

CS-5630 / CS-6630 Visualization

Perception

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Color names if you're a girl...

Maraschino	Red
Cayenne	Red
Maroon	Purple
Plum	Purple
Eggplant	Purple
Grape	Purple
Orchid	Purple
Lavender	Pink
Carnation	Pink
Strawberry	Pink
Bubblegum	Pink
Magenta	Pink
Salmon	Orange
Tangerine	Orange
Cantaloupe	Orange
Banana	Yellow
Lemon	Yellow
Honeydew	Green
Lime	Green
Spring	Green
Clover	Green
Fern	Green
Moss	Green
Flora	Green
Sea Foam	Blue
Spindrift	Blue
Teal	Blue
Sky	Blue
Turquoise	Blue

Color names if you're a guy...

Administrativa

Homeworks 1

Grades are out!

HW 1 Stats

count 70.000000

mean 92.9

std 17.4

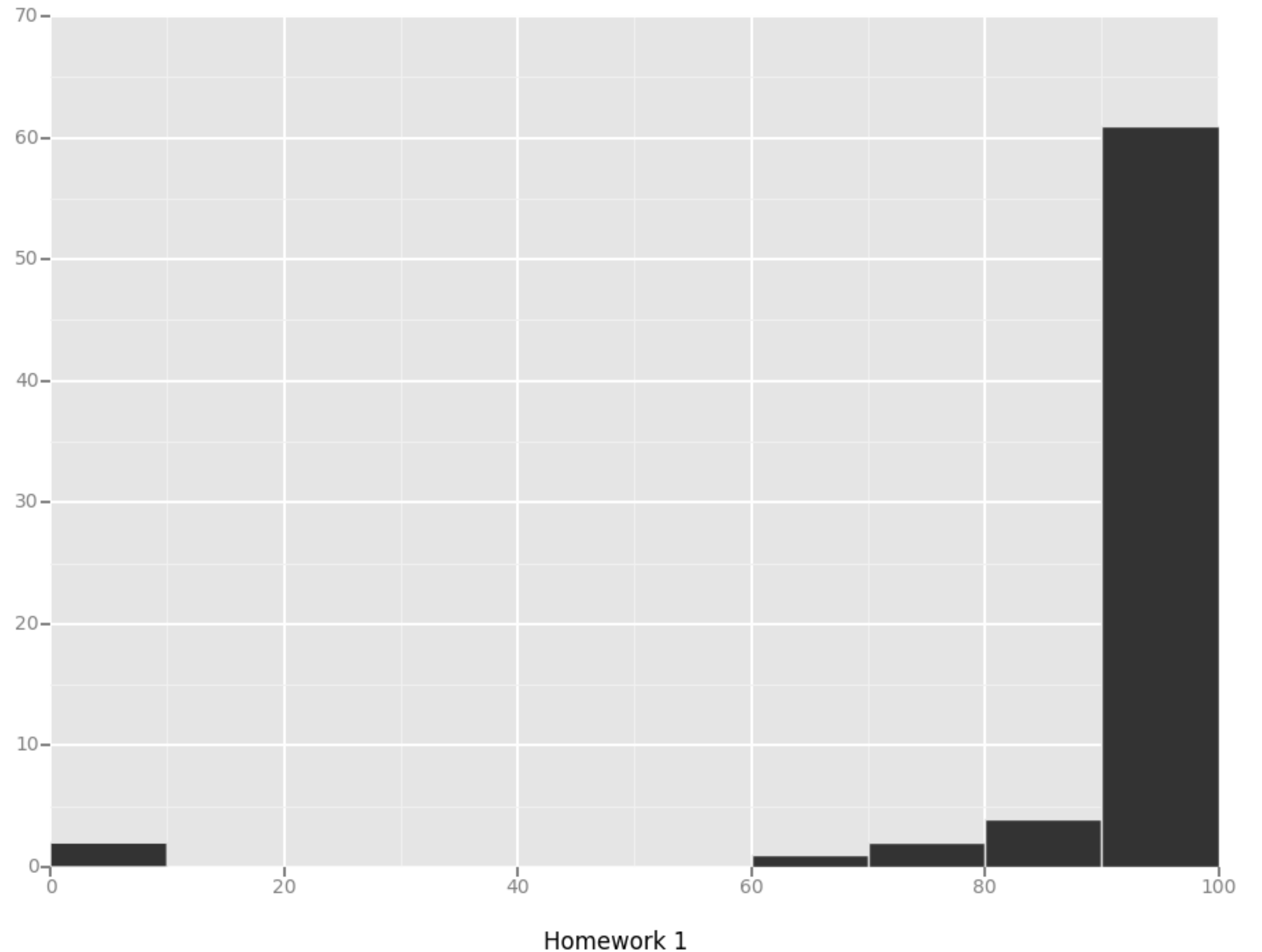
min 0.0

25% 95.0

50% 98.0

75% 100.0

max 100.0



Homework 3

Due Saturday!

Use lecture resources and recommended readings.

Ask on Canvas.

Go to office hours.

Lab introducing homework, today 4-5 in Meldrum, Rm. 2760 at WEB

Exploring FIFA World Cup Statistics: CS-5630/6630 Homework 3

Name: YOURNAME; E-Mail: YOUREMAIL; UID: u0123456

1994 FIFA World Cup USA

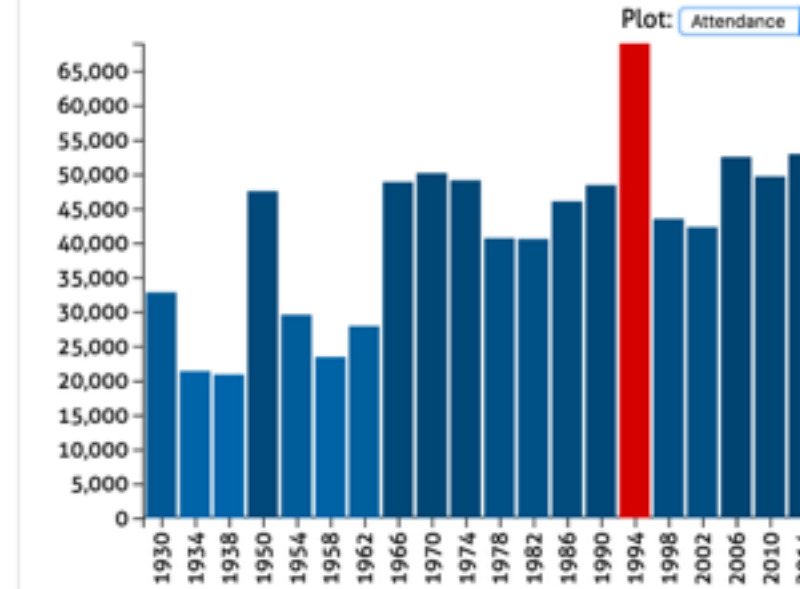
Host
USA

Winner
Brazil

Silver
Italy

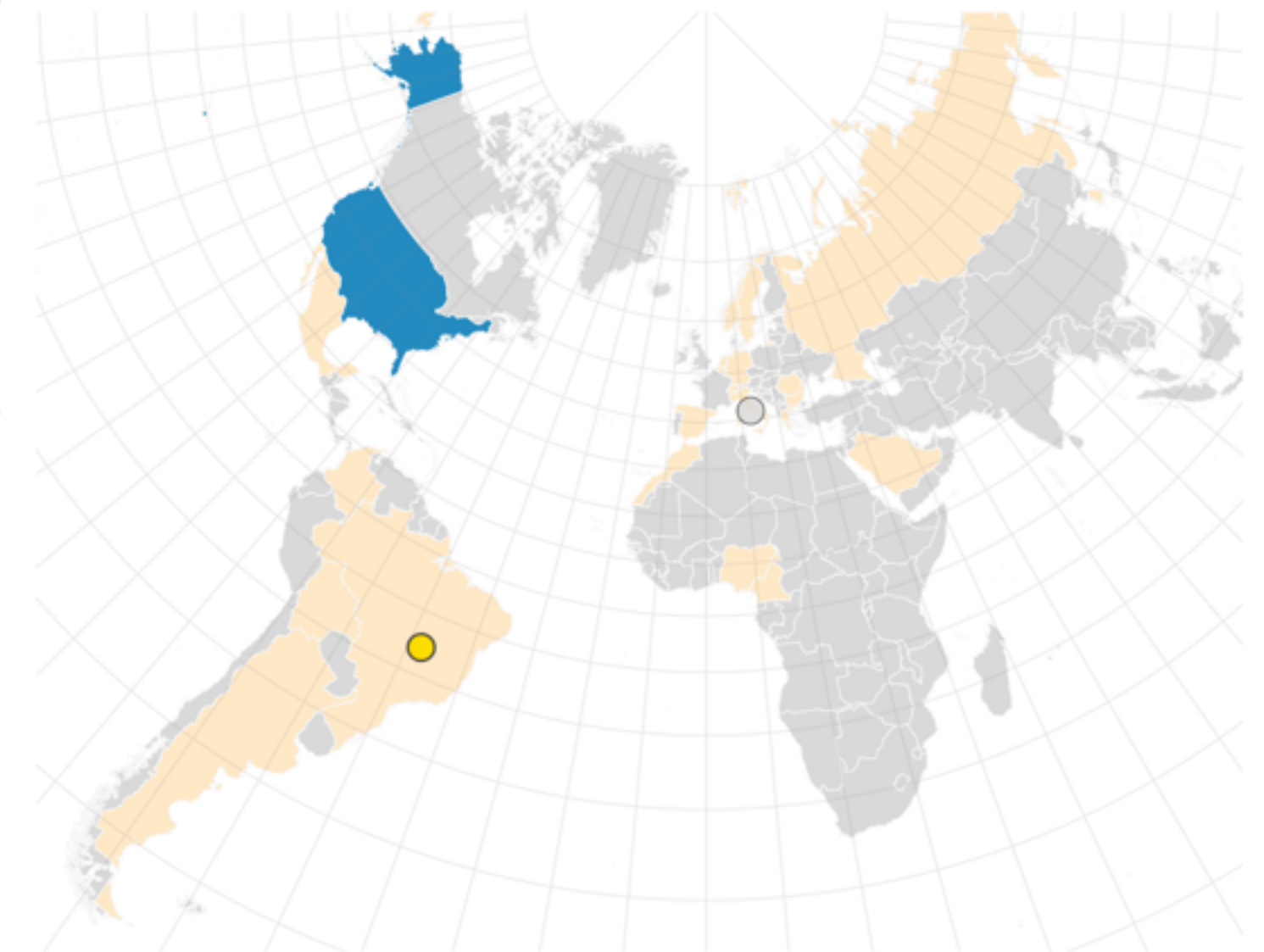
- Teams
- Cameroon
 - Morocco
 - Nigeria
 - Korea Republic
 - Saudi Arabia
 - Belgium
 - Bulgaria
 - Germany
 - Greece
 - Italy
 - Netherlands
 - Norway
 - Republic of Ireland
 - Romania
 - Russia
 - Spain
 - Sweden
 - Switzerland
 - Mexico
 - USA
 - Argentina
 - Bolivia
 - Brazil
 - Colombia

Bar Chart



World Map

Host Participant Winner Runner-Up



RUSSIA 2018

A quick recap of maps

Perception

Perception

Identification and interpretation of sensory information

From the physical stimulus to recognizing information

Shaped by learning, memory, expectation

Cognition

The processing of information, applying knowledge

Hear someone speak: Perception

Understand the language and the words: Cognition

Perception vs. Cognition

Perception

Eye, optical nerve, visual cortex

Basic perception

First processing
(edges, planes)

Not conscious

Reflexes

Cognition

Recognizing objects

Relations between objects

Conclusion drawing

Problem solving

Learning, ...

RED

GREEN

BLUE

YELLOW

PINK

ORANGE

BLUE

GREEN

BLUE

WHITE

GREEN

YELLOW

ORANGE

BLUE

WHITE

BROWN

RED

BLUE

YELLOW

GREEN

PINK

YELLOW

GREEN

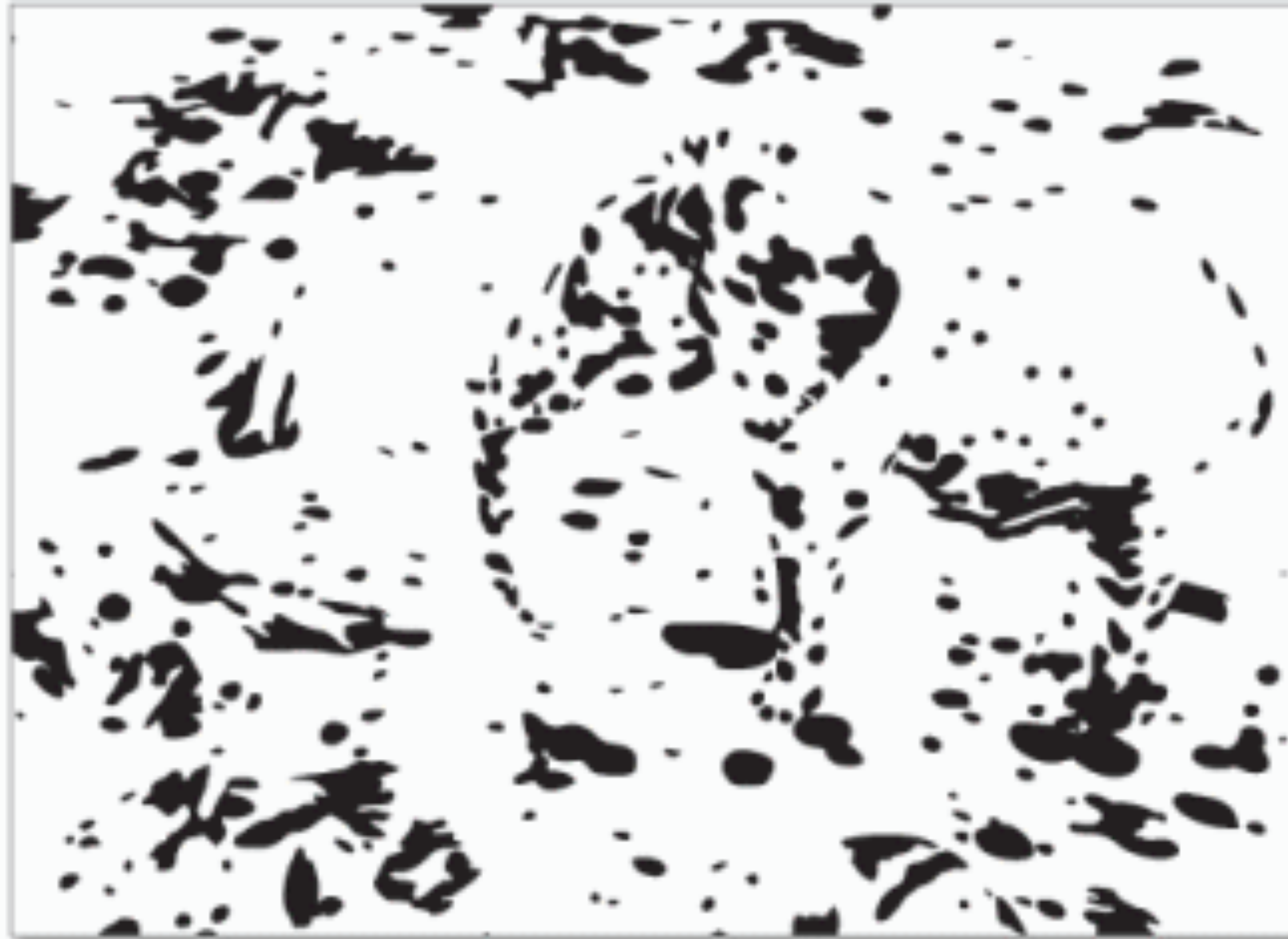
BLUE

RED

Looking vs. Seeing



Emergence Images. perceptual hysteresis



Looking only at patches doesn't work

http://graphics.stanford.edu/~niloy/research/emergence/emergence_image_siga_09.html





we rely on priors



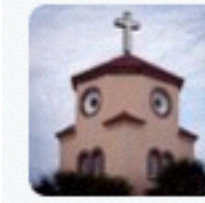
Pareidolia



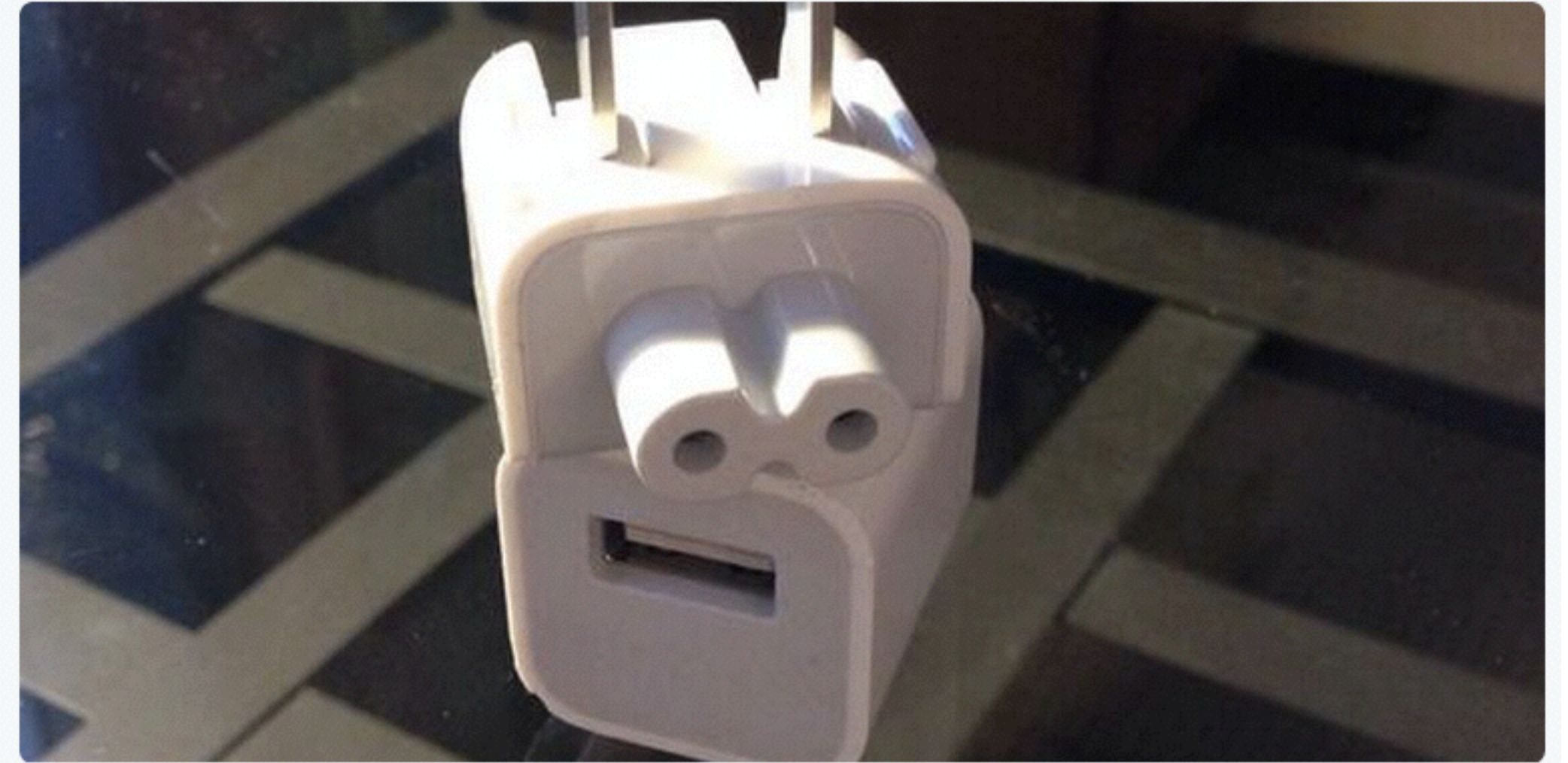
Faces in Things @FacesPics · Mar 9
These chairs have seen some terrible things pic.twitter.com/Gjlc9wuP47



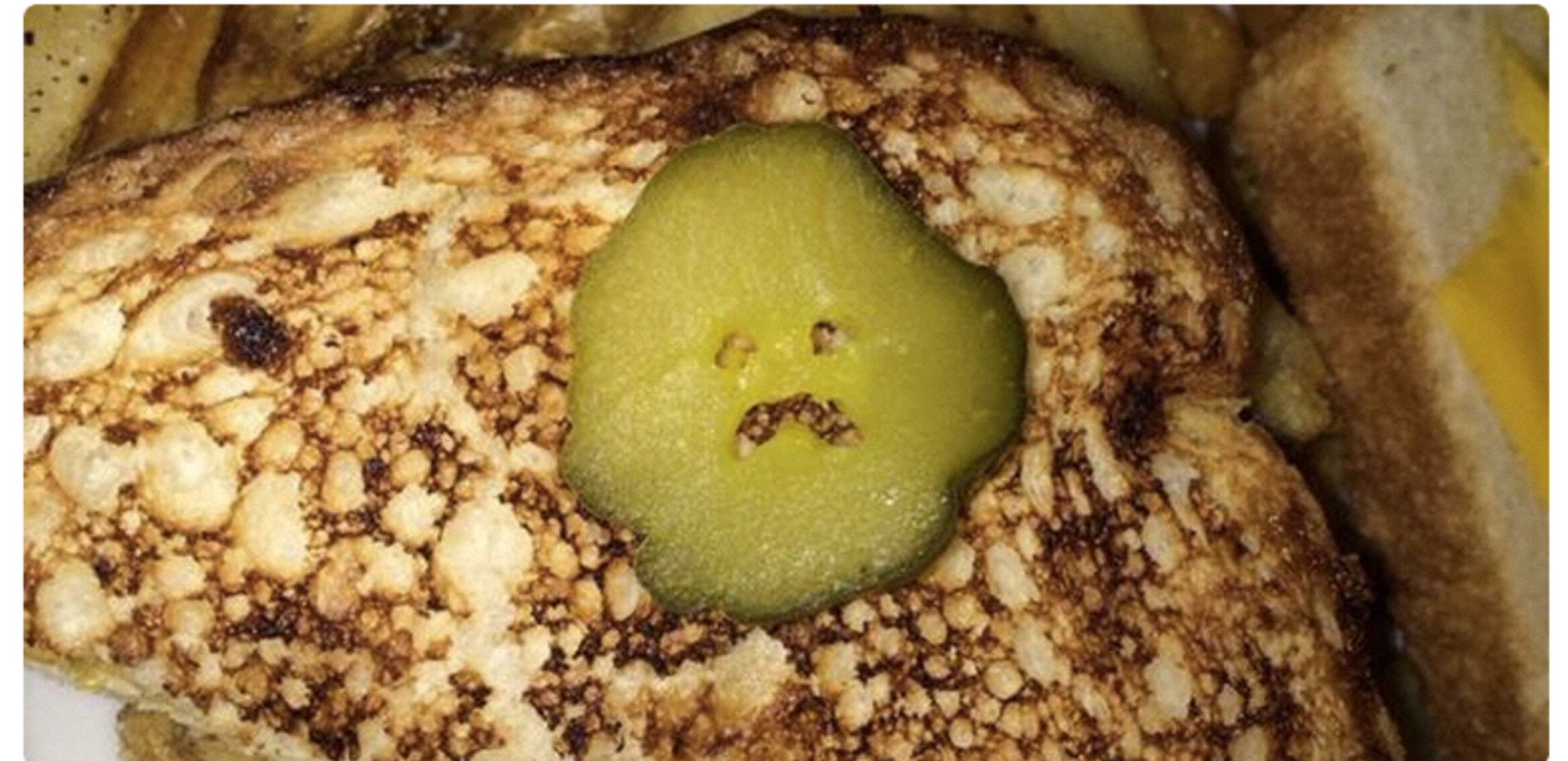
Faces in Things @FacesPics · Feb 14
Deep in thought Deep Fryer pic.twitter.com/1Qyqjmslka



Faces in Things @FacesPics · Mar 22
Hey little guy! pic.twitter.com/nt2BgwZeTR



Faces in Things @FacesPics · Mar 10
A terrified pickle pic.twitter.com/Ffph1wzTyv



Take Home Point

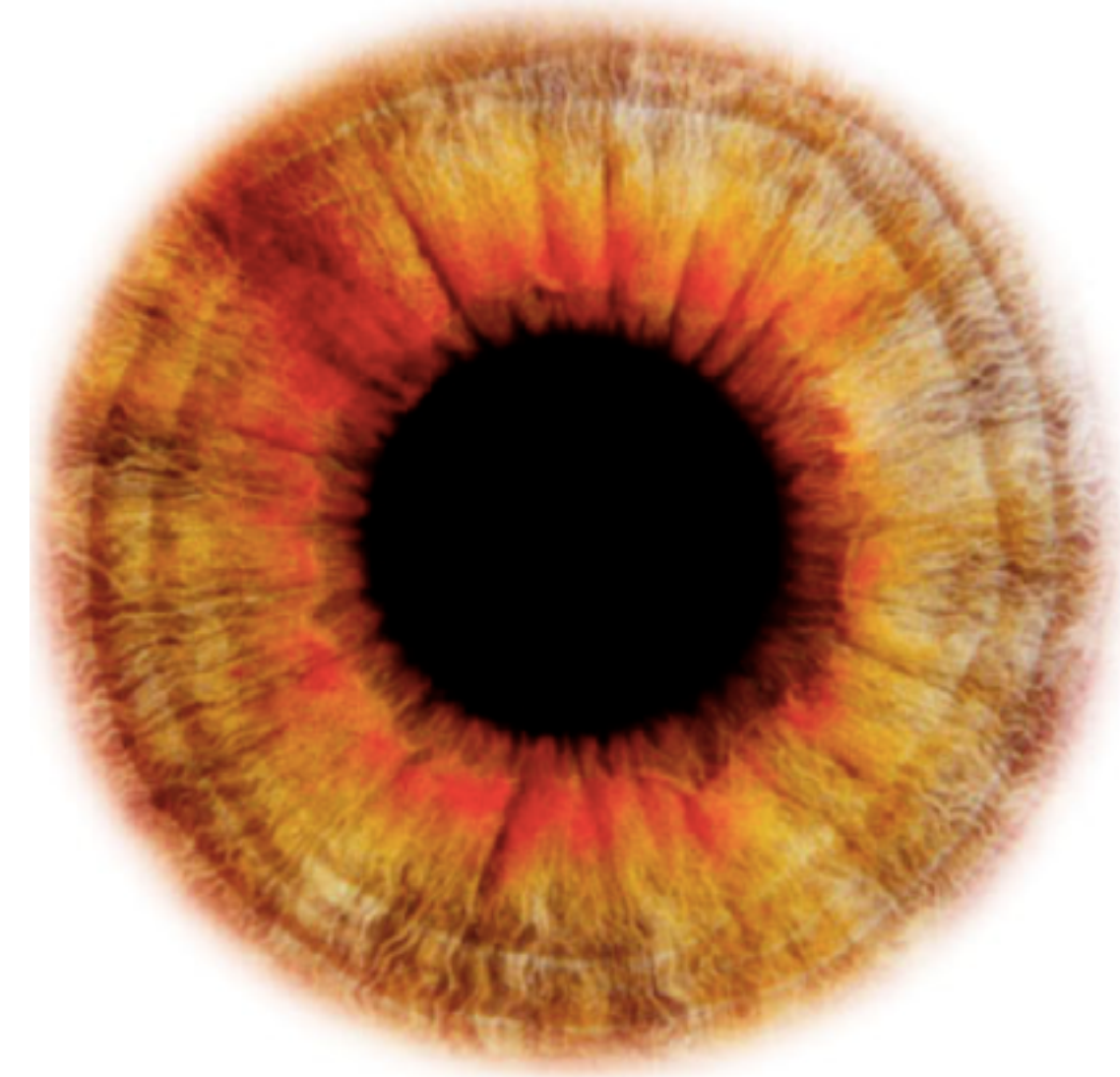
Vision is “constructed” top down from the input

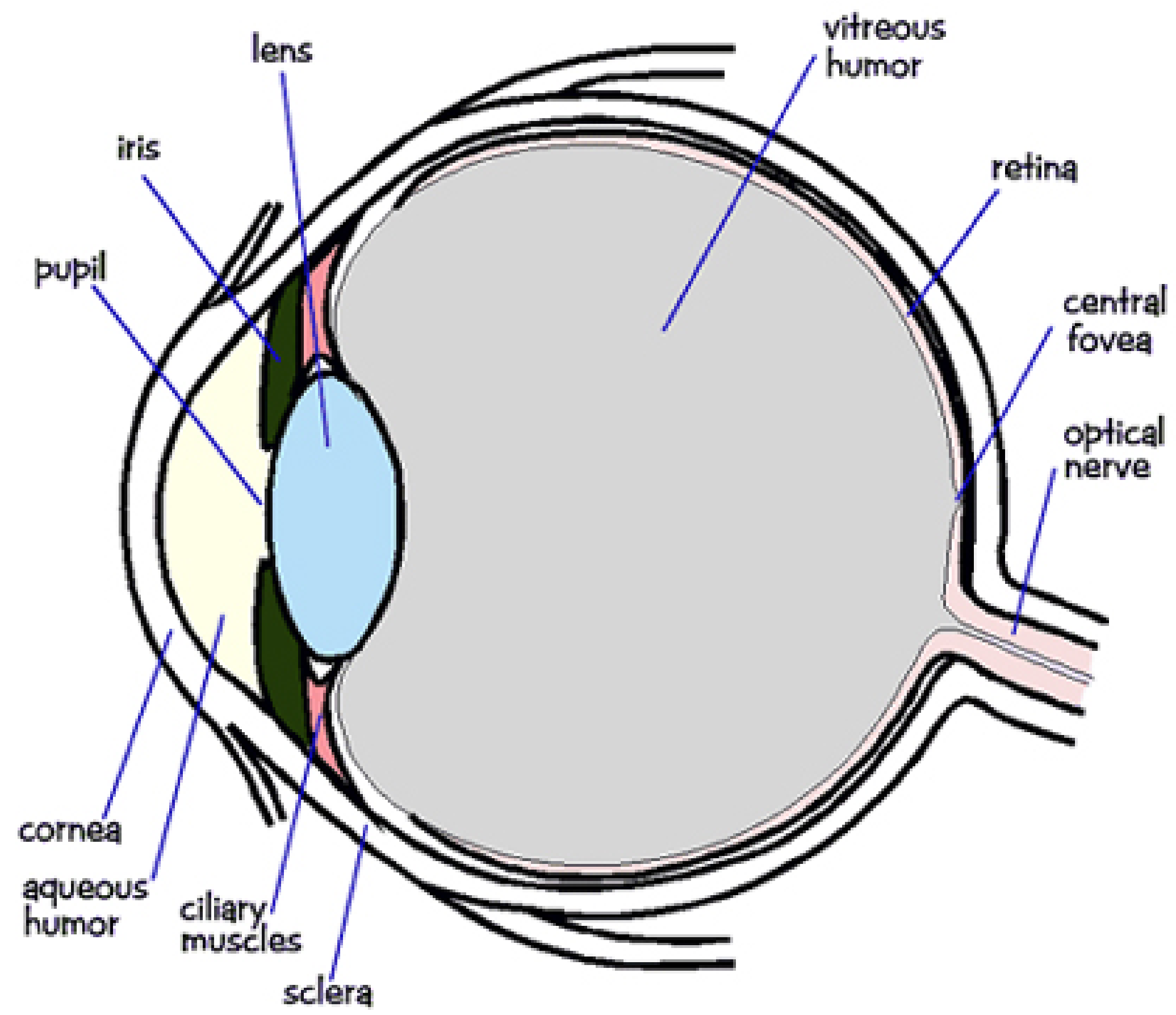
“What you see when you see a thing depends on what the thing is. What you see the thing as depends on what you know about what you are seeing.”

Zenon Pylyshyn
Canadian Cognitive Scientist
and Philosopher



The Eye





Human Visual System

5-6 mio cones

color vision

dense in the center

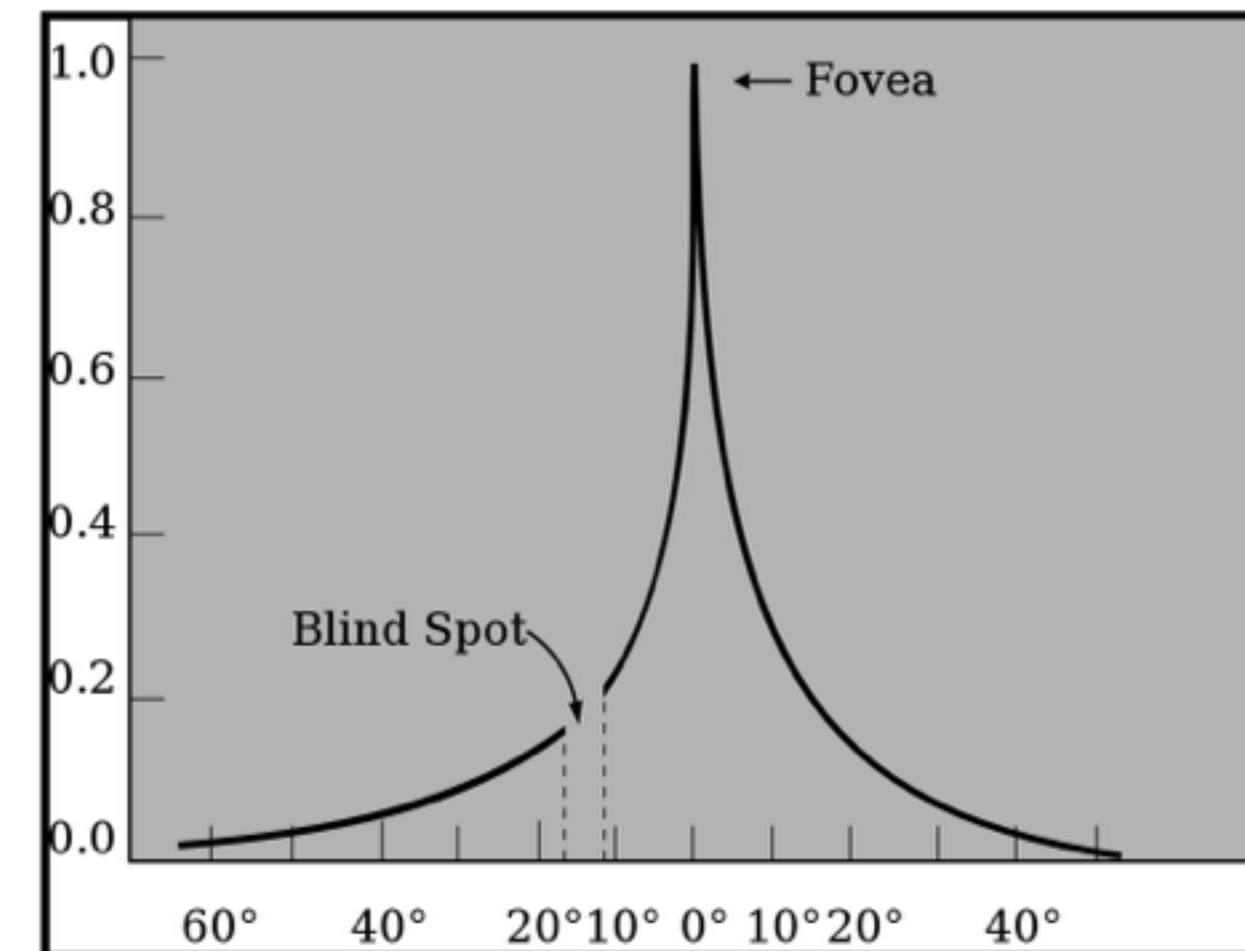
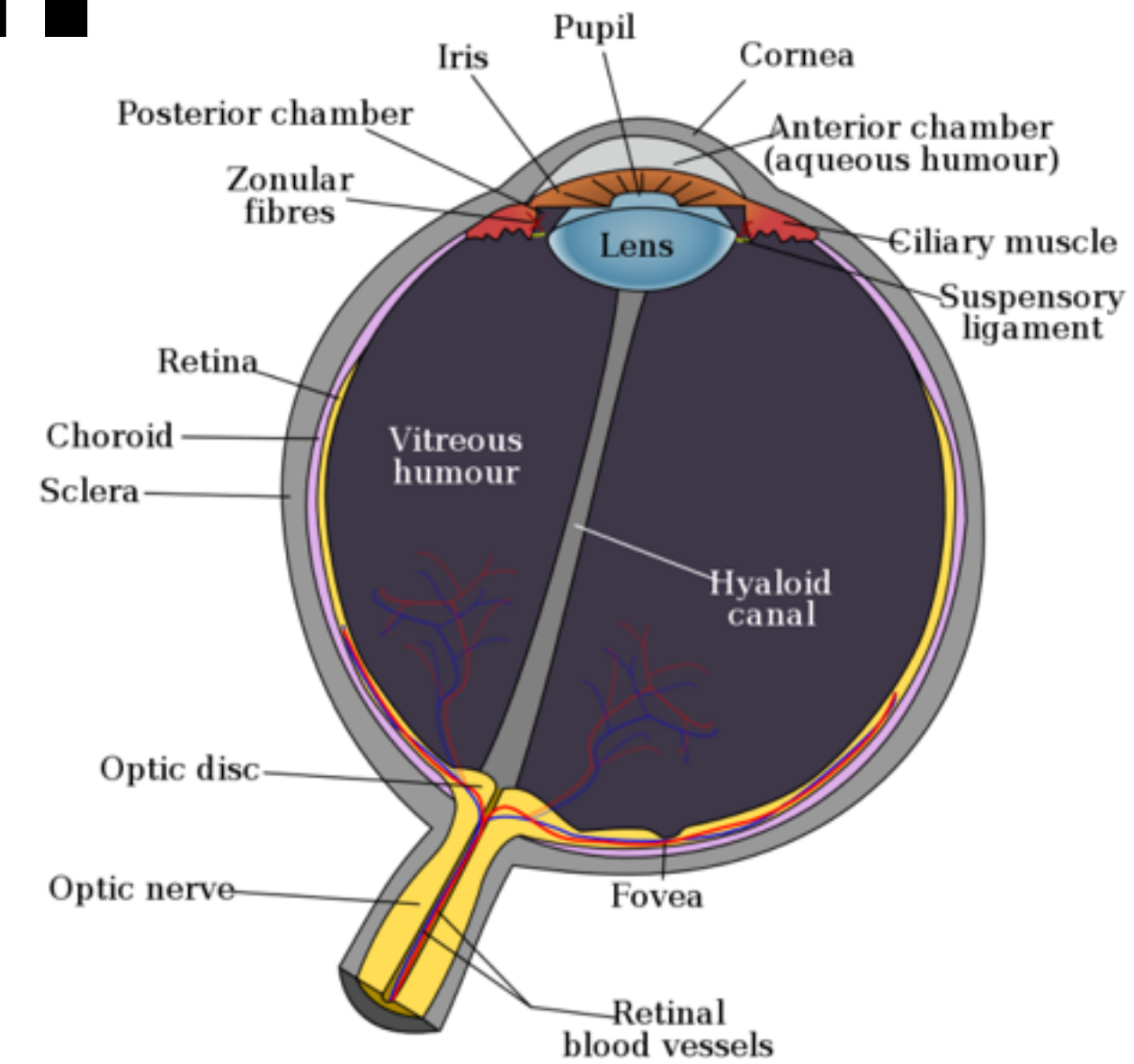
Fovea: 27 times the density

responsible for sharp central vision

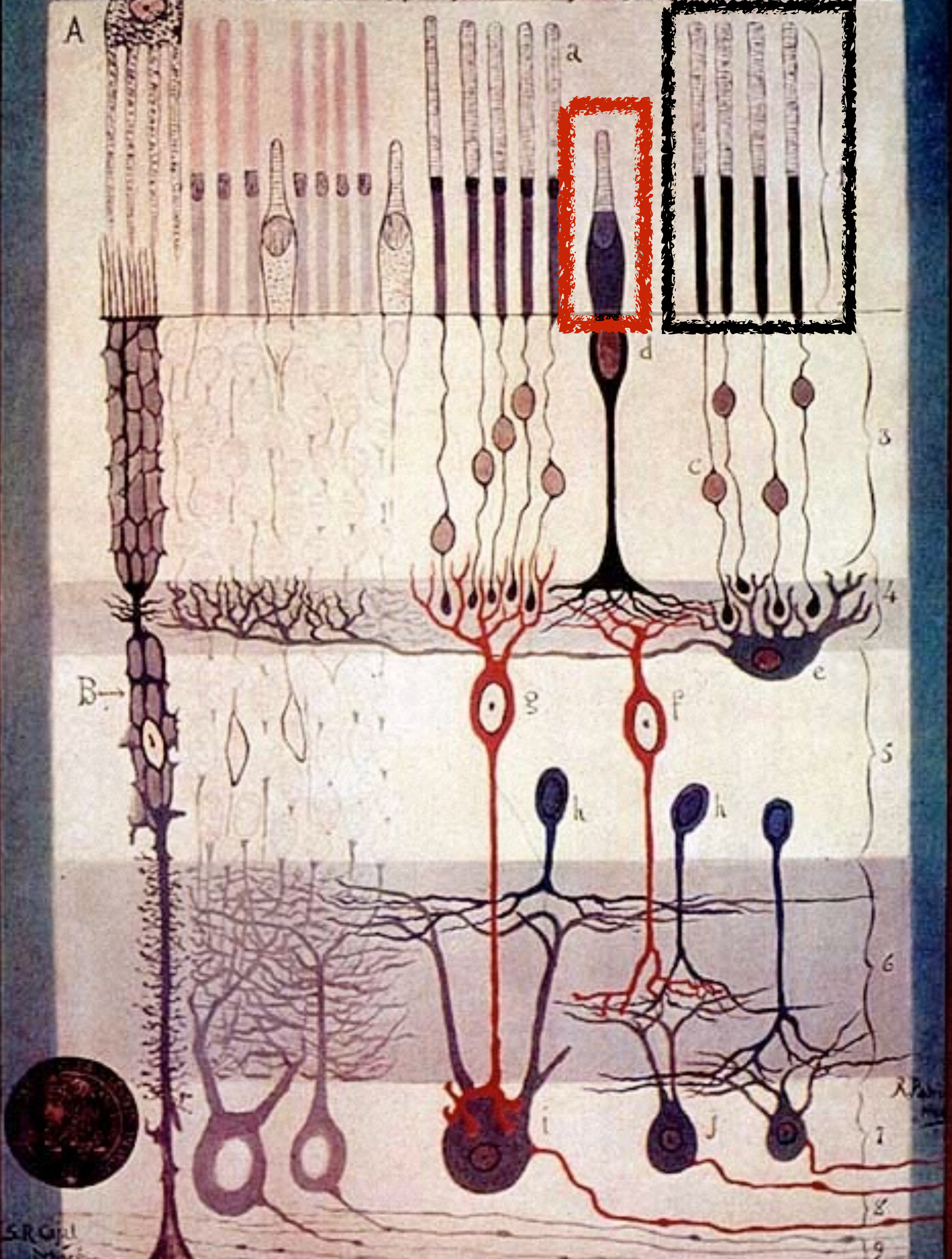
only cone cells

~120 mio rods

black/white



1. Capa de los conos y bastones. 2. Capa limitante externa. 3. Capa de los granos externos. 4. Capa plexiforme externa. 5. Capa de los granos internos. 6. Capa plexiforme interna. 7. Capa de las células ganglionares. 8. Capa de las fibras del nervio óptico. 9. Capa limitante interna.



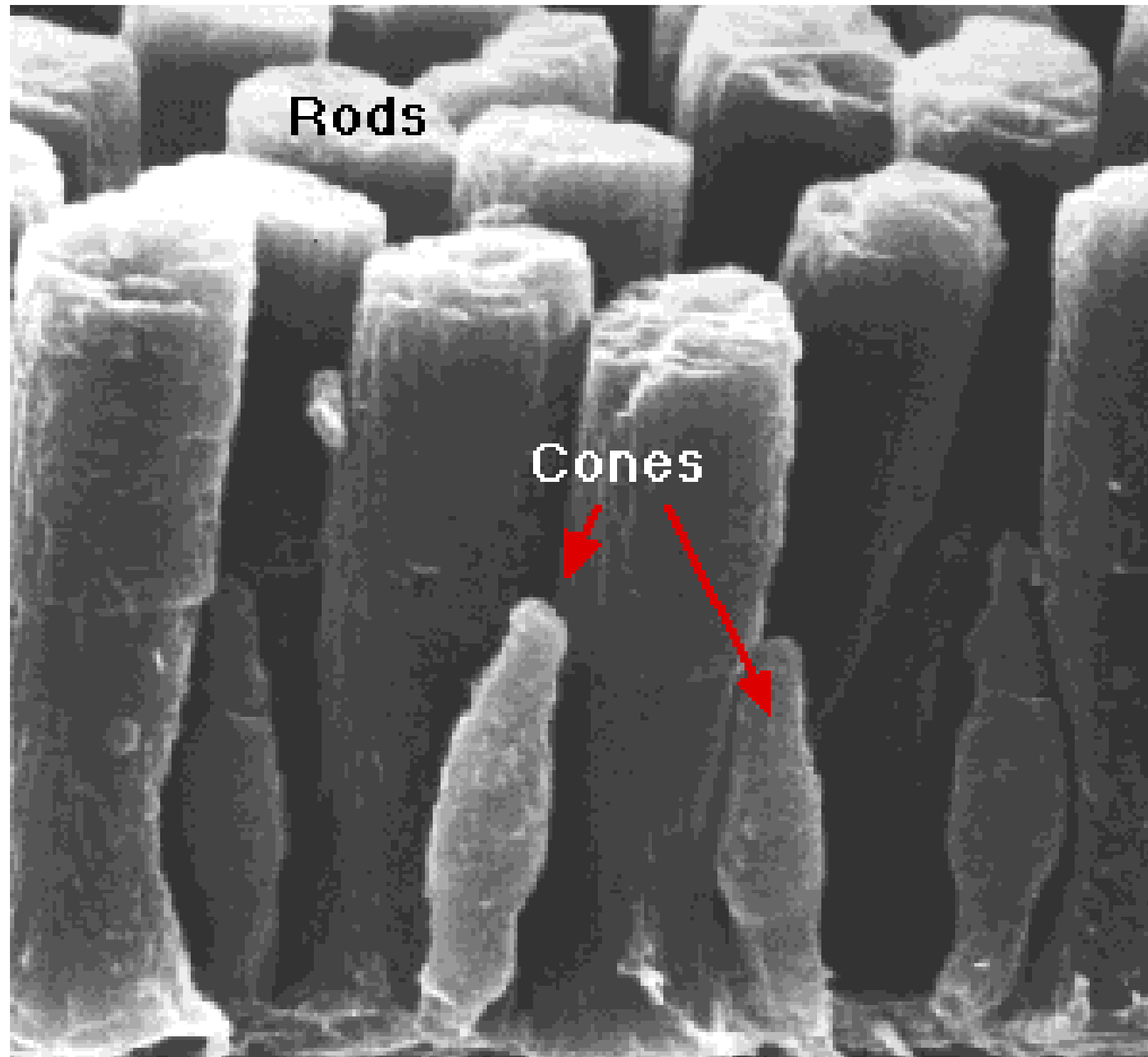
Rods - sensitive black and white

Cones - color vision

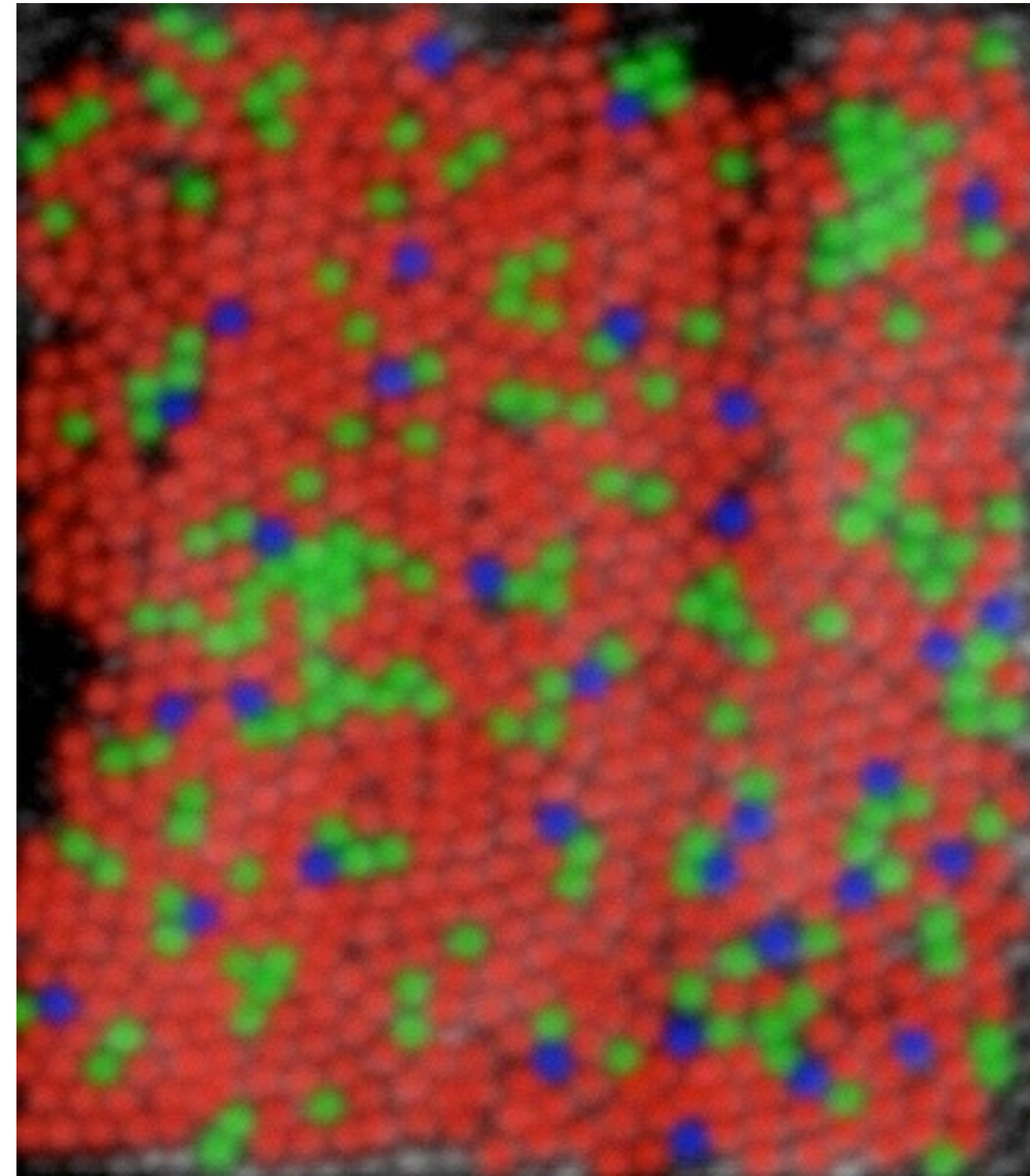
Ganglion Cells

"Structure of the Mammalian Retina"
c.1900 By Santiago Ramon y Cajal

Instituto Cajal. CSIC. Madrid.

