

CS-5630 / CS-6630

Visualization for Data Science

Perception

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Color names if
you're a girl...

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

Color names if
you're a guy...

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

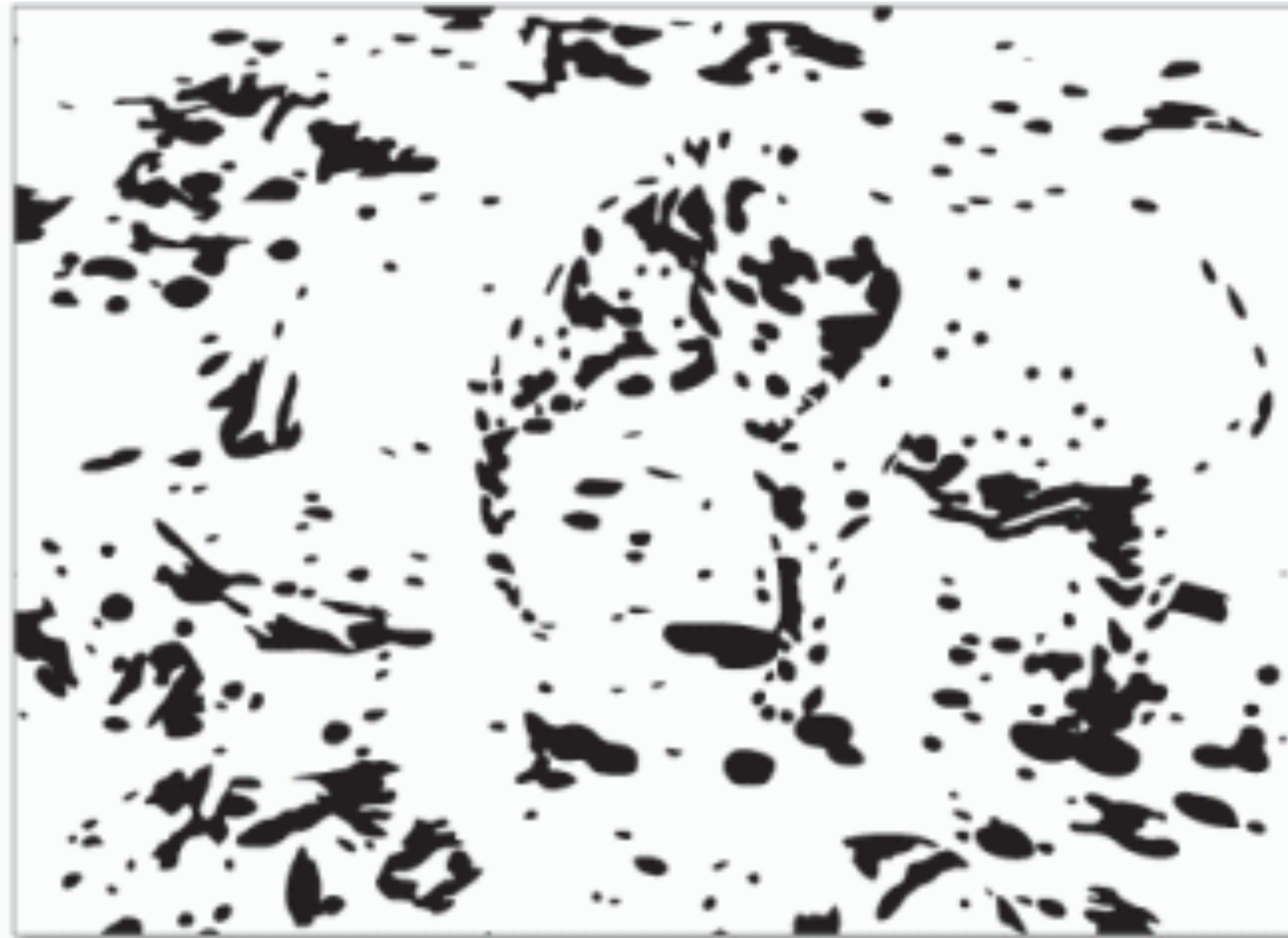
BLUE

RED

What is There vs.
What do we See



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



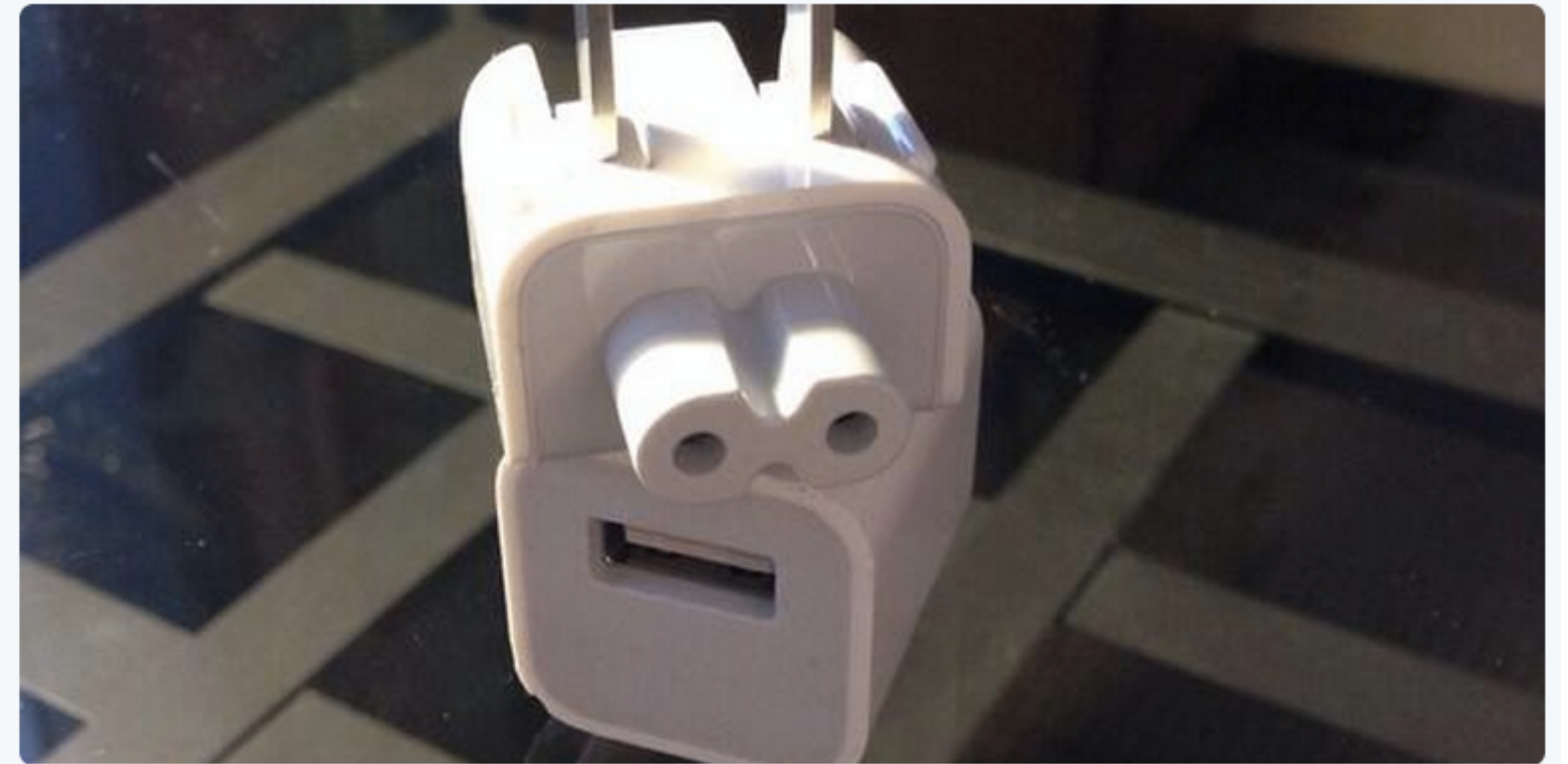
Faces in Things @FacesPics · Feb 14

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

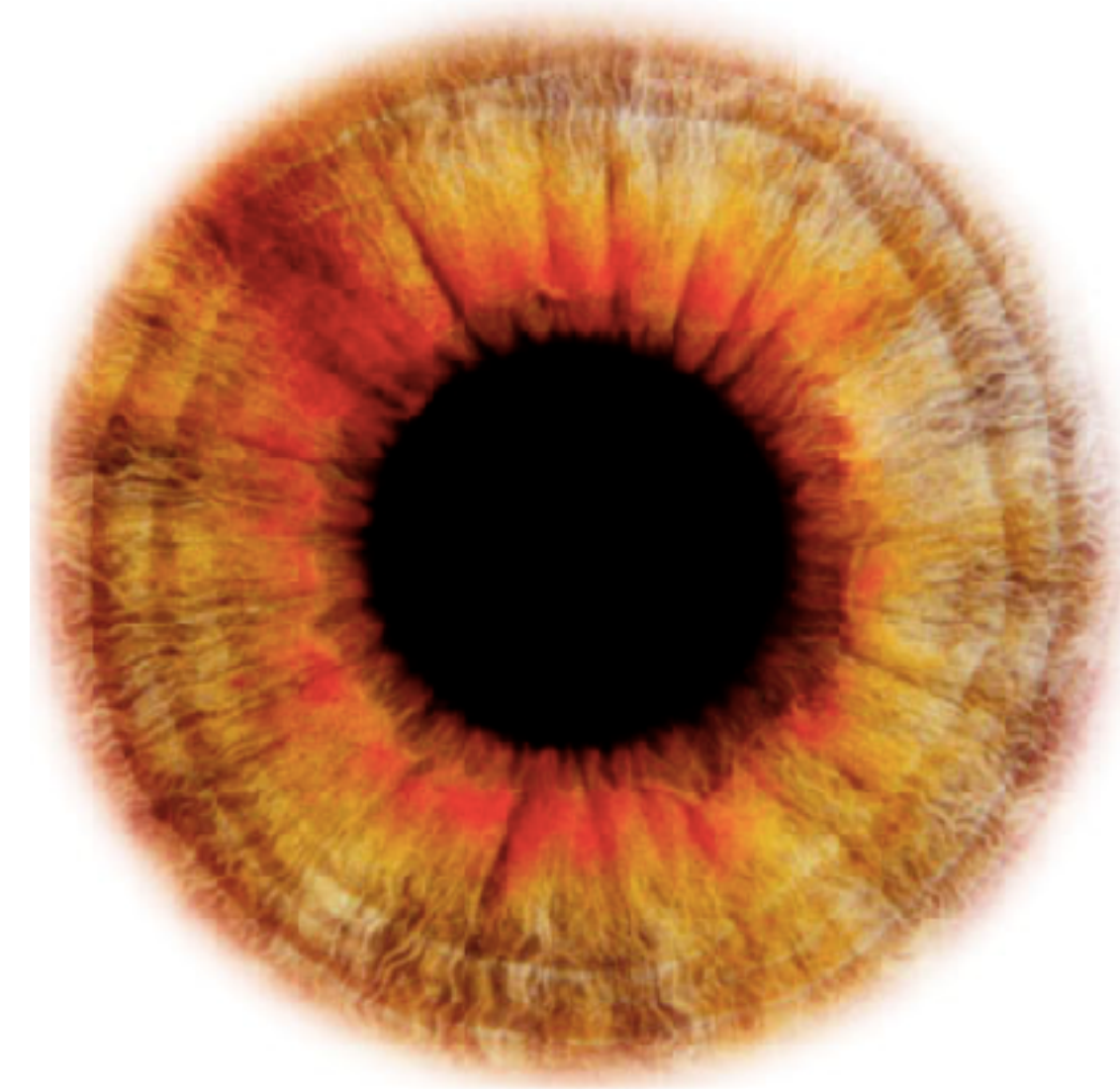
Vision is “constructed” top down from the input

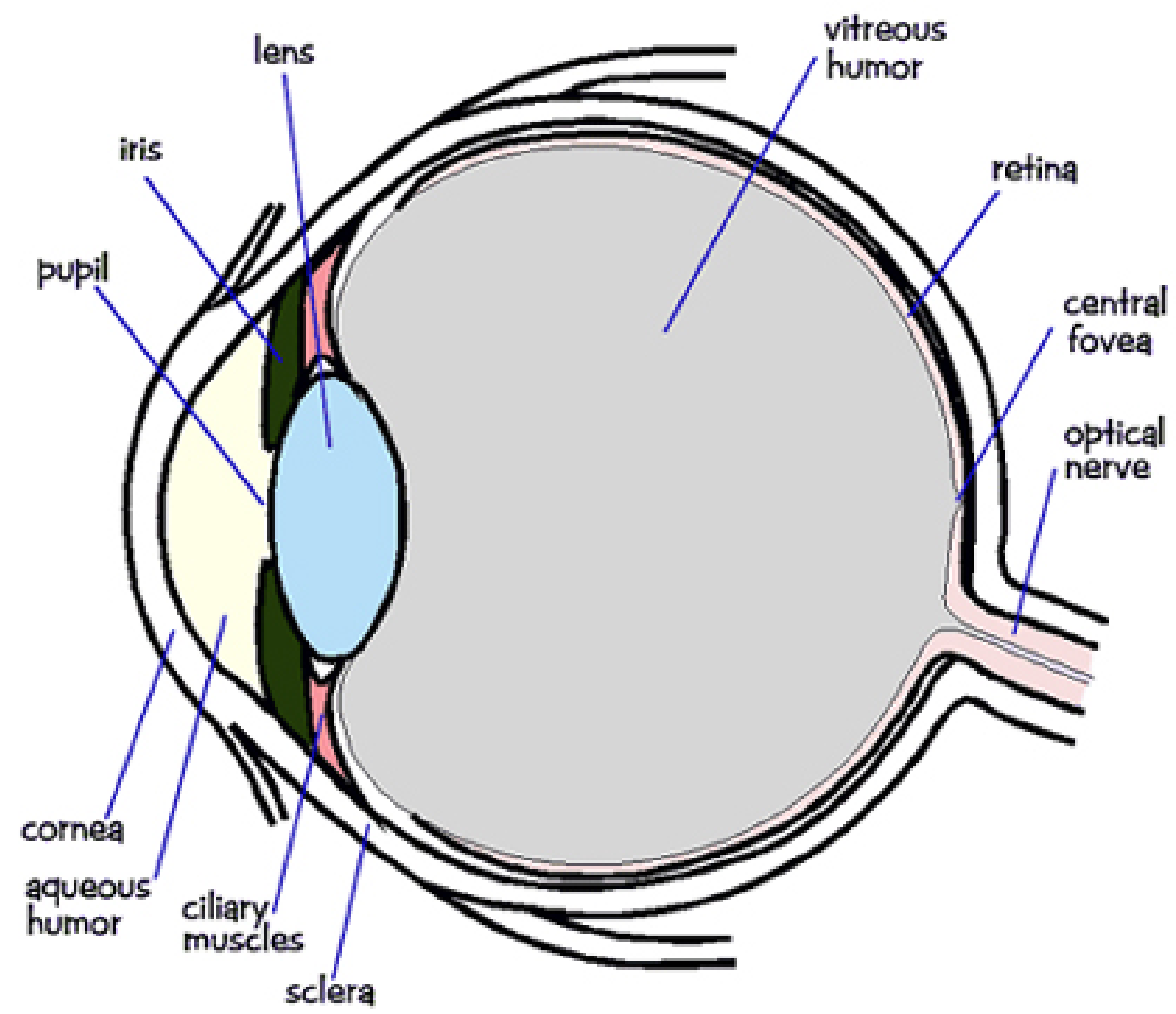
“What you see when you see a thing depends on what the thing is. What you see the thing as depends on what you know about what you are seeing.”

Zenon Pylyshyn
Canadian Cognitive Scientist
and Philosopher



The Eye





Human Visual System

5-6 mio cones

color vision

dense in the center

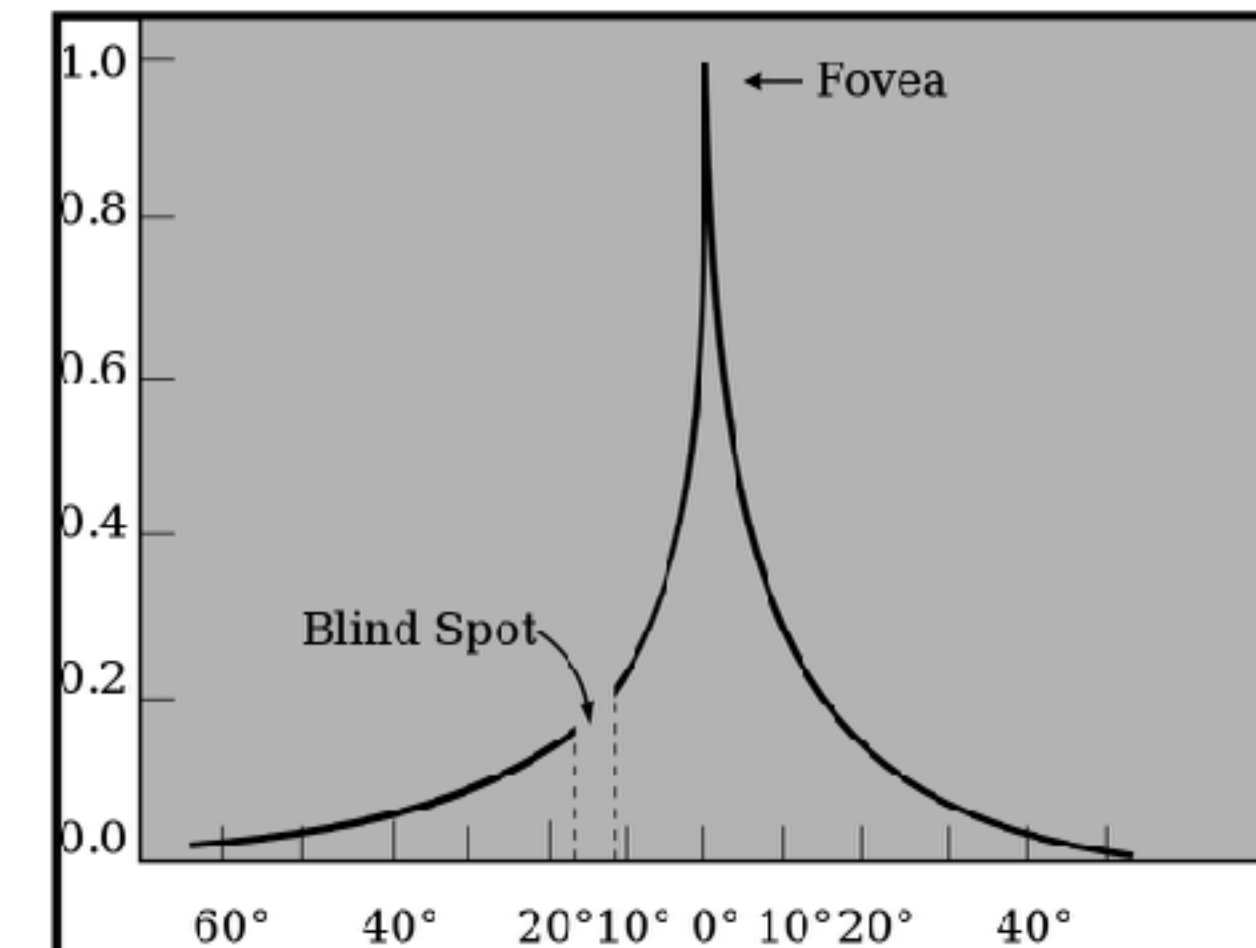
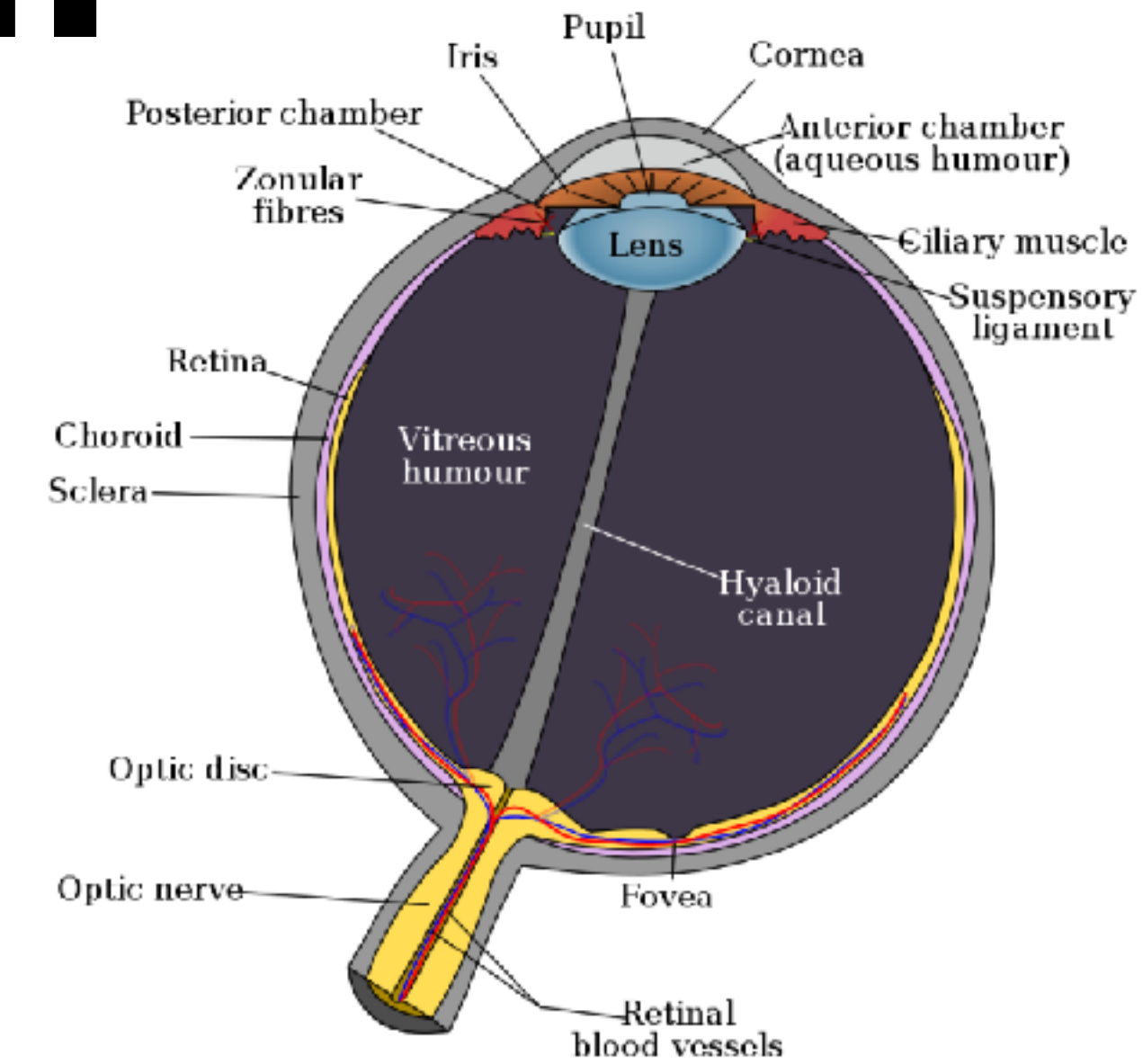
Fovea: 27 times the density

