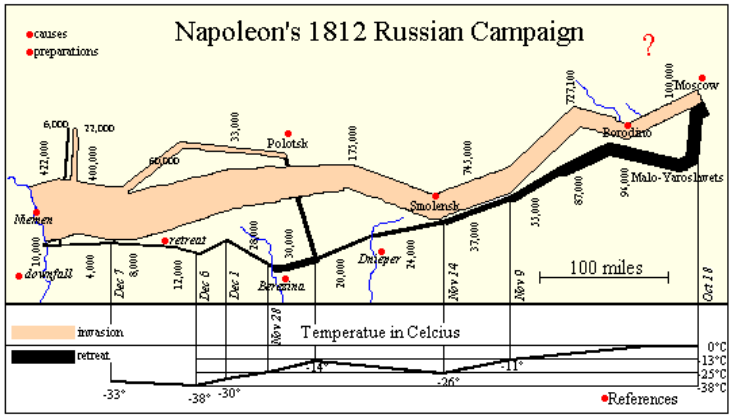
Envisioning Information

Visual Explanations

Tufte - Minard's *Napoleon's March to Moscow*



Tufte - Escape Flatland: Napoleon's March



Enforce Visual Comparisons

Width of tan and black lines gives you an immediate comparison of the size of Napoleon's army at different times during march.

Show Causality

Map shows temperature records and some geographic locations that shows that weather and terrain defeated Napoleon as much as his opponents.

Show Multivariate data

Napoleon's March shows six: army size, location (in 2 dimensions), direction, time, and temperature.

Use Direct Labeling

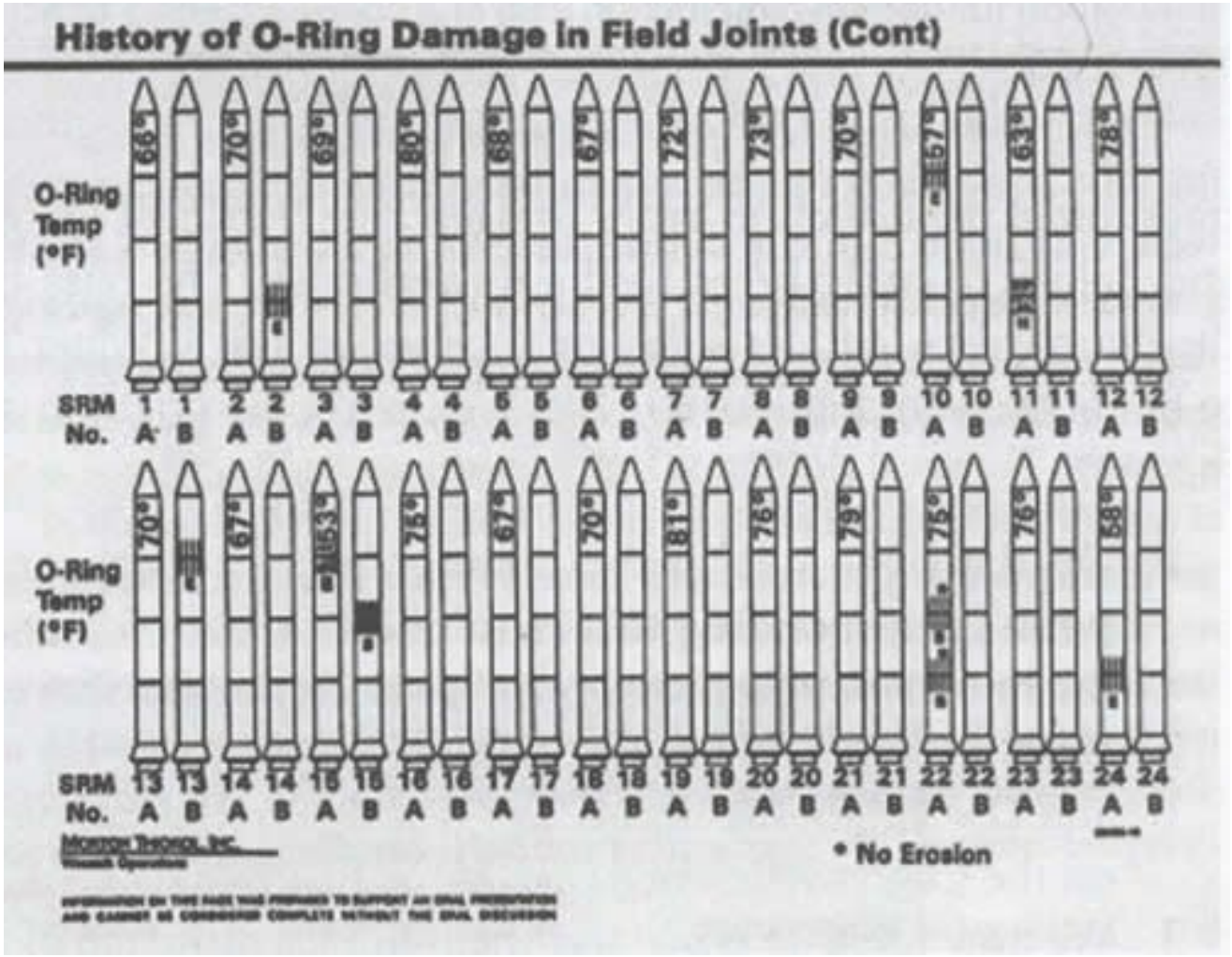
Integrate words, numbers & images

Don't make user work to learn your "system."

Legends or keys usually force the reader to learn a system instead of studying the information they need.

