

PERCEPTION, COLOR

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Perception

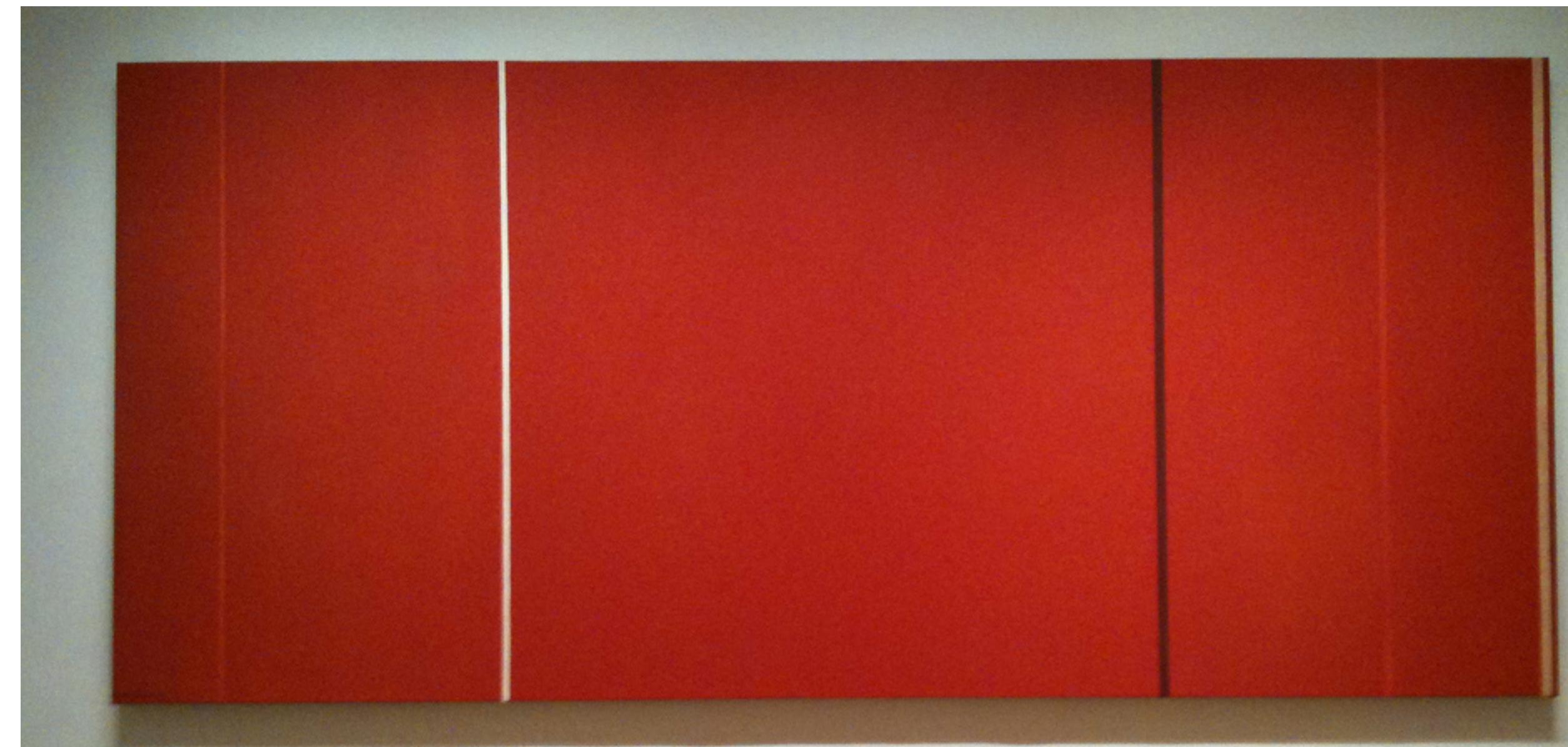
Perception: interpretation of our surroundings through sensory stimuli

sight, sound, taste, smell, and touch

Depends on what you have learned, what you remember and what you expect!

Not conscious, reflexes

Vir heroicus sublimis - Barnett Newman



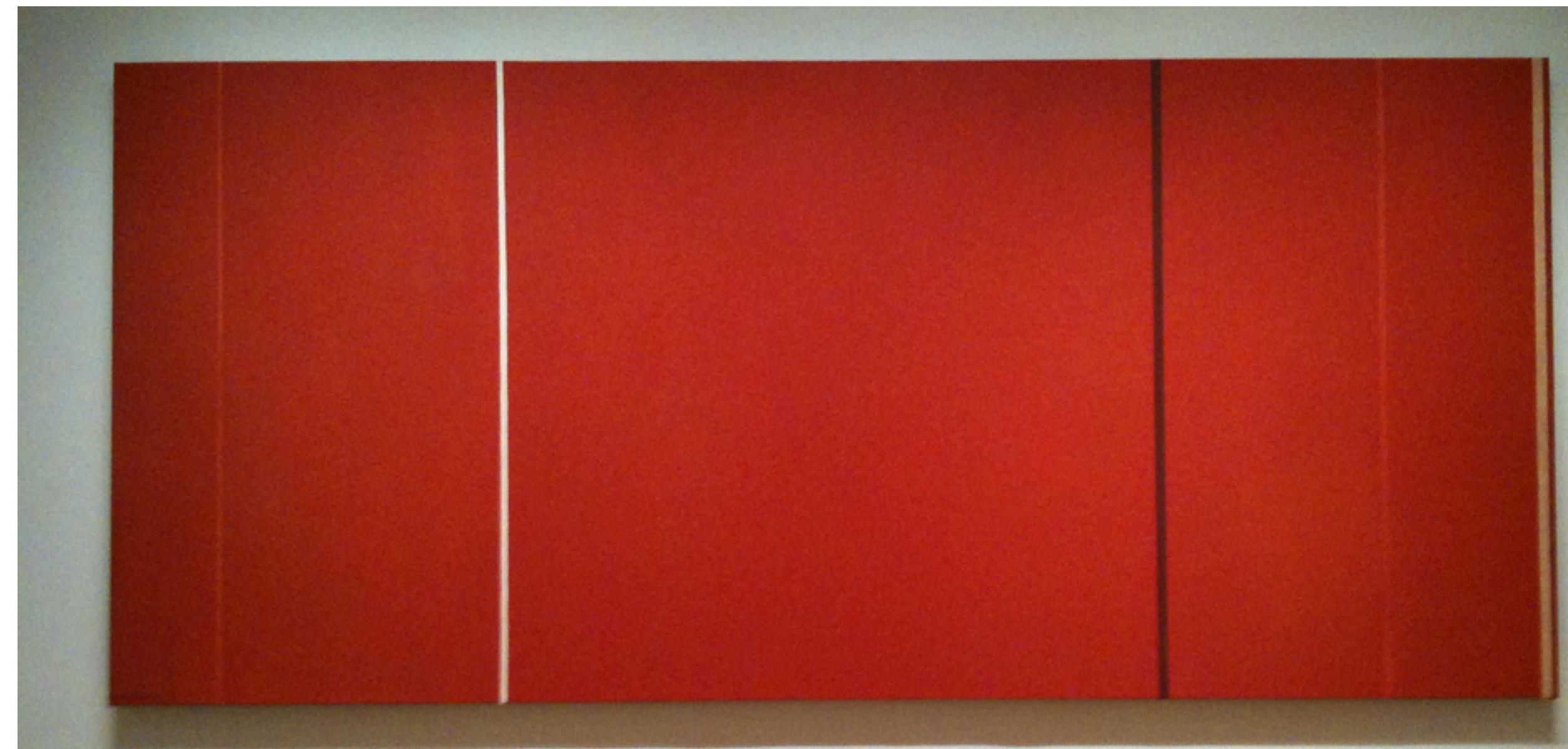
Cognition

Cognition: mental processes to remember, think, know, judge, solve problems

information processing

Vir heroicus sublimis - Barnett Newman

sold for \$105.7 Million



Perception vs cognition

Classic conflict in the brain perception vs cognition: Stroop effect





Human visual system

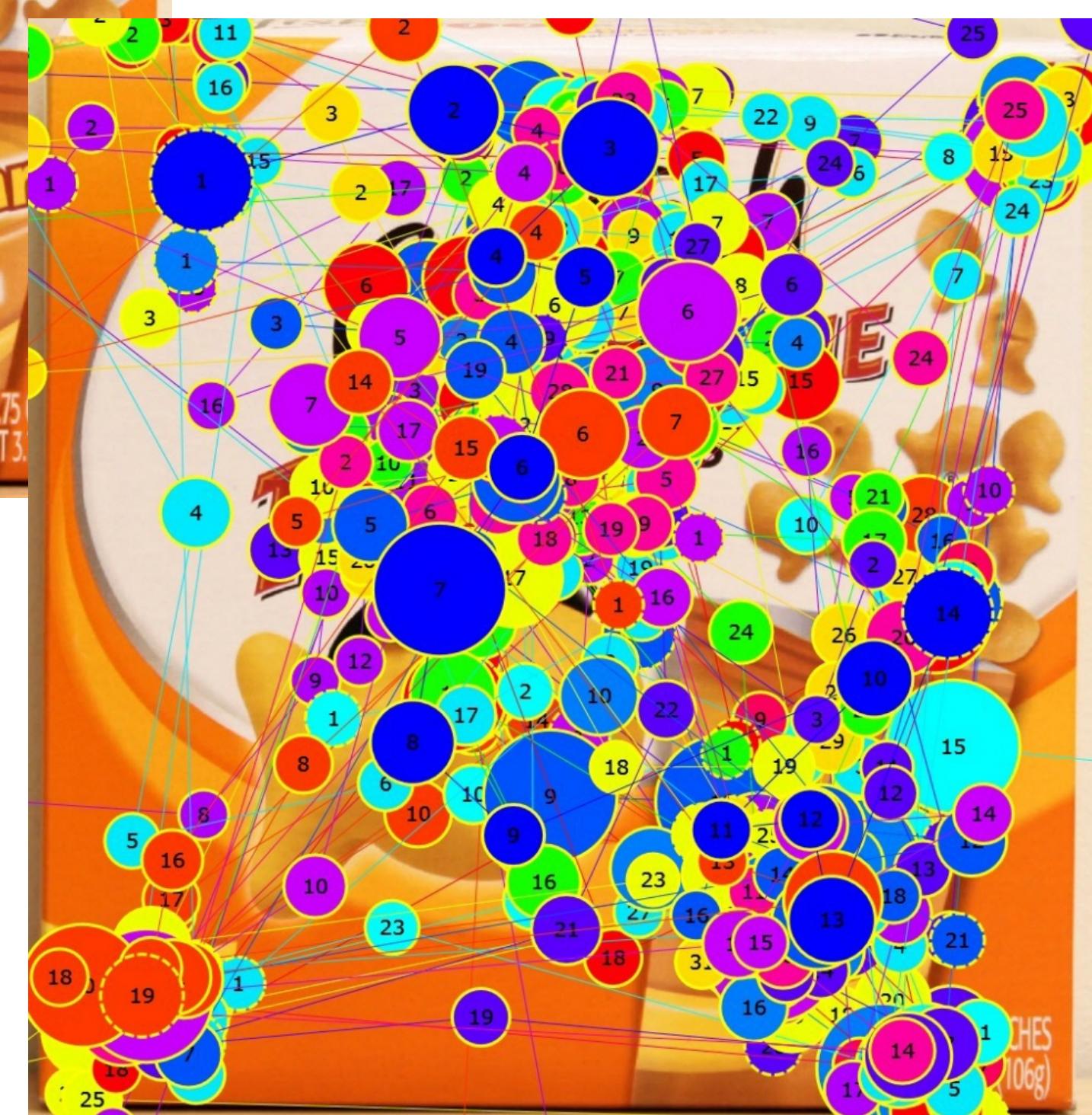
Vision works as a sequence of rapid eye movements: **fixations** and **saccades**

Fixation: maintaining gaze on a location during 200-600 ms

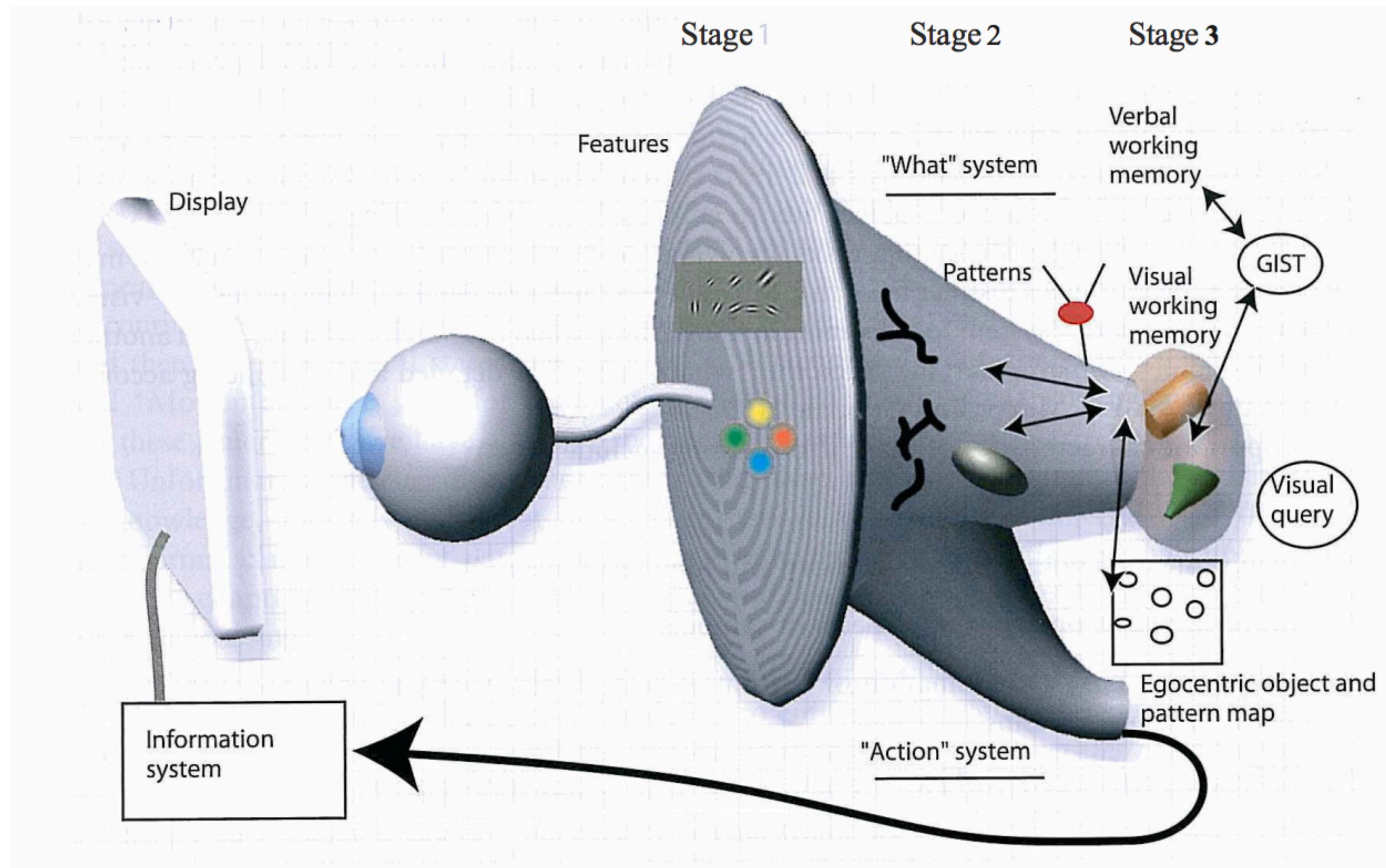
Saccade: quickly switching between different locations 20-100ms



Gaze plot example



Visual information processing model



A three-stage model of human visual information processing.

[Ware]

Implications for data viz

“Visual thinking consists of a series of acts of attention called visual queries, driving eye movements and tuning our pattern-finding circuits”
[Colin Ware]

Our goal is to design visualizations so that **visual queries are processed both rapidly and correctly for every important cognitive task we support in our viz.**



Vision and colors

The eye

Light -> cornea -> pupil -> lens -> retina

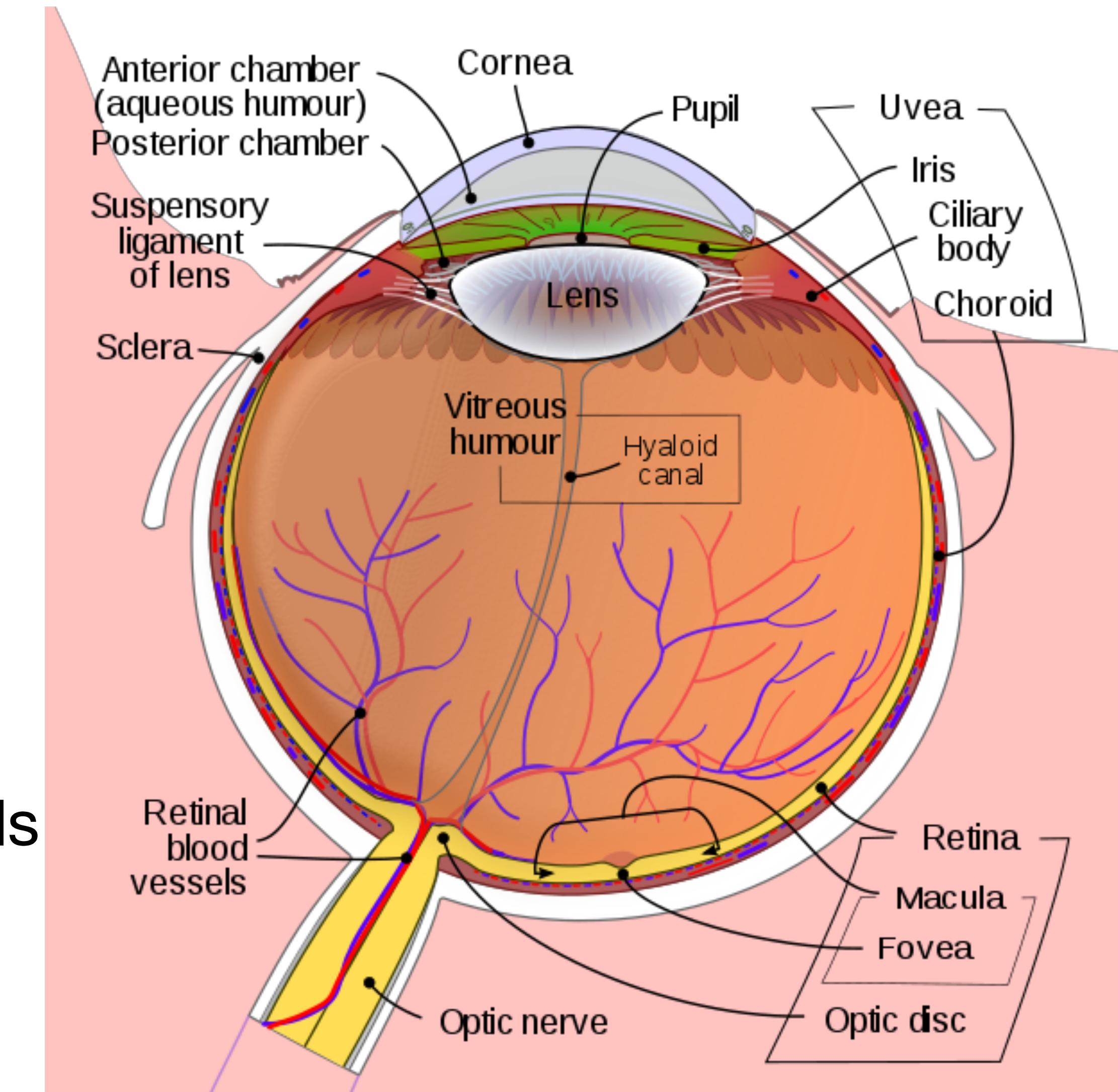
Retina consists of a large number of photoreceptor cells: **Rods and Cones**