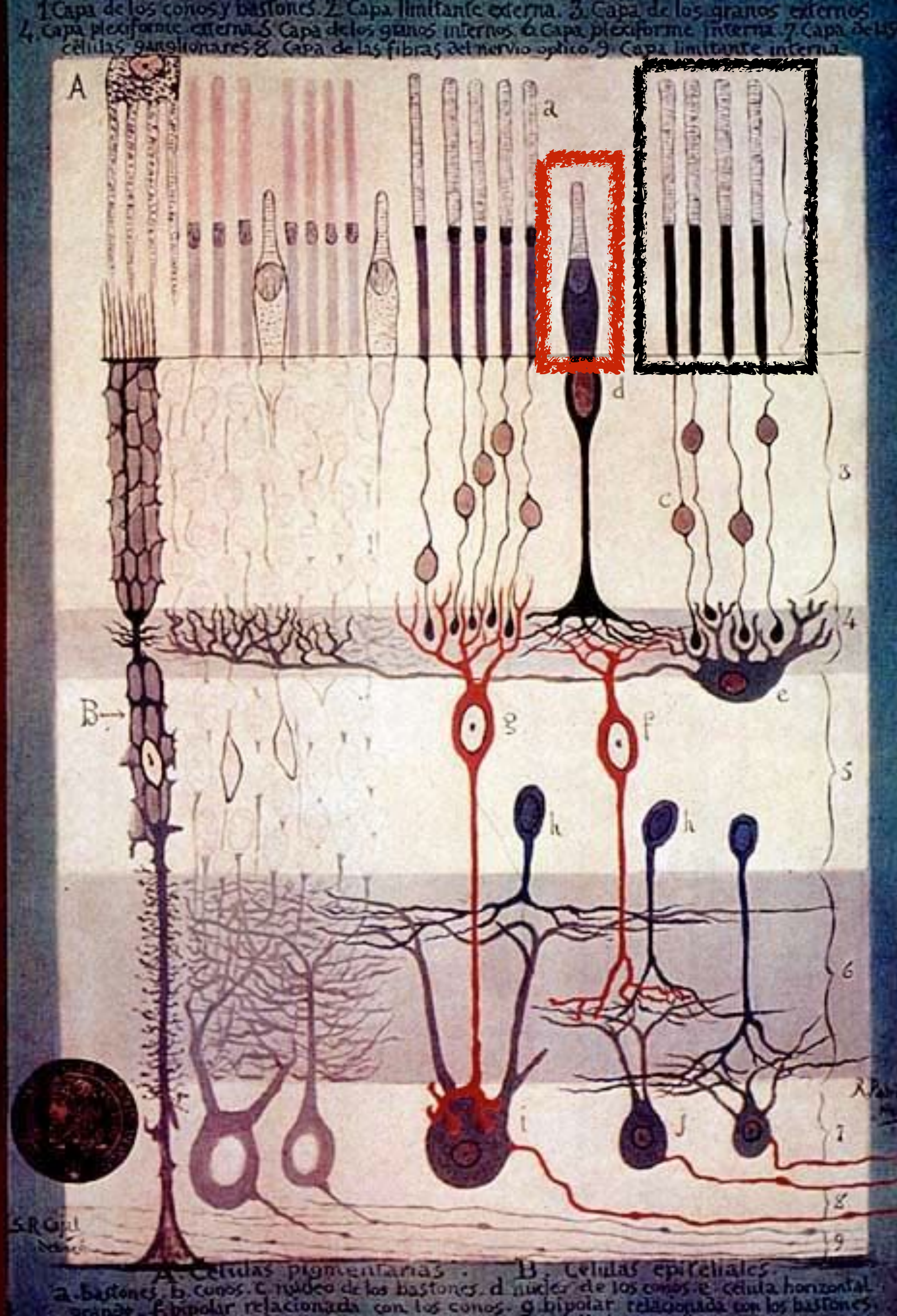
responsible for sharp central vision

only cone cells

~120 mio rods

black/white



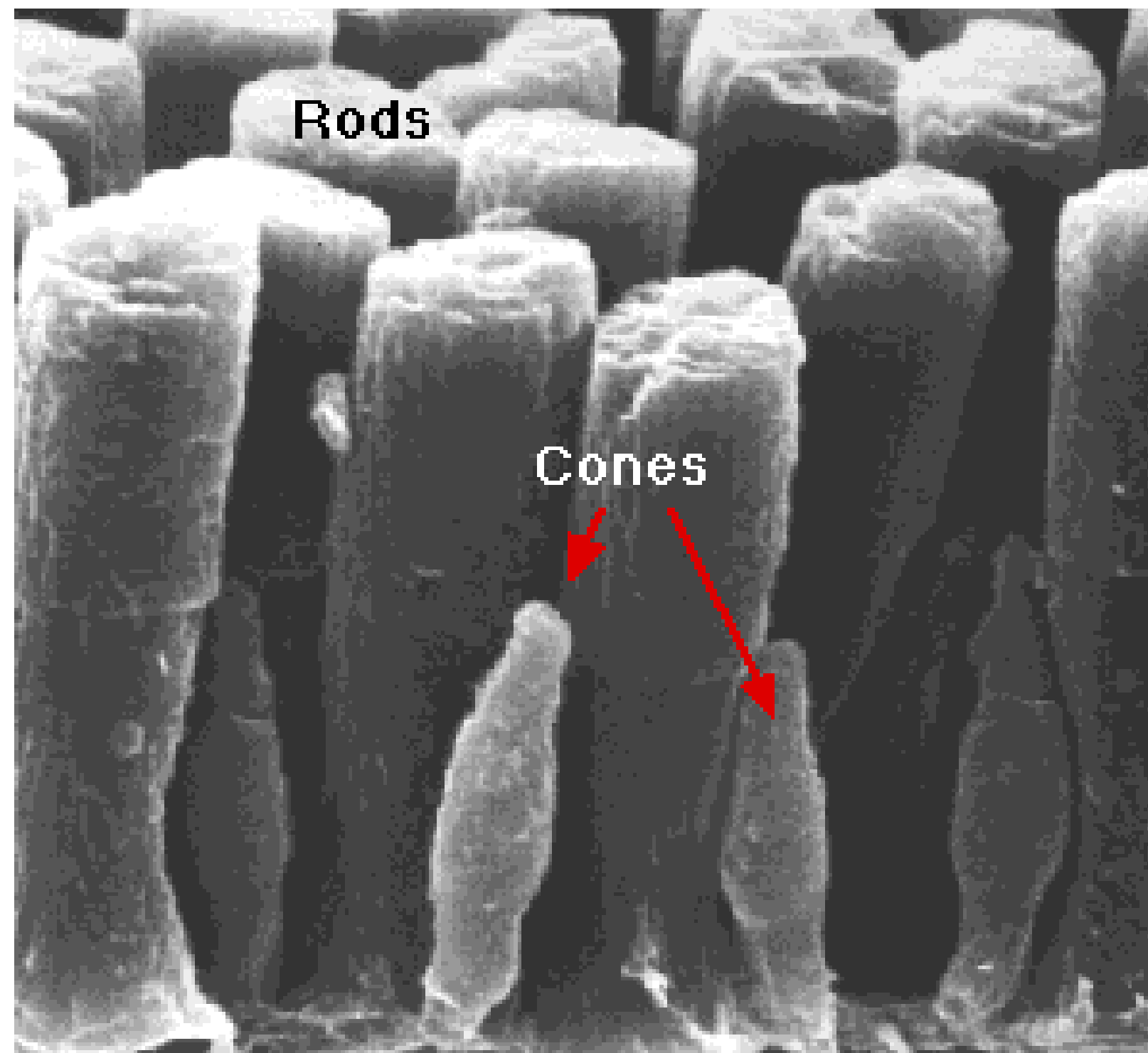


Rods - sensitive black and white

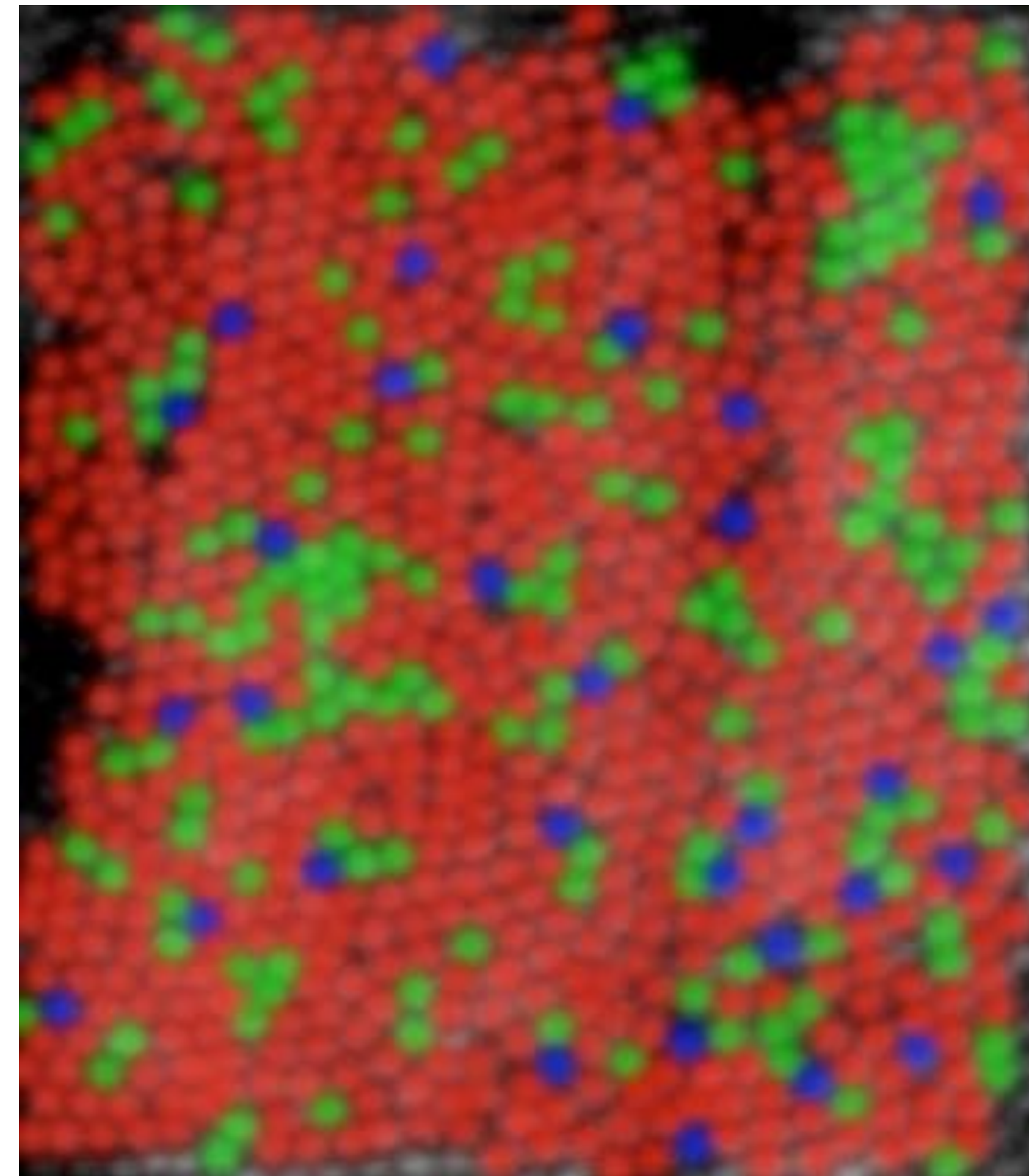
Cones - color vision

Ganglion Cells

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

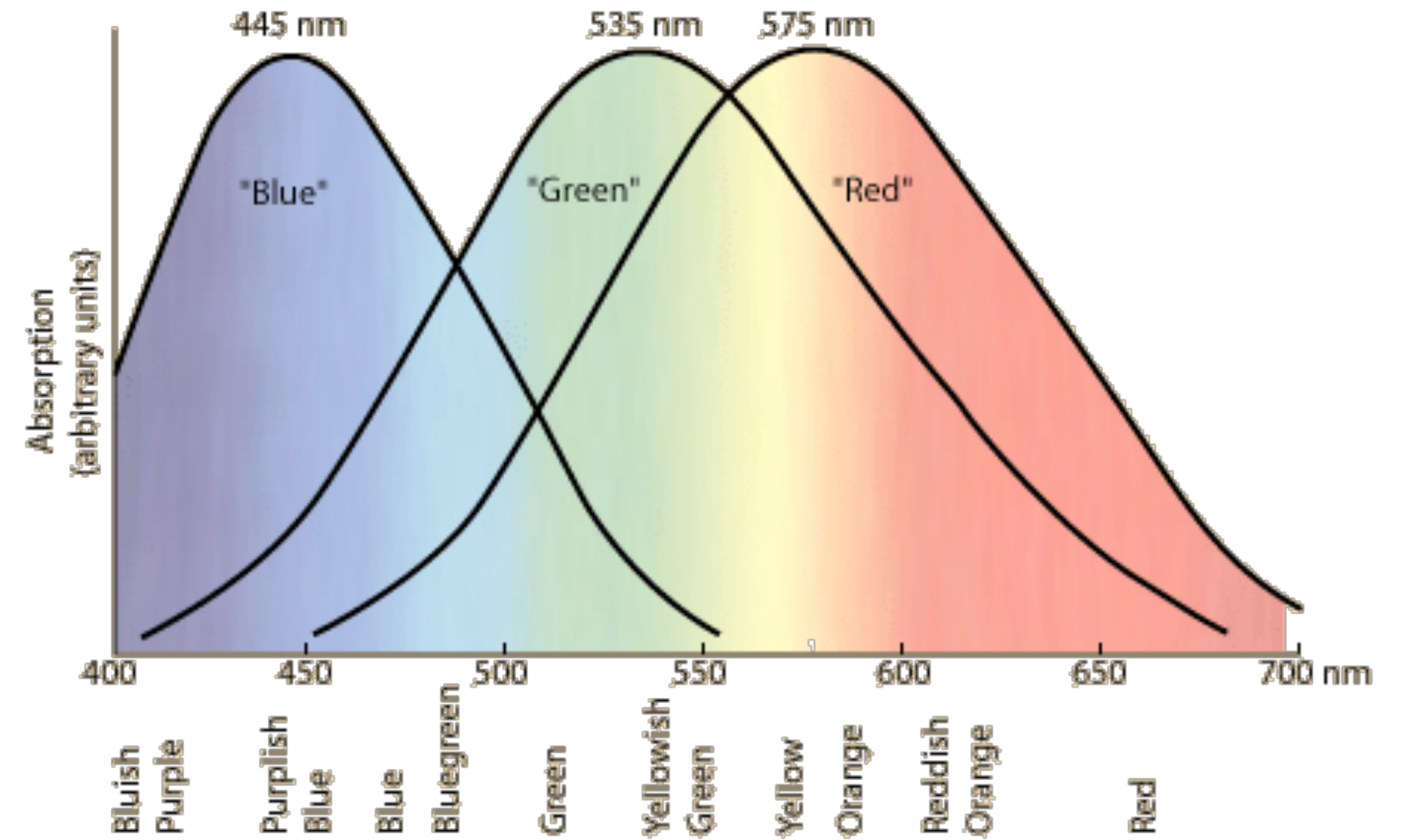
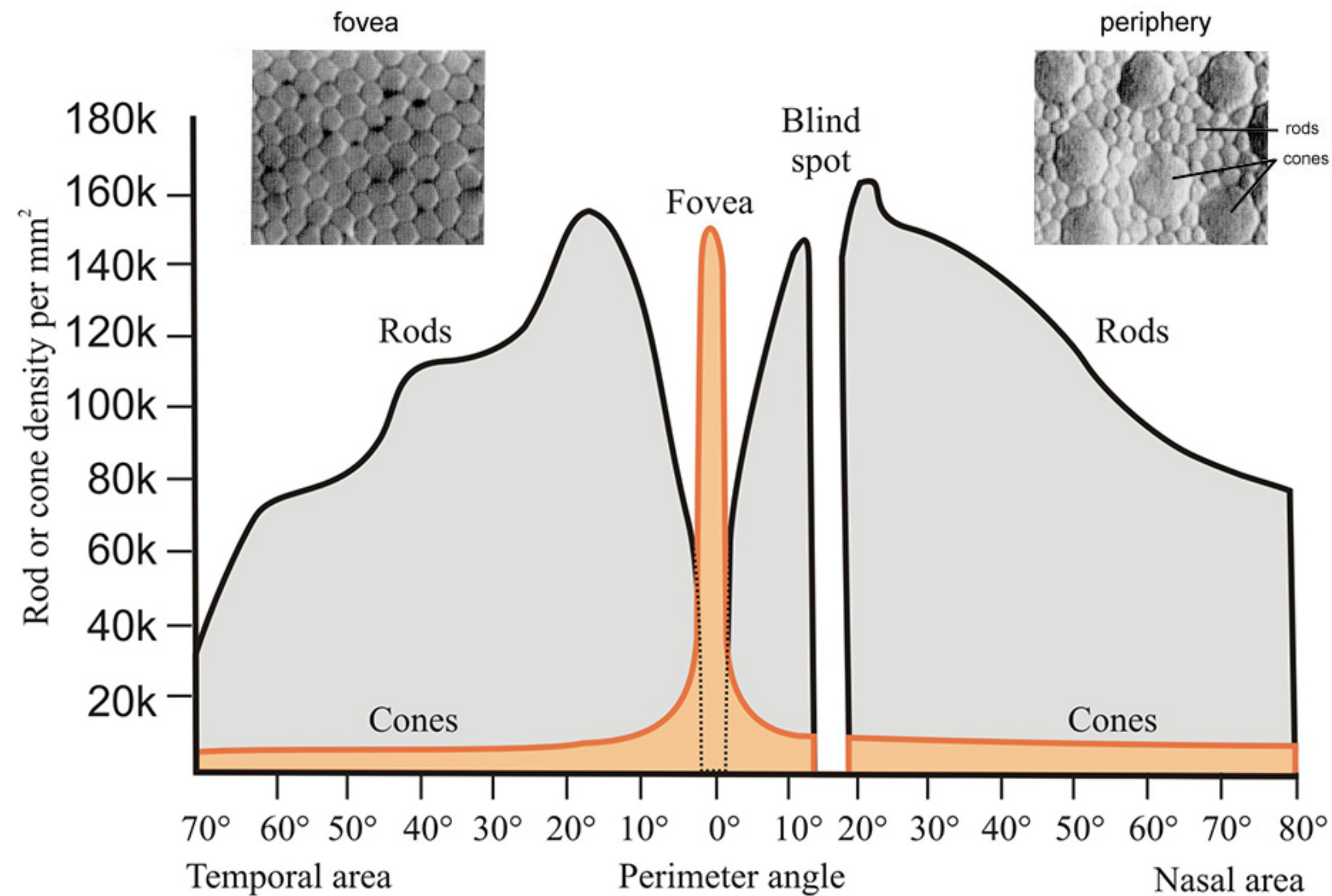


~120 million rods
~5-6 million cones



R 63% - G 31% - B 6%

Cone Response



Human Visual System

VIDEO!

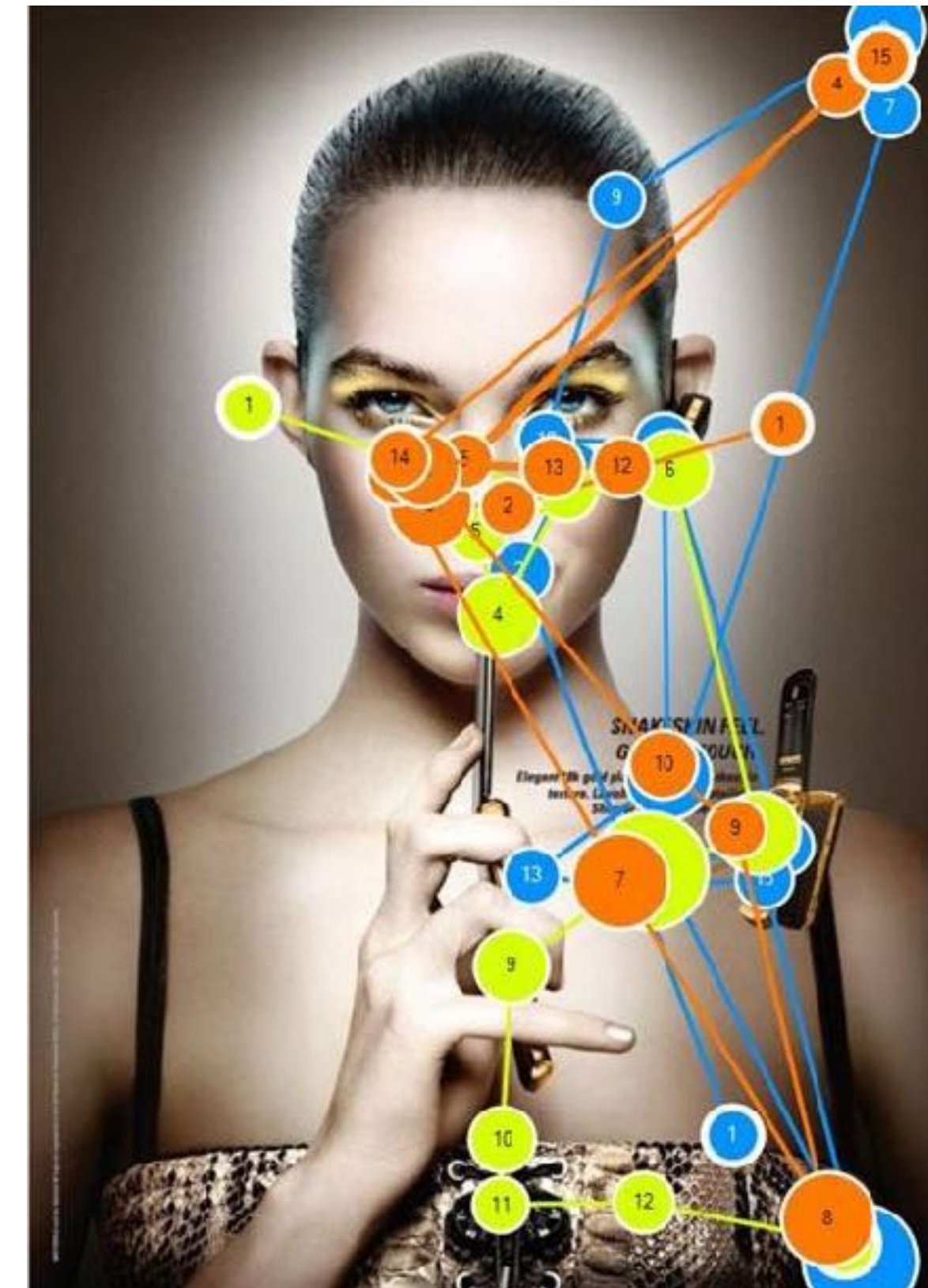
Vision works as sequence of **fixations** and **saccades**

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

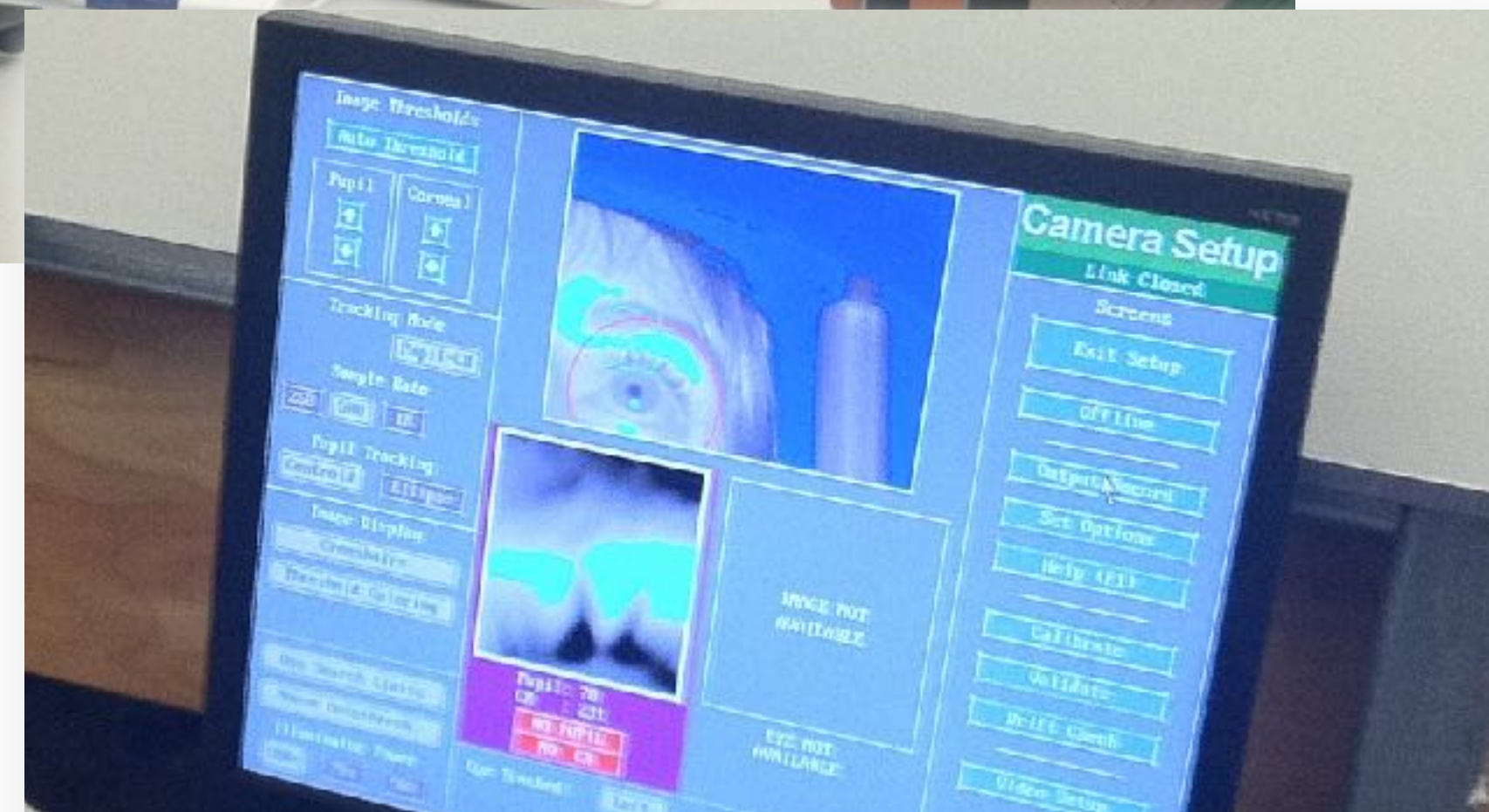


Eye-Tracking Experiment

Visualization
display

Eye-tracking control computer

Infrared
camera



Video!

Human Visual System

VIDEO!

No general purpose vision

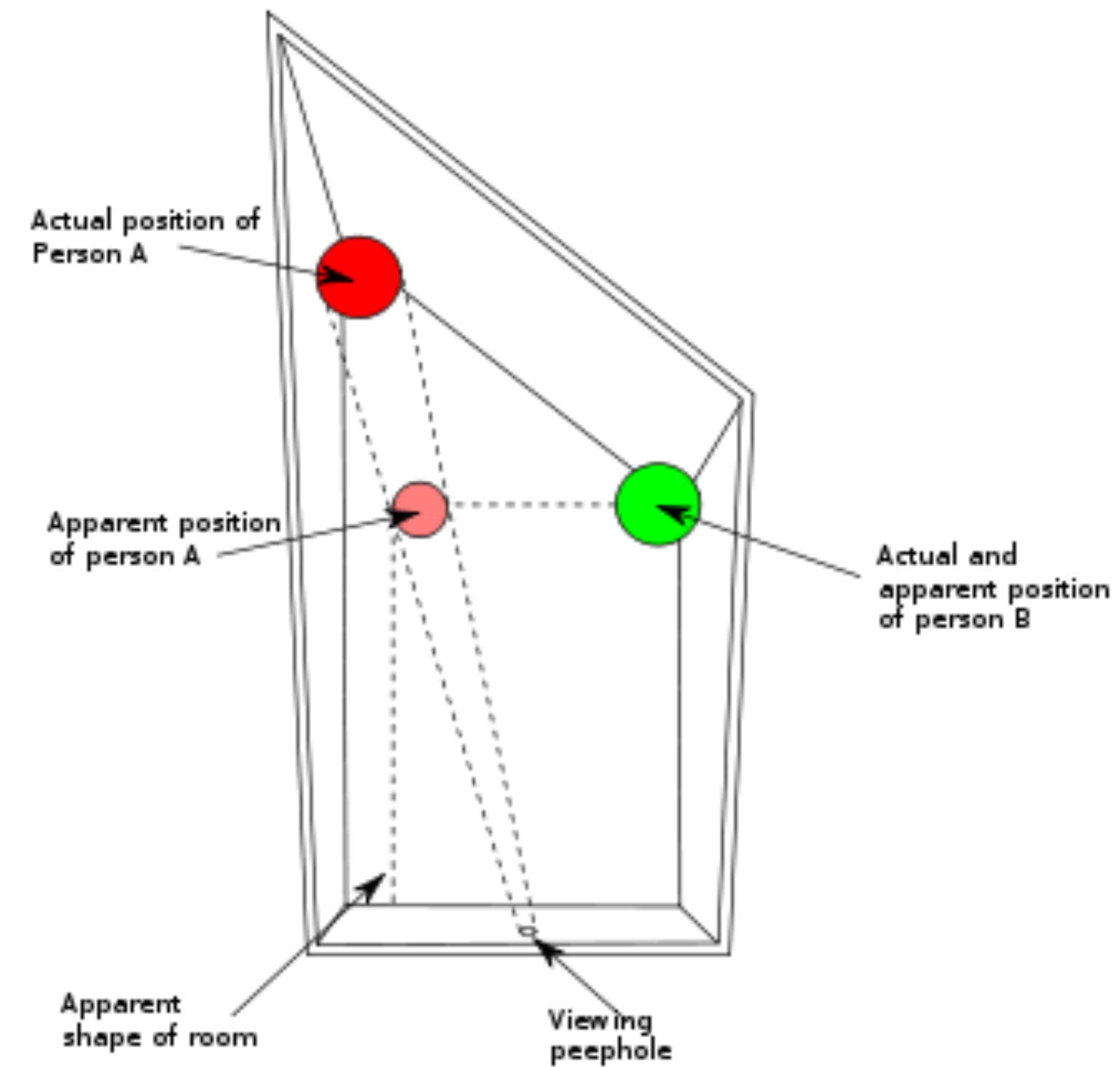
What we see depends on our goals and expectations

Relative judgments: strong

Absolute judgments: weak



Ames Room



Color

Color Basics

Visible part of the electromagnetic spectrum

390-750 nm

Spectral colors

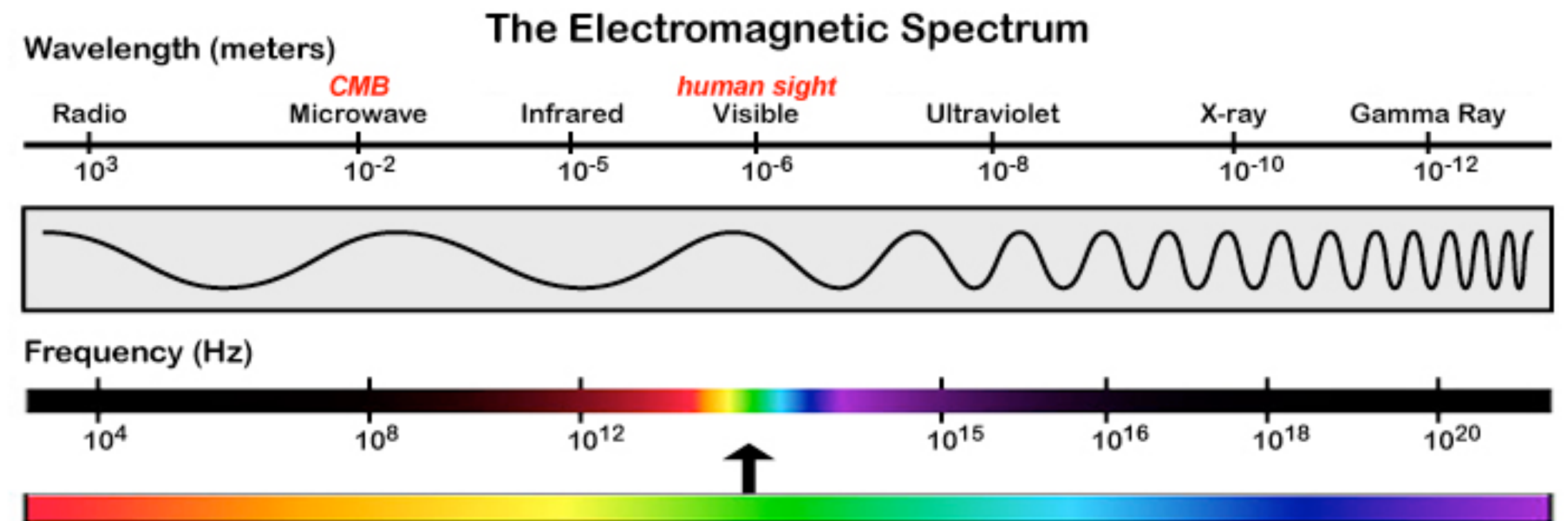
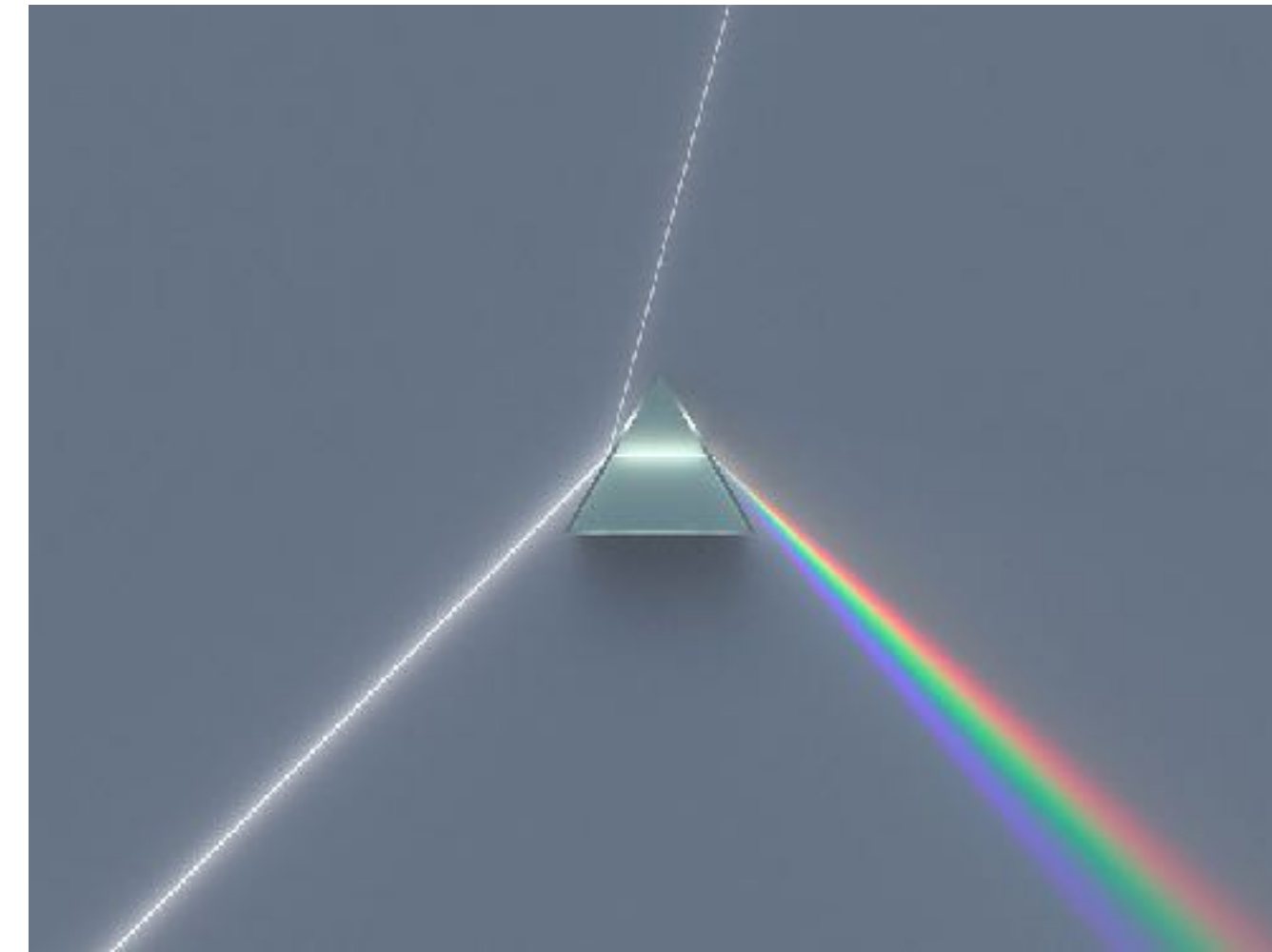
evoked by a single wavelength

Other colors: unsaturated colors

Gray scale (achromatic colors)