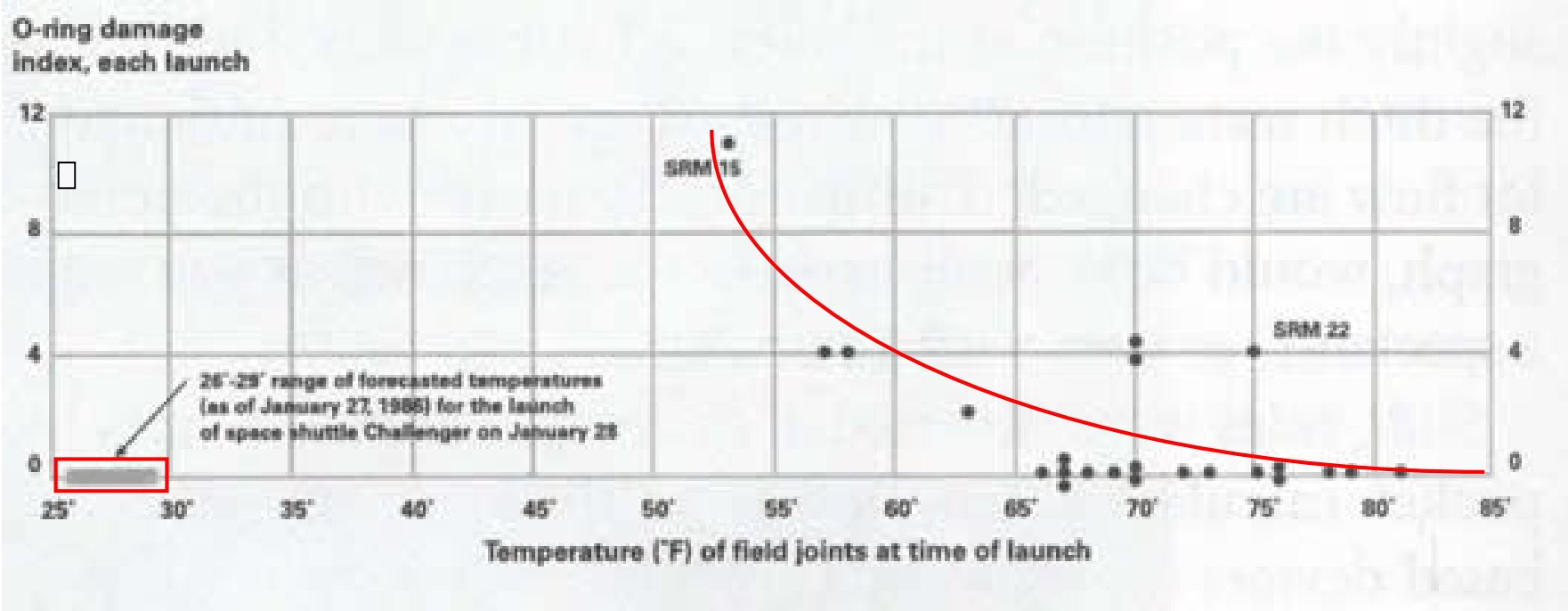
Design Content-Driven

Tufte – Challenger Data: Launch?



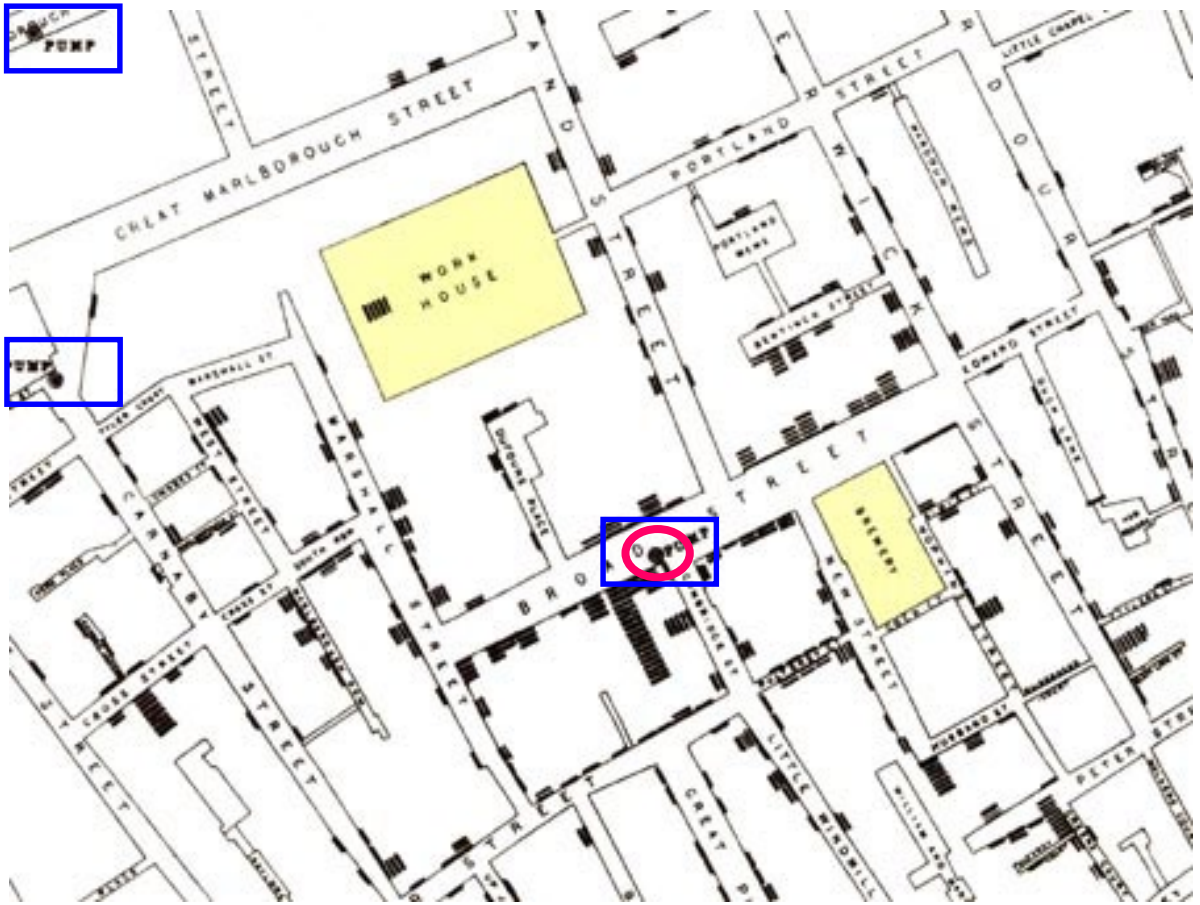
Graph obscures important variables of interest: temperature is shown textually and graphically; degree of damage is not mapped onto a nominal scale

Tufte – Challenger Data: Launch?