Cones: color vision, dense in the center

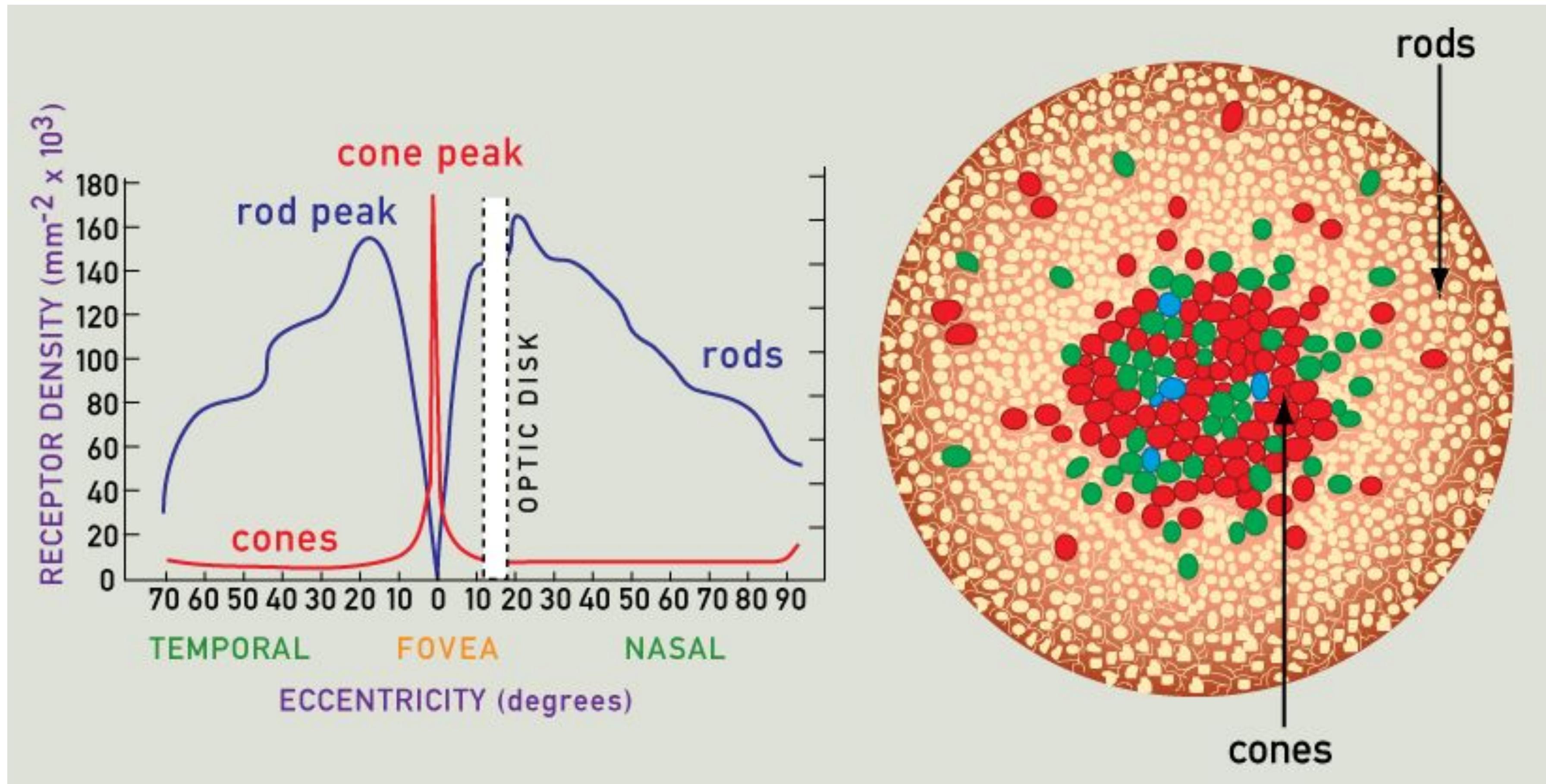
Rods: black/white, low light vision

Fovea: 27 times denser with only cones cells

Responsible of the sharp central vision



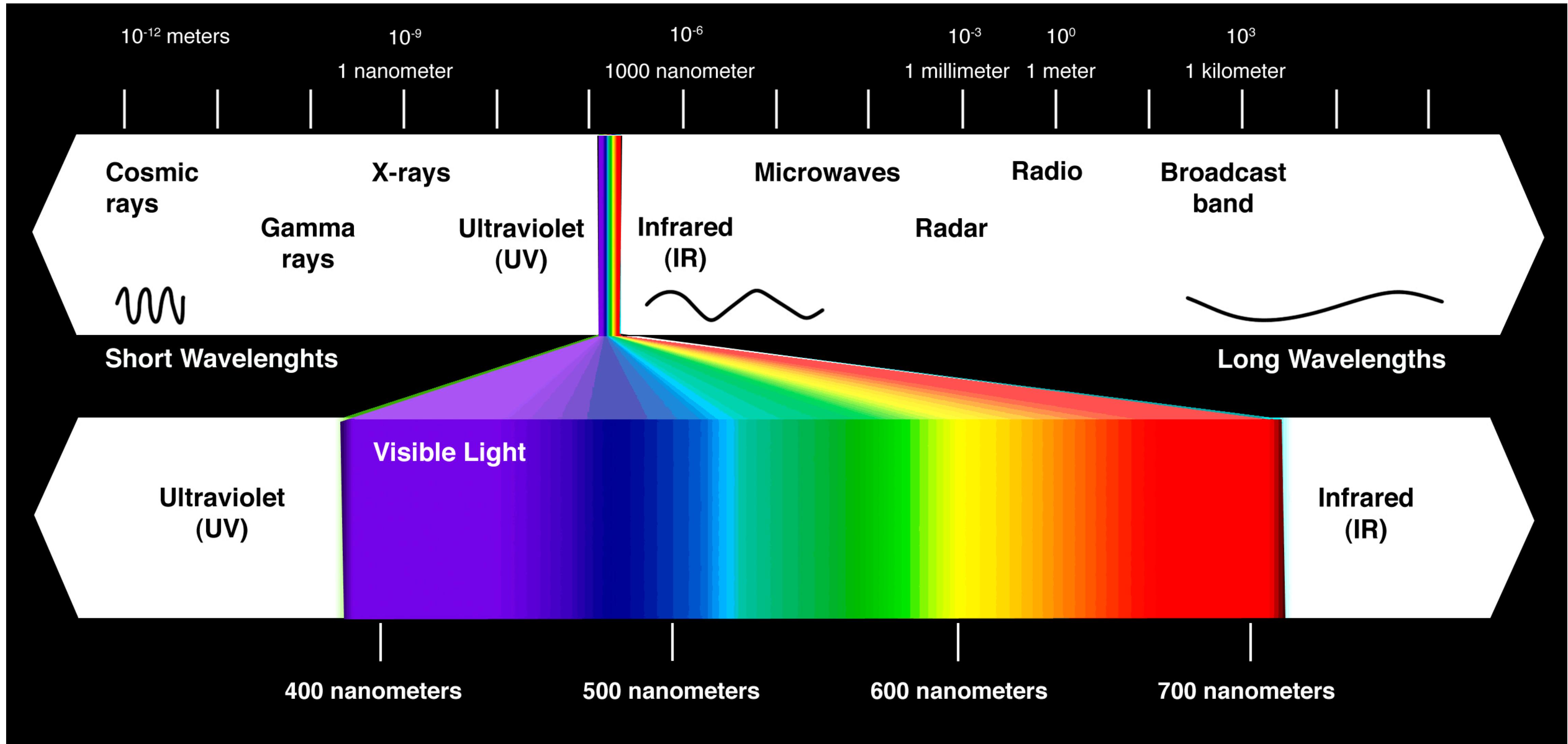
Rods and cones distribution



$\approx 6 \text{ mio cones}$

R 63% - G 31% - B 6%

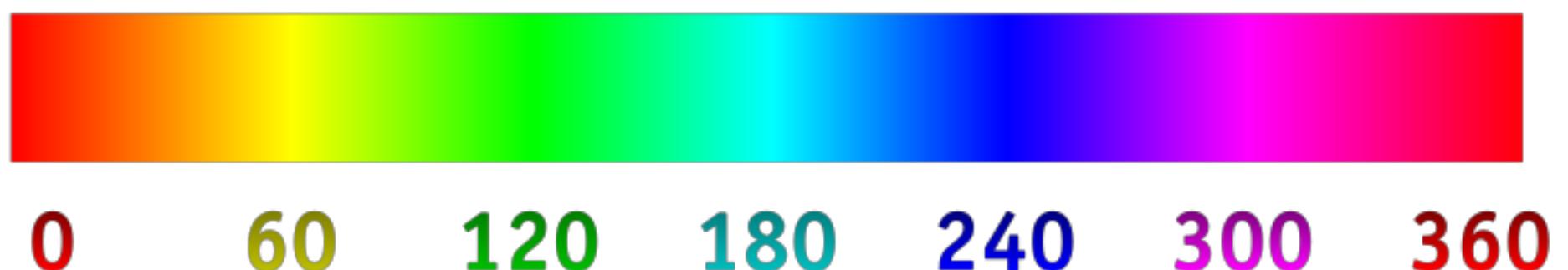
Color and light



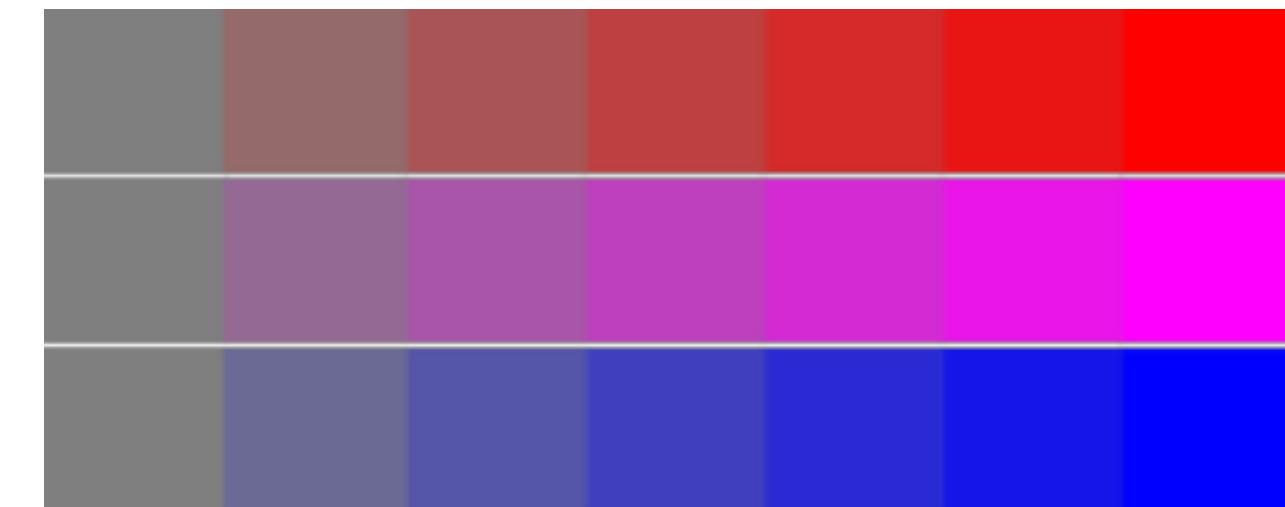
Color attributes

Any color can be described in terms of its hue, value and saturation

Hue: pure color without tint or shade



Saturation: purity of a color, the purest would be one wavelength at high intensity (laser)



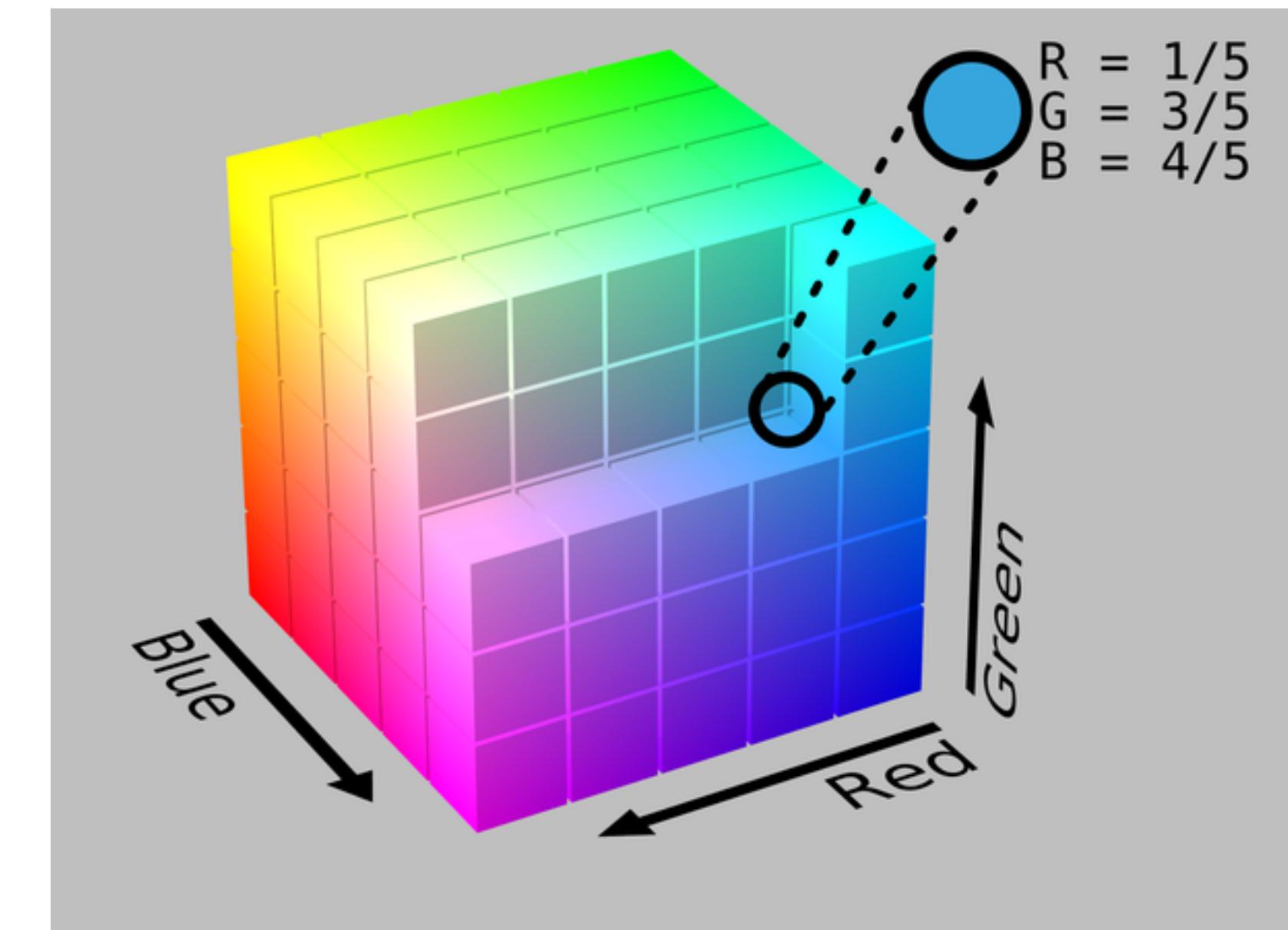
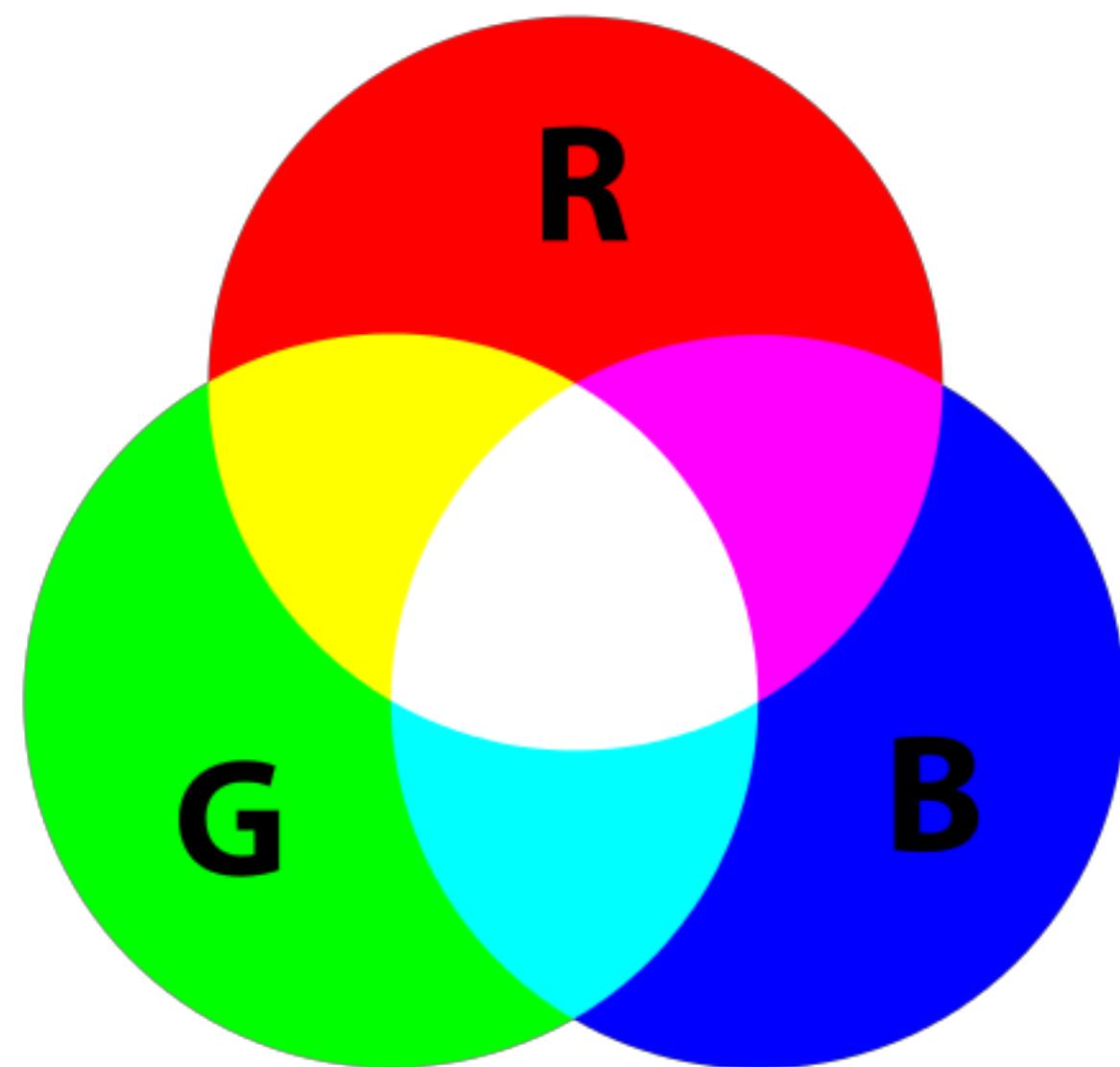
Value (luminance, brightness): lightness or darkness of a color



RGB color space

RGB color space: based on an **additive** color model in which red, green and blue light are added together.

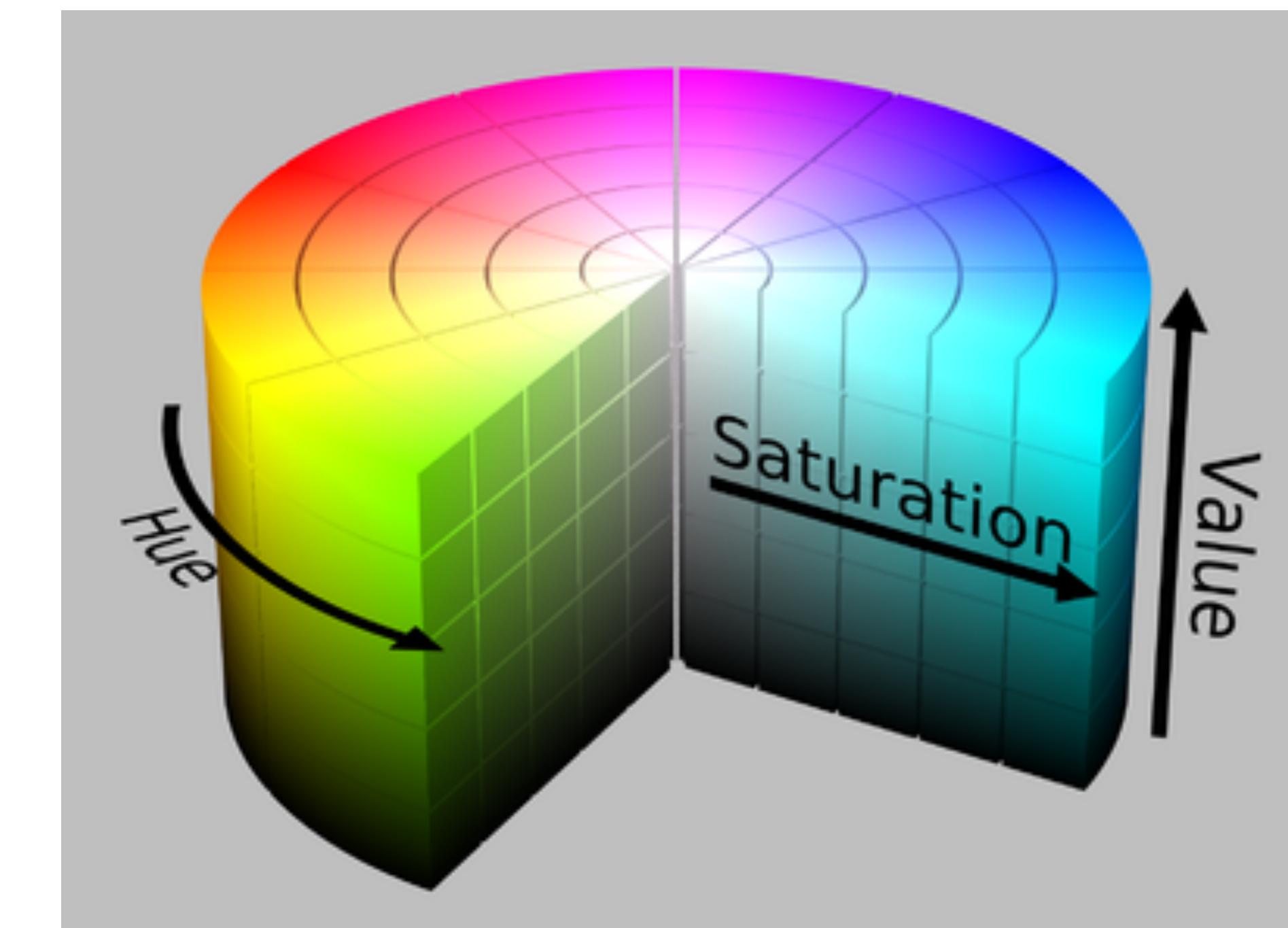
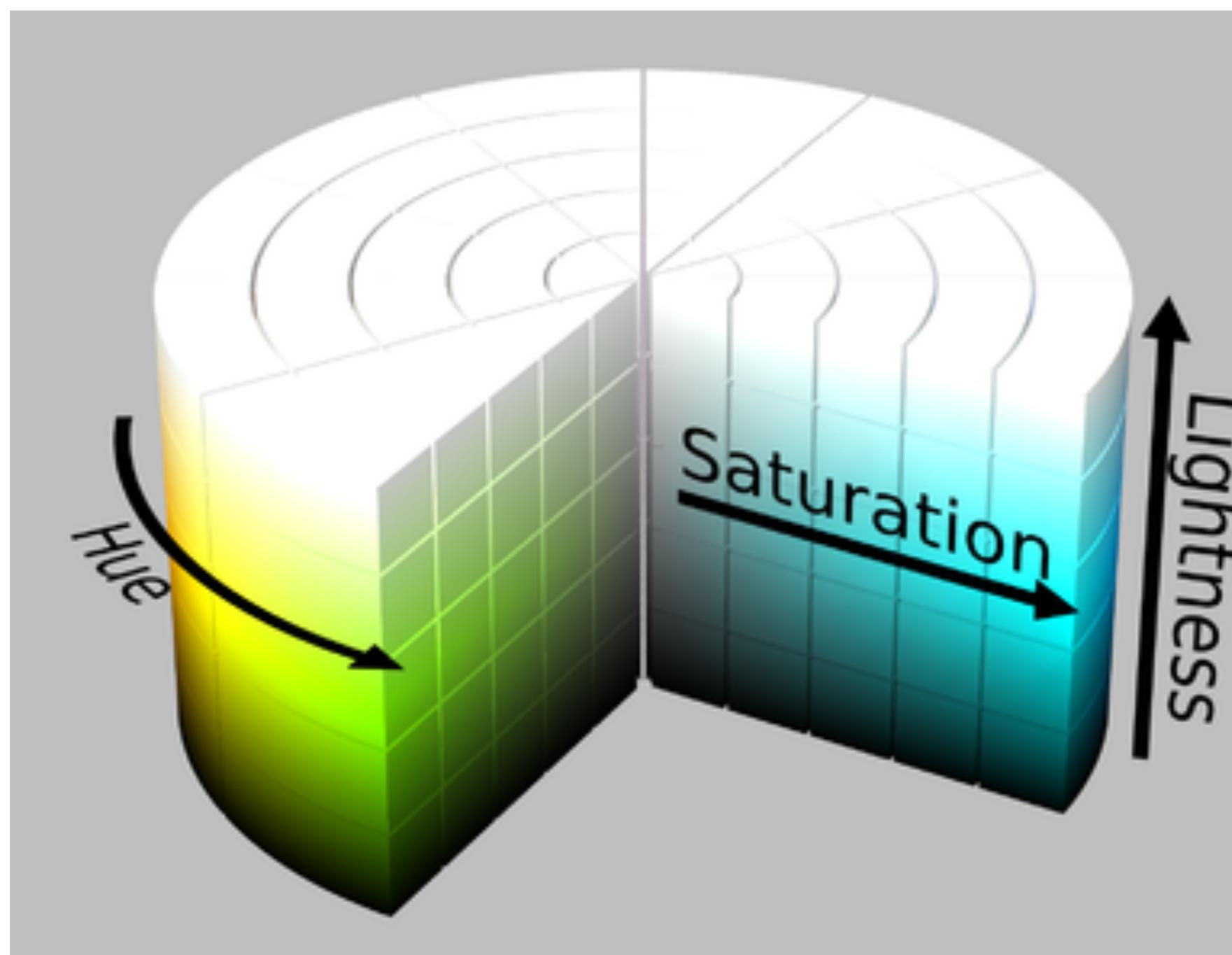
Used everywhere to display images via electronic systems