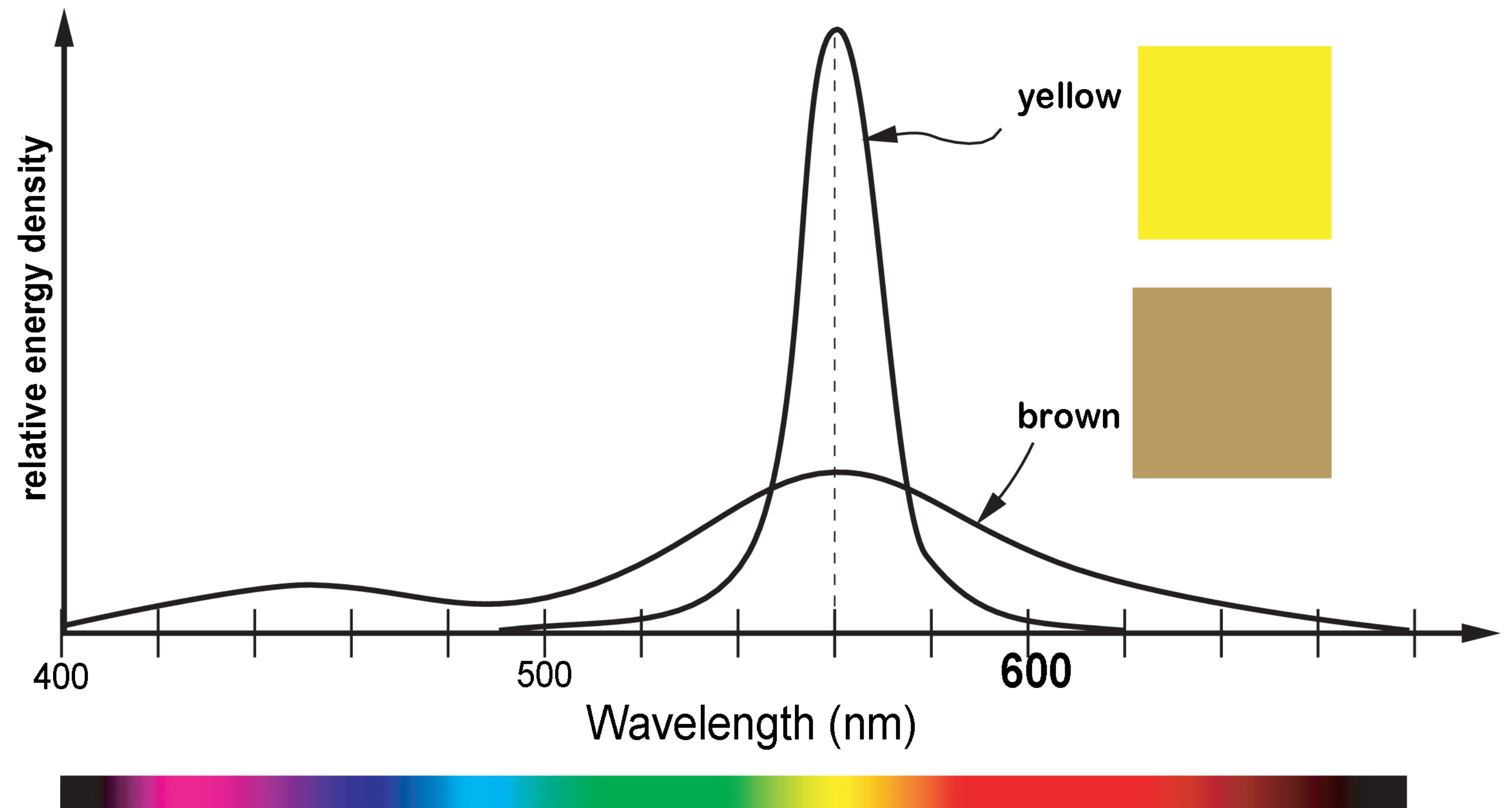
Mix of multiple wavelengths

e.g. purple, magenta

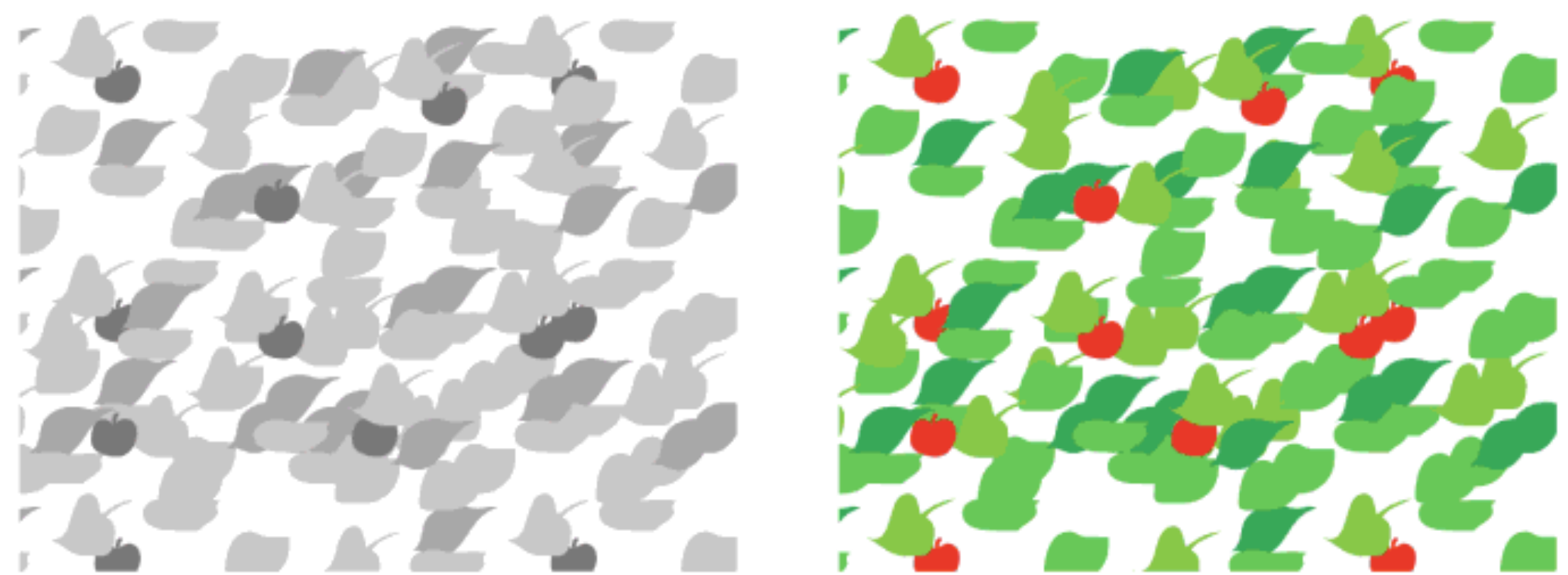


color != wavelength

but rather, a combination of
wavelengths and energy



Color



Color vision is irrelevant to much of normal vision!

does not help to perceive layout of objects

how they are moving

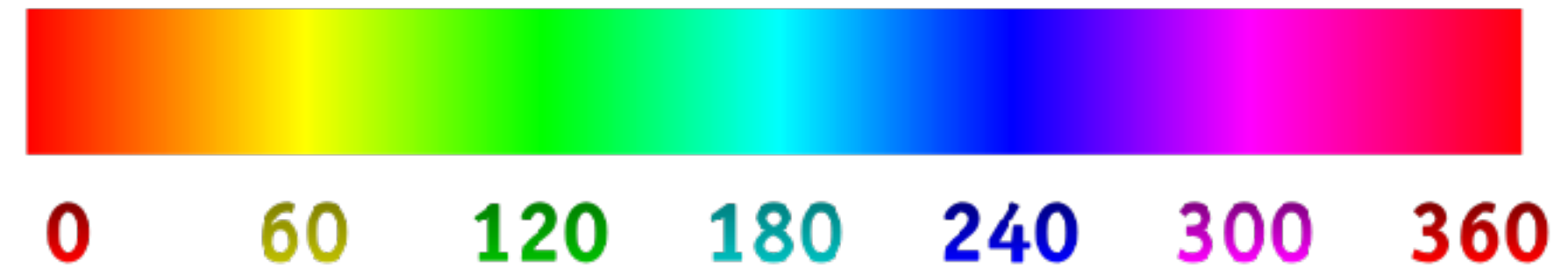
what shape they are

Color breaks camouflage

Tells about material properties (judging quality of food)

Dimensions of Color

Hue



Saturation

The purity of a color



Different Saturation, medium Value

Value (Luminance, Brightness)

lightness or darkness of a color

high saturation colors have medium values
values



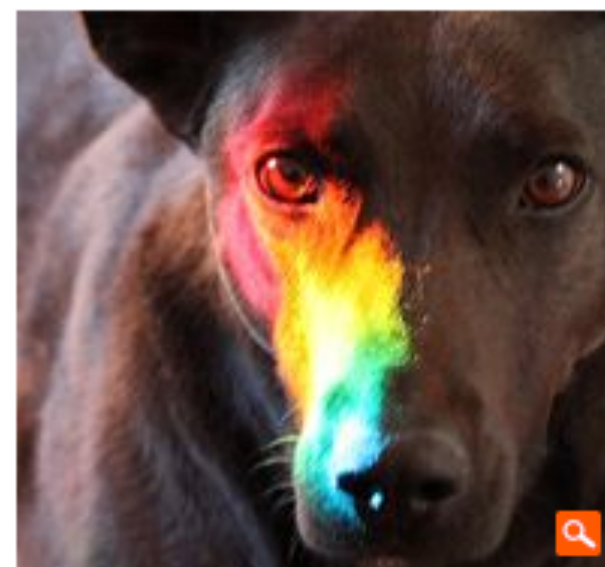
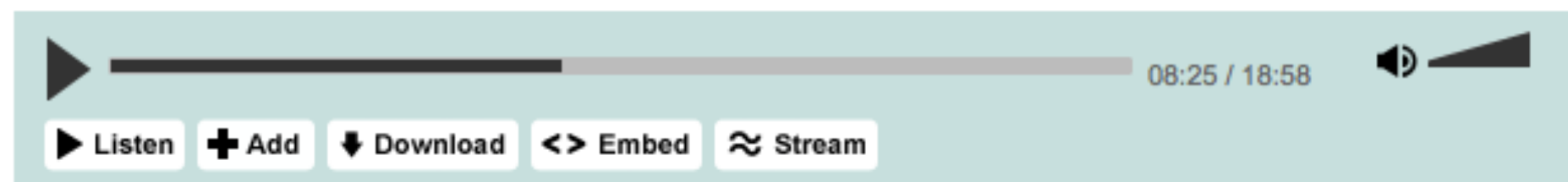
Different Values, low Saturation



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Rippin' the Rainbow a New One

« Back to Episode



(jared/flickr/CC-BY-2.0)

We tear into this show with a dark scene from 1665. A young Isaac Newton, hoping to ride out the plague by heading to the country to puzzle over the deep mysteries of the universe, finds himself wondering about light. And vision. He wants to get to the bottom of where color comes from—is it a physical property in the outside world, or something created back inside your eyeball somewhere? **James Gleick** explains how Newton unlocked the mystery of the rainbow. And, as **Victoria Finlay** tells us, sucked the poetry out of the heavens.

Jonah Lehrer restores some of the lost magic by way of Goethe—who turned a simple observation into a deep thought: even though color starts in the physical world, it is finished in our minds.

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>> Download the hit podcast.

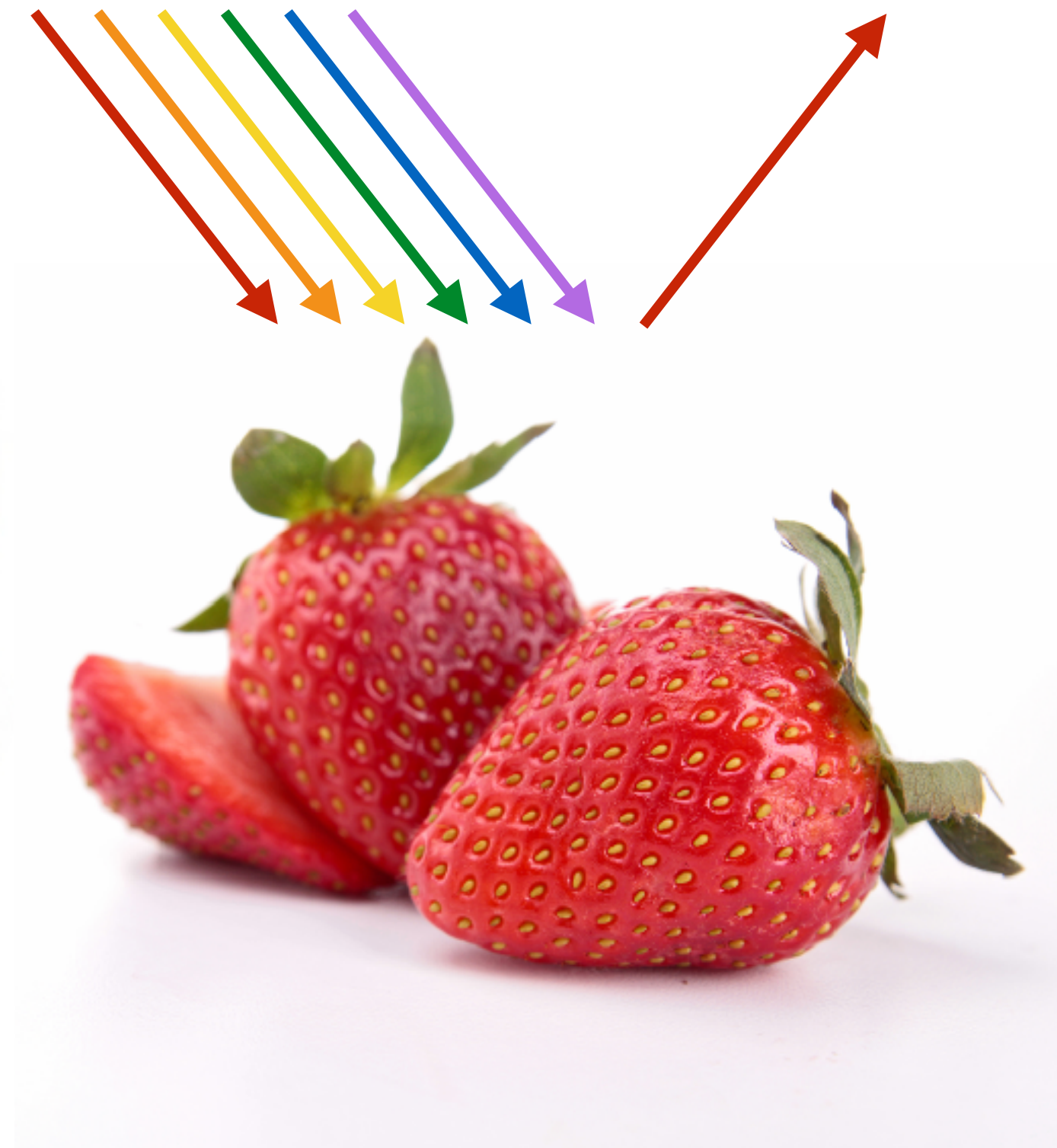
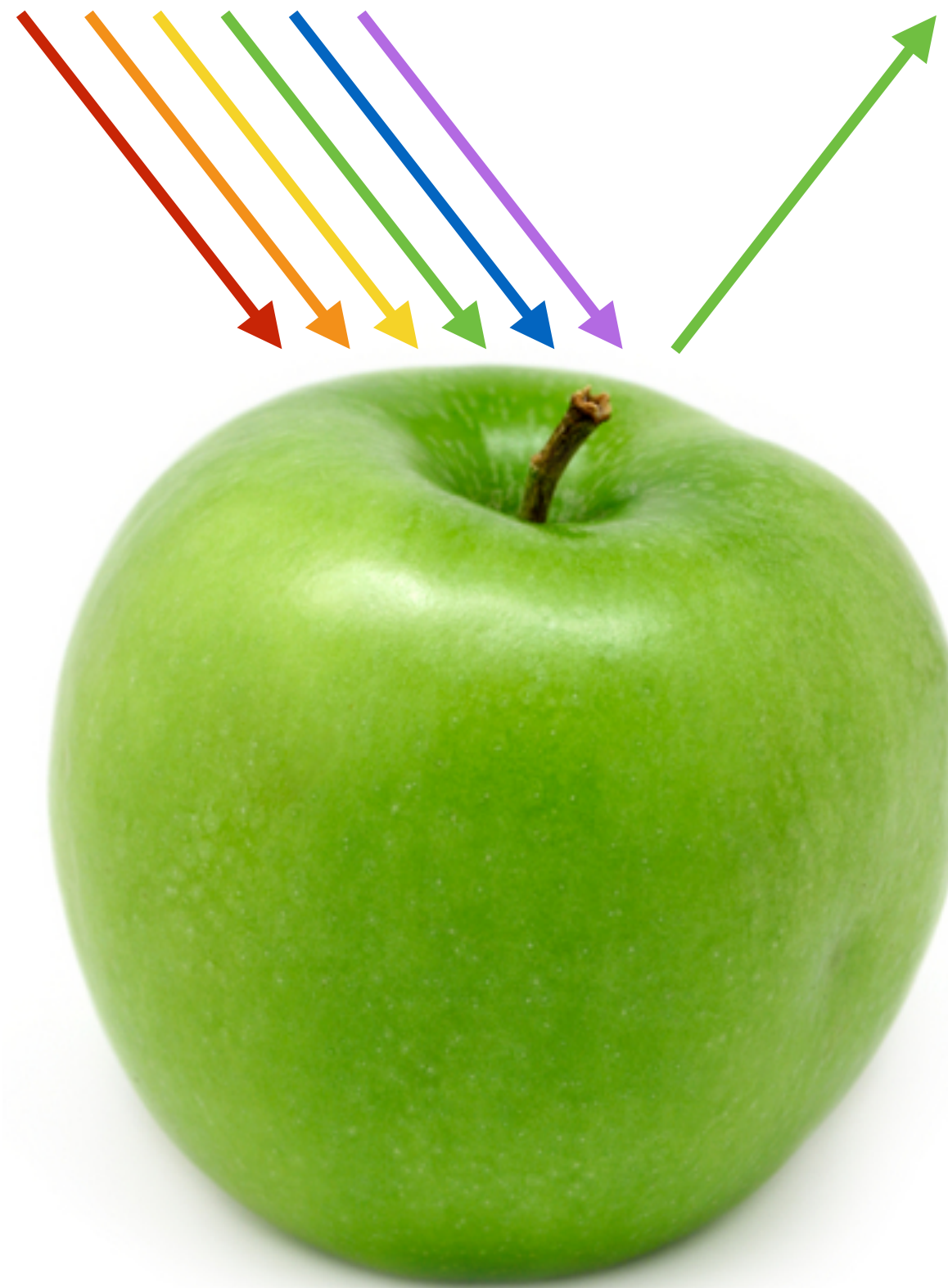
The Most

Viewed | Listened | Commented

- ▶ If You're Born In The Sky, What's Your Nationality? An Airplane Puzzler
- ▶ Cities
- ▶ Hello
- ▶ Roadways You Can Install Like Throw Rugs
- ▶ 9-Volt Nirvana
- ▶ Galapagos
- ▶ Glenn Gould In Rapture
- ▶ Black Box

The role of objects

real light is more than a single wavelength:



what are the primary colors?

- 1.red, green, blue
- 2.red, yellow, blue
- 3.orange, green, violet
- 4.cyan, magenta, yellow
- 5.all of the above

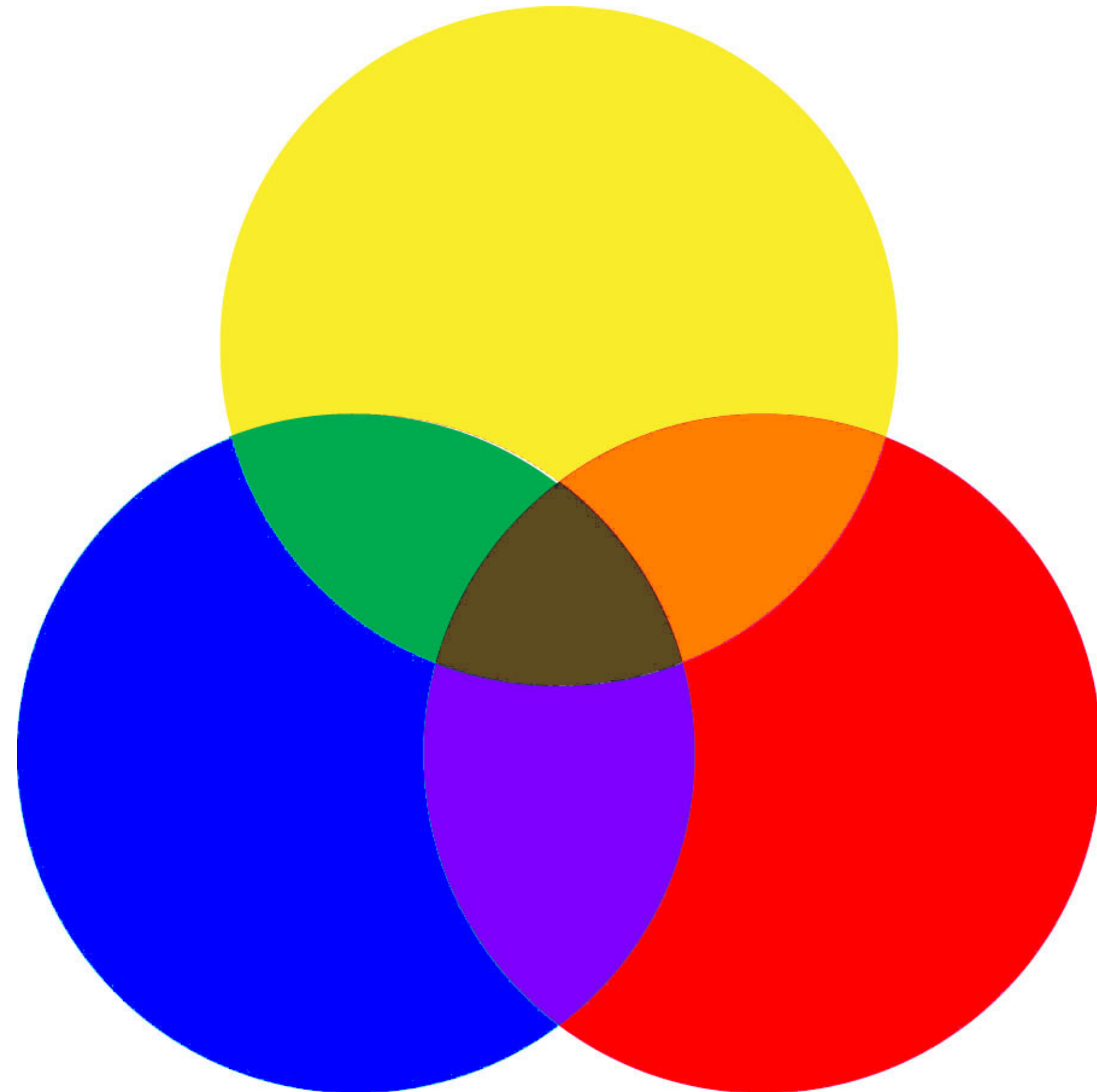
paint mixing

physical mixing of opaque
paints

primary: RYB

secondary: OGV

subtractive



ink mixing

subtractive mix of transparent inks

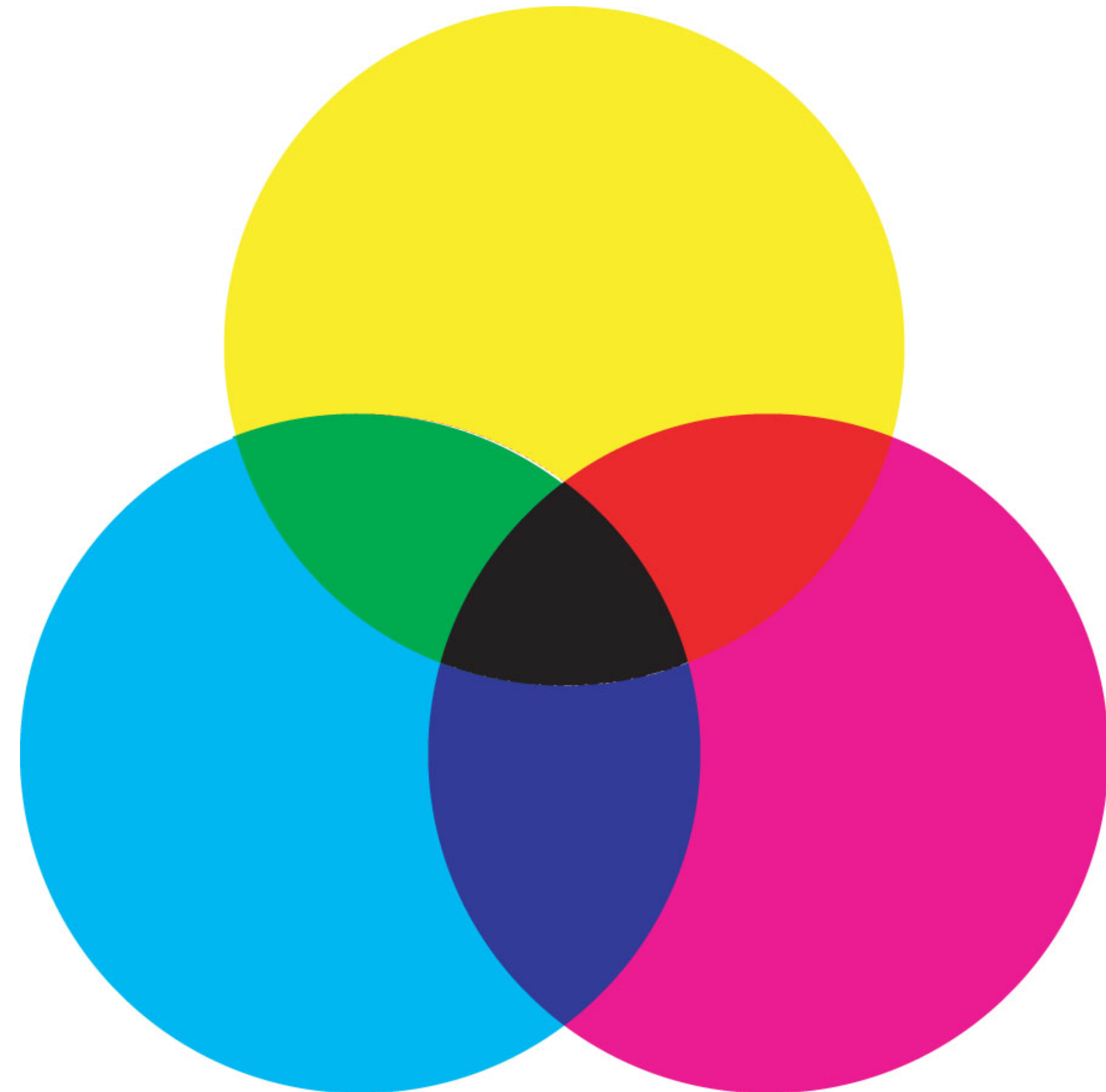
primary: CMY

secondary: RGB

approx. black = $C+M+Y$

true black = $C+M+Y+K$

subtractive



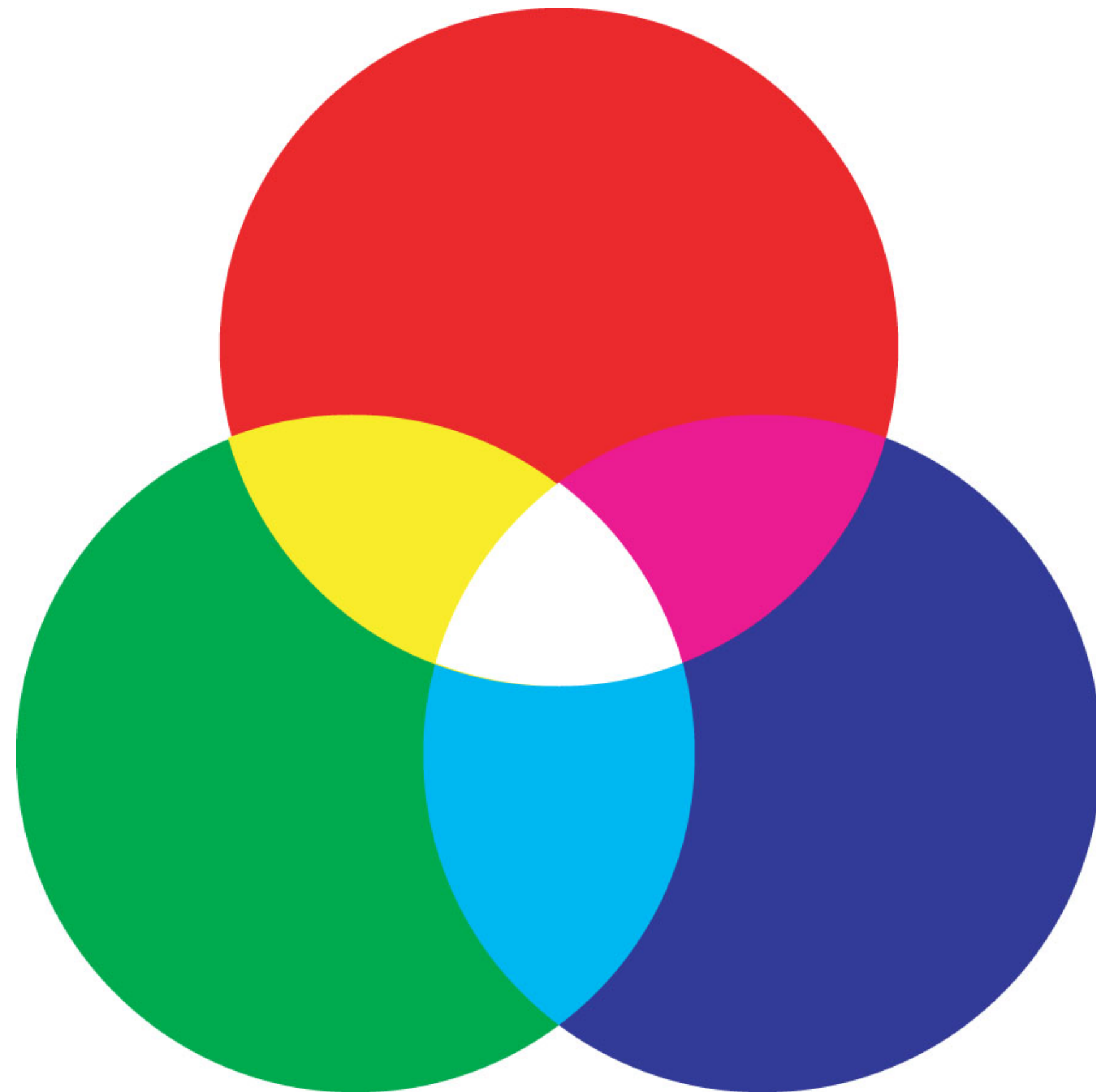
light mixing

additive mix of colored lights

primary: RGB

secondary: CMY

additive

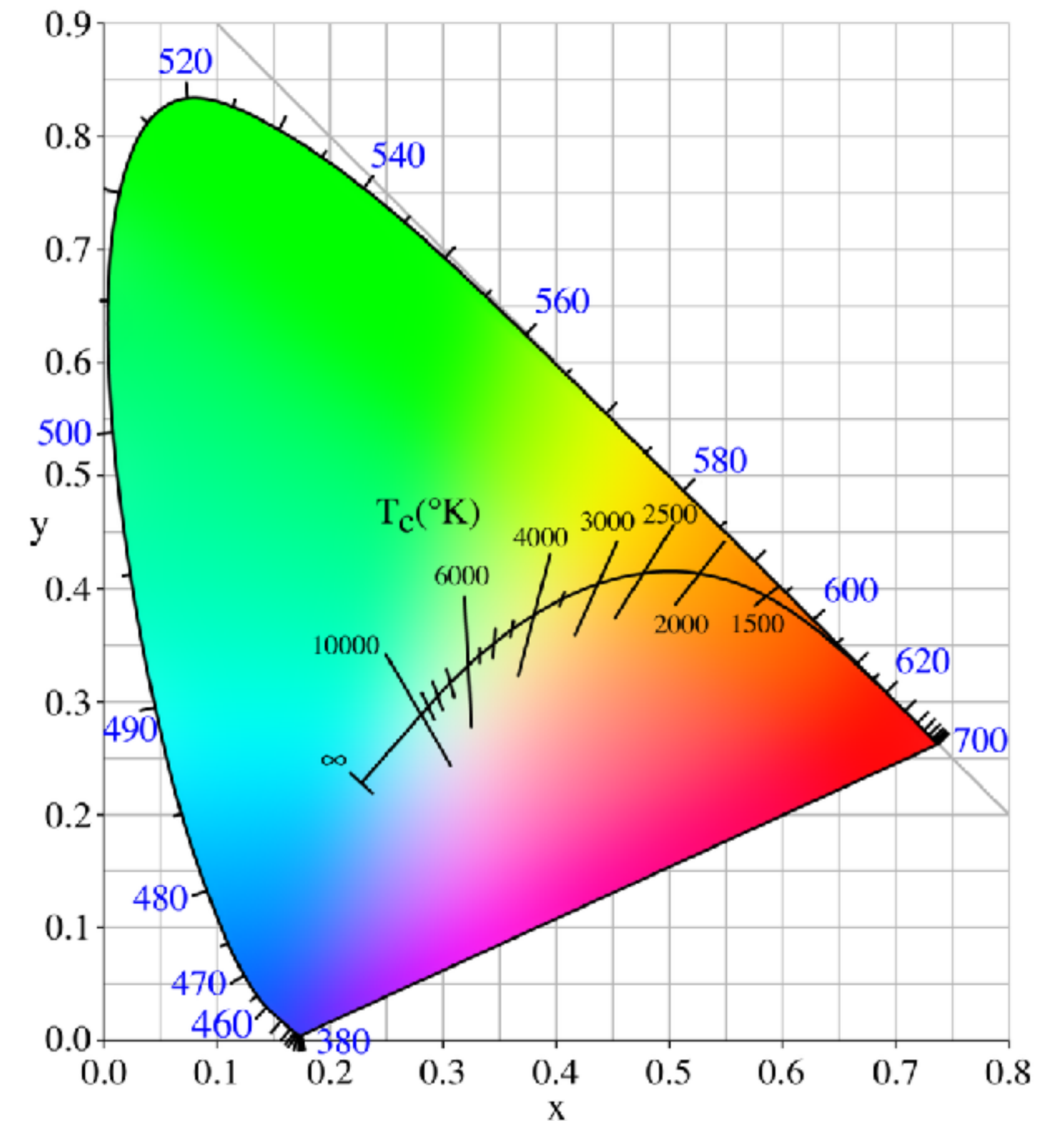


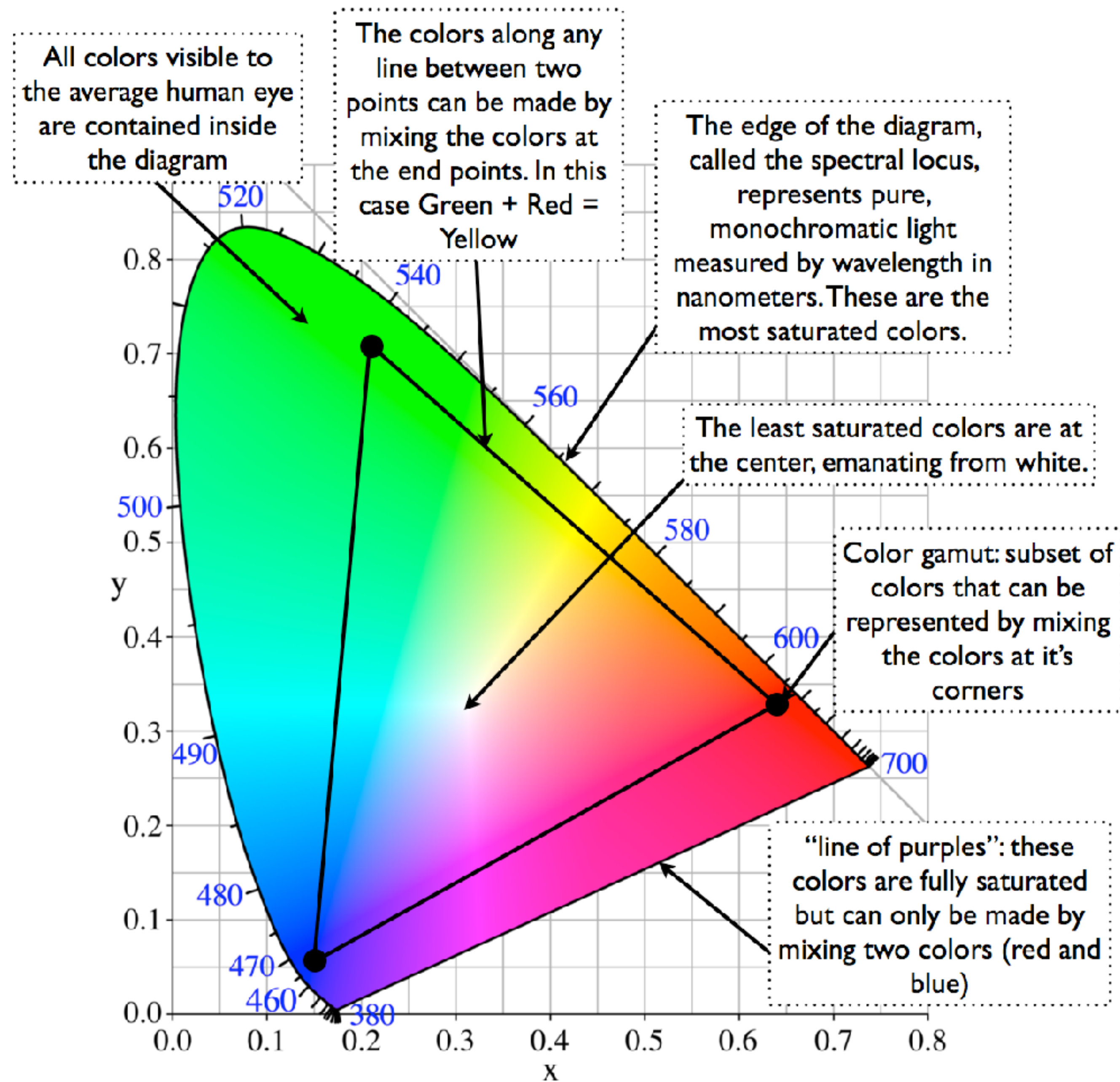
CIE Color Model

Chromaticity Diagram

Specifies color by hue and saturation

Pure colors of visible spectrum along the curve (wavelength)