Diagrams can lead to great insight, but also to lack of it

Cause of cholera epidemic in London in 1854?



John Snow's deduction that a cholera epidemic was caused by a bad water pump

Modified in **Visual Explanations** by Edward Tufte, Graphics Press, 1997

Tufte's Measures

Maximize data-ink ratio

$$\text{Data ink ratio} = \frac{\text{Data ink}}{\text{Total ink used in graphic}}$$

Maximize data density

$$\text{Data density of graphic} = \frac{\text{Number entries in data matrix}}{\text{Area of data graphic}}$$

Measuring Misrepresentation → close to 1

$$\text{Lie factor} = \frac{\text{Size of effect shown in graphic}}{\text{Size of effect in data}}$$

Tufte - Graphical Displays Should

Show Data

Focus on Content instead of graphic production

Avoid Distorting what **Data** has to say

Make Large Data Sets Coherent

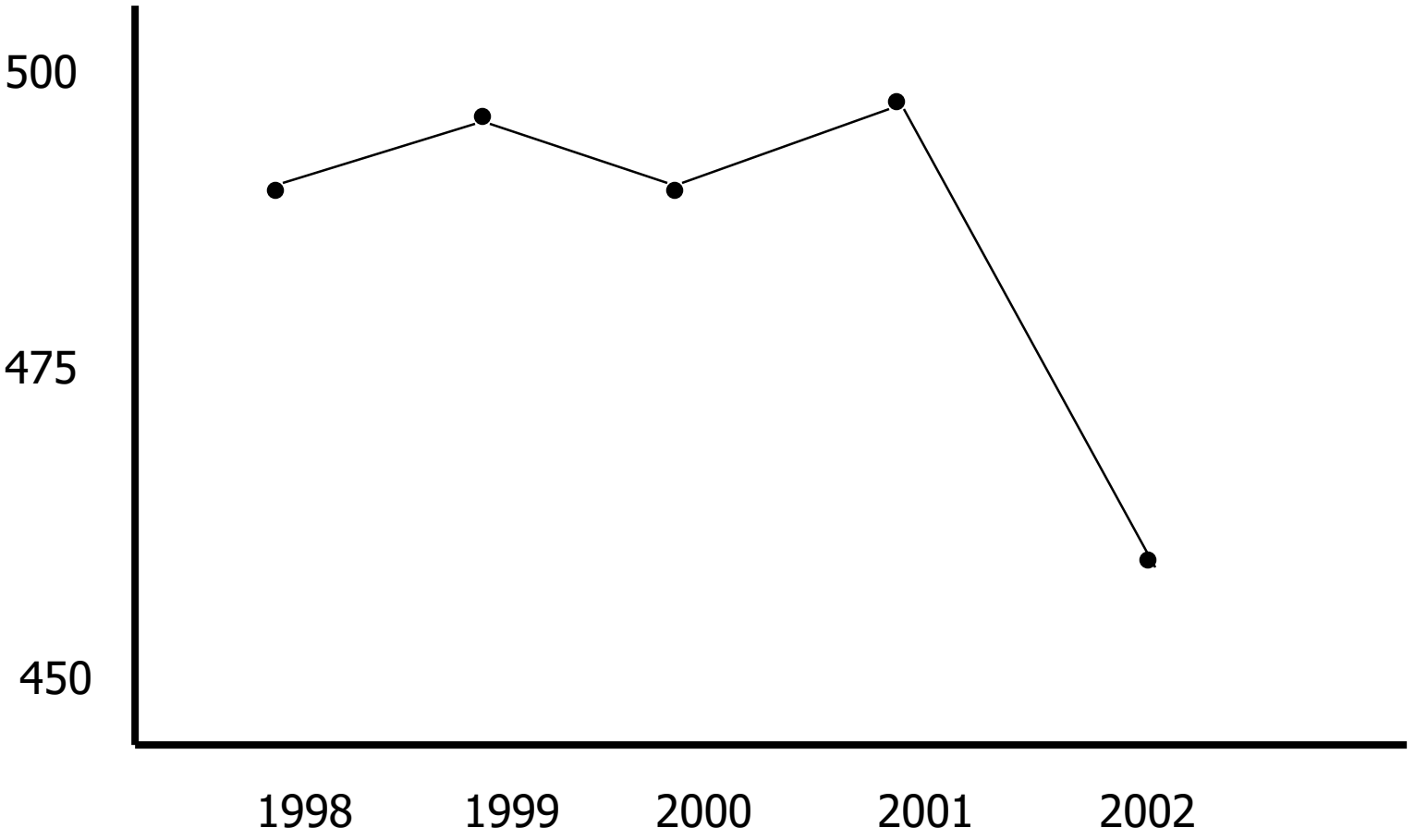
Encourage Eye to Compare Different Pieces of Data