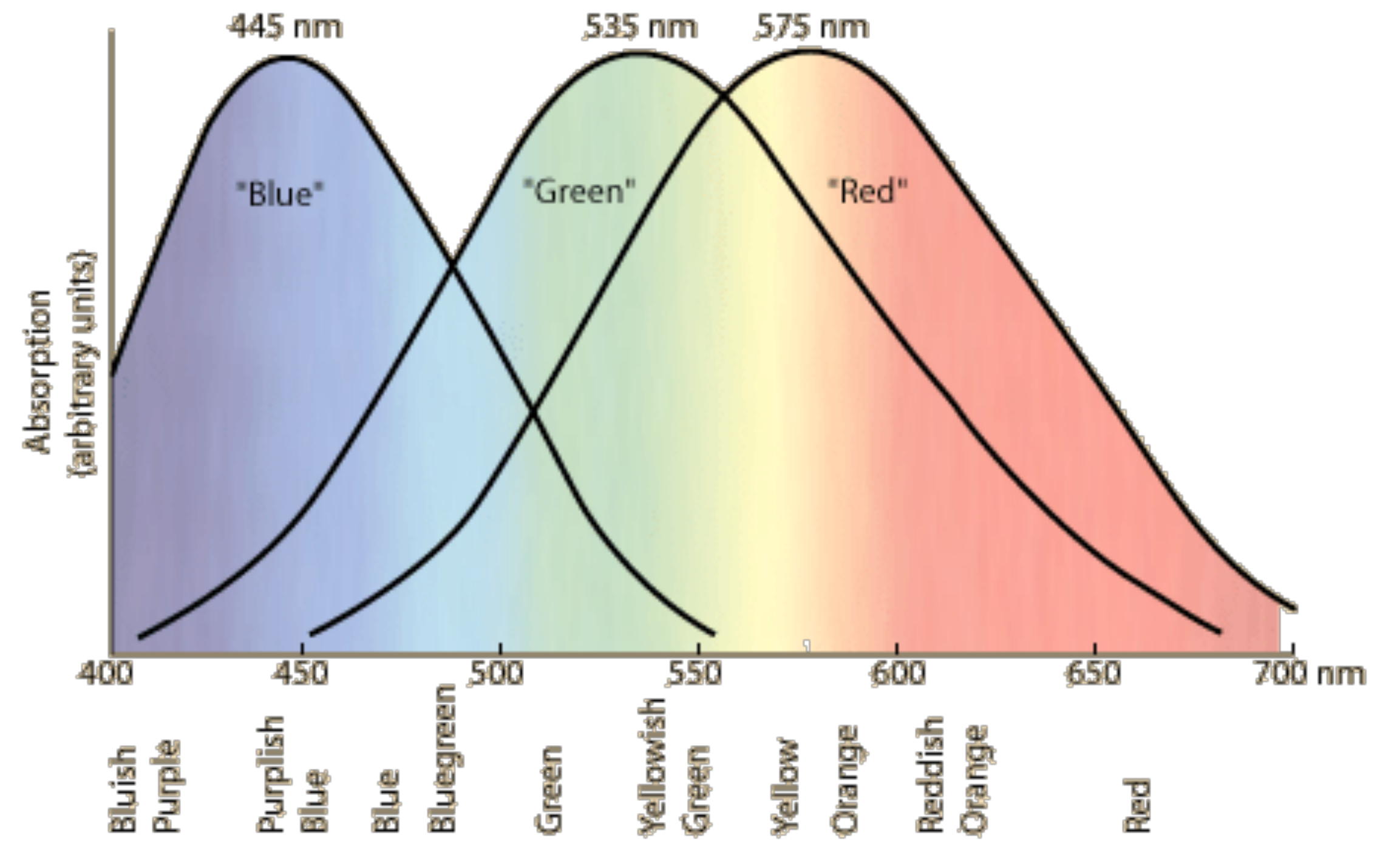
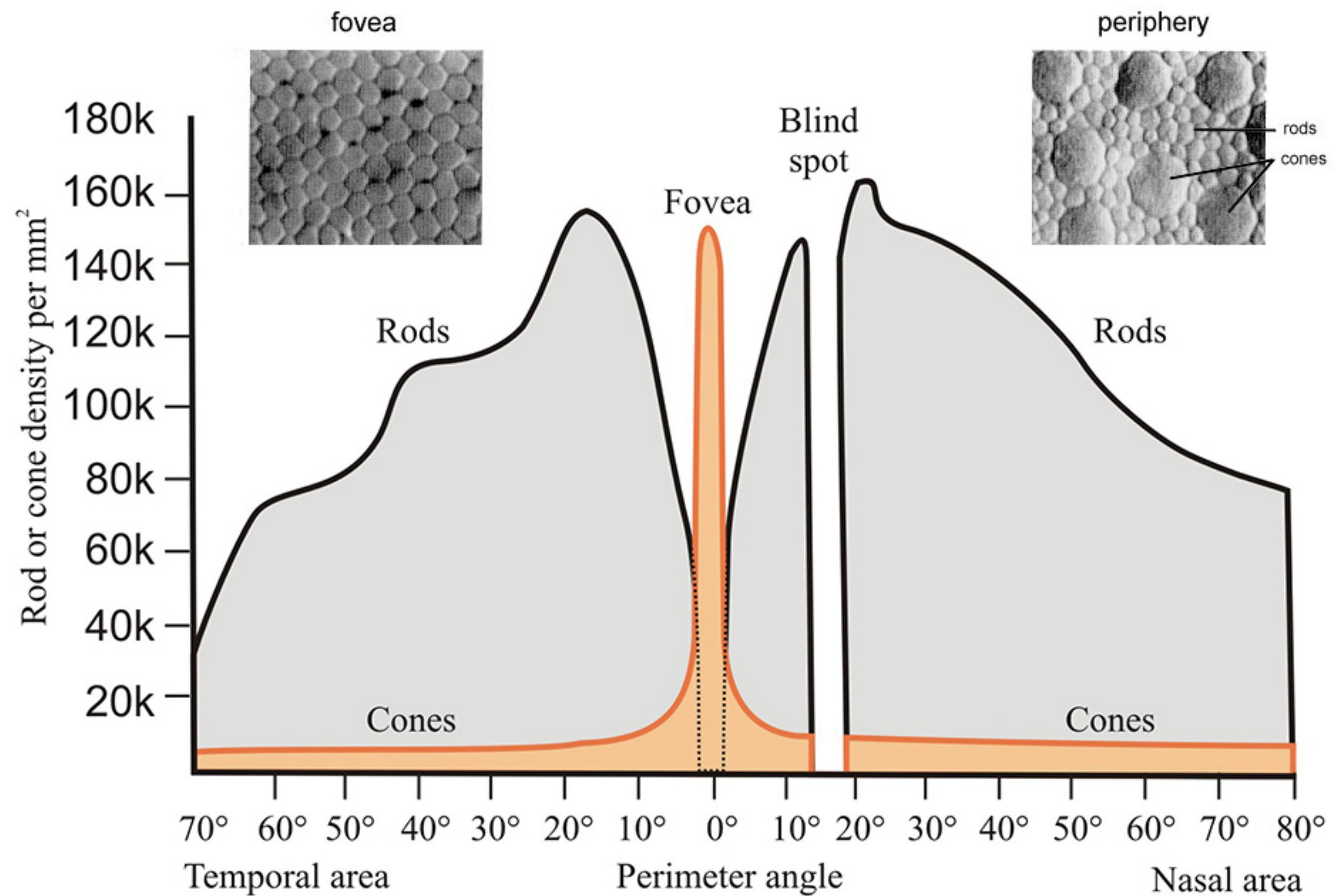


~120 million rods
~5-6 million cones



R 63% - G 31% - B 6%

Cone Response



Human Visual System

VIDEO!

Vision works as sequence of **fixations** and **saccades**

fixations: maintaining gaze on single location (200-600 ms)

saccades: moving between different locations (20-100 ms)

Vision not similar to a camera

More similar to a dynamic and ongoing construction project



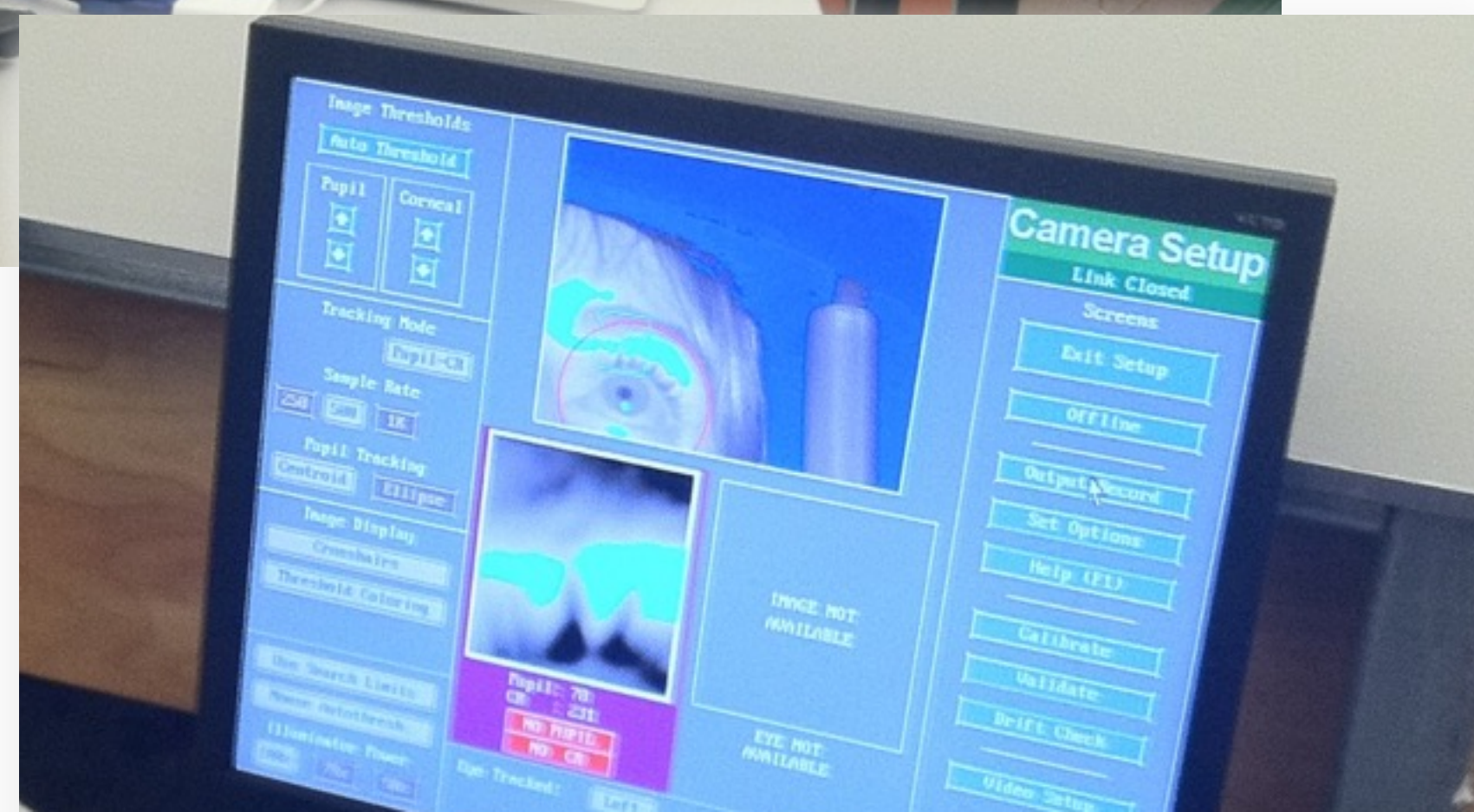
Eye-Tracking Experiment

Visualization display

Eye-tracking control computer



Infrared camera



Video!

Human Visual System

VIDEO!

No general purpose vision

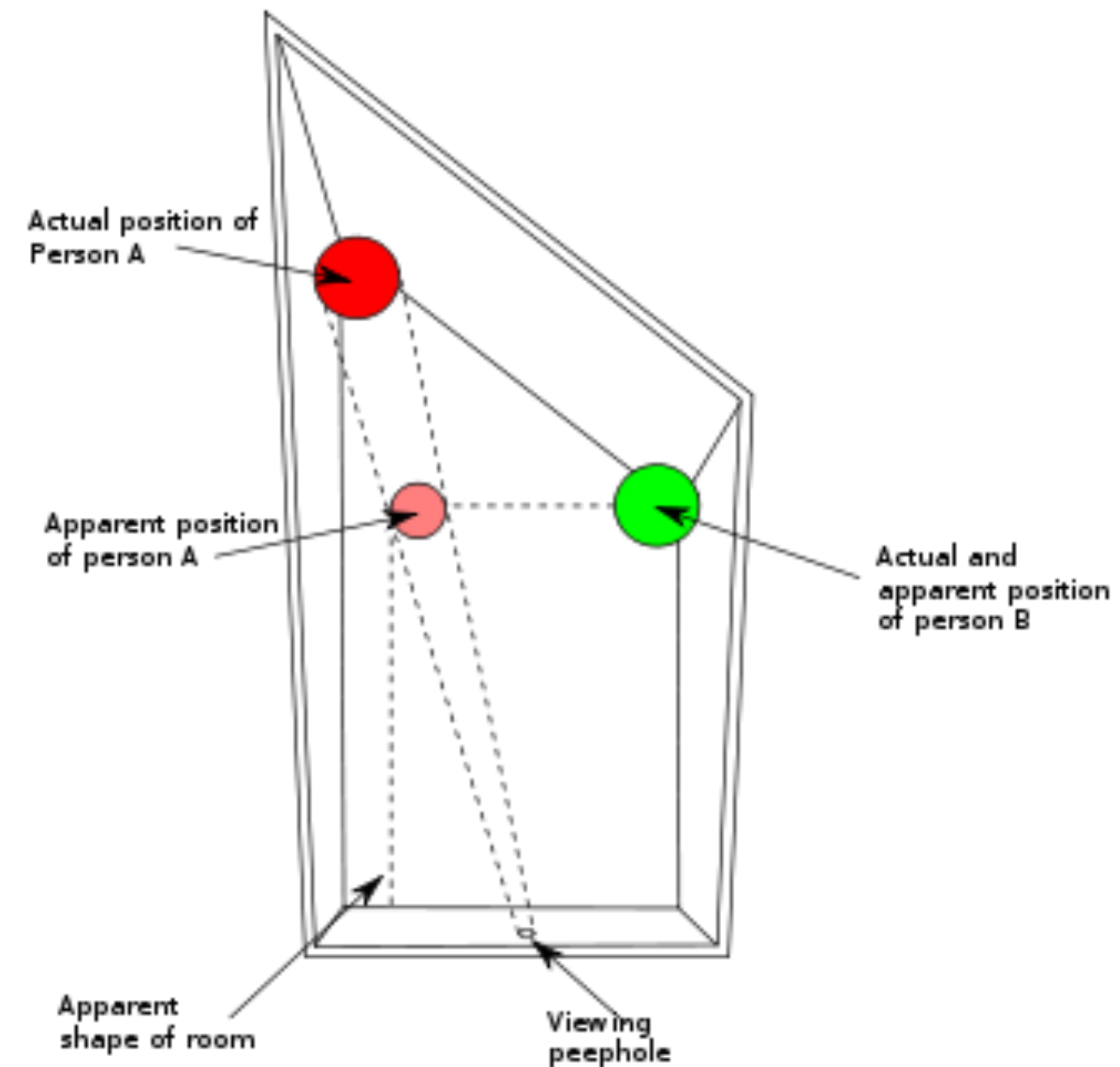
What we see depends on our goals and expectations

Relative judgments: strong

Absolute judgments: weak



Ames Room



Color

Color Basics

Visible part of the electromagnetic spectrum

390-750 nm

Spectral colors

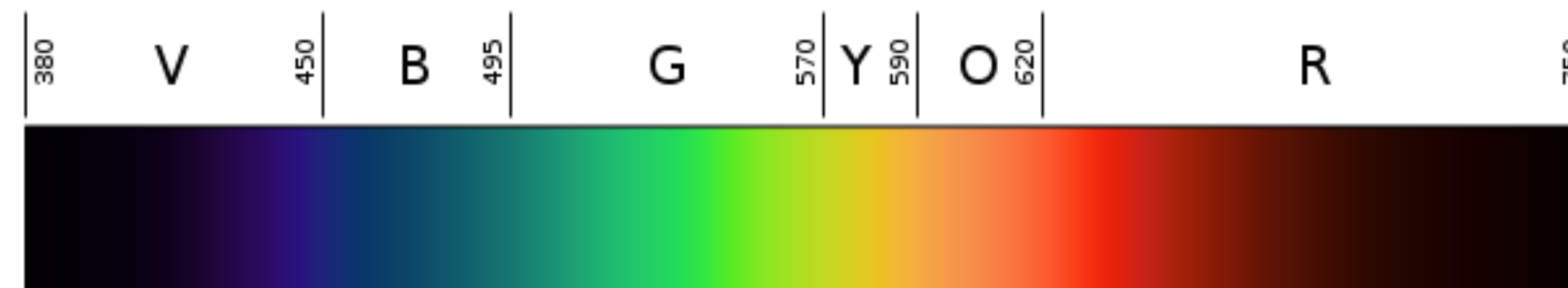
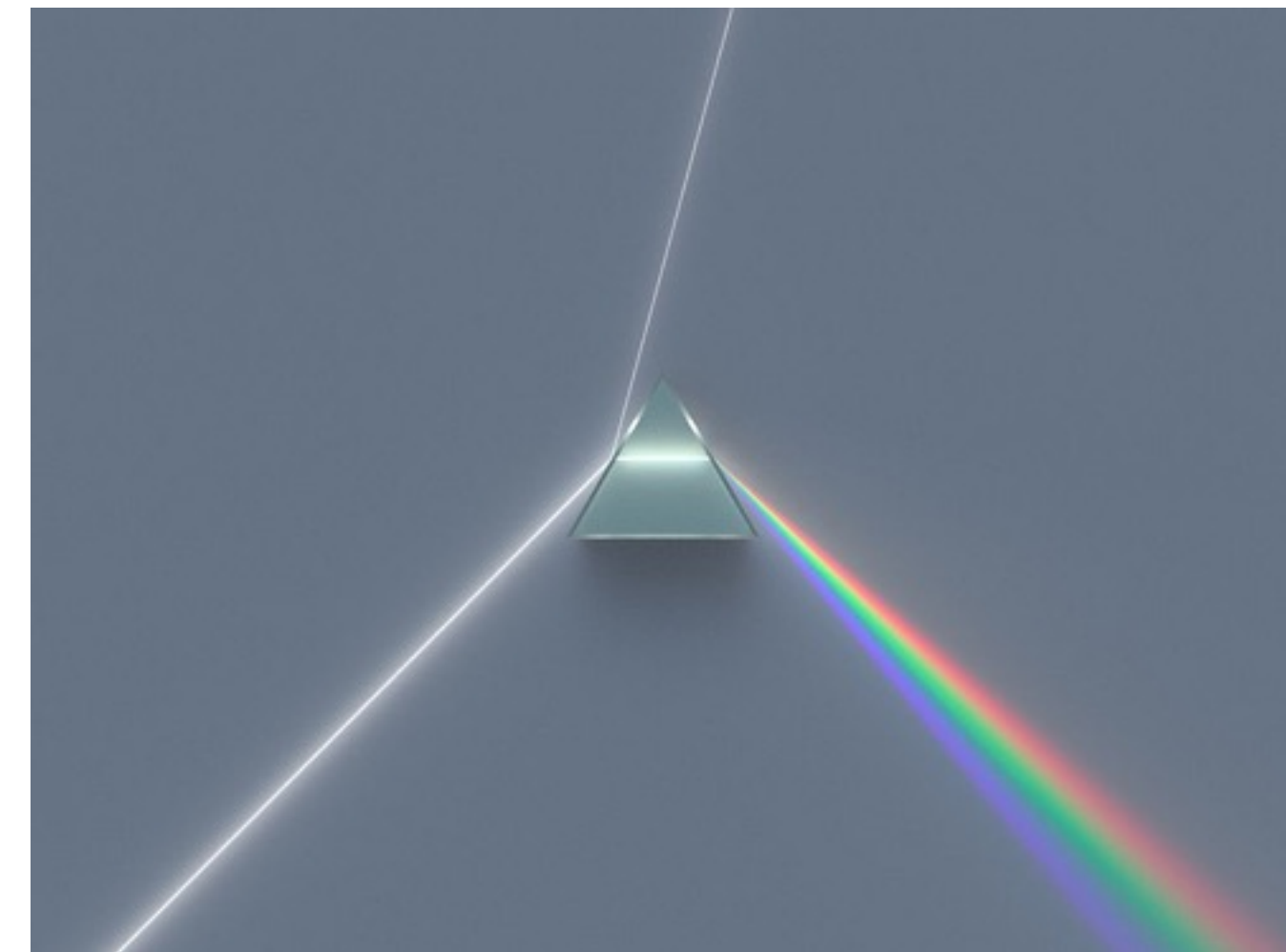
evoked by a single wavelength

Other colors: unsaturated colors

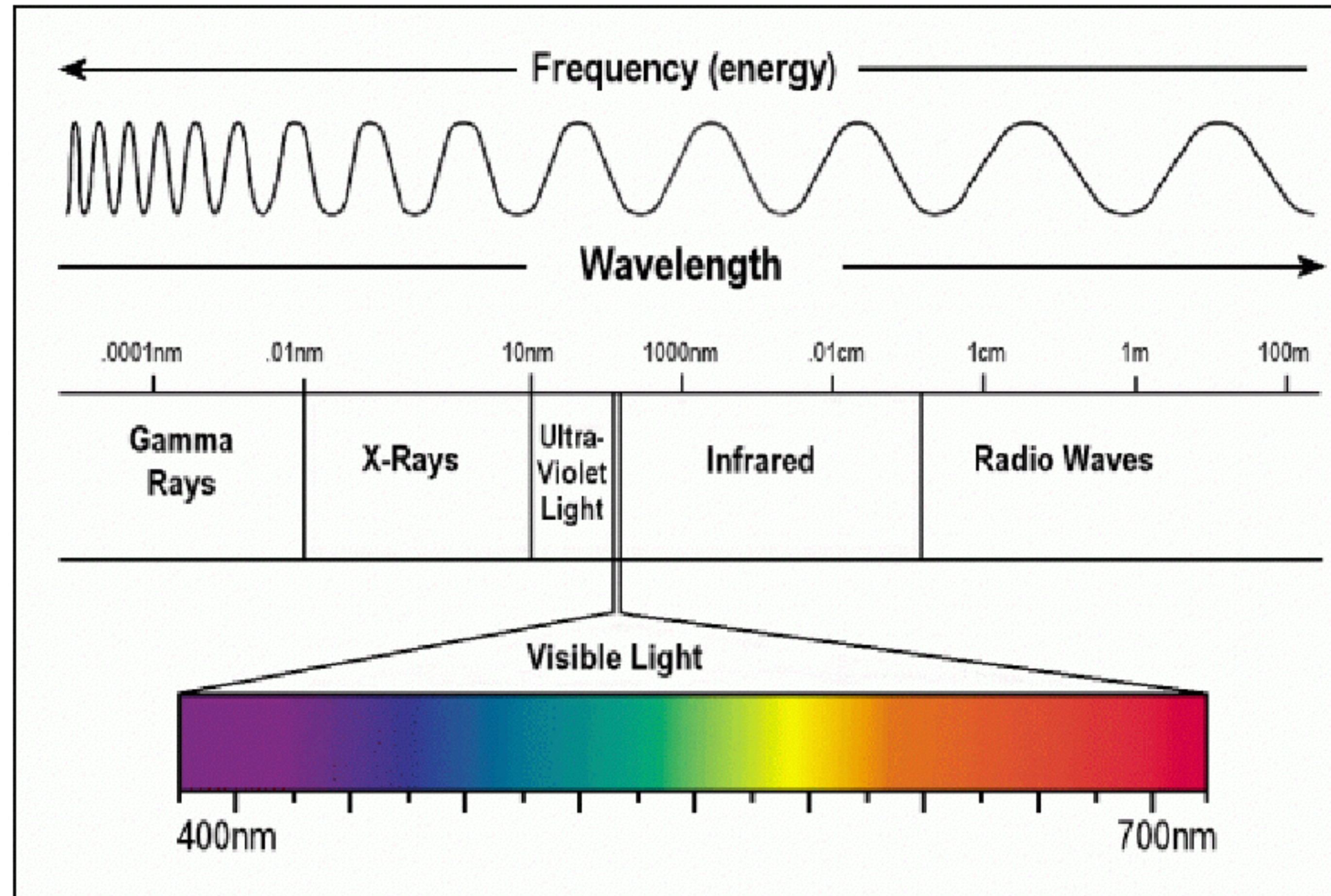
Gray scale (achromatic colors)

Mix of multiple wavelengths

e.g. purple, magenta



Visible Spectrum



Dimensions of Color

Hue



Saturation

The purity of a color

Value (Luminance, Brightness)

lightness or darkness of a color

high saturation colors have medium values



Different Saturation, medium Value



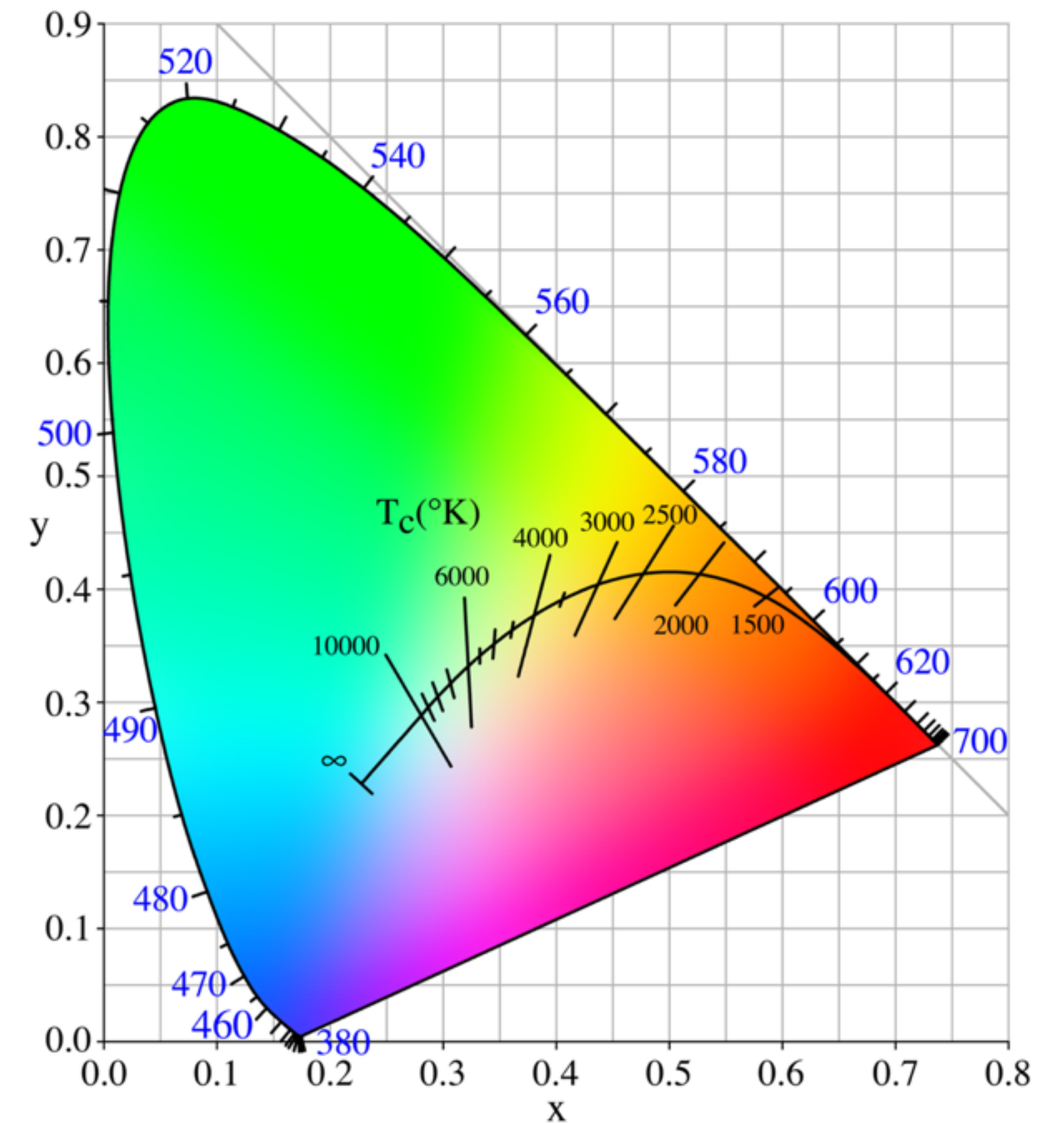
Different Values, low Saturation

CIE Color Model

Chromaticity Diagram

Specifies color by hue and saturation

Pure colors of visible spectrum along the curve (wavelength)

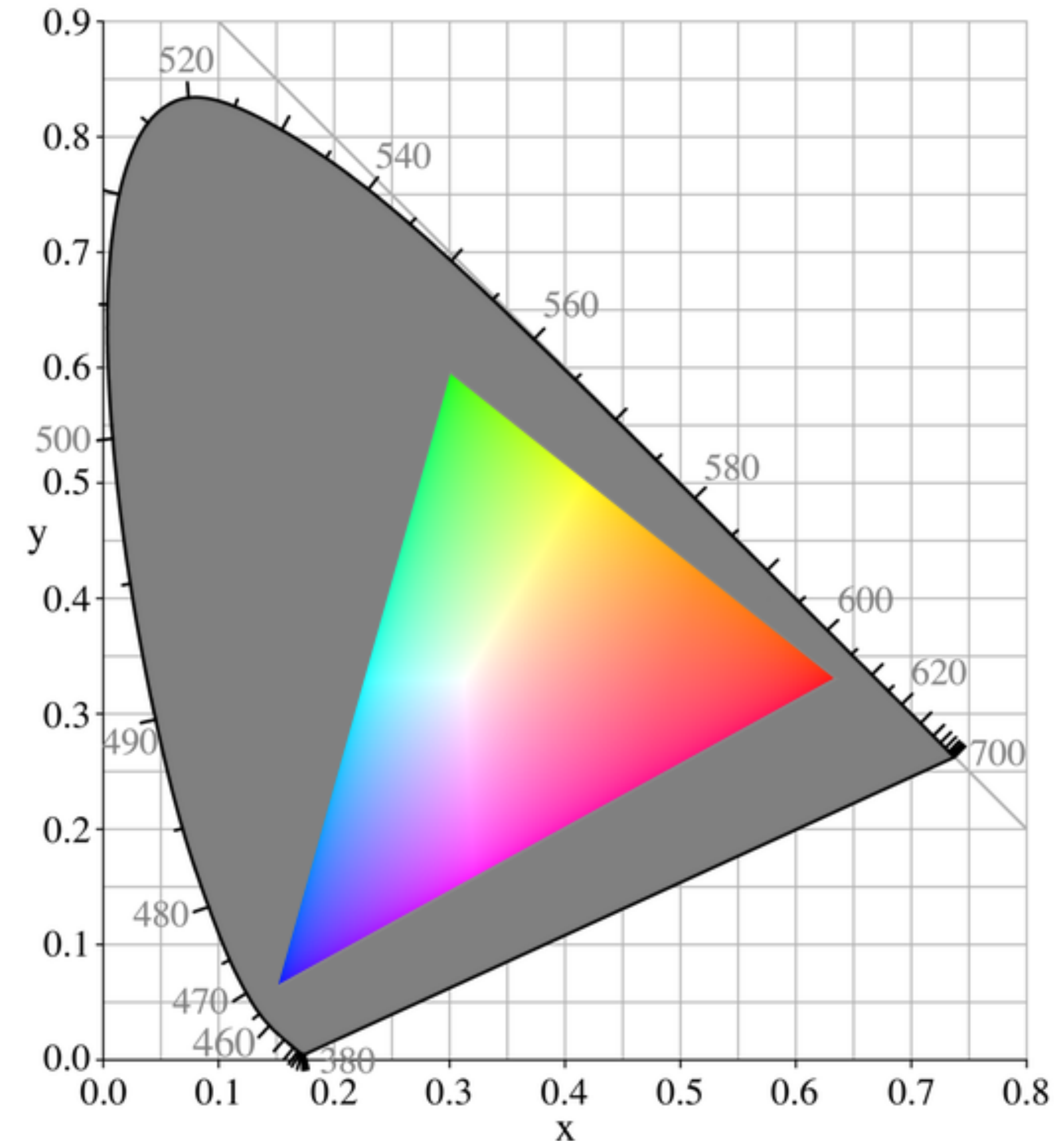
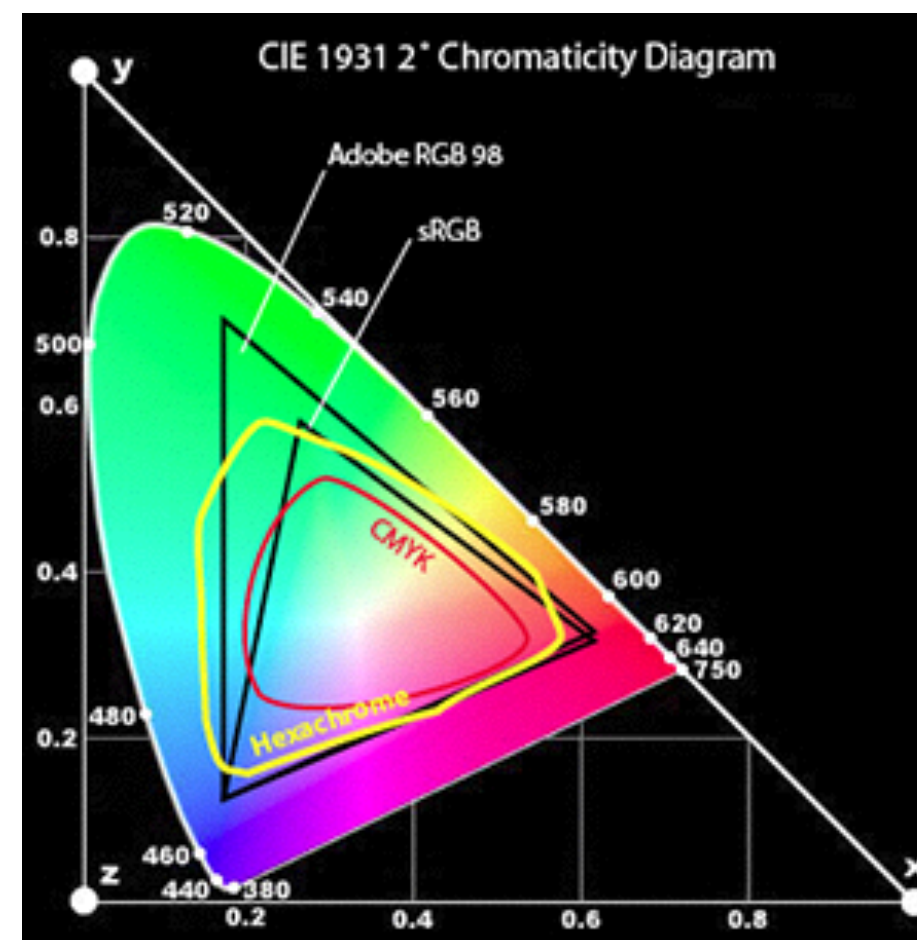


Gamut

Set of all colors that can be produced by a device

Area between the primary colors used can be shown

Primaries are arbitrary



Color Composition

Additive (e.g., RGB)

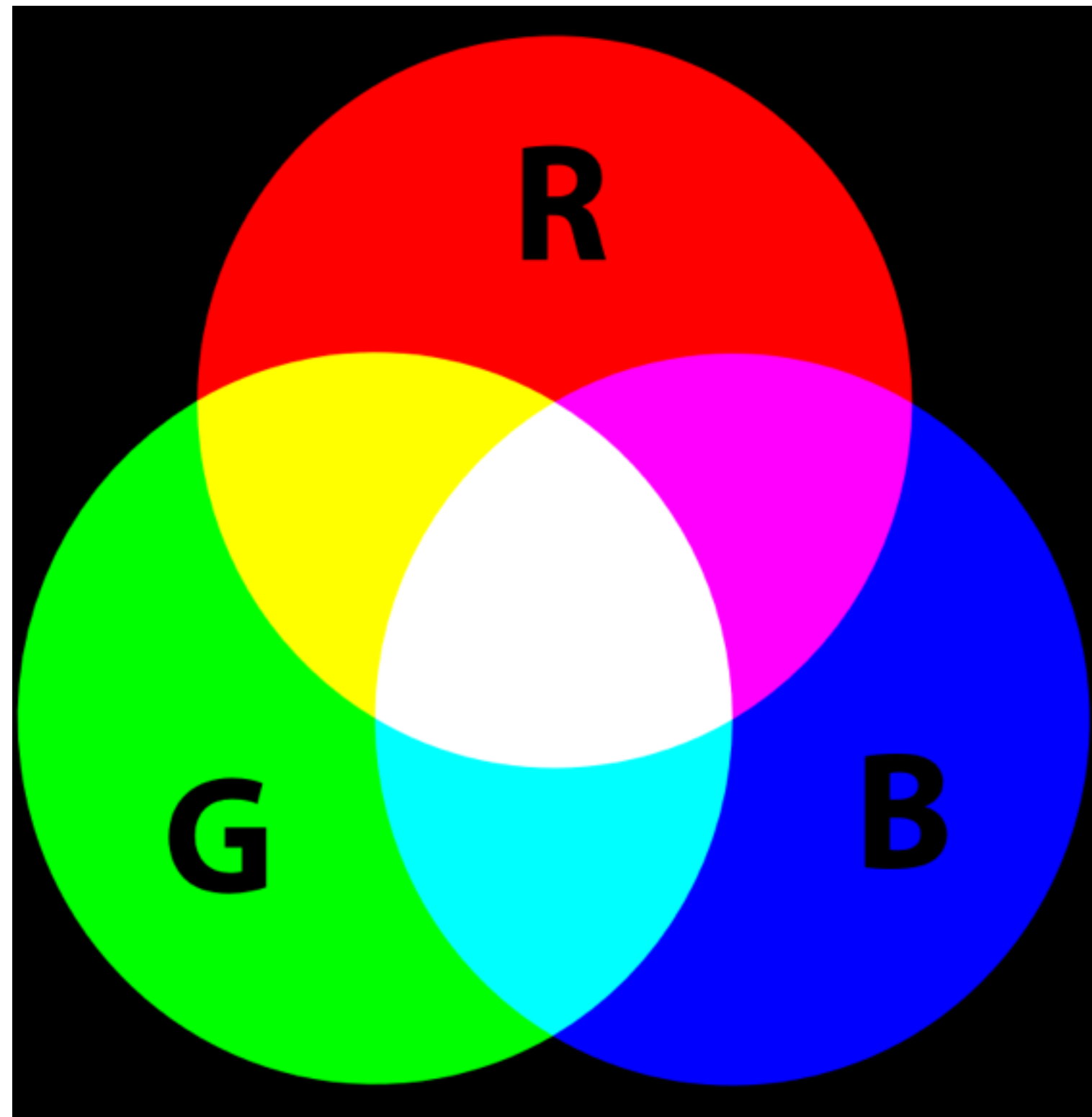
light

white: all three cones stimulated
with same intensity,
at high brightness

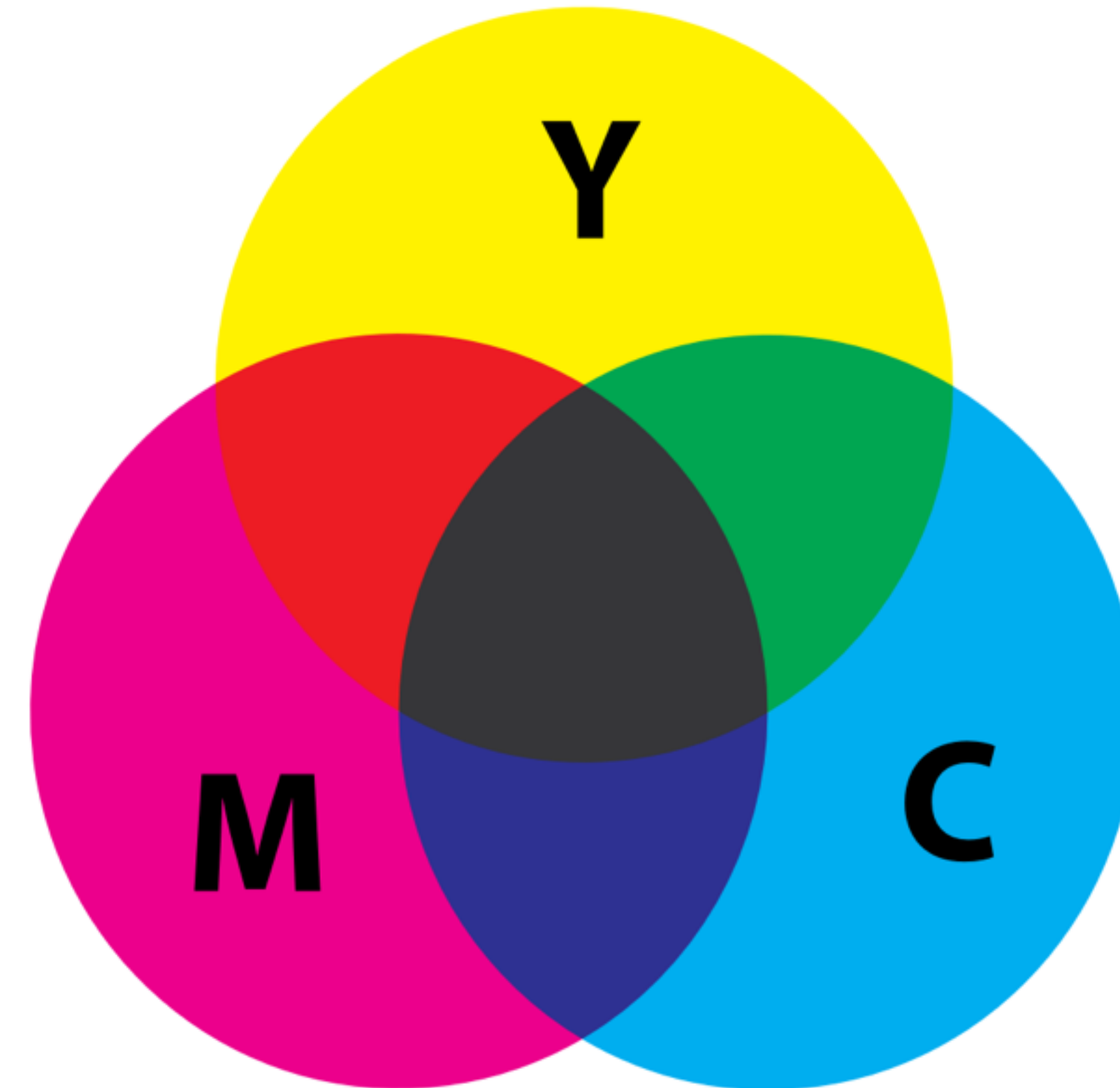
Subtractive

pigment (e.g., CMYK)

Additive / Subtractive Color

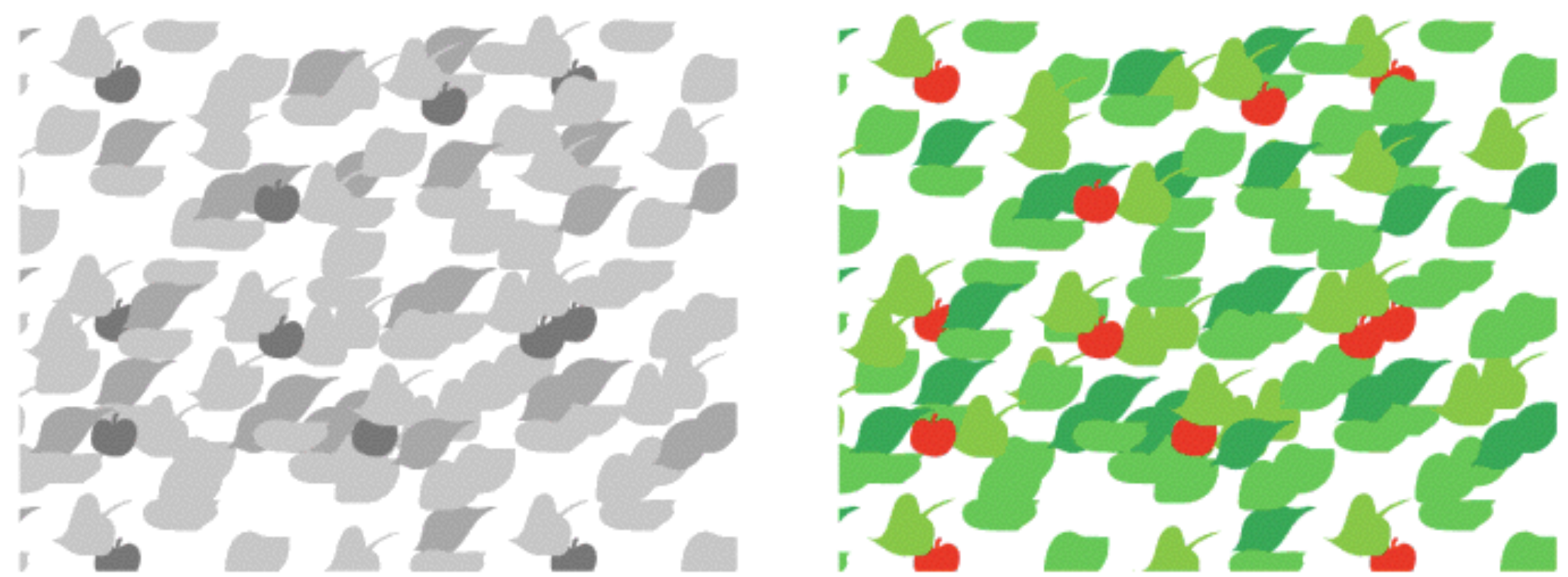


Add colors by adding light of certain wavelength



Subtract colors using pigments, inks by absorbing light

Color



Color vision is irrelevant to much of normal vision!

does not help to perceive layout of objects

how they are moving

what shape they are

Color breaks camouflage

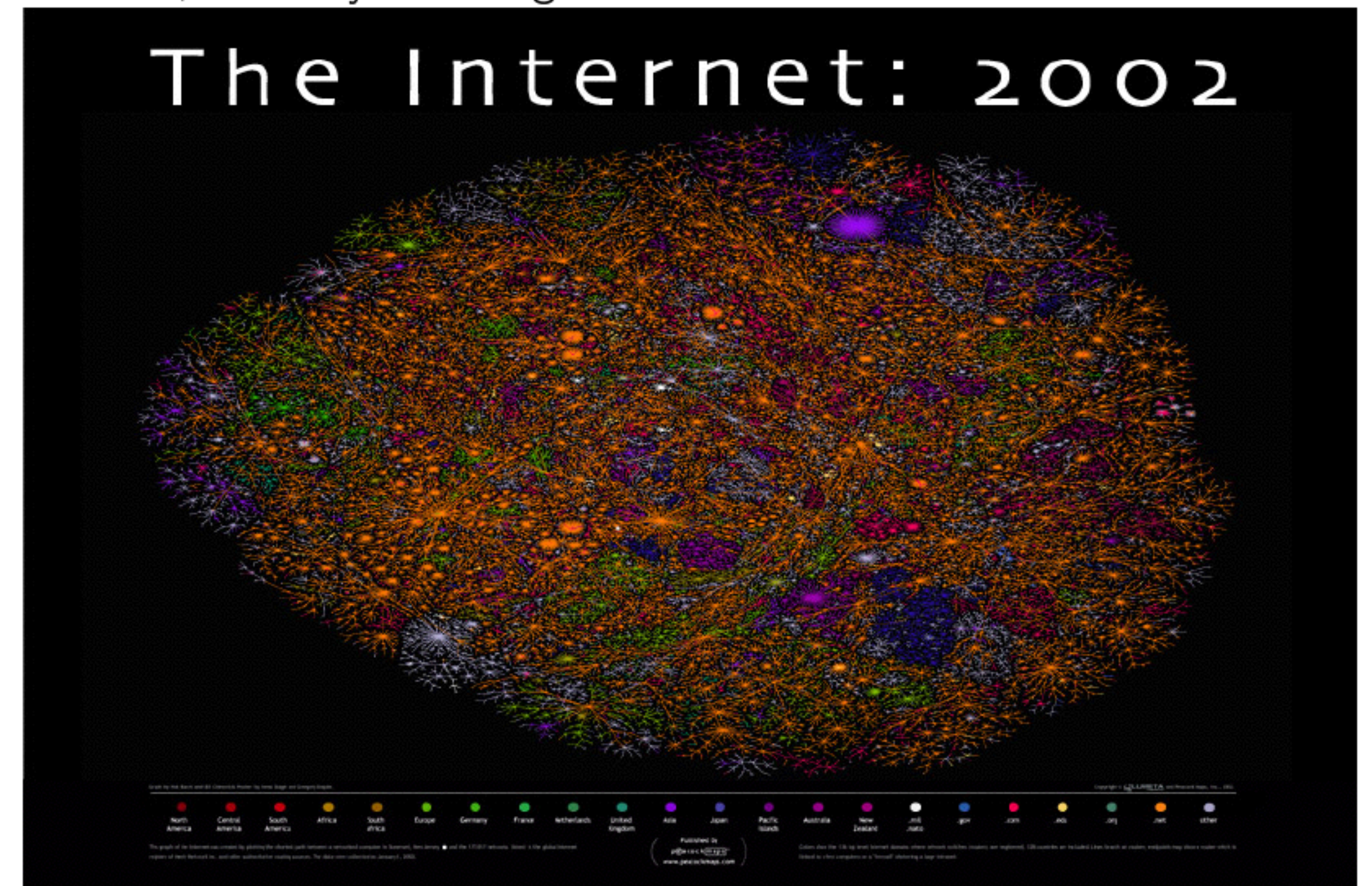
Tells about material properties (judging quality of food)