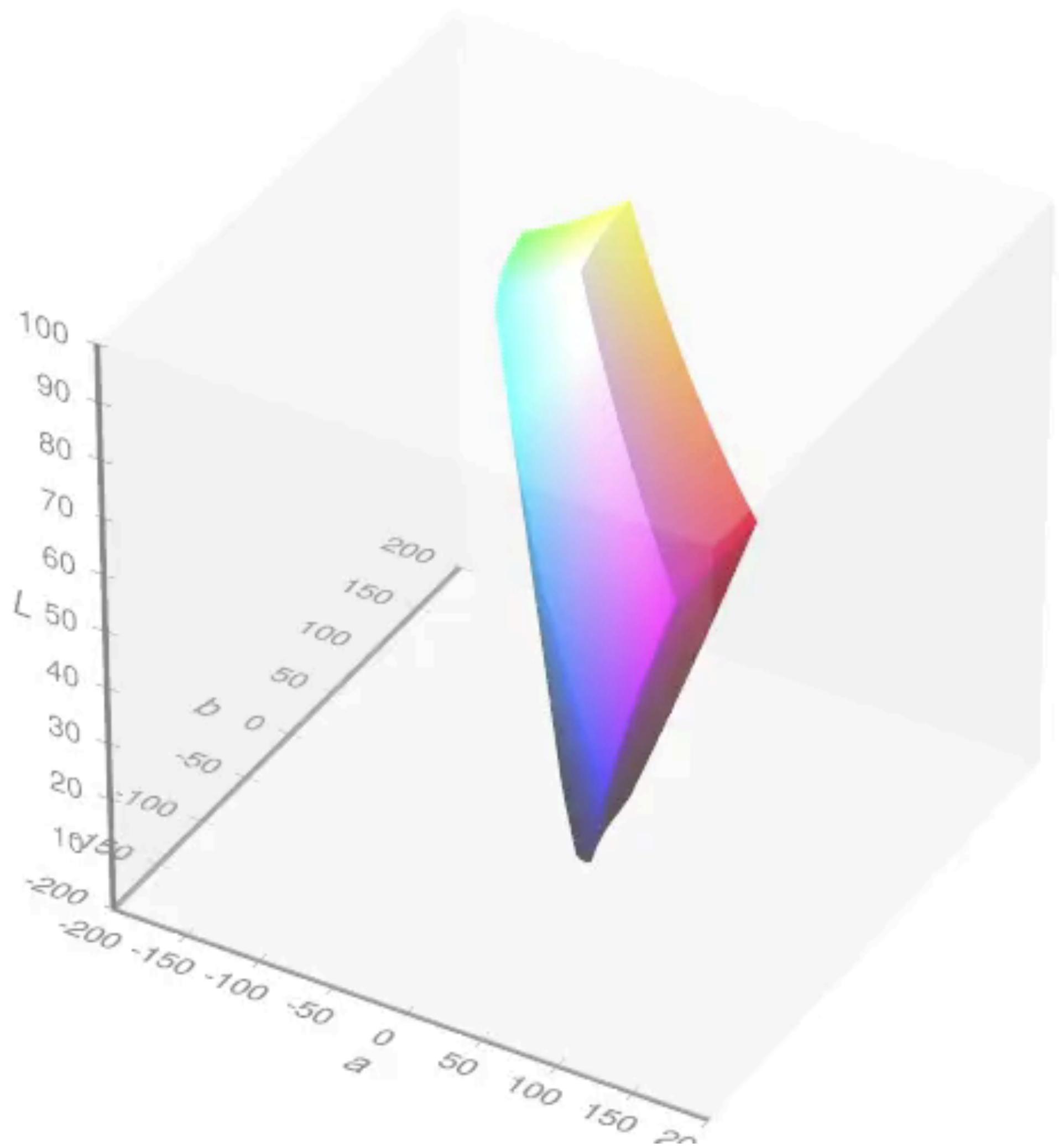
HSL and HSV

Cylindrical-coordinate representations of points in an RGB color model.

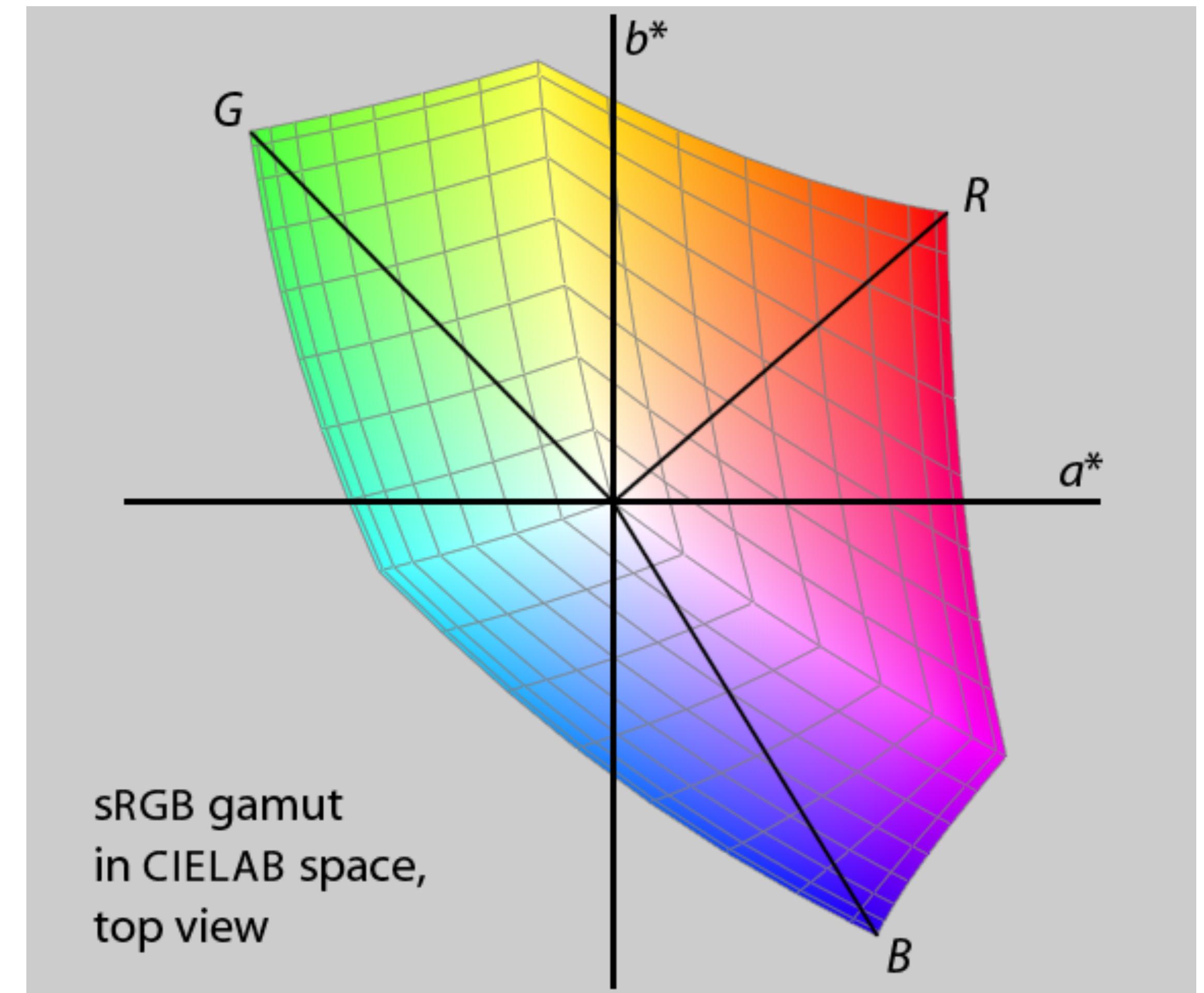
More intuitive and more perceptually relevant than the cartesian (cube) representation



CIE L*a*b*



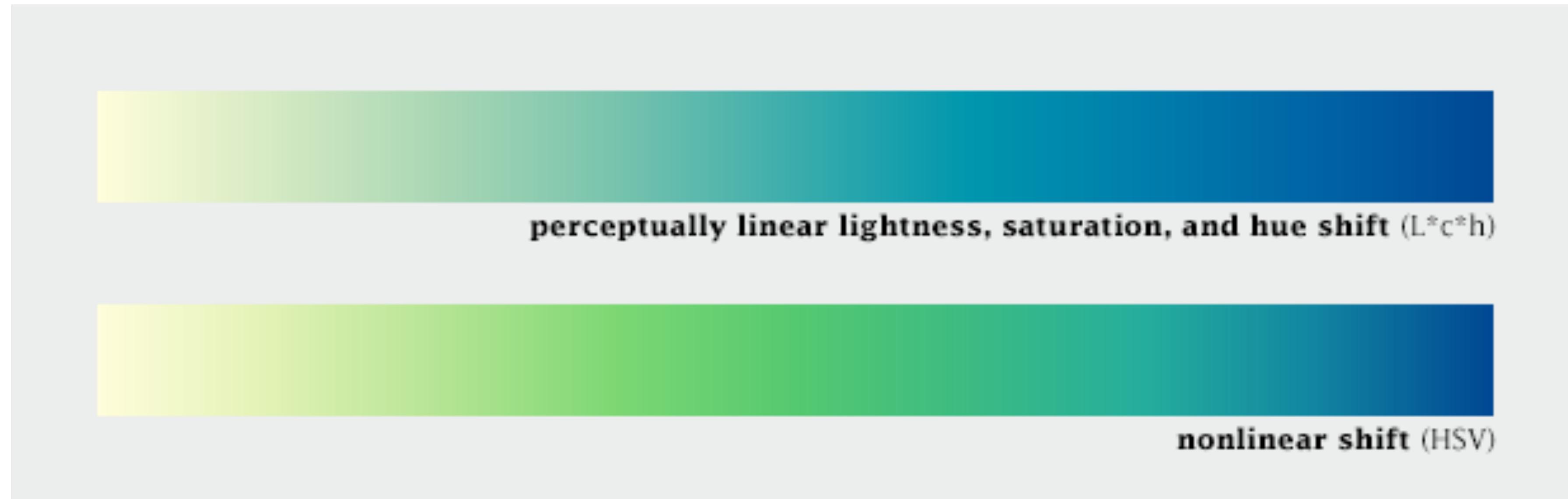
sRGB gamut within CIELAB



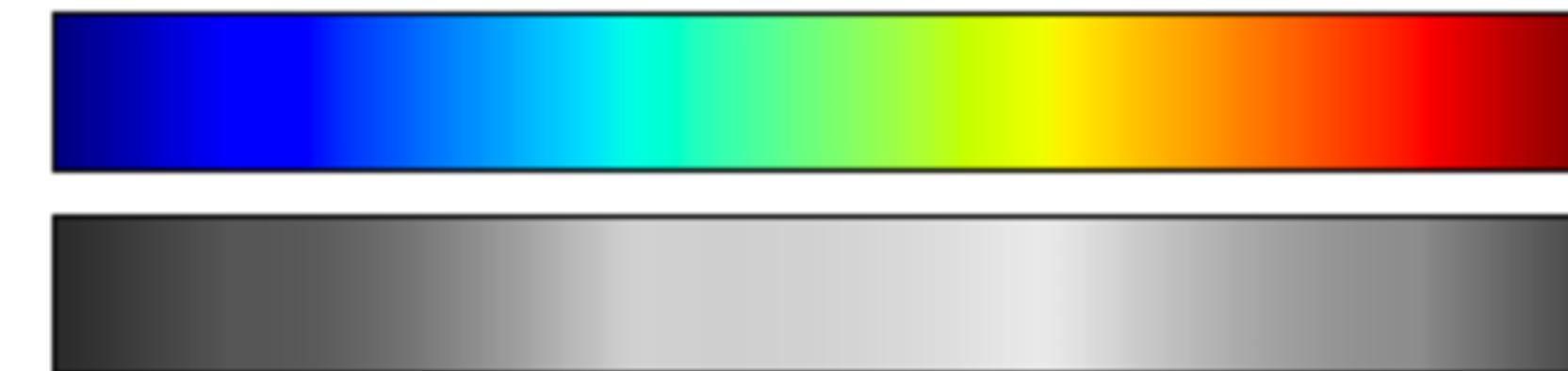
https://en.wikipedia.org/wiki/CIELAB_color_space

Color perception

A colormap specifies a mapping between colors and data values

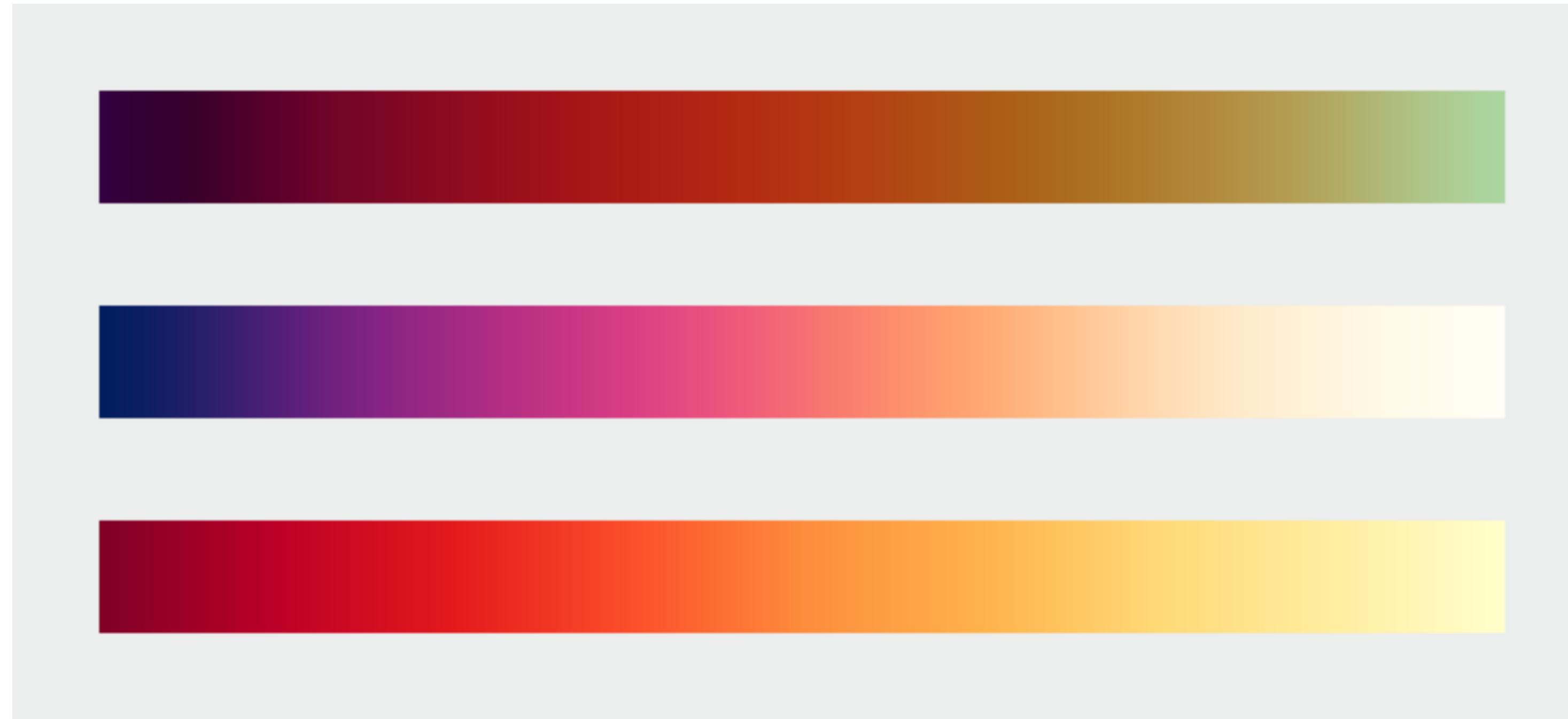


Never use Matlab jet!



[Robert Simmon]

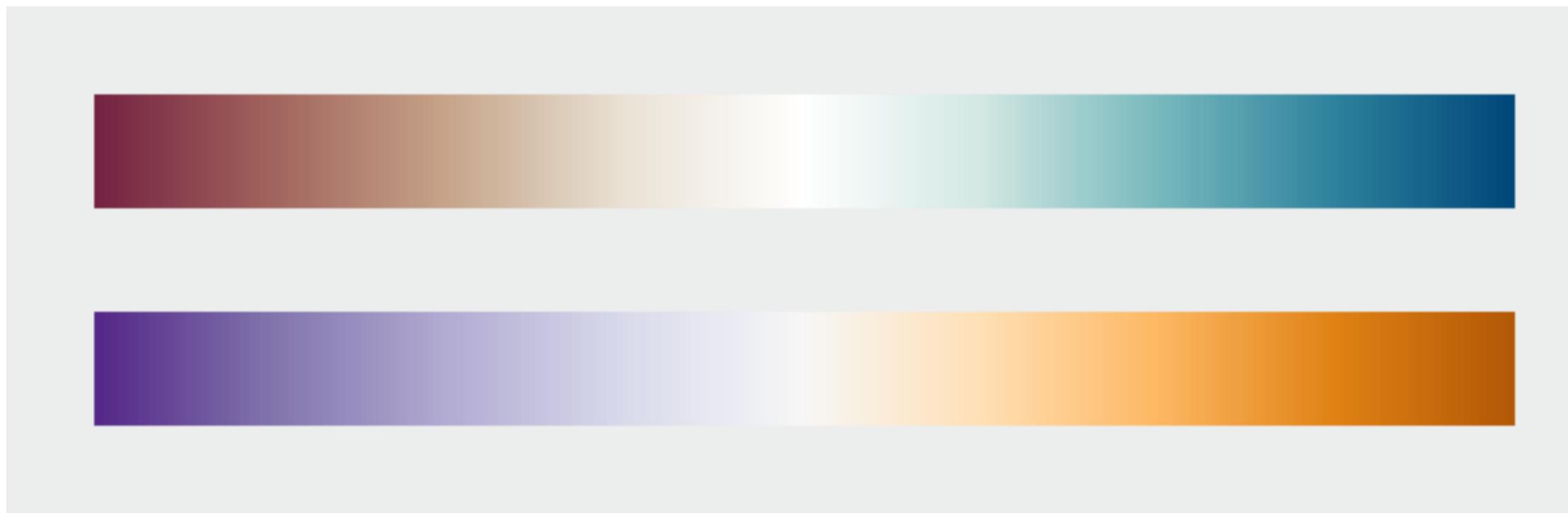
Sequential data



Linear proportional change in lightness with a simultaneous change in hue

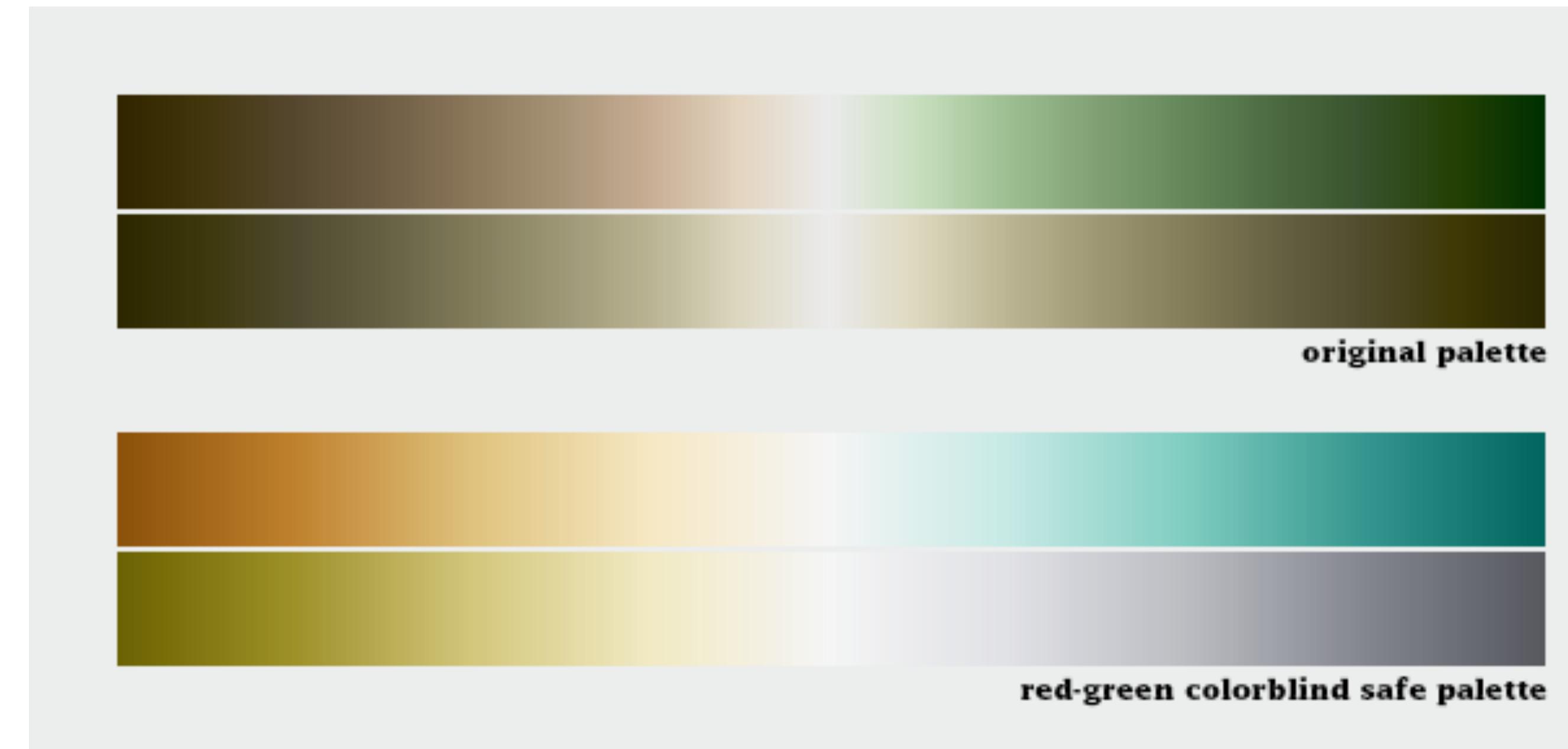
Divergent data

Two sequential palettes with equal variation in lightness and saturation are merged together