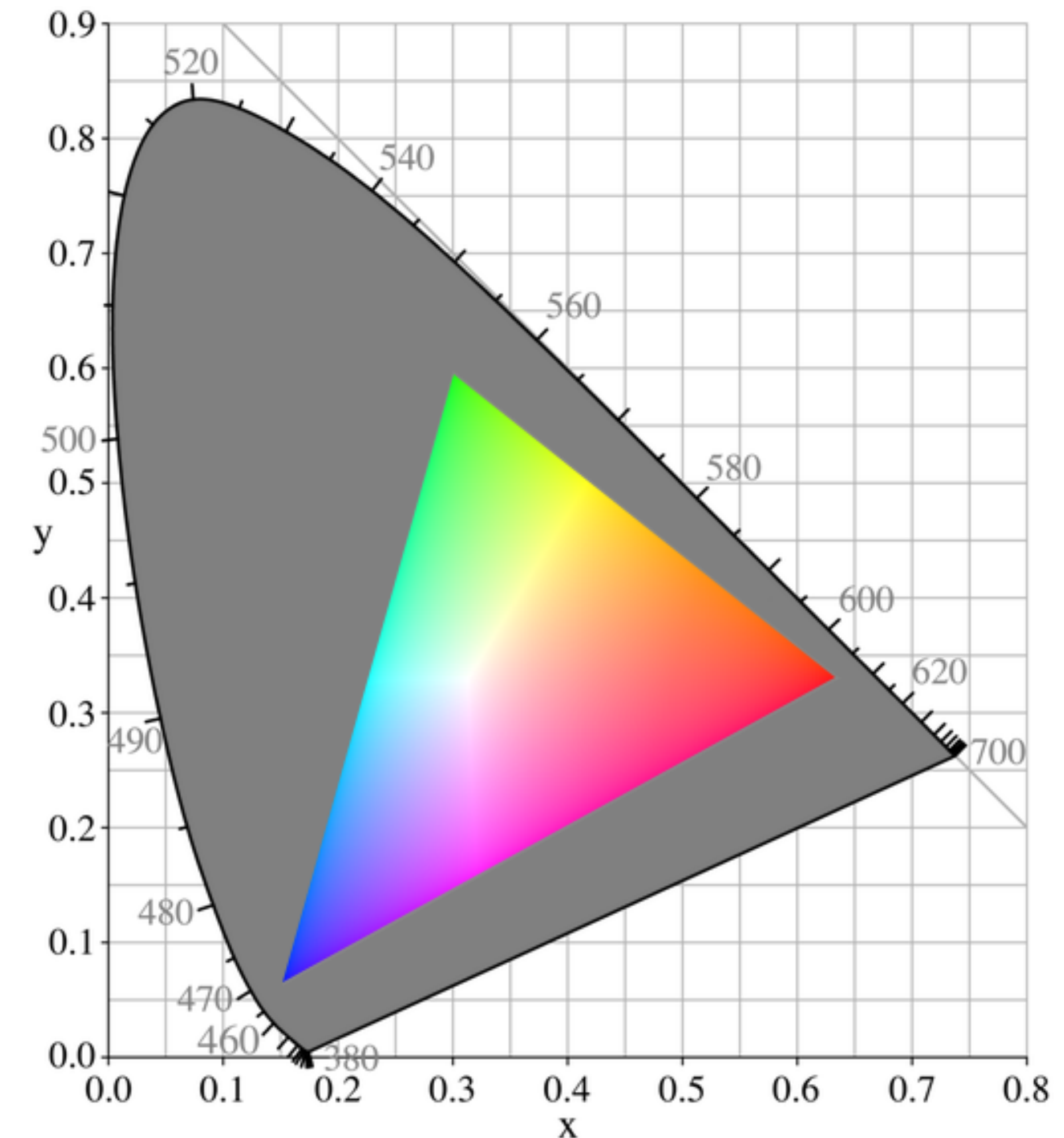
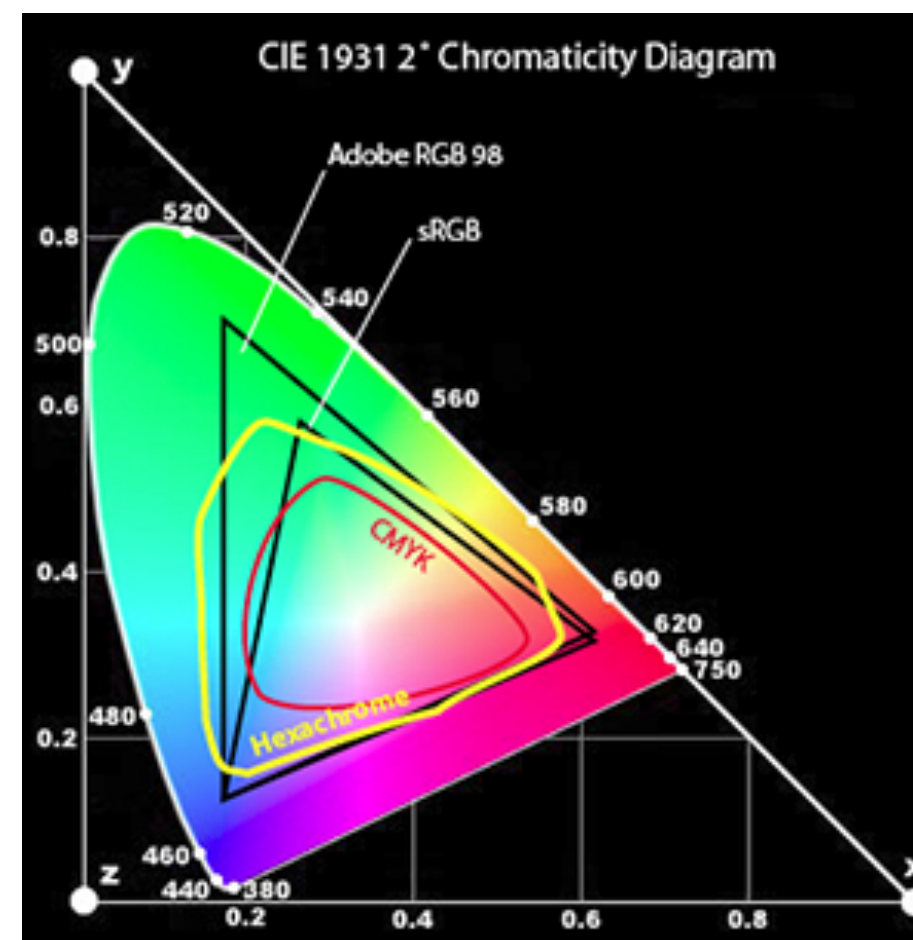
Anatomy of a CIE Chromaticity Diagram

Gamut

Set of all colors that can be produced by a device

Area between the primary colors used can be shown

Primaries are arbitrary



What is a colormap?

specifies a mapping between color and values

categorical vs ordered

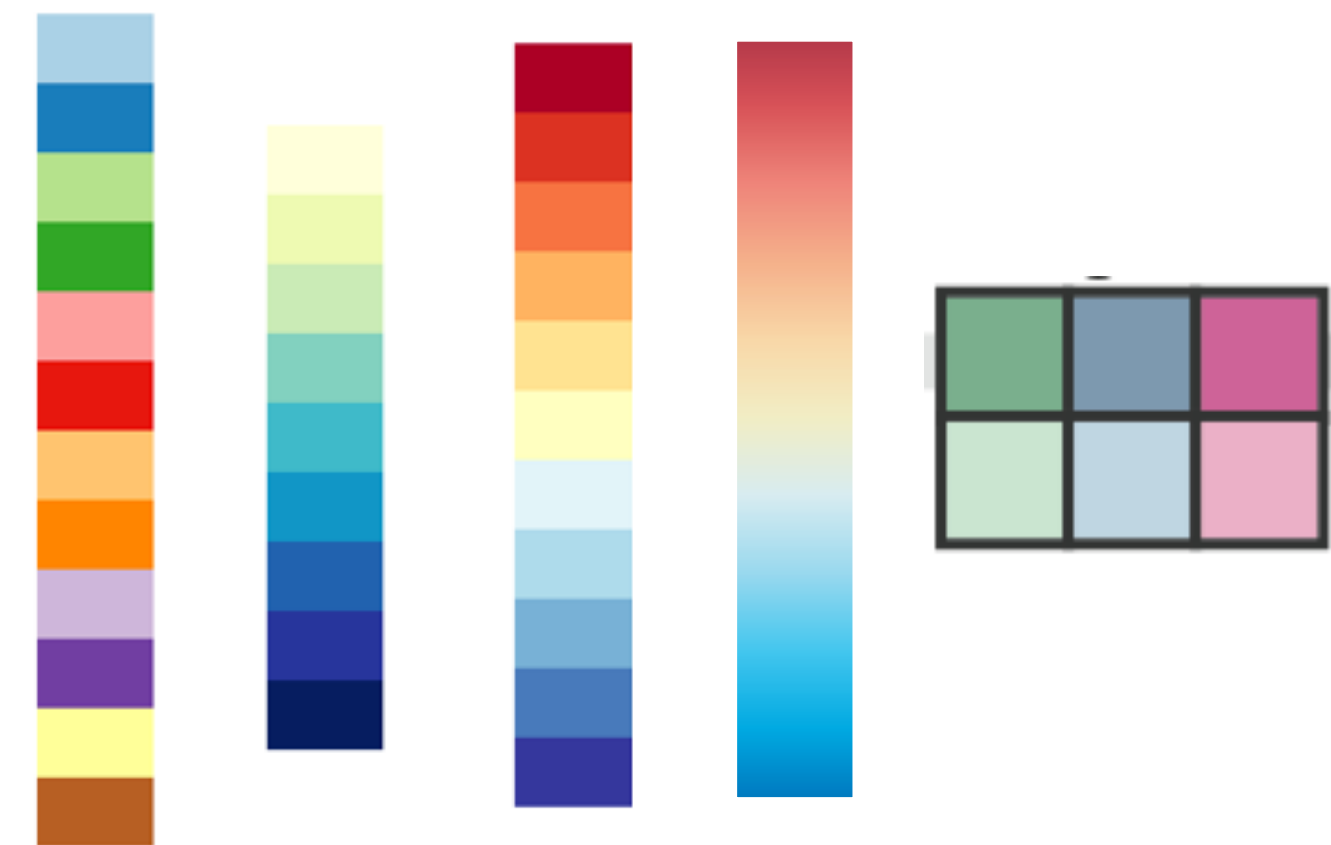
sequential vs diverging

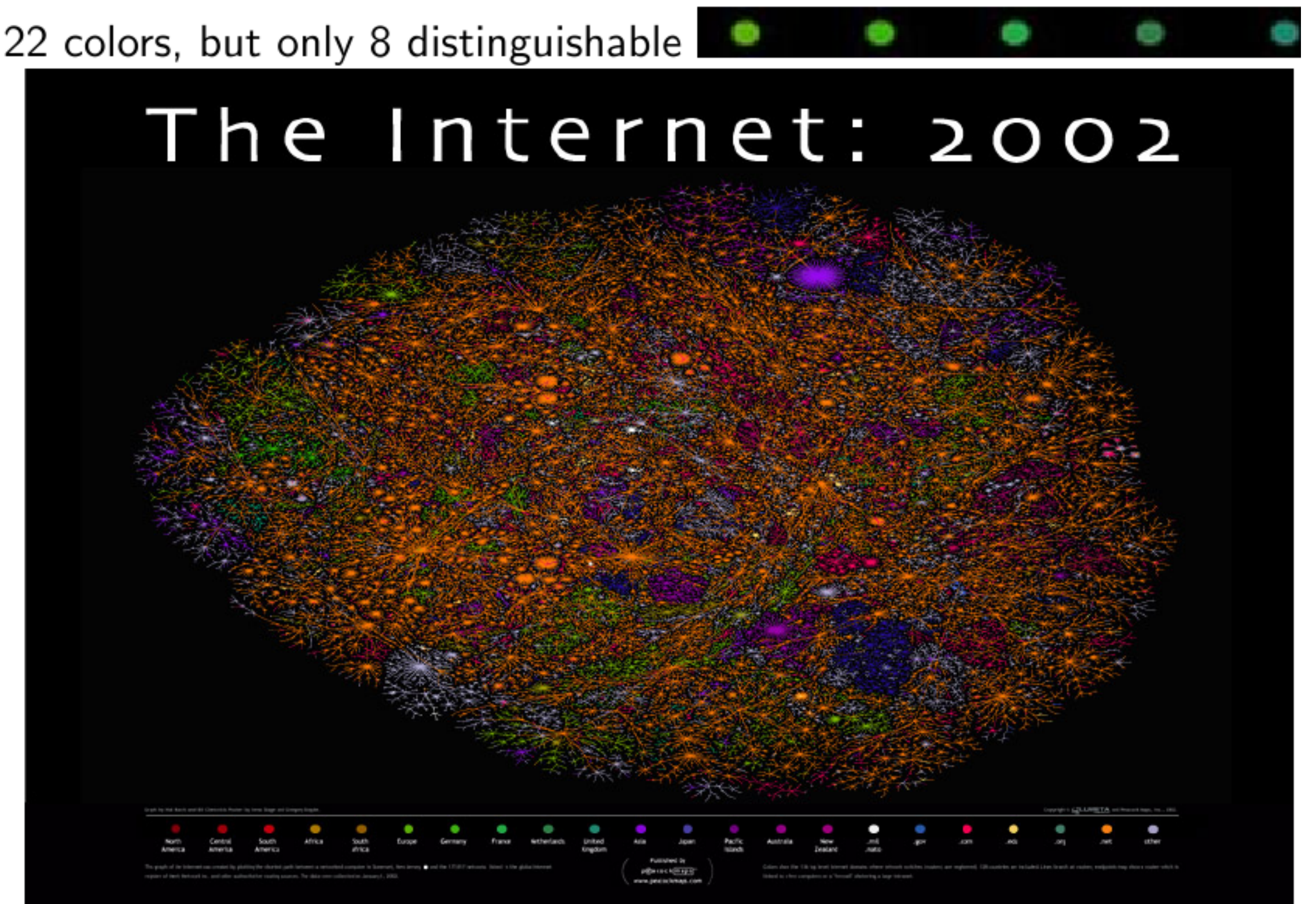
segmented vs continuous

univariate vs bivariate

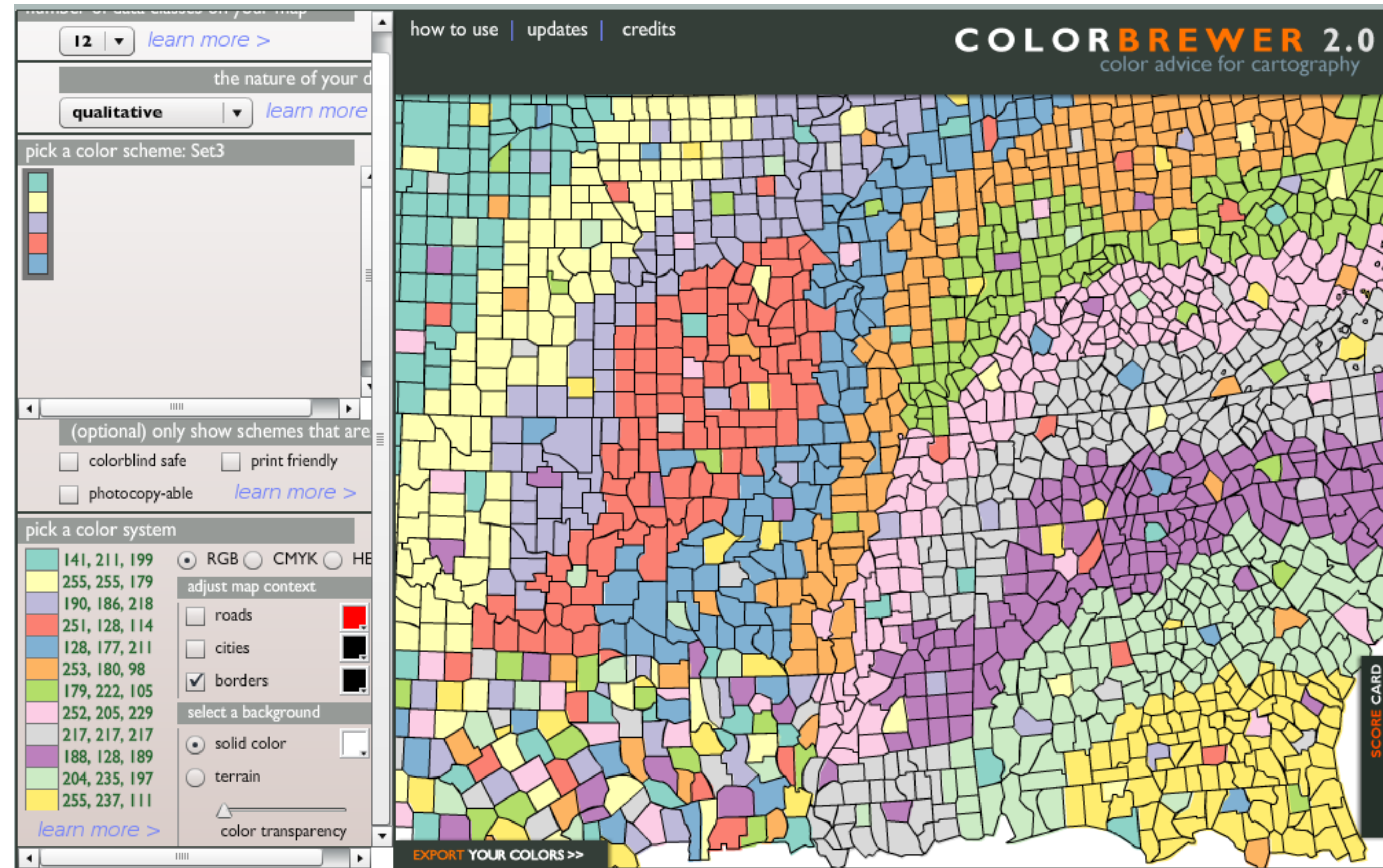
expressiveness: match colormap to attribute characteristics!

$[0, 8]$ →





Application: Labeling



Carefully designed color scheme for 12 colors [colorbrewer]

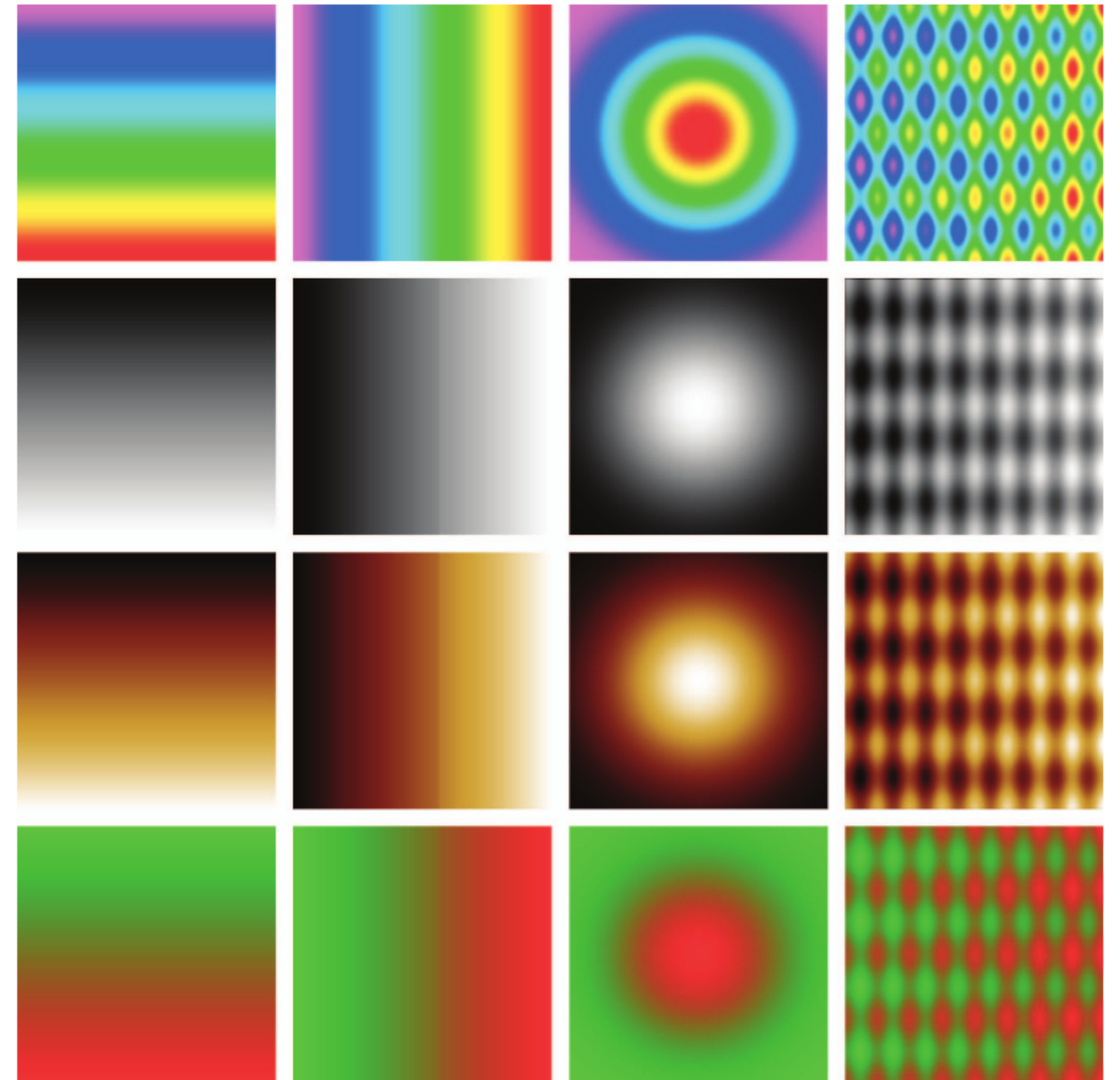
Quantitative Data Vis

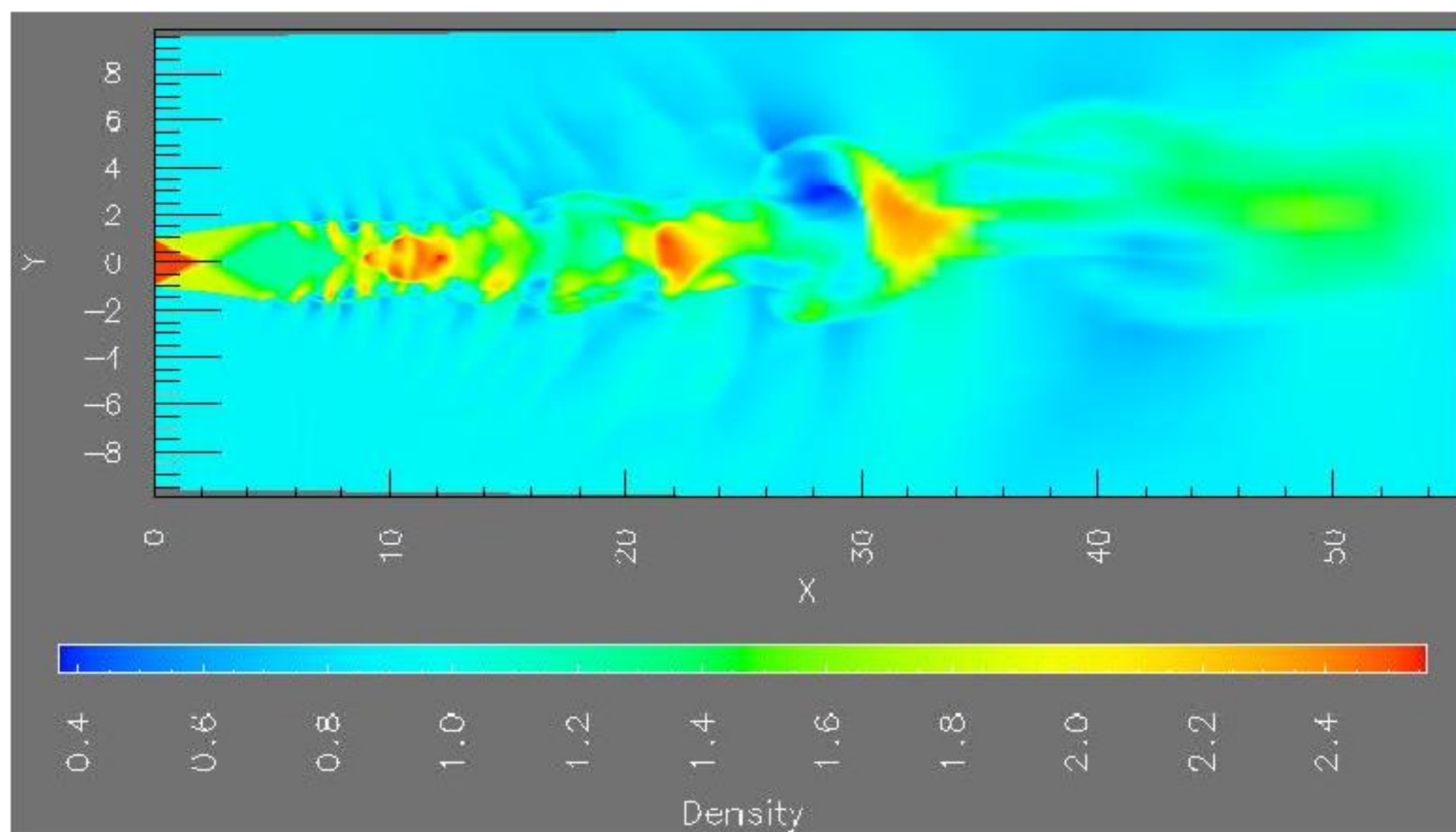
use value

saturation works but not as good

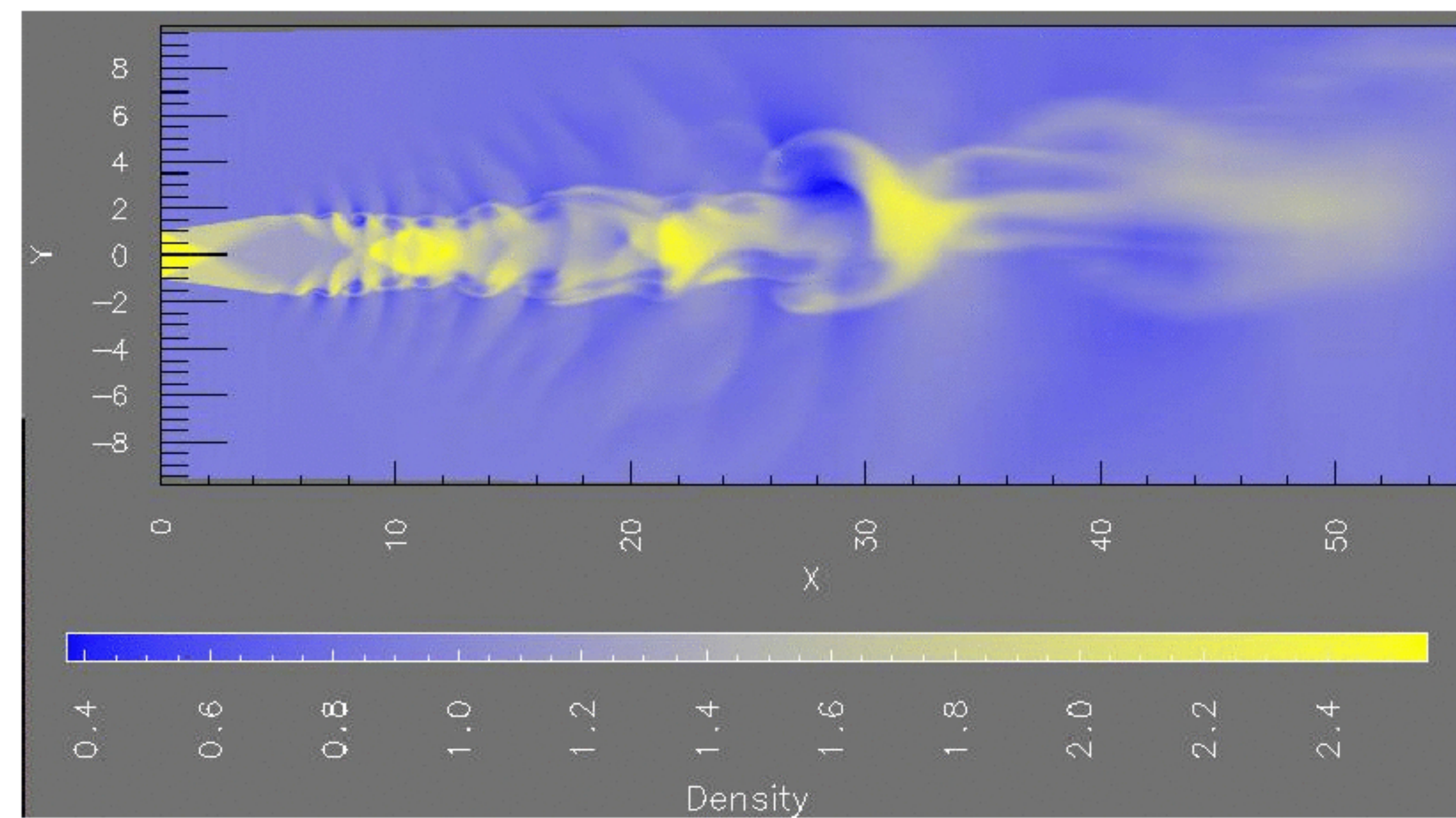
don't use hue!