Reveal Data at several Levels of Detail

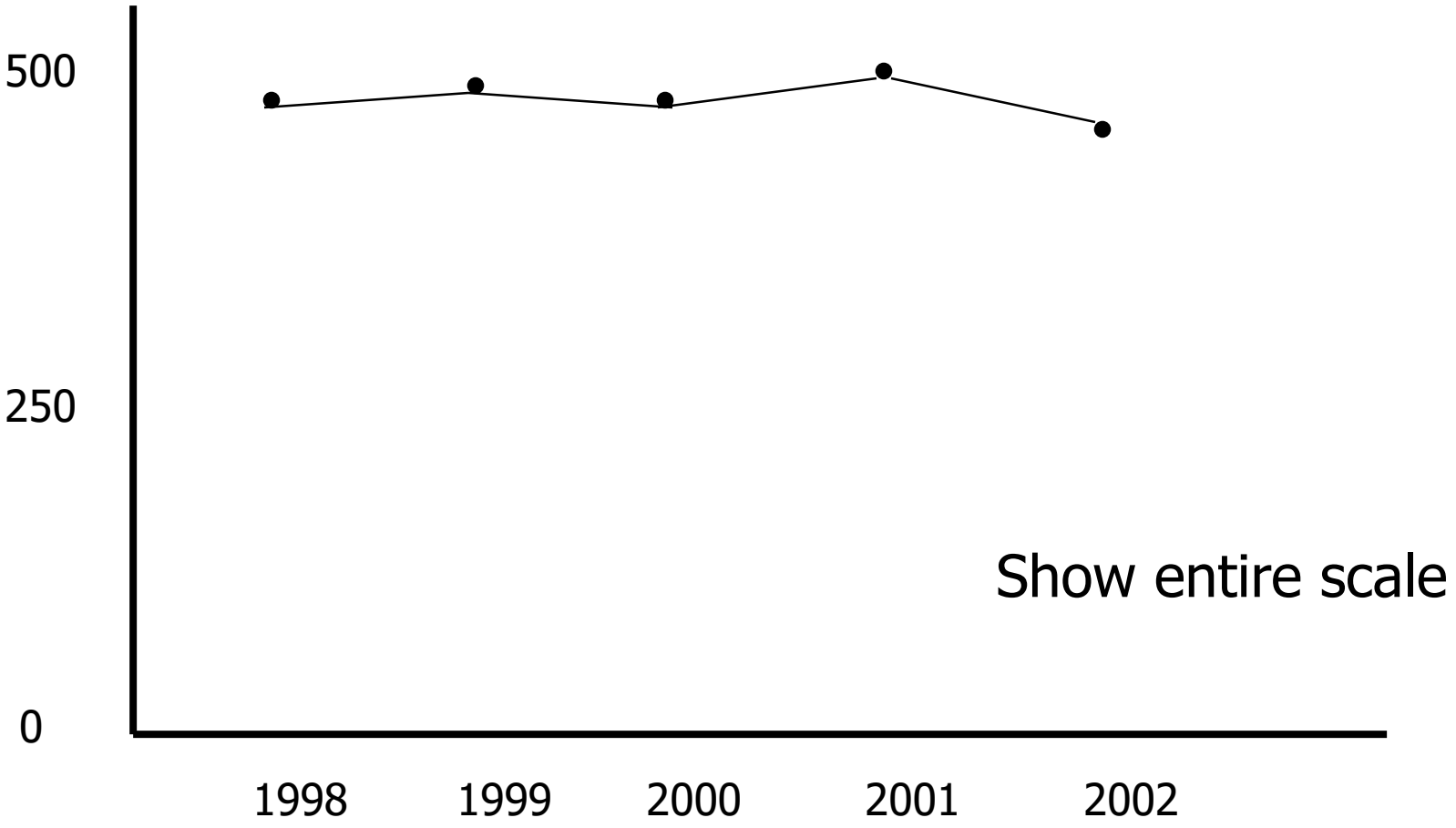
Closely integrate Statistical and Verbal Descriptions

Example

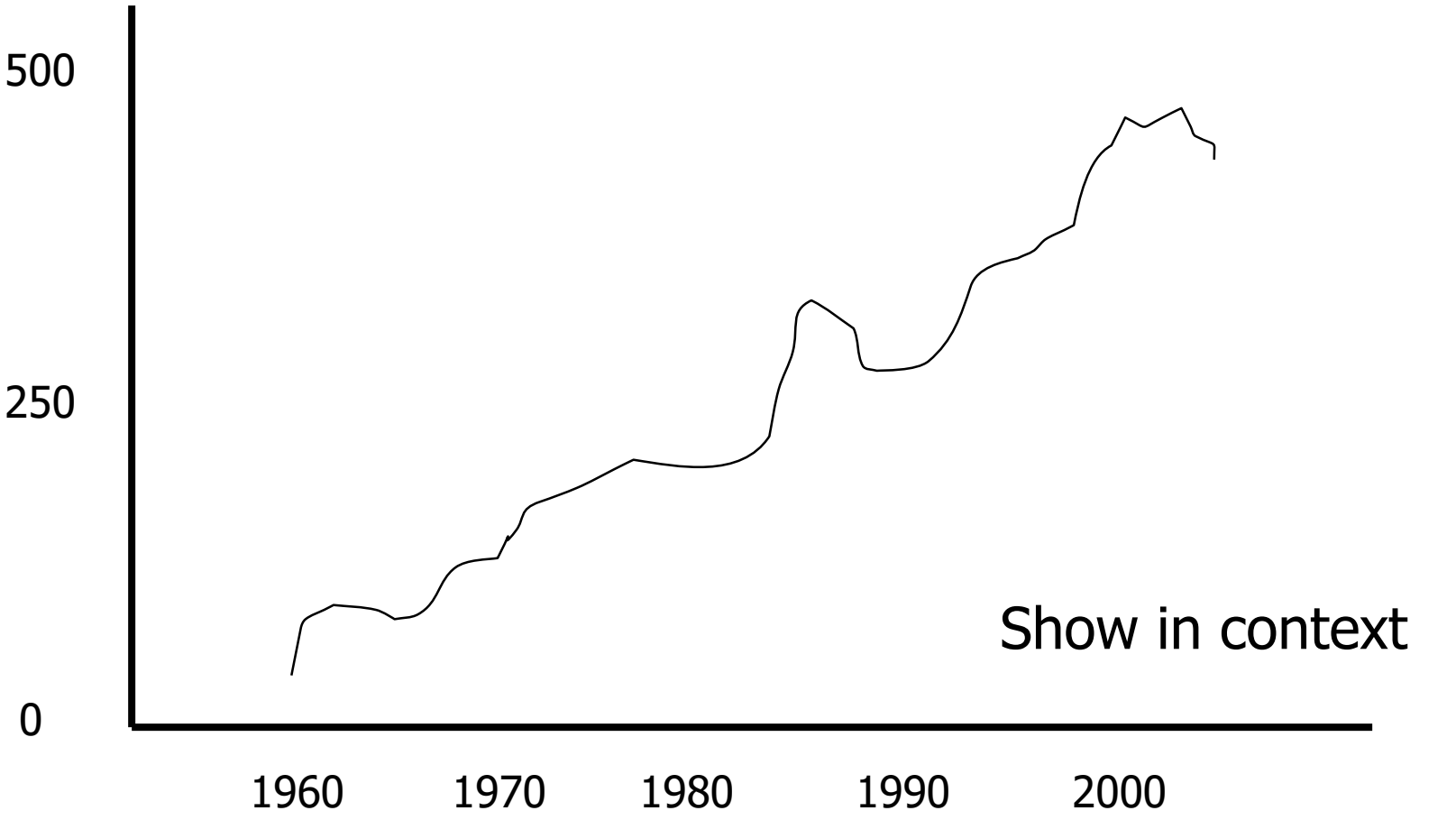
Stock market crash?