Qualitative Data Vis

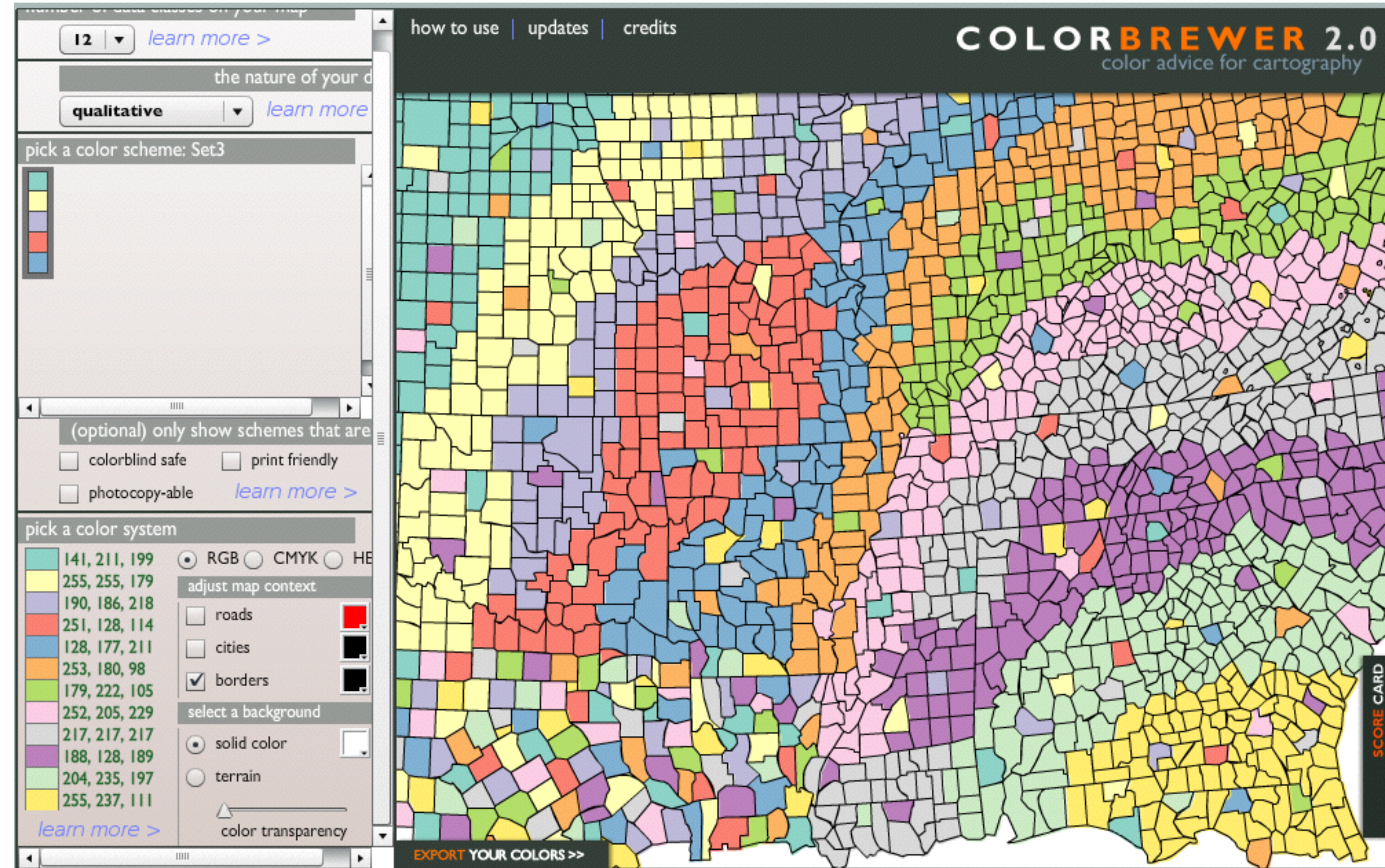
Color labeling (nominal information coding)

recommended: about 6, no more than 10

22 colors, but only 8 distinguishable



Application: Labeling



Carefully designed color scheme for 12 colors [colorbrewer]

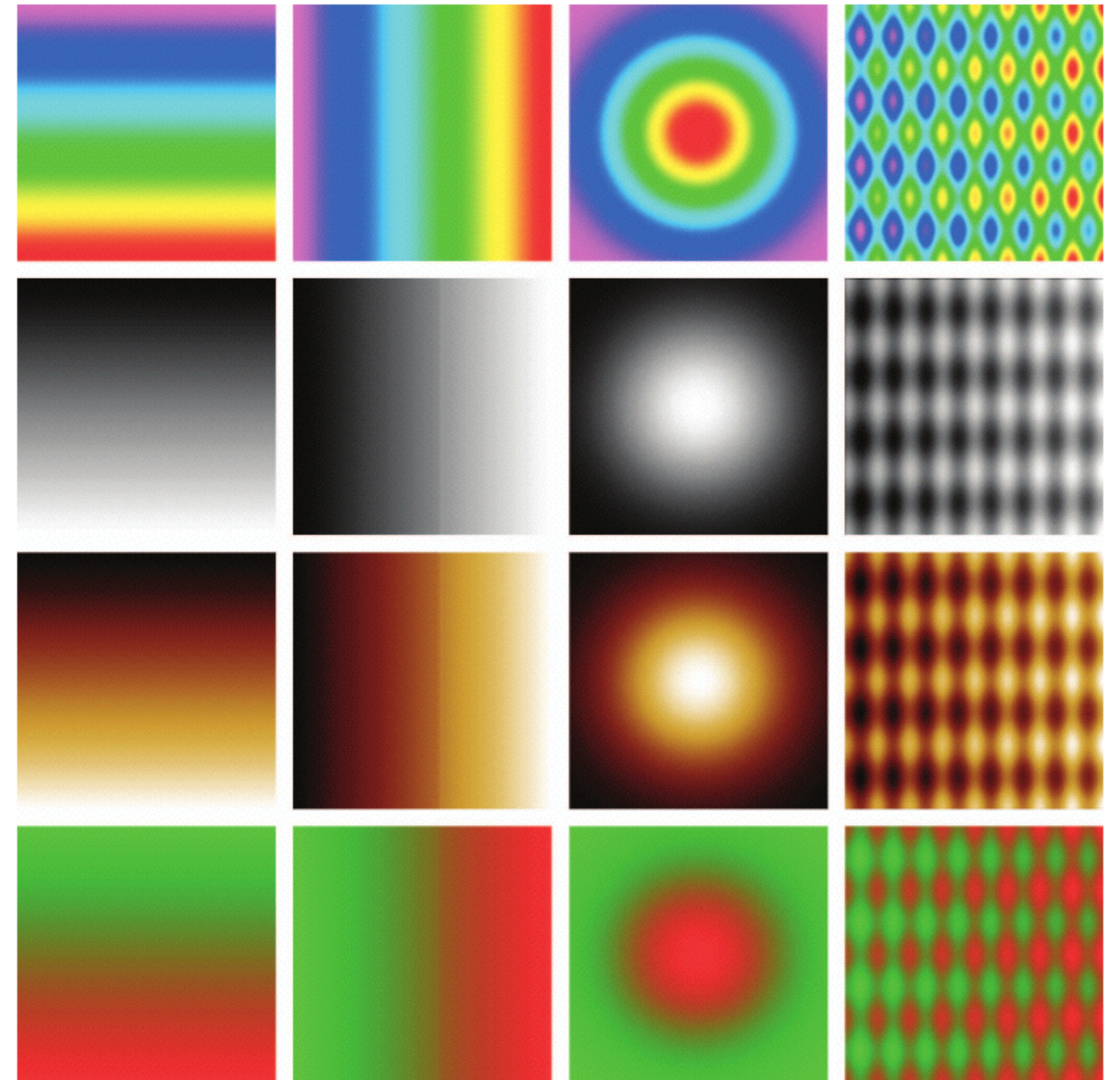
Quantitative Data Vis

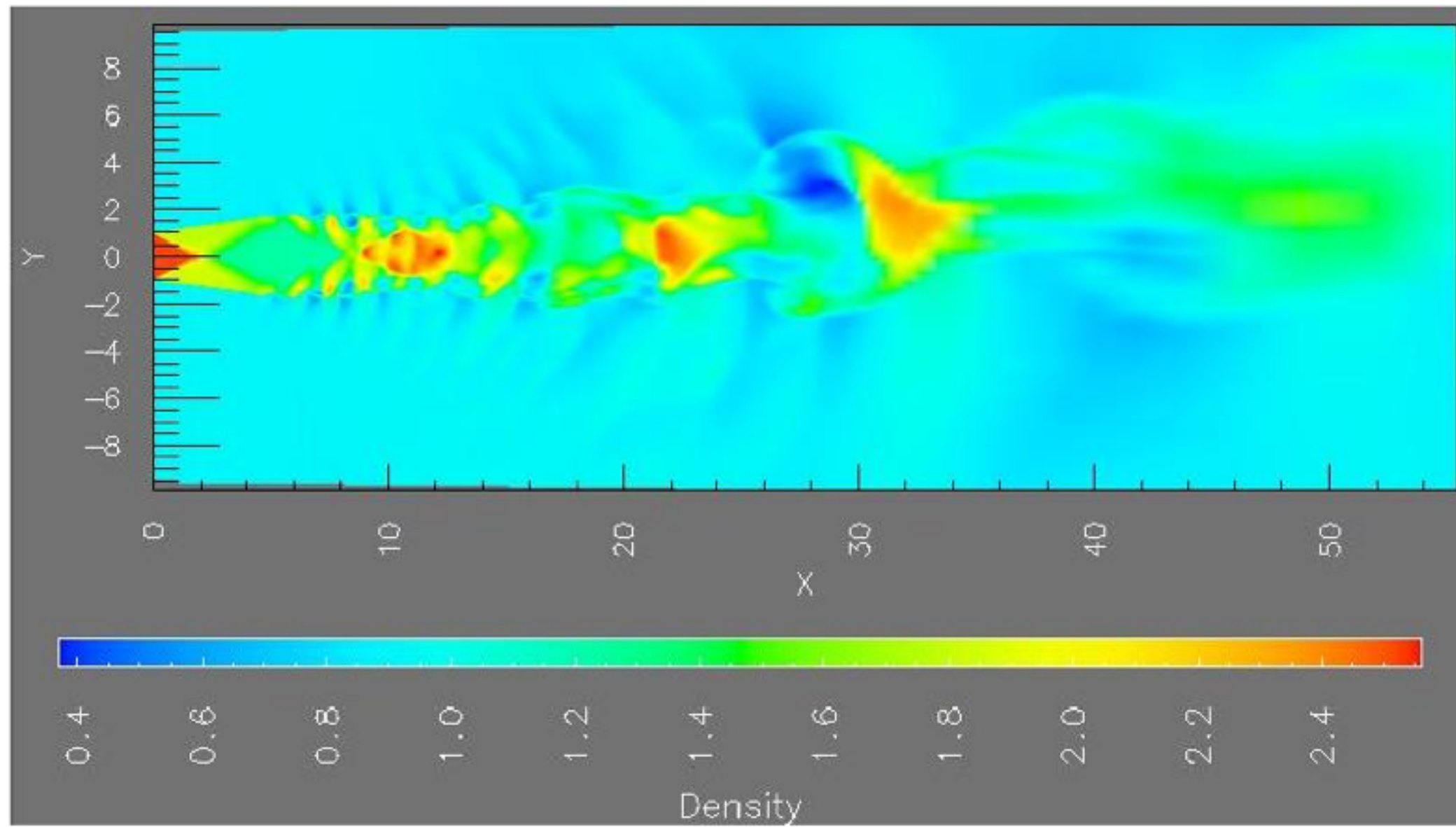
use value

saturation works but not as good

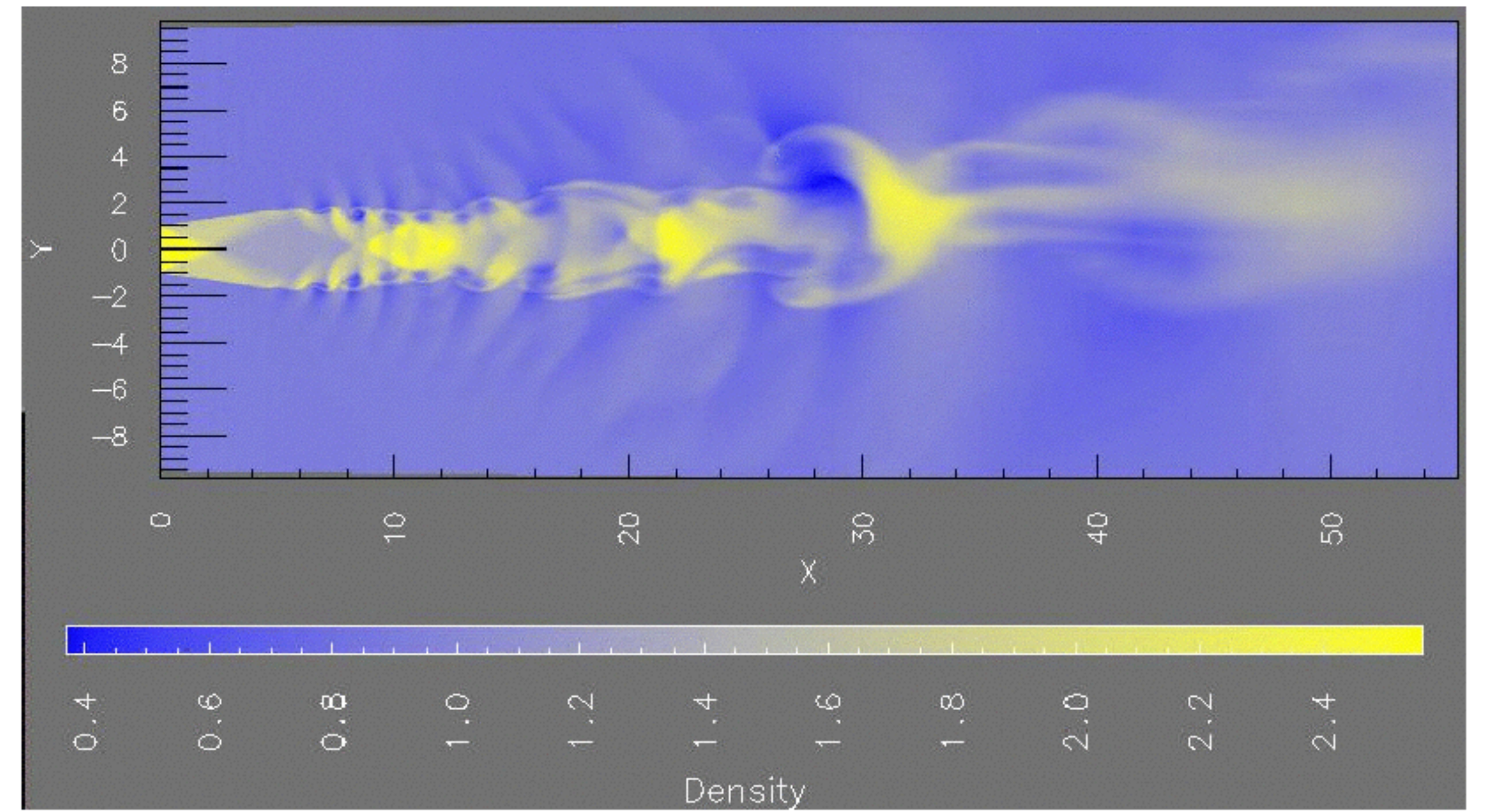
don't use hue!

Danger: rainbow color map



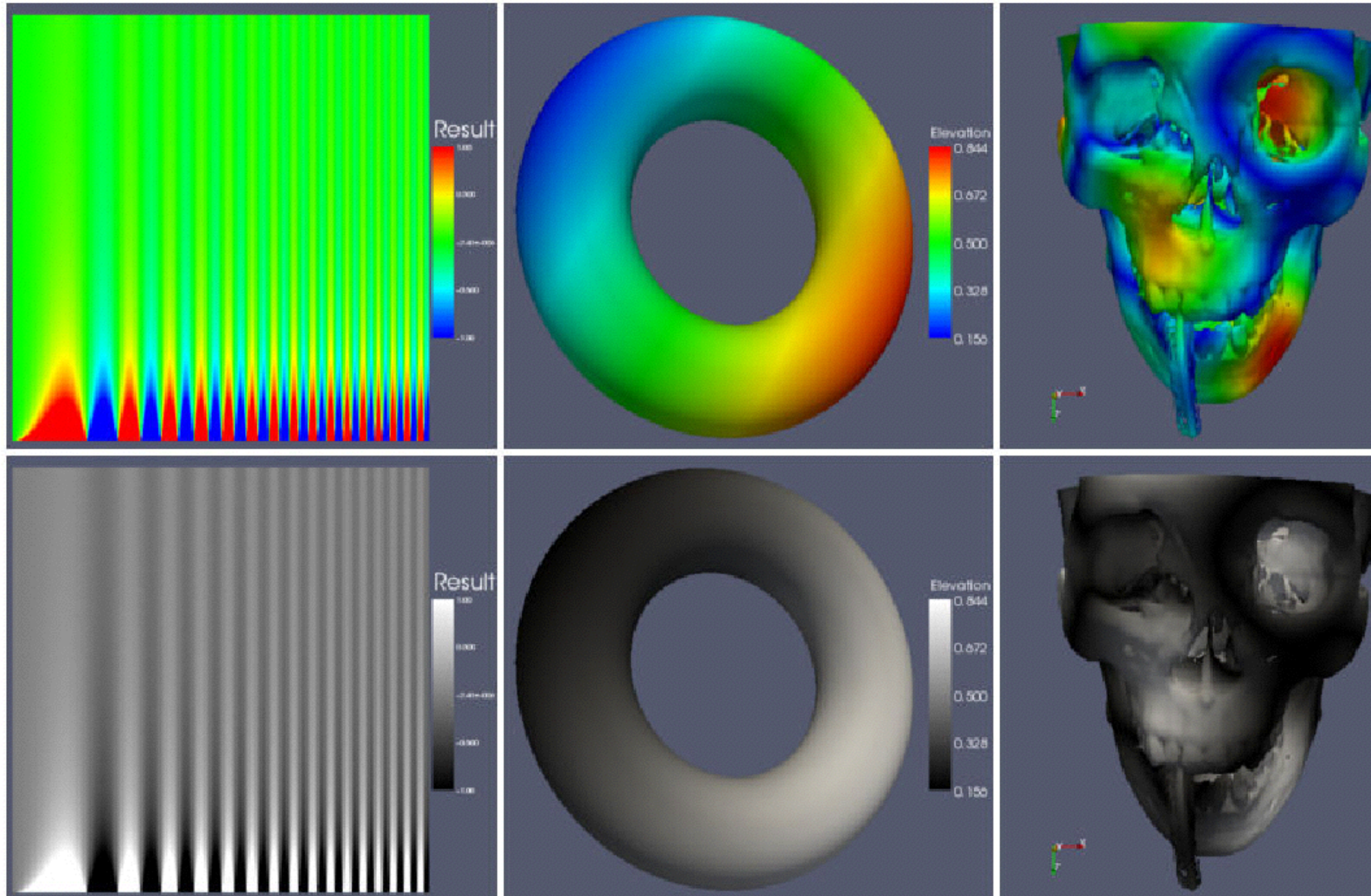


[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color? <http://www.research.ibm.com/people/l/lloyd/color/color.HTM>]

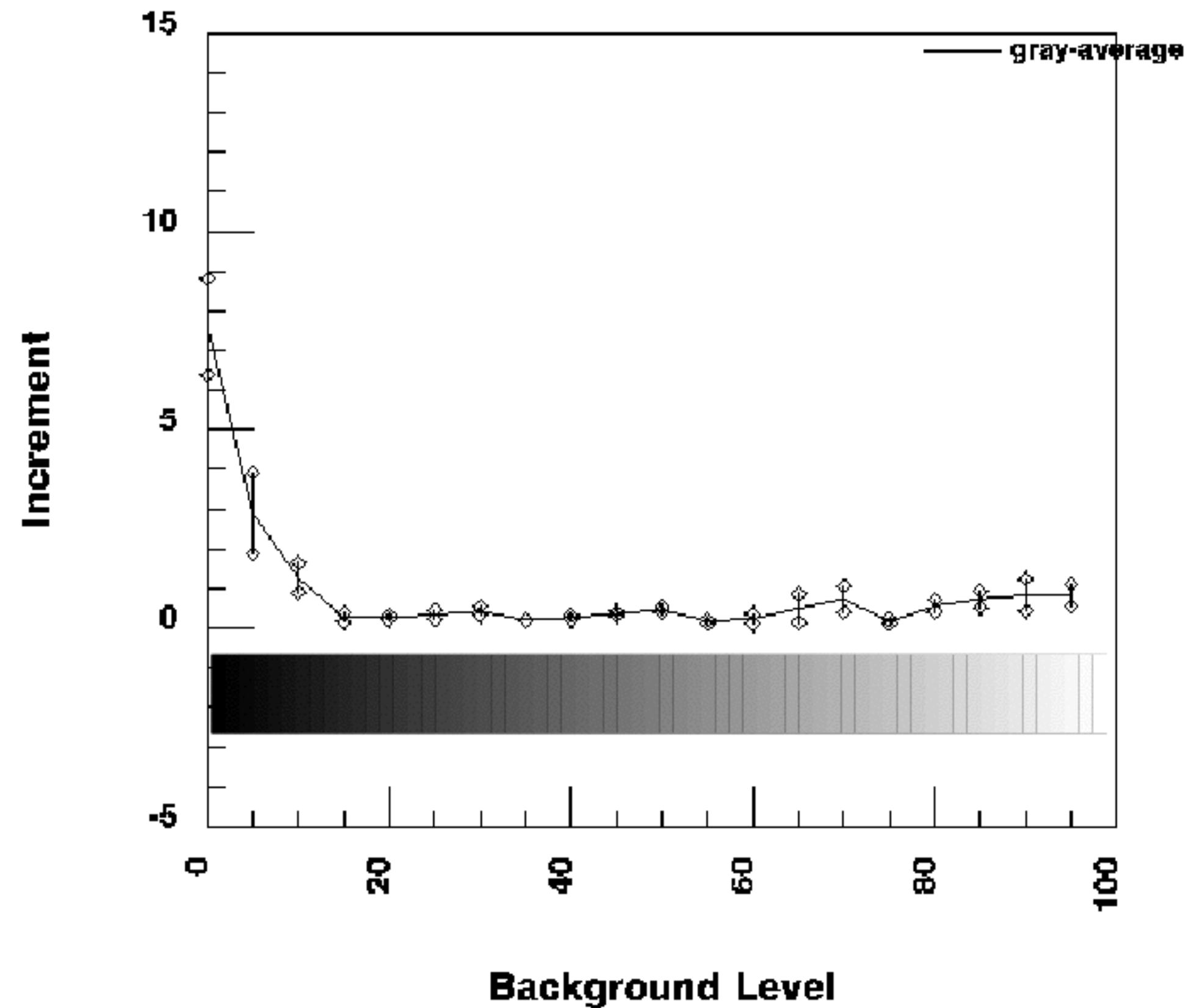
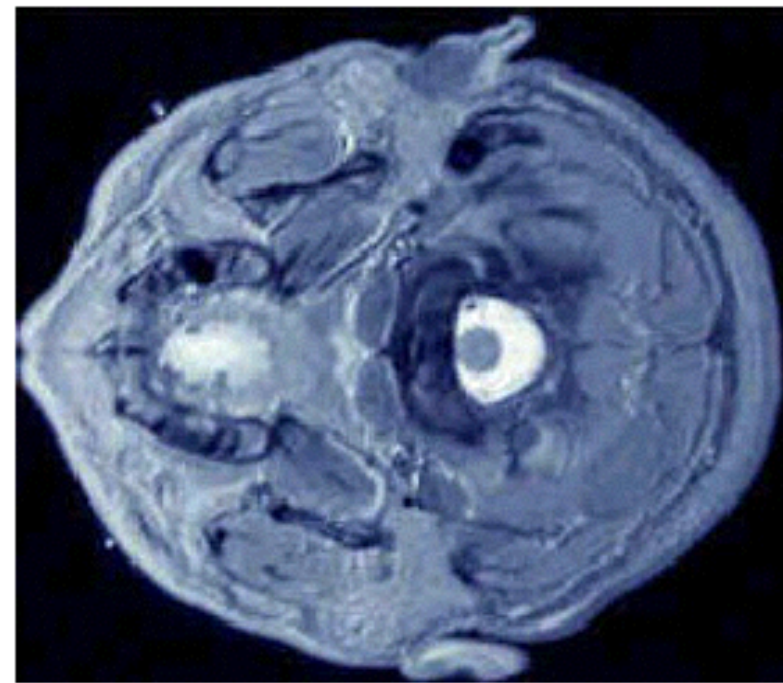


[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm]

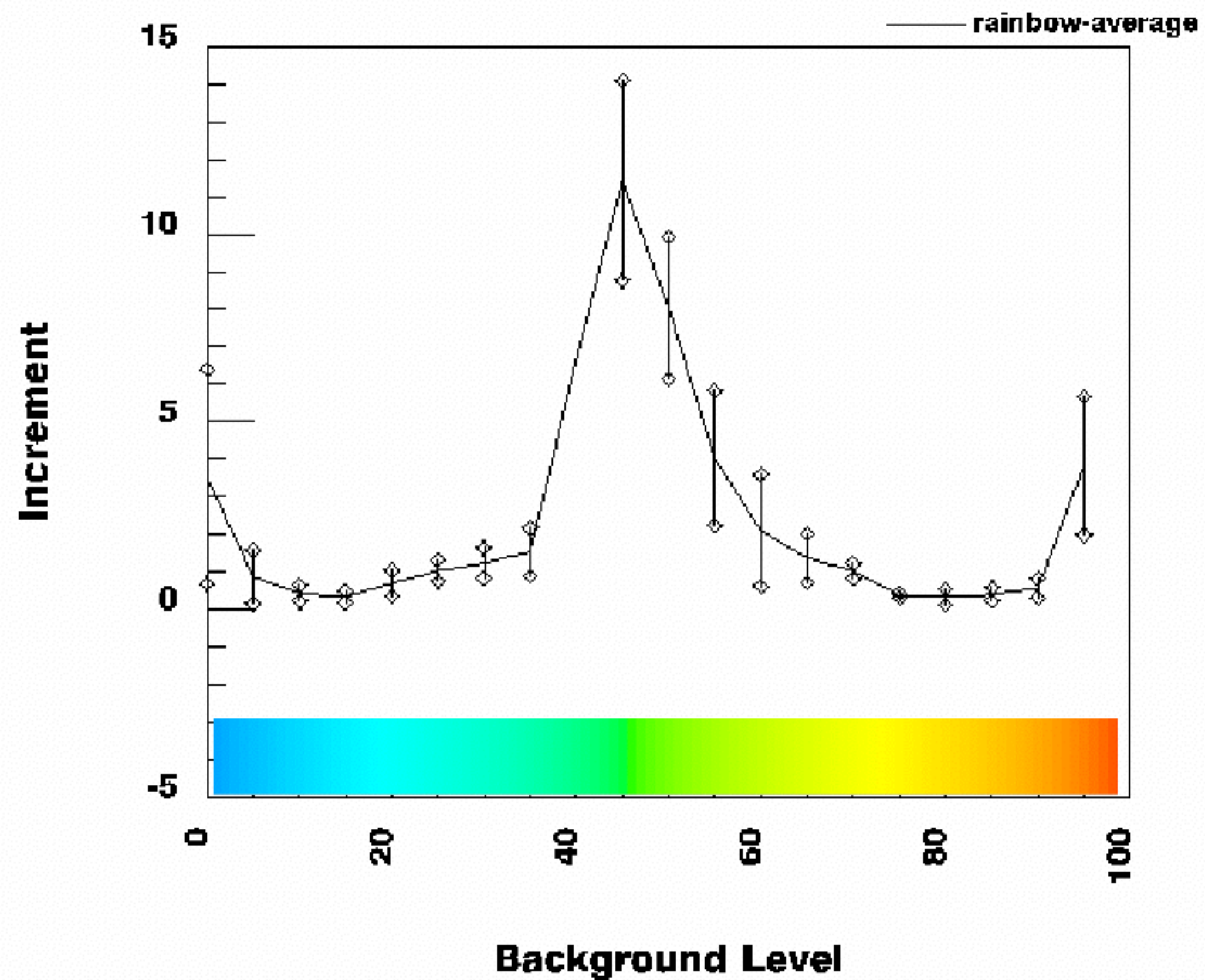
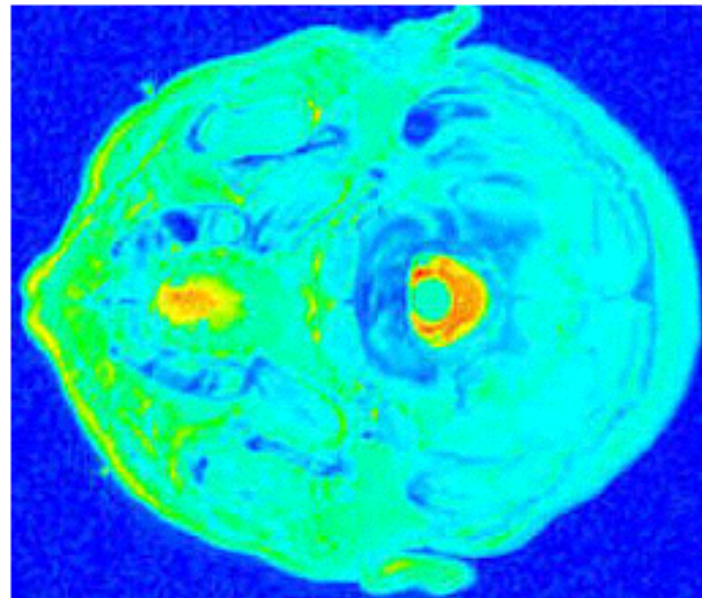
Rainbow vs. Value Color map



Increment Threshold Experiment: Luminance



Increment Threshold Experiment: Rainbow Color Scale



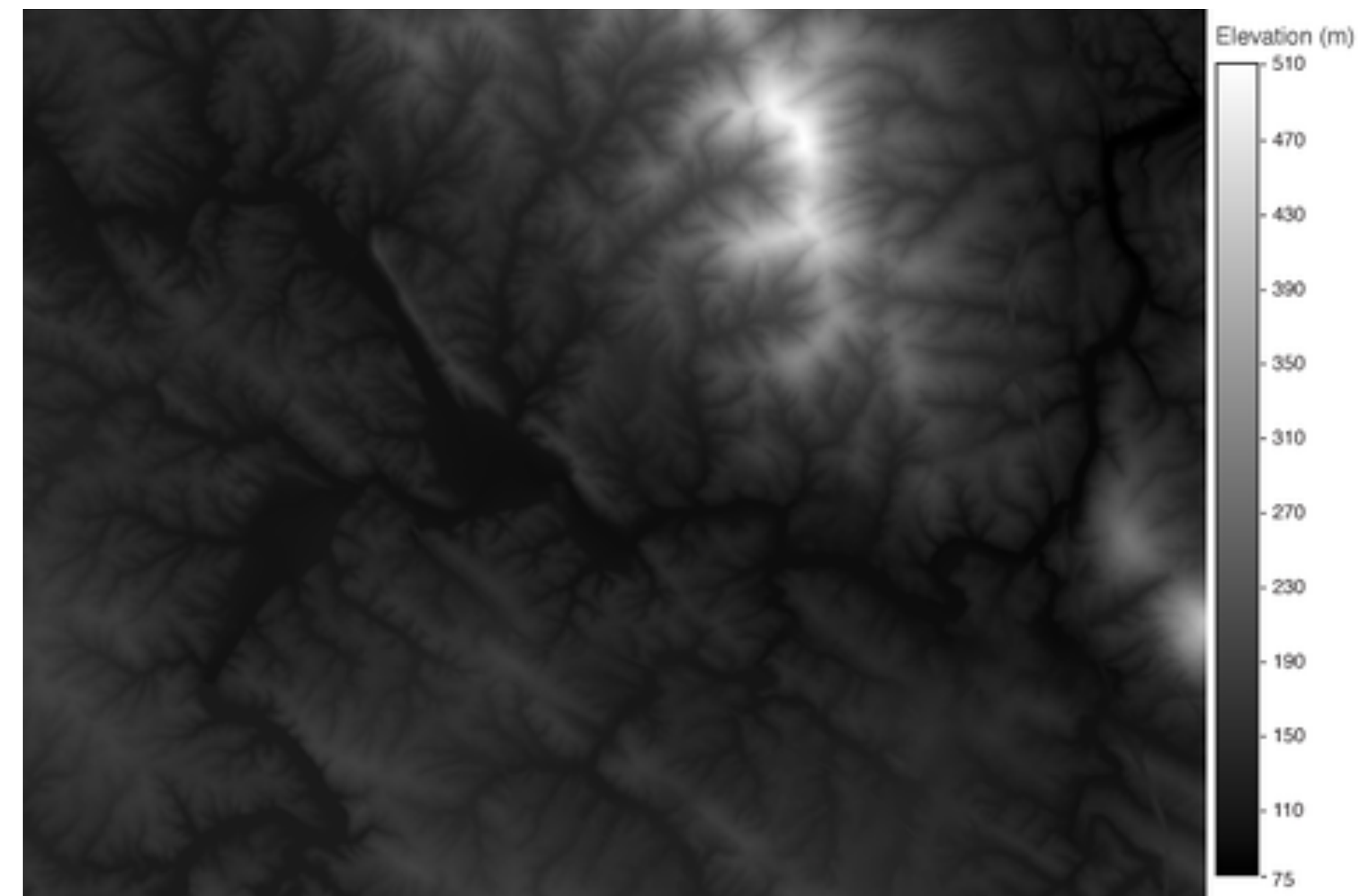
To bin or not to bin?

Study: what is faster? What is more accurate?

Example: Elevation

Continuous was faster

Binned was often more accurate



Design Critique

Four Ways to Slice Obama's 2013 Budget Proposal

Explore every nook and cranny of President Obama's federal budget proposal.

All Spending Types of Spending Changes Department Totals

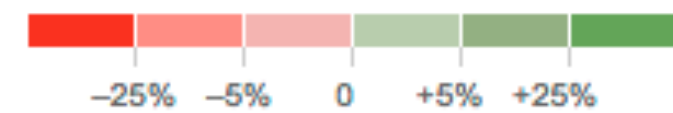
How \$3.7 Trillion Is Spent

Mr. Obama's budget proposal includes \$3.7 trillion in spending in 2013, and forecasts a \$901 billion deficit.

Circles are sized according to the proposed spending.



Color shows amount of cut or increase from 2012.



The proposal forecasts a \$901 billion deficit.

Critique Document: <http://goo.gl/ey7g6E>

Source: <http://goo.gl/gZf9D2>

Color Blindness

10% of males, 1% of females (probably due to X-chromosomal recessive inheritance)

Most common: red-green weakness / blindness

Reason: lack of medium or long wavelength receptors, or altered spectral sensitivity (most common: green shift)



Normal Color Perception

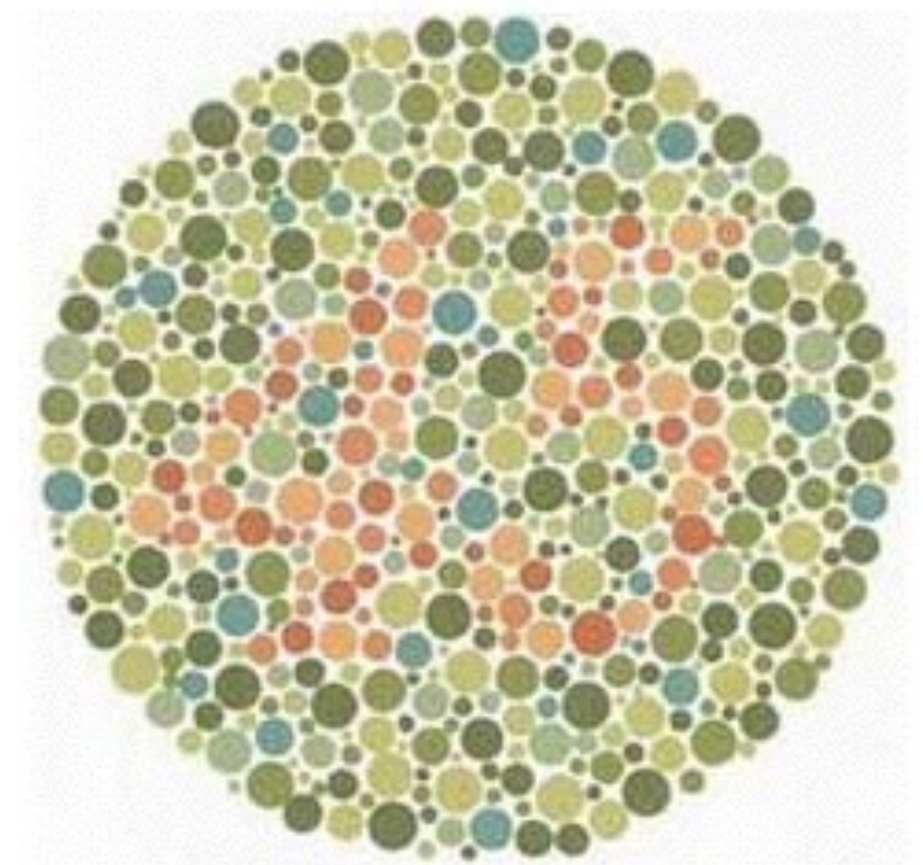
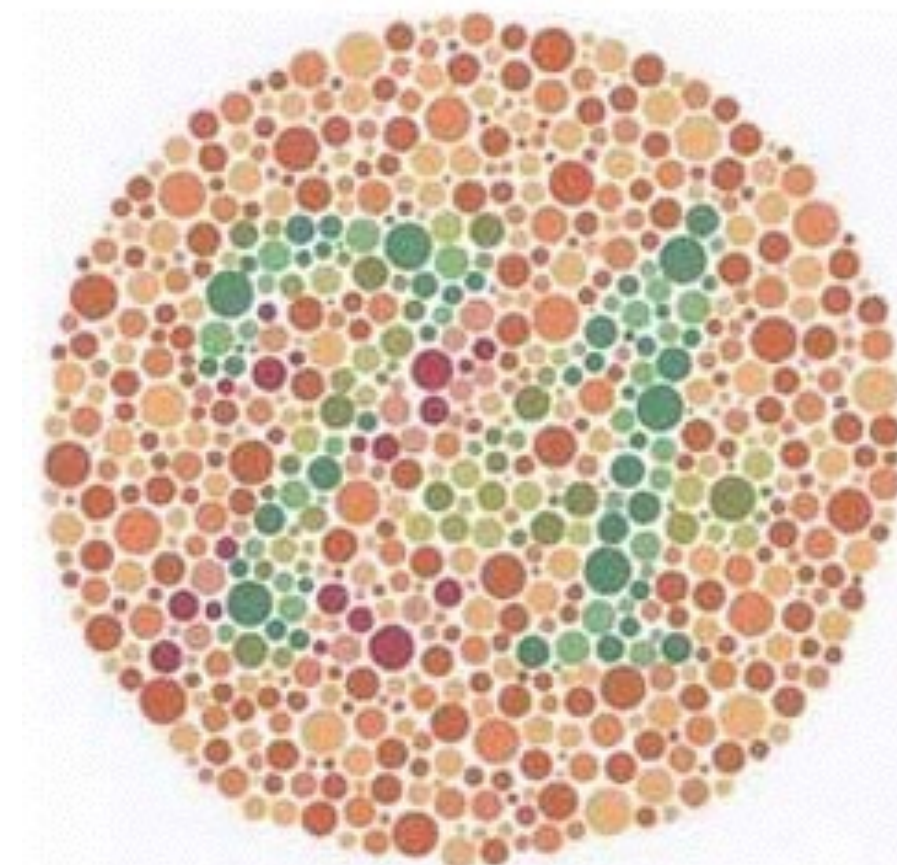
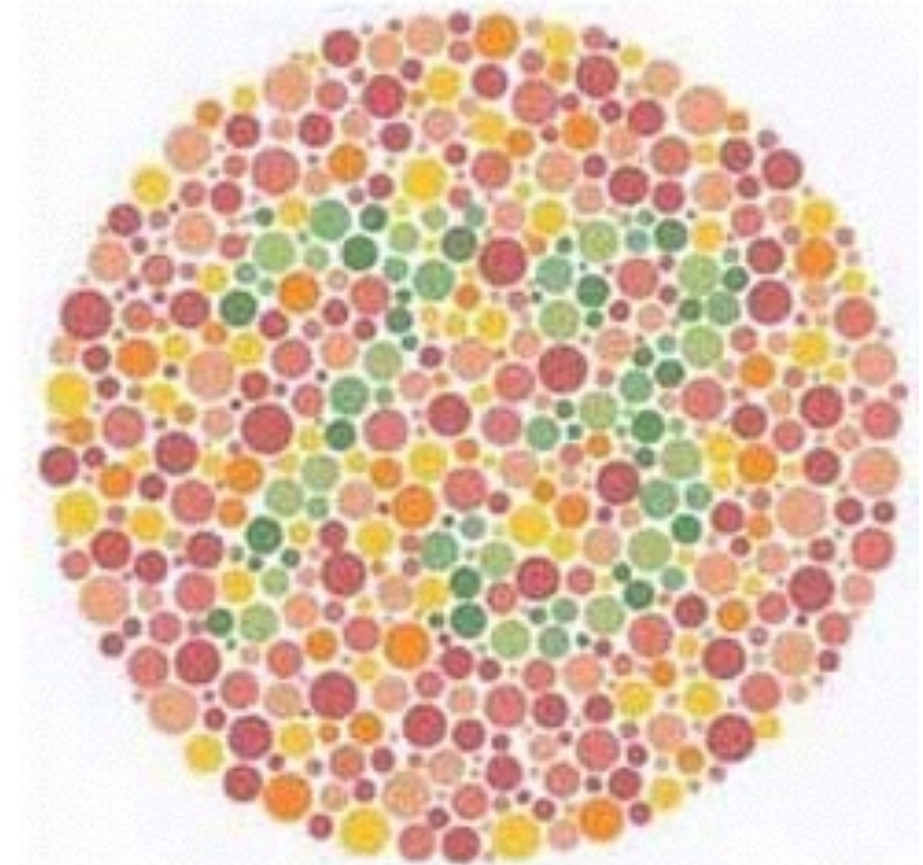
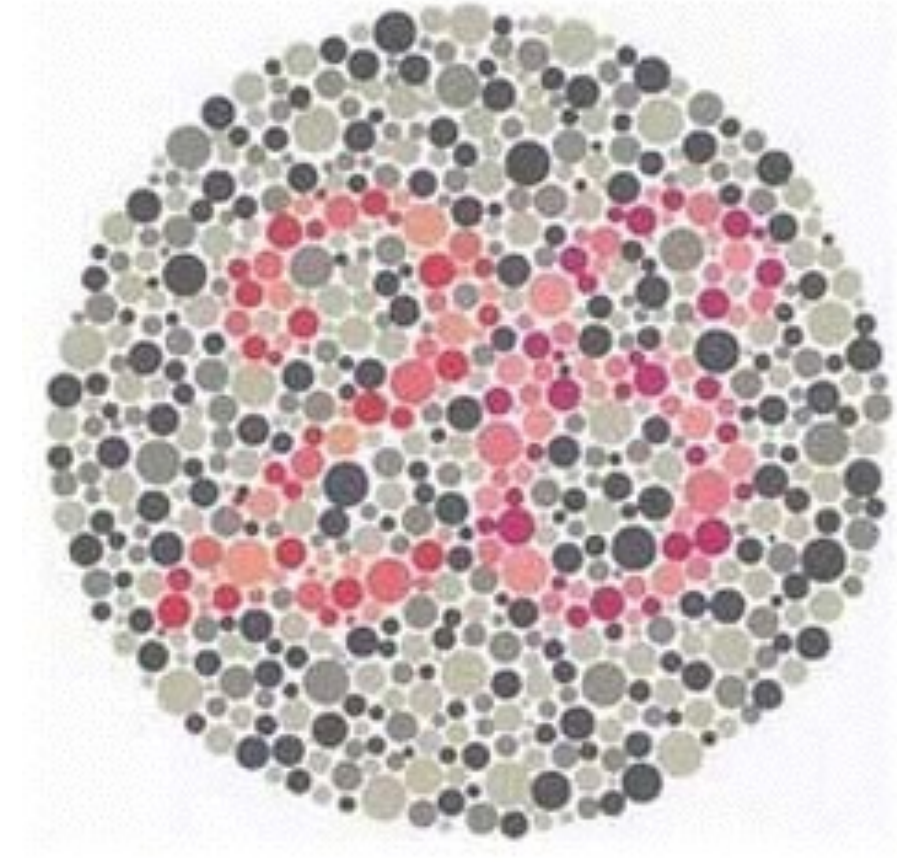
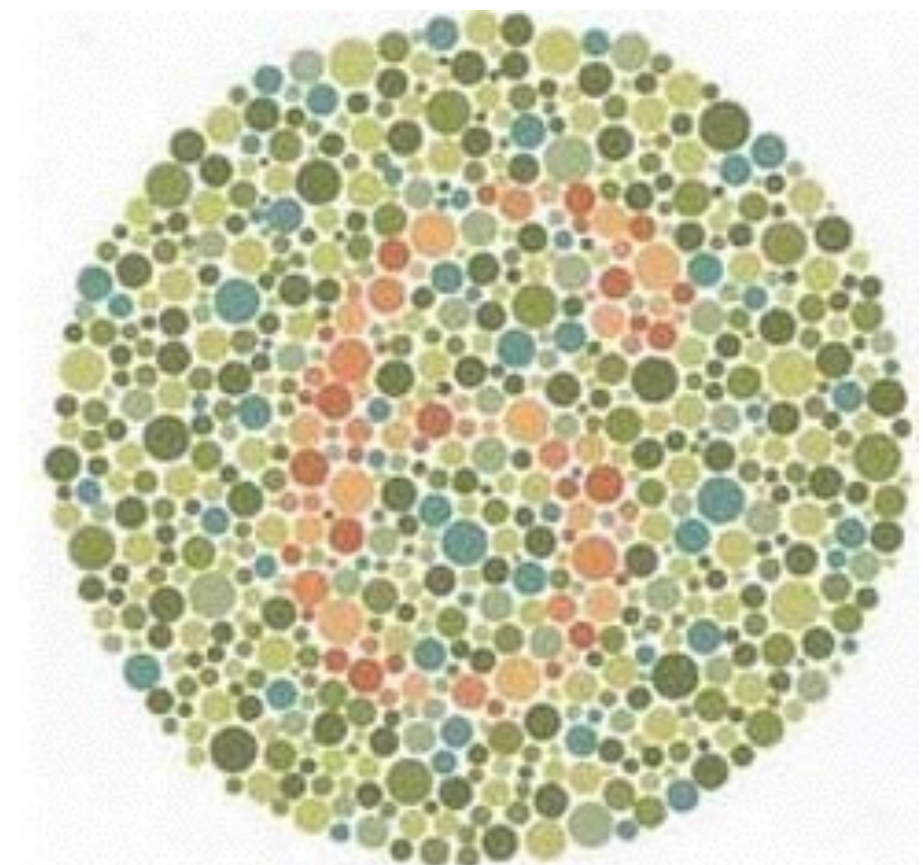
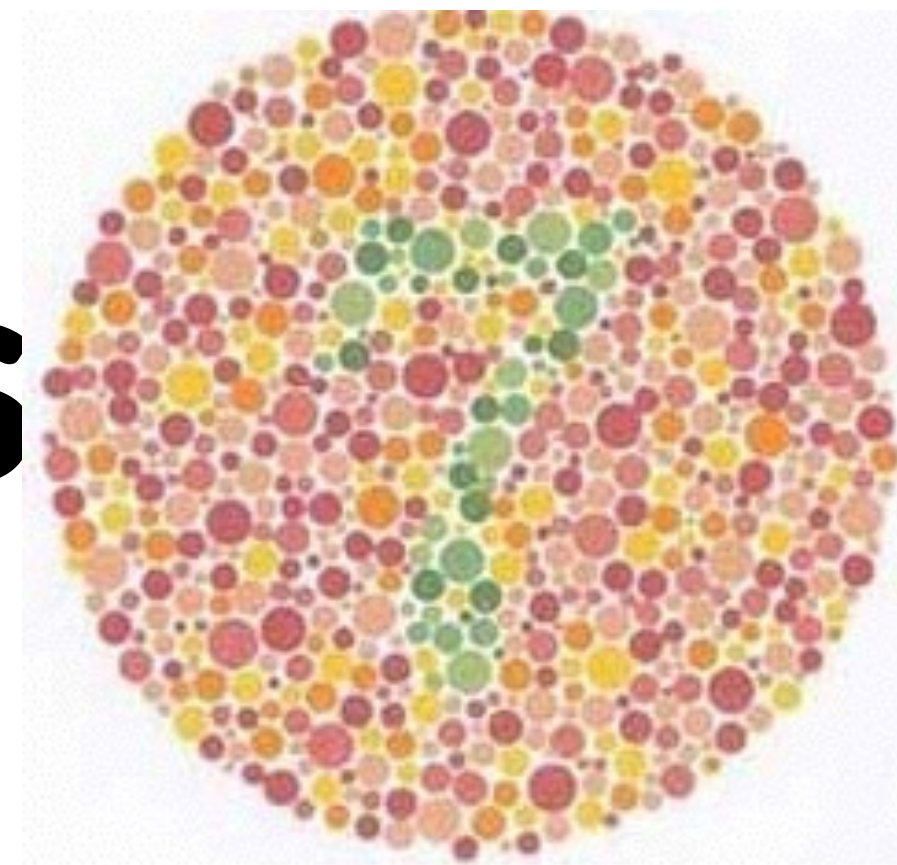
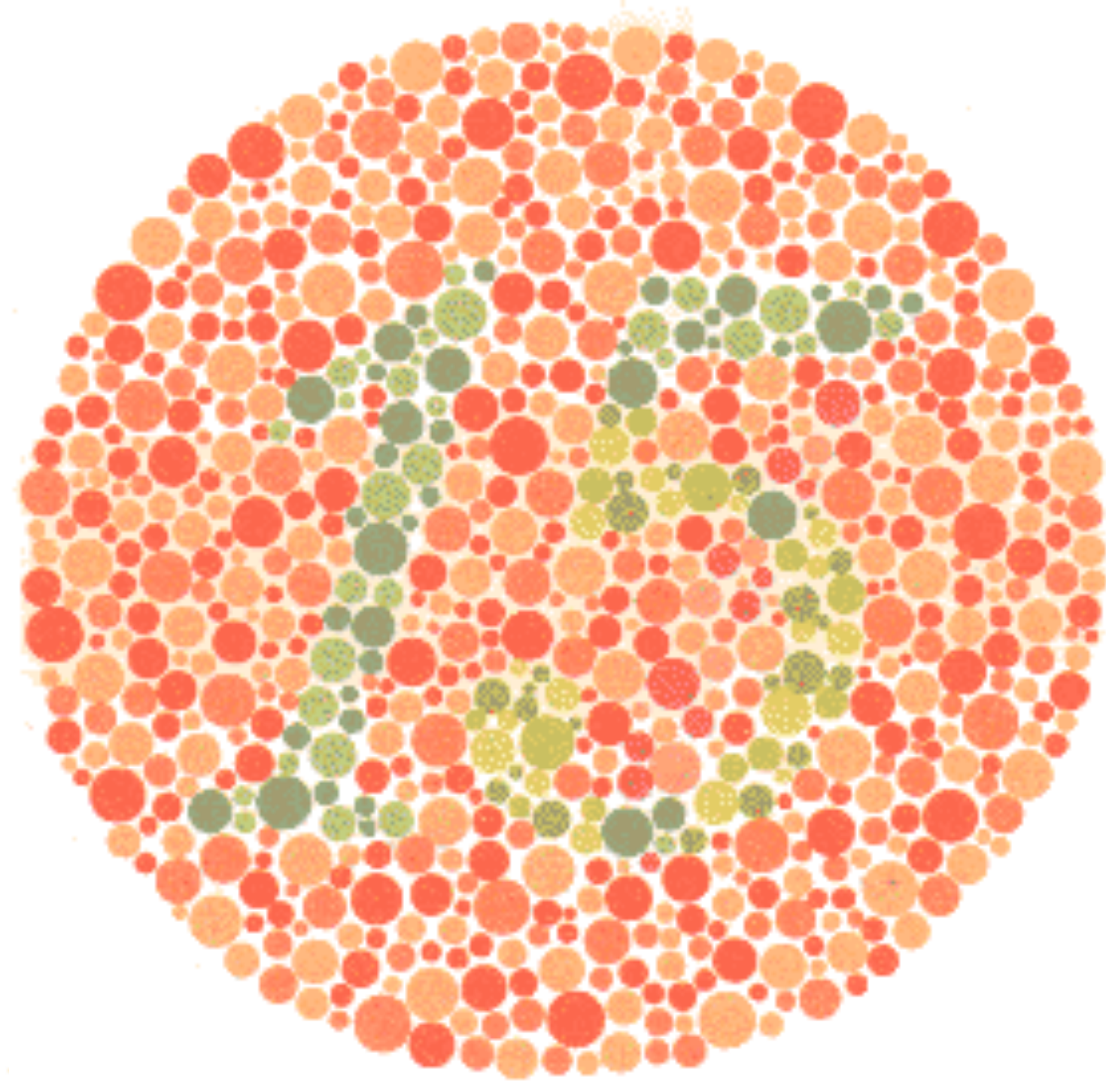
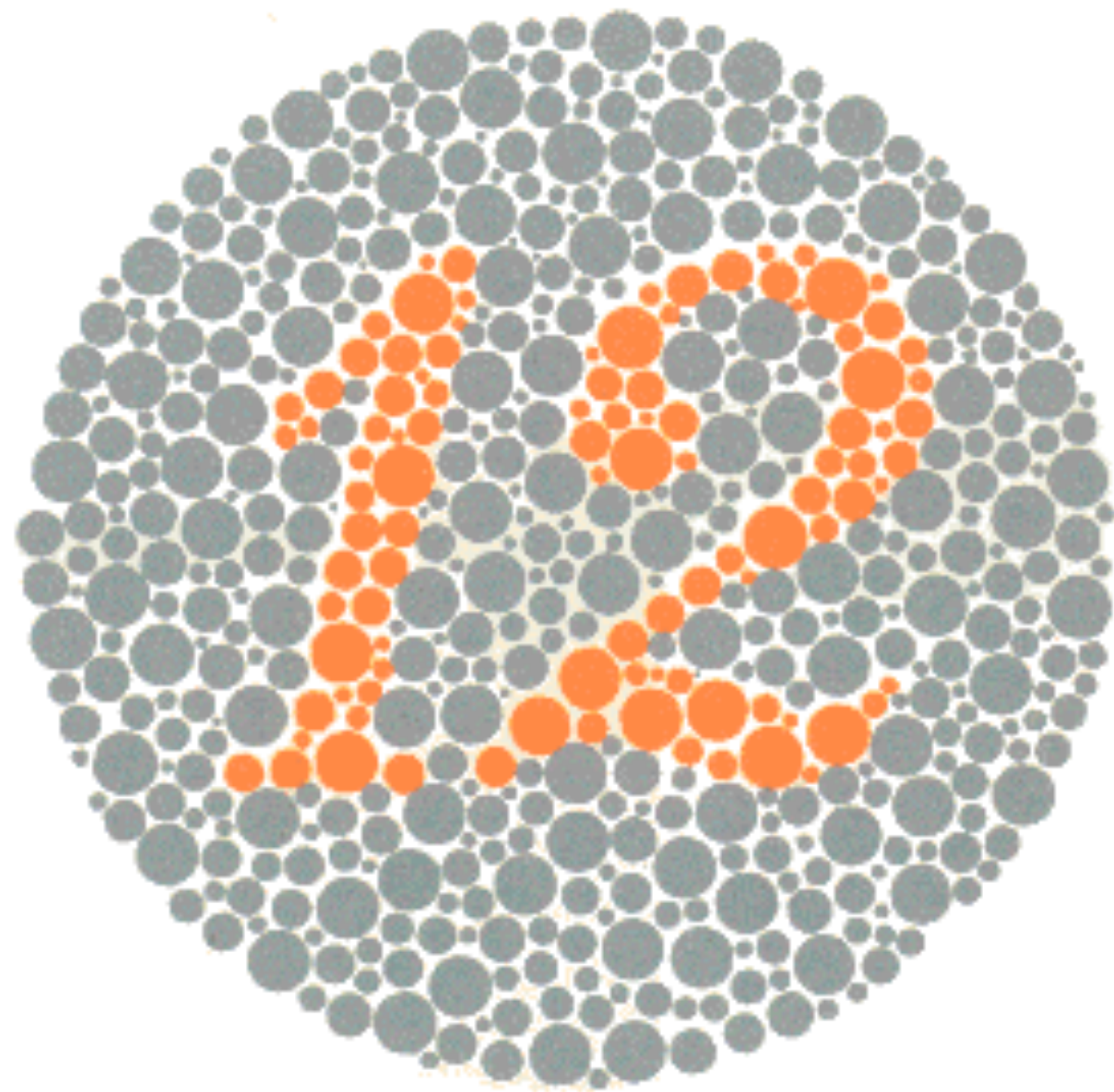