Danger: rainbow color map



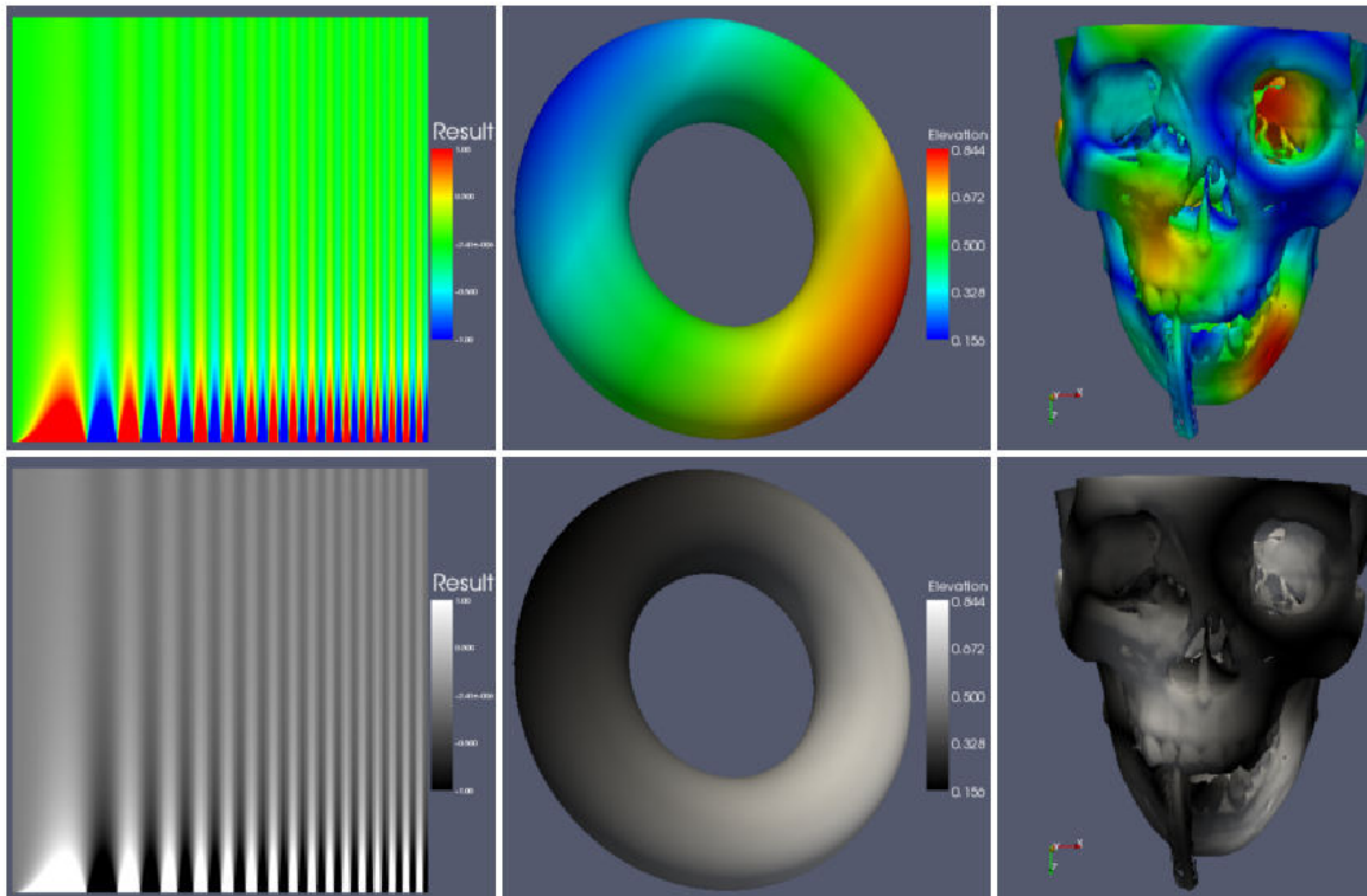


[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color? <http://www.research.ibm.com/people/l/lloydt/color/color.HTM>]

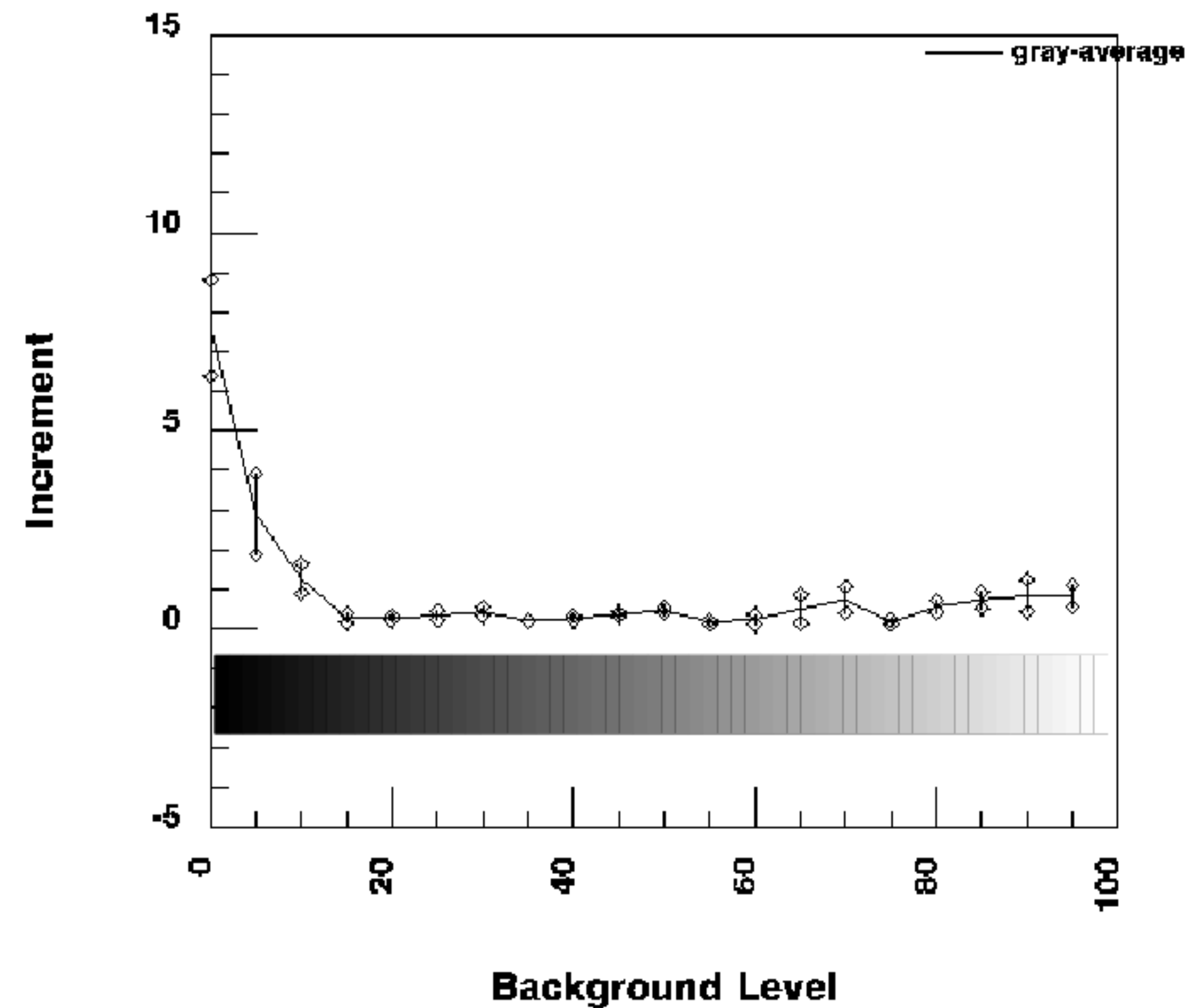
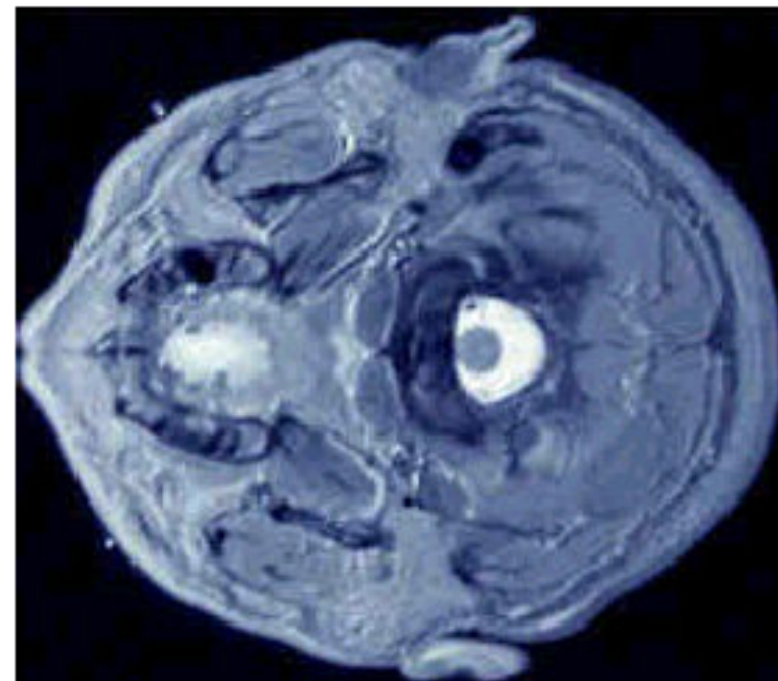


[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm]

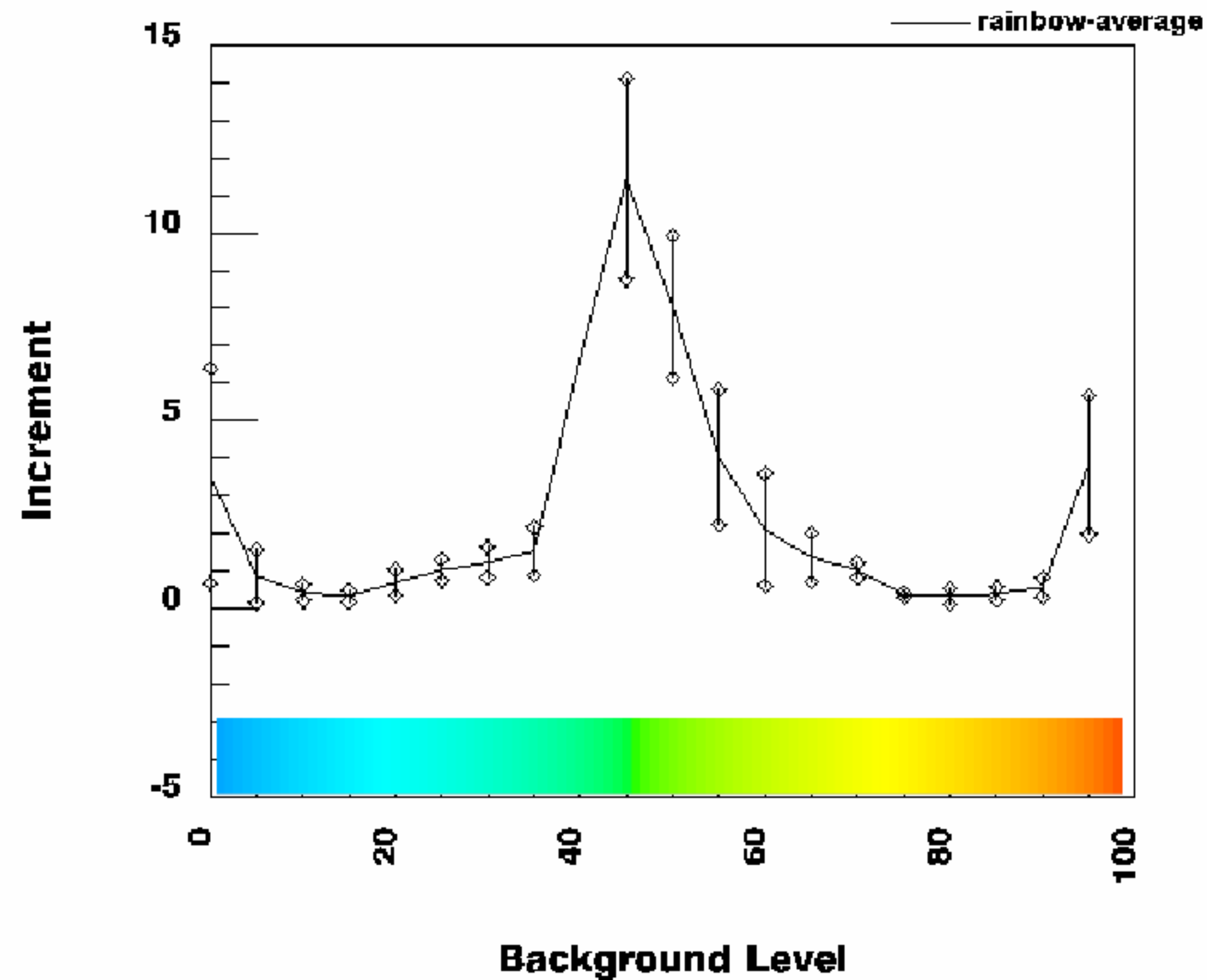
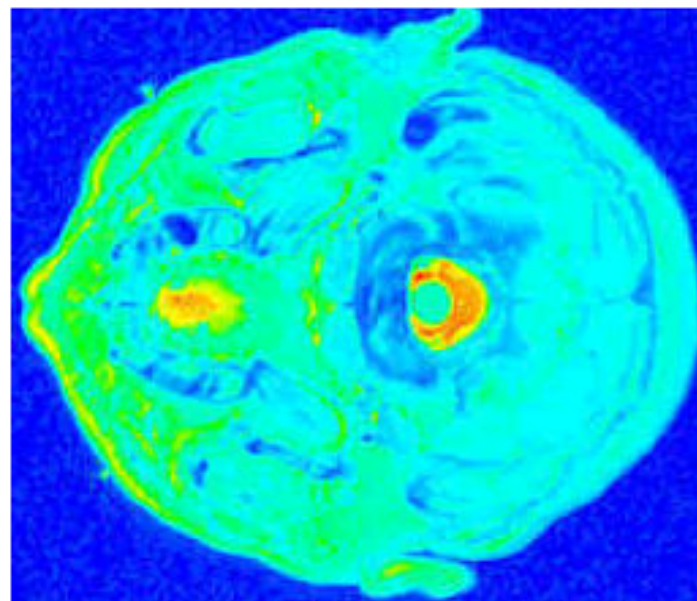
Rainbow vs. Value Color map



Increment Threshold Experiment: Luminance



Increment Threshold Experiment: Rainbow Color Scale



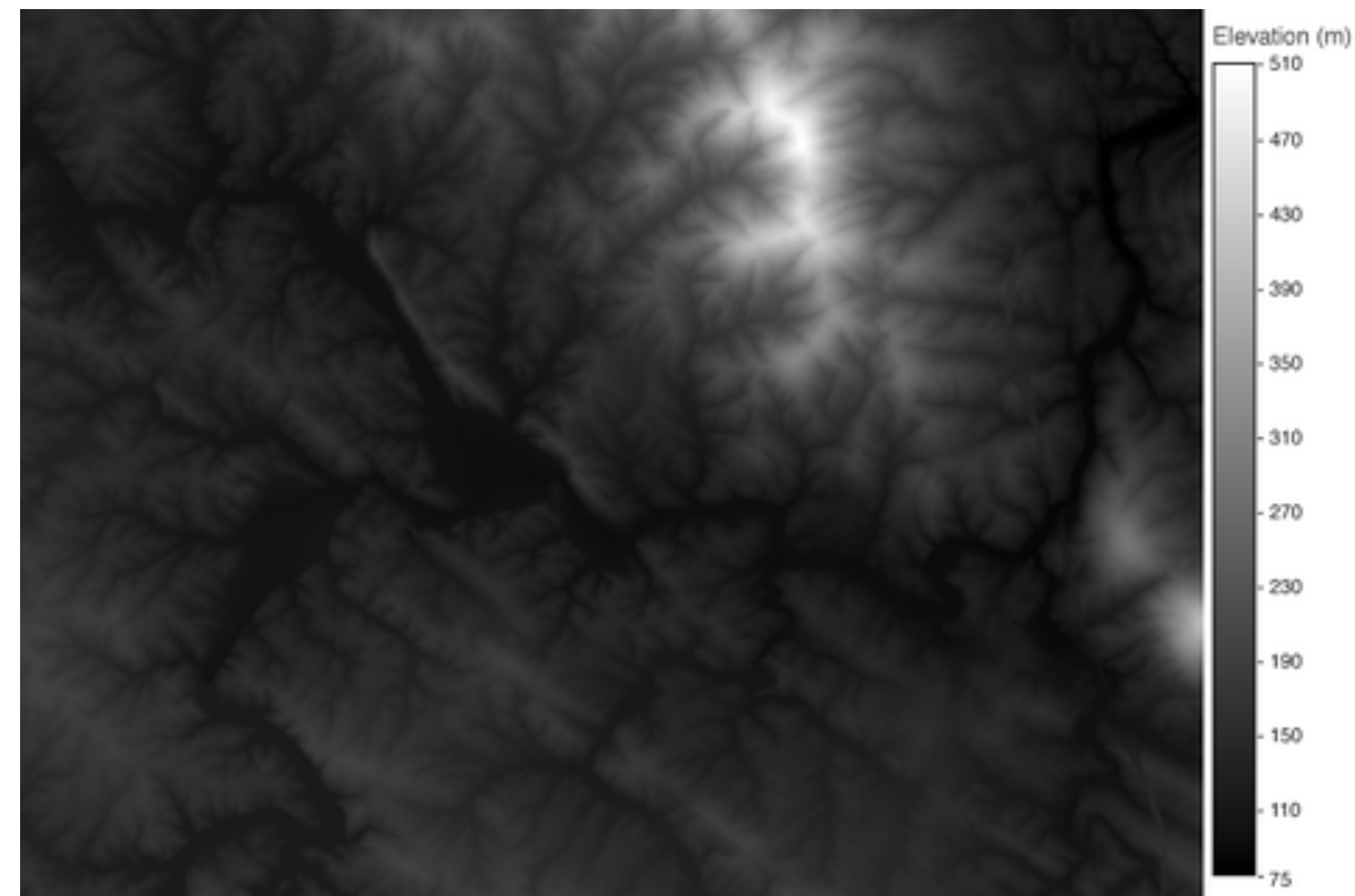
To bin or not to bin?

Study: what is faster? What is more accurate?

Example: Elevation

Continuous was faster

Binned was often more accurate



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

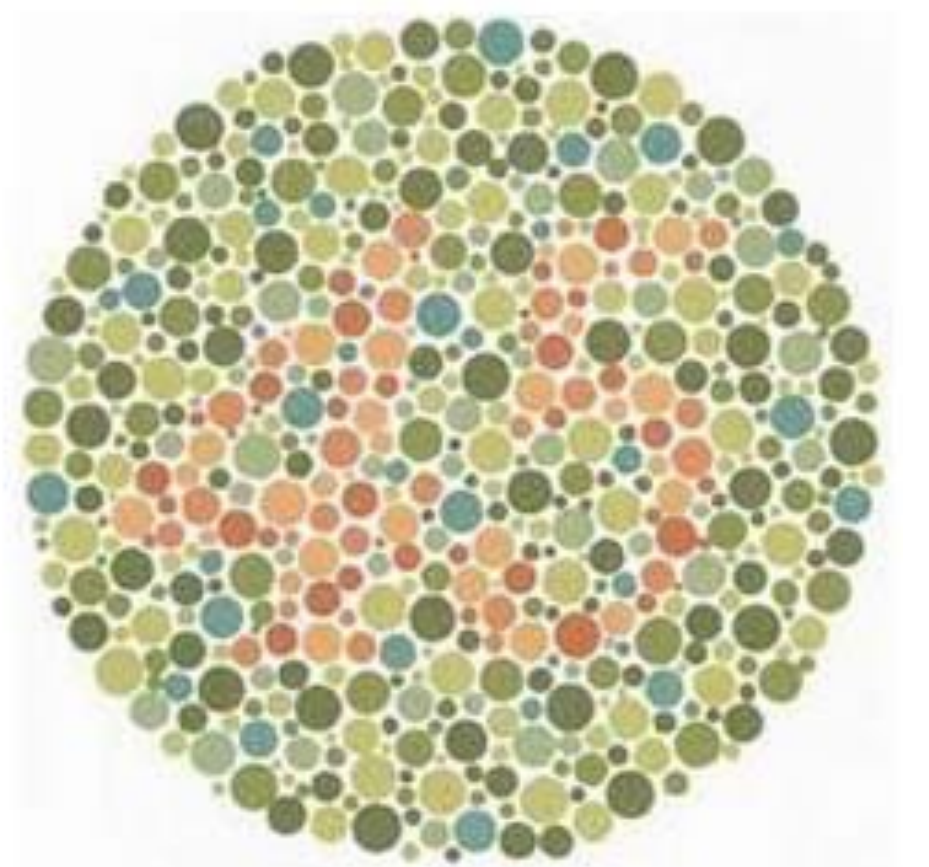
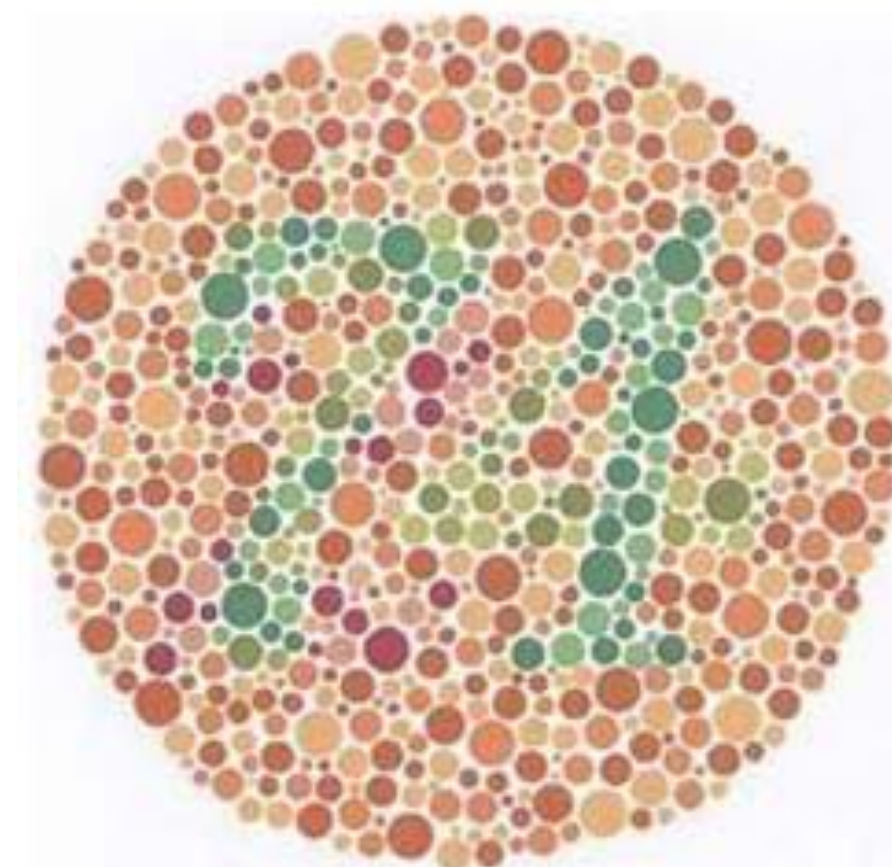
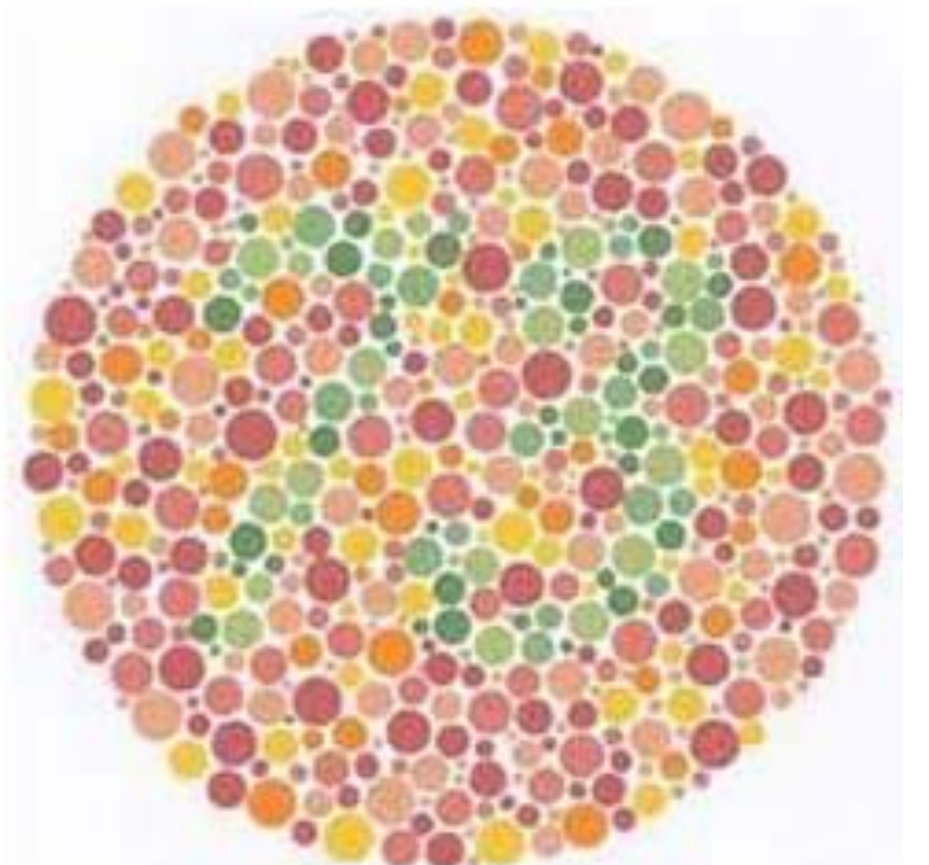
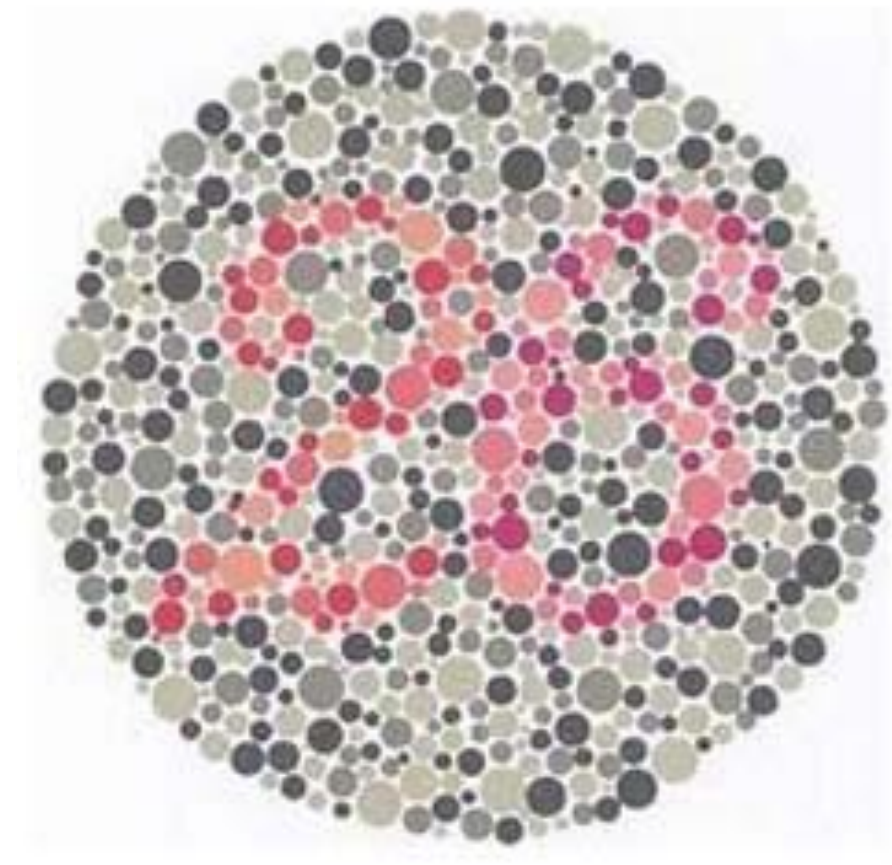
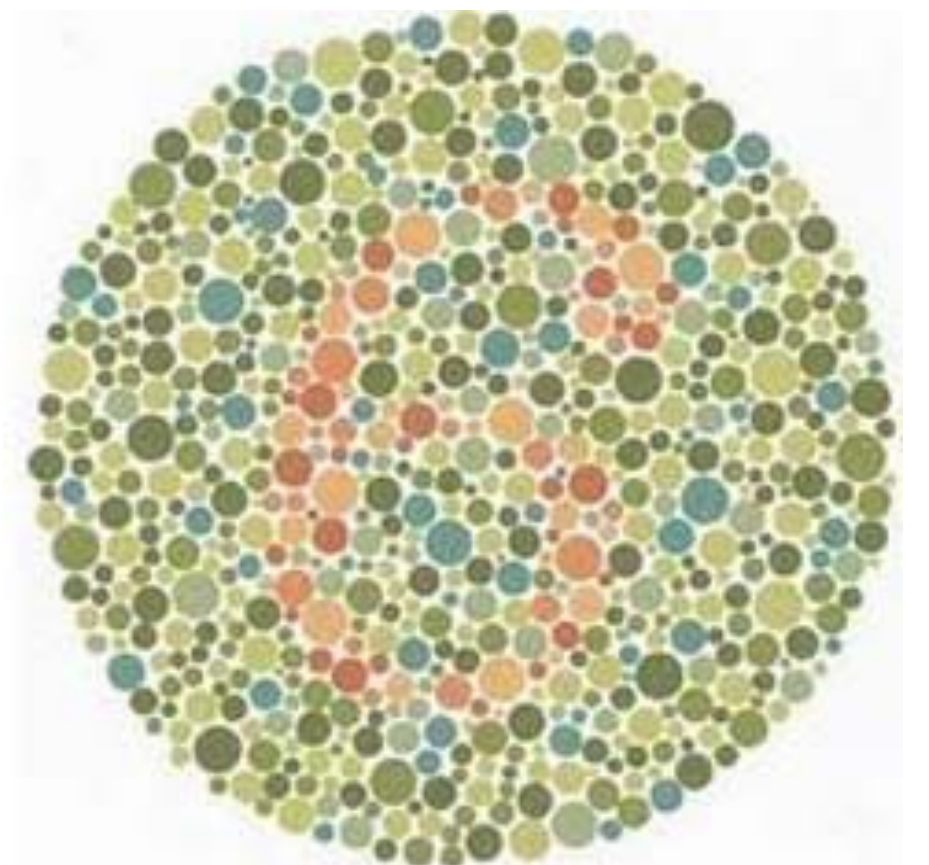
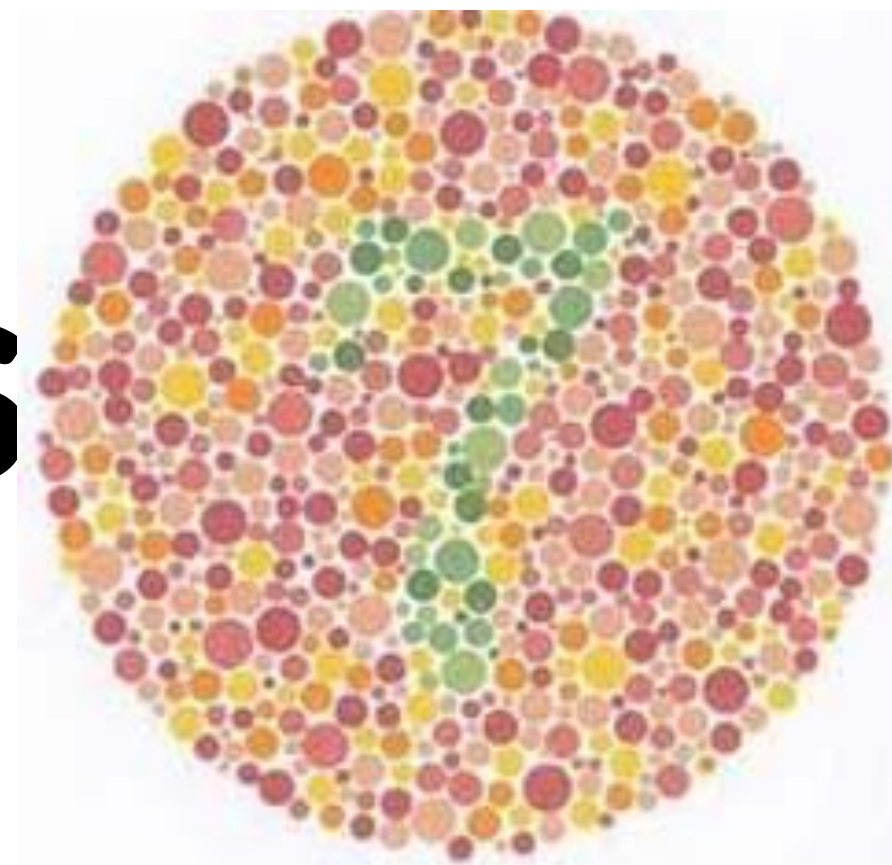
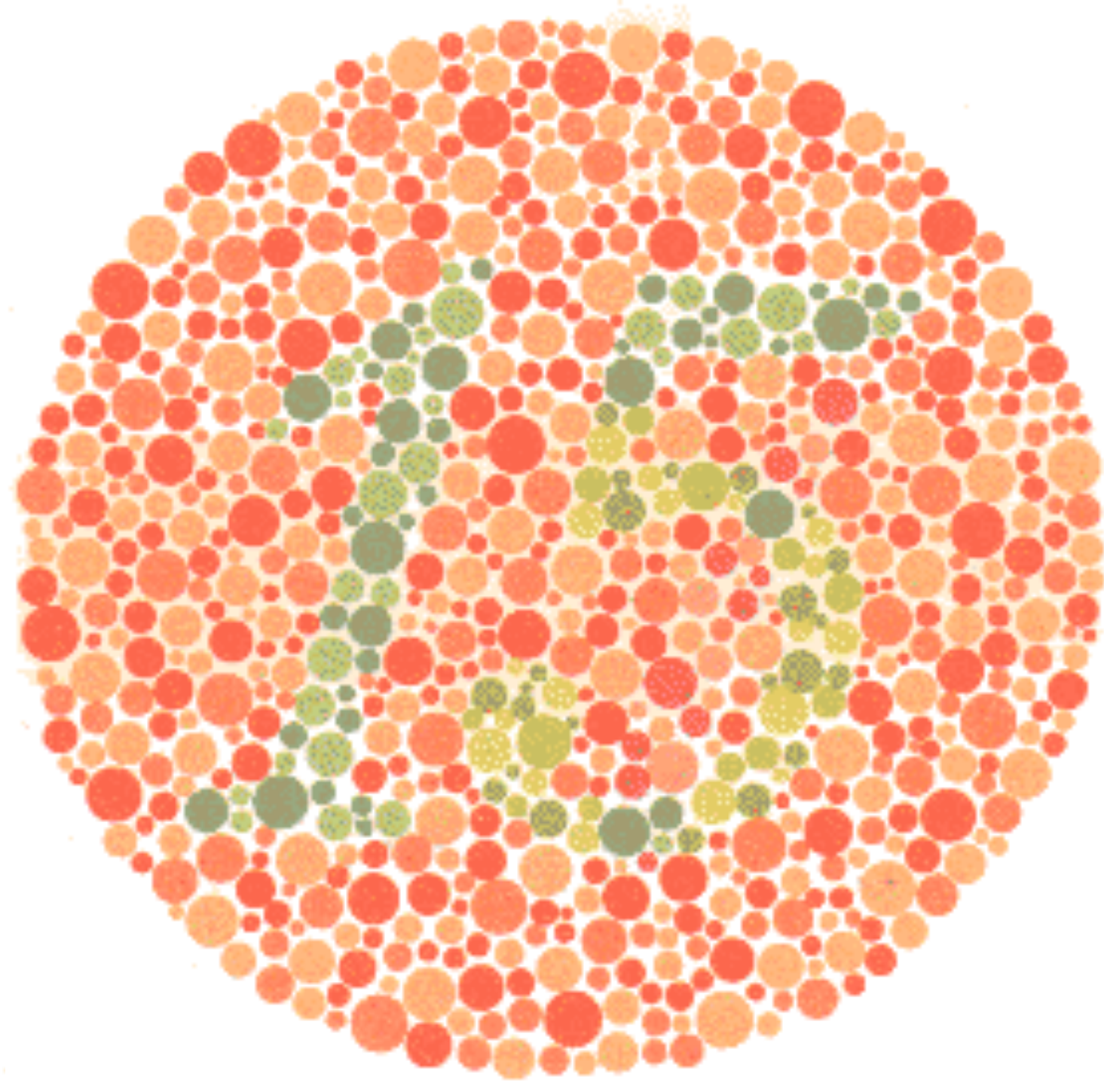
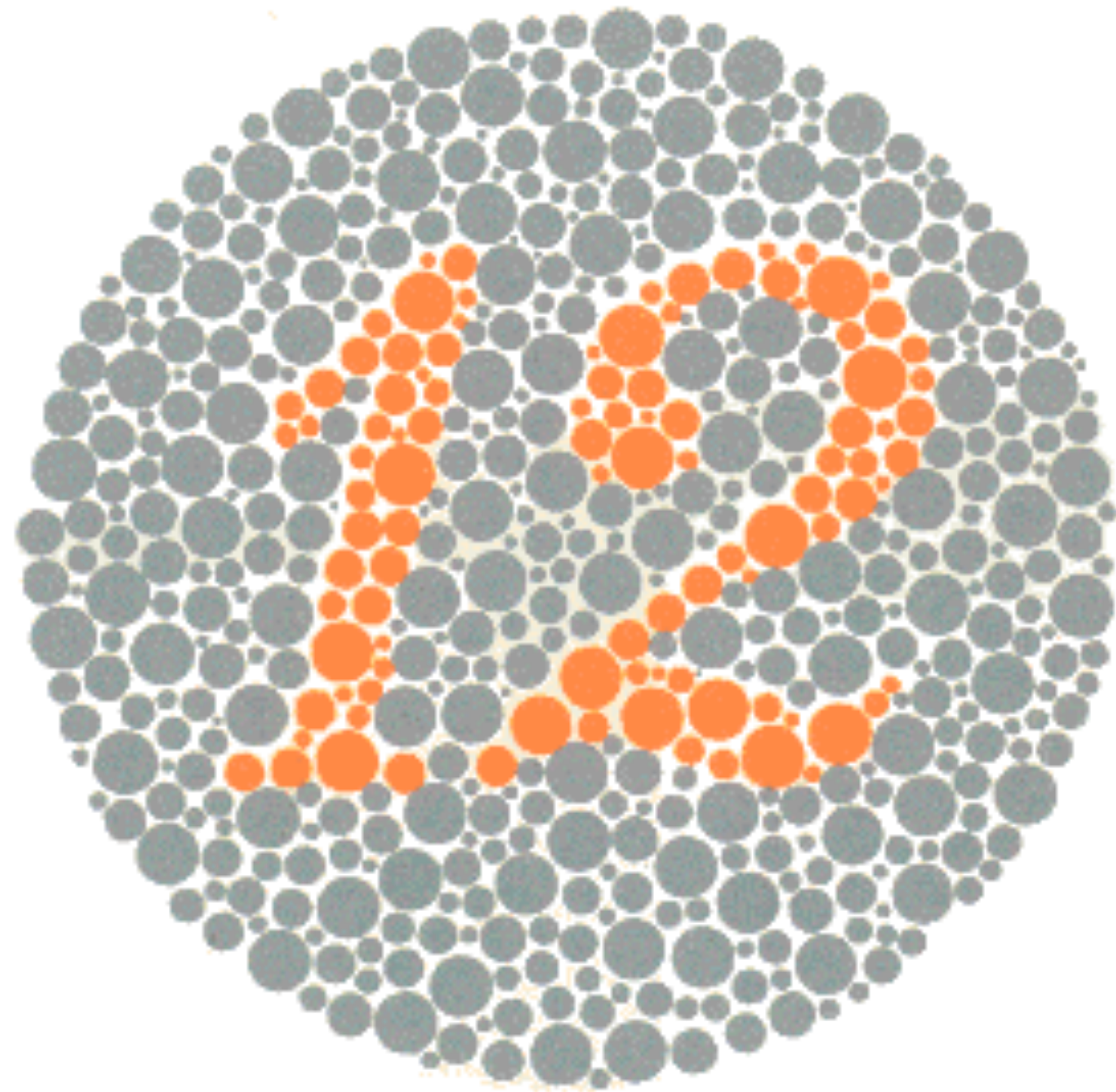