Check for black/white printed results

Check for colorblindness

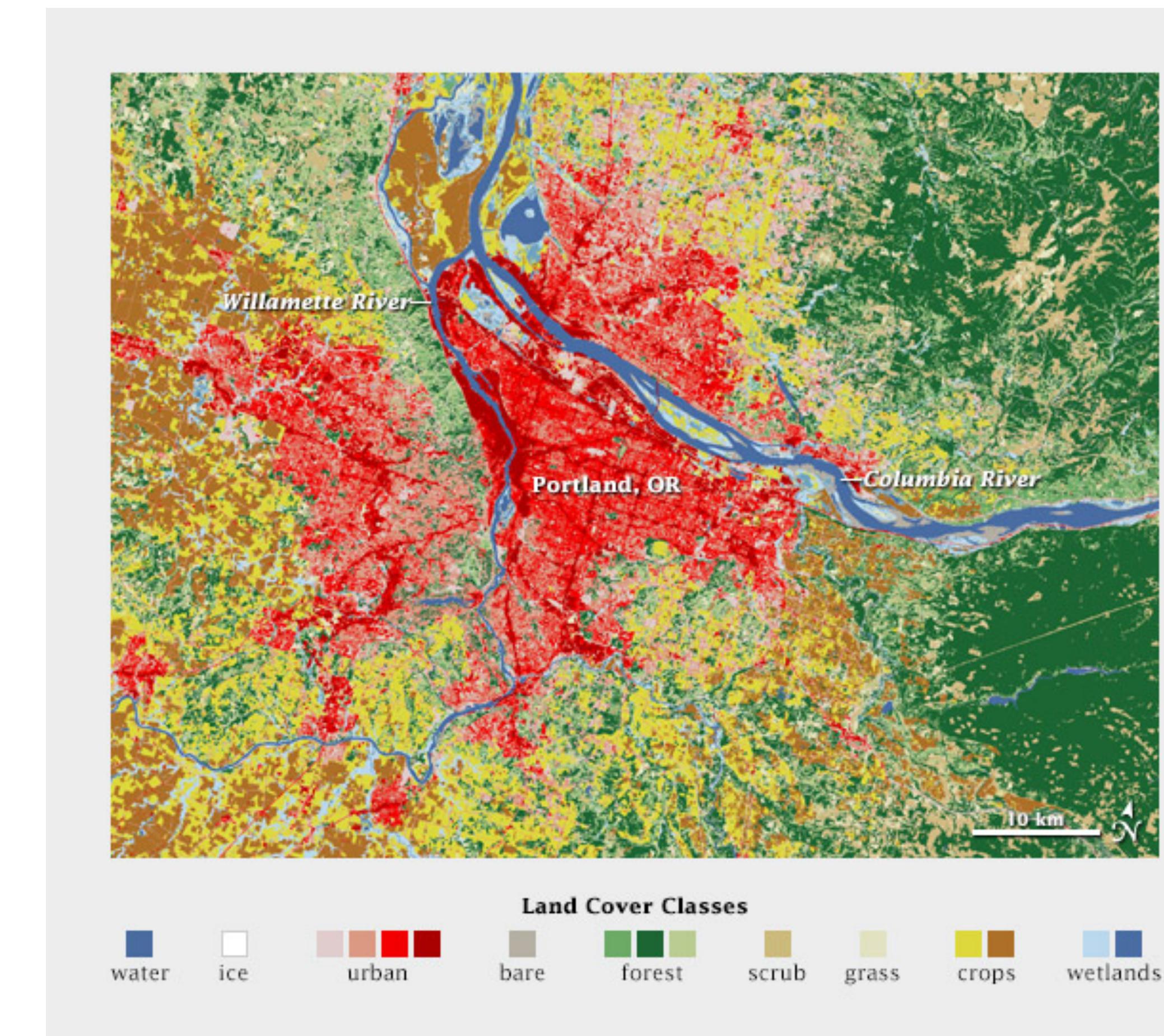
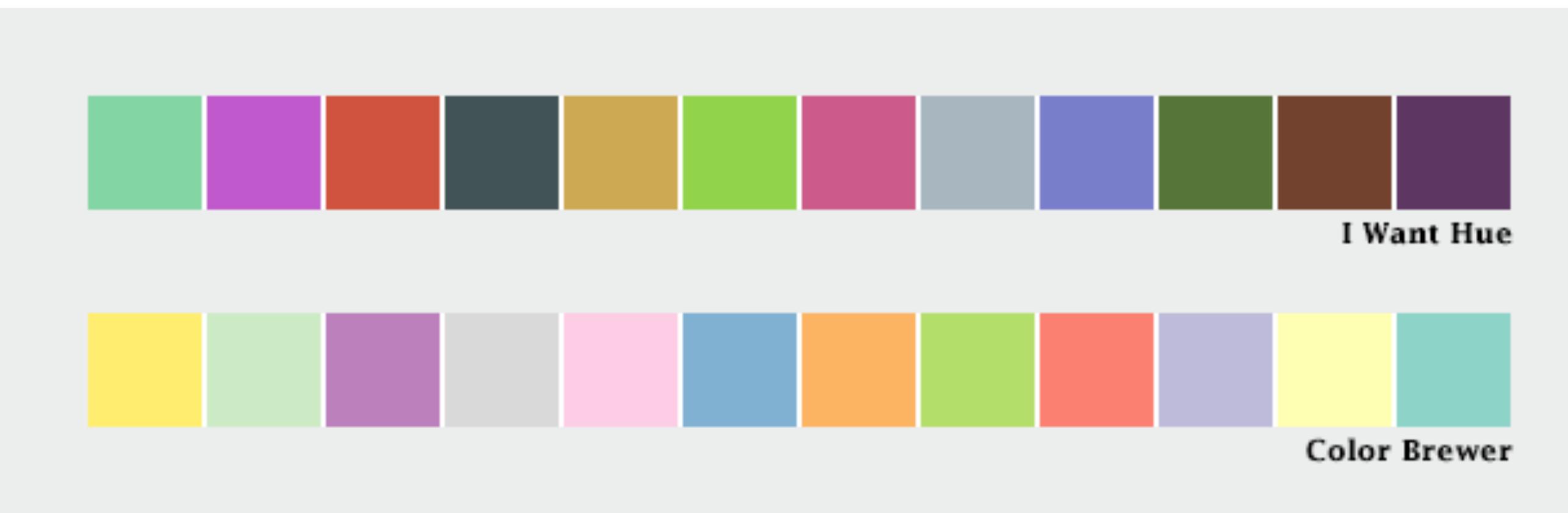


Categorical data

Colors can be used to show categorical (nominal) data

Recommended usage is between 6-8 and no more than 12

If you want more than 12, group into similar classes



Tools



Color space

All colors

H 0 360
C 0 100
L 0 100

Improve for the colorblind (slow)
 Dark background

Palette

15 colors hard (Force vector)

Reroll palette

Sort by diff hue chroma lightness random

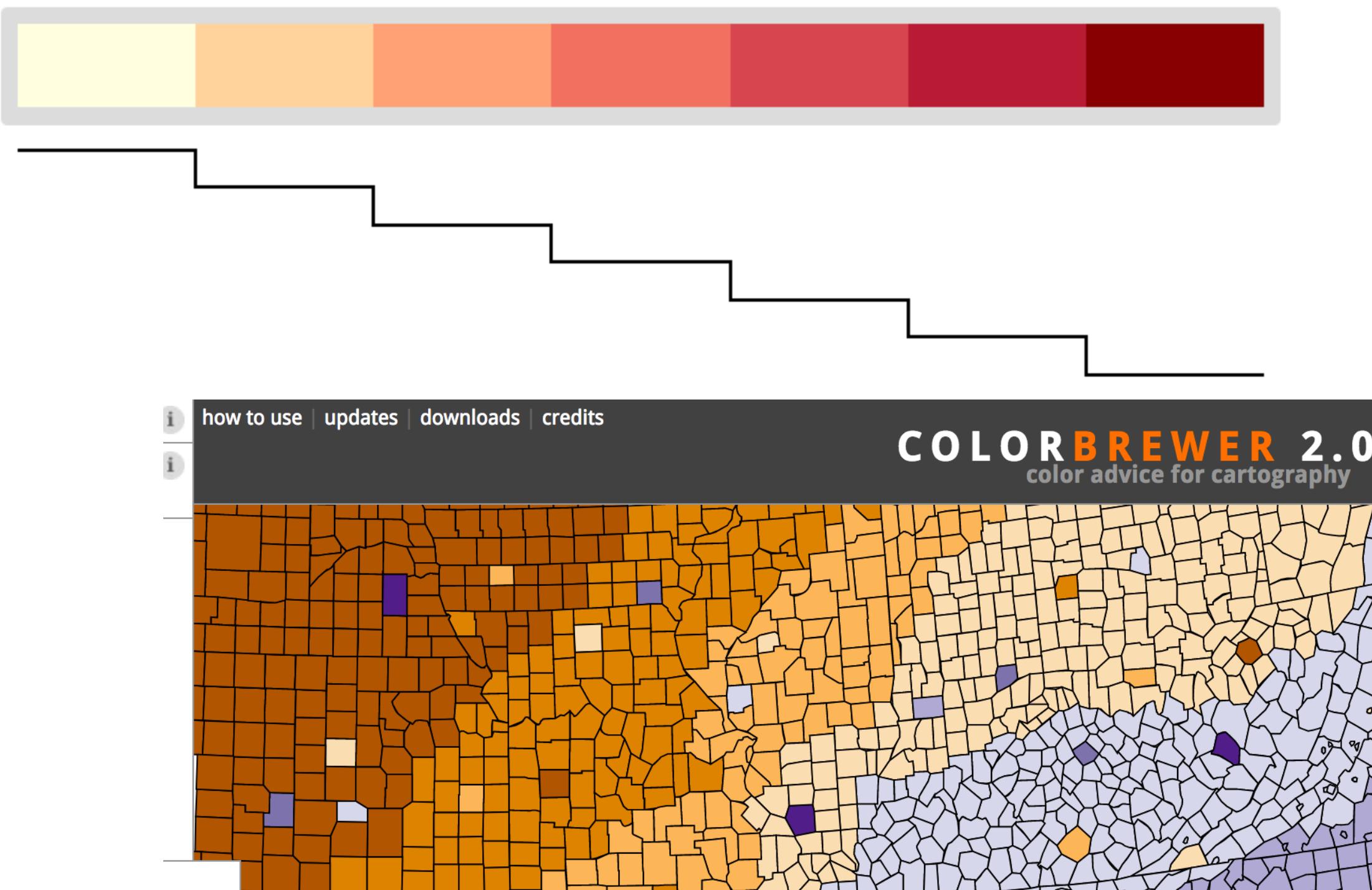
Chroma.js Color Scale Helper

This [chroma.js](#)-powered tool is here to help us mastering multi-hued, multi-stops color scales.

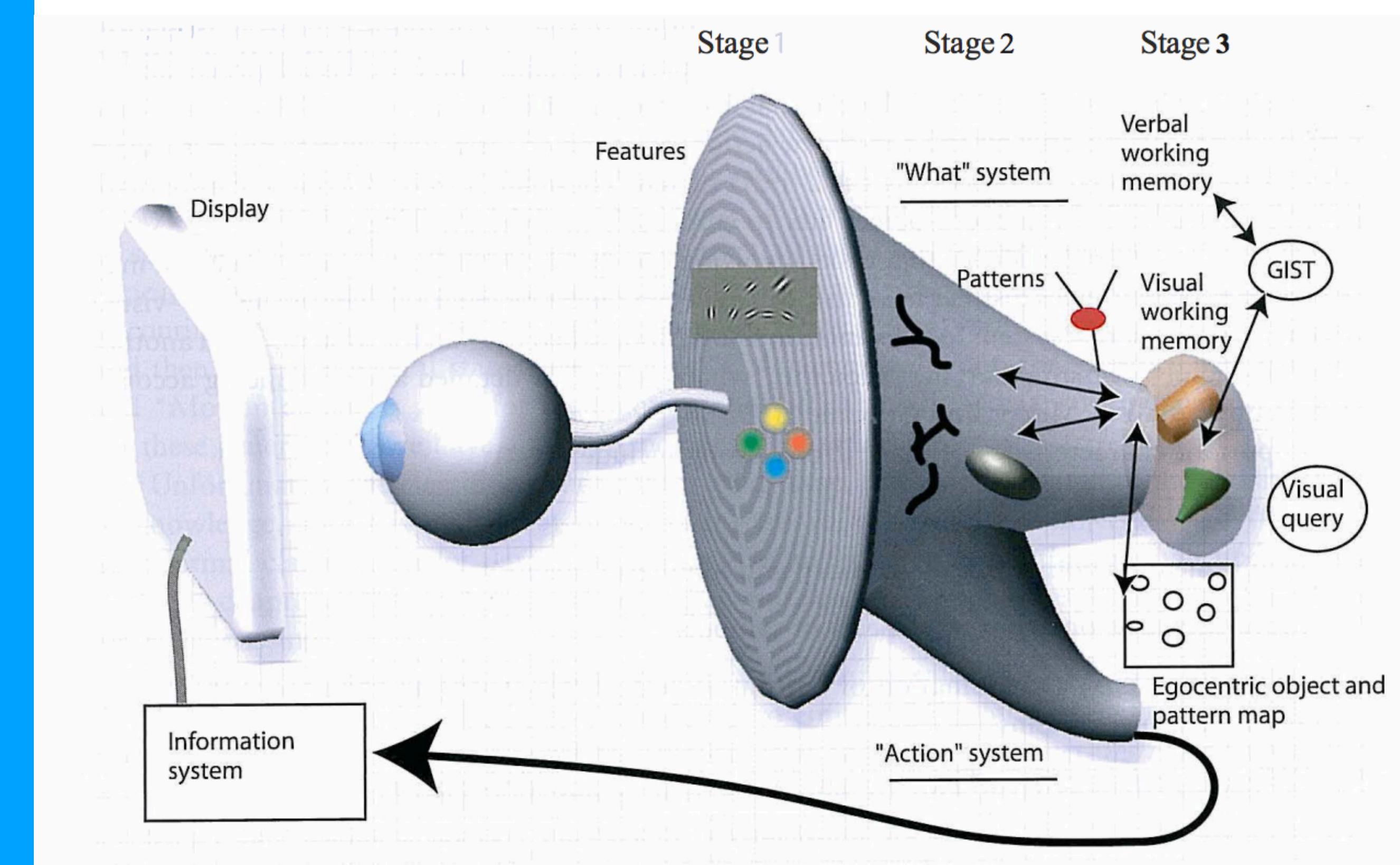
Enter named colors or hex codes:

Step count: 7

Bezier interpolation Correct lightness gradient



Preattentive processing



Visual popout

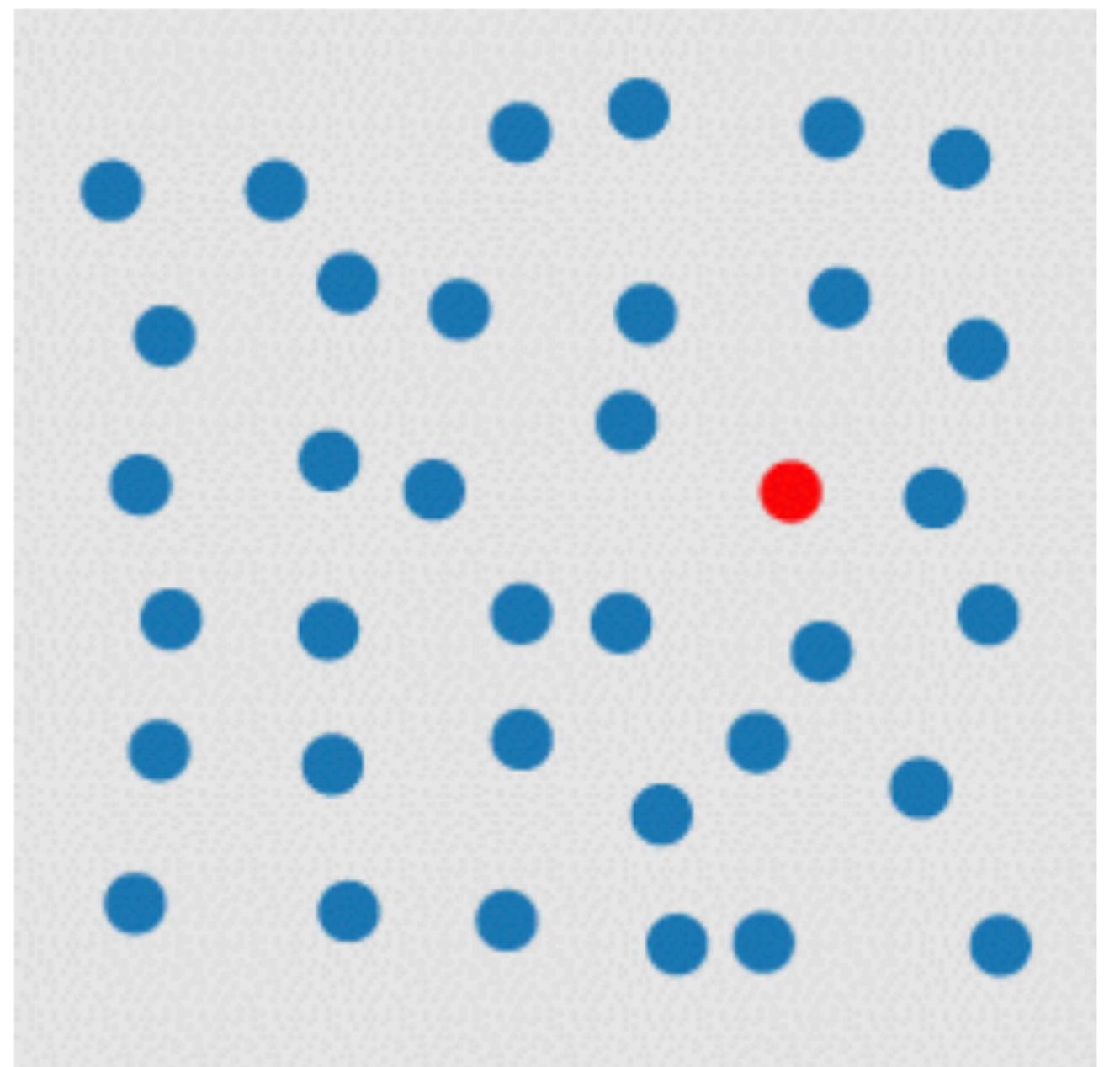
Properties detected by the low-level visual system

very fast and very accurate (200-250 milliseconds)