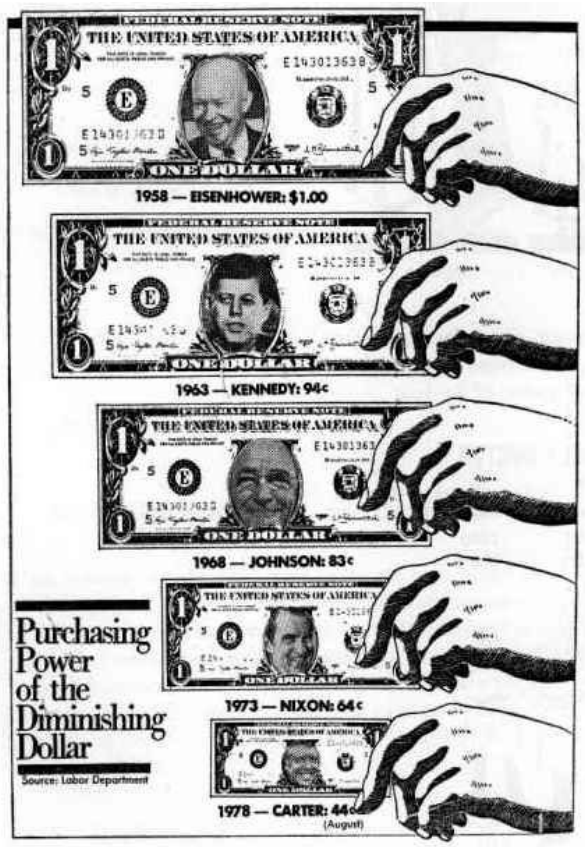
Example



Example



Tufte - How to Exaggerate with Graphs



Washington Post, October 25, 1978, p. 1.

Error: Shrinking along both dimensions

Tufte - Graph & Chart Tips

Avoid Separate Legends and Keys

Make Grids, labeling, etc., Very Faint so that they recede into background

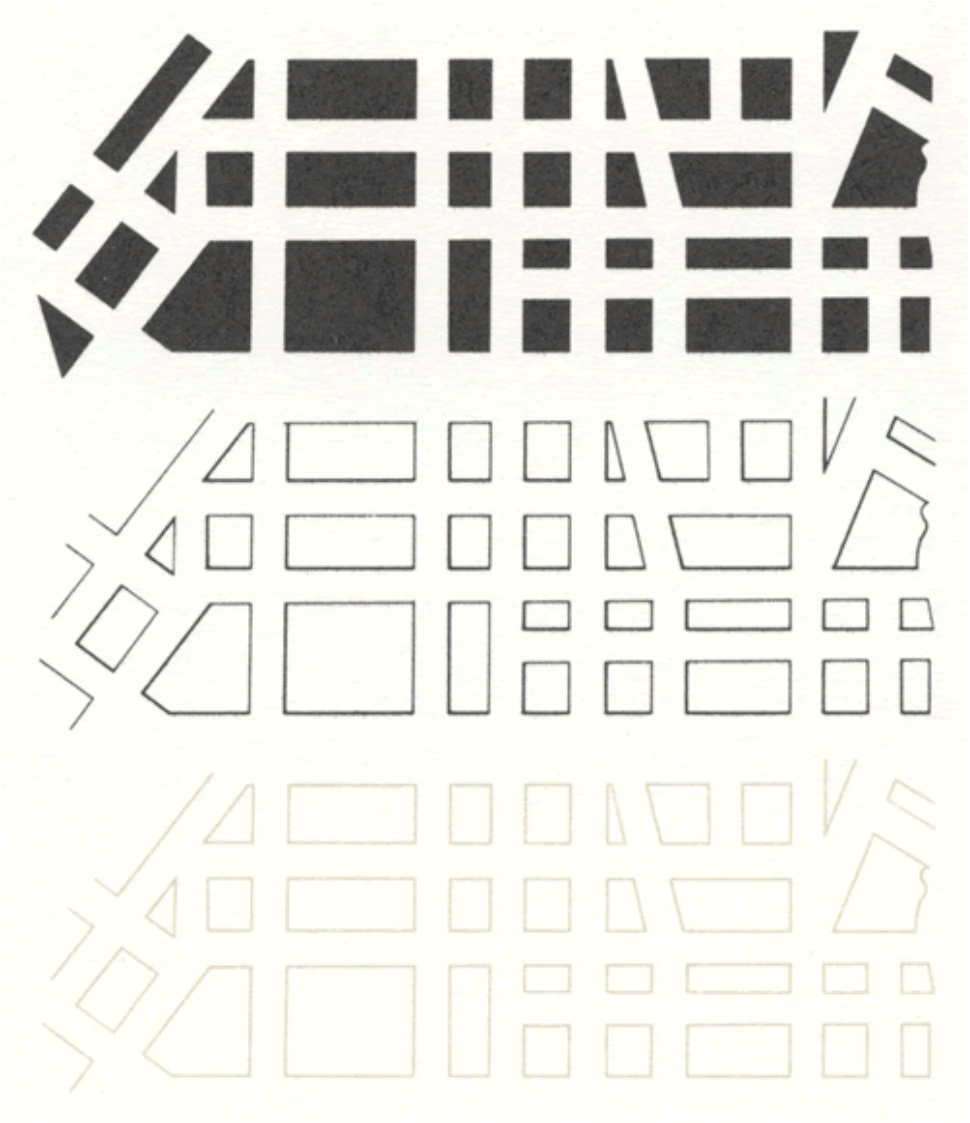
Graphical Integrity

- Where's baseline?
- What's scale?
- What's context?
- Watch Size Coding: Height/width vs. area vs. volume