Deuteranopia (no green receptors)

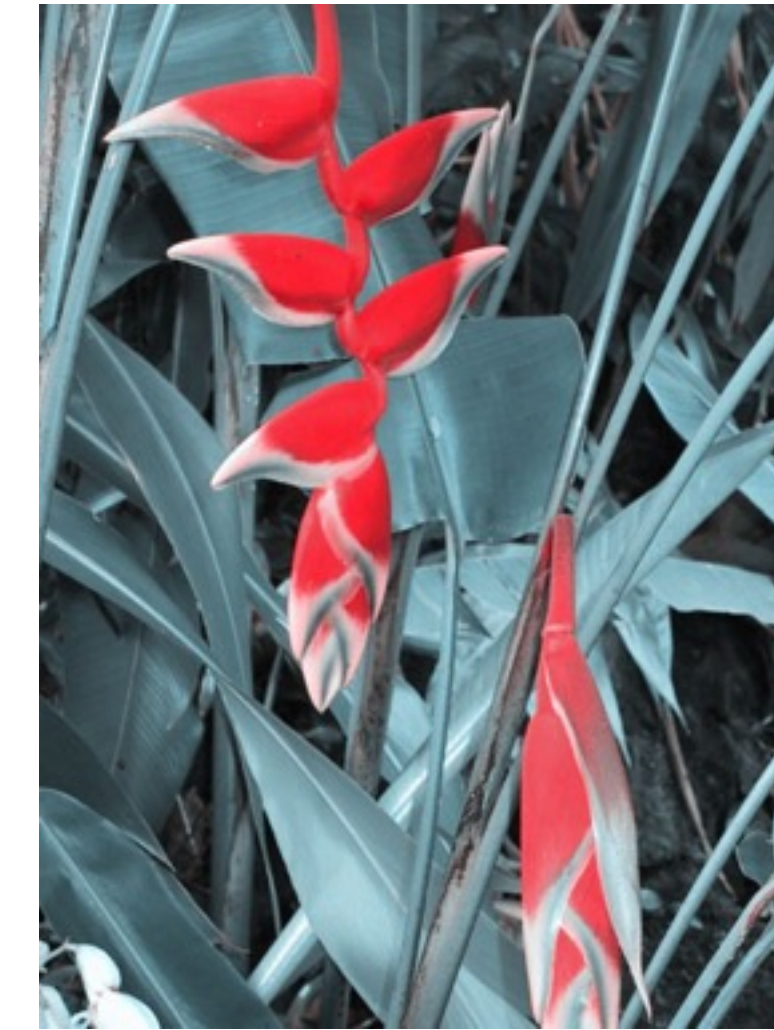


Protanopia (no red receptors)

Color Blindness Tests



Color Blindness



Protanope

Deuteranope

Tritanope

No L cones

No M cones

No S cones

Red / green
deficiencies

Blue / Yellow
deficiency

All Spending | Types of Spending | Changes | Department Totals

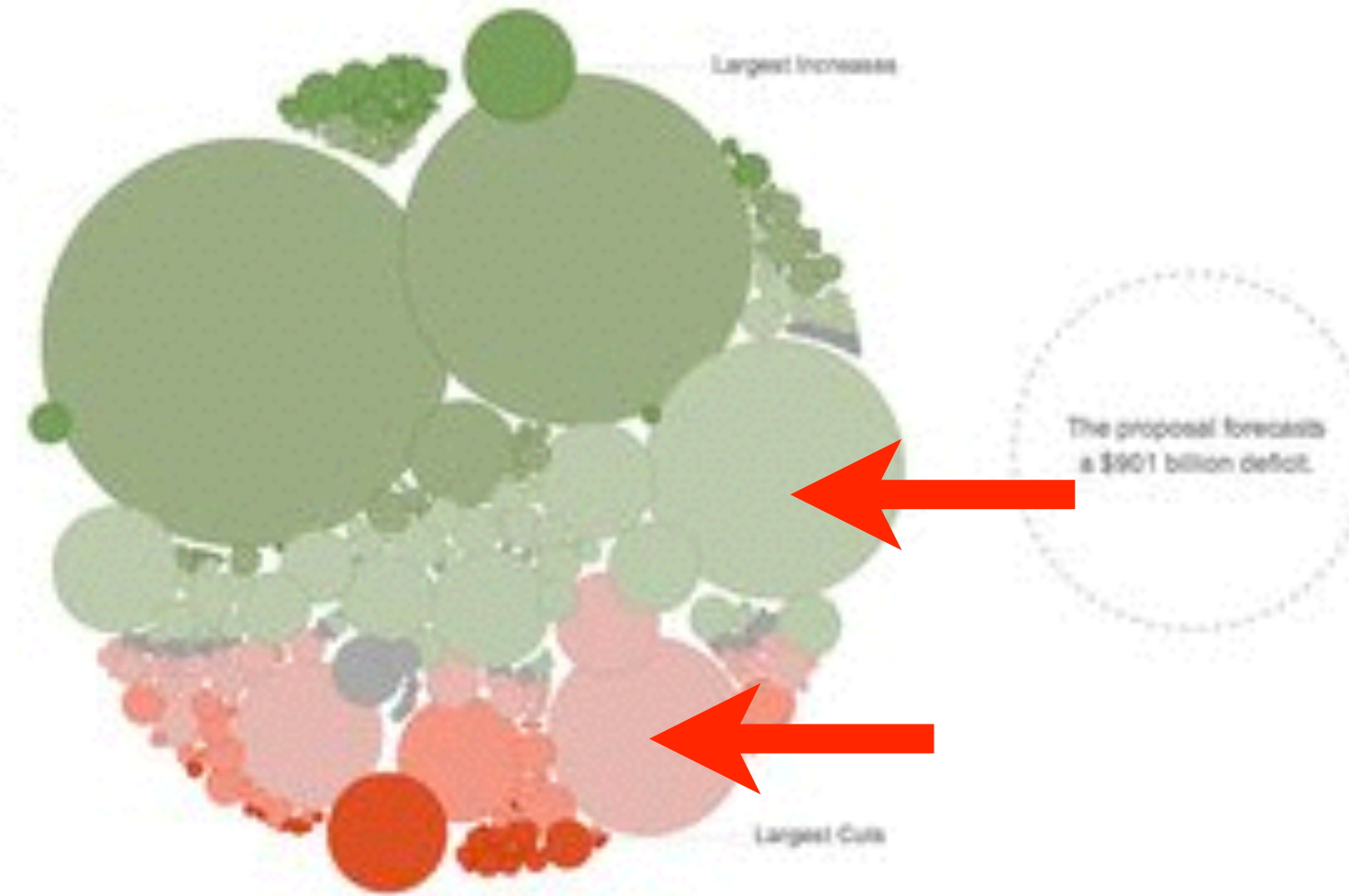
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All Spending | Types of Spending | Changes | Department Totals

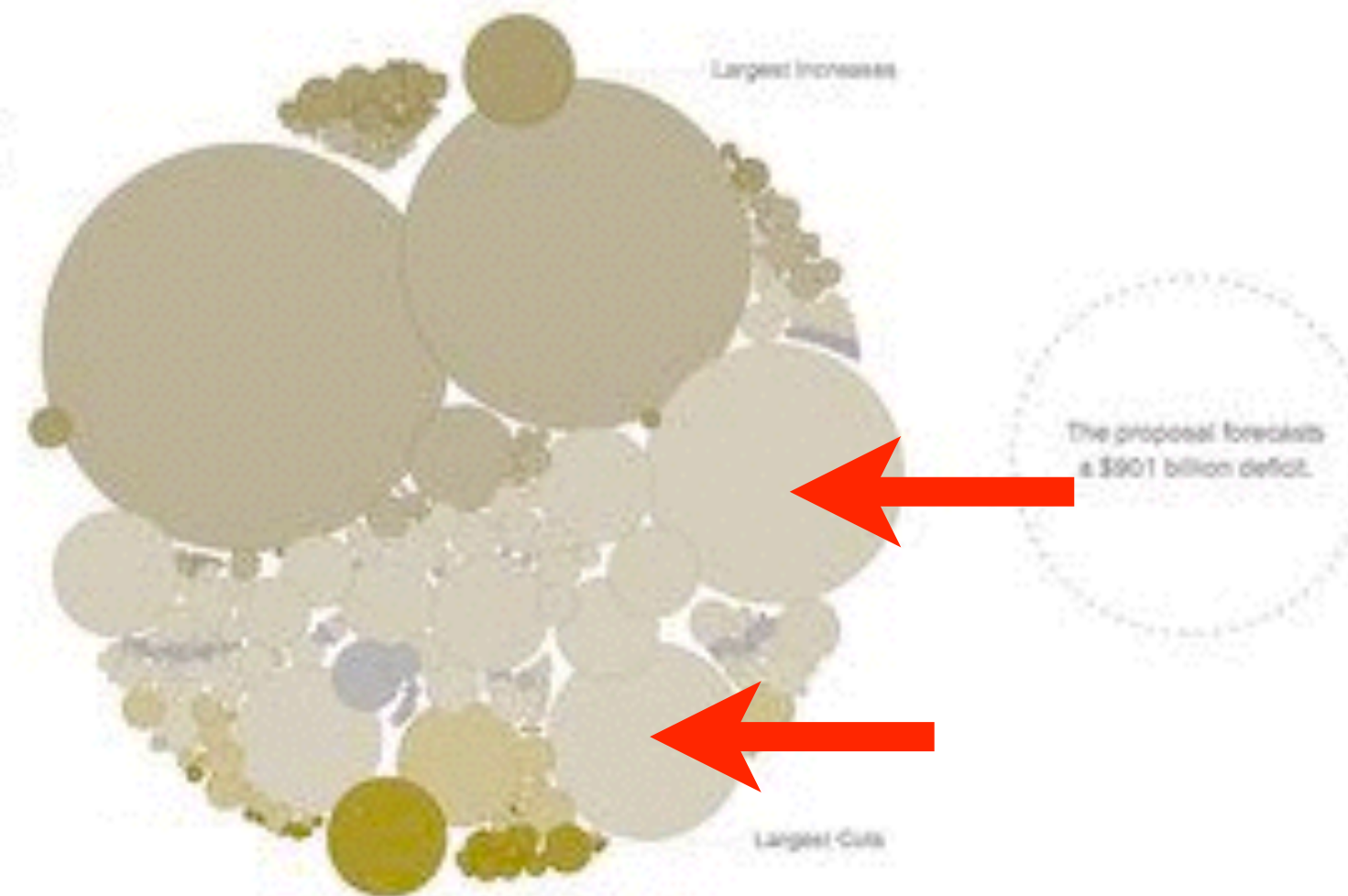
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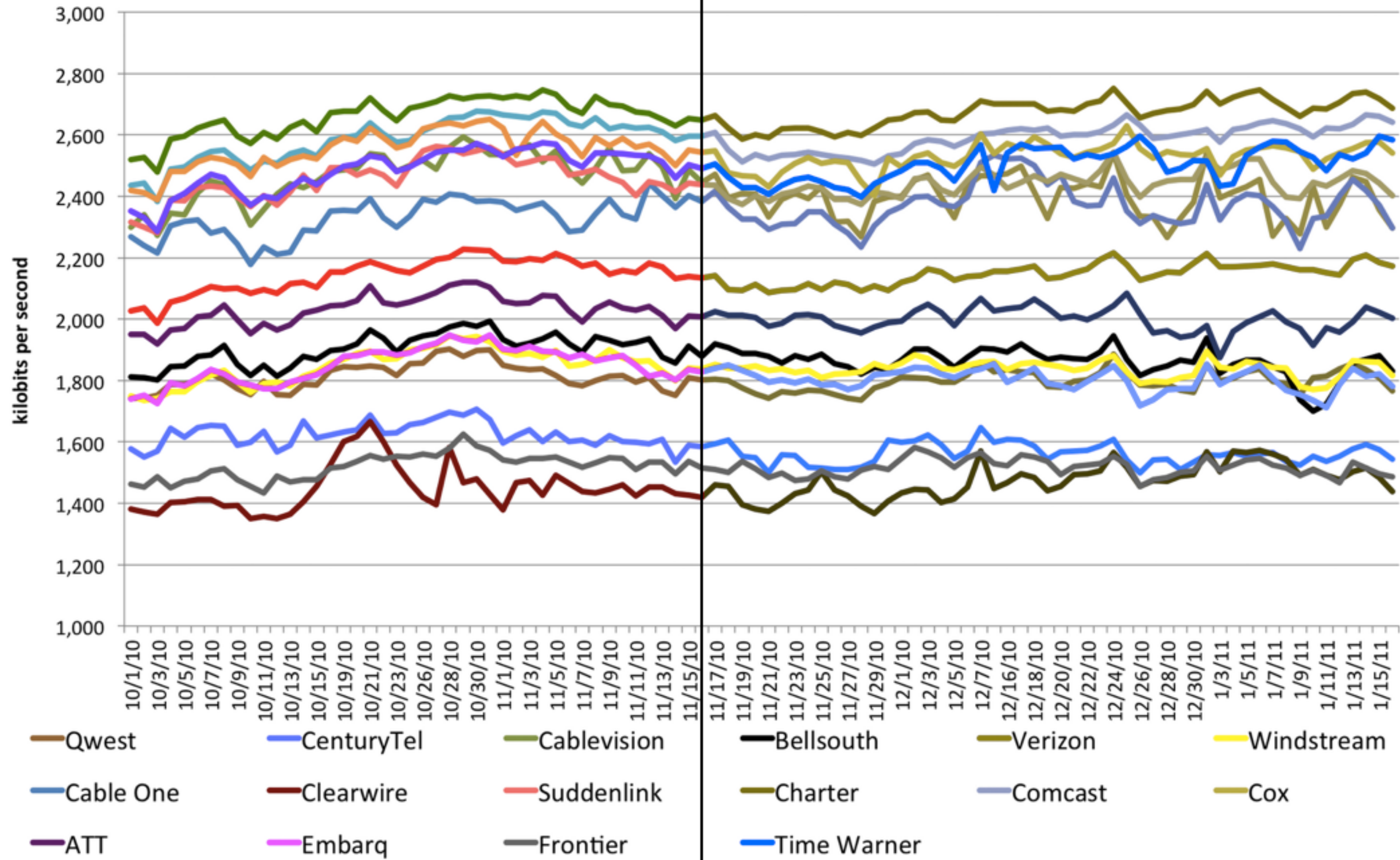


Color shows amount of cut or increase from 2012.



Normal Vision

Red-Green Colorblind



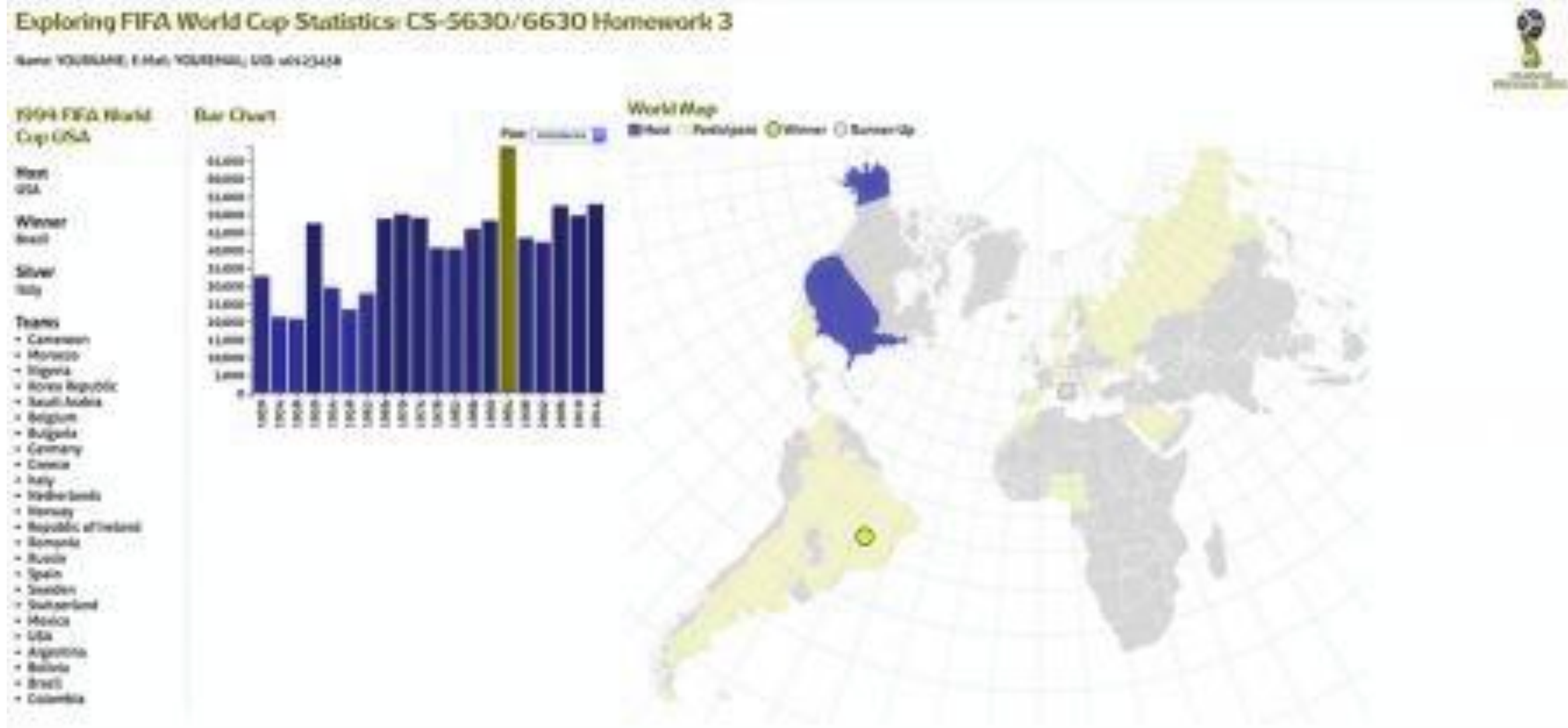
Simulate Color Vision Deficiencies

<http://www.color-blindness.com/coblis-color-blindness-simulator/>

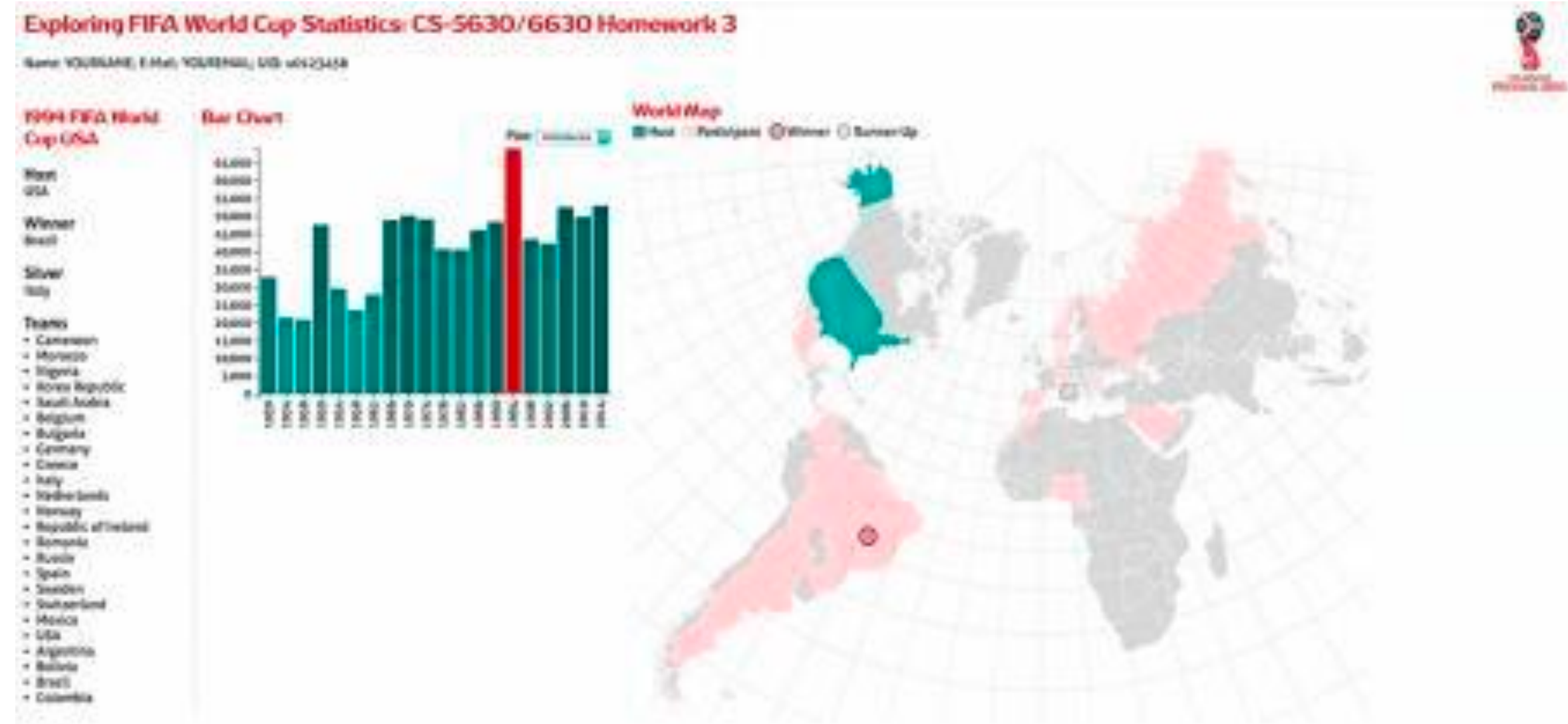
<http://www.vischeck.com/>



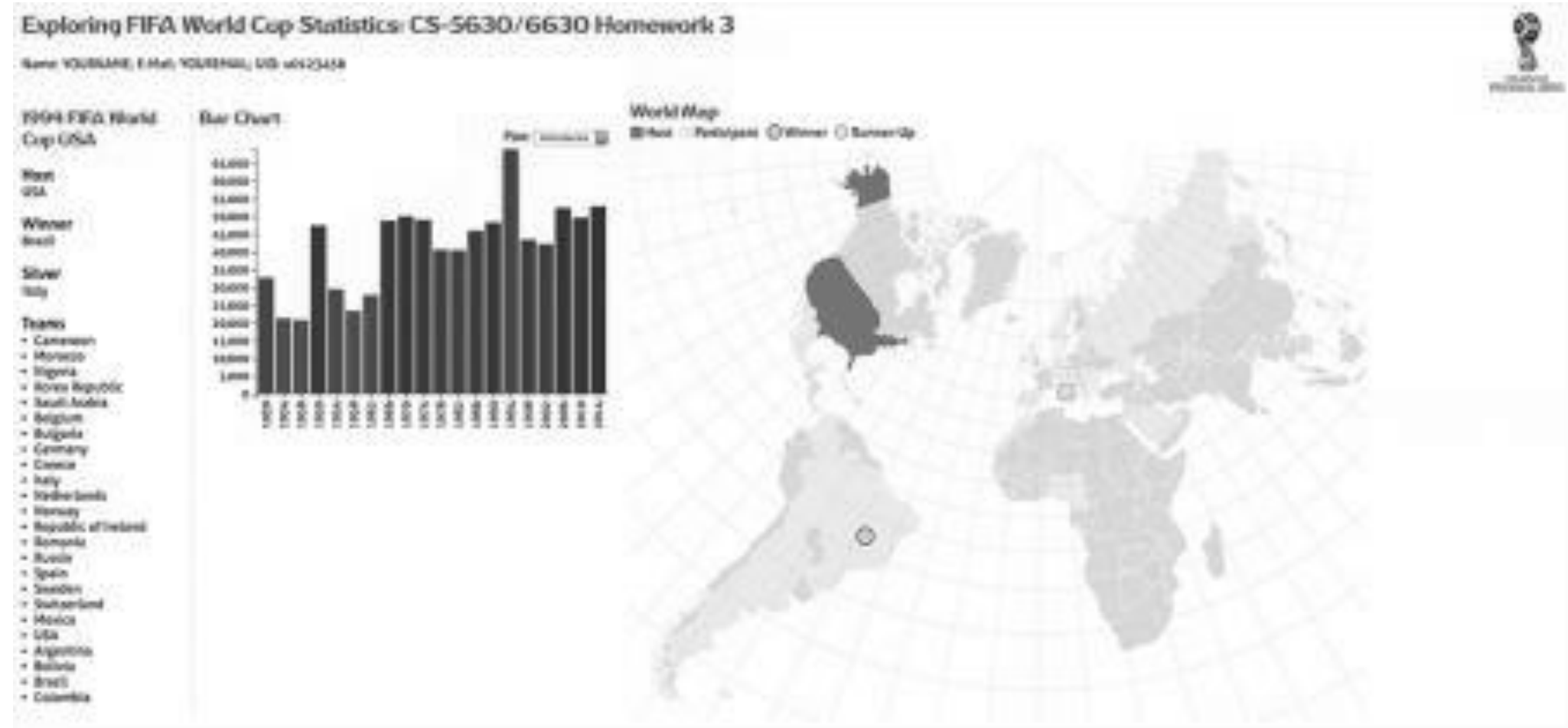
The screenshot shows the Colblindor website interface. At the top, there is a navigation menu with links for Home, CVD Essentials, Color Blindness Tests, Color Tools, and Contact. The main heading is "Coblis — Color Blindness Simulator". Below the heading, there is a search bar and a "Subscribe to News by Email" form. The central part of the page features the "CVD Simulator" interface, which includes a file upload field (currently showing "overview.png"), a "Select" button, and an "Upload Image" button. A list of color vision deficiency options is displayed, with "Blue Cone Monochromacy" selected. The options are: Normal Color Vision, Red-Blind/Protanopia, Green-Blind/Deuteranopia, Blue-Blind/Tritanopia, Red-Weak/Protanomaly, Green-Weak/Deuteranomaly, Blue-Weak/Tritanomaly, Monochromacy/Achromatopsia, and Blue Cone Monochromacy. To the right of the simulator, there is a "FREE Color Blind Check" section with a "Color Blind Test" button and a "Red Green Color Blind" button. The bottom right corner features a "CVD Categories" section with a "Google play" logo and a target icon.



Red-Blind



Blue Blind



Monochromacy

Luminance, Brightness, Lightness

Luminance

measured amount of light (luminous intensity per area)

Brightness

perceived amount of light

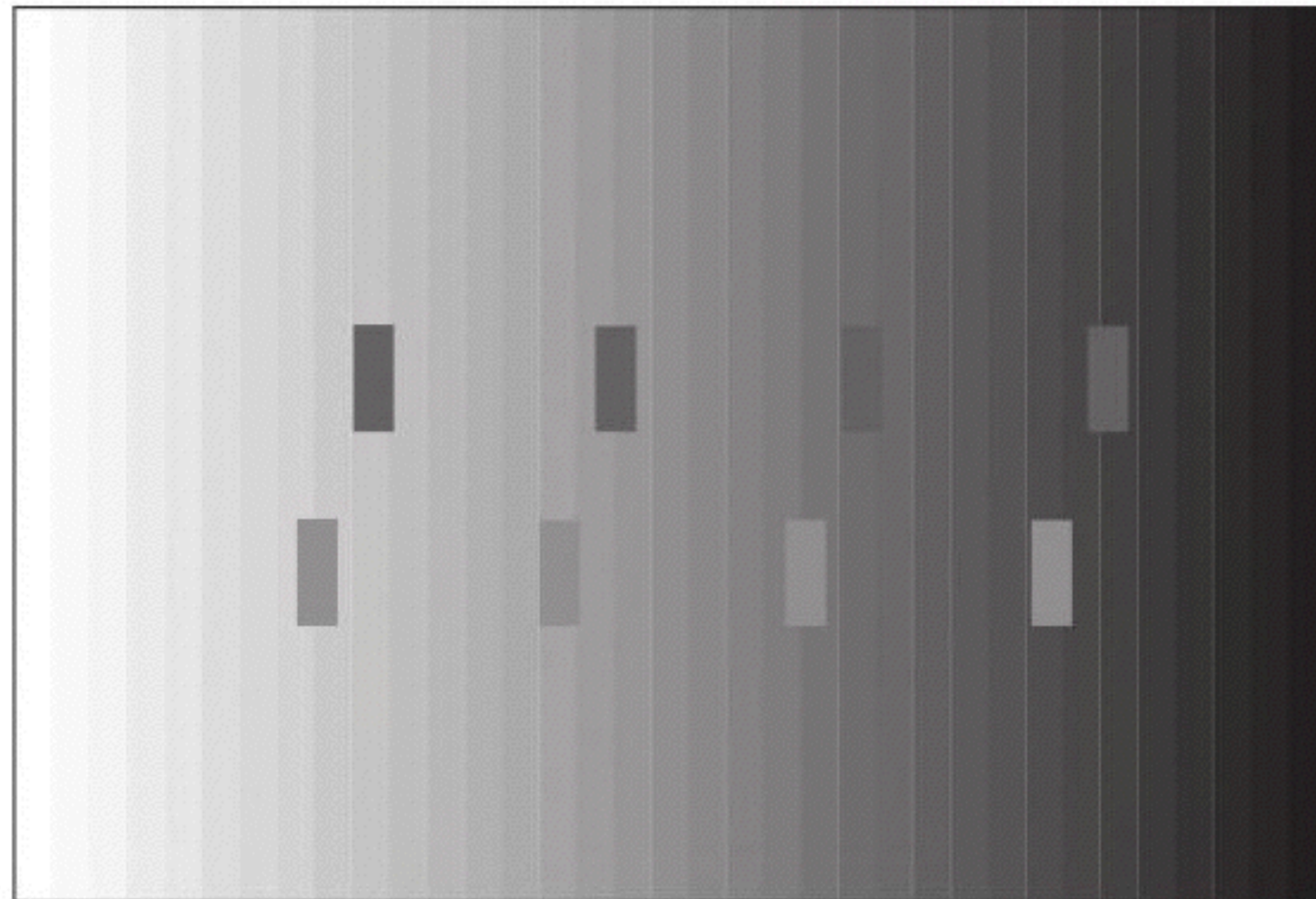
Lightness

perceived reflectance of a surface

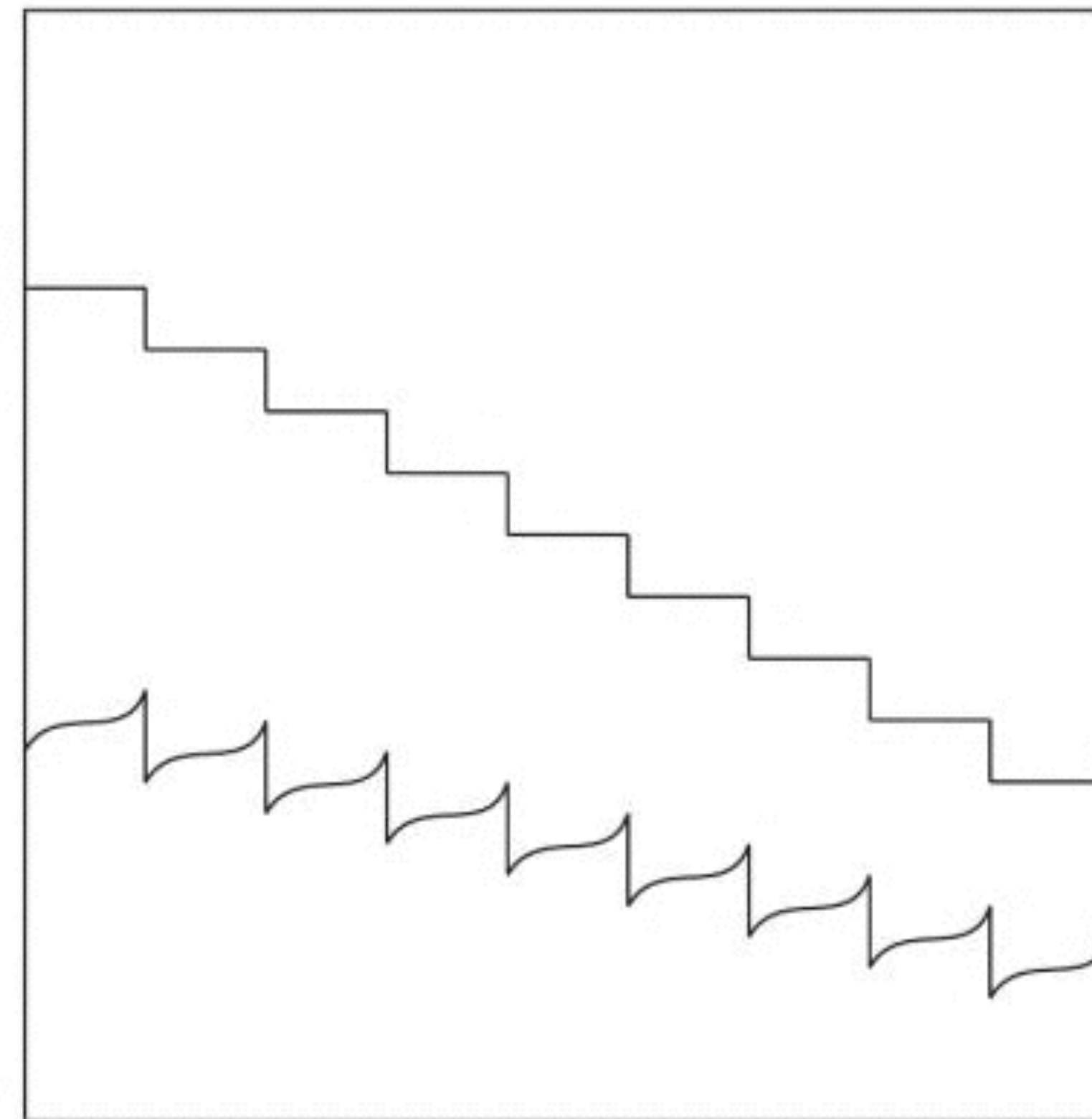
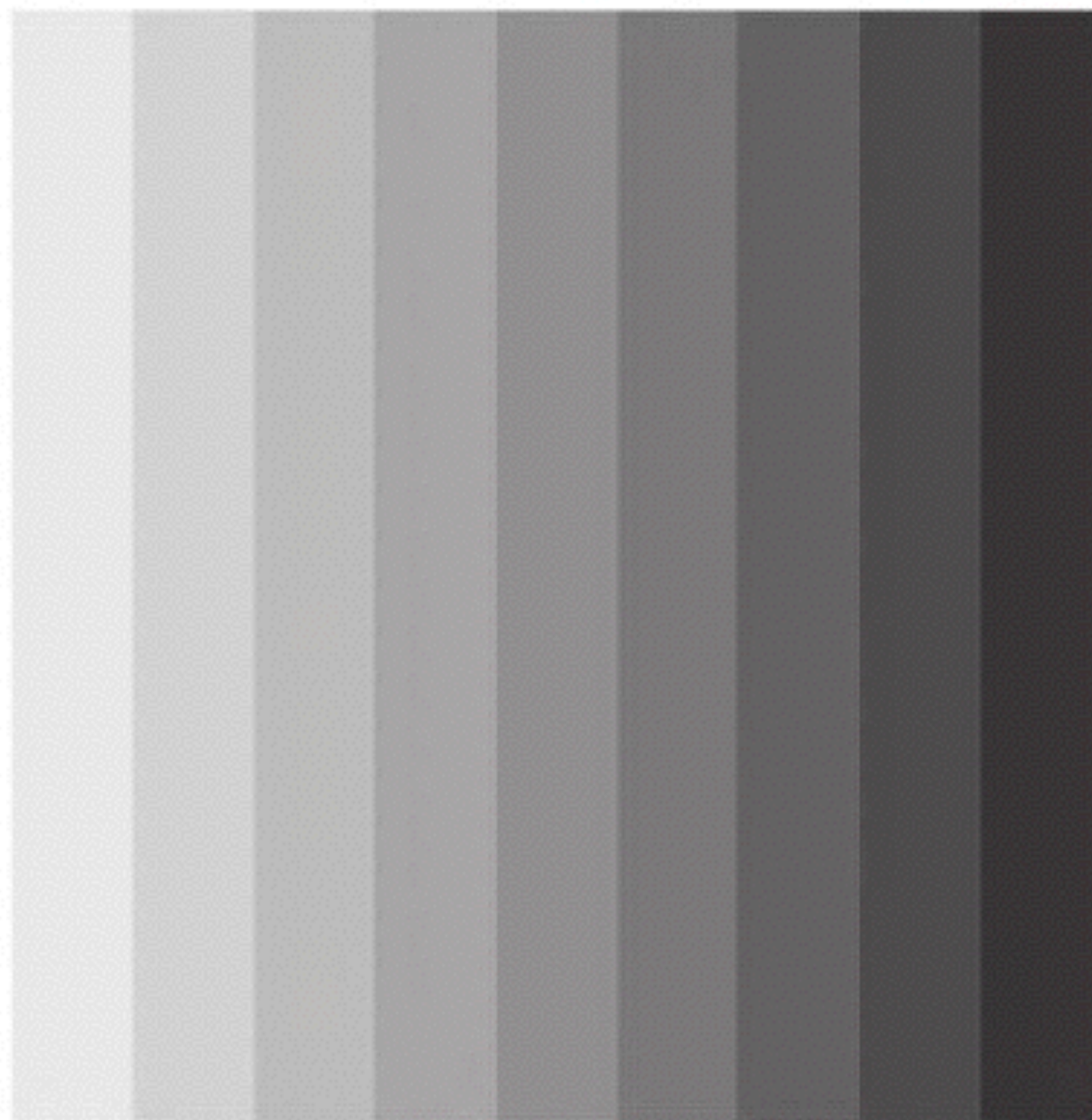
lightness of a color

Simultaneous Brightness Contrast

The perceived brightness of an object is relative to its background



Chevreul Illusion



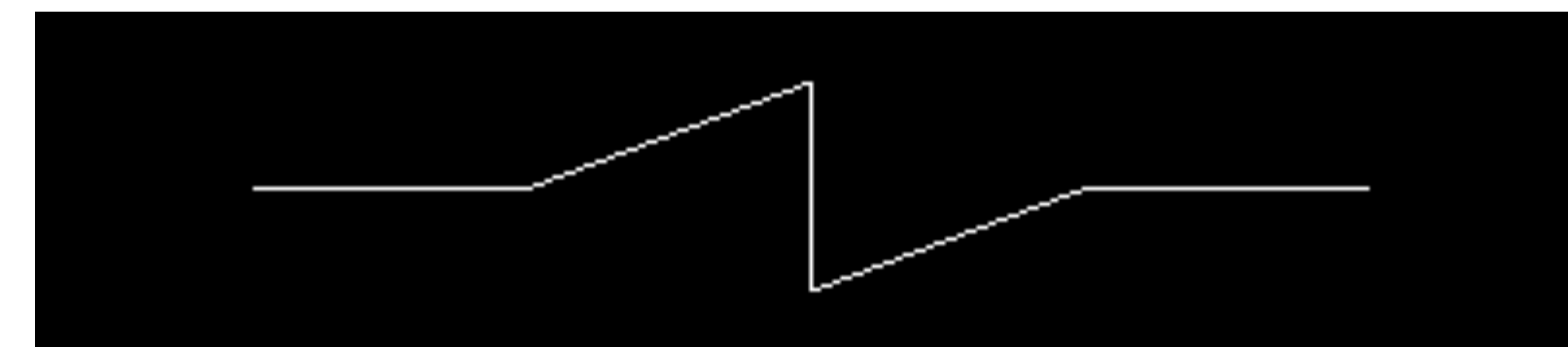
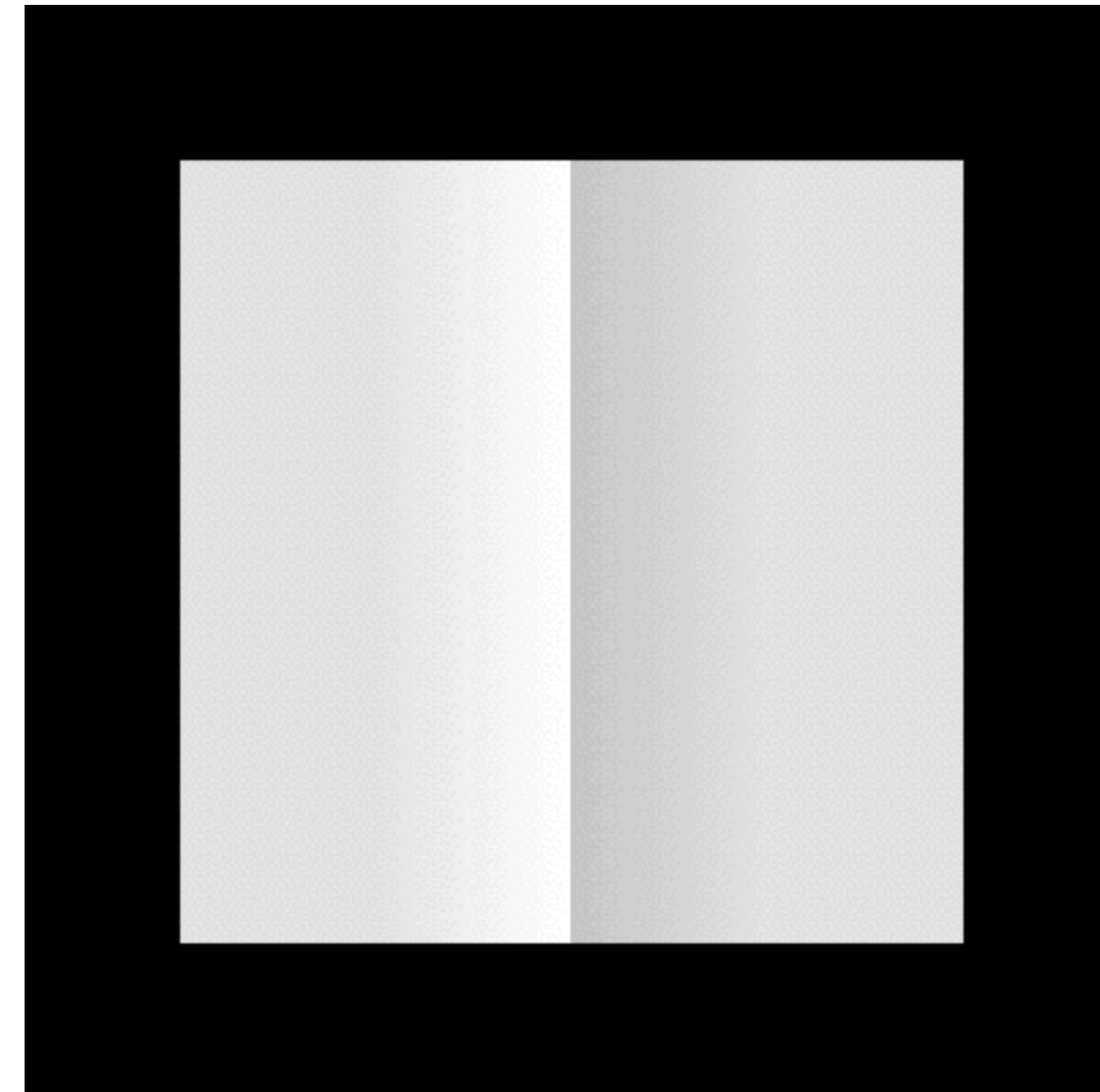
Edge Enhancement

Cornsweet effect

Make objects more distinct



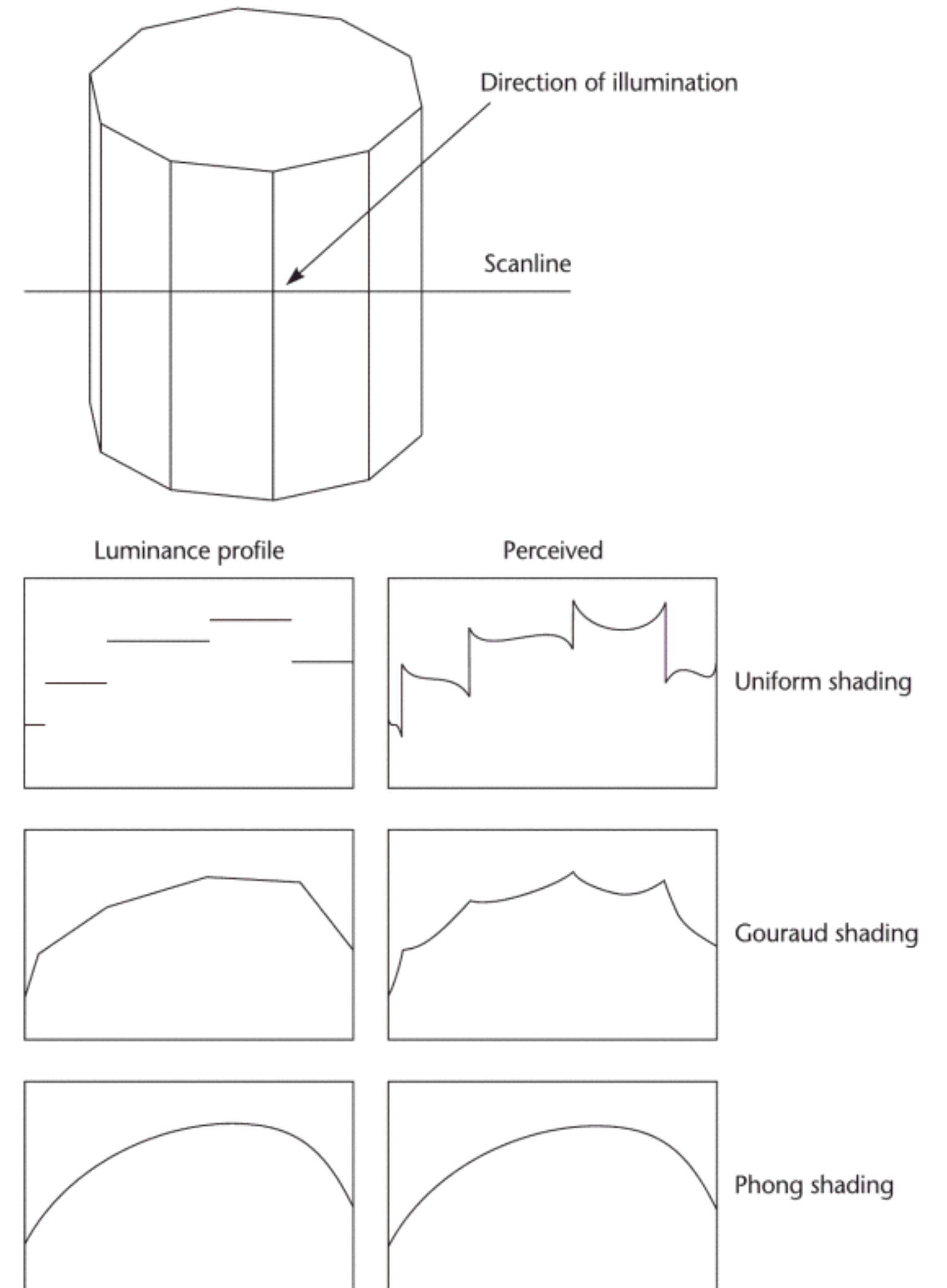
Seurat's Bathers



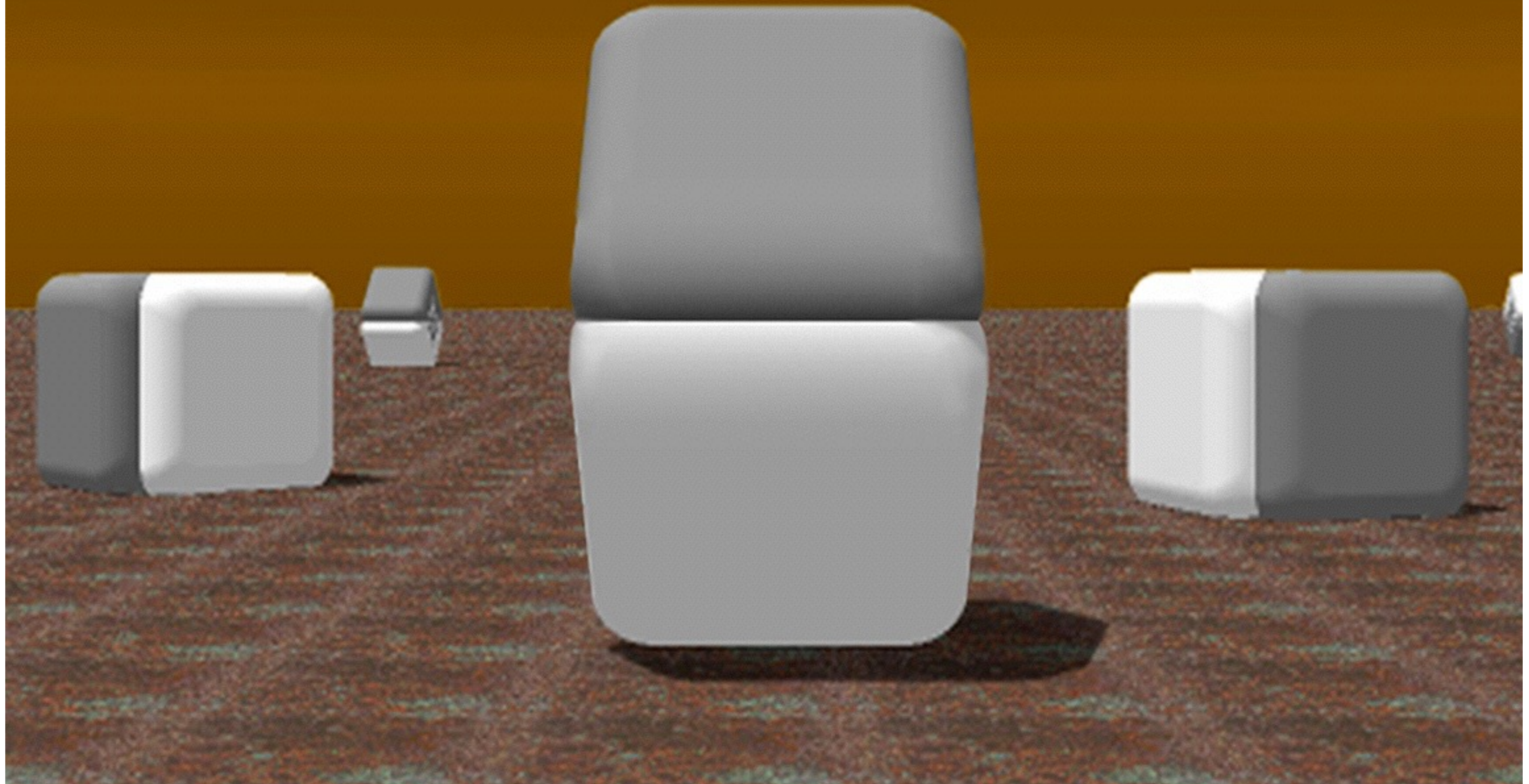
Why is this an issue?