processed in parallel

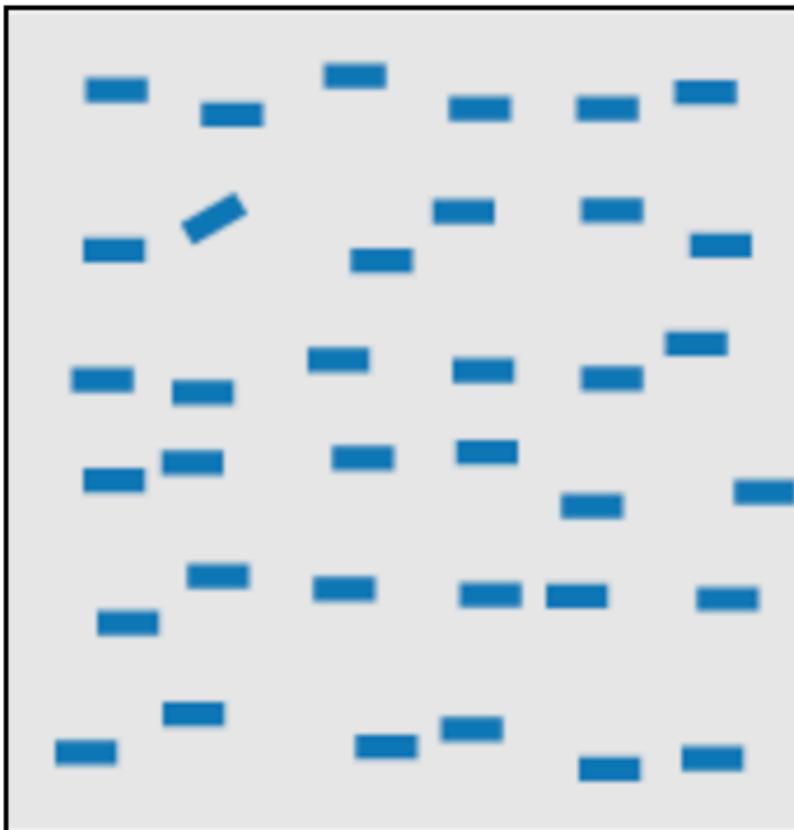
Happens before attention

Also called: **preattentive processing features**

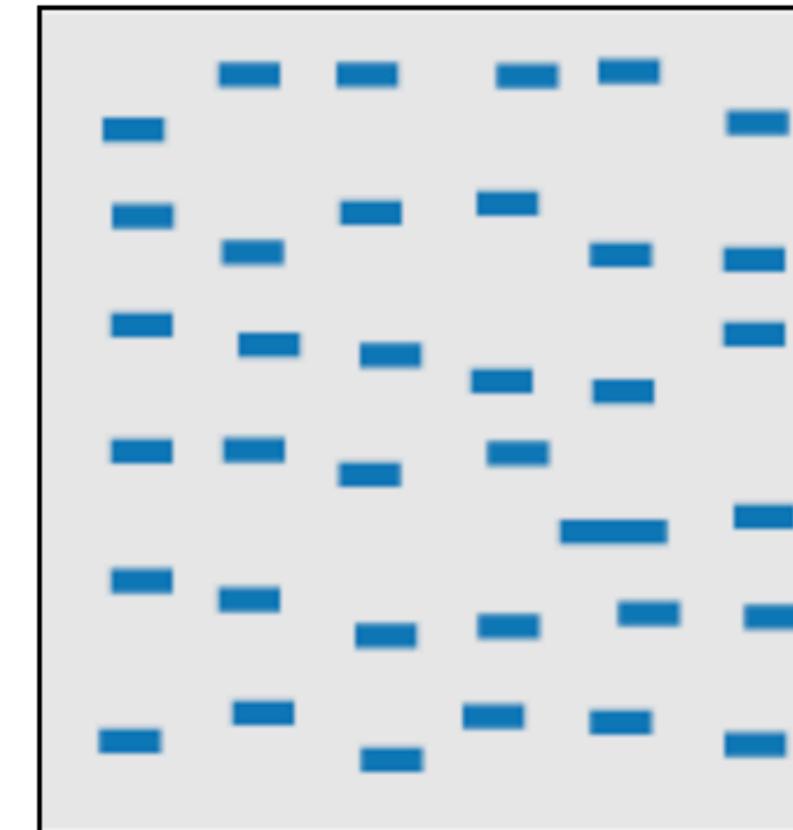


Difference in hue

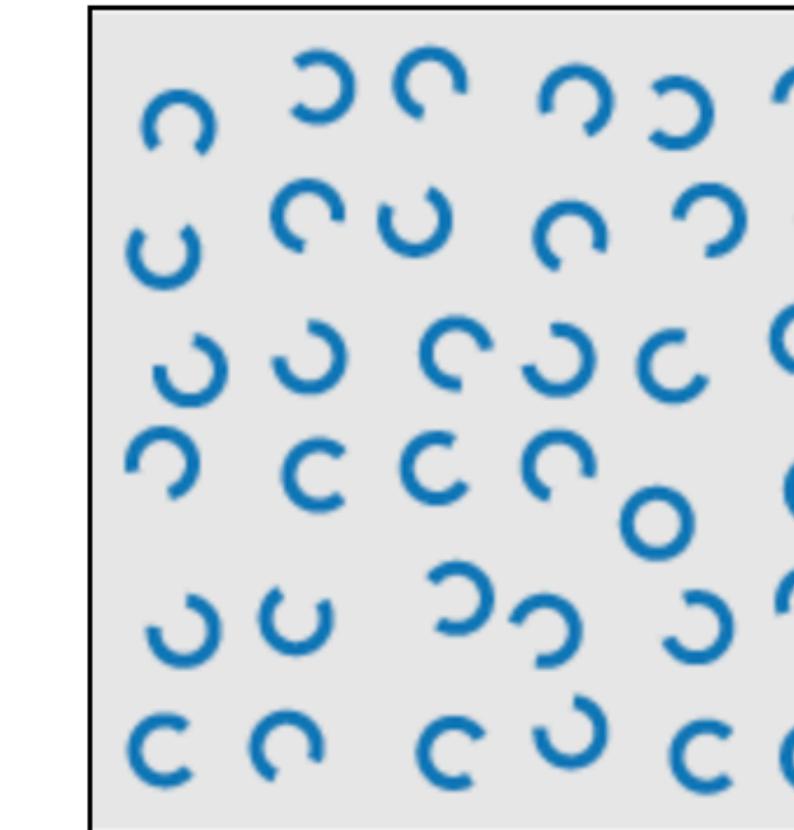
Example of features



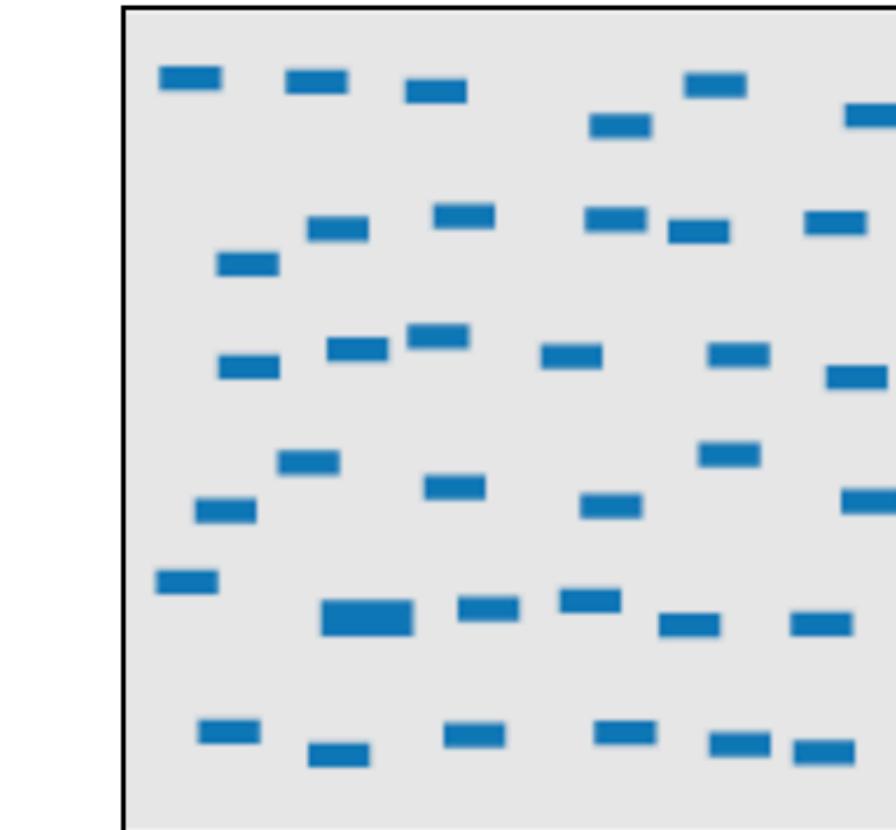
line (blob) orientation
Julész & Bergen 83; Sagi &
Julész 85a, Wolfe et al. 92; Wei-
gle et al. 2000



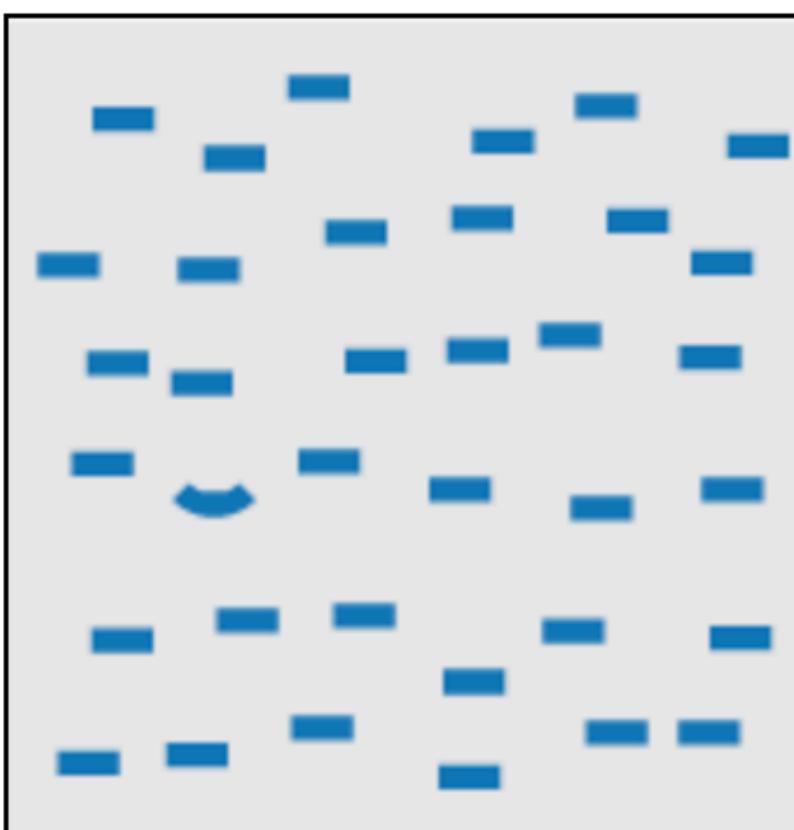
length, width
Sagi & Julész 85b; Treisman &
Gormican 88



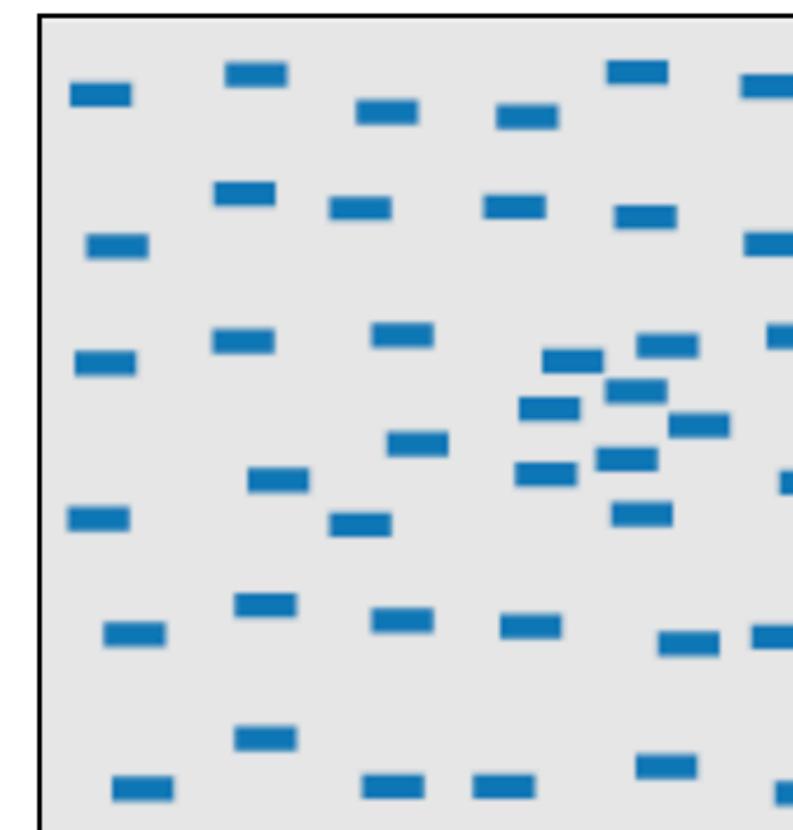
closure
Julész & Bergen 83



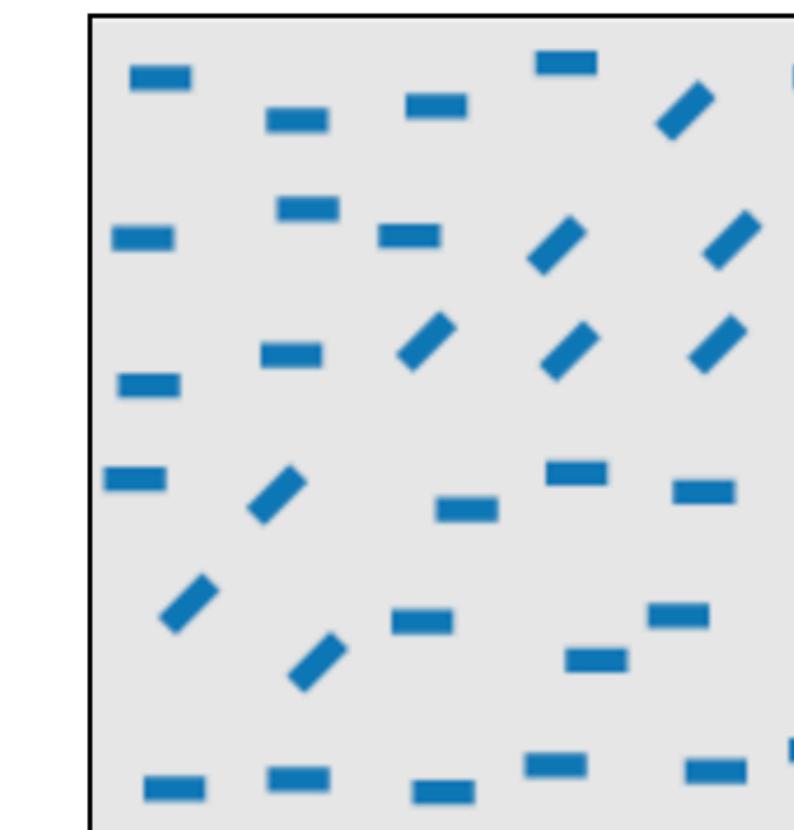
size
Treisman & Gelade 80; Healey &
Enns 98; Healey & Enns 99



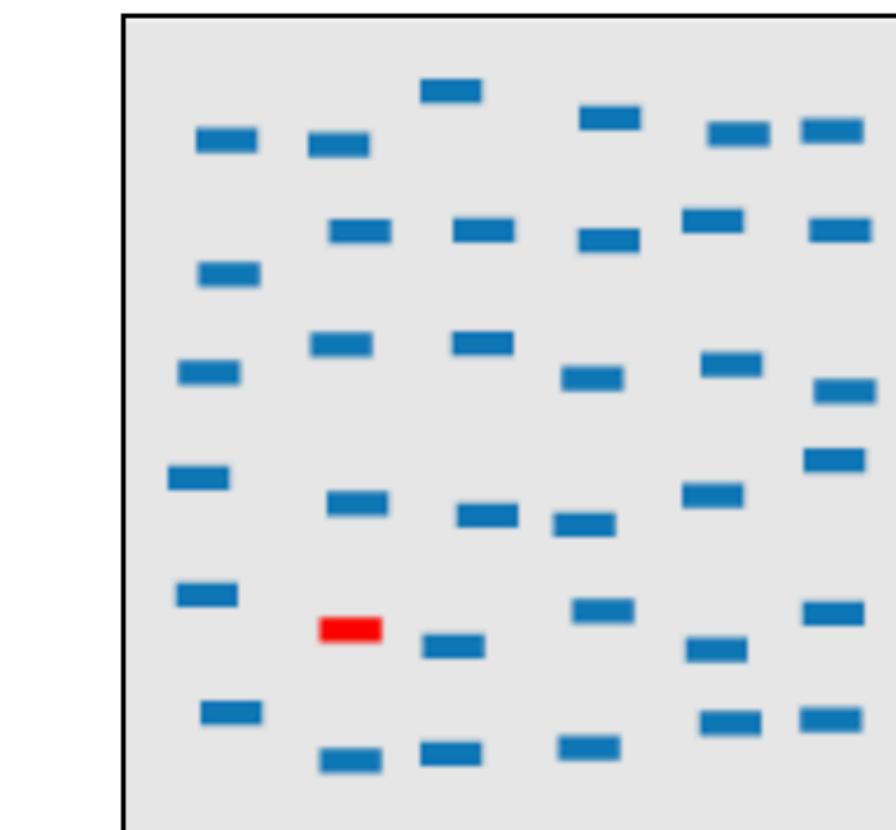
curvature
Treisman & Gormican 88



density, contrast
Healey & Enns 98; Healey &
Enns 99



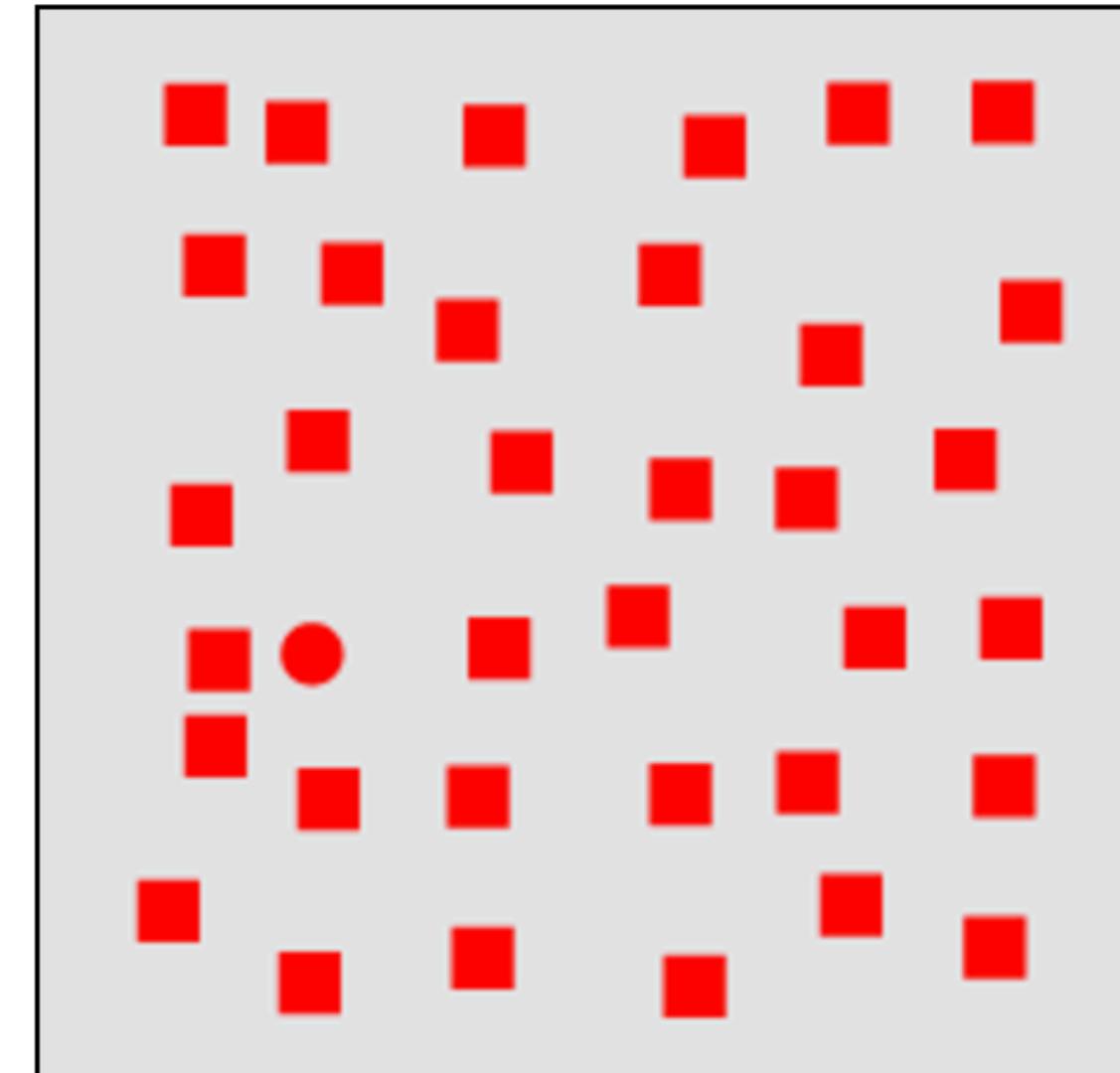
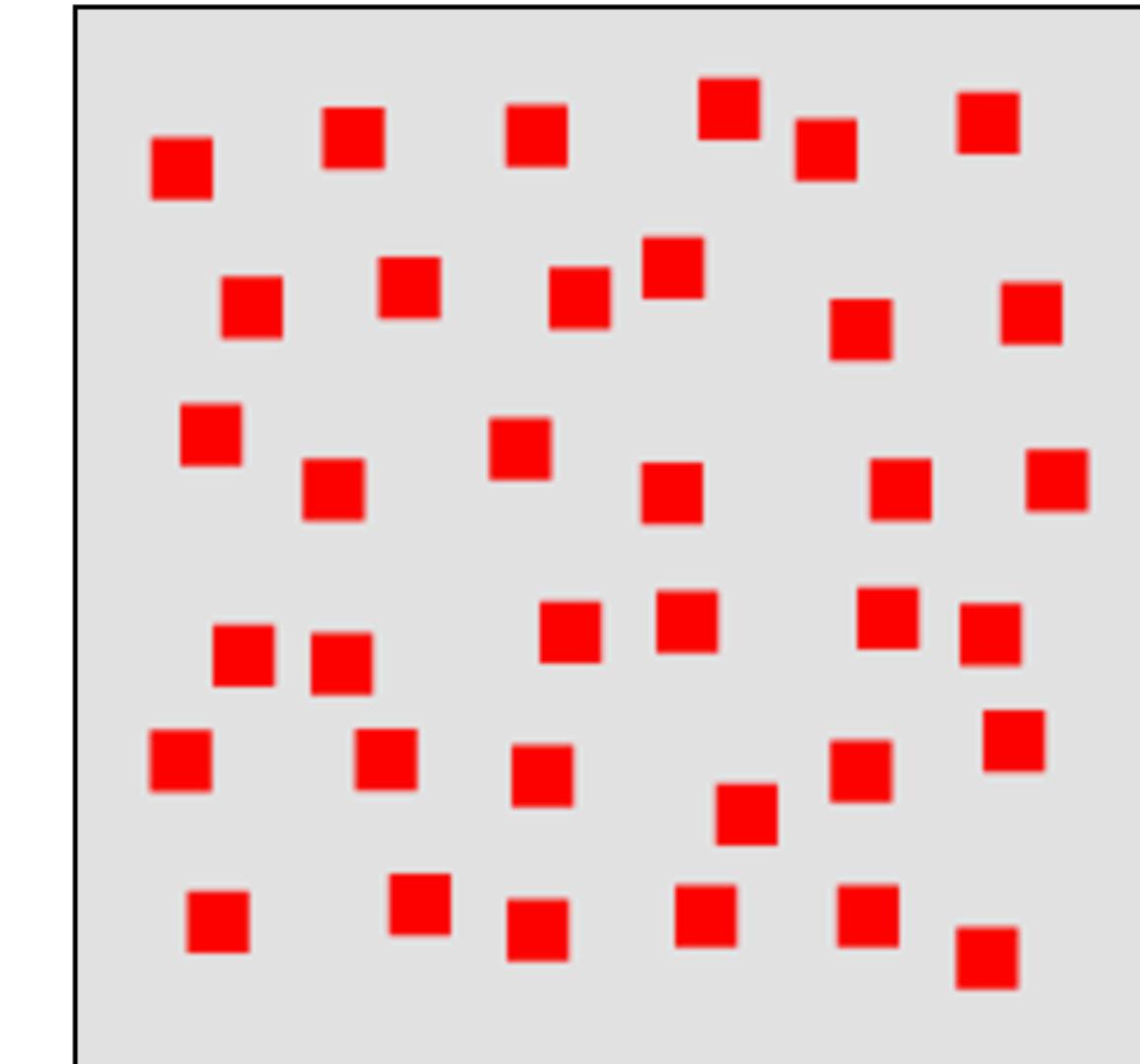
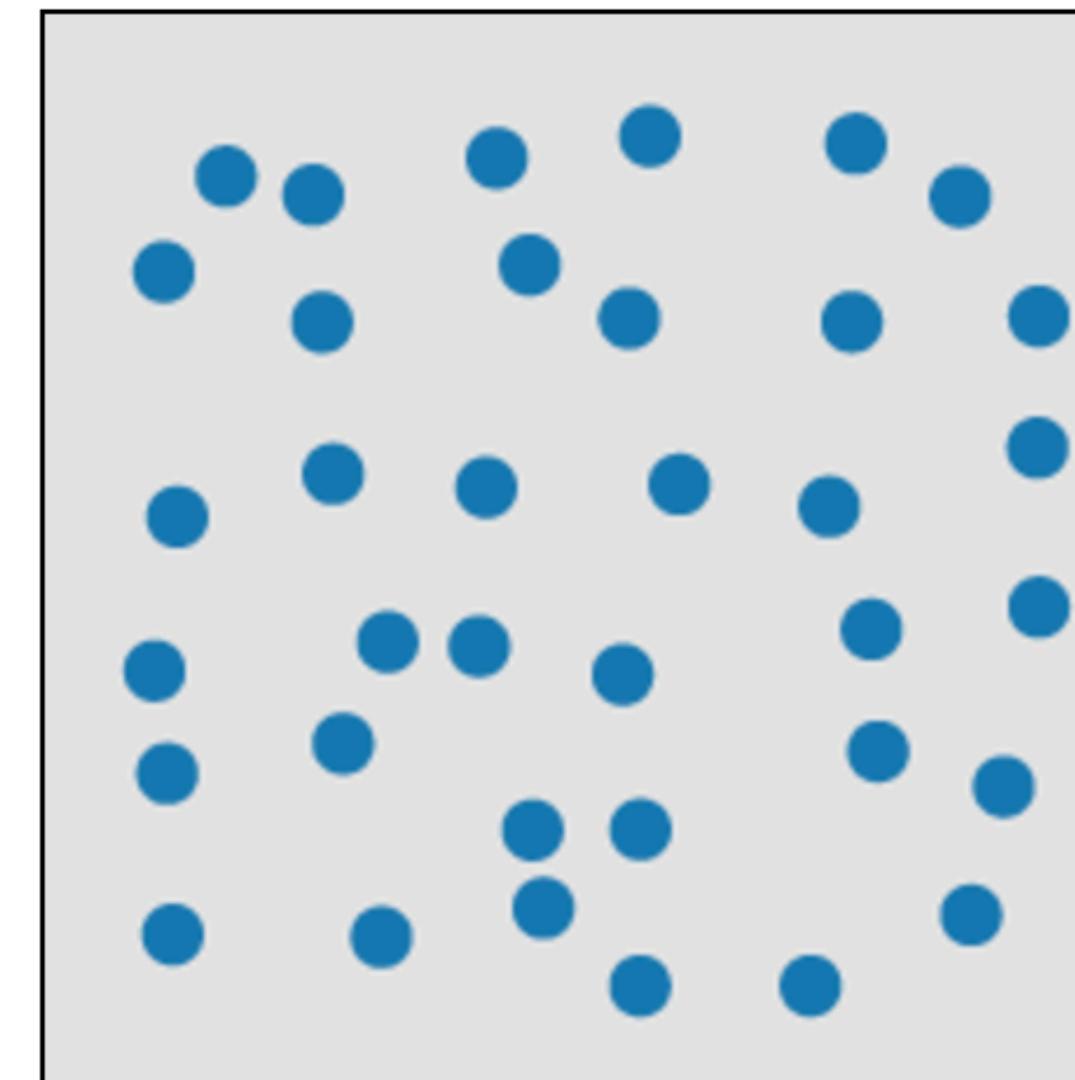
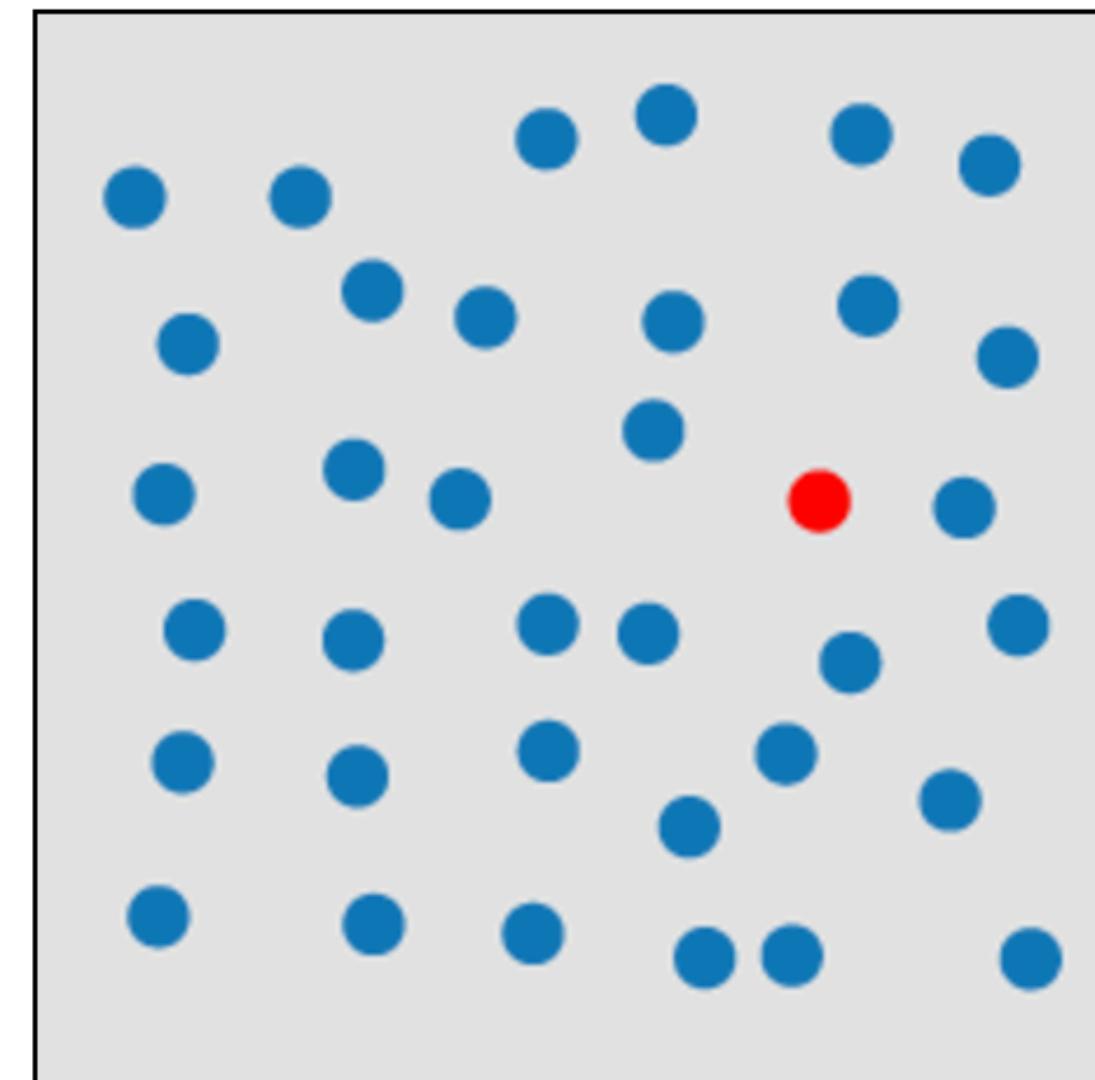
number, estimation
Sagi & Julész 85b; Healey et al.
93; Trick & Pylyshyn 94