Deuteranopia (no green receptors)



Protanopia (no red receptors)

Color Blindness Tests



Color Blindness



Protanope

No L cones

Red / green
deficiencies



Deuteranope

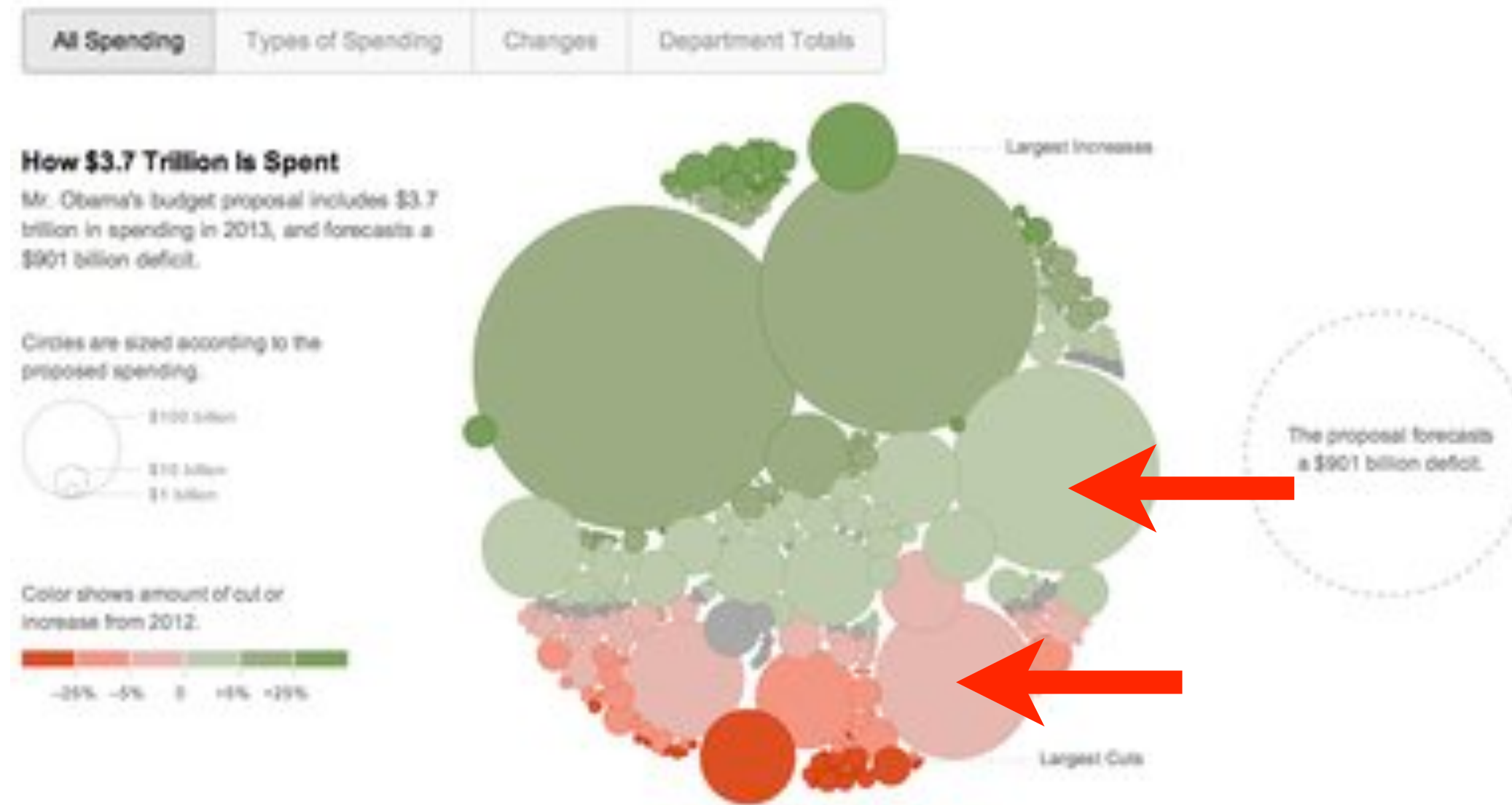
No M cones

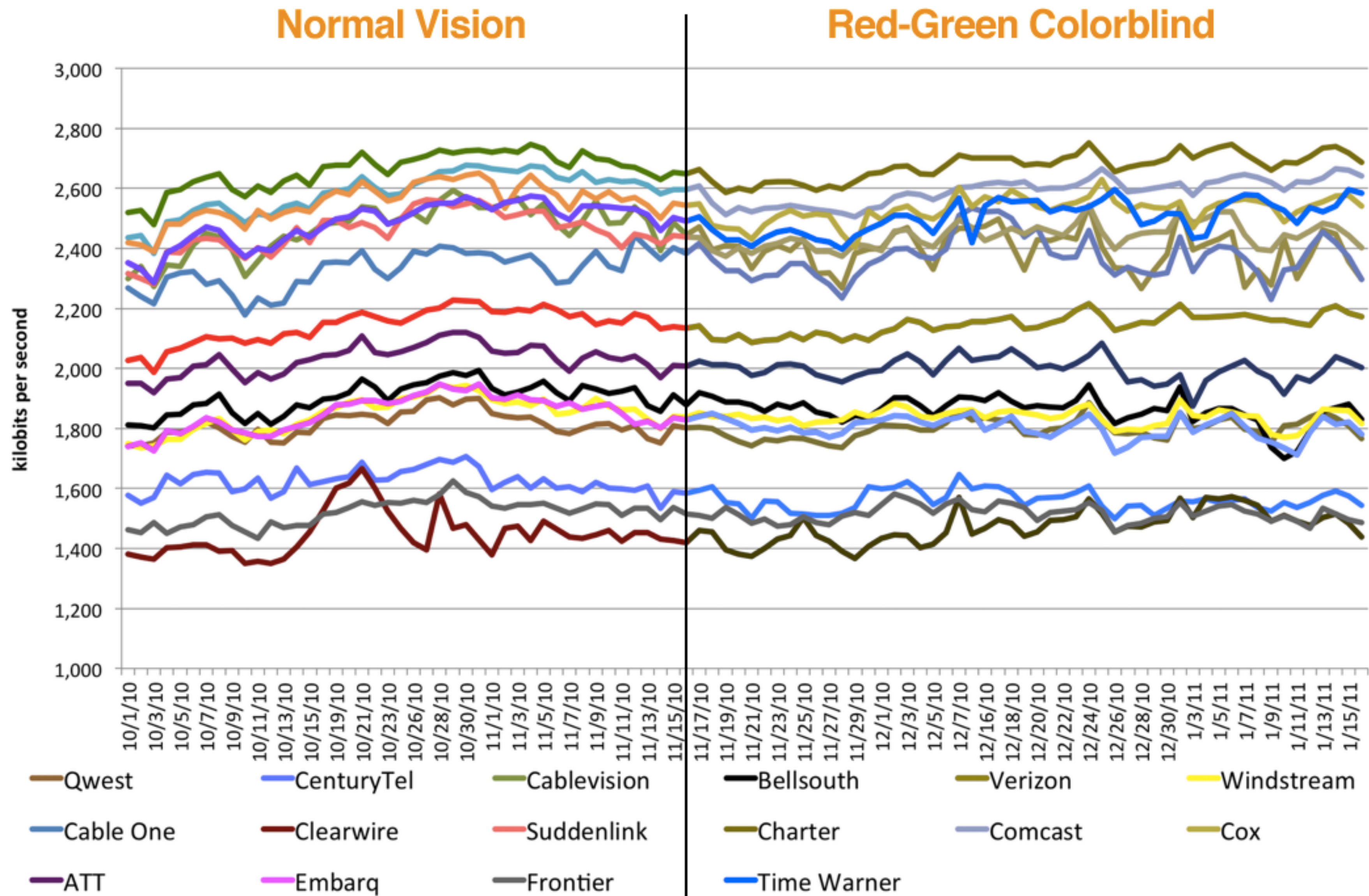


Tritanope

No S cones

Blue / Yellow
deficiency





Simulate Color Vision Deficiencies

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

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



The screenshot displays the Colblindor website, which is a resource for simulating color vision deficiencies. The header includes the Colblindor logo, social media icons, and a navigation menu with links to Home, CVD Essentials, Color Blindness Tests, Color Tools, and Contact. The main heading is "Coblis — Color Blindness Simulator". Below this, a paragraph explains the simulator's purpose: "If you are not suffering from a color vision deficiency it is very hard to imagine how it looks like to be colorblind. The Color BLindness Simulator can close this gap for you. Just play around with the sample picture or upload your own images. Please make sure that you just use JPG, GIF or PNG images with a size below 600kB." The simulator interface shows a selected image "overview.png" and a list of color vision deficiency options: 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, there is a search bar, a newsletter subscription form, and a "FREE Color Blind Check" section with a "Color Blind Test" button. At the bottom, there is a "CVD Categories" section and a Google Play store link.

Colblindor

Home ▾ CVD Essentials ▾ Color Blindness Tests ▾ Color Tools ▾ Contact

Coblis — Color Blindness Simulator

If you are not suffering from a color vision deficiency it is very hard to imagine how it looks like to be colorblind. The Color BLindness Simulator can close this gap for you. Just play around with the sample picture or upload your own images. Please make sure that you just use JPG, GIF or PNG images with a size below 600kB.

Search for: Search

Subscribe to News by Email: your email

CVD Simulator

Image:

☐ Normal Color Vision

☐ Red-Blind/Protanopia

☐ Green-Blind/Deuteranopia

☐ Blue-Blind/Tritanopia

☐ Red-Weak/Protanomaly

☐ Green-Weak/Deuteranomaly

☐ Blue-Weak/Tritanomaly

☐ Monochromacy/Achromatopsia

☒ Blue Cone Monochromacy

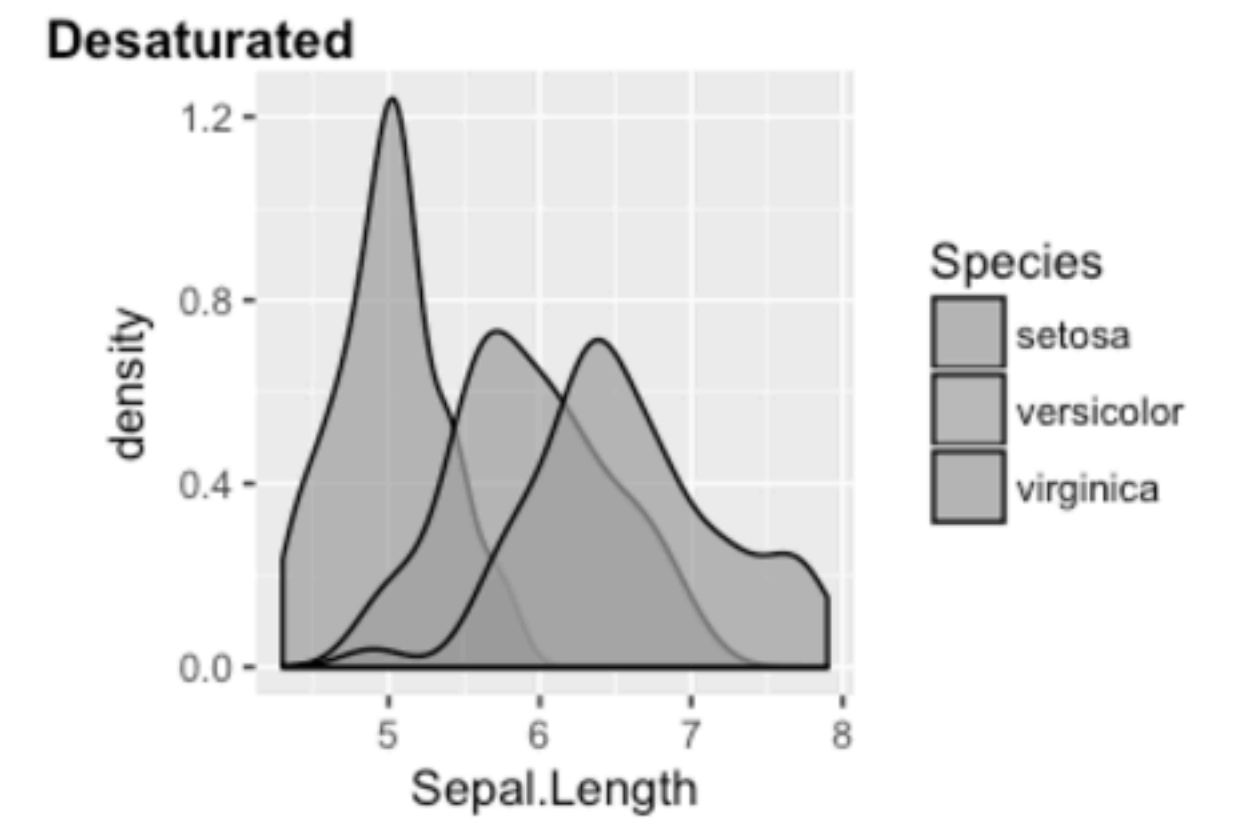
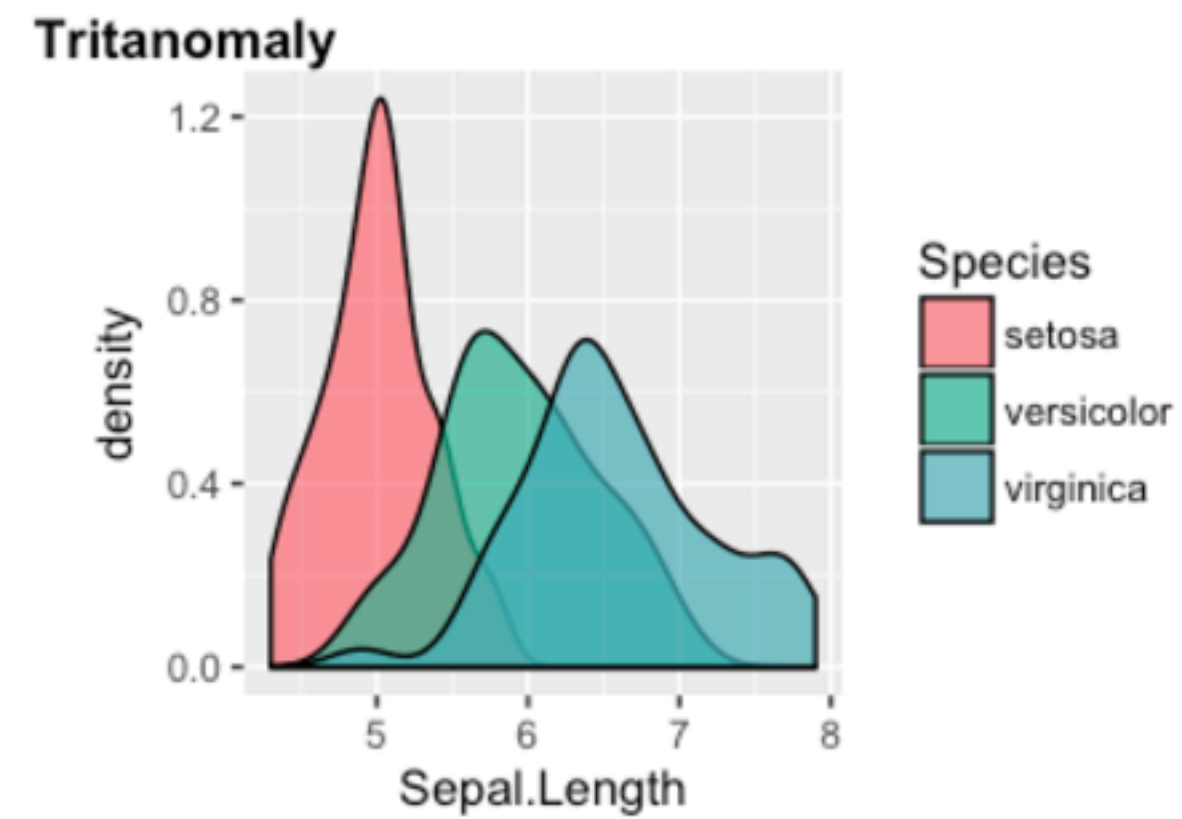
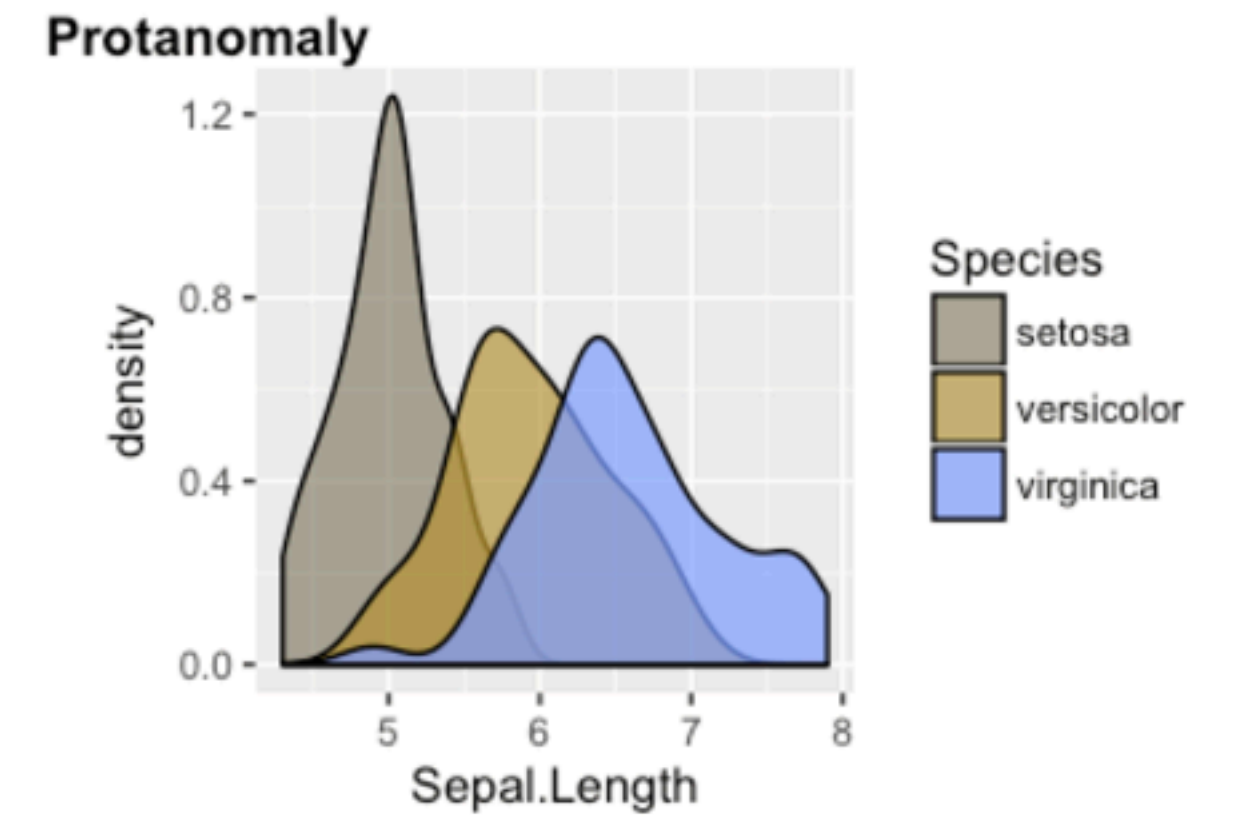
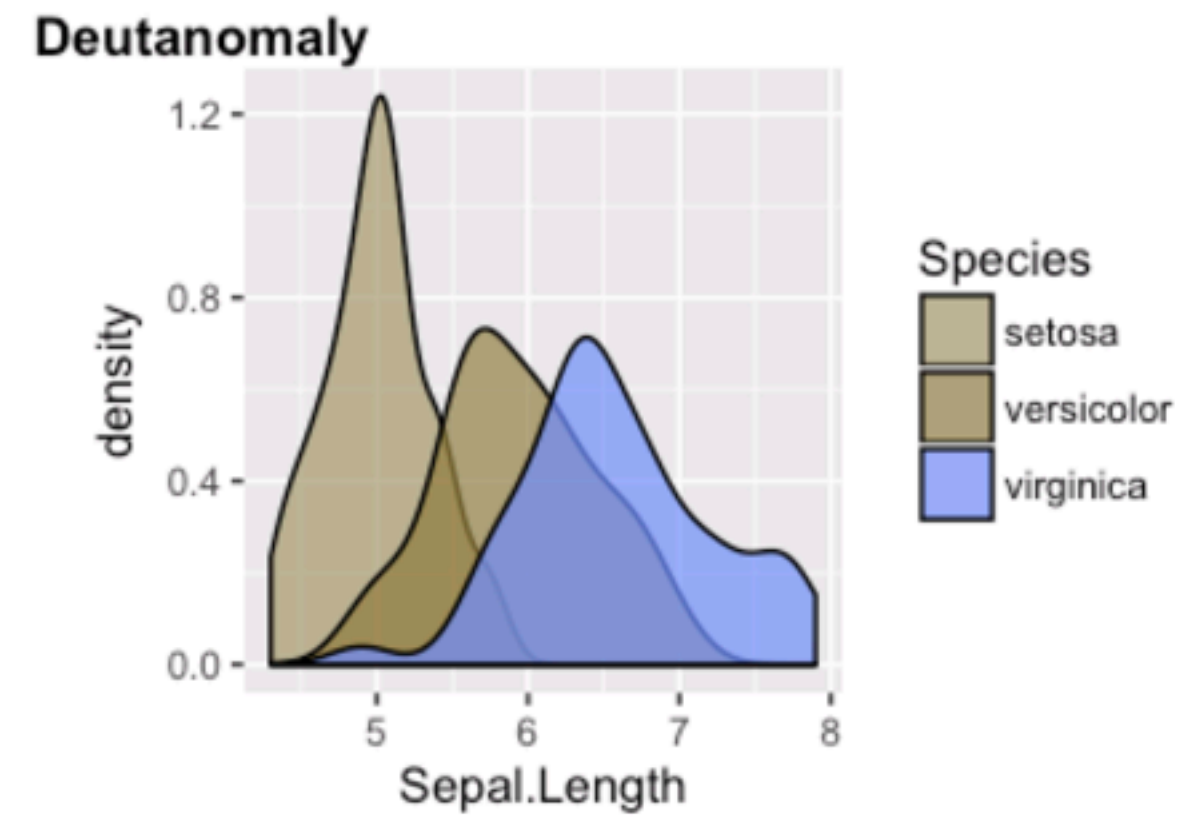
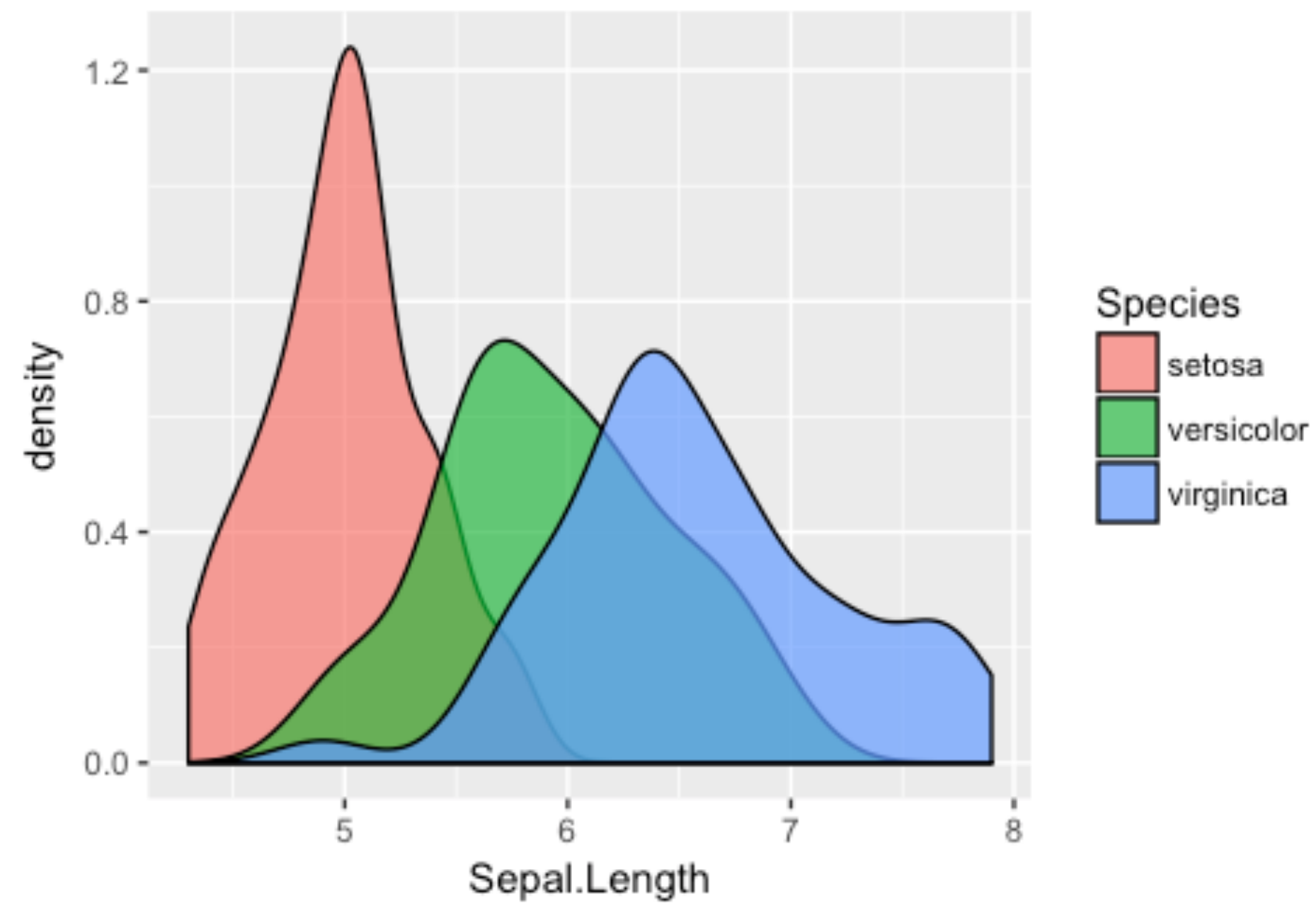
FREE Color Blind Check