Can result in large errors of judgment

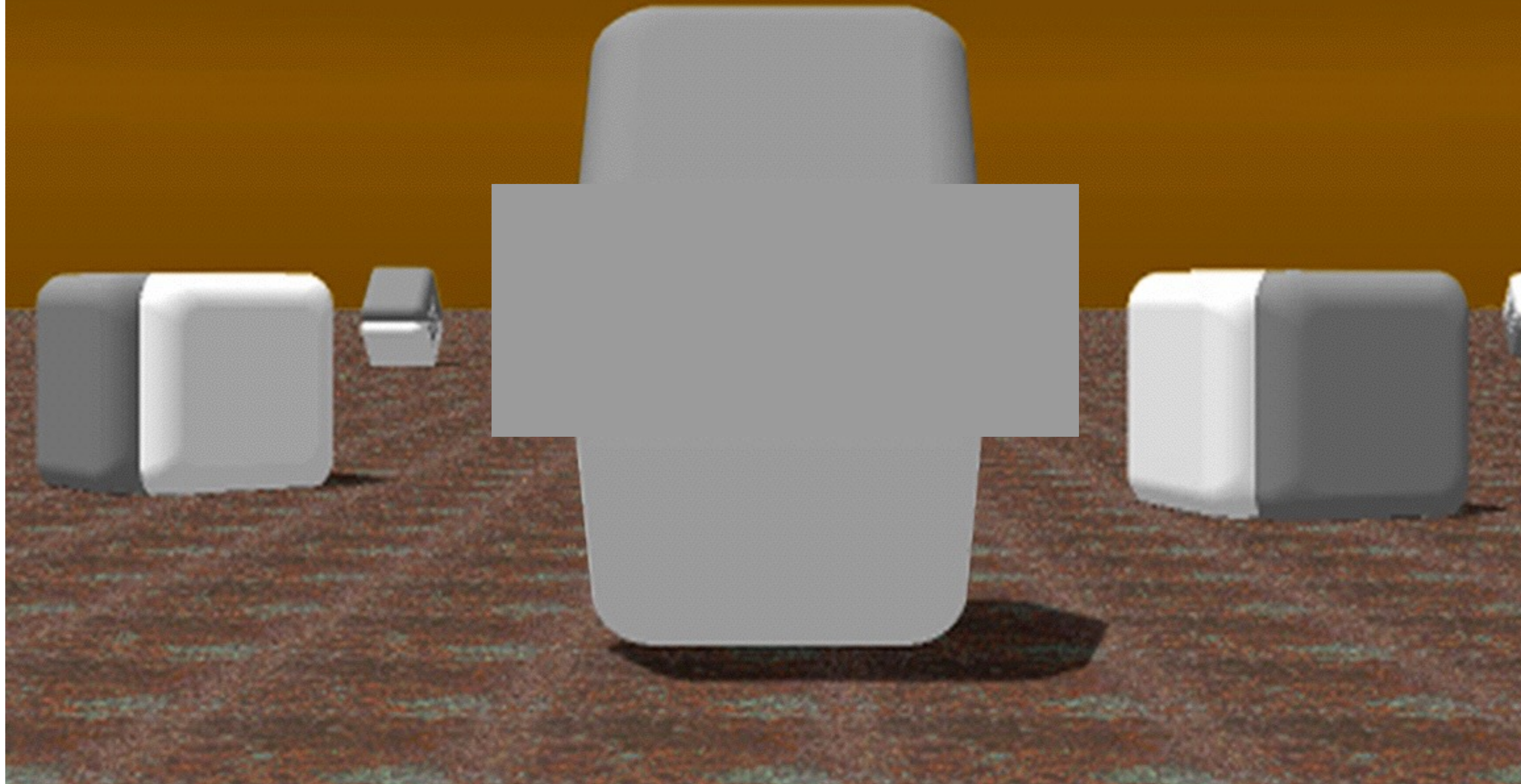
Amplifies artifacts in computer graphics shading



Cornsweet Illusion



Cornsweet Illusion

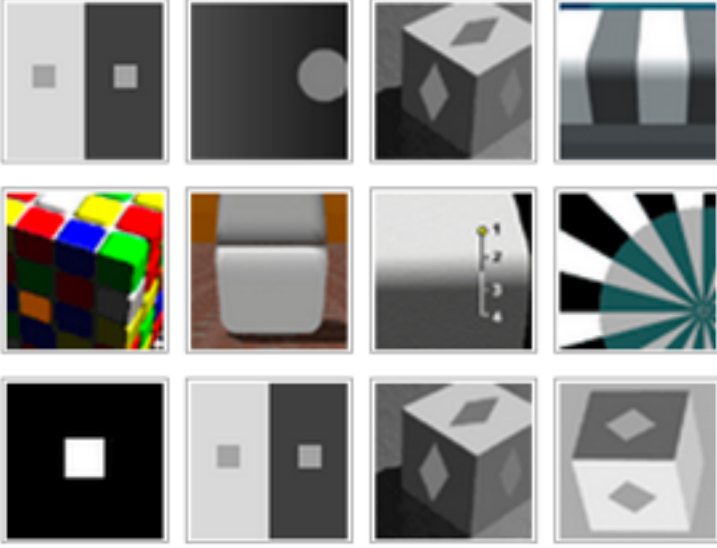
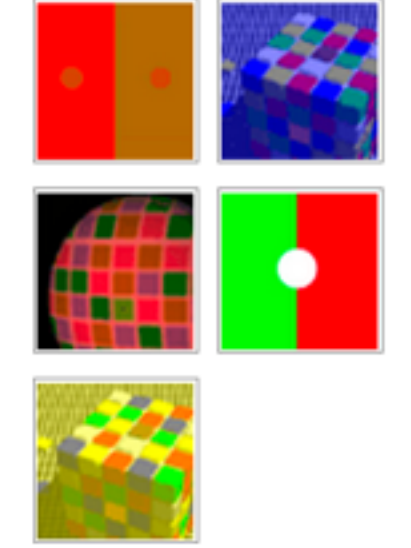
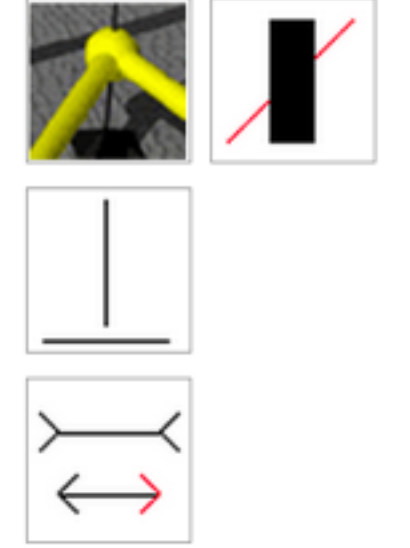
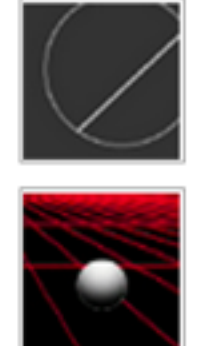
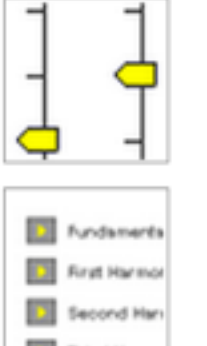


Demo

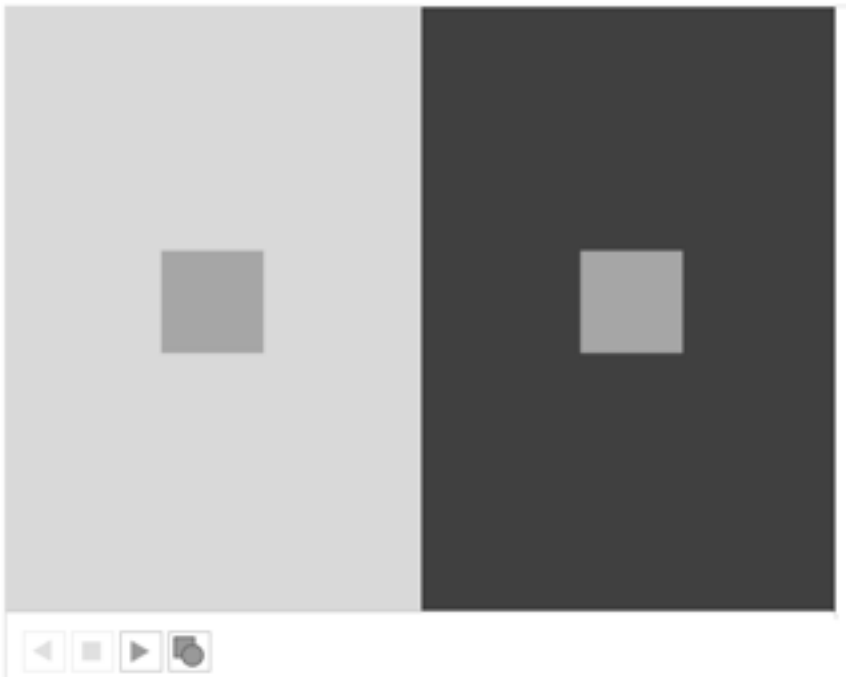
<http://purveslab.net/see-for-yourself/>

purves-lab Laboratory of Dale Purves, M.D. Center for Cognitive Neuroscience Duke University

MAIN NEWS PEOPLE RESEARCH PUBLICATIONS RESOURCES [SEE FOR YOURSELF](#) CONTACT

Lightness/Brightness	Color	Lines and Angles	Motion	Sound and Music
				

Brightness contrast: standard
In viewing this stimulus, people invariably perceive the square on the brighter surround (left) to be darker than the square on the darker surround (right). Click on the "Play" button to convince yourself that the squares are equiluminant or click on the "Move mask" button to manually position the mask over the squares.
[» Read the empirical explanation](#)
[» Download high resolution images](#)



Preattentive Processing

Preattentive Processing

Properties detected by the low-level visual system

very rapid - 200-250 milliseconds

very accurate

processed in parallel

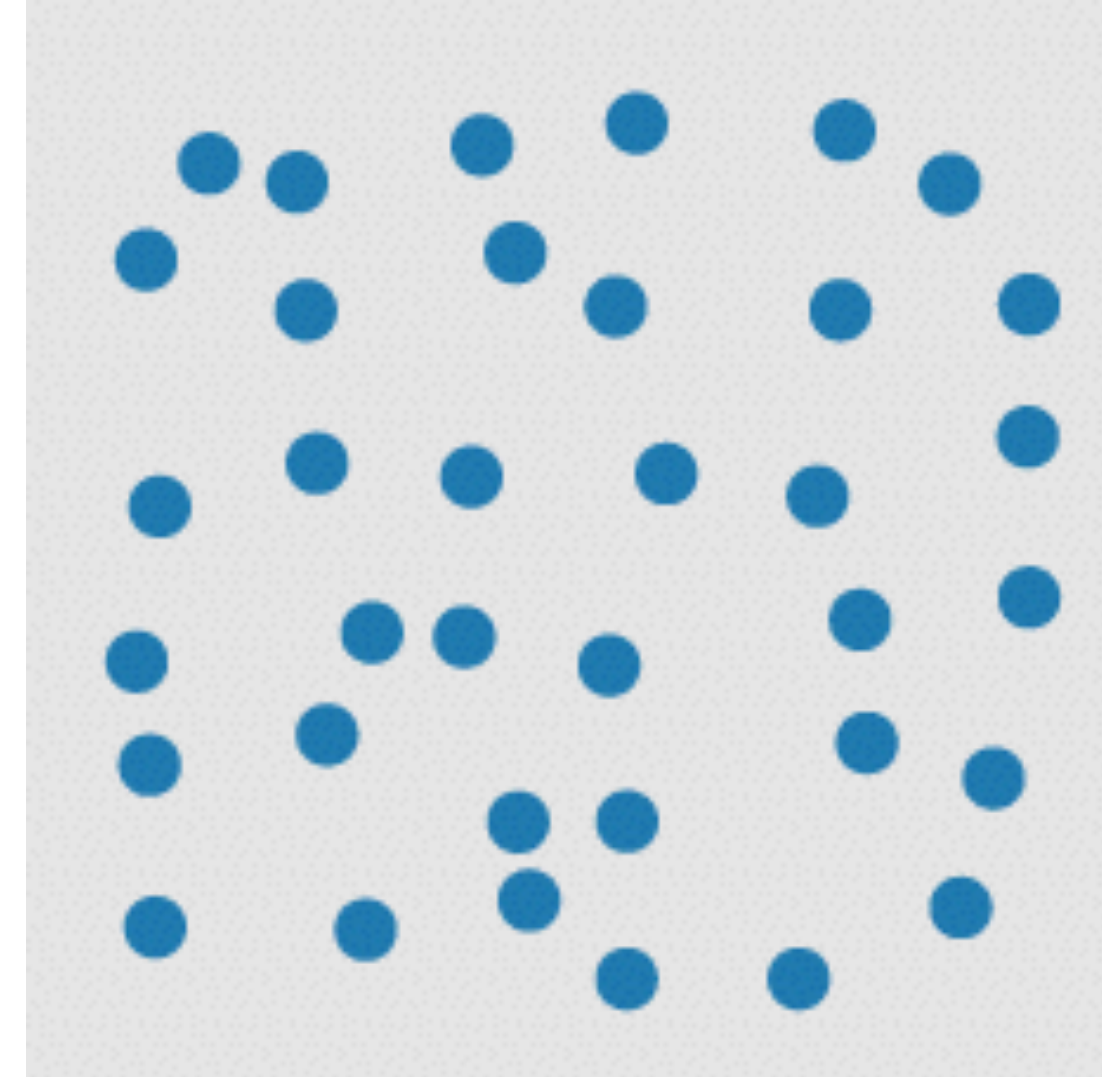
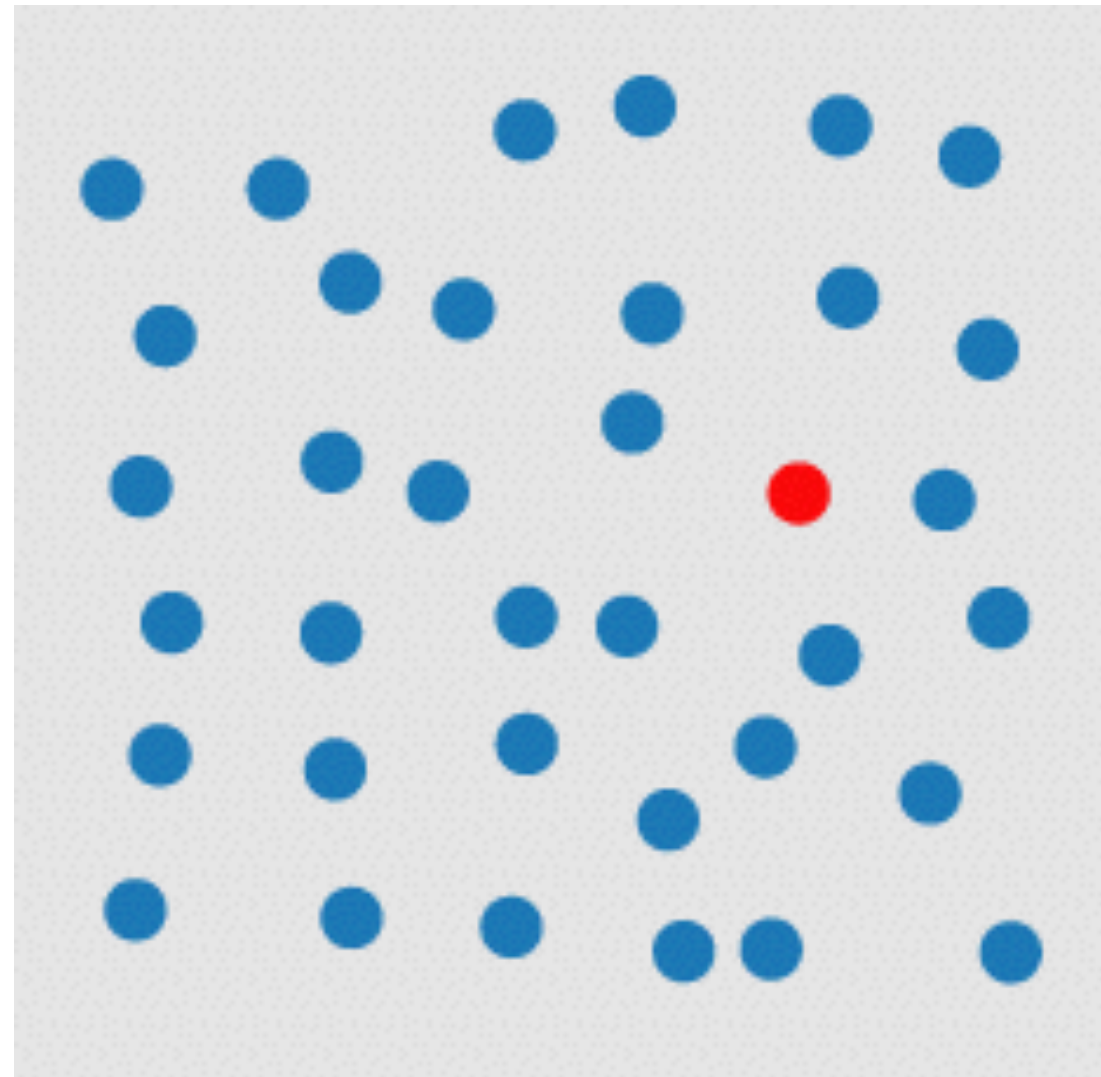
happens before focused attention -> „pre“attentive

attention is very important for cognition

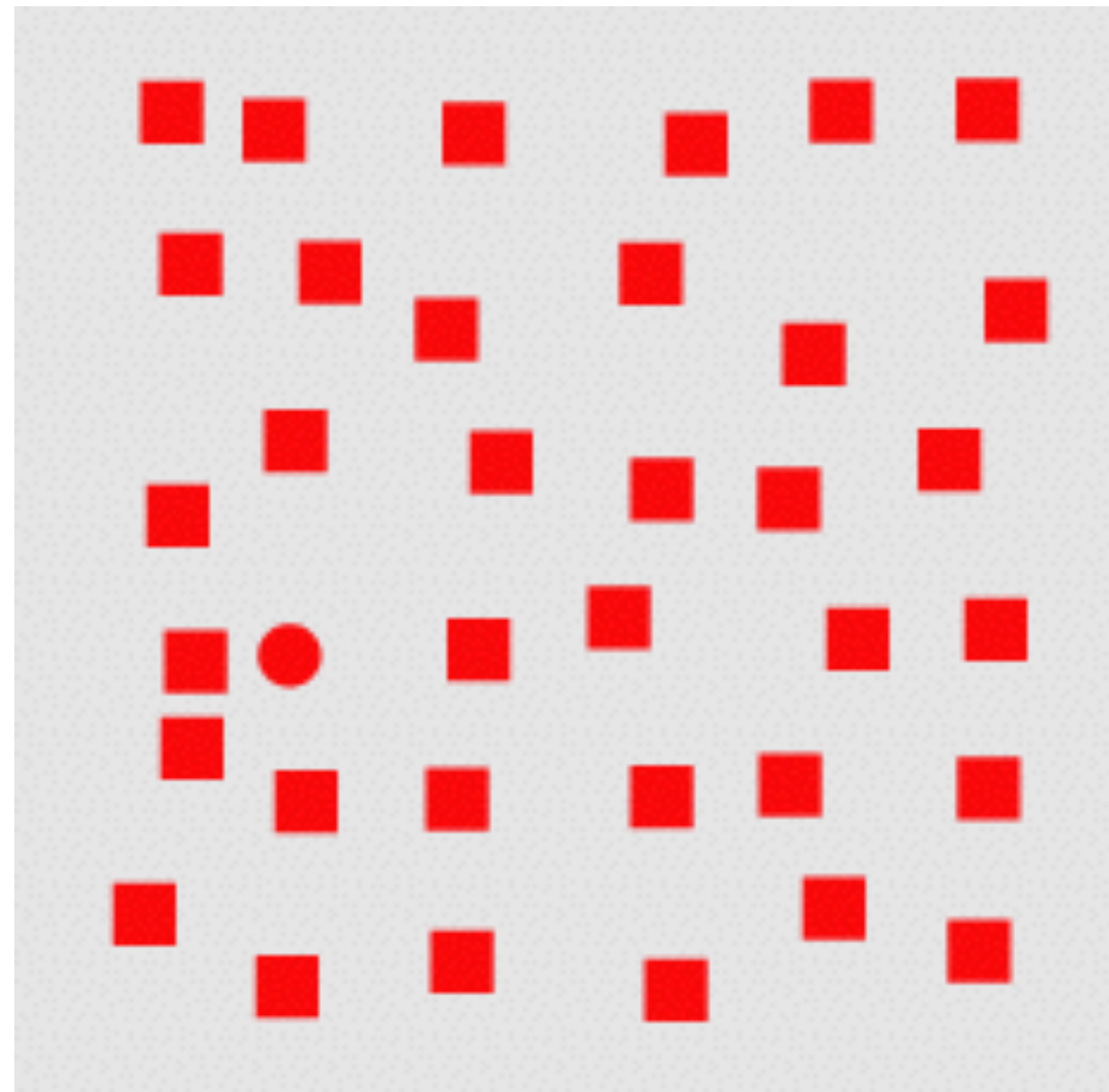
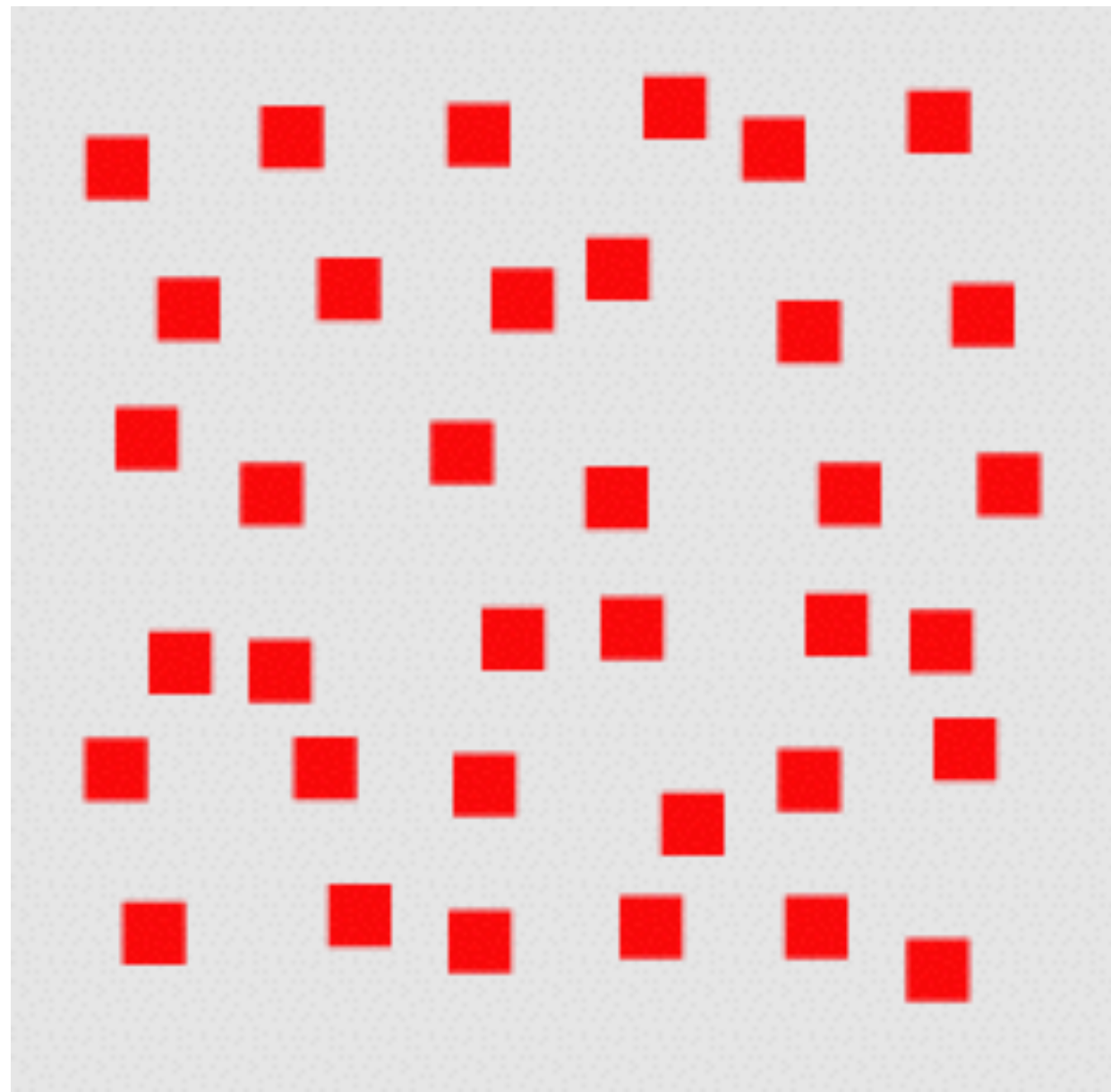
Independent of the number of distractors!

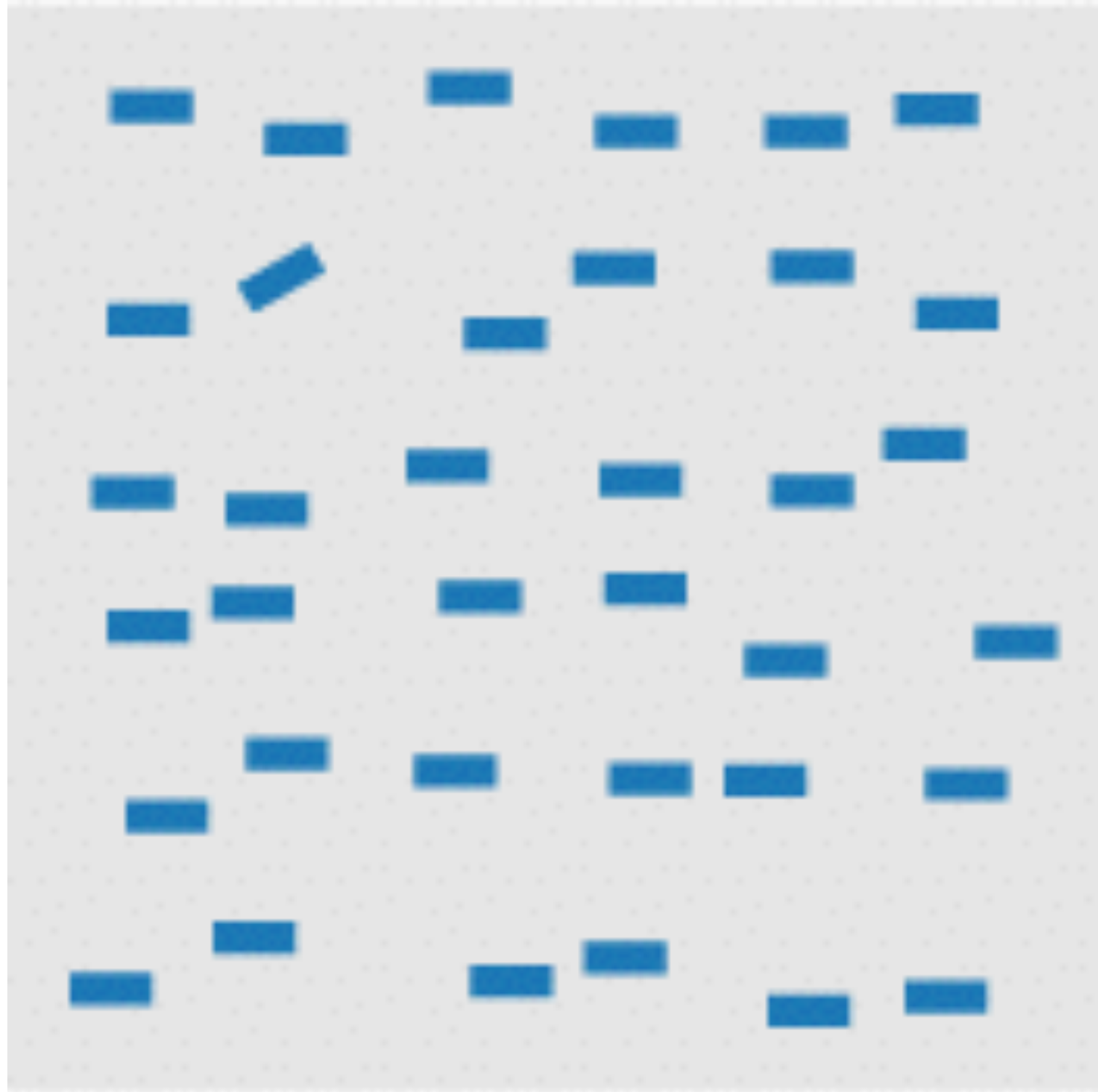
Opposite: sequential search (processed serially)

Difference in Hue

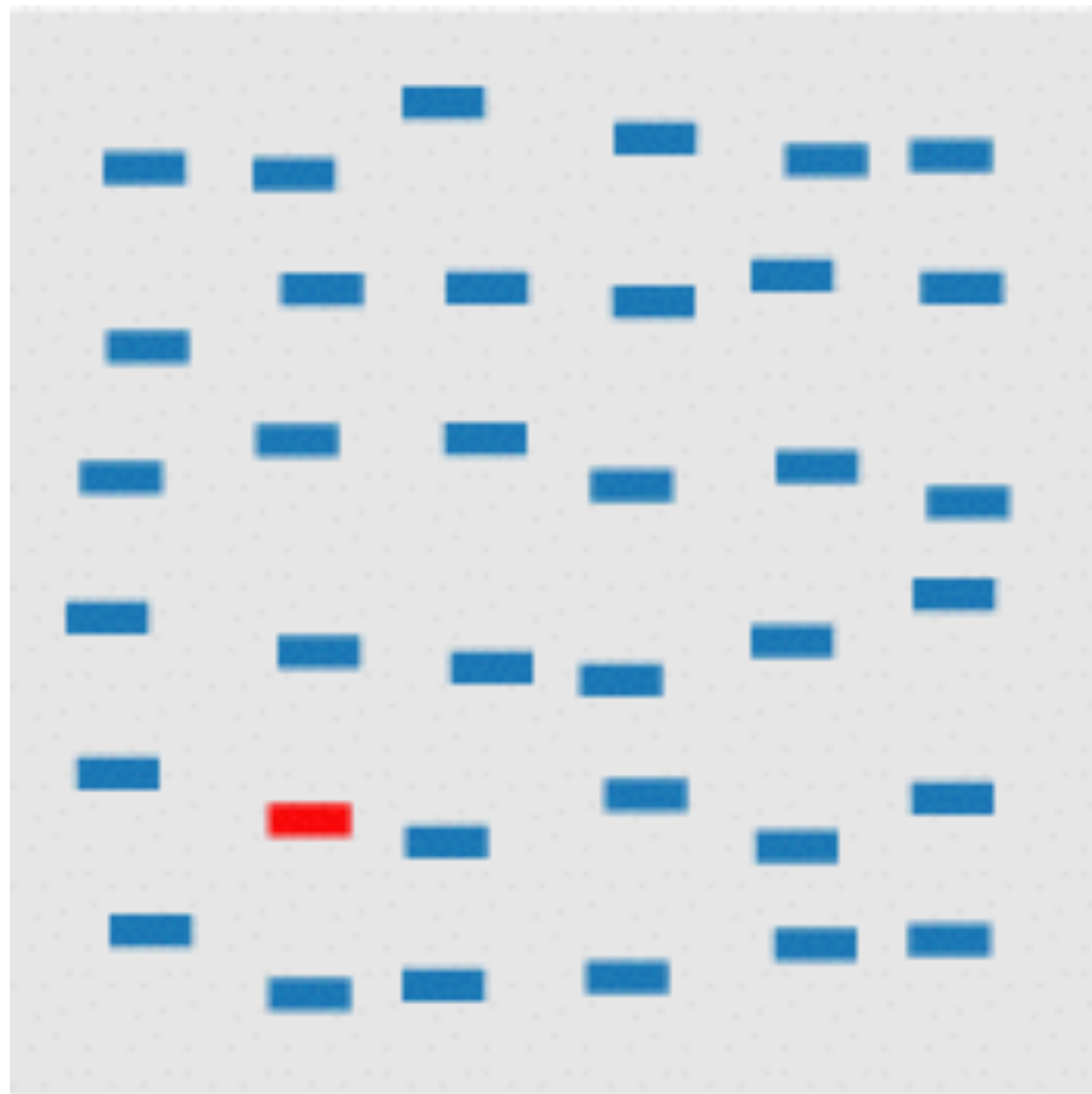


Difference in Curvature / Form





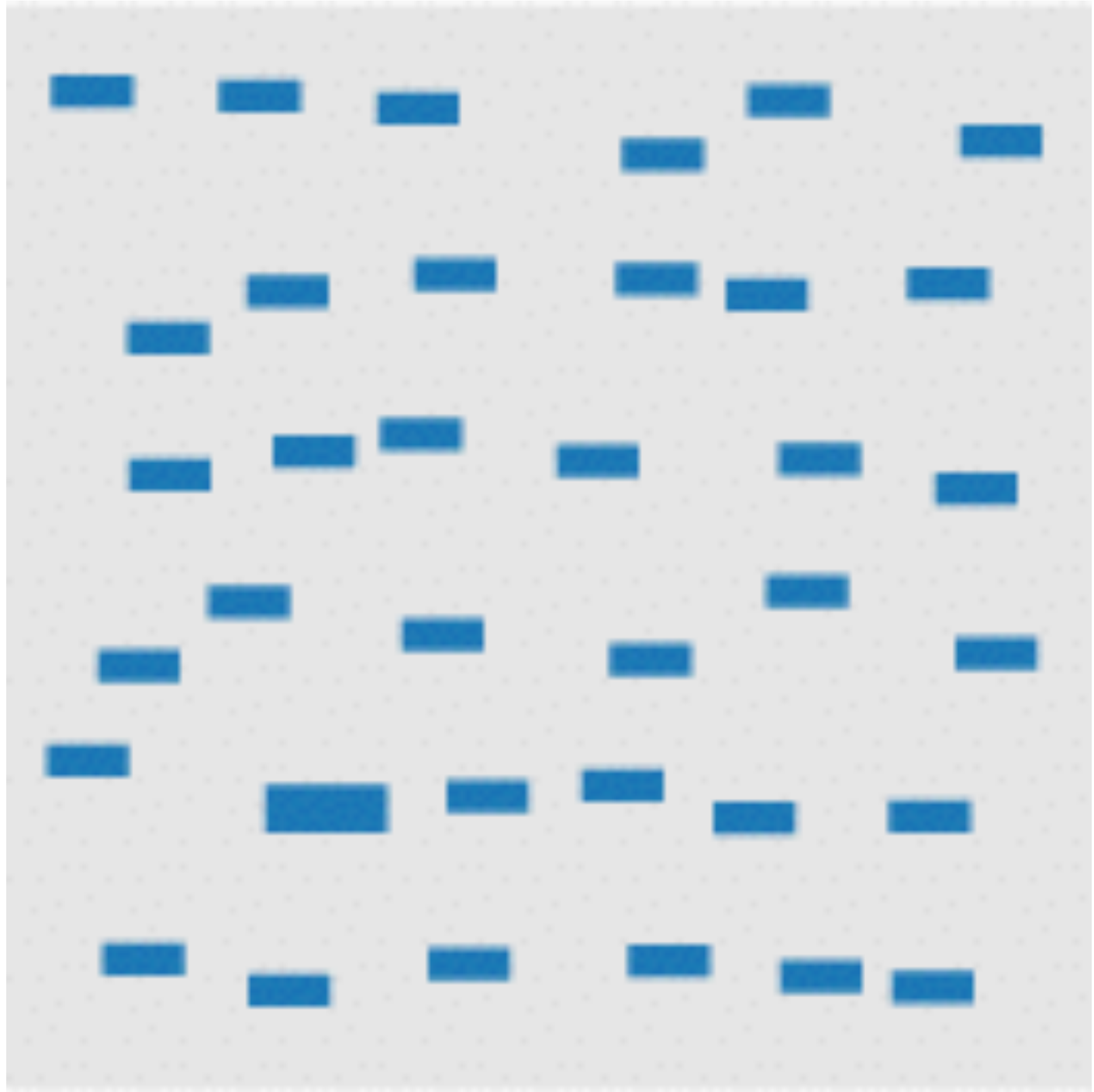
orientation



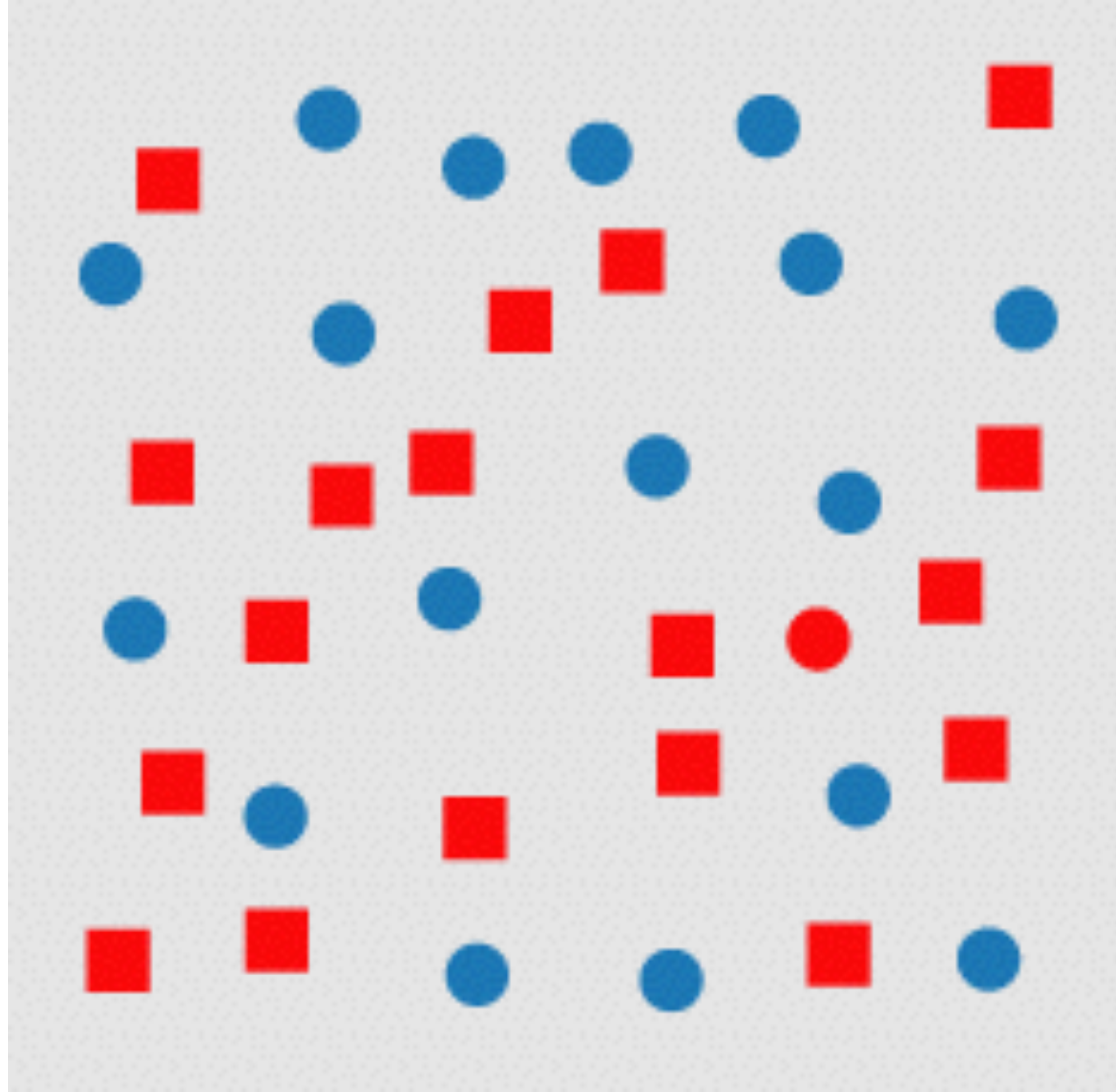
hue



closure

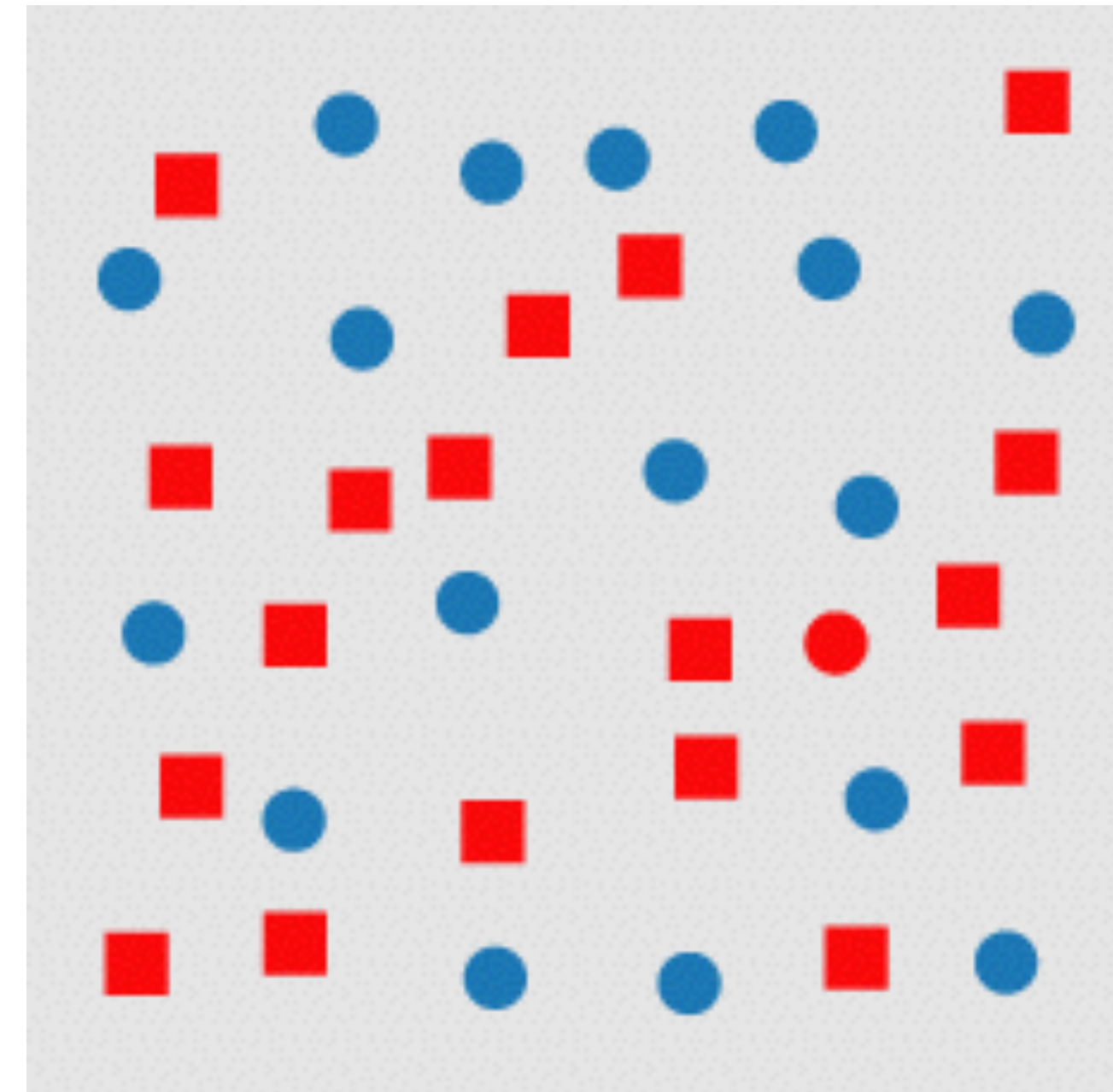
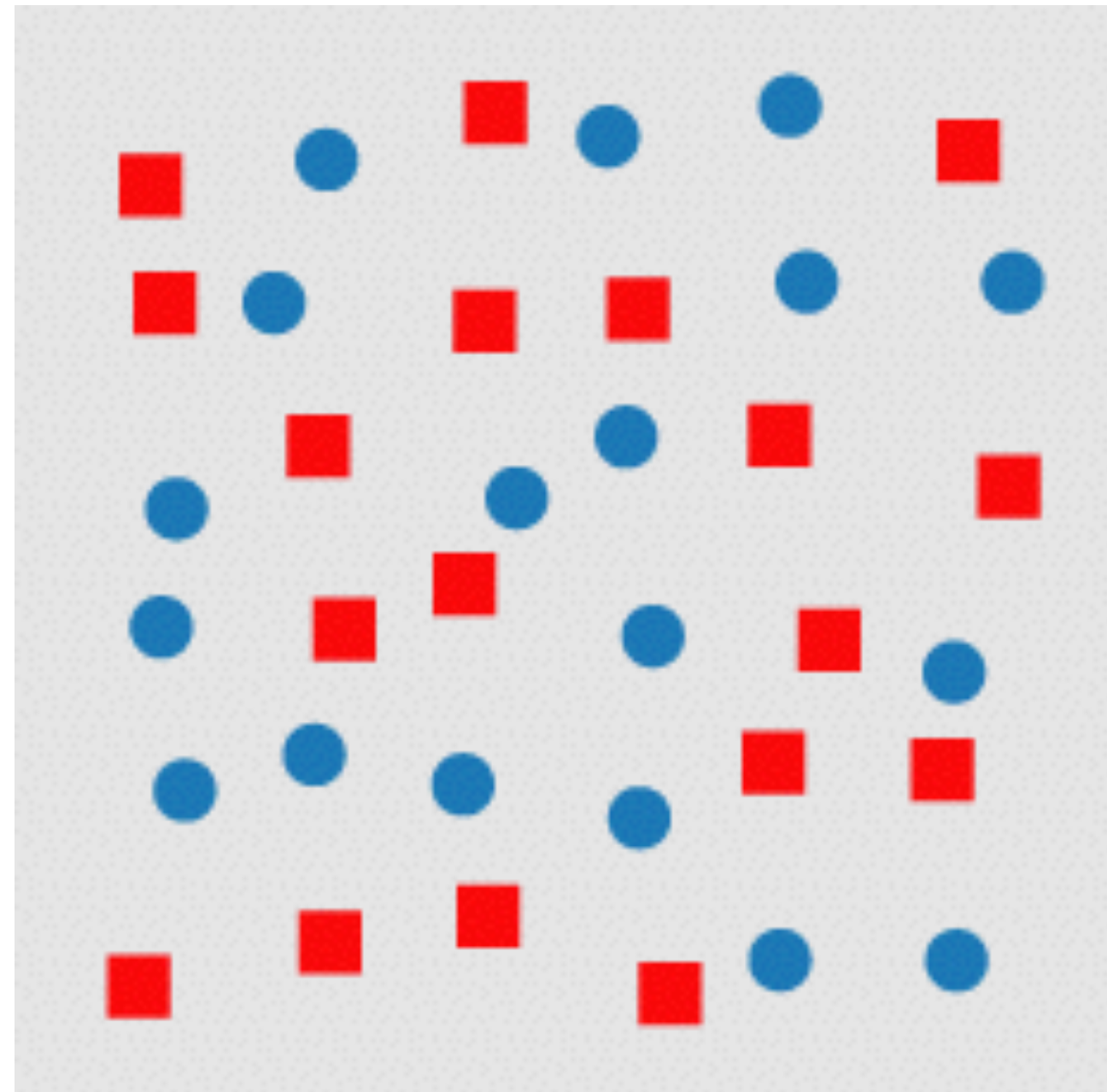


size



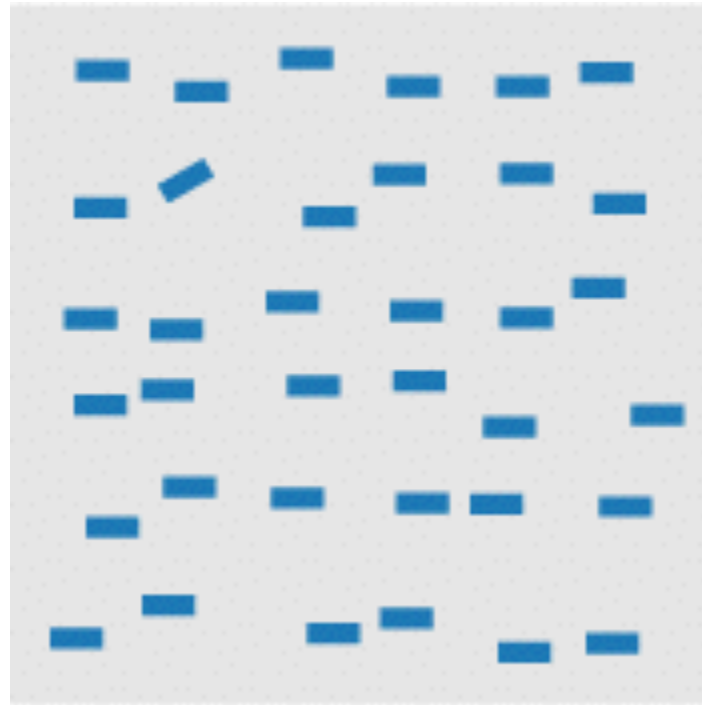
?