colour (hue)
Nagy & Sanchez 90; Nagy et al.
90; D'Zmura 91; Kawai et al. 95;
Bauer et al. 96; Healey 96; Bauer

Target detection

Detect the presence or absence of a "target" (red circle) element rapidly and accurately



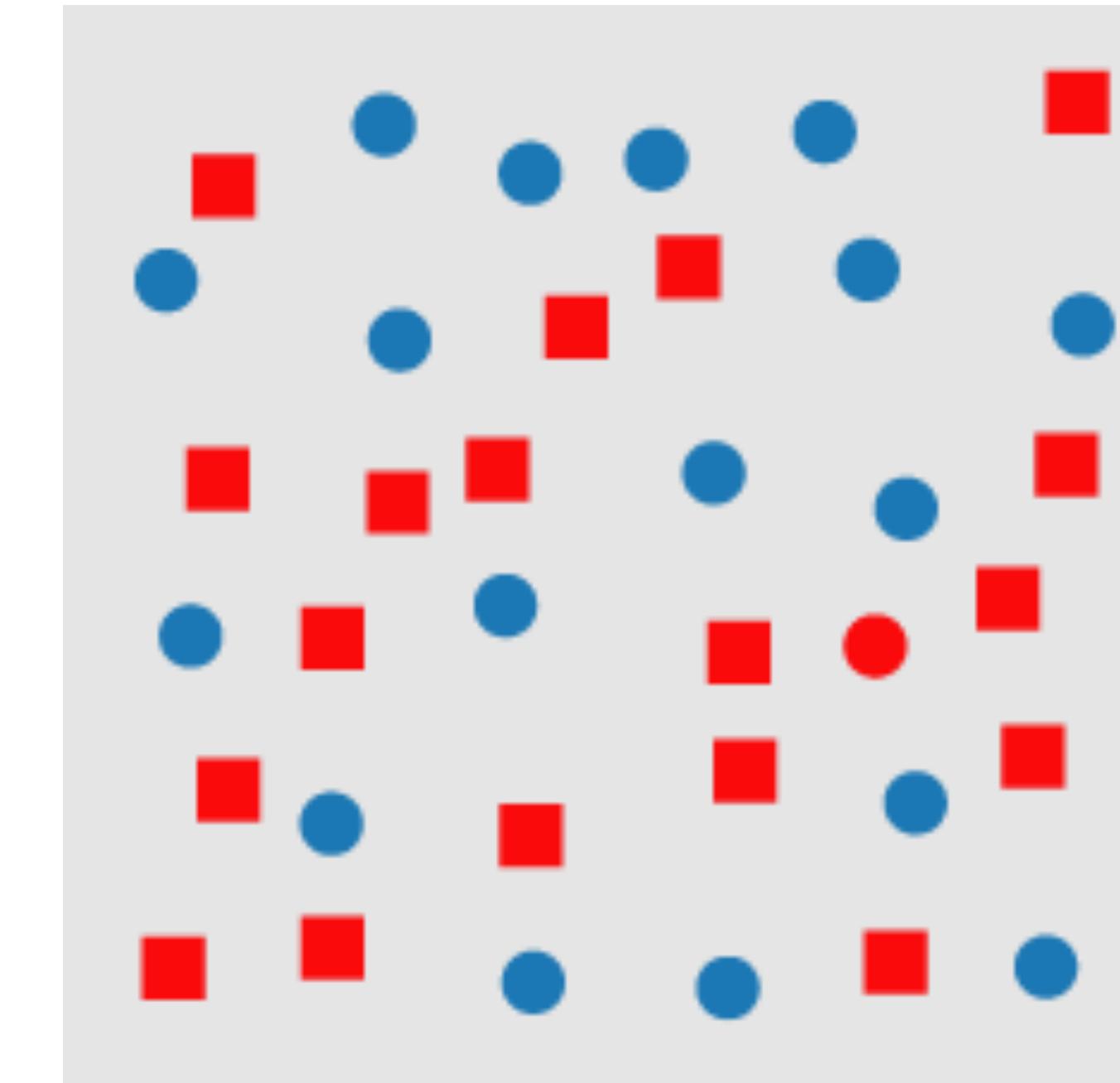
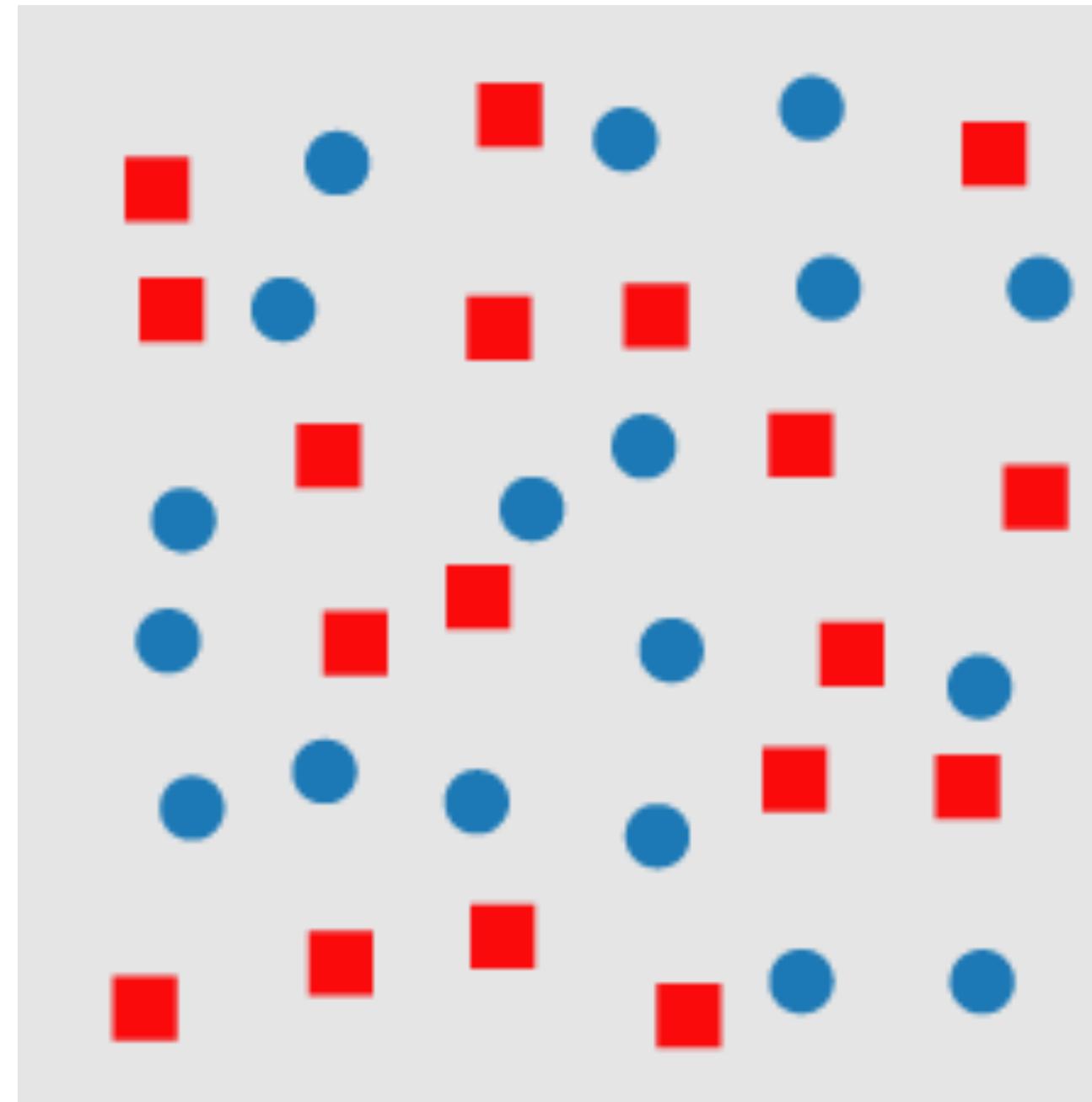
Difference in hue

Difference in curvature

Failed target detection

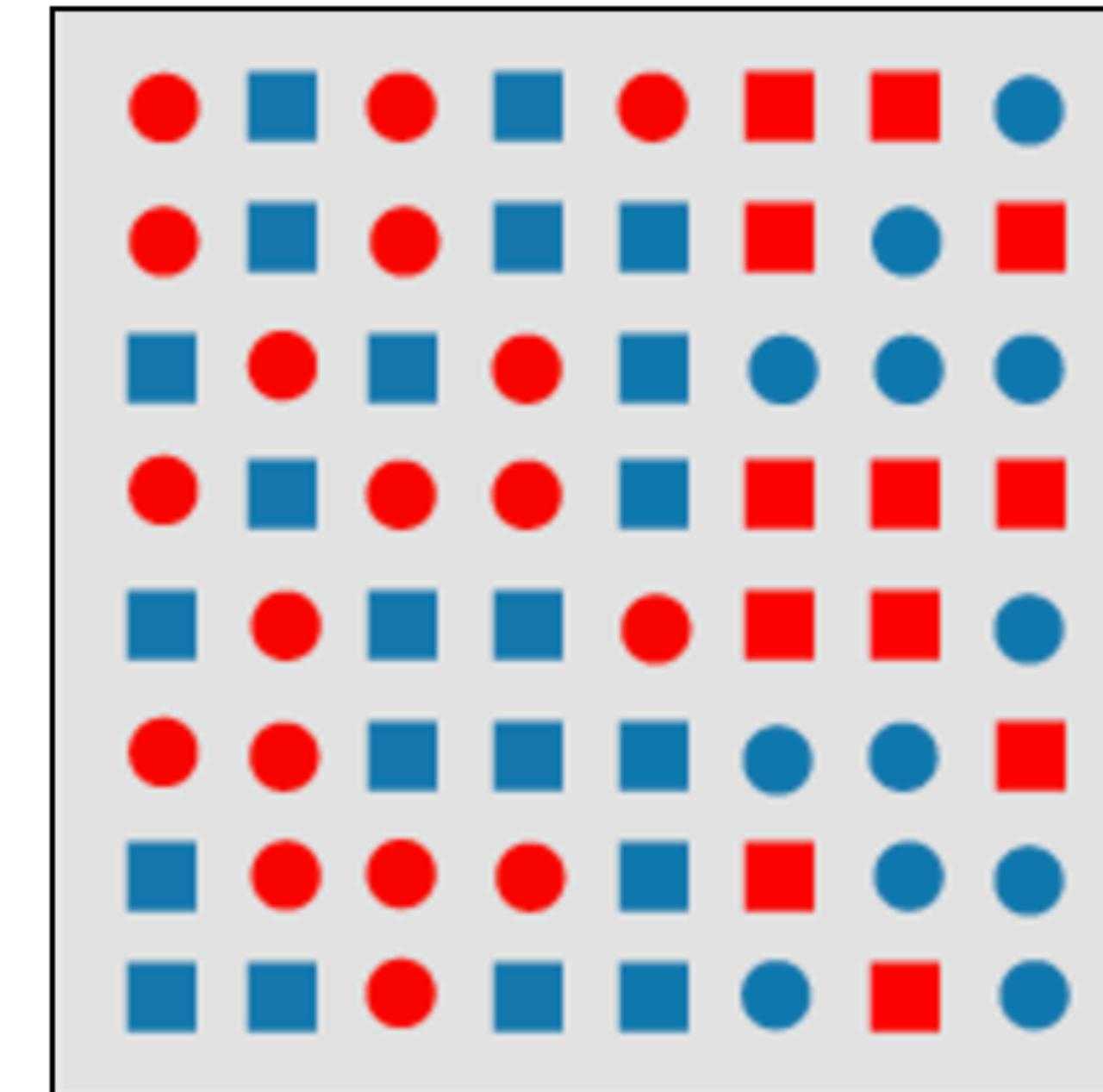
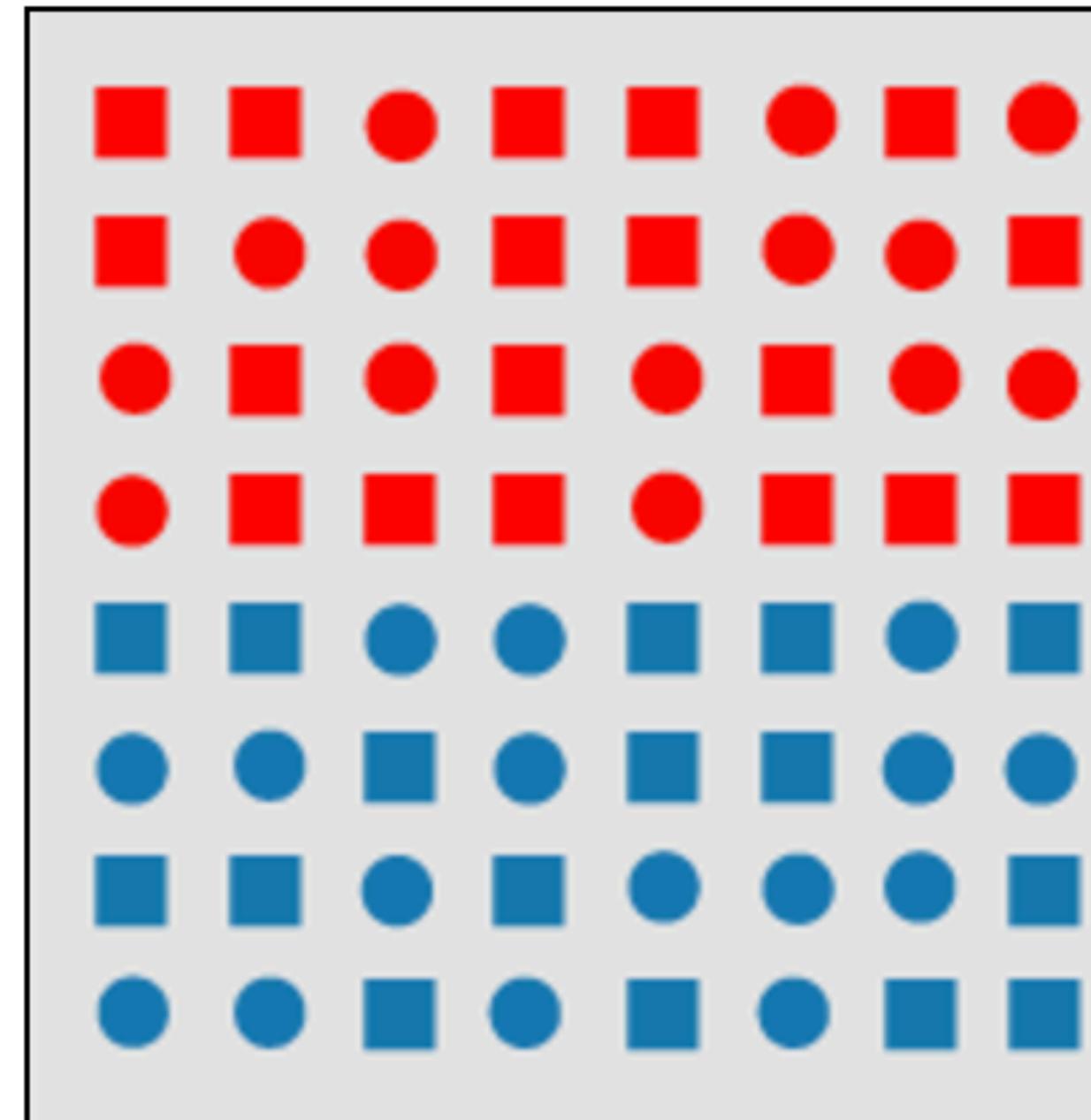
- A target made up of a combination of non-unique features, here hue and curvature, normally cannot be detected preattentively
- Painful serial search

no unique visual property



Boundary detection

Detect a texture boundary between two groups of elements rapidly and accurately, where all of the elements in each group have a common visual property