New kind of color blindness test!
Try [Color Blind Check](#) and test type and severity of your color vision deficiency. Easy and fun!
Info at www.colorblindcheck.com

ANDROID APP ON Google play

CVD Categories

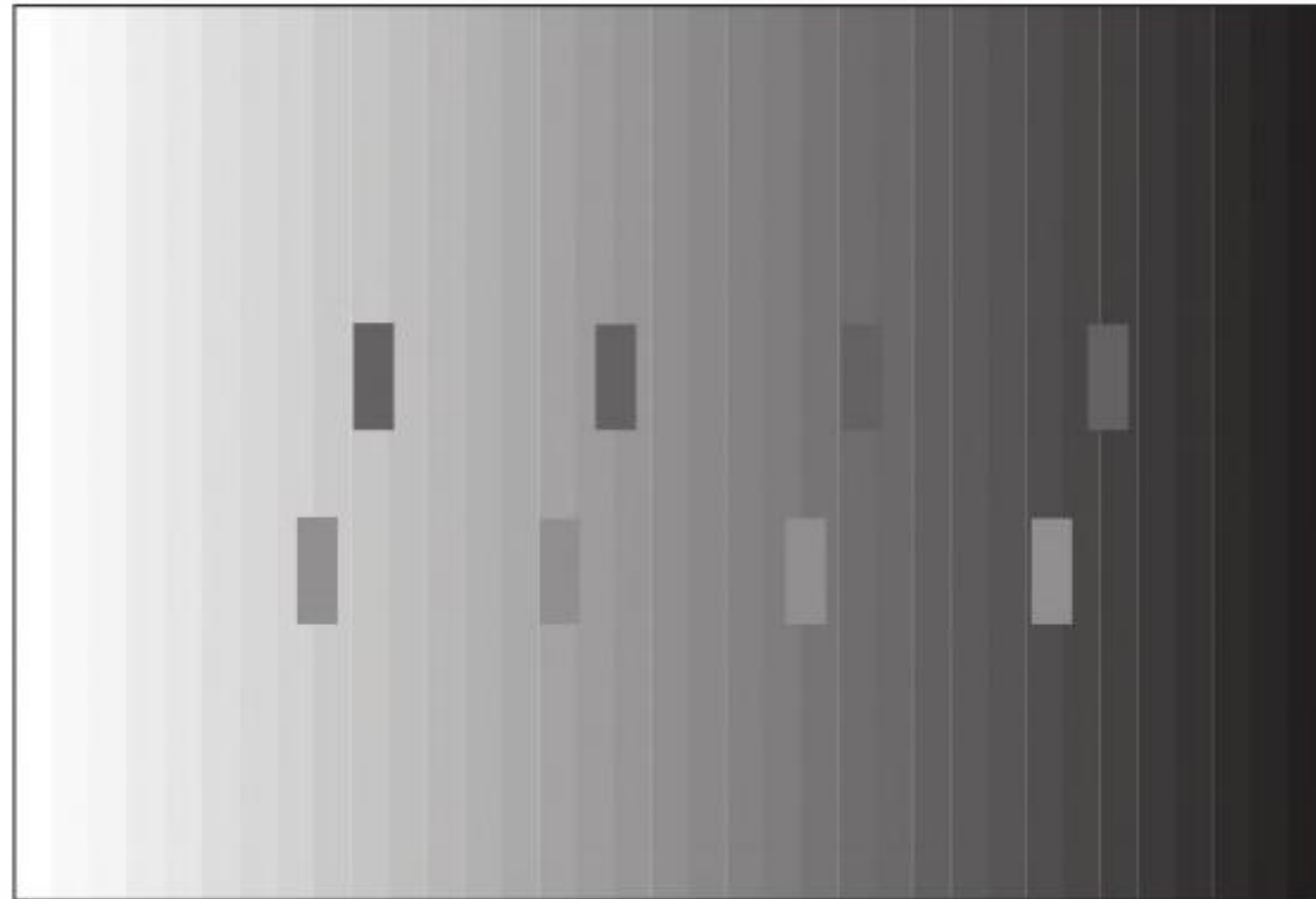
Simulate in R



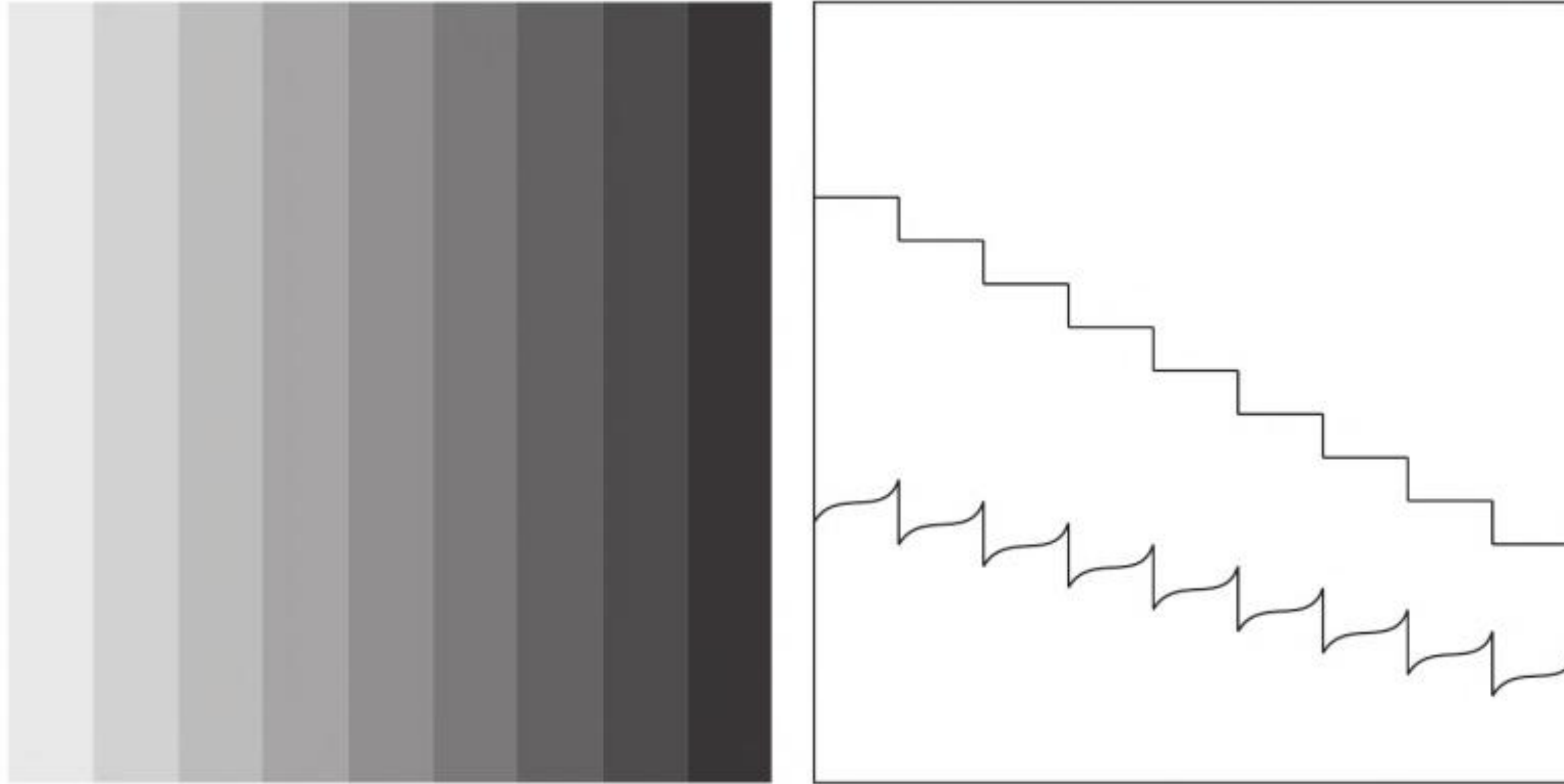
Color / Brightness is
Relative!

Simultaneous Brightness Contrast

The perceived brightness of an object is relative to it's background



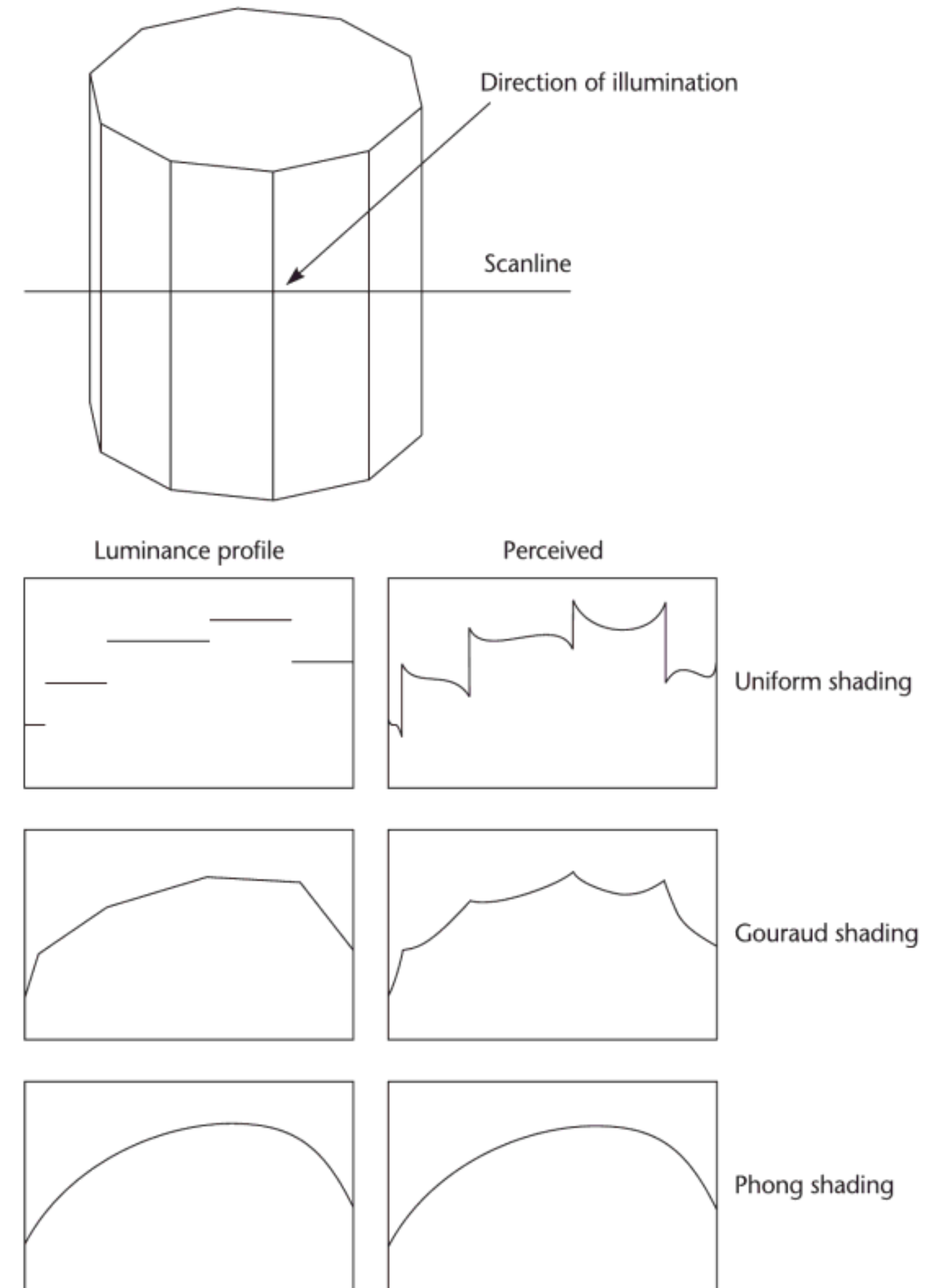
Chevreul Illusion



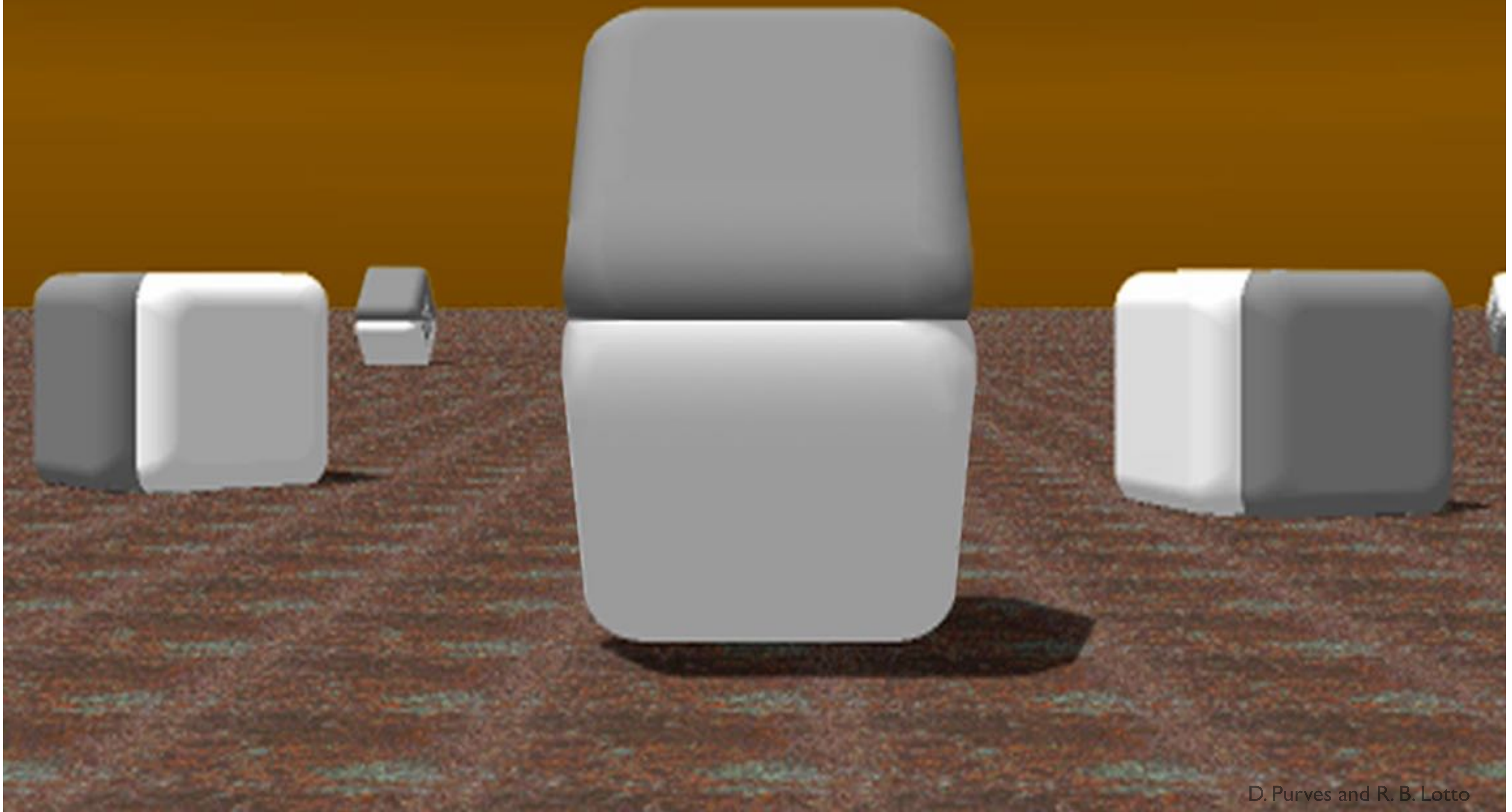
Why is this an issue?

Can result in large errors of judgment

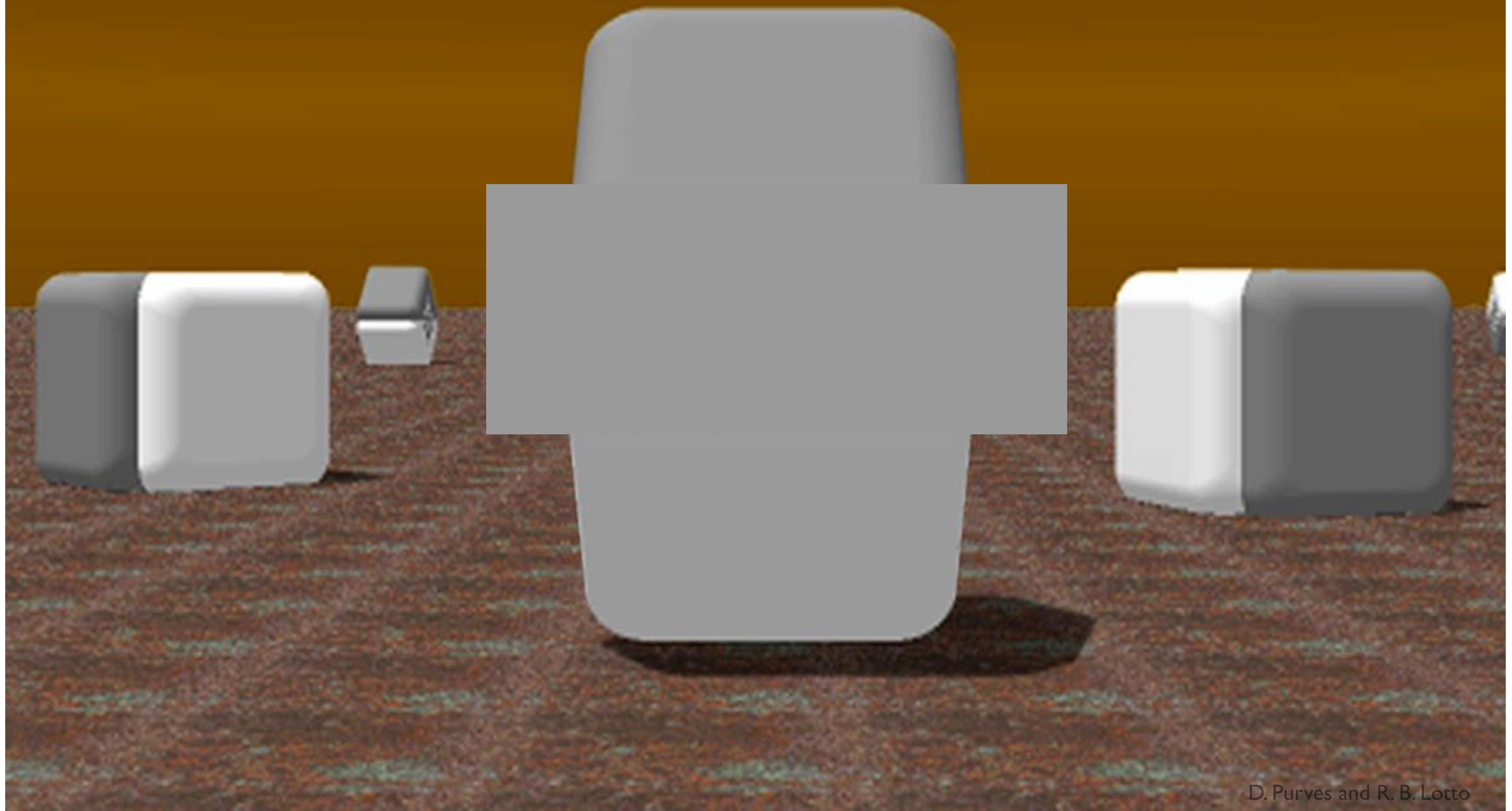
Amplifies artifacts in computer graphics shading



Cornsweet Illusion



Cornsweet Illusion








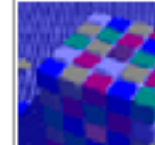








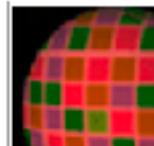



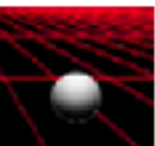

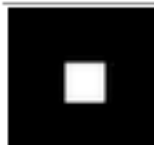



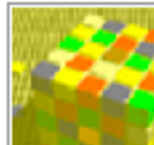

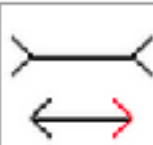



Demo

<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
									
									
									

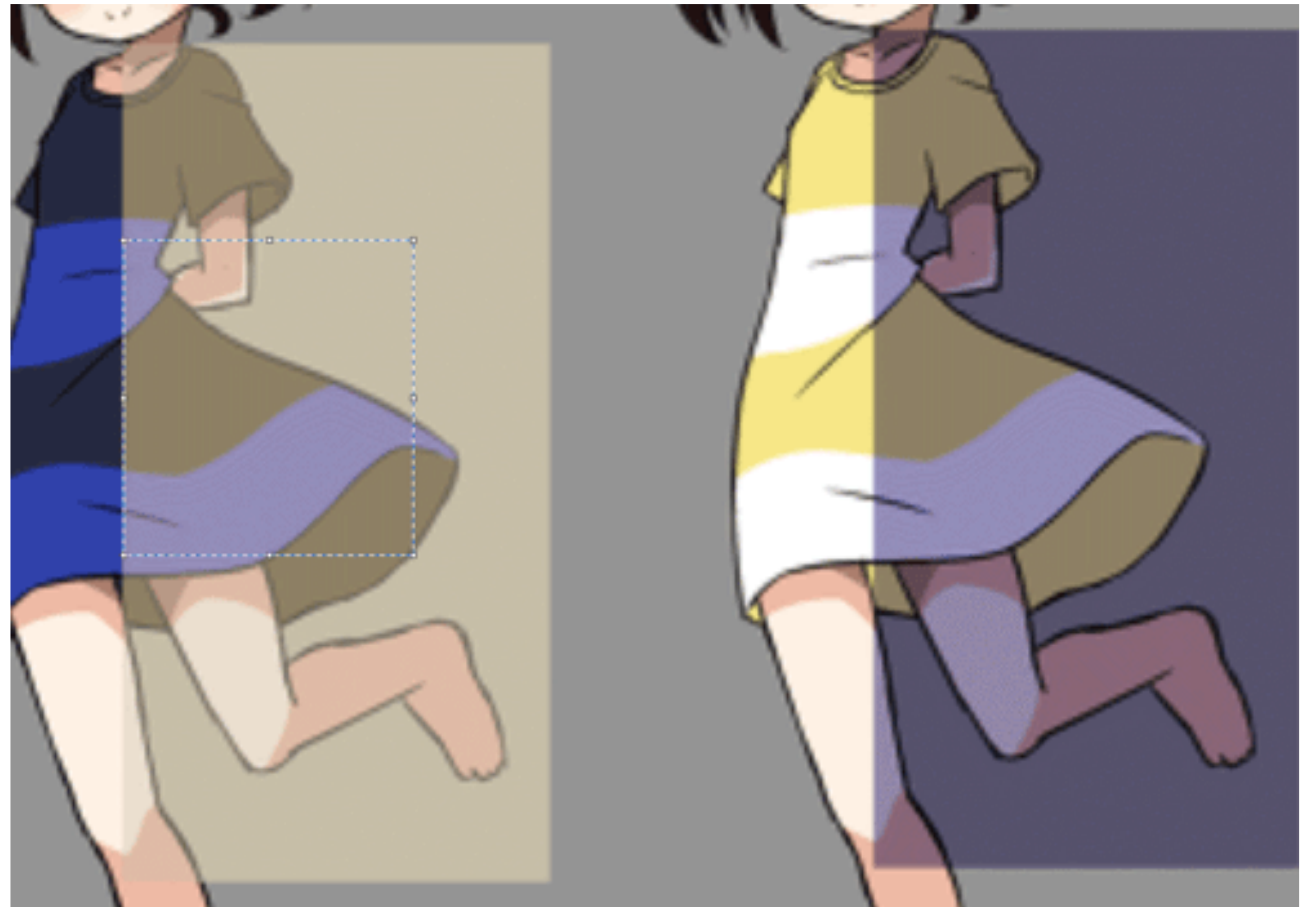
Brightness contrast: standard

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](#)



The Dress Meme

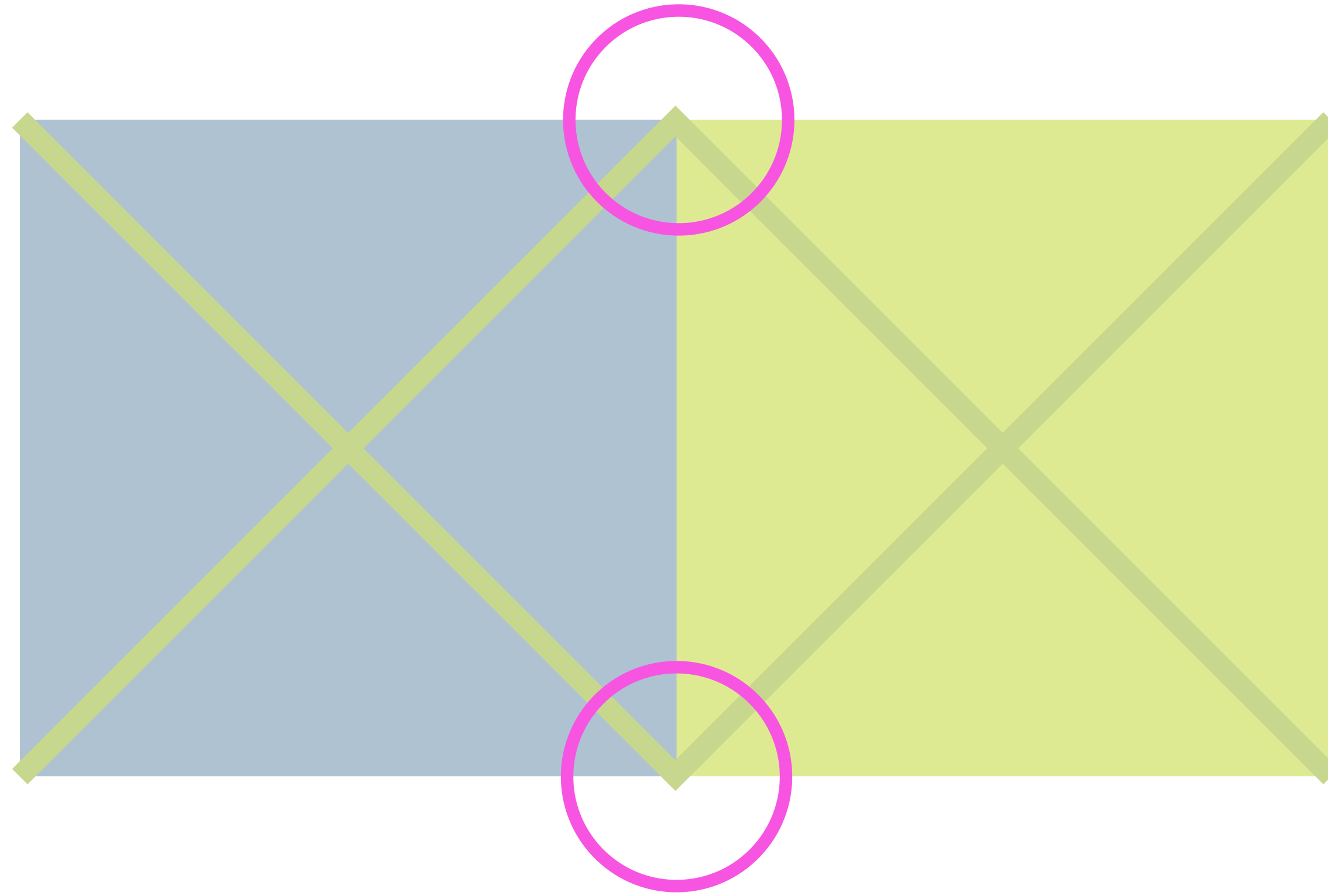


black and blue or white and gold?