Not Valid for Combinations

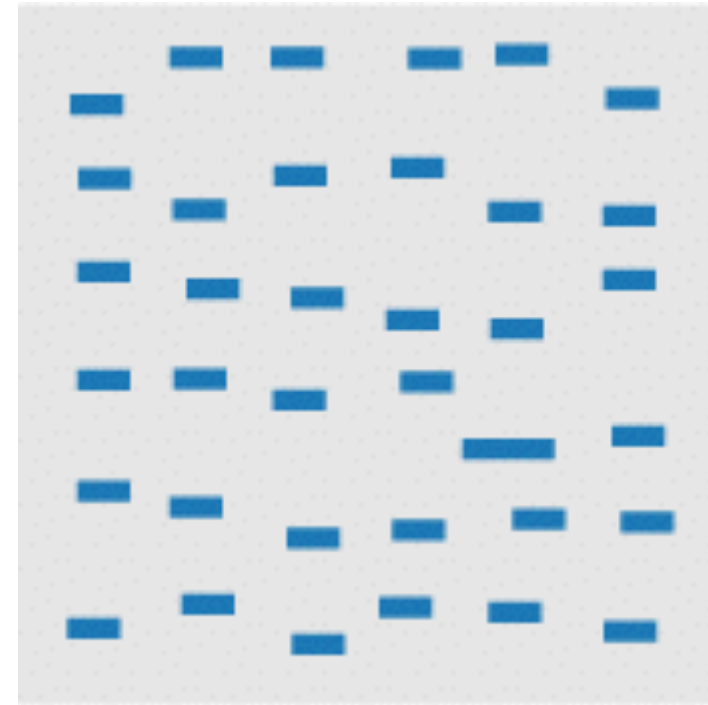


Conjunction Targets – no unique visual property
target: red, circle
distractor objects have both properties

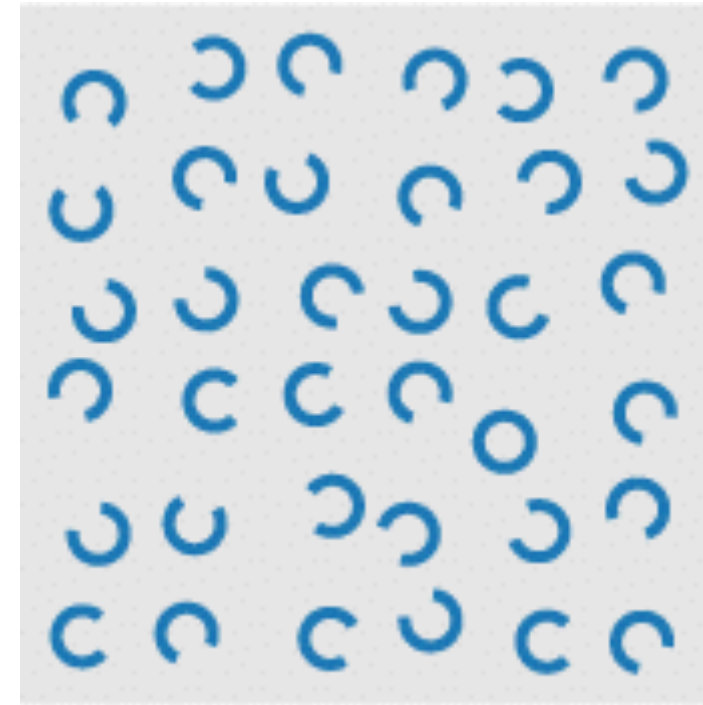
Some Preattentive Properties



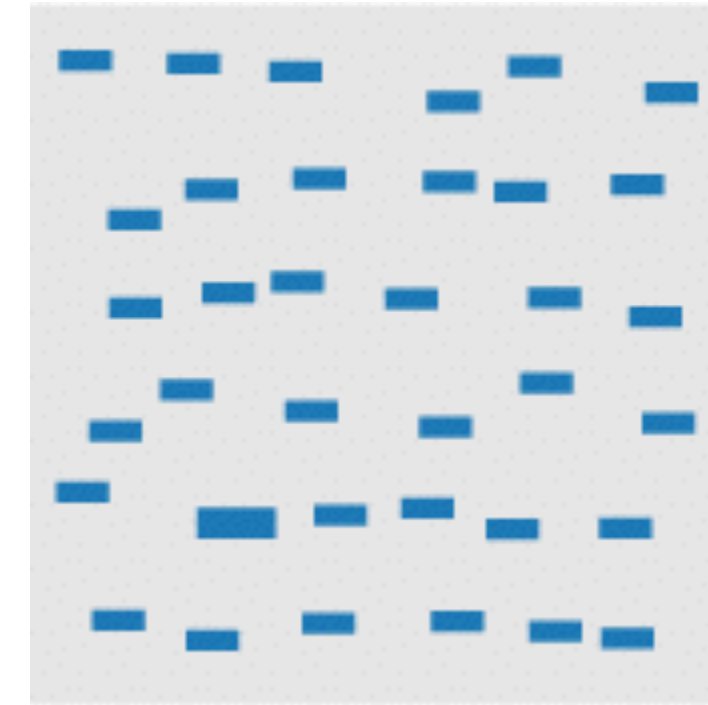
orientation



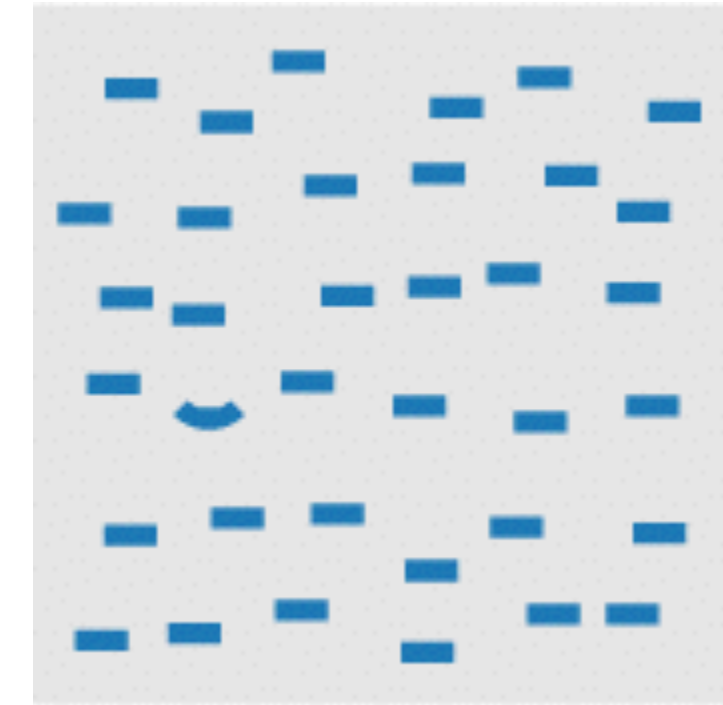
length



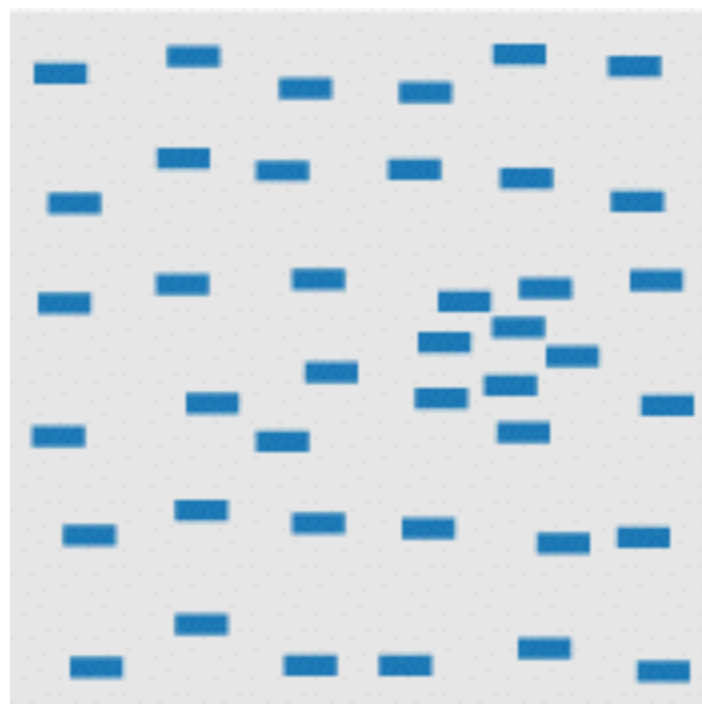
closure



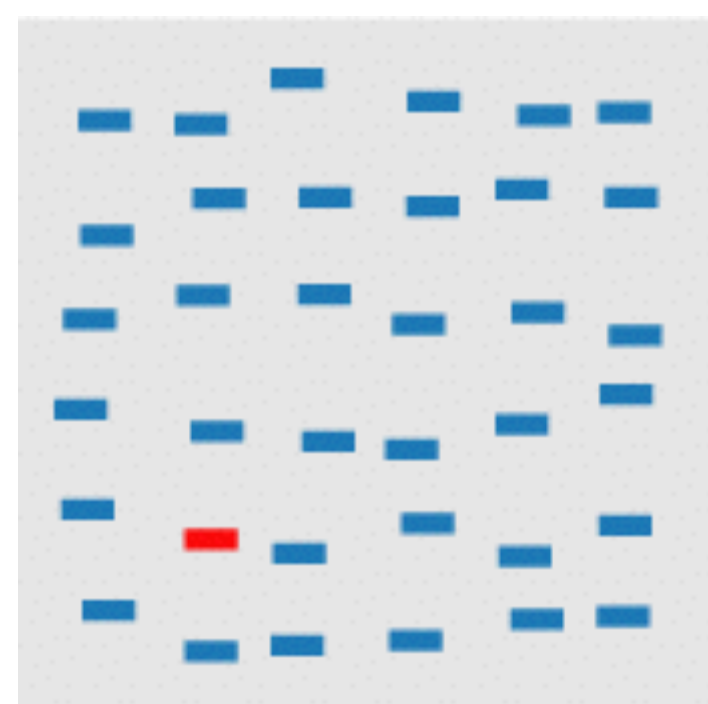
size



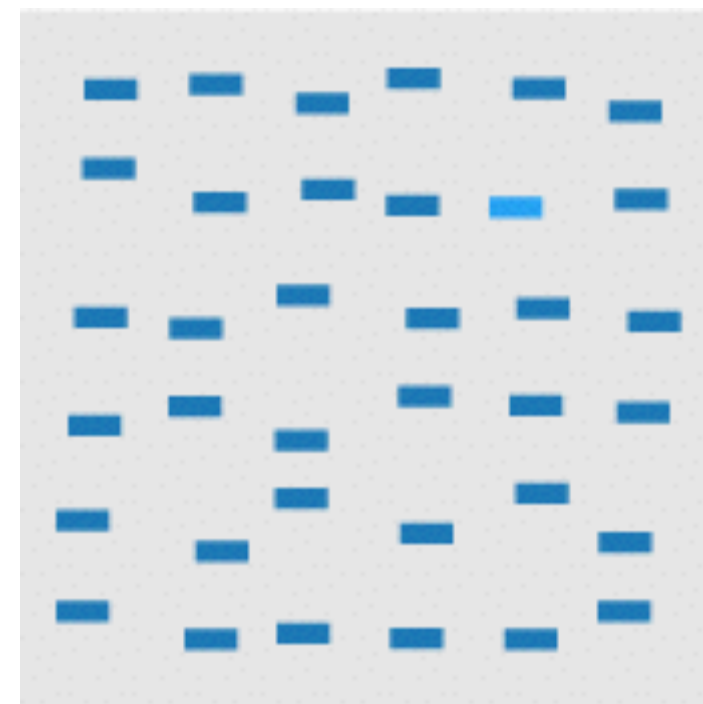
curvature



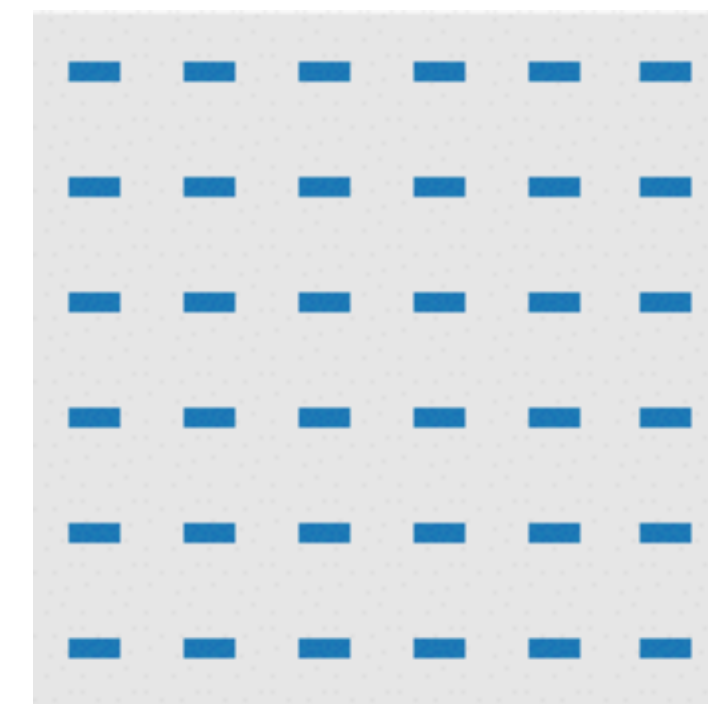
density



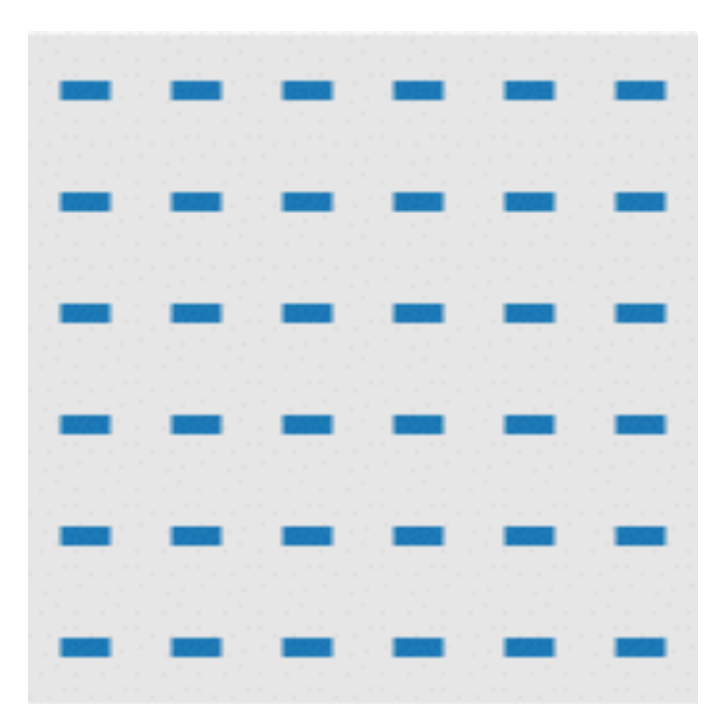
hue



hue



flicker



direction of motion

Tasks

target detection

detect the presence or absence of a target

boundary detection

detect a texture boundary between two groups of elements, where all of the elements in each group have a common visual property

region tracking

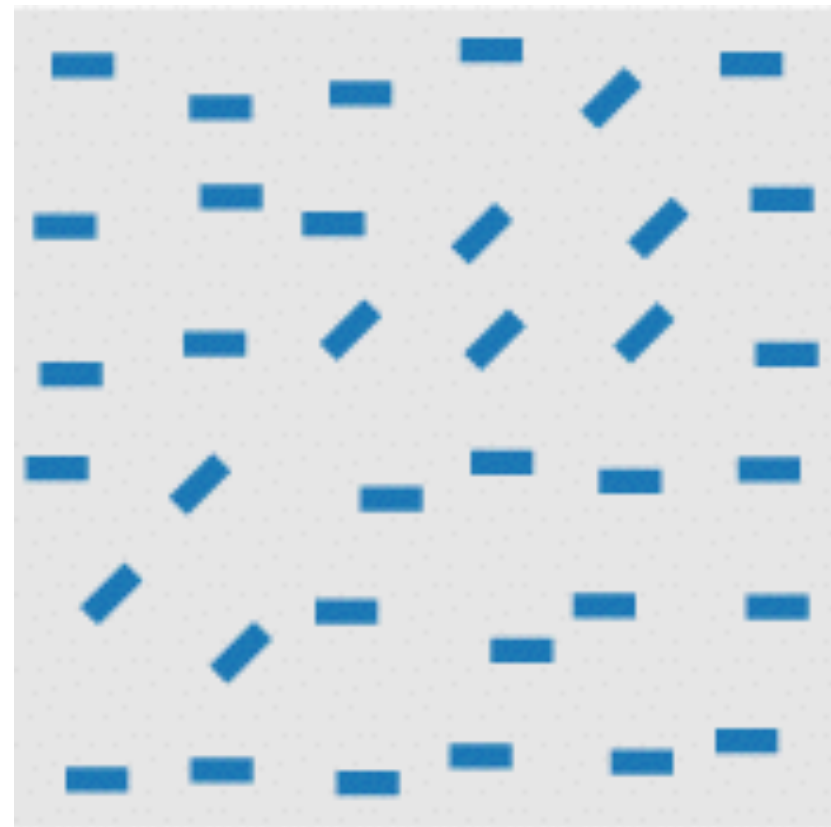
track one or more elements with a unique visual feature as they move in time and space

counting and estimation

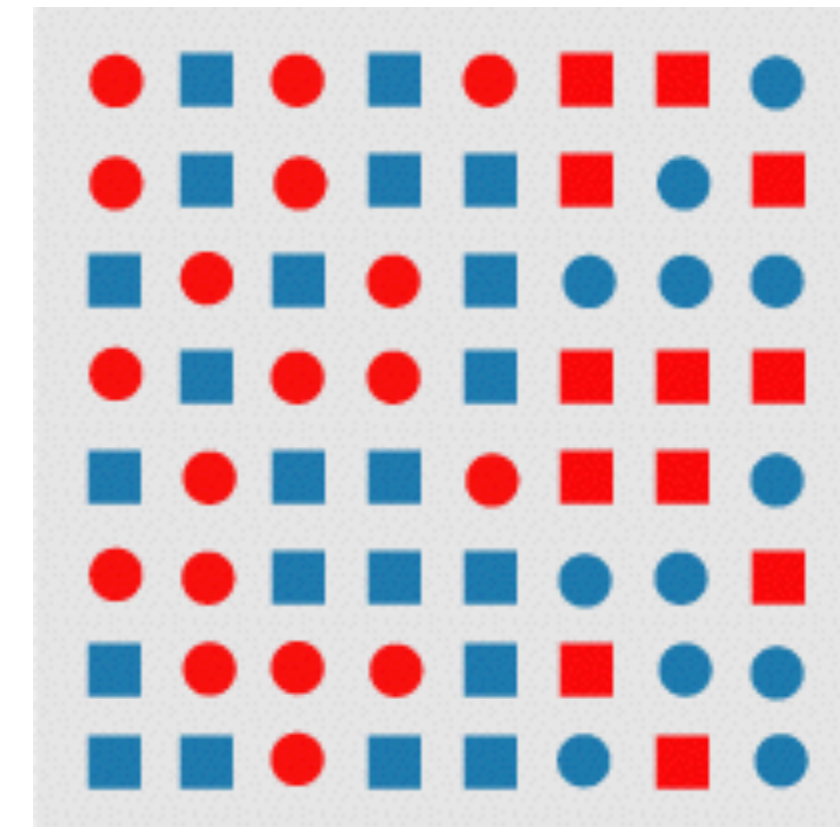
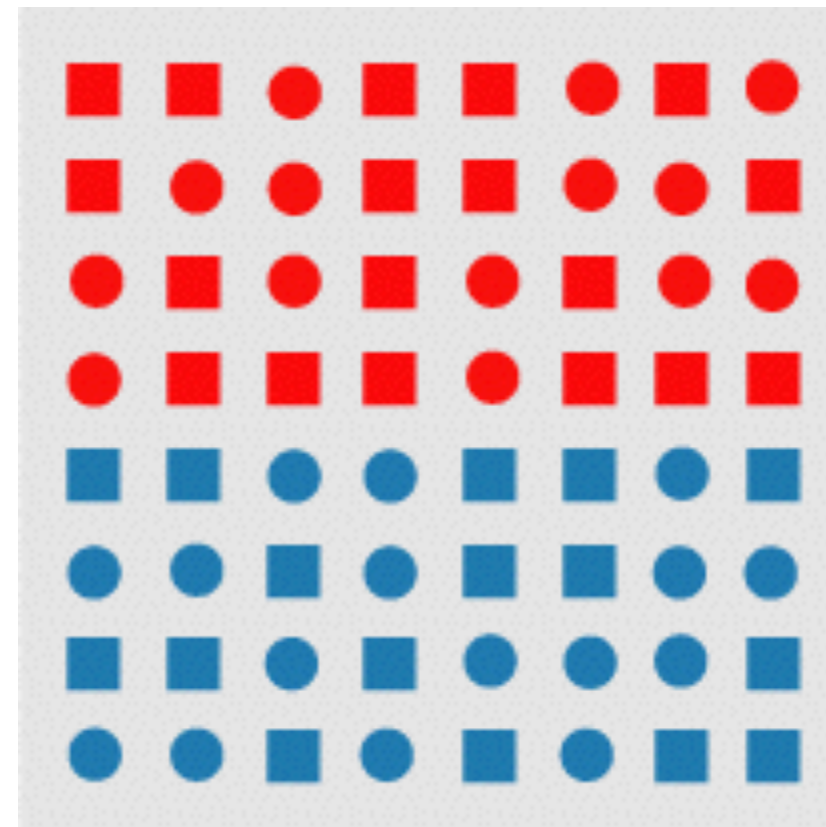
users count or estimate the number of elements with a unique visual feature.

Tasks

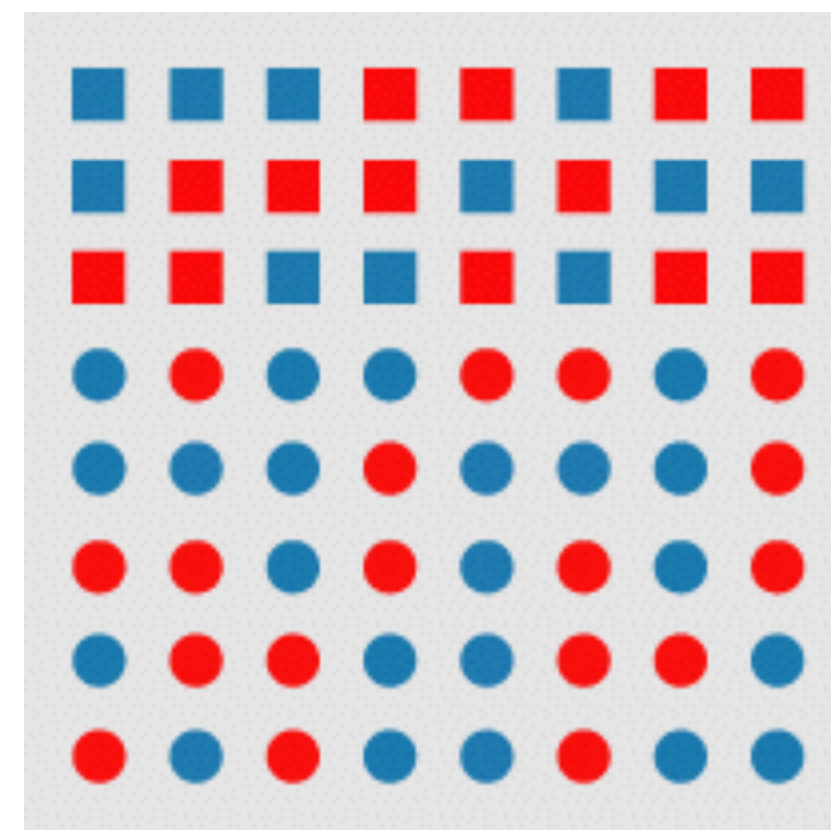
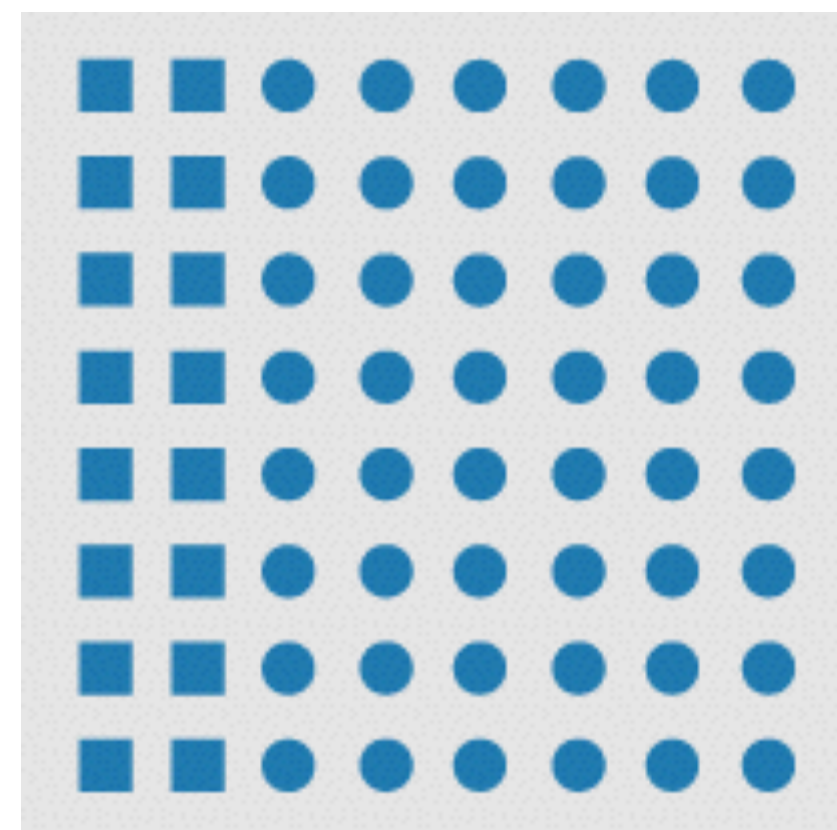
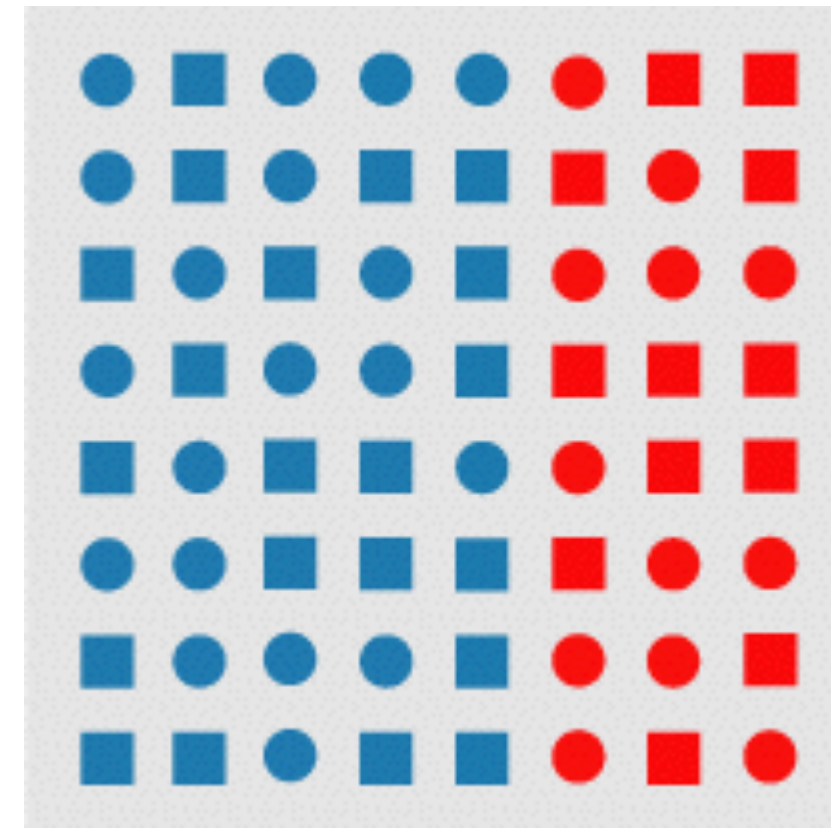
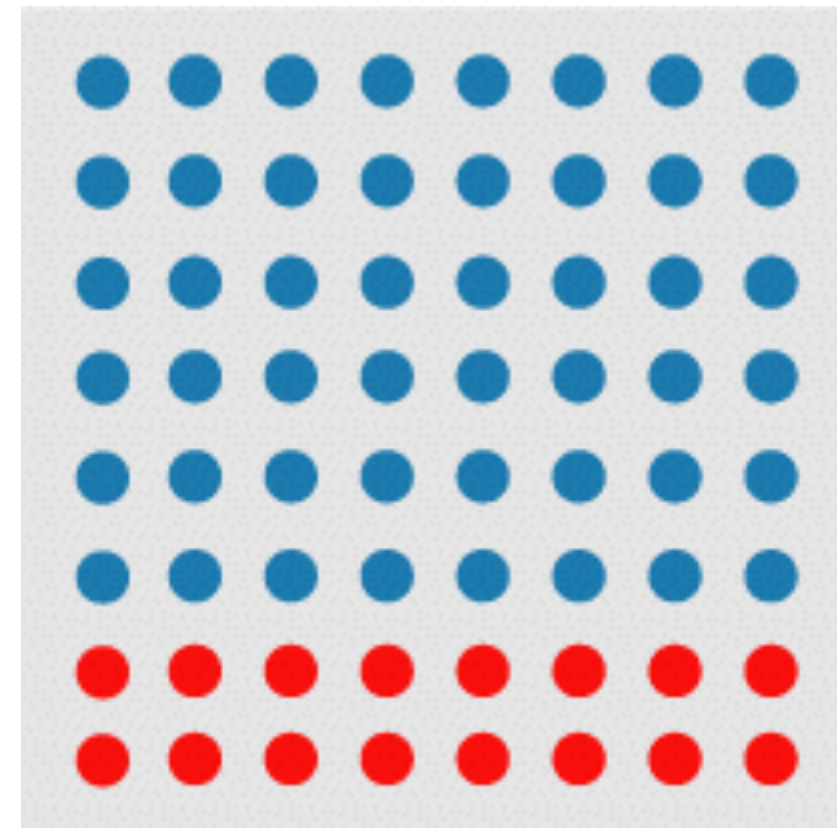
Number Estimation



Boundary Detection



Hierarchy of Preattentive Features



Examples online!

Theories of Preattentive Processing

Not known for sure how it works

Several theories:

<http://www.csc.ncsu.edu/faculty/healey/PP/index.html>

Preattentive Processing in Vis

Can be used to draw attention to areas of interest

Can be used to express similarity/group memberships

Visual features must be carefully designed

Conjunctions must be avoided

Examples are „Cues“ (Focus and Context technique)

Change Blindness

Change Blindness

Details of an image cannot be remembered across separate scenes

except in areas with focused attention

Interruption (e.g. a blink, eye saccade or blank screen) amplifies this effect

Not failure of vision system

failure due to inappropriate attentional guidance







Ron Rensink 2002





Change Blindness

Various theories about causes

Overwriting: Information that was not abstracted is lost

First Impression: Only initial view is abstracted

Nothing is Stored: Only abstract concepts are committed to memory

Everything is Stored, Nothing is Compared: We compare only when we are forced to

Feature Combination: scenes are combined as long as they make sense

Influencing factors

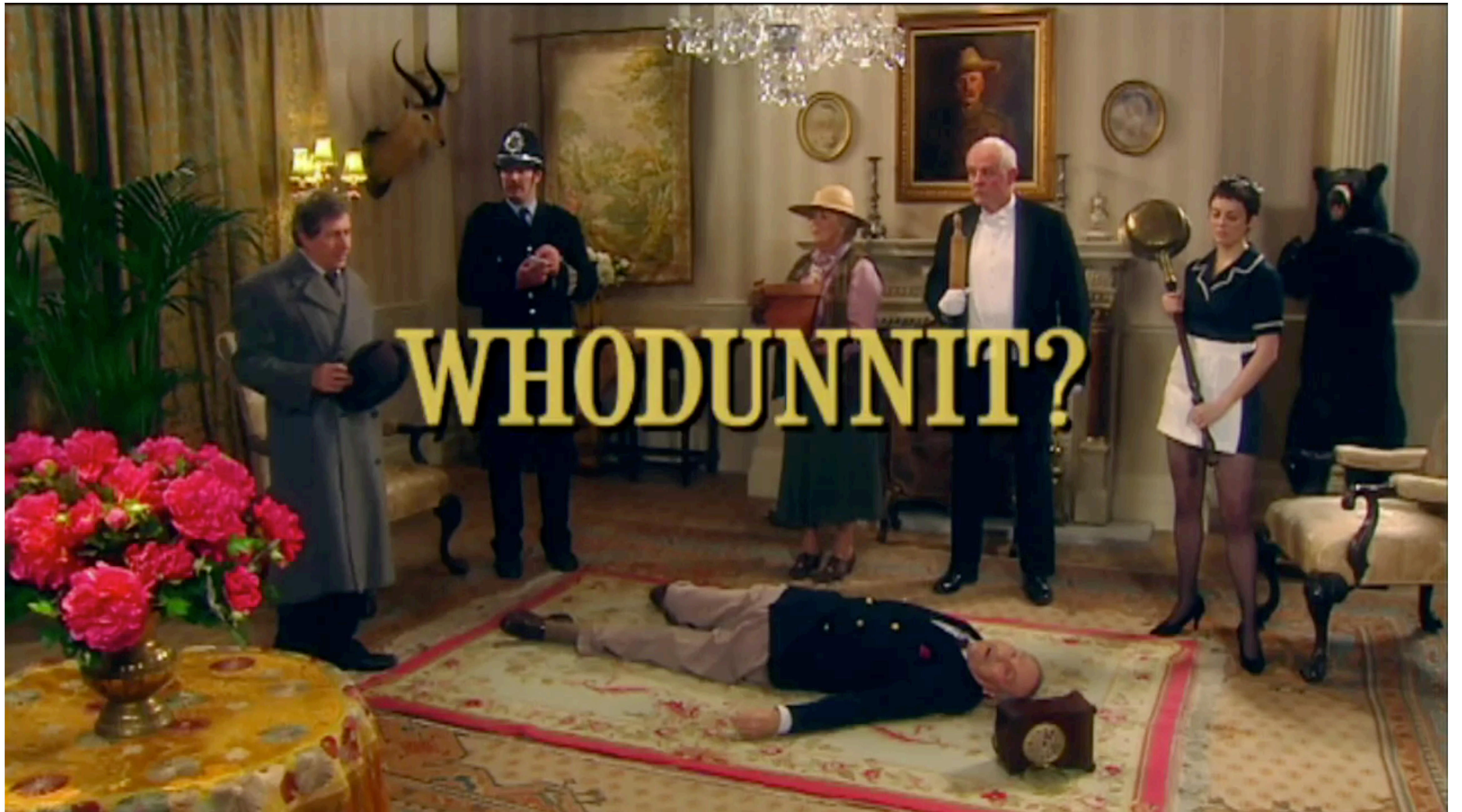
attention

expectation (knowing something will change)

semantic importance of changed object

low level object properties overlooked more easily

Attention Blindness



Transport for London

Other Videos

Take Home Points

To find meaning in what we see **we must selectively pay attention** to what is important

Low-level vision is driven by object features rather than a conscious effort where to look (e.g., pre-attentive processing)

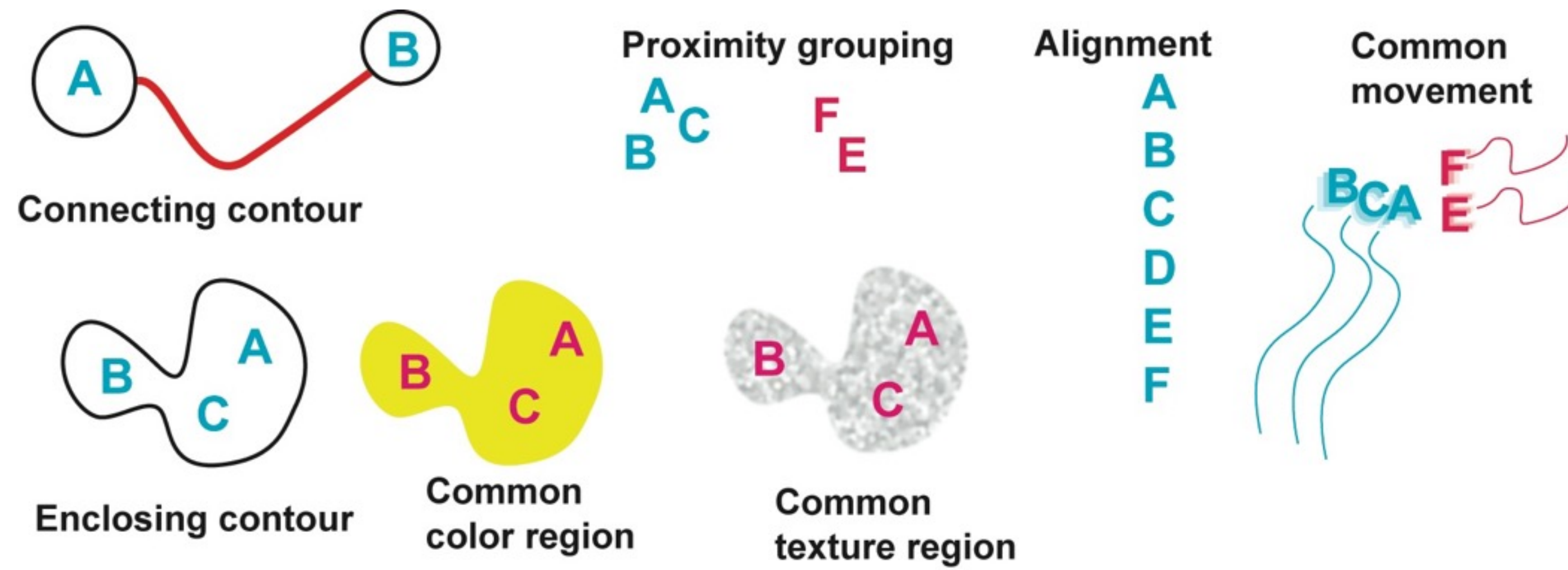
Attention is driven by preexisting knowledge, expectations, and goals stored in long-term memory

Gestalt Principles

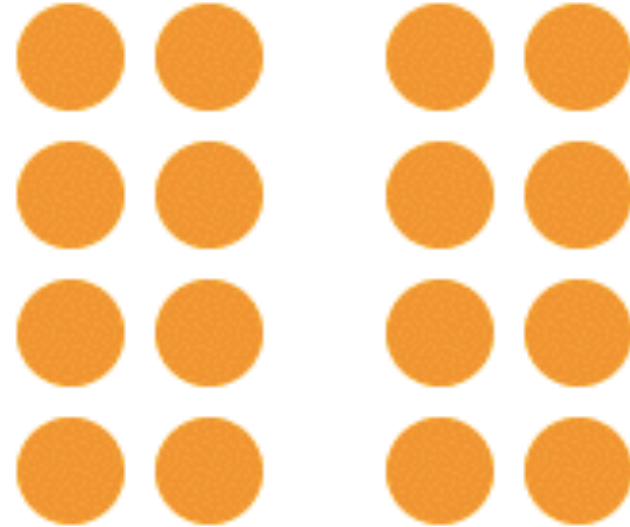
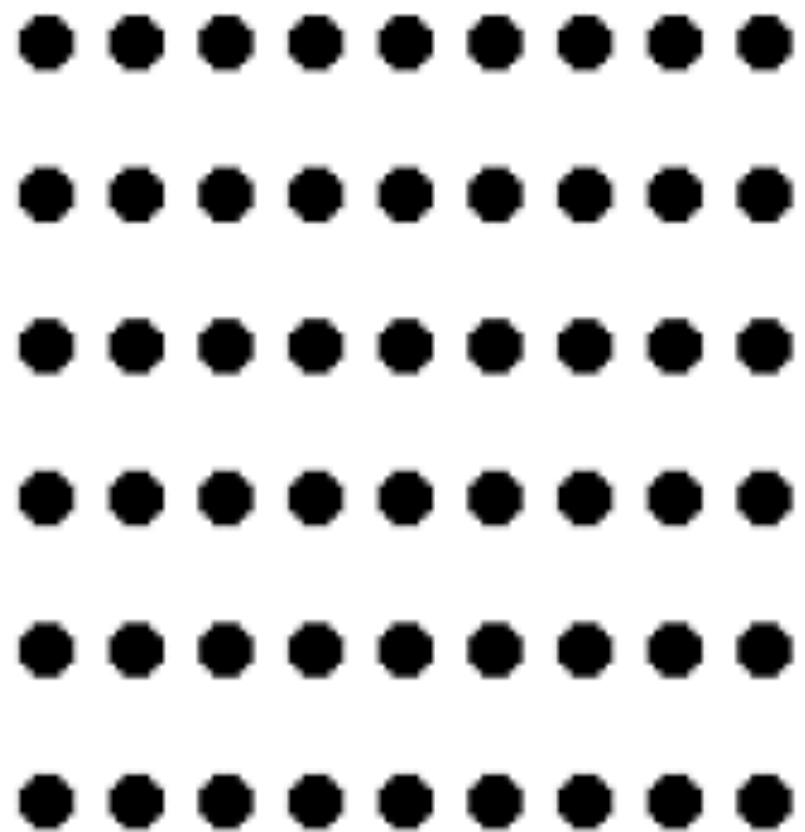
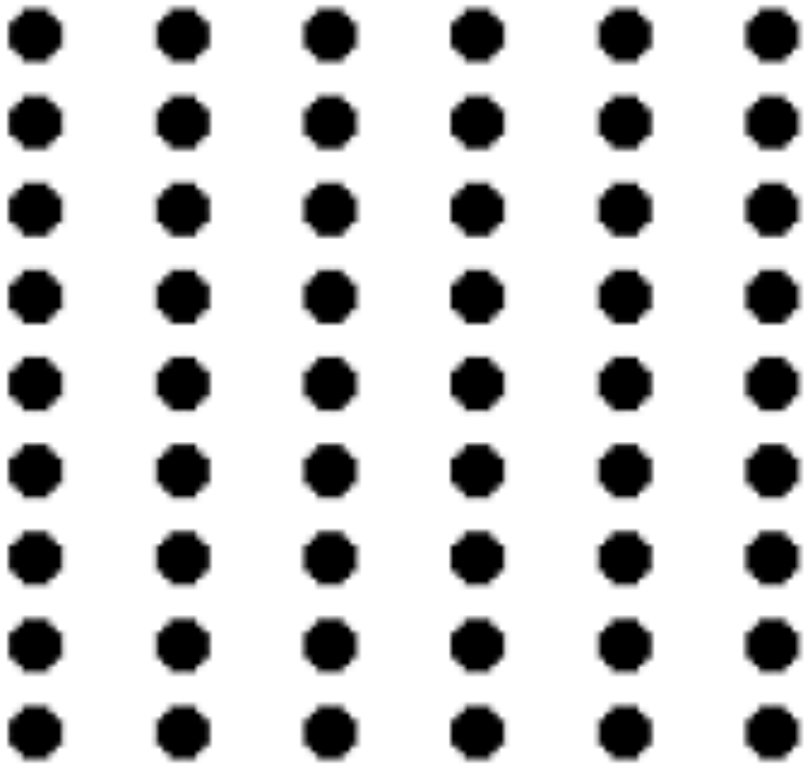
Wertheimer, 1923, and recent extensions

Gestalt Principles

Patterns that transcend the visual stimuli that produced them

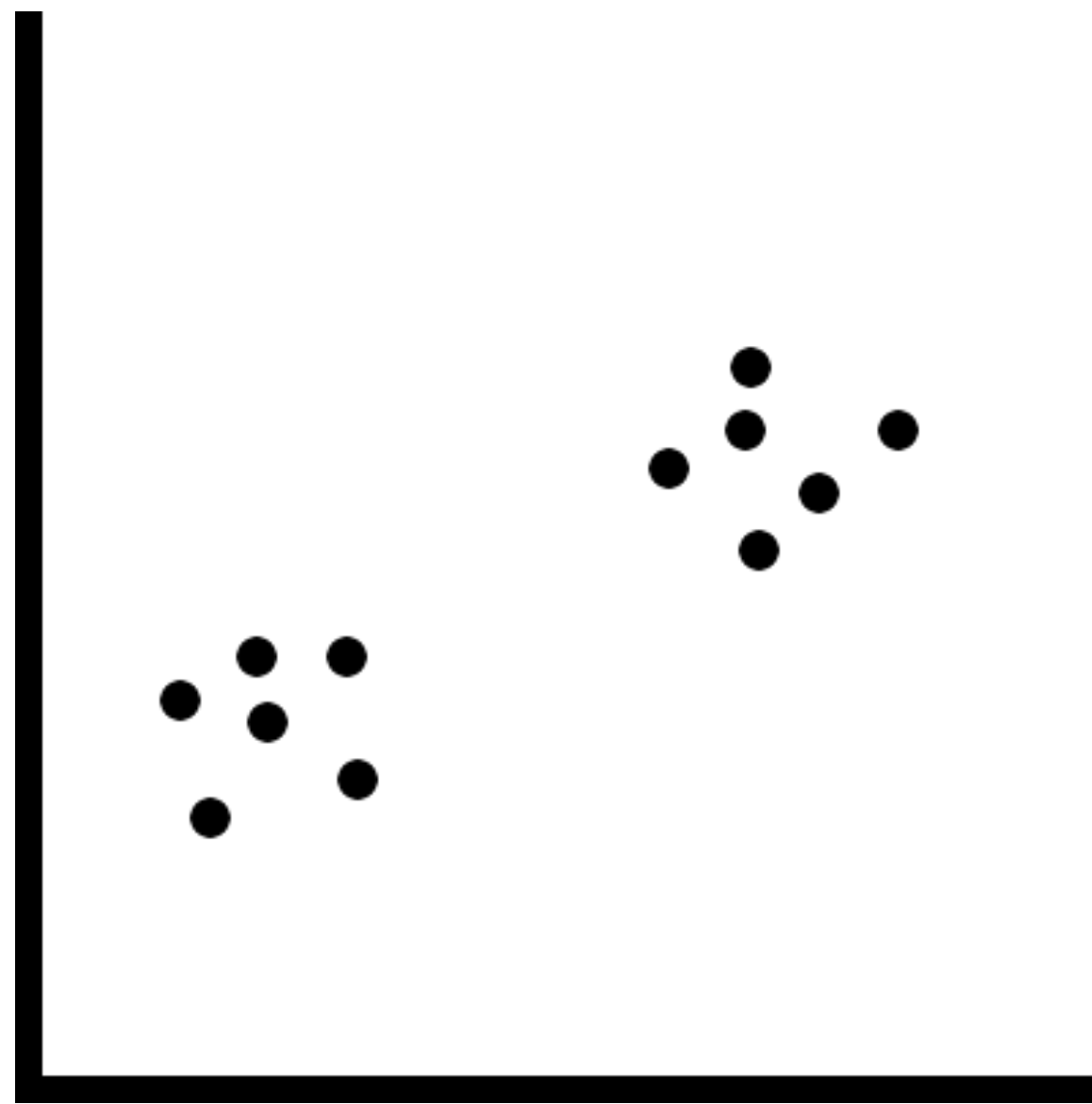


Proximity

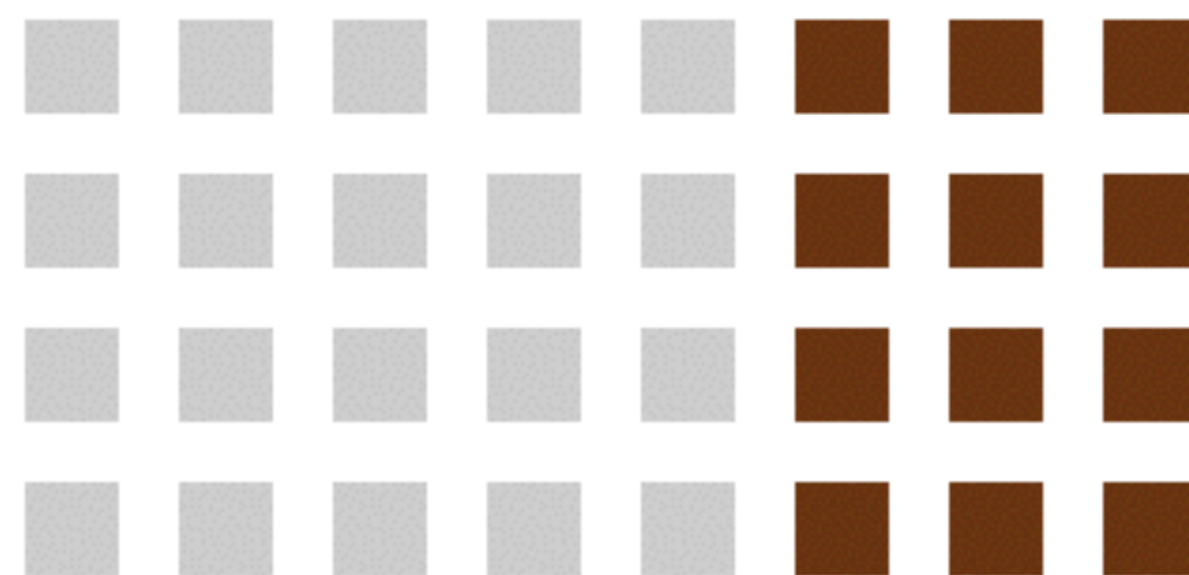
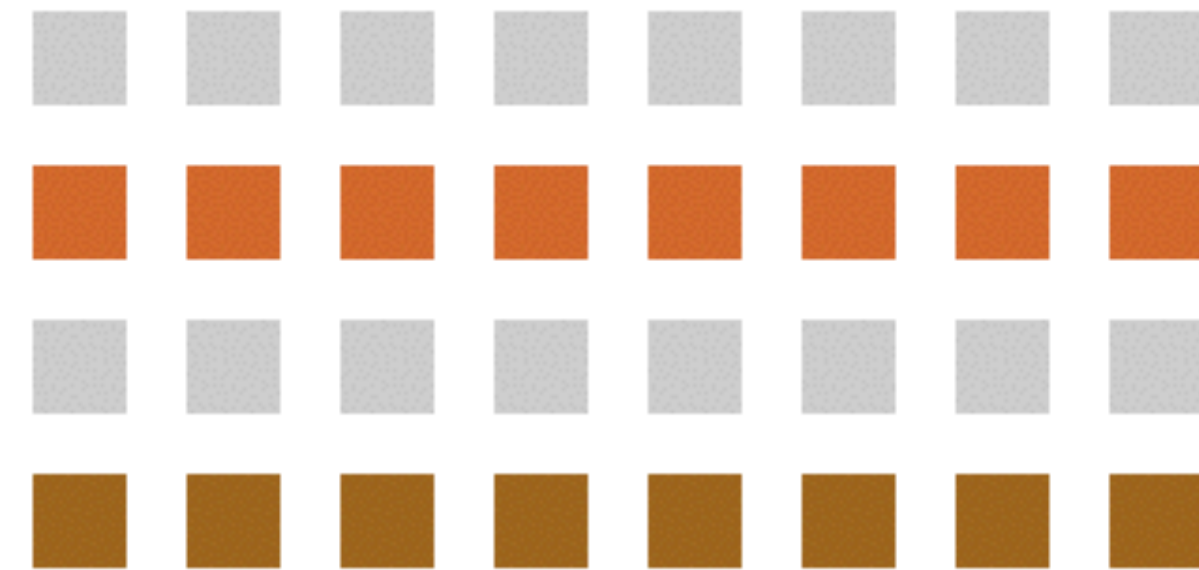