Implications for data viz

Preattentive features can be used to:

draw attention to areas of interest

express similarity/group memberships

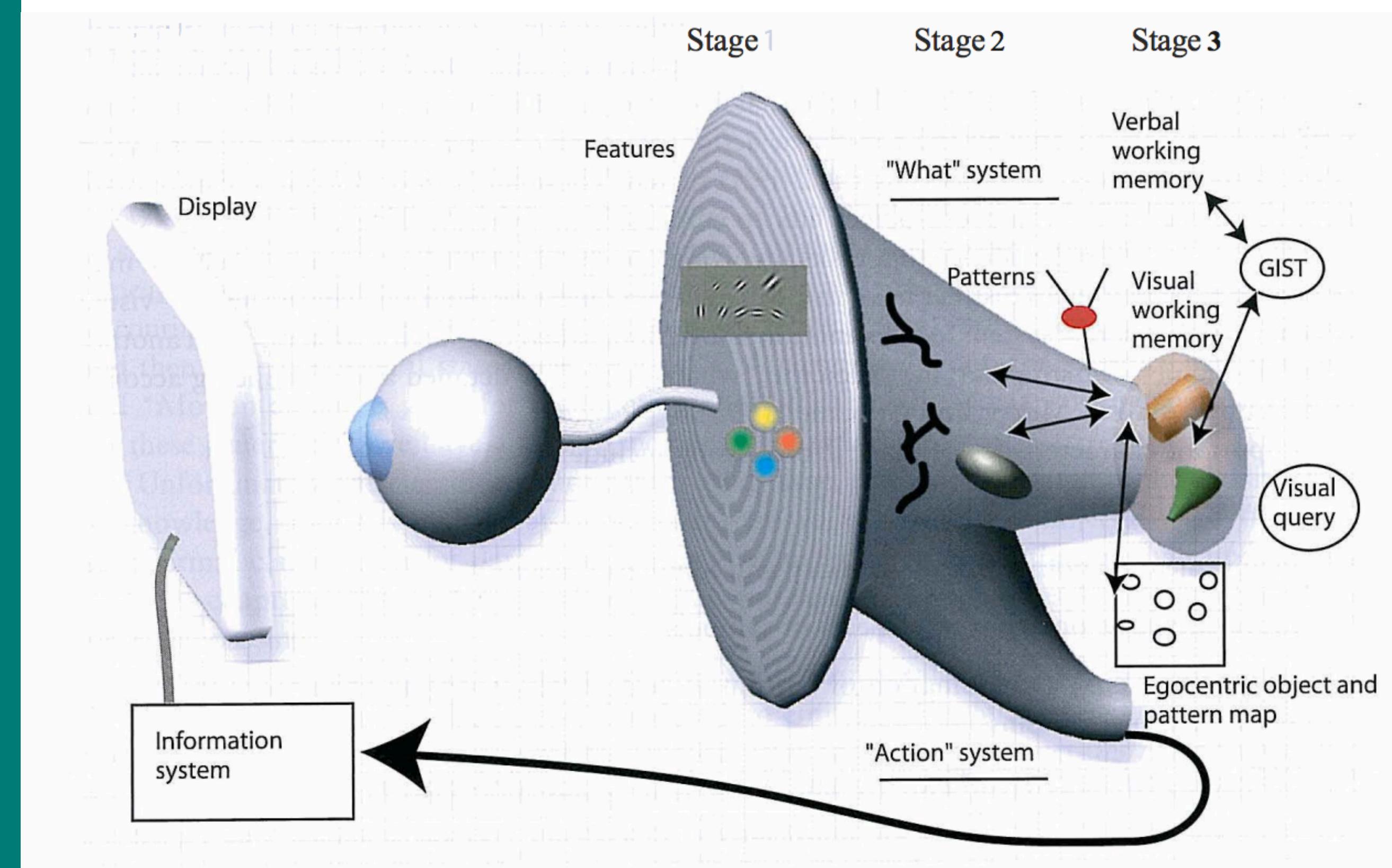
However:

visual features must be carefully designed

conjunctions (combination of non-unique properties) **must be avoided**



Pattern extraction

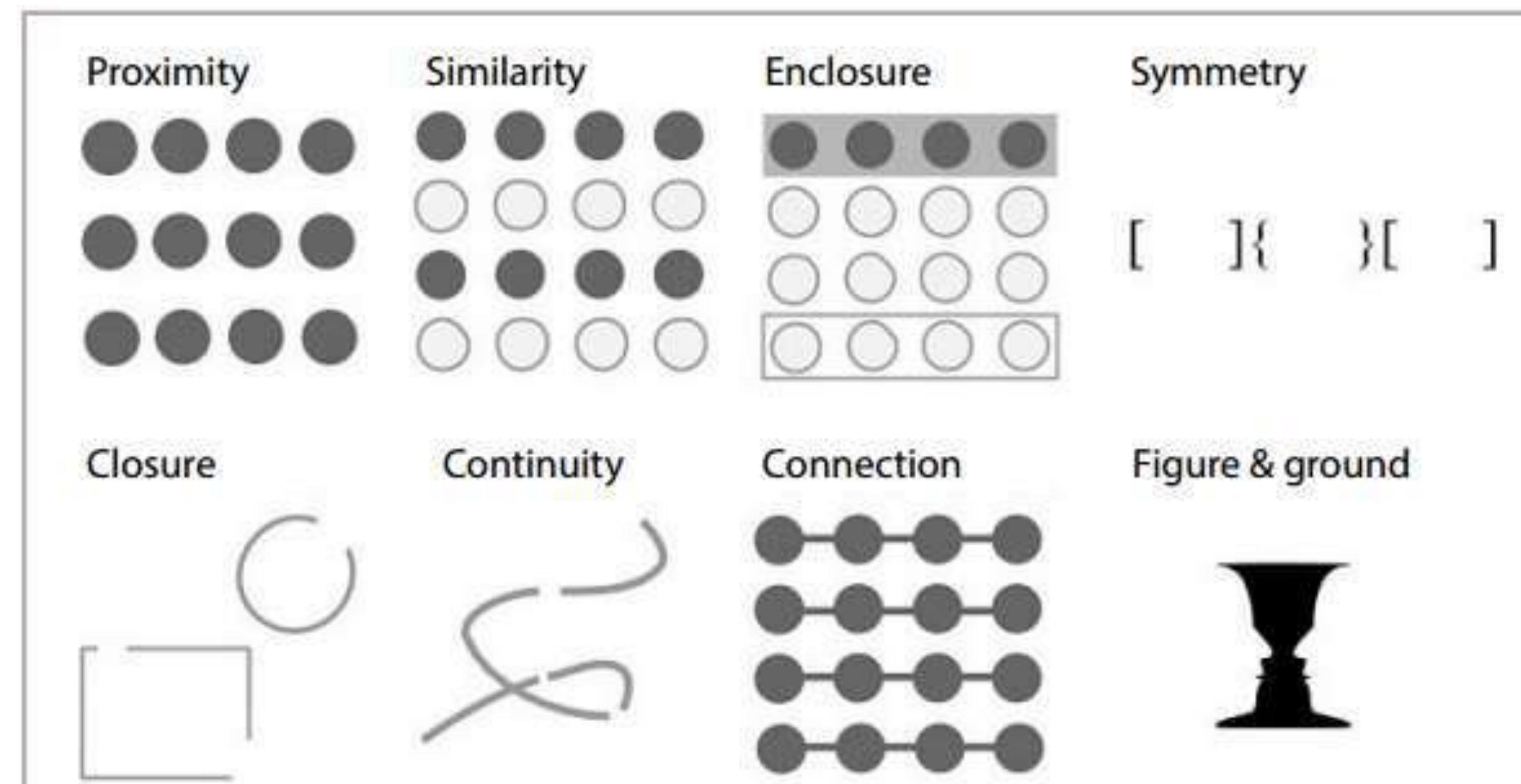


Principles of grouping

Also known as **Gestalt principles** from 1920's

Humans naturally organize visual elements into groups of objects

Gestalt is a pragmatic aspect of data viz



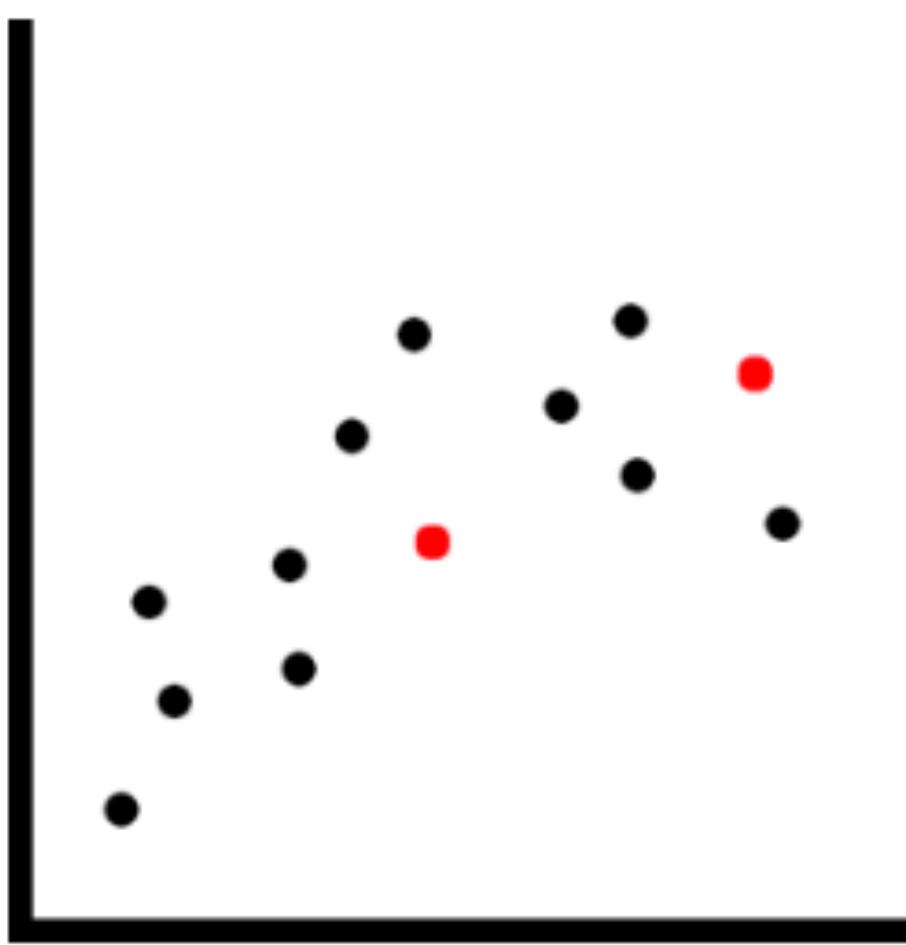
Proximity

Group or link elements next to each other

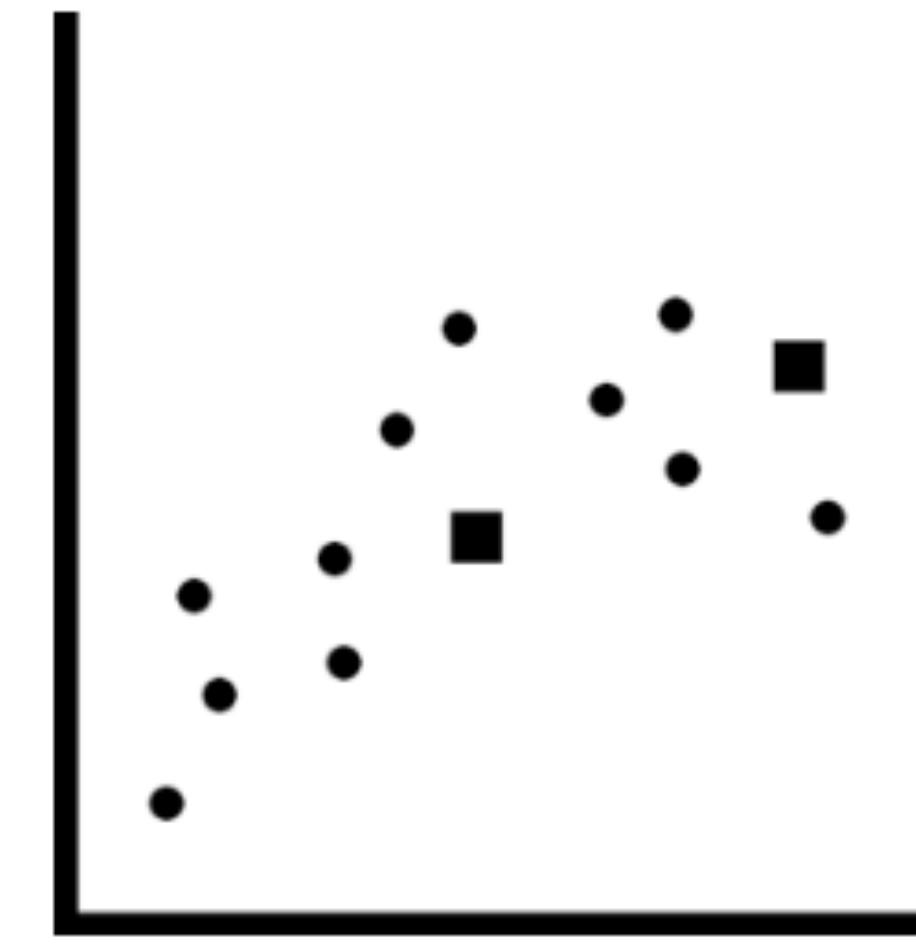


Similarity

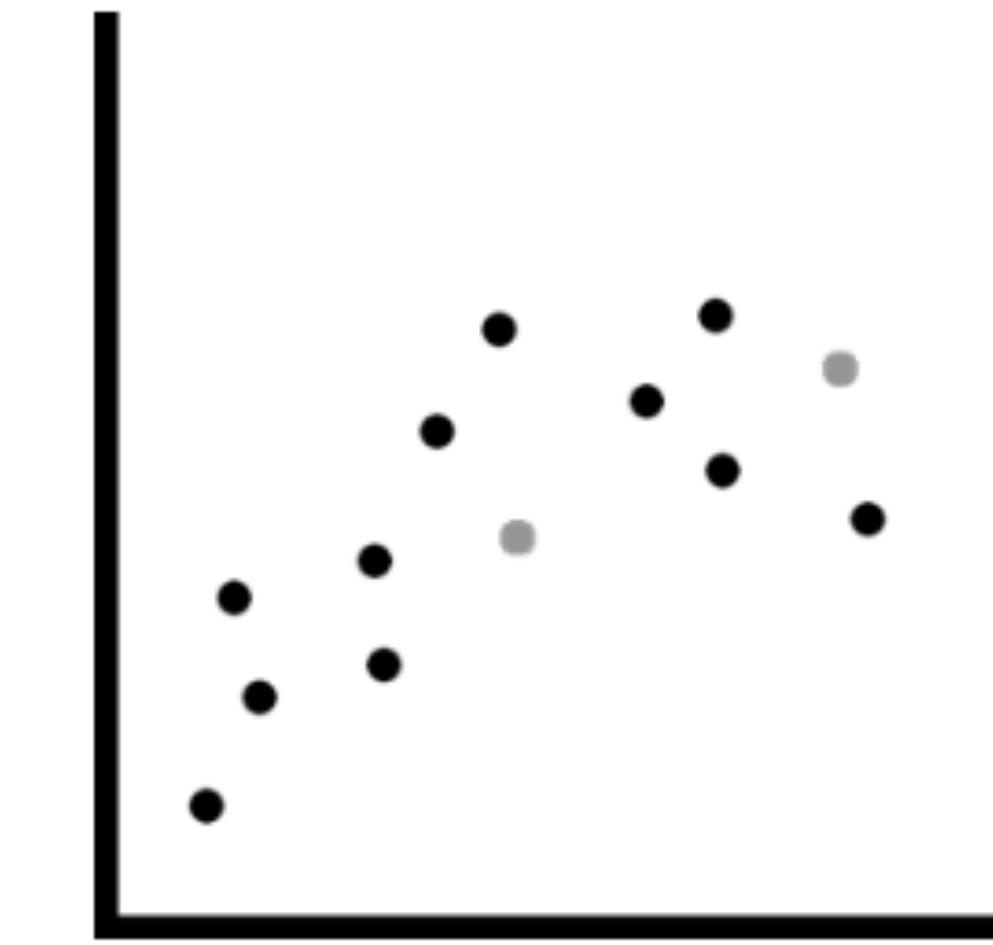
Elements with shared visual properties are considered to be in the same group