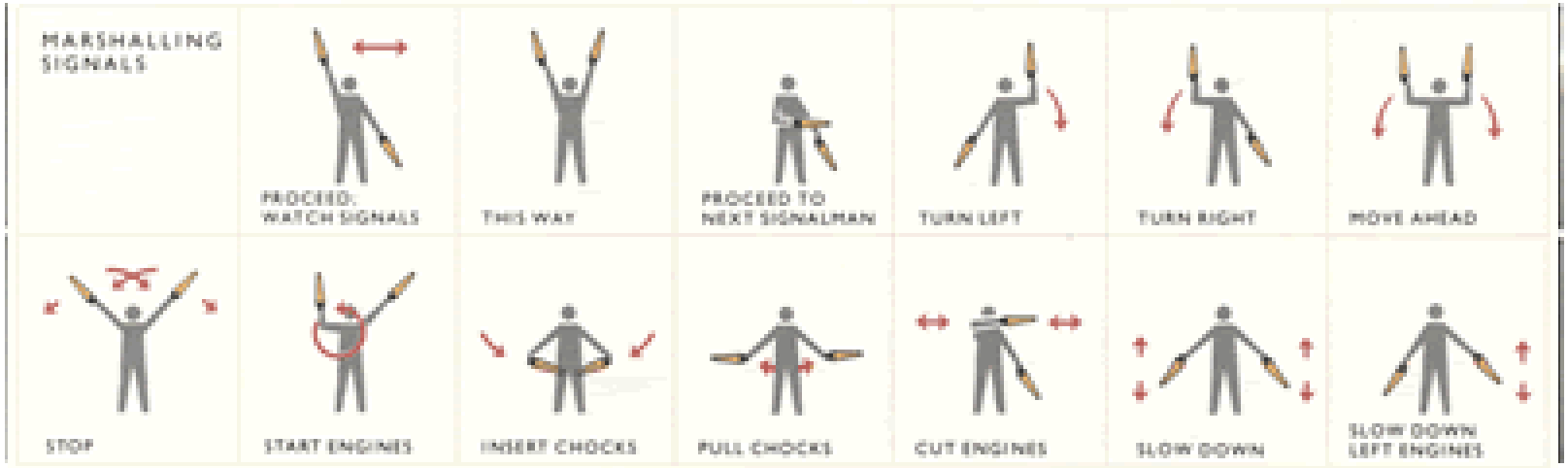
Using Color Effectively

- To label
- To measure
- To represent or imitate reality
- To enliven or decorate