Proximity

Grouping/linking by placing entities in close proximity



Similarity

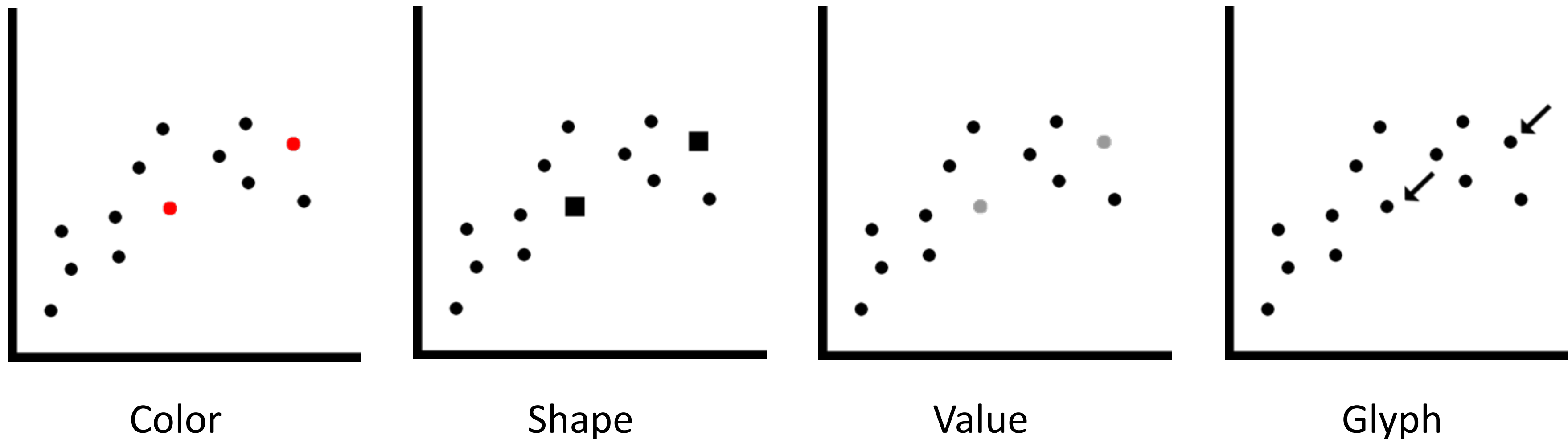


Similarity

Co-modulation of a **channel**

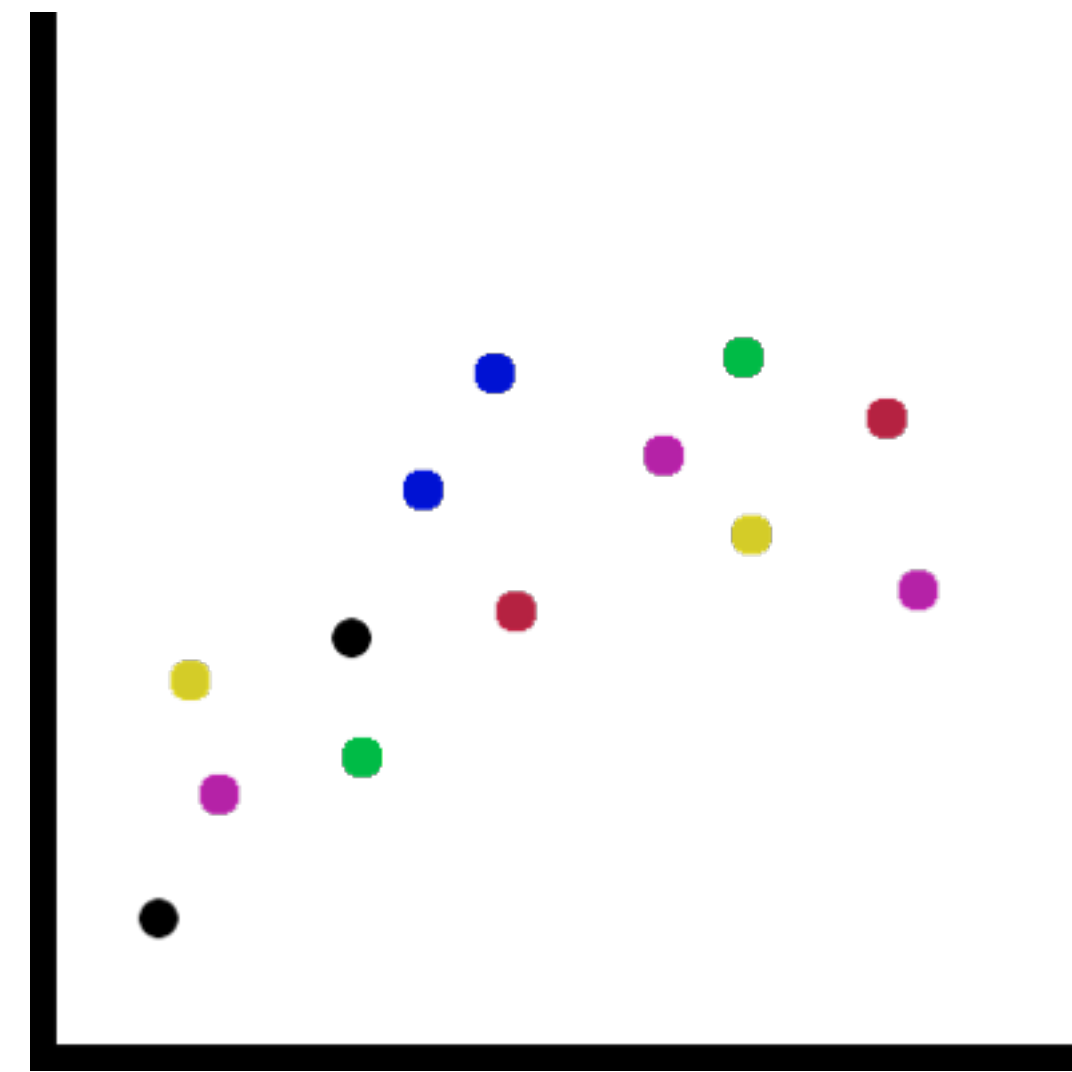
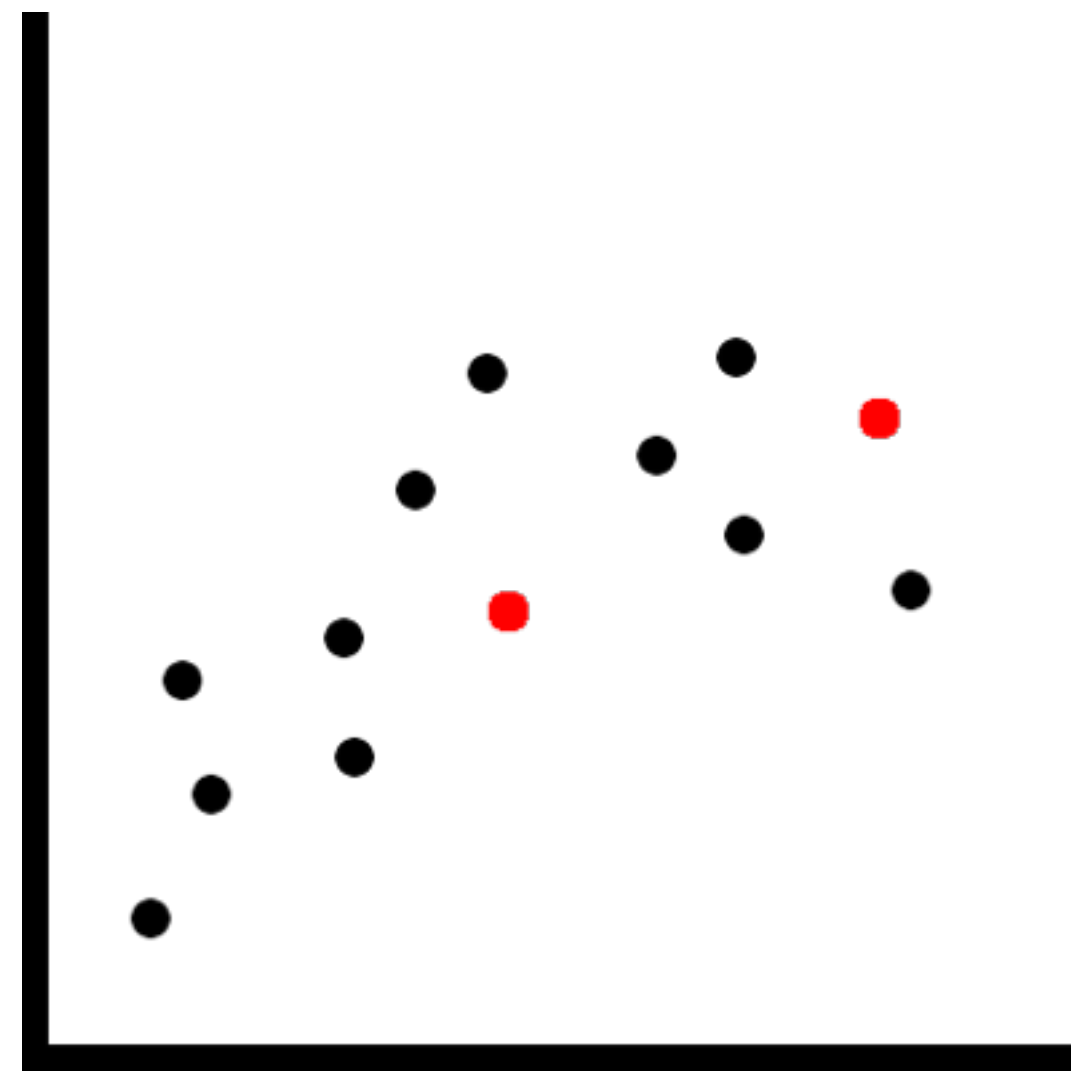
color, shape, size, value, orientation, texture, ...

Adding a glyph, label, frame, background



Color – Perception Issues (1/2)

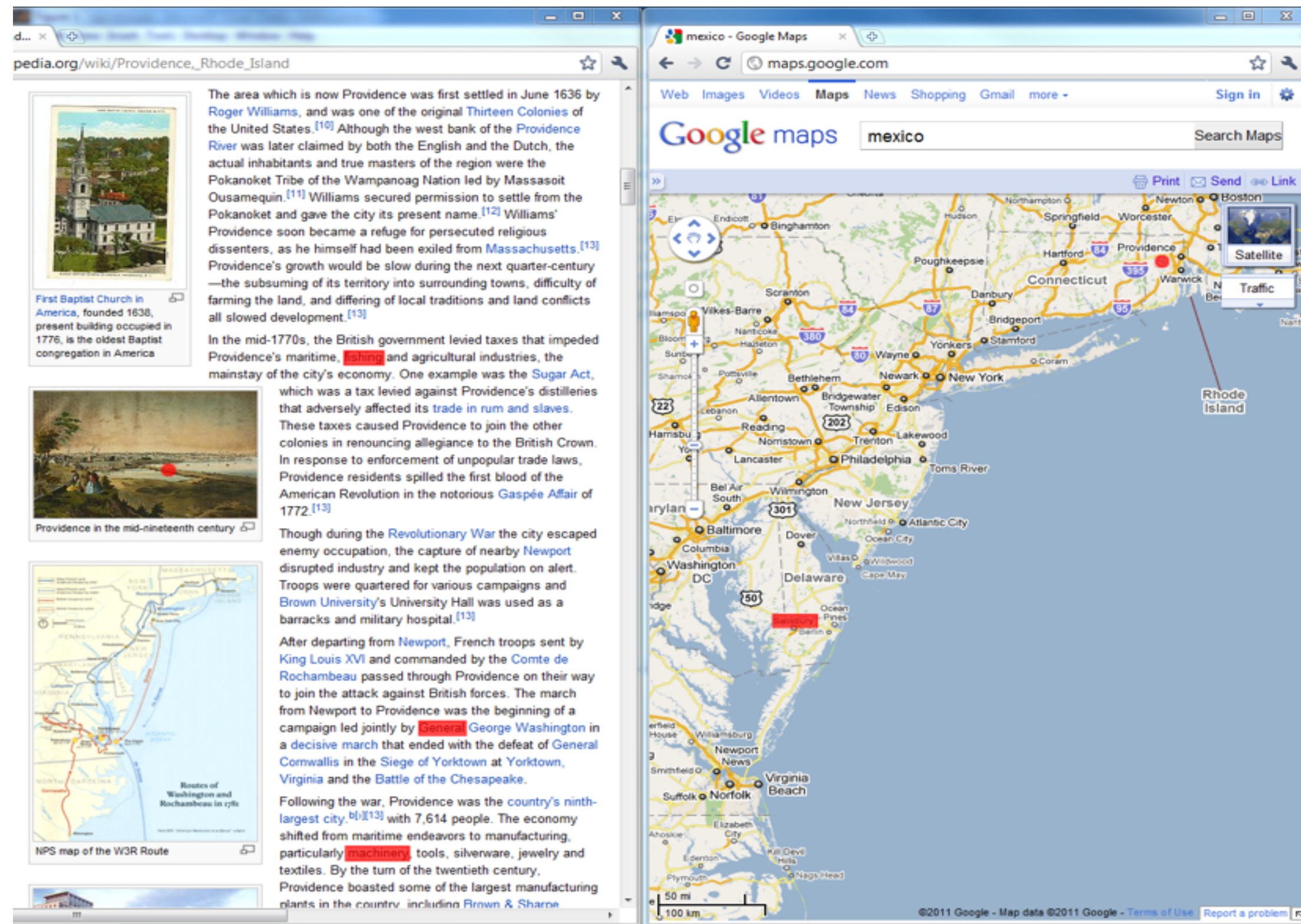
Preattentive properties: Very good for 1-2 simultaneous,
serial search for more



Color - Perception Issues (2/2)

Slower in a cluttered environment

Size of colored object relevant.



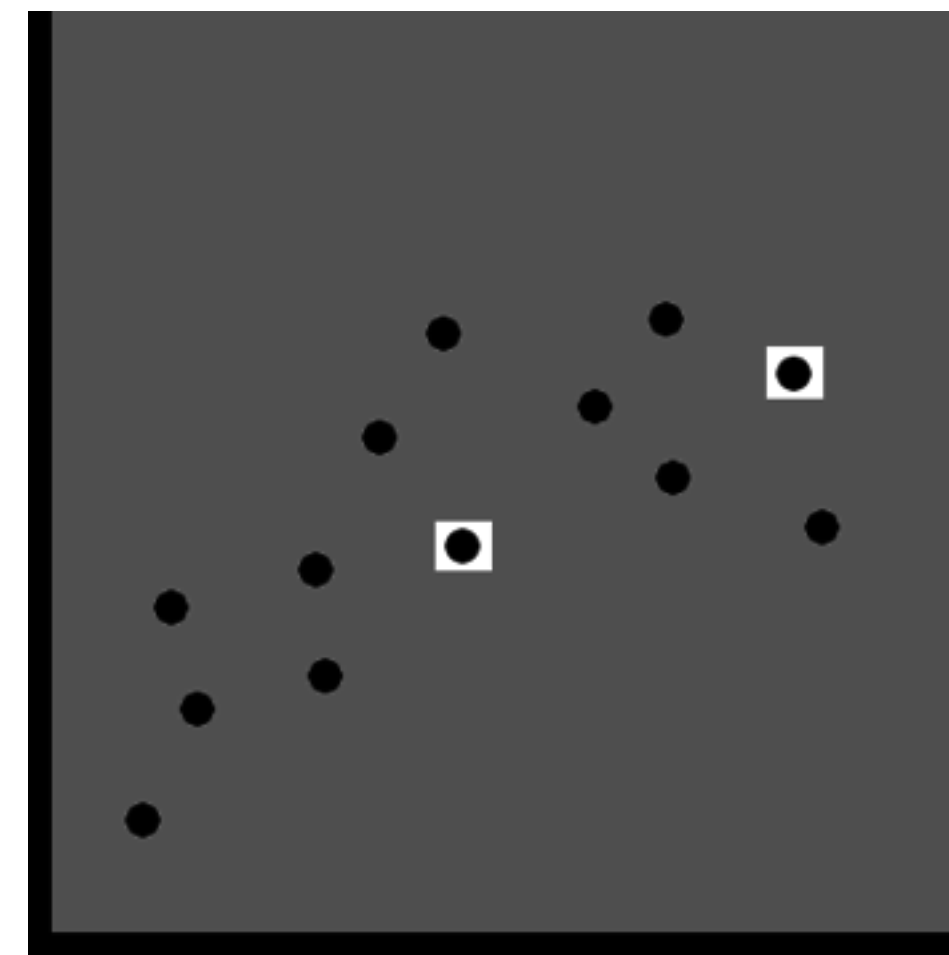
Similarity

Modulate everything else

Blurring, darkening, desaturating, etc.



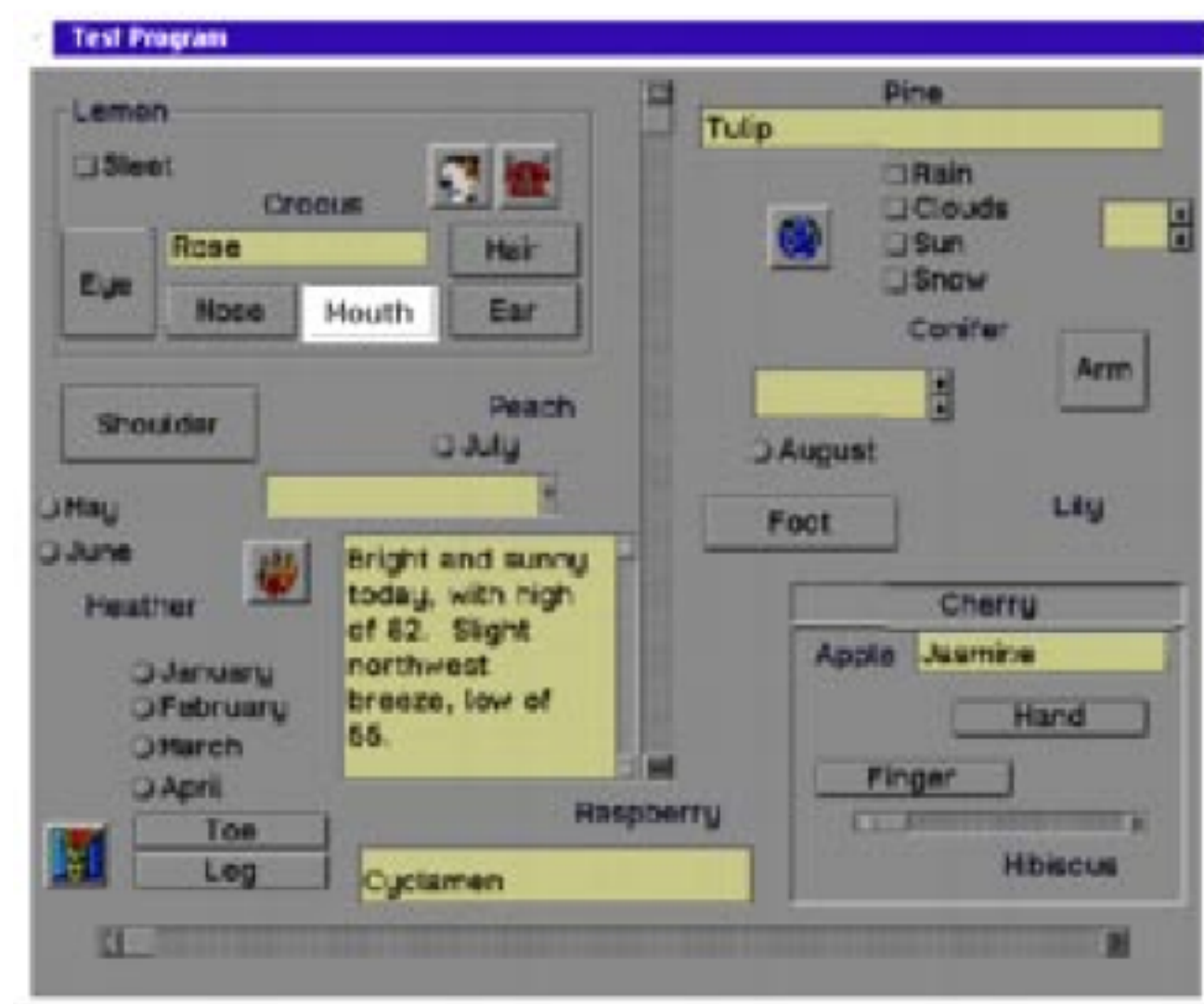
Blur



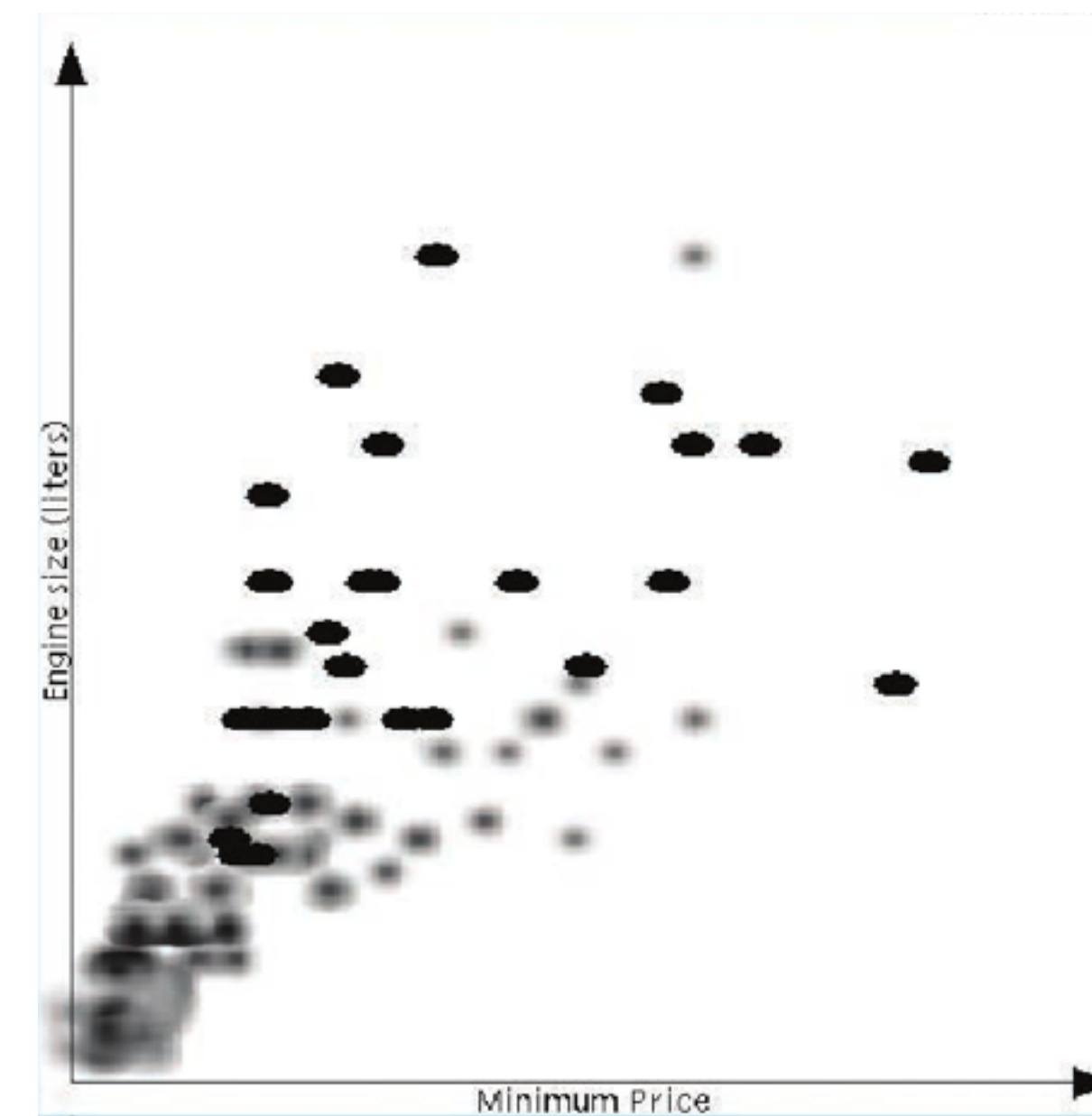
Darkening

Modulating Everything Else: Recommendation, Example

Don't use unless the sole objective is to guide attention toward one (set of) items

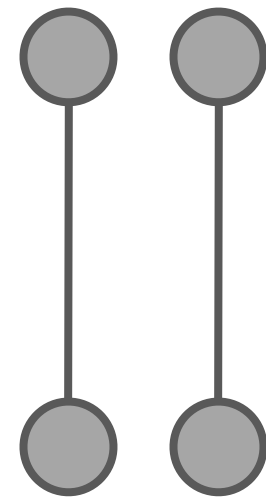


[Zhai et al., 1997]

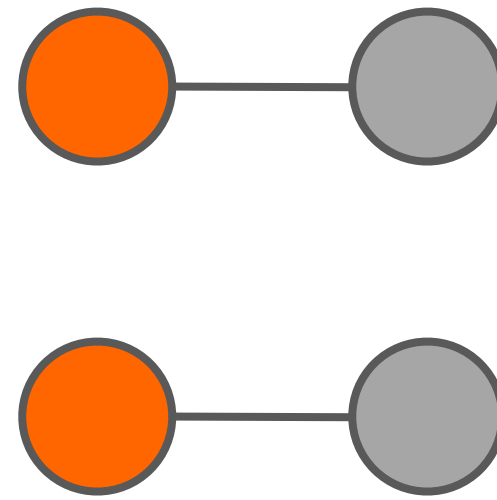


[Kosara et al., 2002]

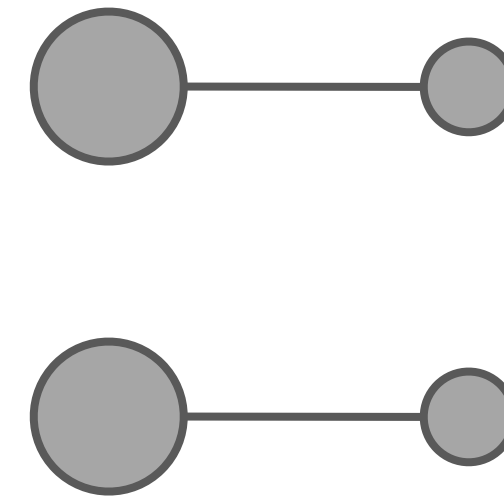
A Little Experiment...



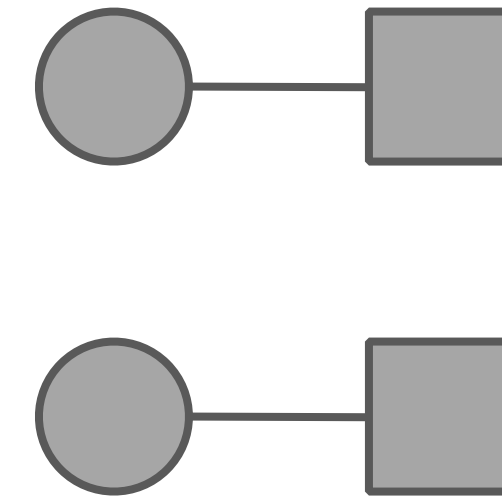
Proximity



Color



Size

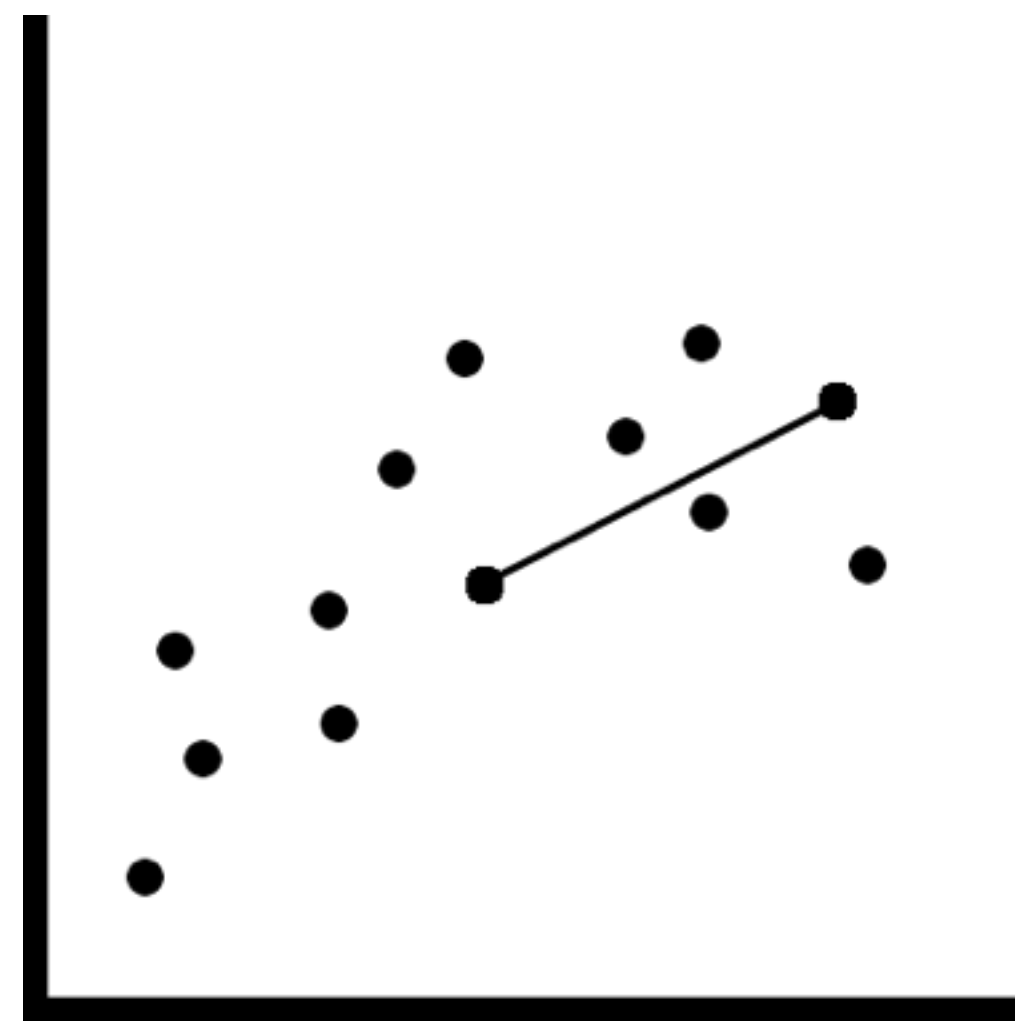


Shape

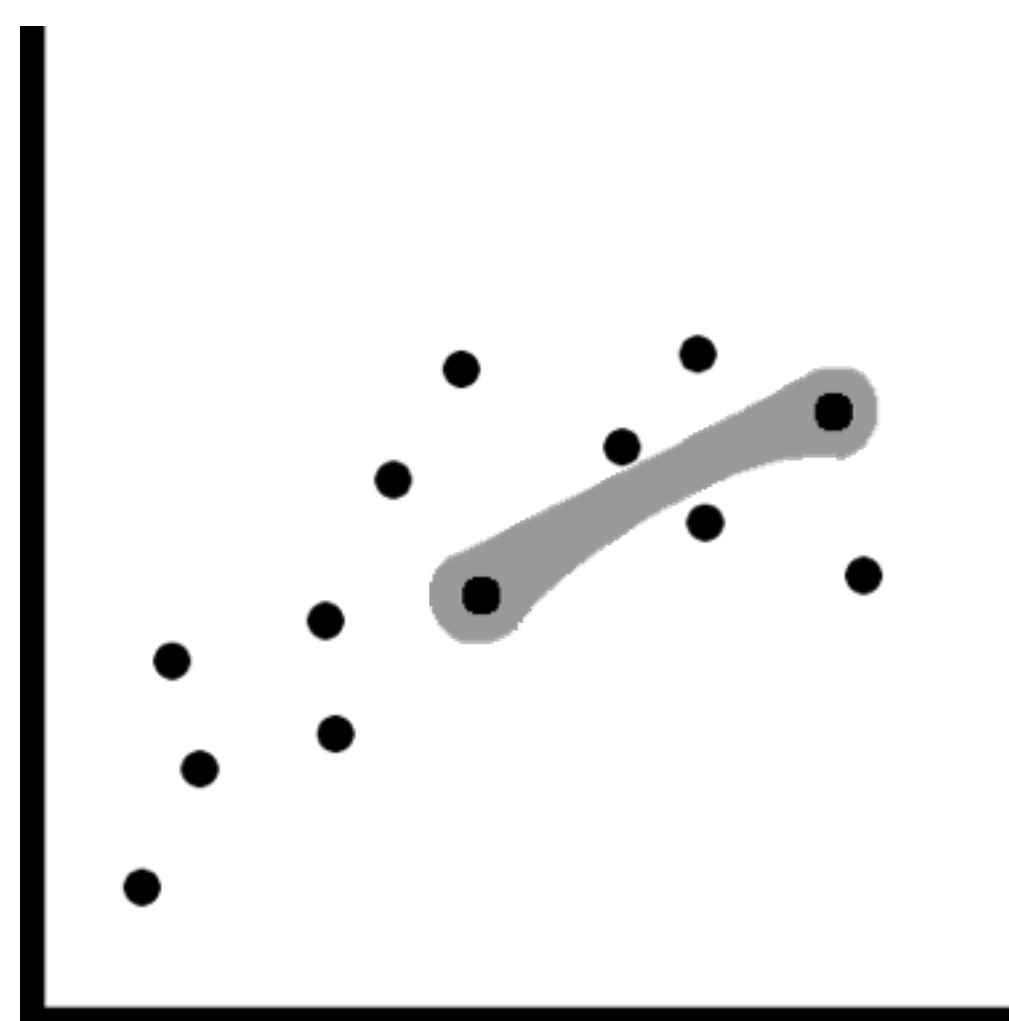
Connectedness and Common Region

Connected items with a line or curve

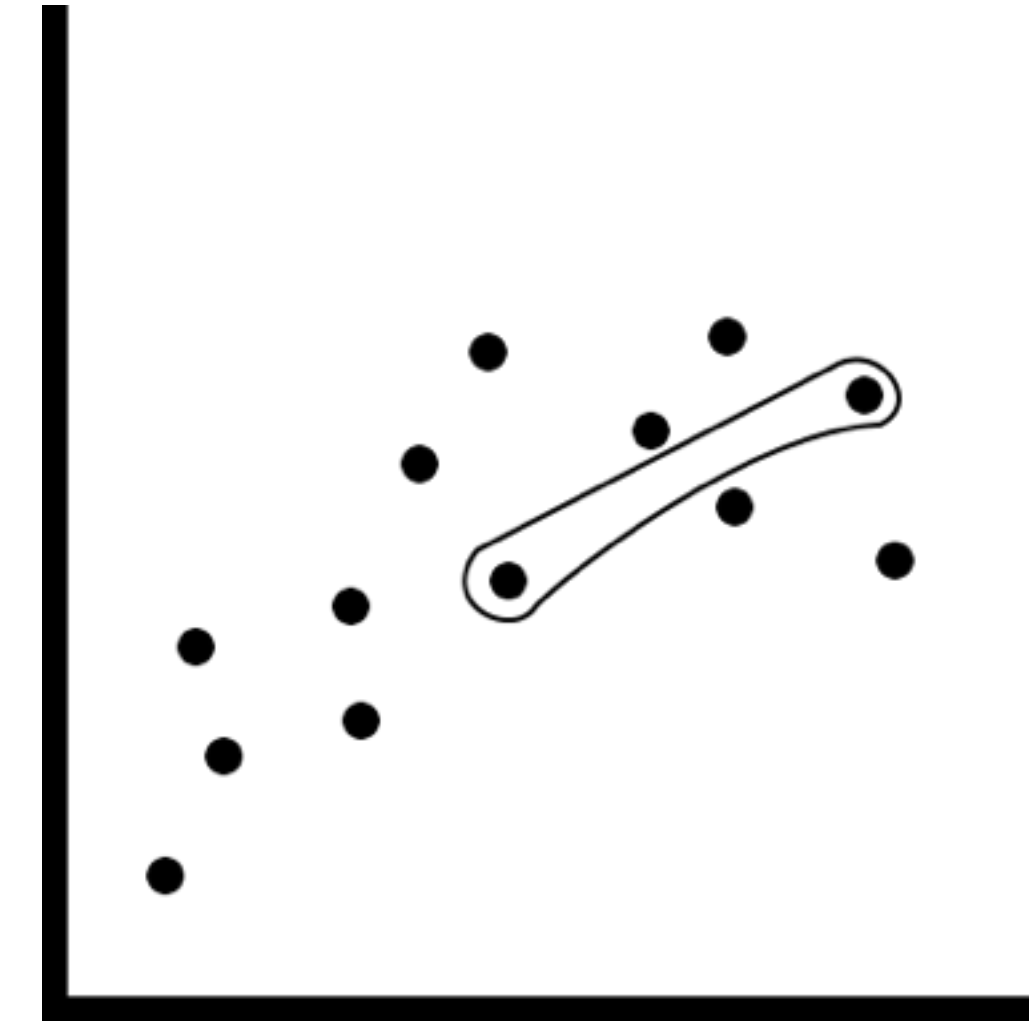
Surround items with a outline, surface, volume



Connectedness



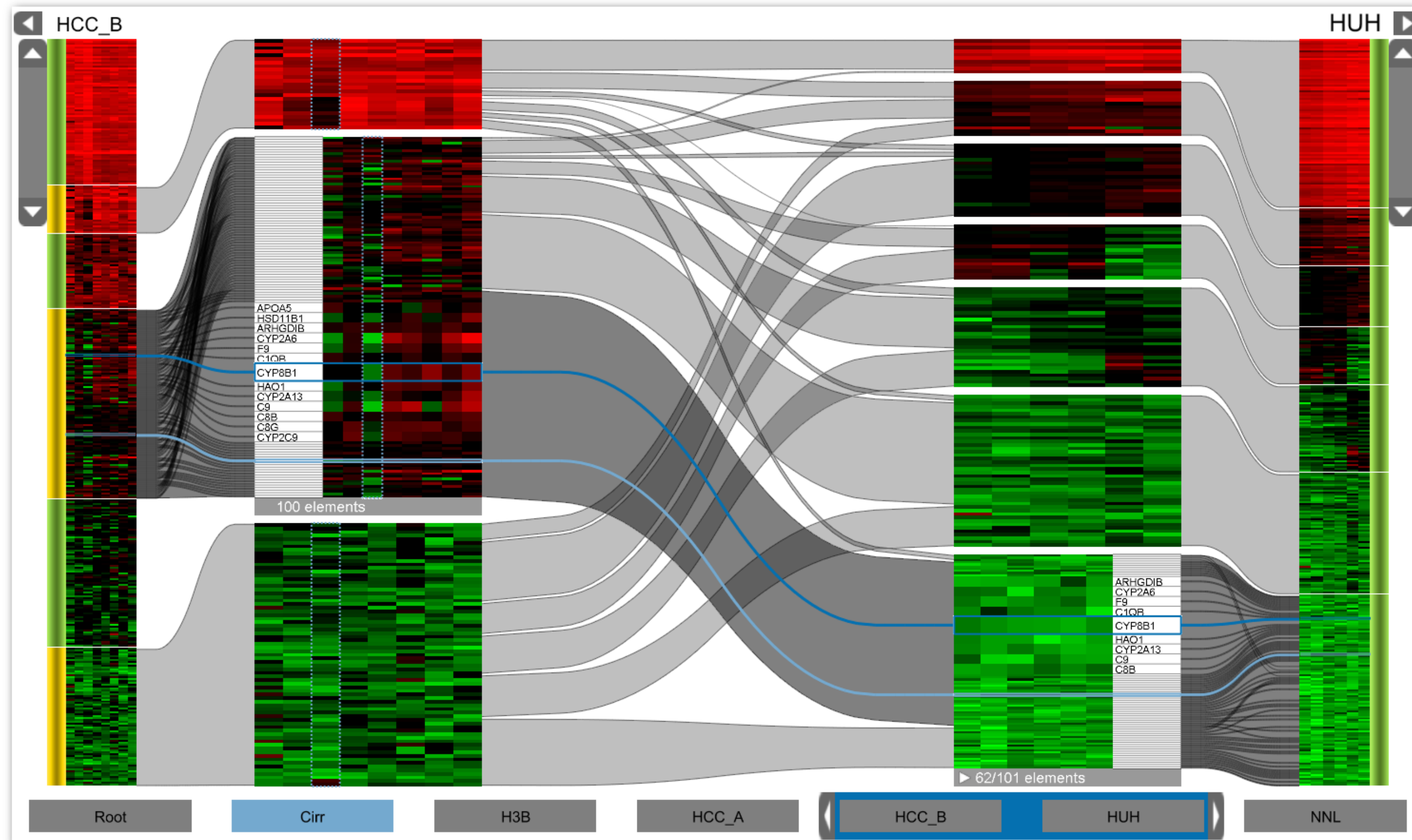
Surface



Outline

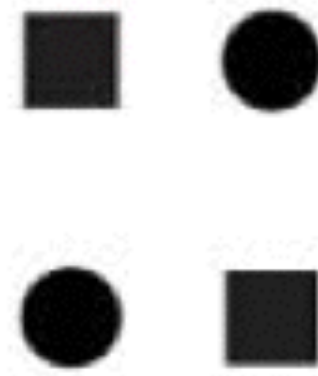
Common Region

Connection

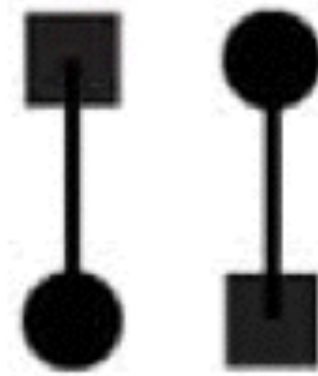


Enclosure

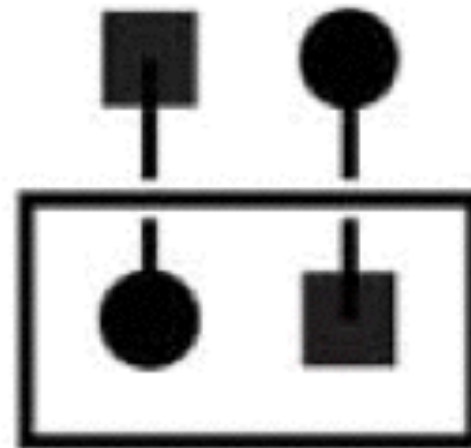
Similarity



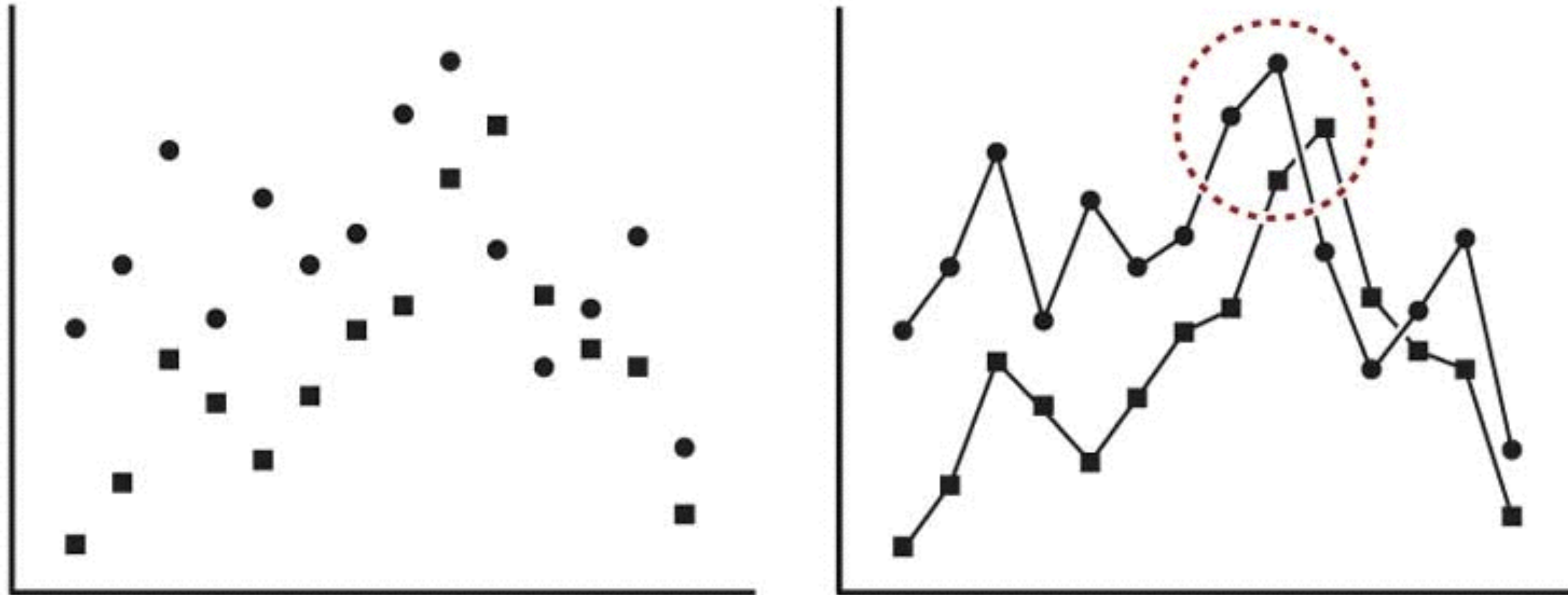
Connection



Enclosure



Enclosure



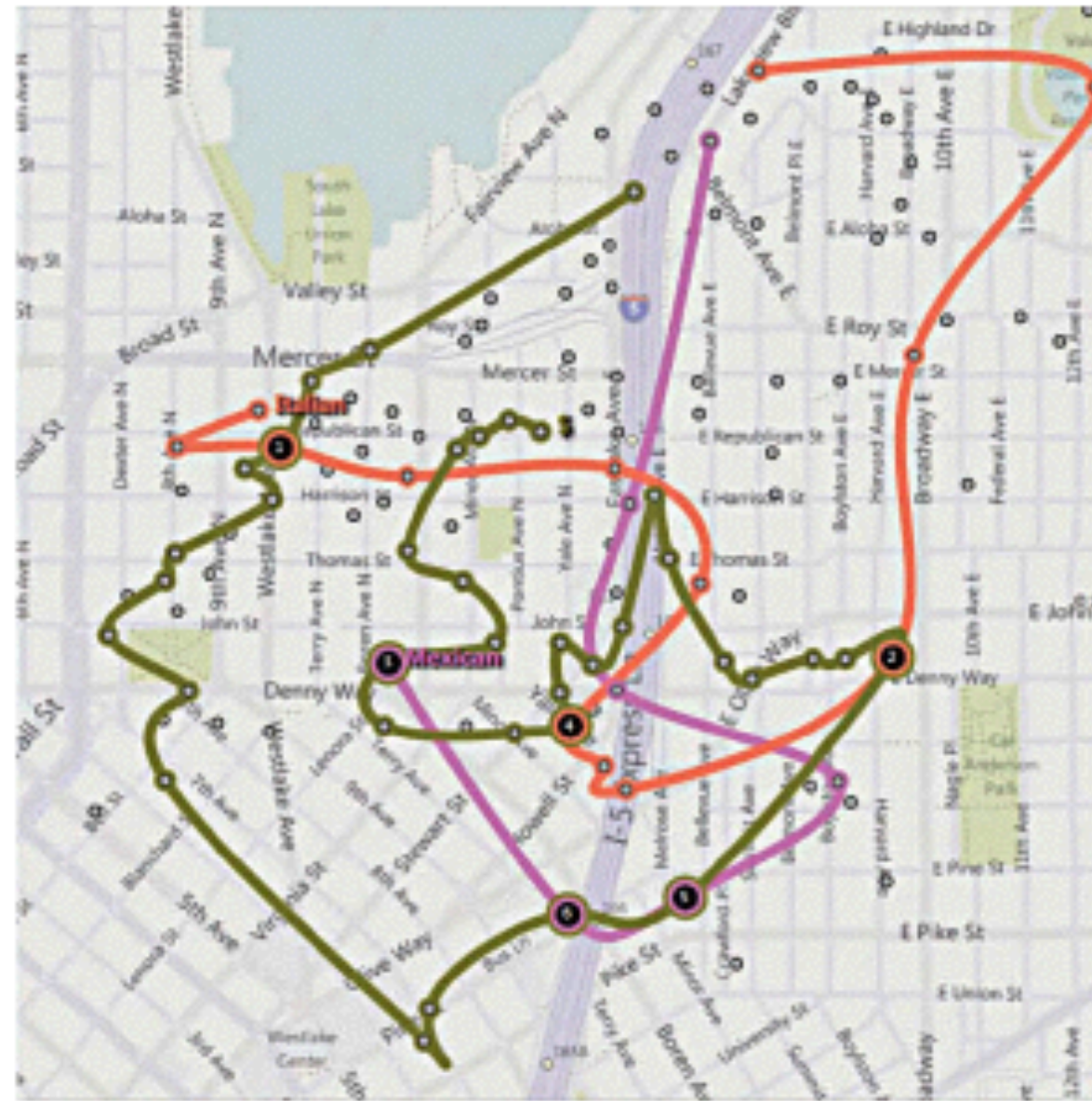
Connectedness Varieties

Bubble Sets



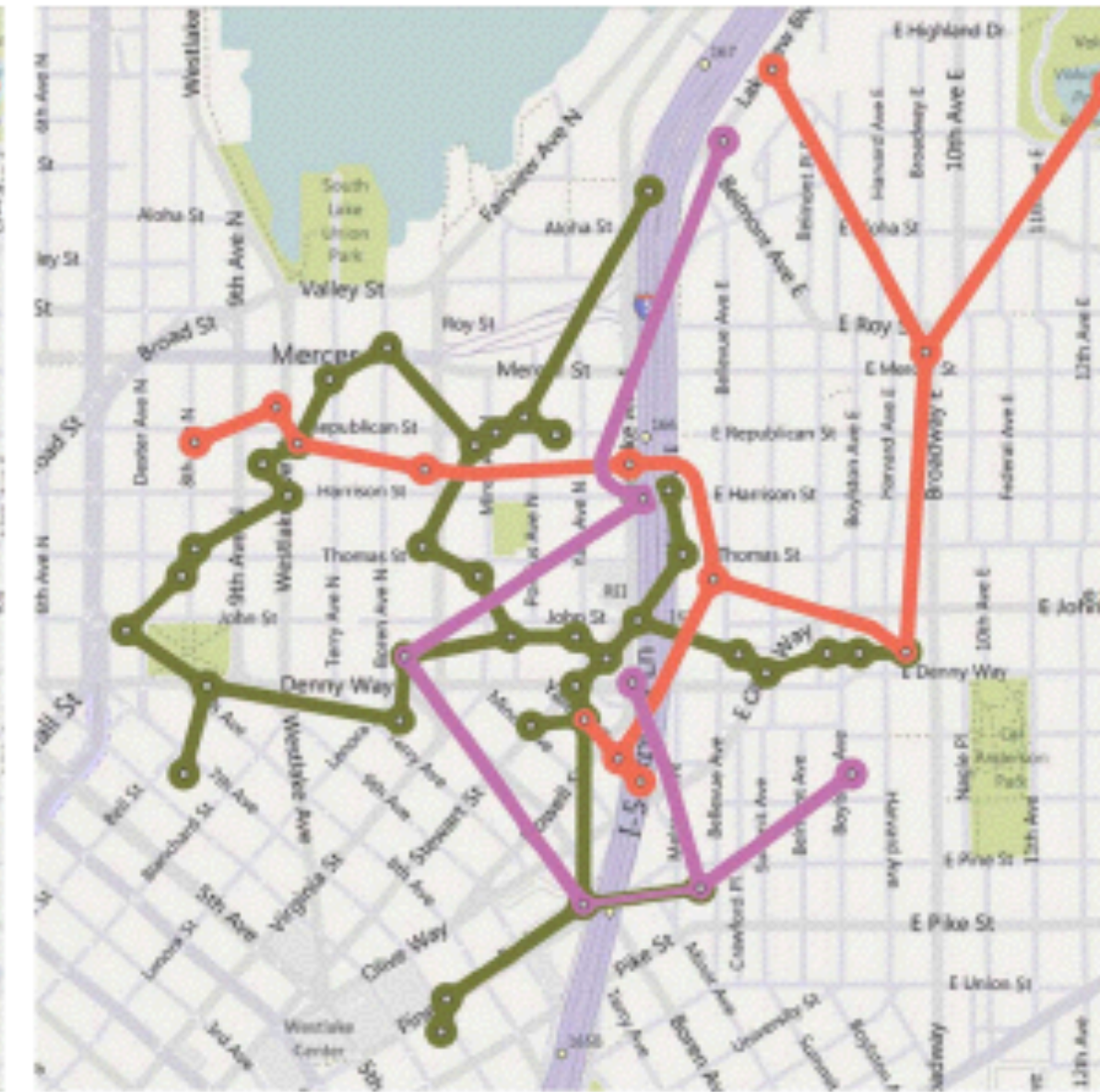
Image by [Dinkla et al., 2011]
Technique by [Collins et al., 2009]