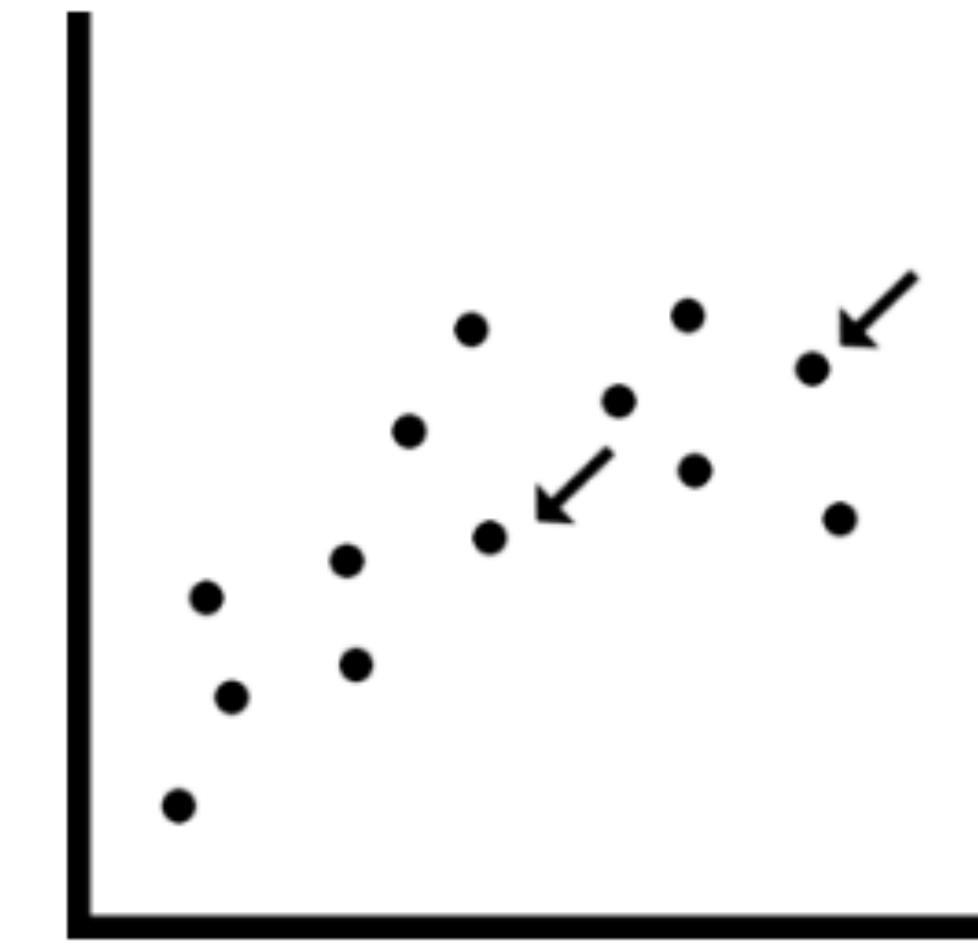
Color



Shape



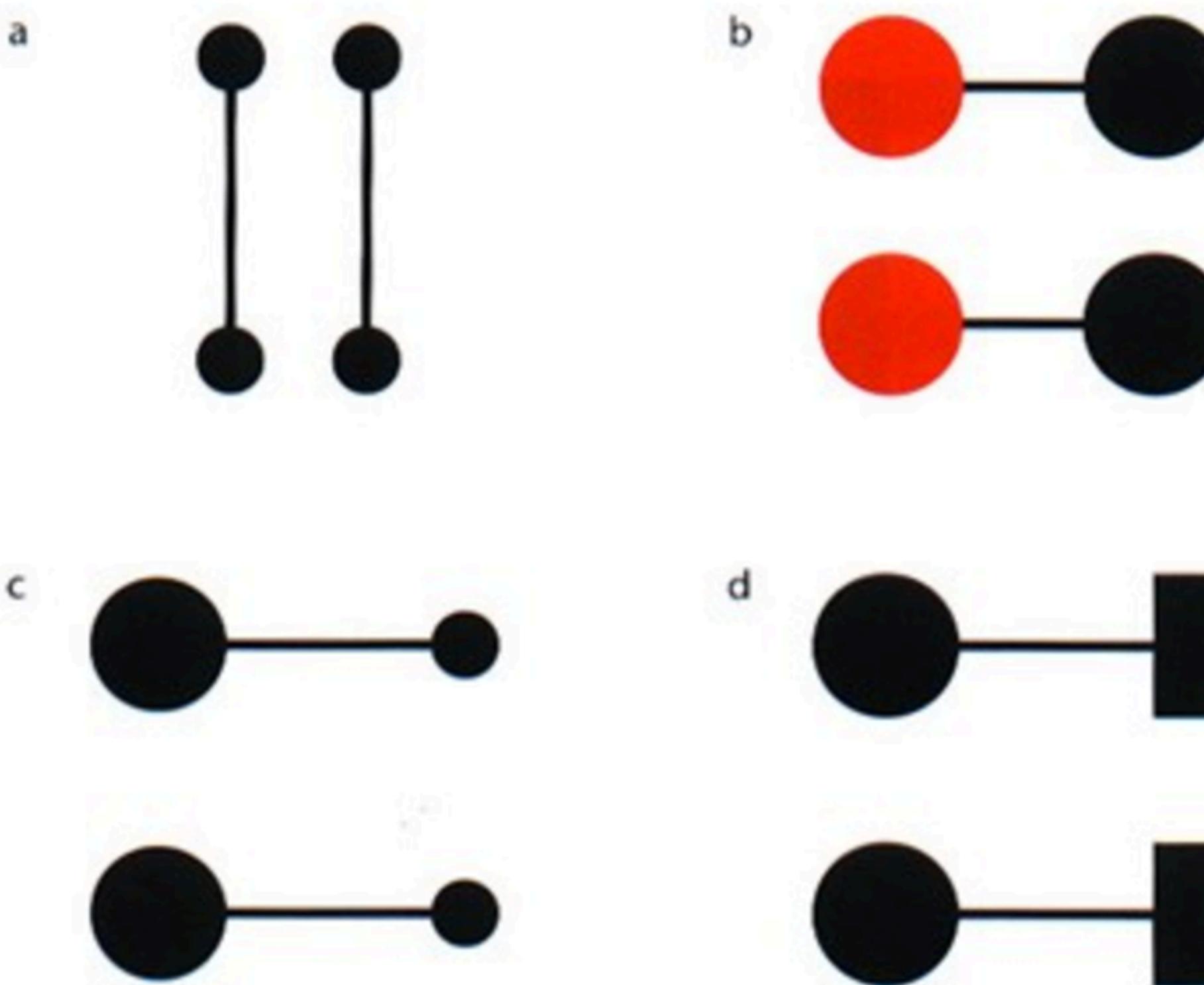
Value



Glyph

Connectedness

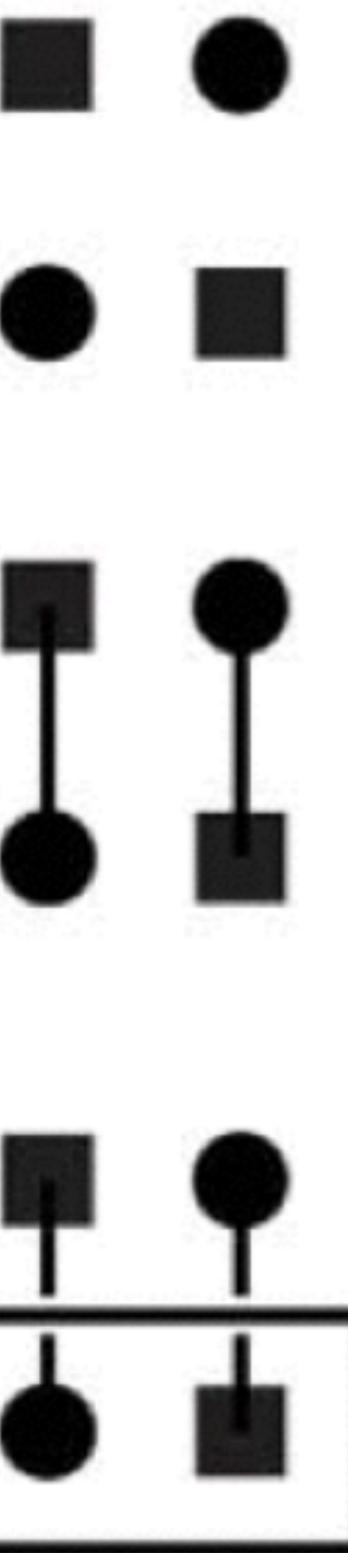
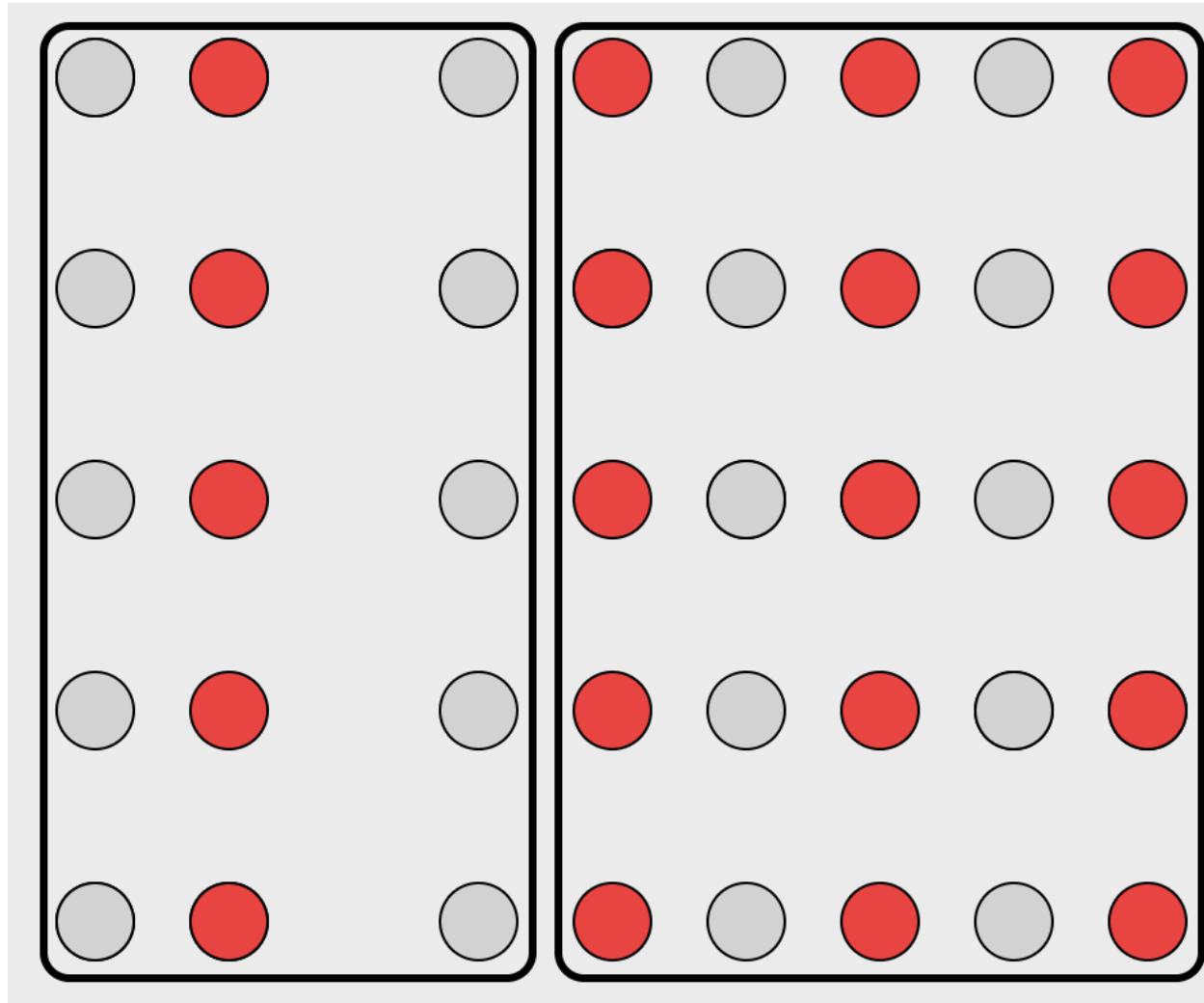
Stronger than proximity, color, size or shape



Enclosure

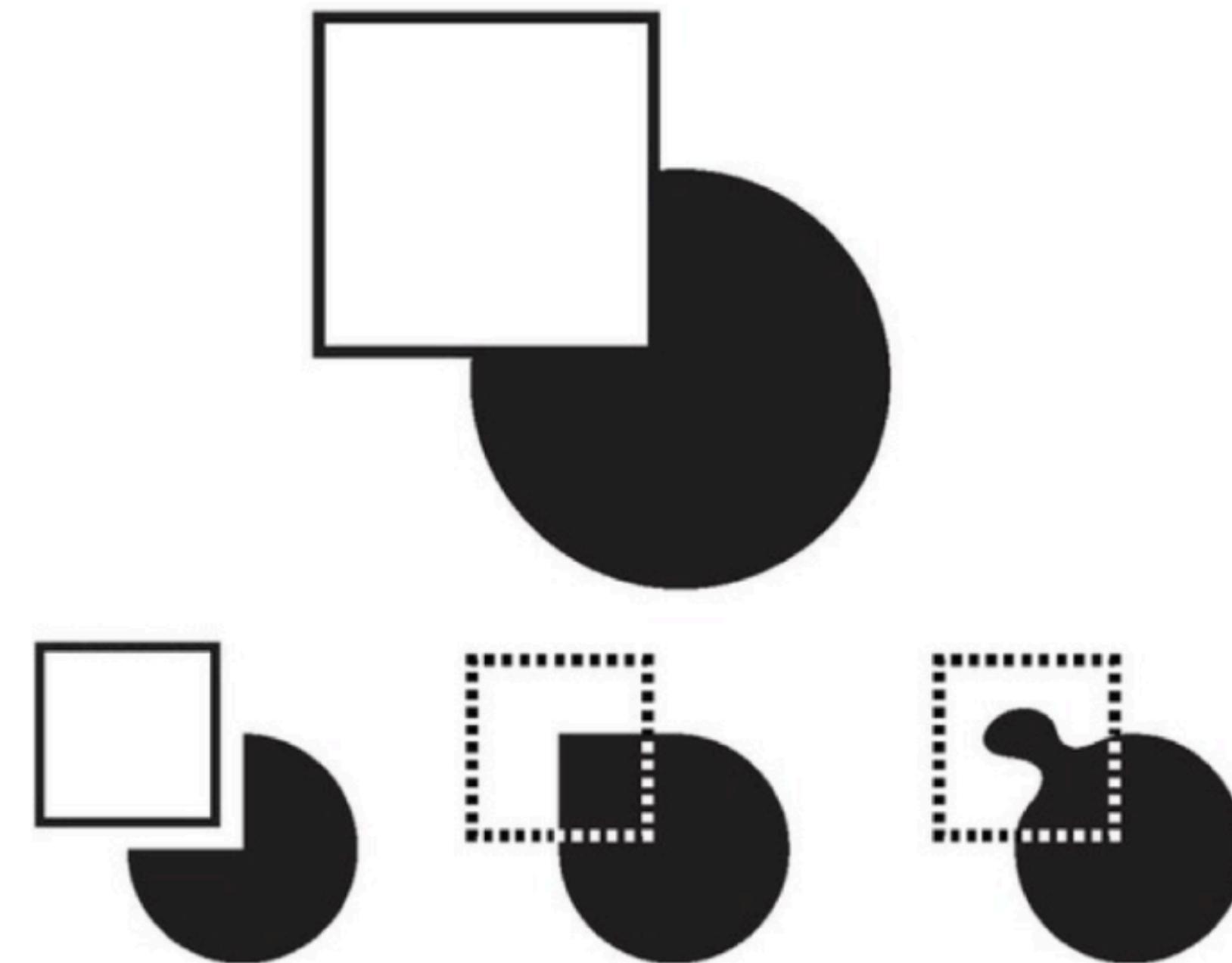
Surrounding a group of related elements with a visual element

Stronger than connectedness

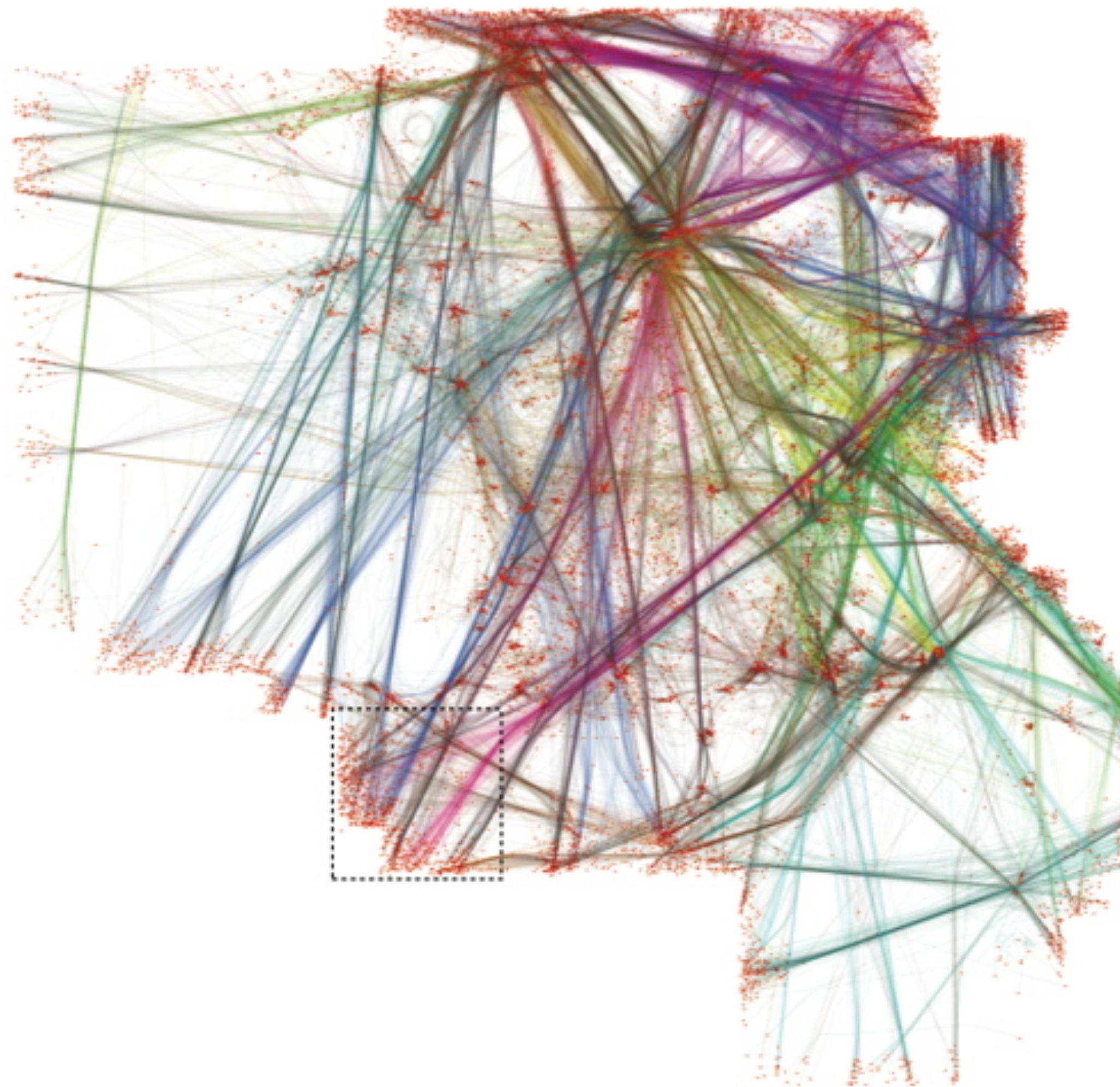


Continuity

Complex shapes are reduced to familiar simpler ones

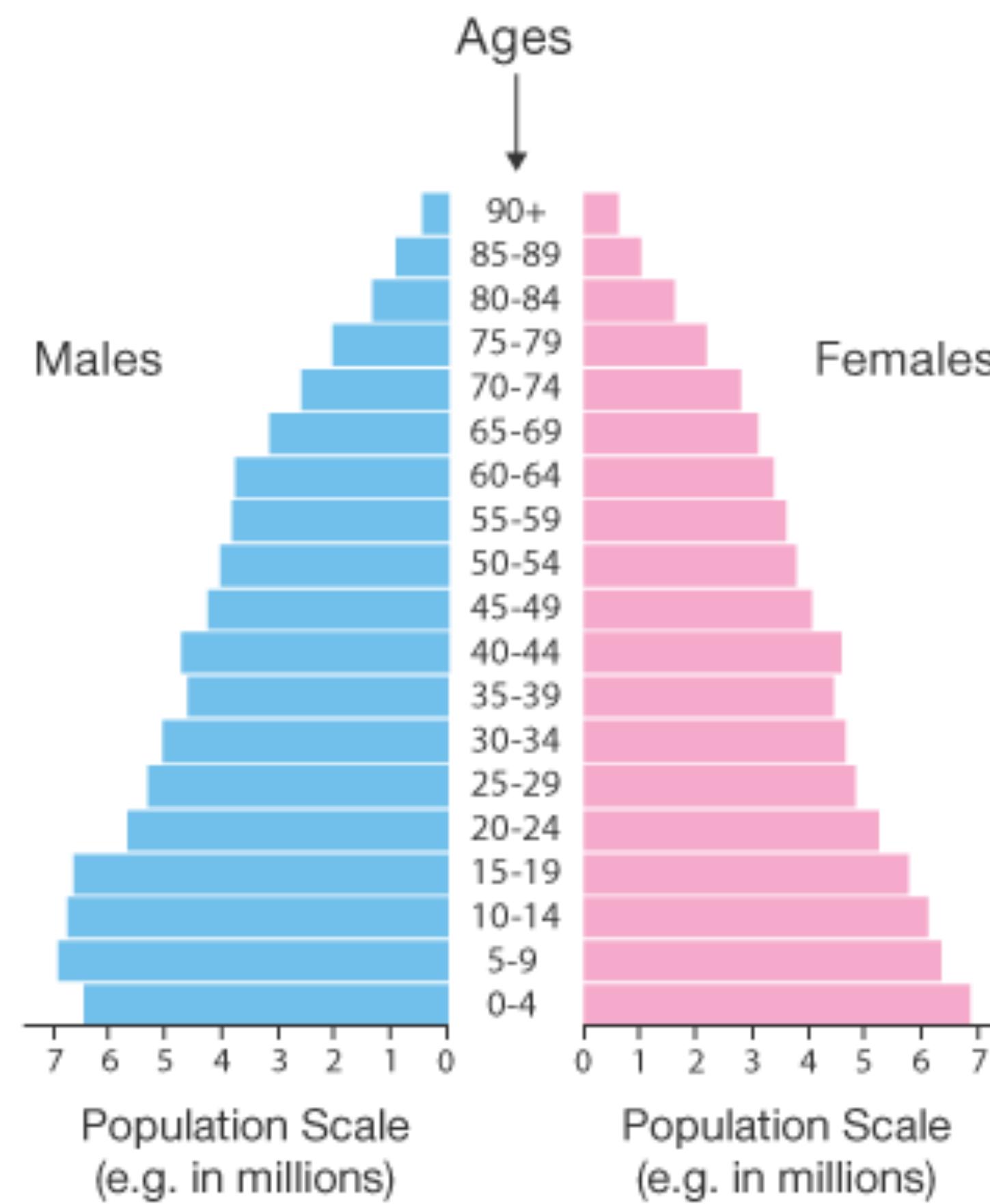


Continuity



Symmetry

Symmetrical elements are perceived as part of the same group



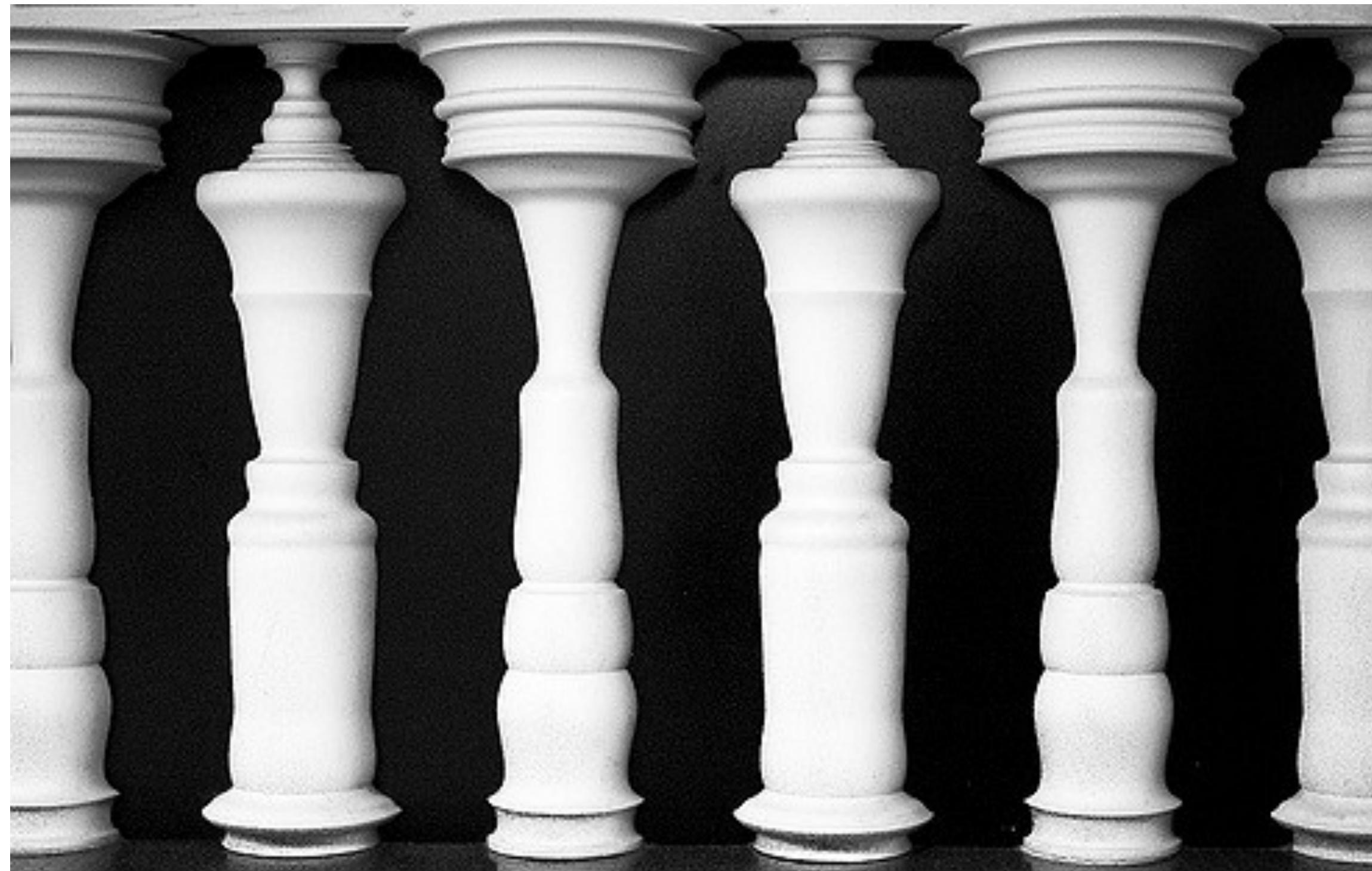
Closure

Elements are in the same group if they are part of a closed figure



Figure / ground

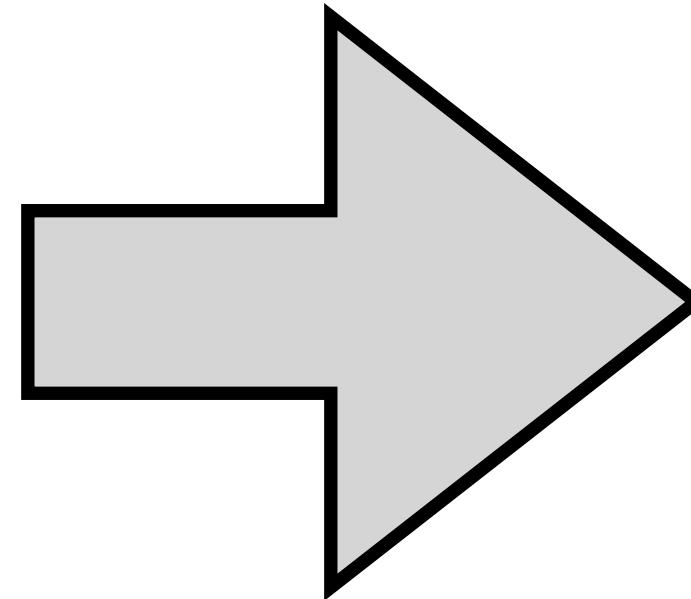
Elements are perceived as either figures (front) or background



Take home message

Perception

- Human visual system
- Color
- Preattentive processing
- Gestalt principles



**Be an effective
data viz designer**