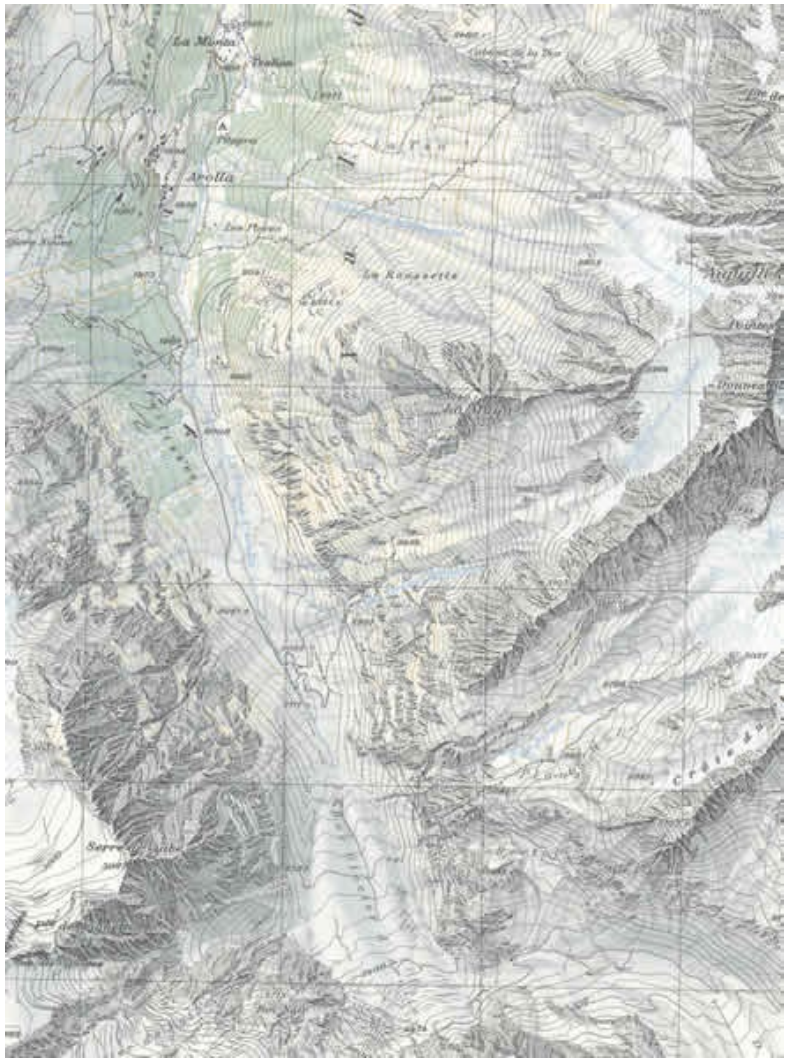
Tufte – Hierarchy of Visual Effects



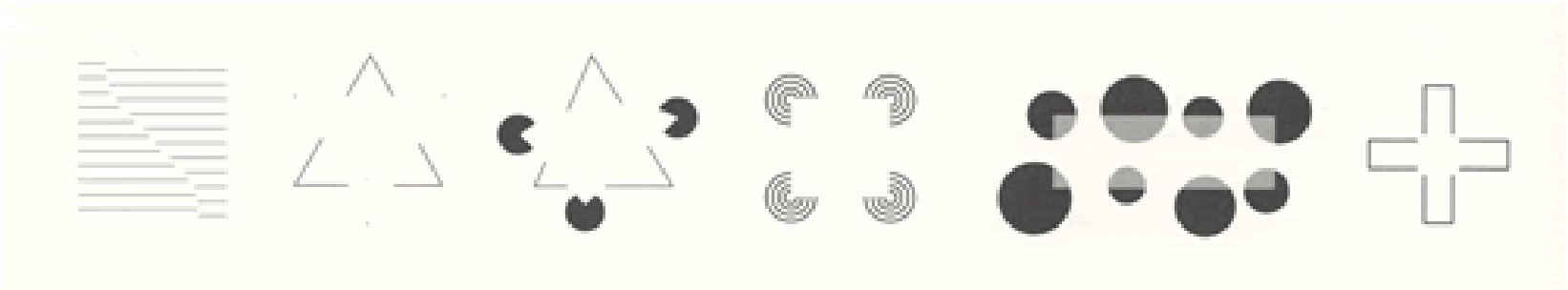
Tufte – Hierarchy of Visual Effects



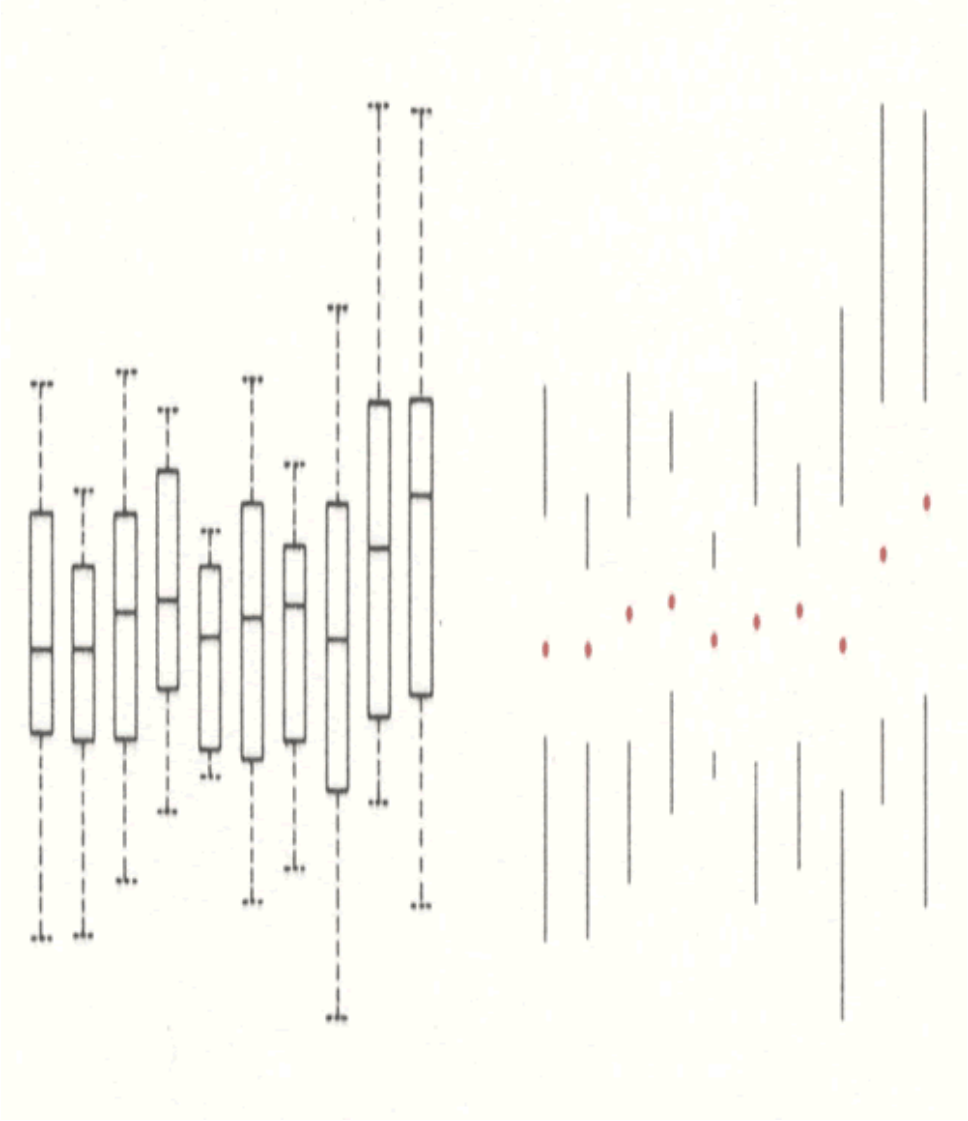
Tufte – Hierarchy of Visual Effects in Maps