Line Sets



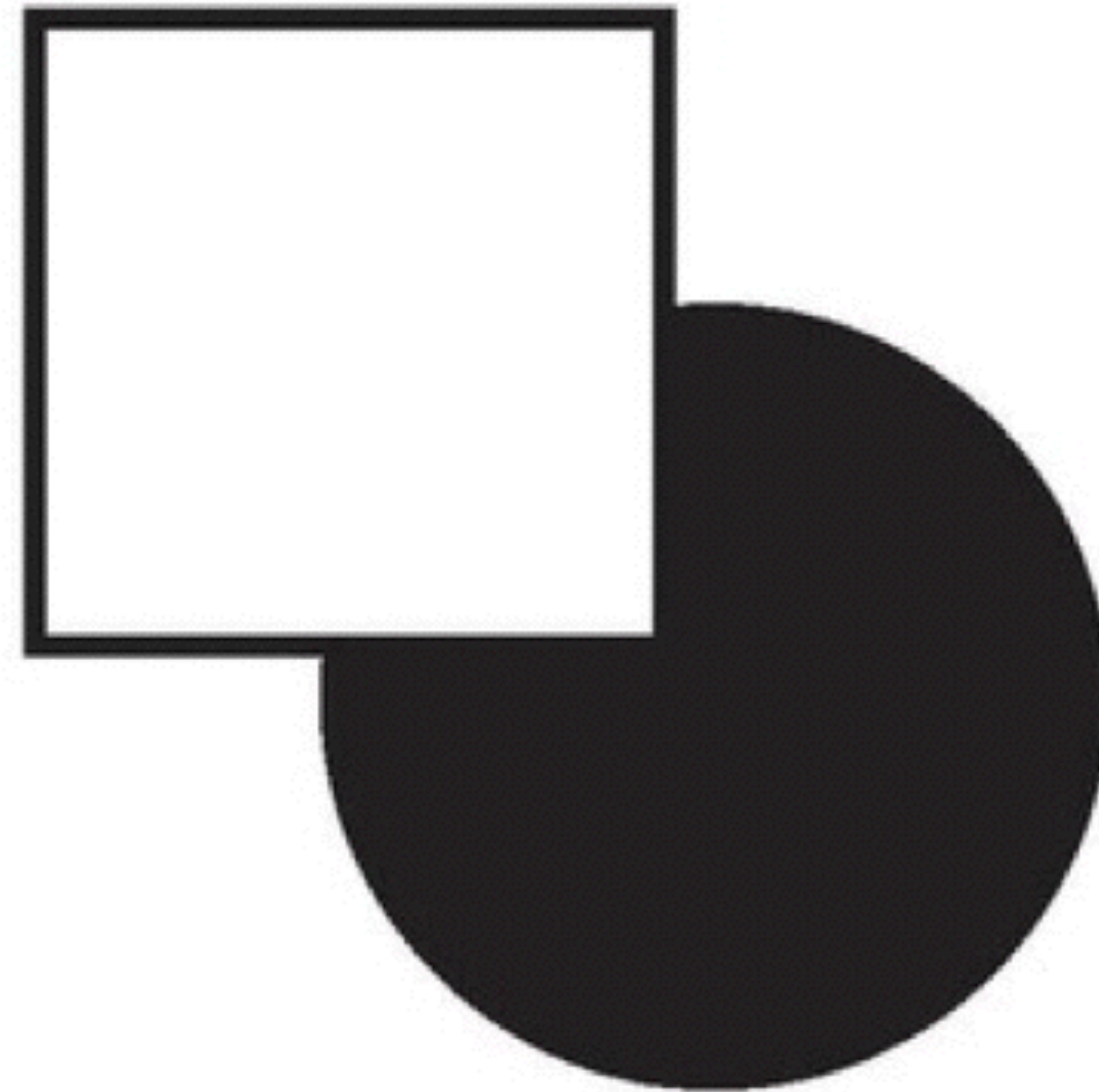
[Alper et al., 2011]

Kelp Diagrams

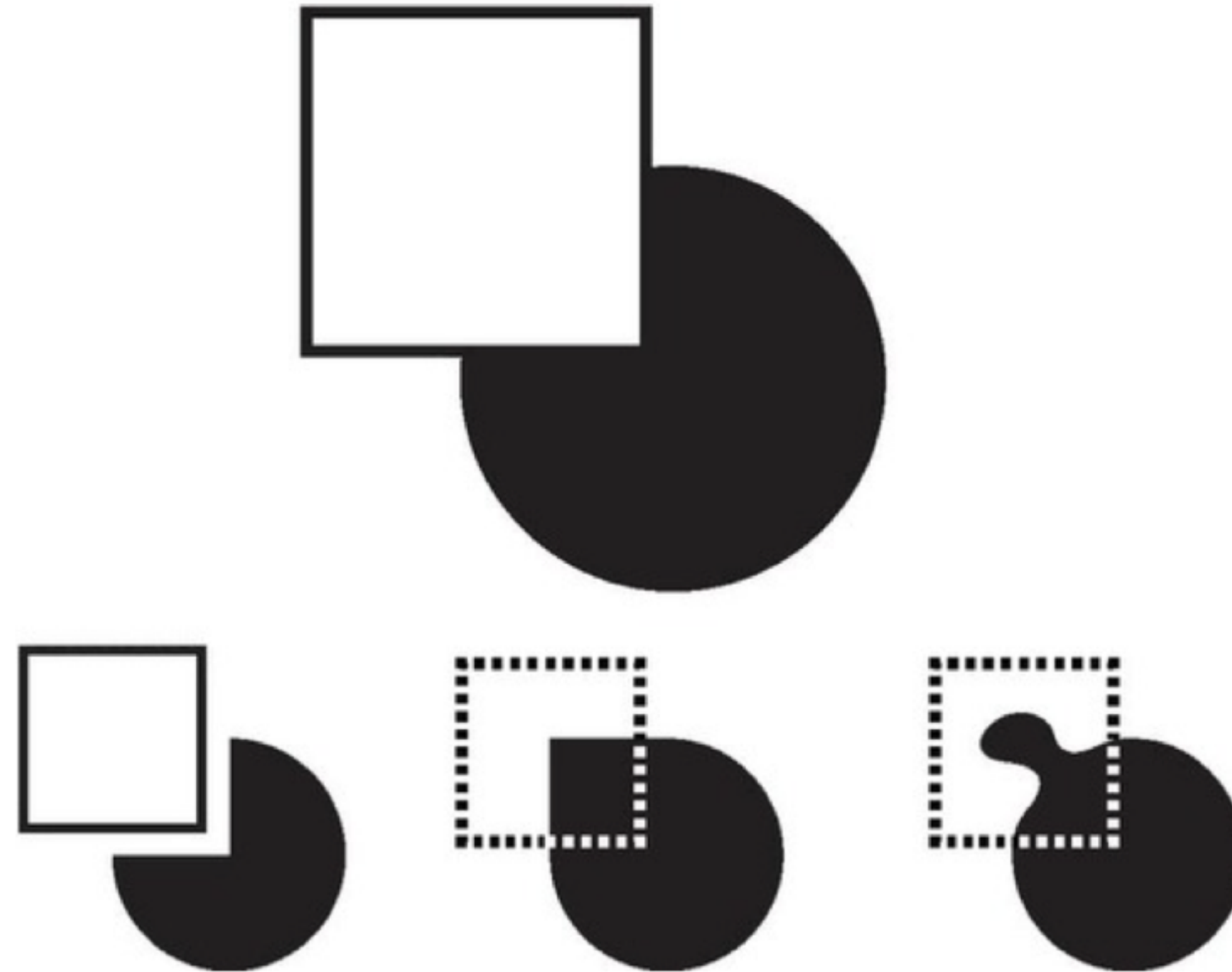


[Dinkla et al., 2012]

Continuity

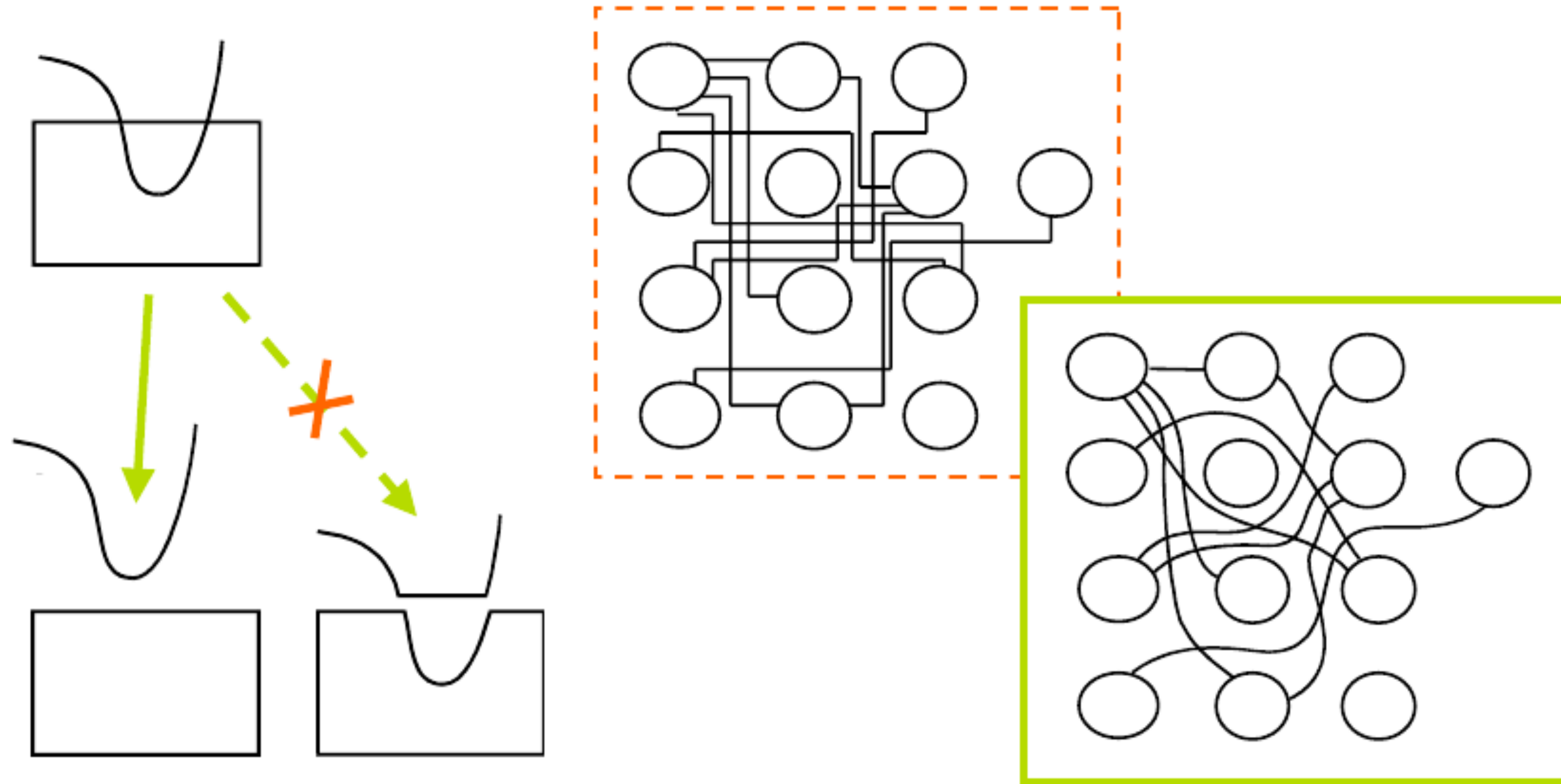


Continuity

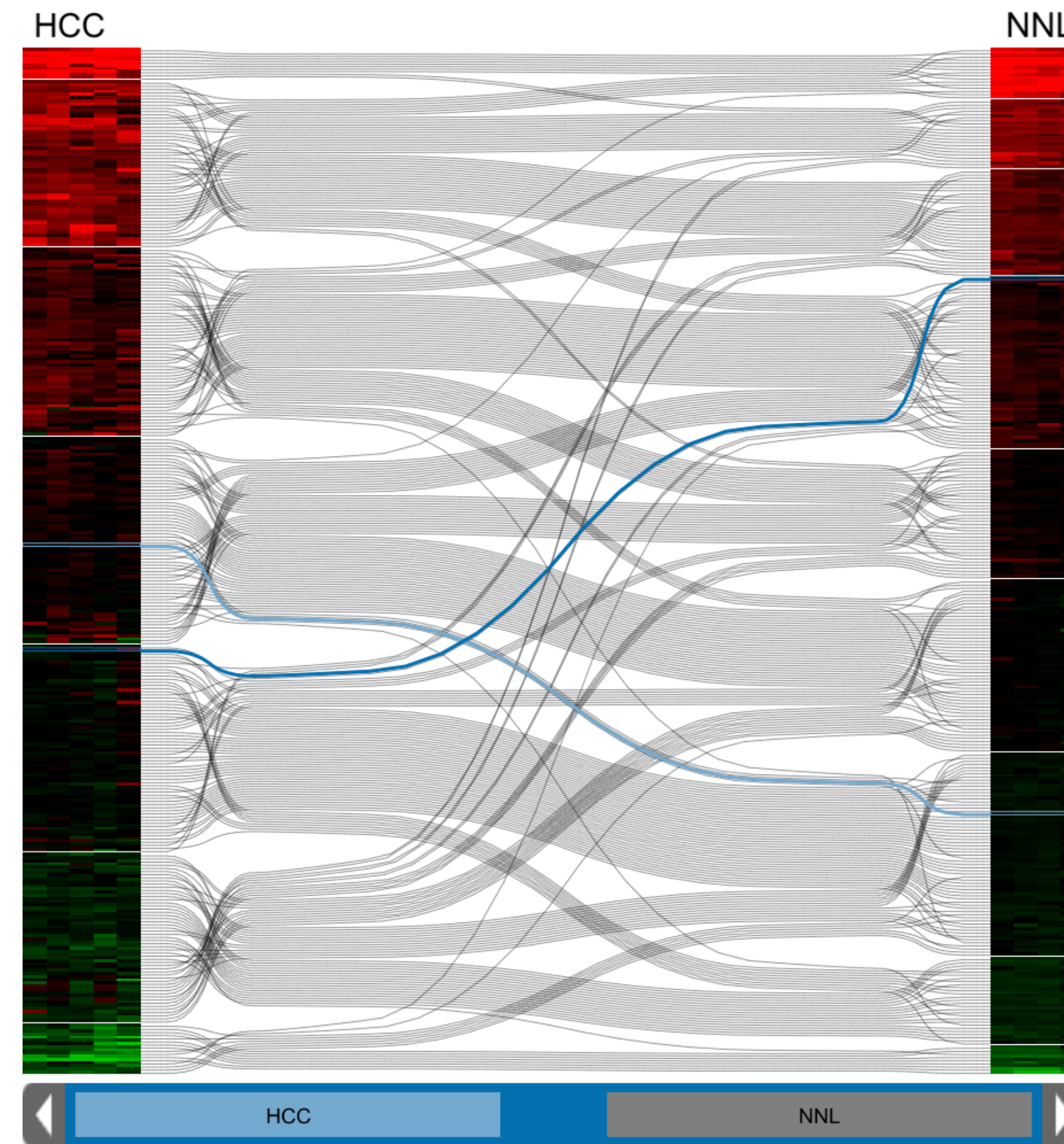
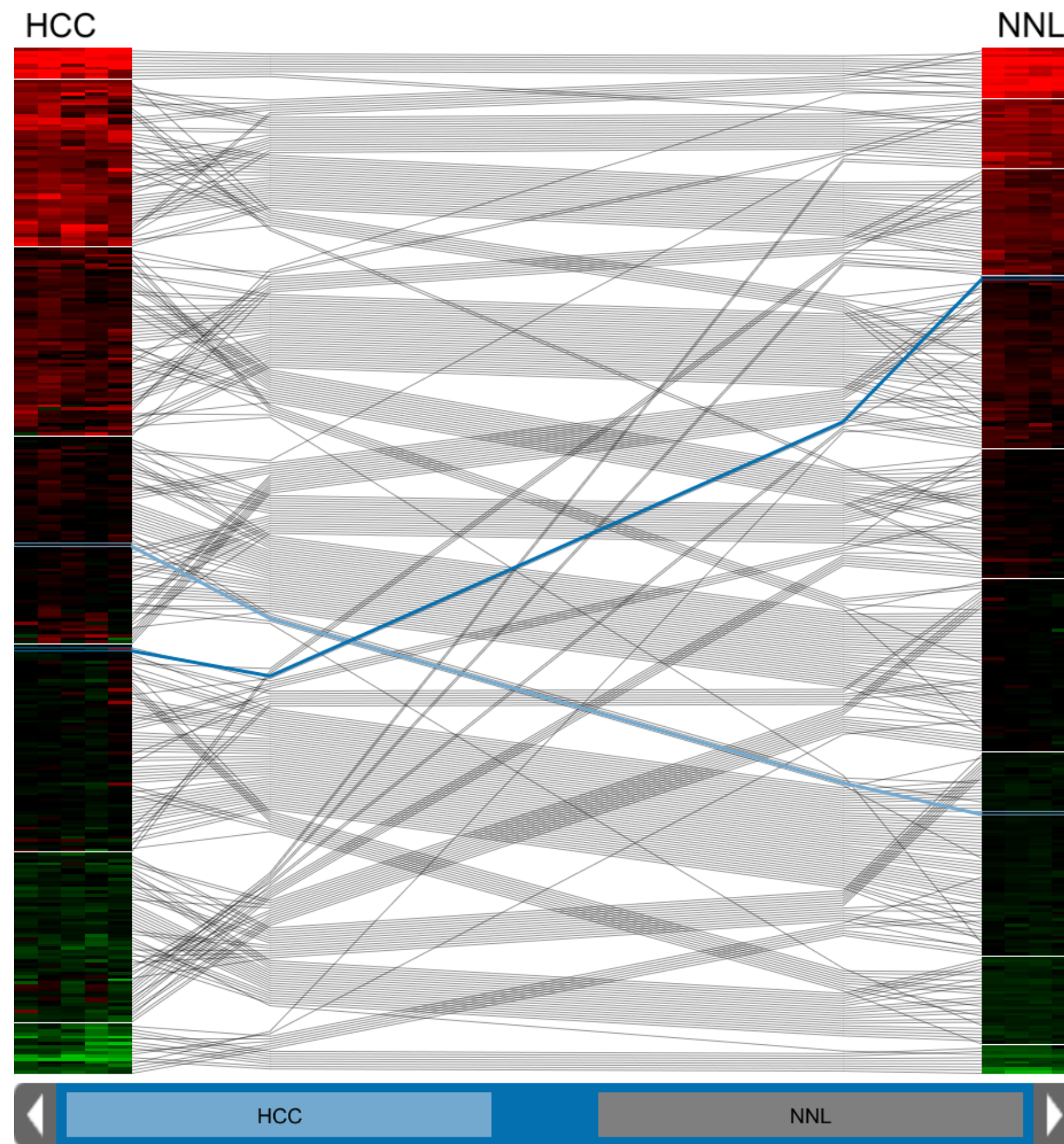


Continuity

Things: smooth & continuous



Continuity



Closure

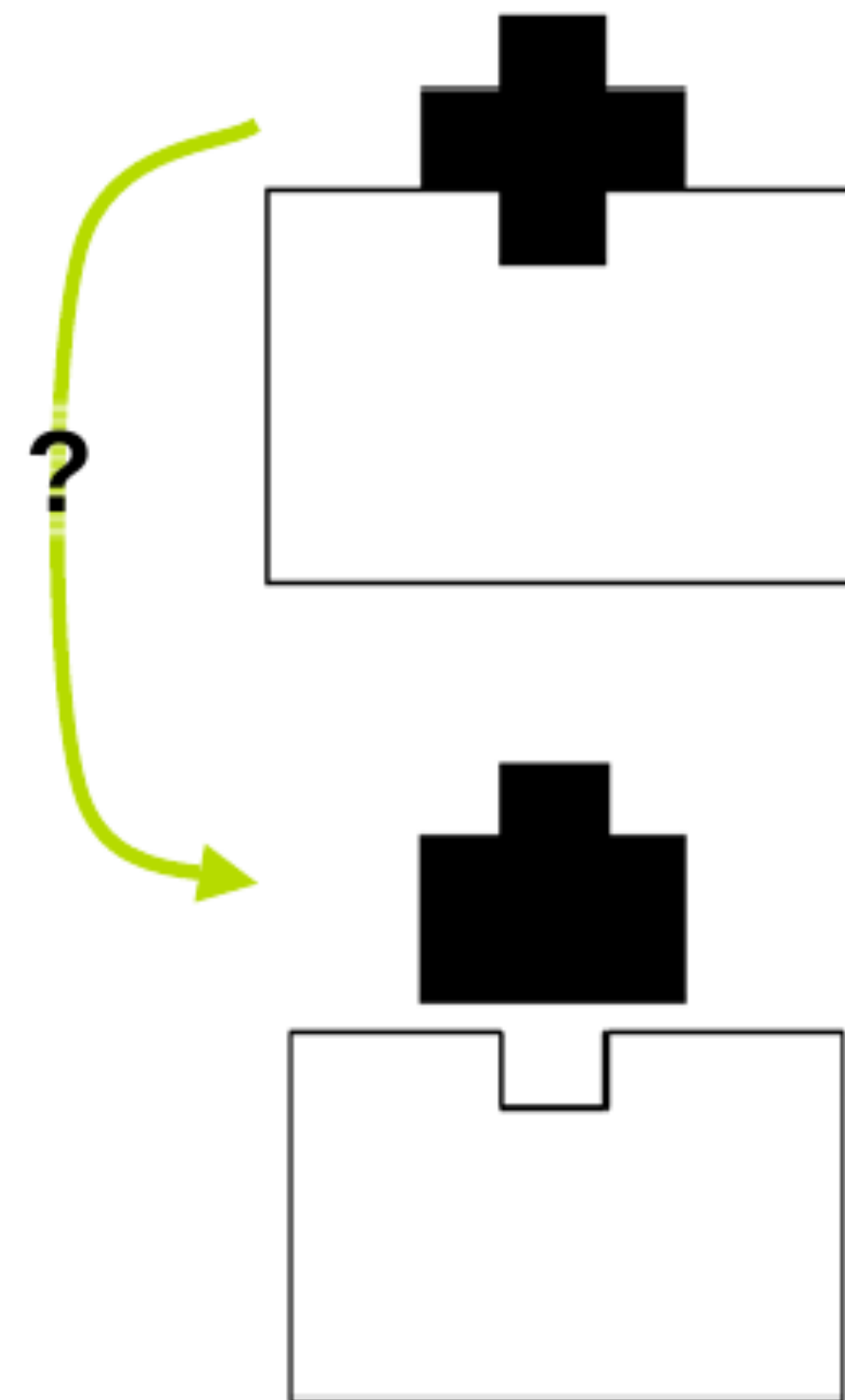
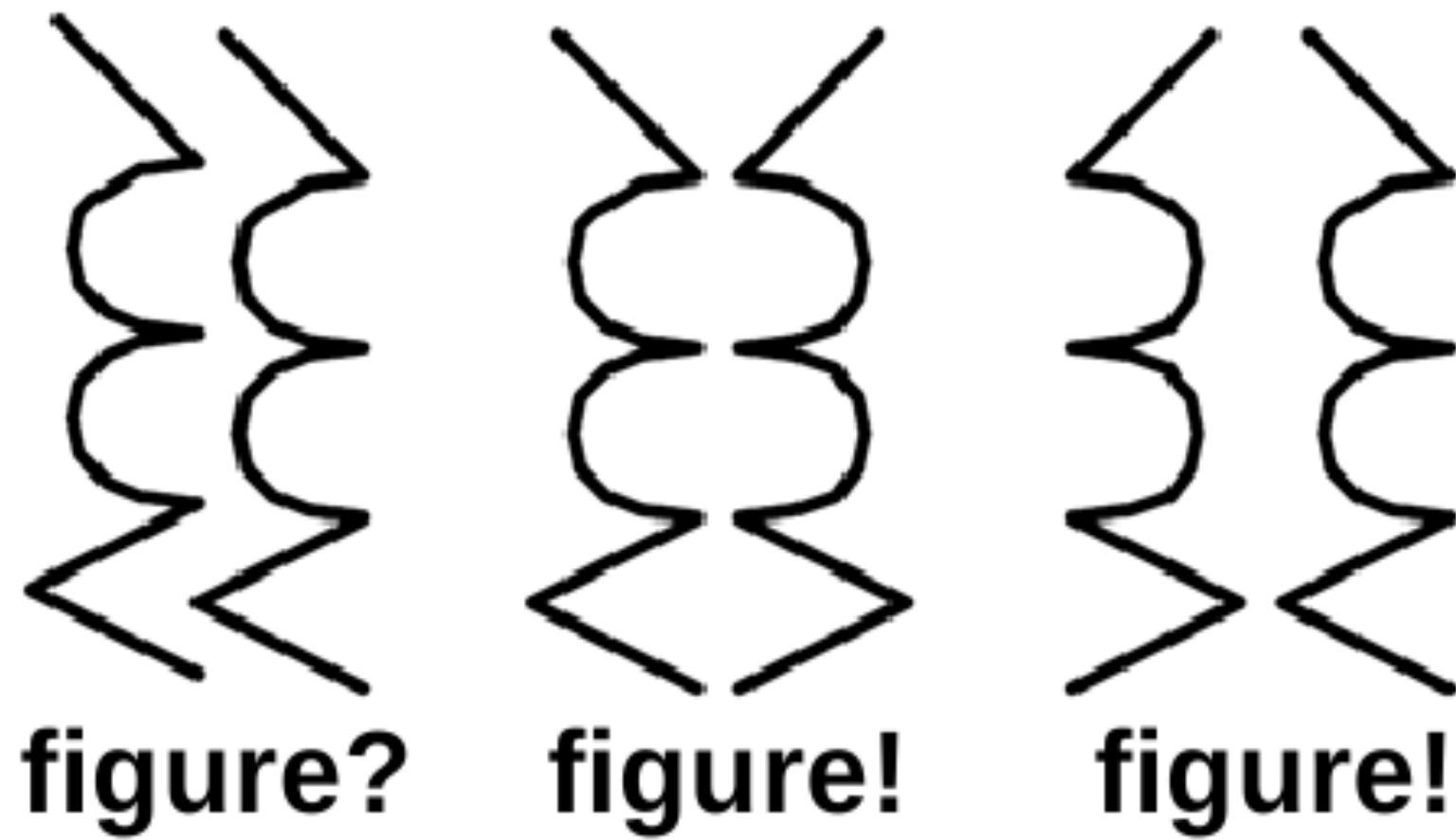


Closure



Symmetry

Things: symmetric



Population Pyramid

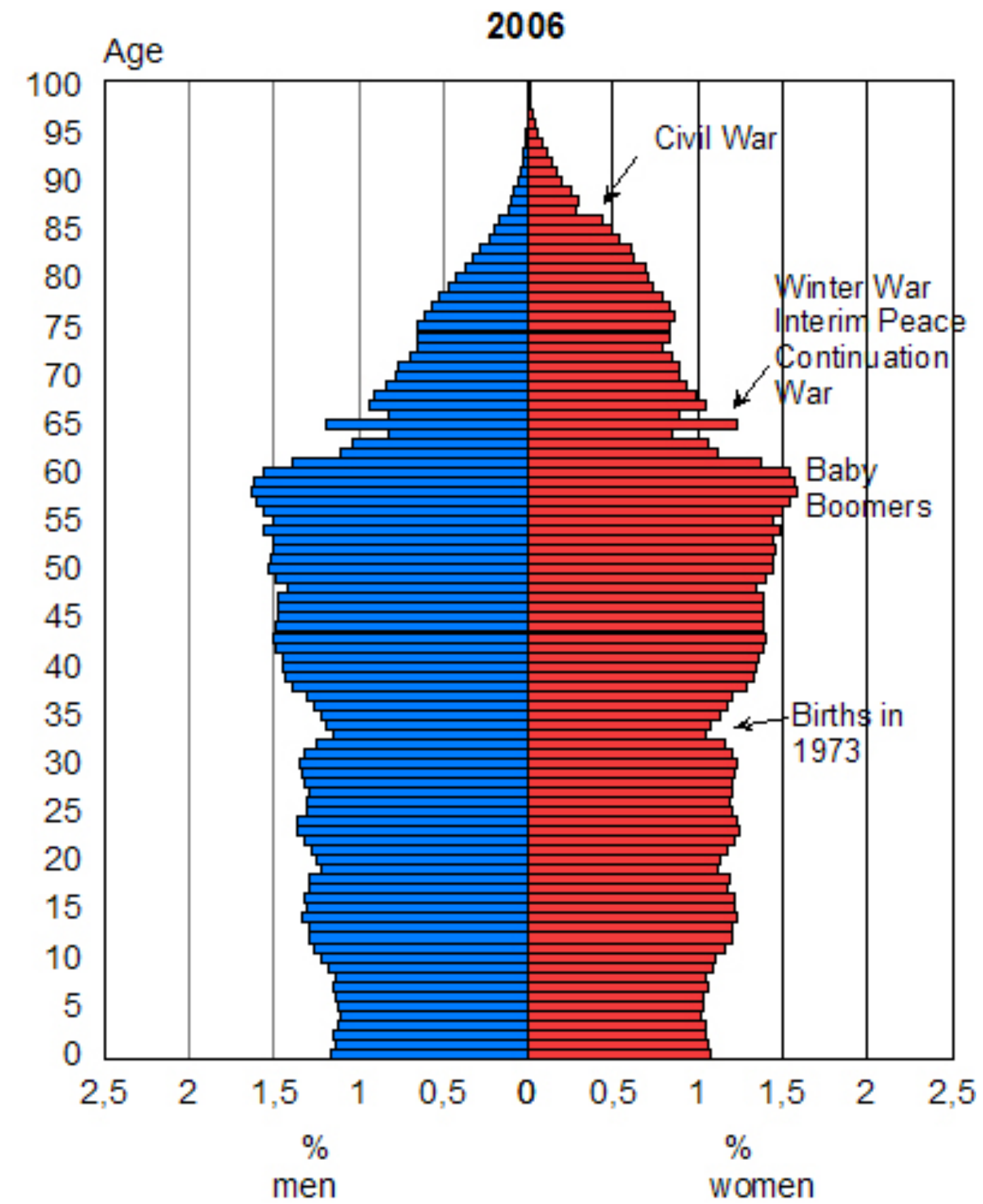
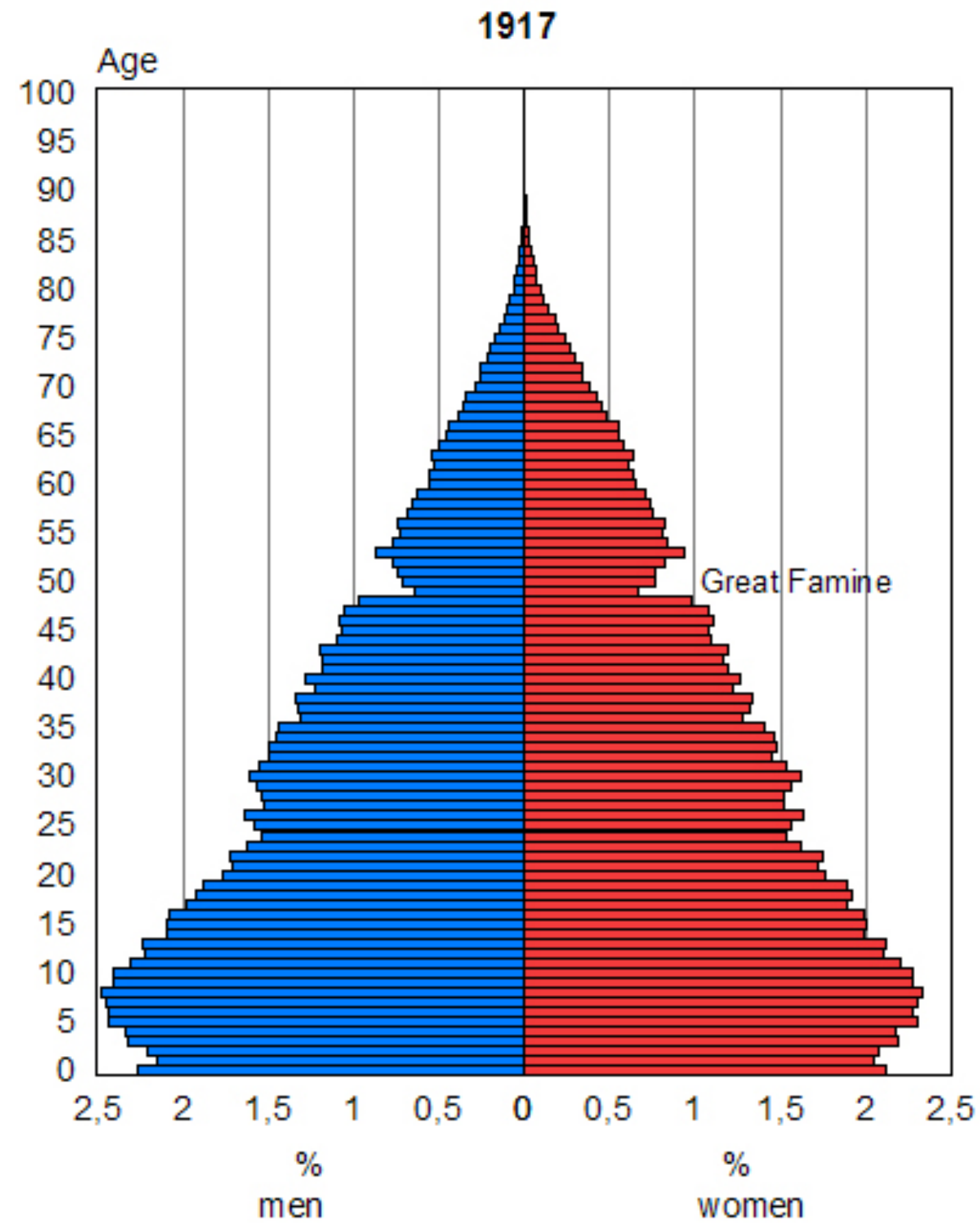
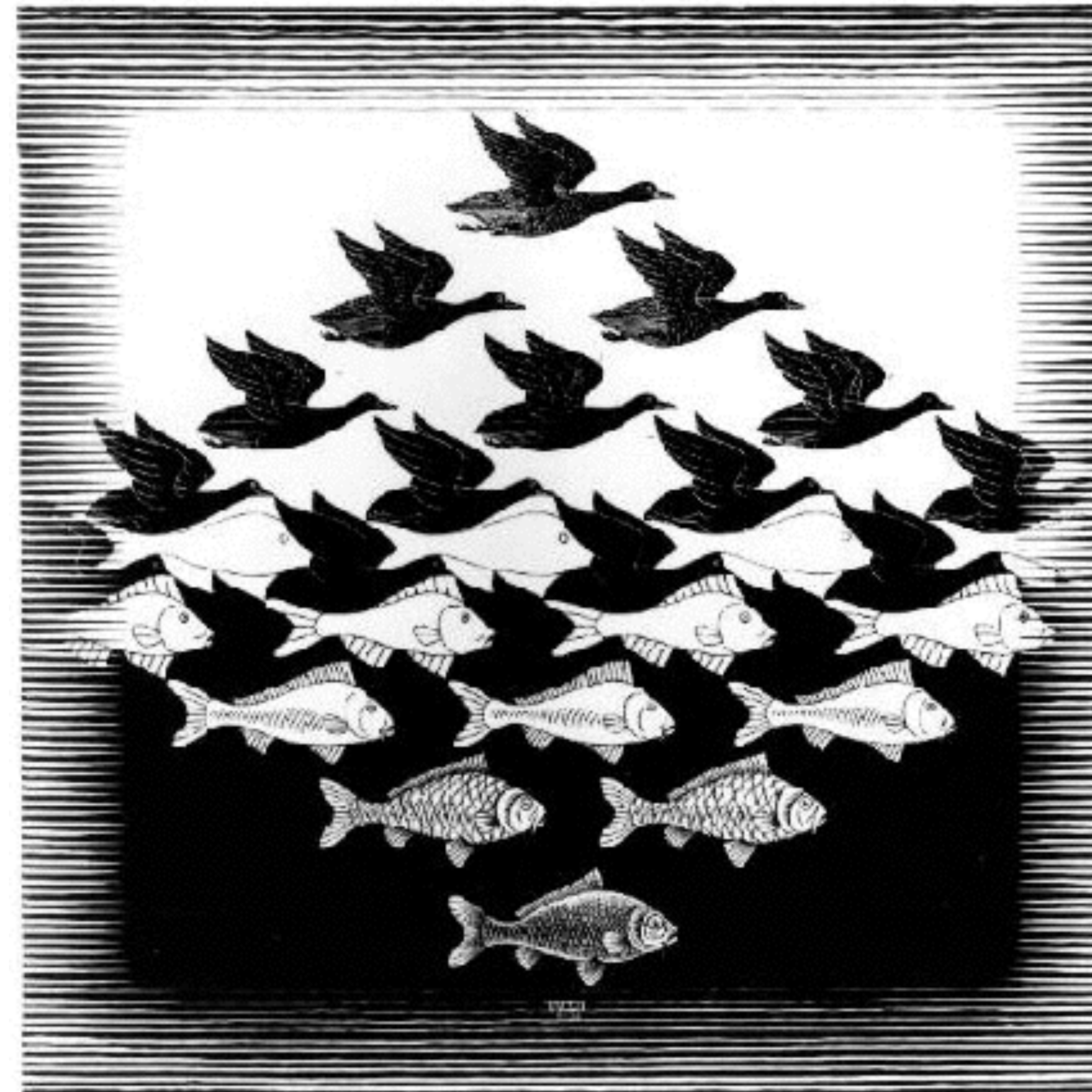
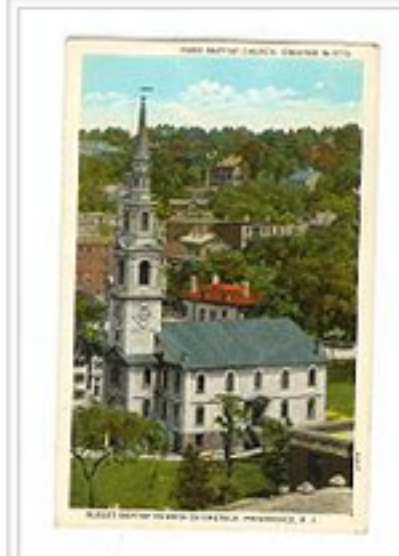


Figure / Ground



M.C. Escher: *Sky and Water I* 1938 woodcut

Applications in Vis



First Baptist Church in America, founded 1638, present building occupied in 1776, is the oldest Baptist congregation in America

The area which is now Providence was first settled in June 1636 by Roger Williams, and was one of the original Thirteen Colonies of the United States.^[10] Although the west bank of the Providence River was later claimed by both the English and the Dutch, the actual inhabitants and true masters of the region were the Pokanoket Tribe of the Wampanoag Nation led by Massasoit Ousamequin.^[11] Williams secured permission to settle from the Pokanoket and gave the city its present name.^[12] Williams' Providence soon became a refuge for persecuted religious dissenters, as he himself had been exiled from Massachusetts.^[13] Providence's growth would be slow during the next quarter-century—the subsuming of its territory into surrounding towns, difficulty of farming the land, and differing of local traditions and land conflicts all slowed development.^[13]

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Though during the Revolutionary War the city escaped enemy occupation, the capture of nearby Newport disrupted industry and kept the population on alert. Troops were quartered for various campaigns and Brown University's University Hall was used as a barracks and military hospital.^[13]

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Following the war, Providence was the country's ninth-largest city,^{bj}^[13] with 7,614 people. The economy shifted from maritime endeavors to manufacturing, particularly machinery, tools, silverware, jewelry and textiles. By the turn of the twentieth century, Providence boasted some of the largest manufacturing plants in the country, including Brown & Sharpe



Providence in the mid-nineteenth century



NPS map of the W3R Route





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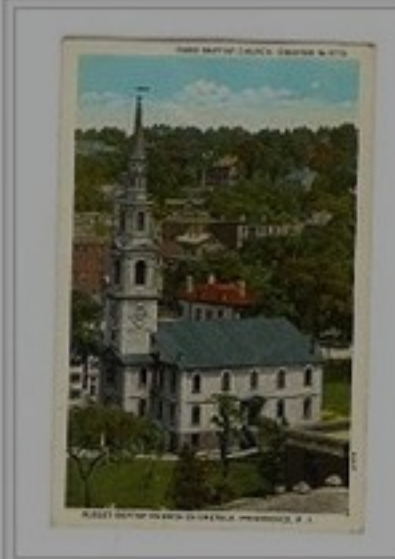


Providence in the mid-nineteenth century



NPS map of the WCR Route





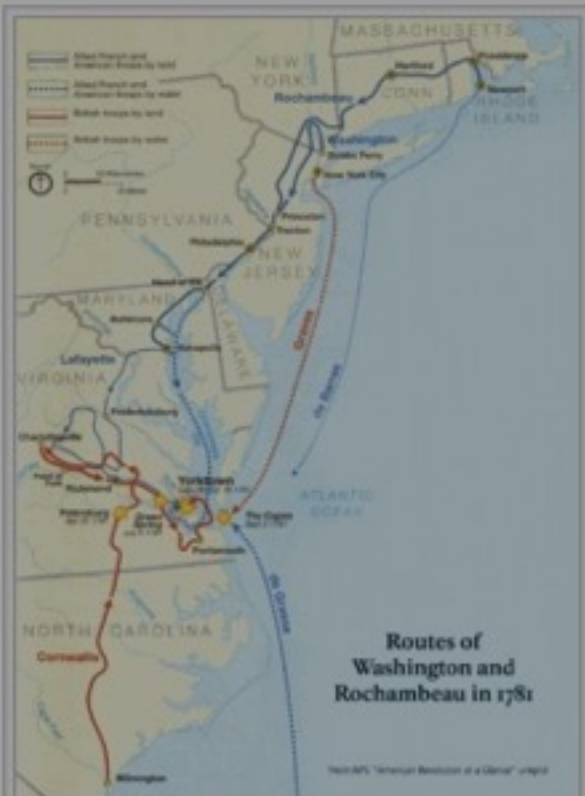
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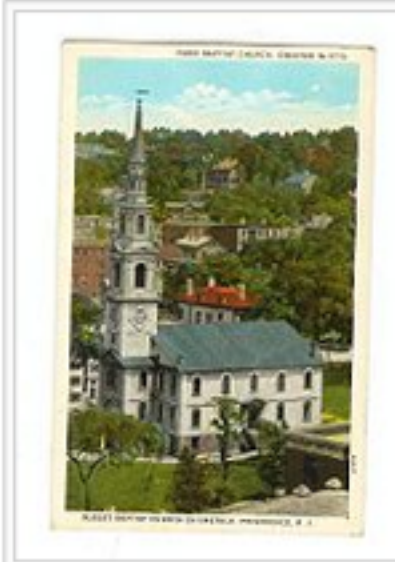
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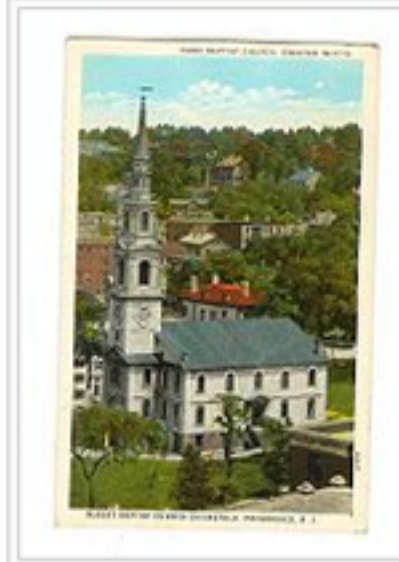
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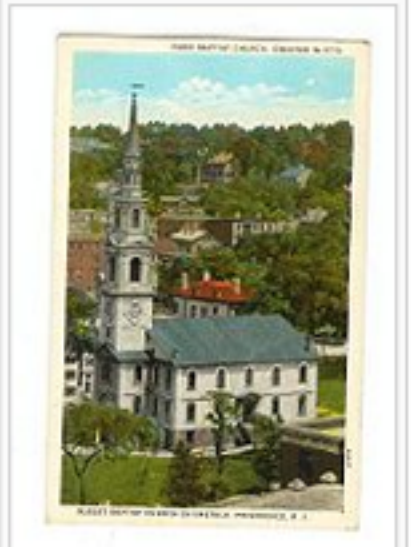


NPS map of the W3R Route



A screenshot of a Google Maps interface showing a map of the Northeastern United States. The map is centered on Providence, Rhode Island, with a red pin. The interface includes navigation controls, a search bar with 'mexico' entered, and various map layers like Satellite and Traffic. A scale bar at the bottom indicates 50 miles and 100 kilometers. The copyright notice at the bottom reads '©2011 Google - Map data ©2011 Google - Terms of Use Report a problem'.

edia.org/wiki/Providence,_Rhode_Island





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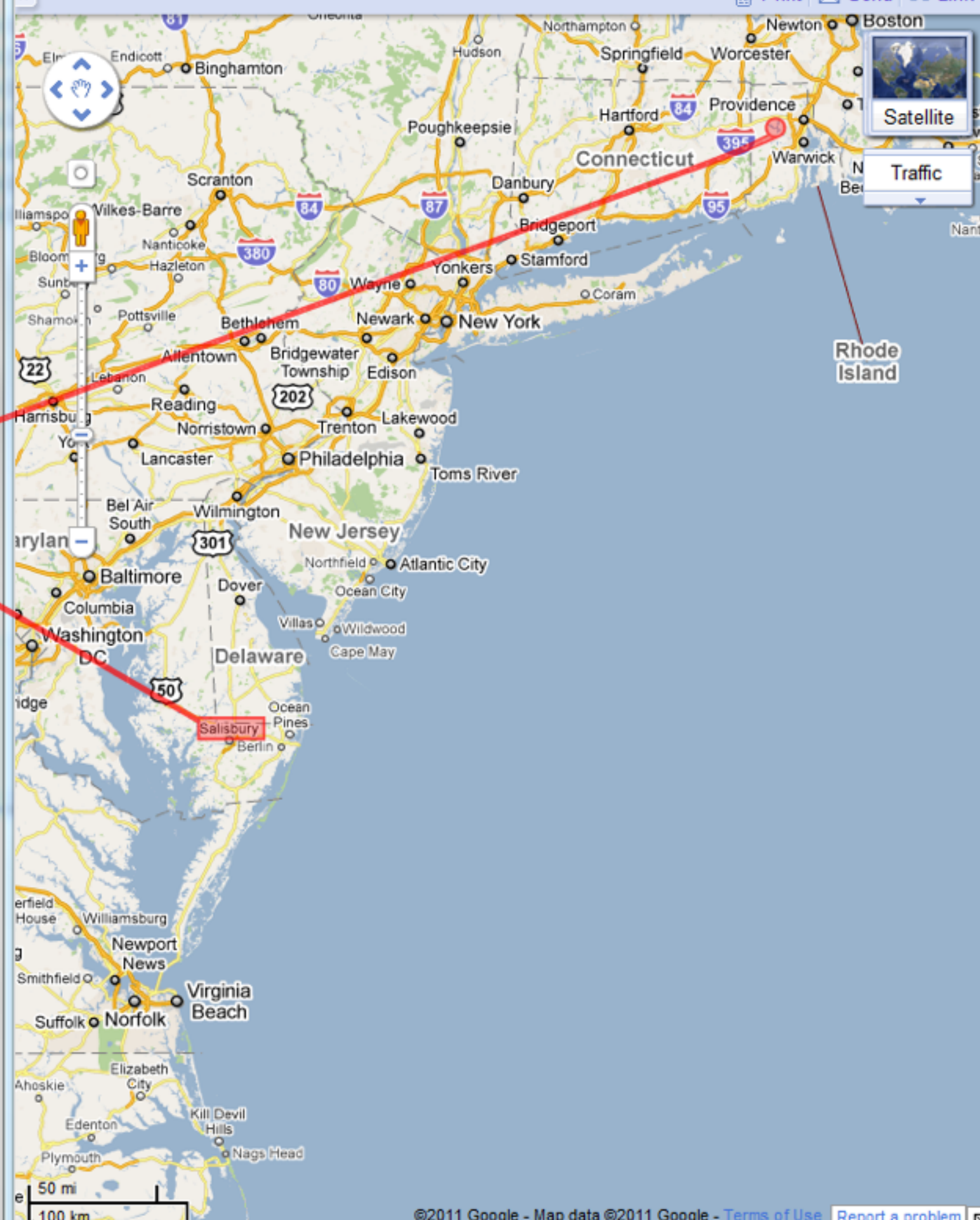
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What is the problem?

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Routes of Washington and Rochambeau in 1781

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Context-Preserving Visual Links

Takeaways

Knowing about Perception is important for Vis and UI design

How to choose your colors

How to show relationships

How to draw attention

How to minimize risk of overlooking