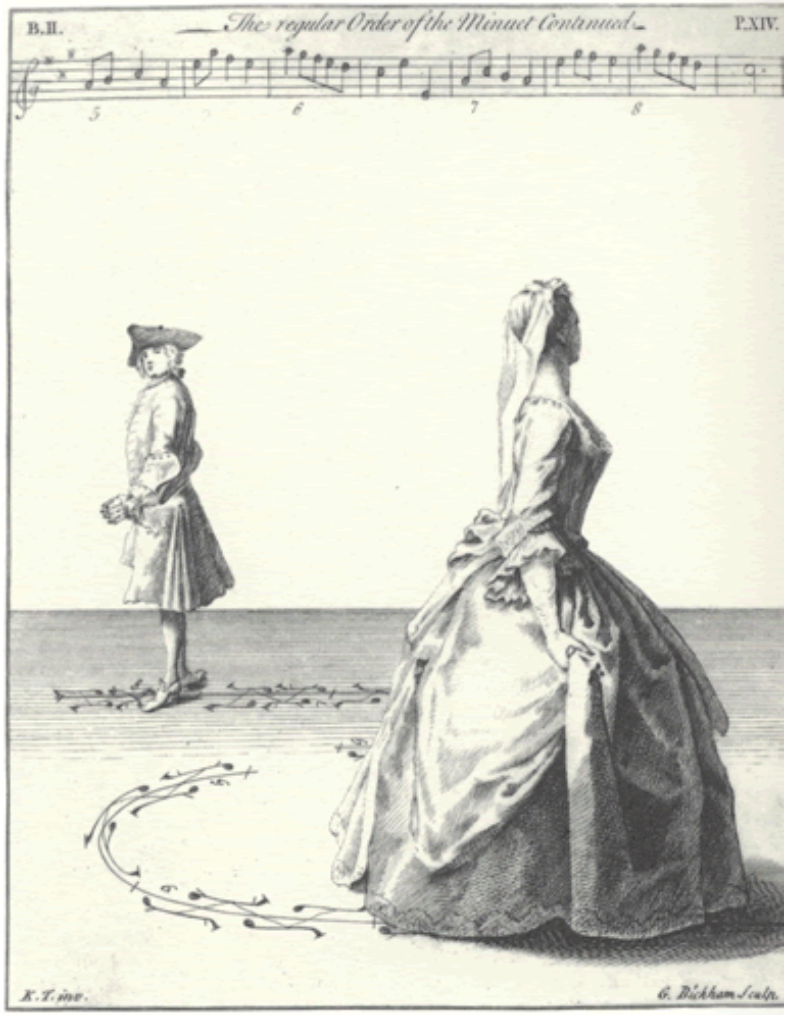
Tufte – Be aware of visual artifacts



Tufte – Leverage Illusionary Contours



Tufte – Narratives of Space & Time

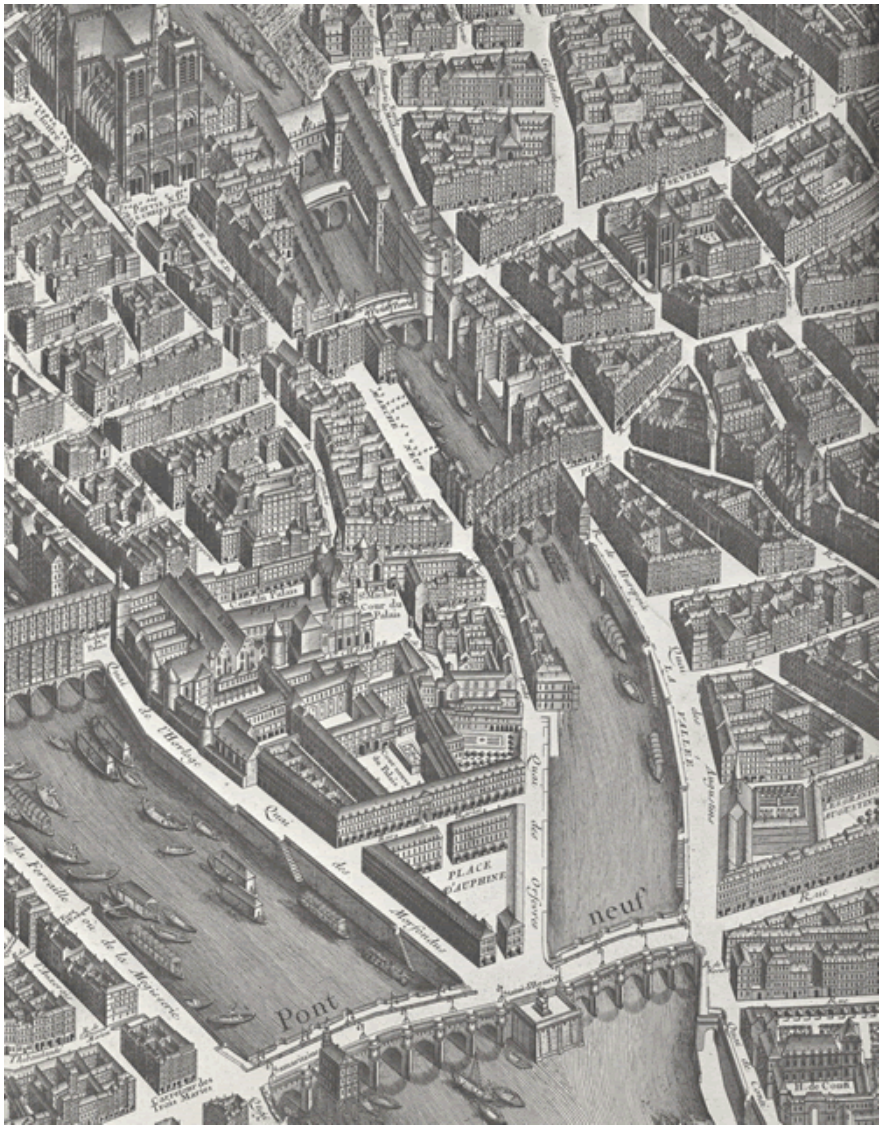


Tufte – Micro / Macro Readings - 2½ Displays

Axonometric Projection

To Clarify, Add Detail

Tufte – Micro / Macro Readings - 2½ Displays



Tufte's Principles – Summary

Good Information Design = Clear Thinking Made Visible

Greatest number of **Ideas**
in **Shortest Time**
with **Least Ink** in the **Smallest Space**

Principles

- **Enforce Visual Comparisons**
  Show Comparisons Adjacent in Space
- **Show Causality**
- **Show Multivariate Data**
- **Use Direct Labeling**
- **Use Small Multiples**
- **Avoid "Chart Junk":** Not needed extras to be cute