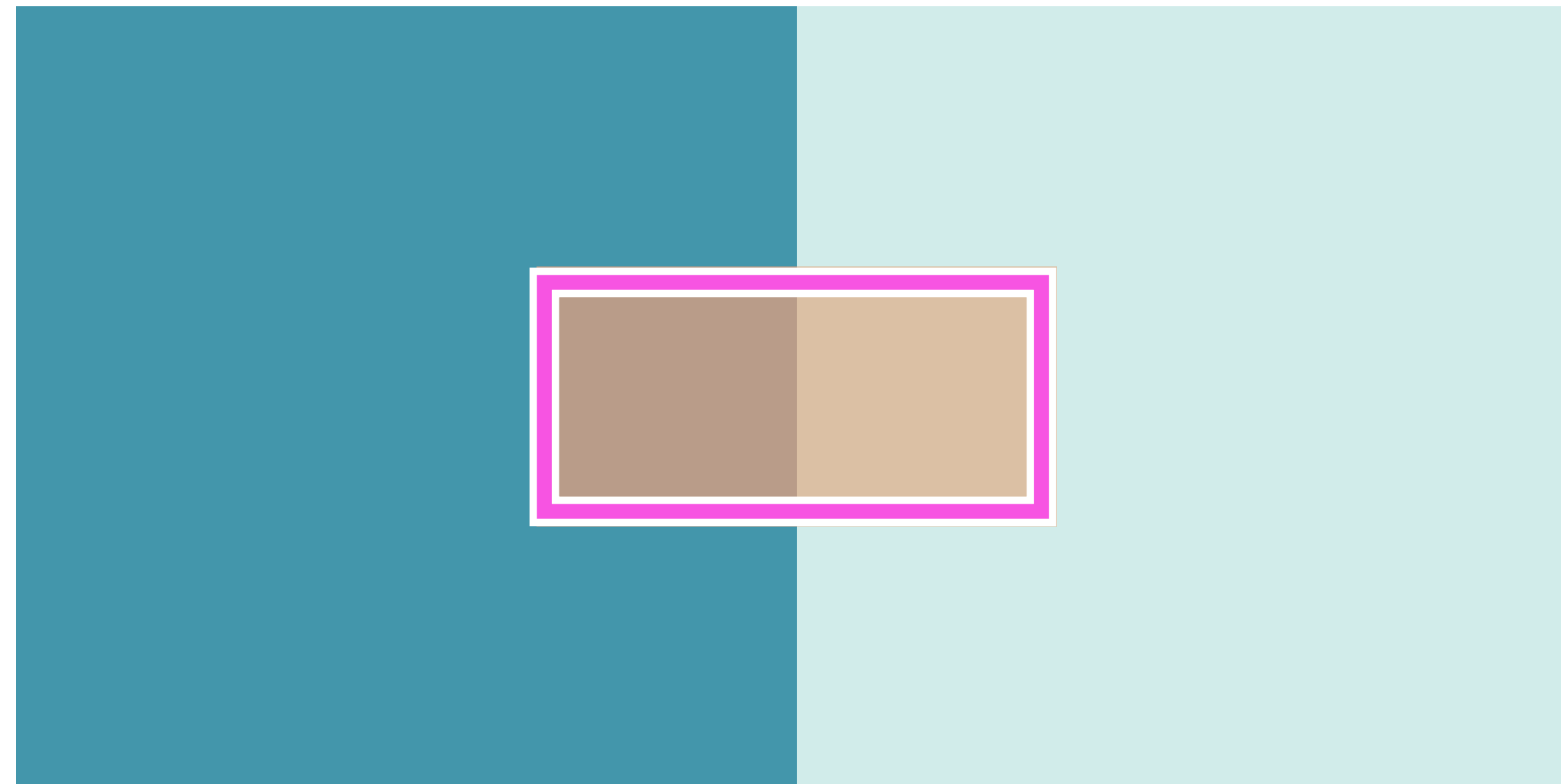
<https://imgur.com/hxJjUQB>

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

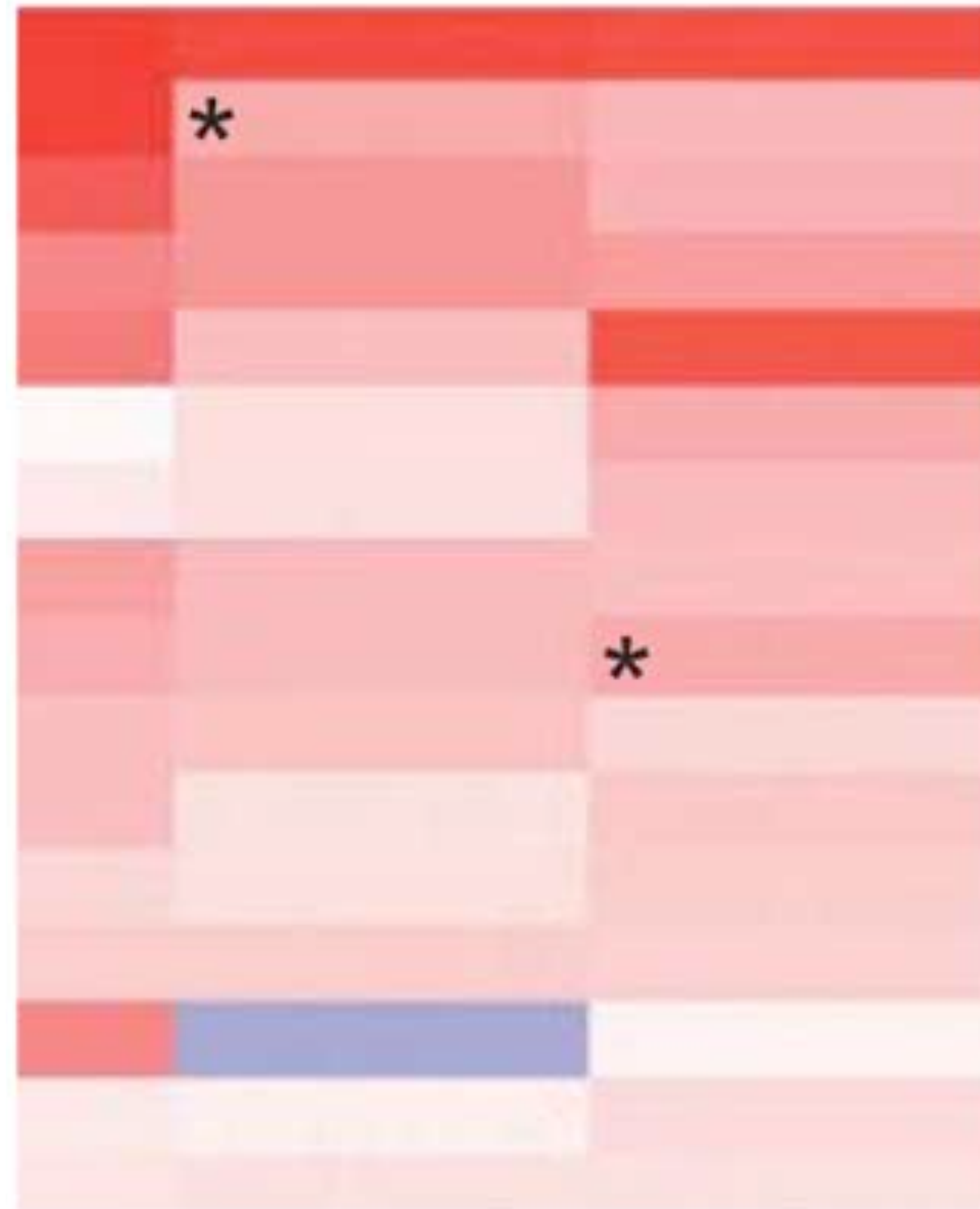
INTERACTION OF COLOR



INTERACTION OF COLOR



INTERACTION OF COLOR



Design Critique

Popout

Popout

Properties detected by the low-level visual system

very rapid - 200-250 milliseconds

very accurate

processed in parallel

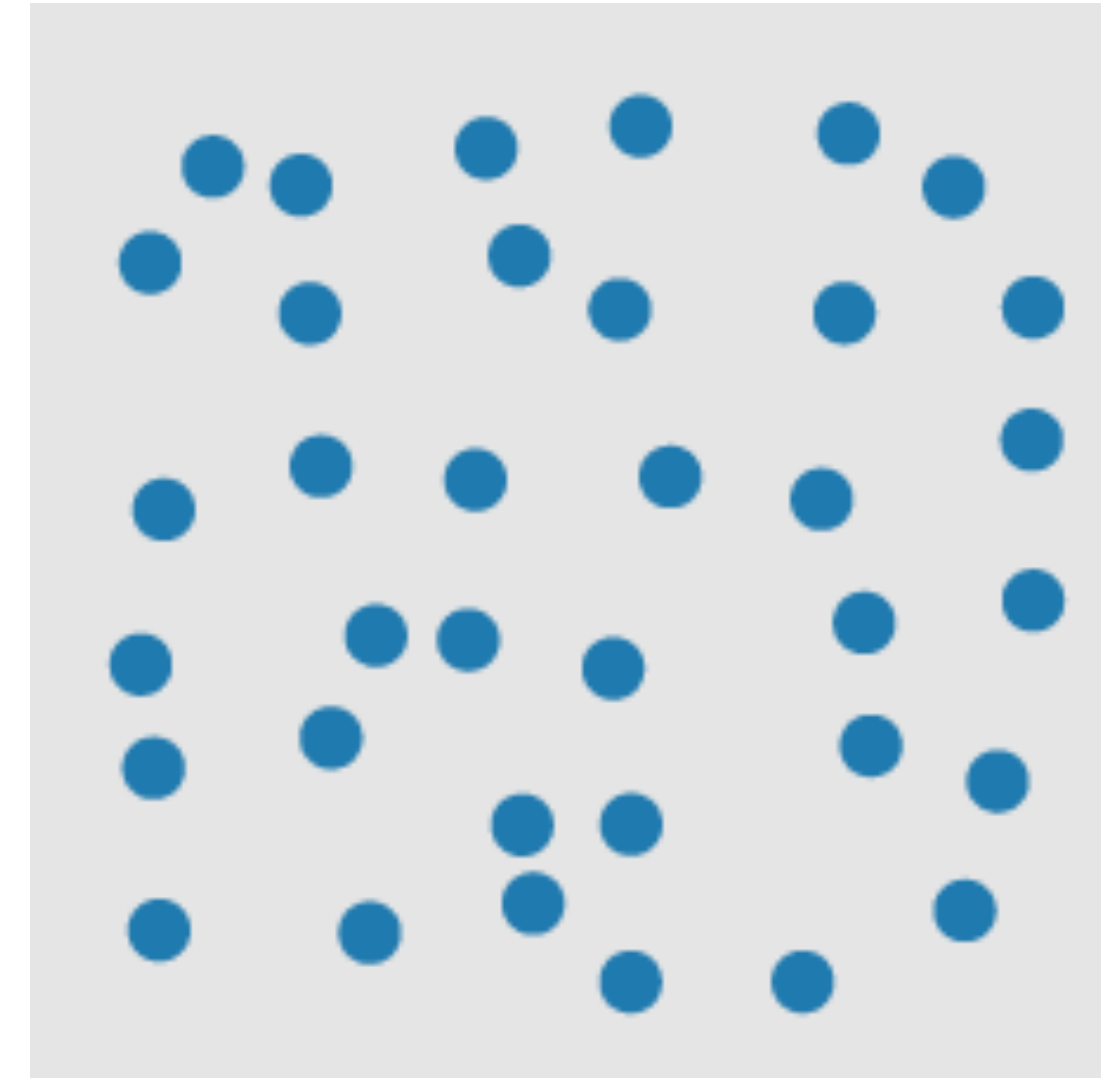
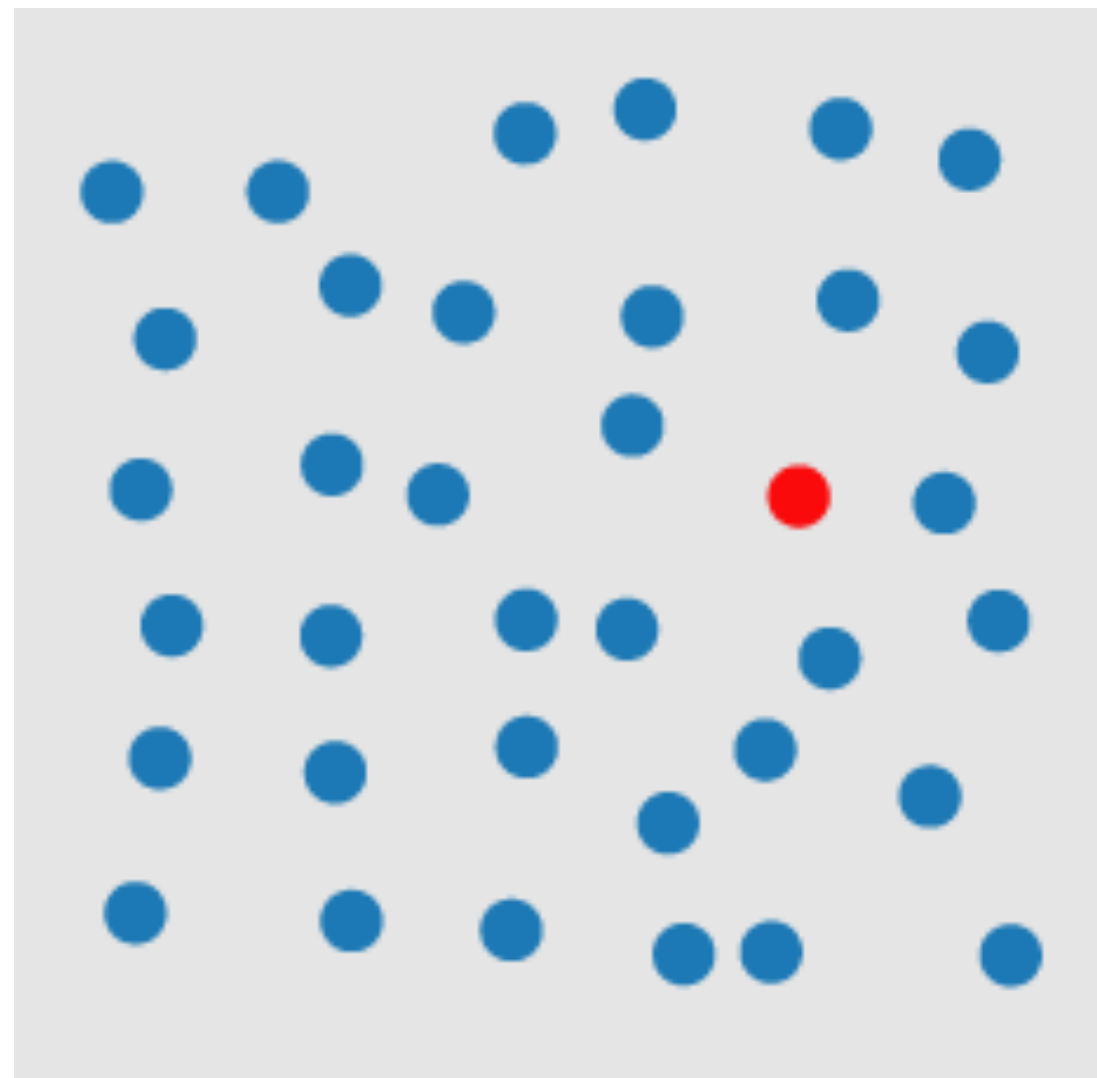
happens before focused attention -> „pre“attentive

attention is very important for cognition

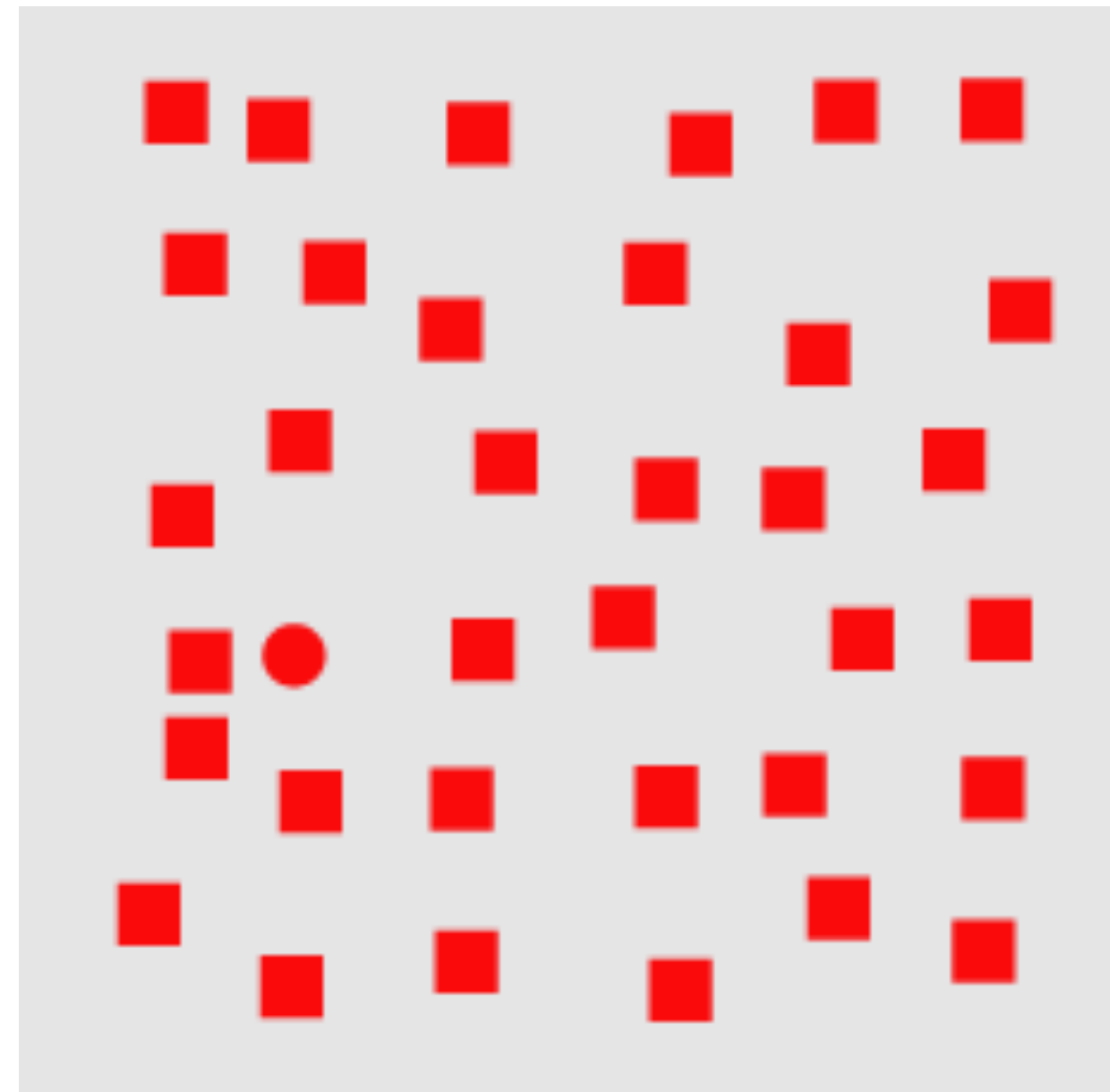
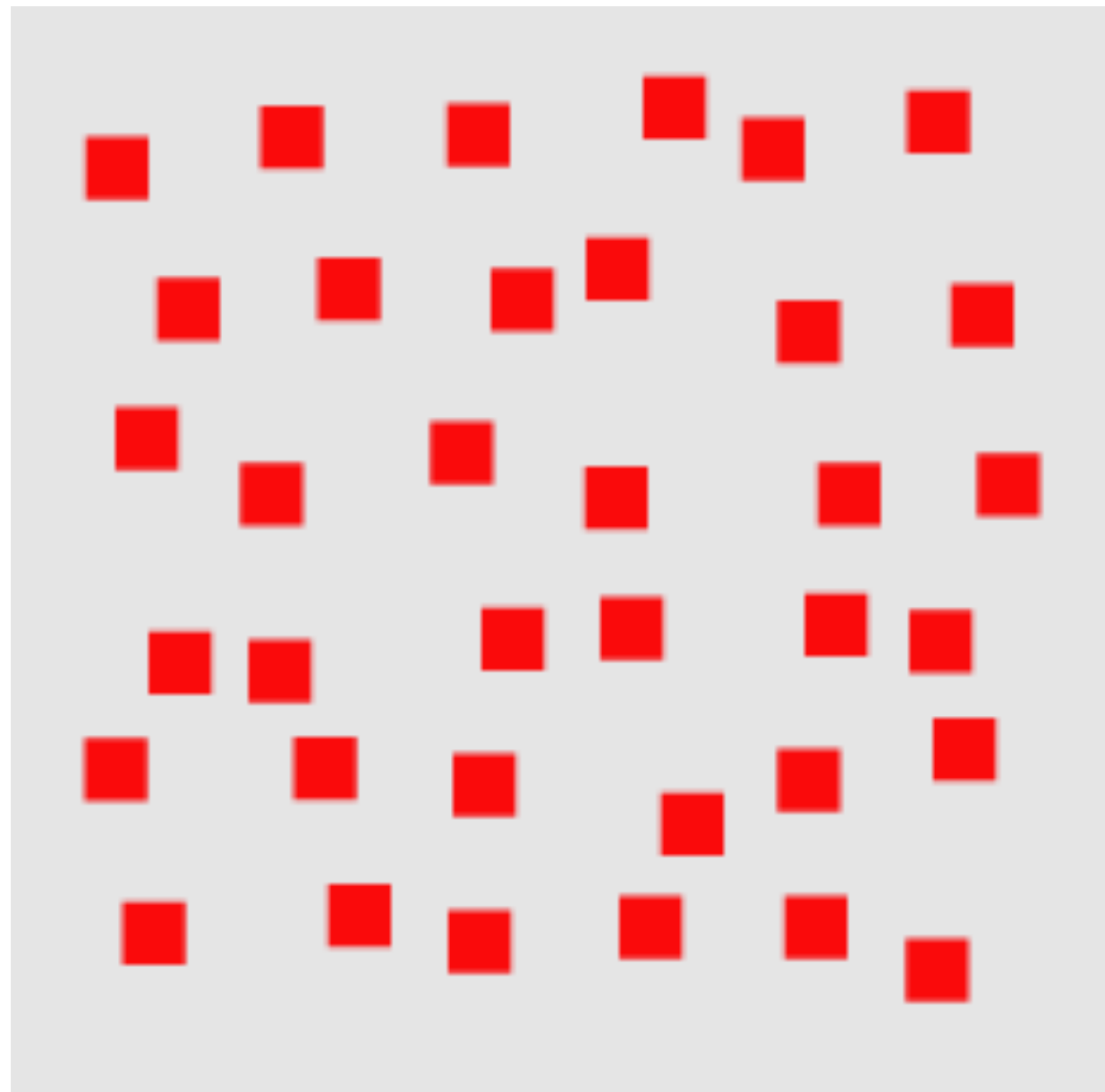
Independent of the number of distractors!

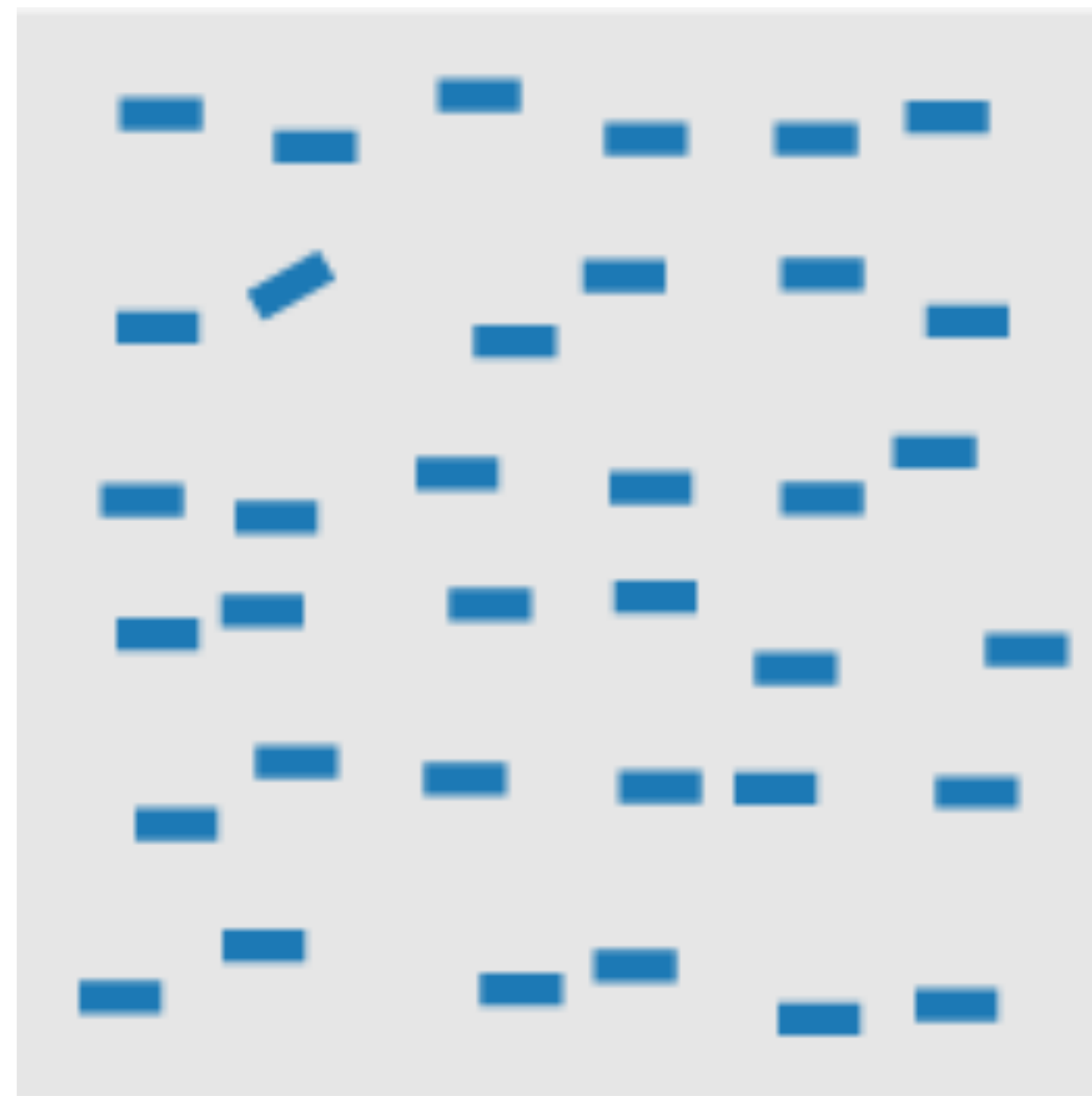
Opposite: sequential search (processed serially)

Difference in Hue

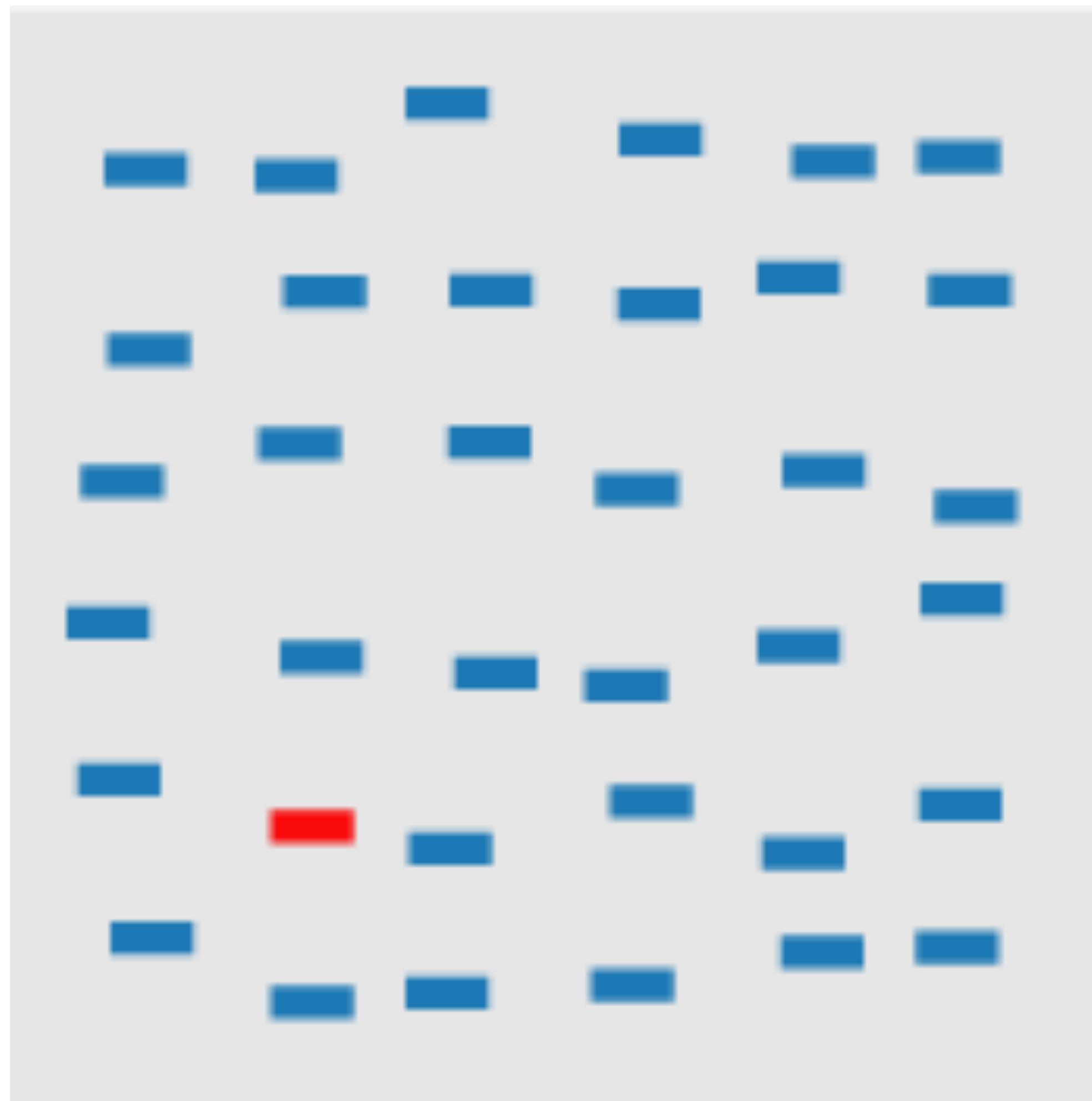


Difference in Curvature / Form





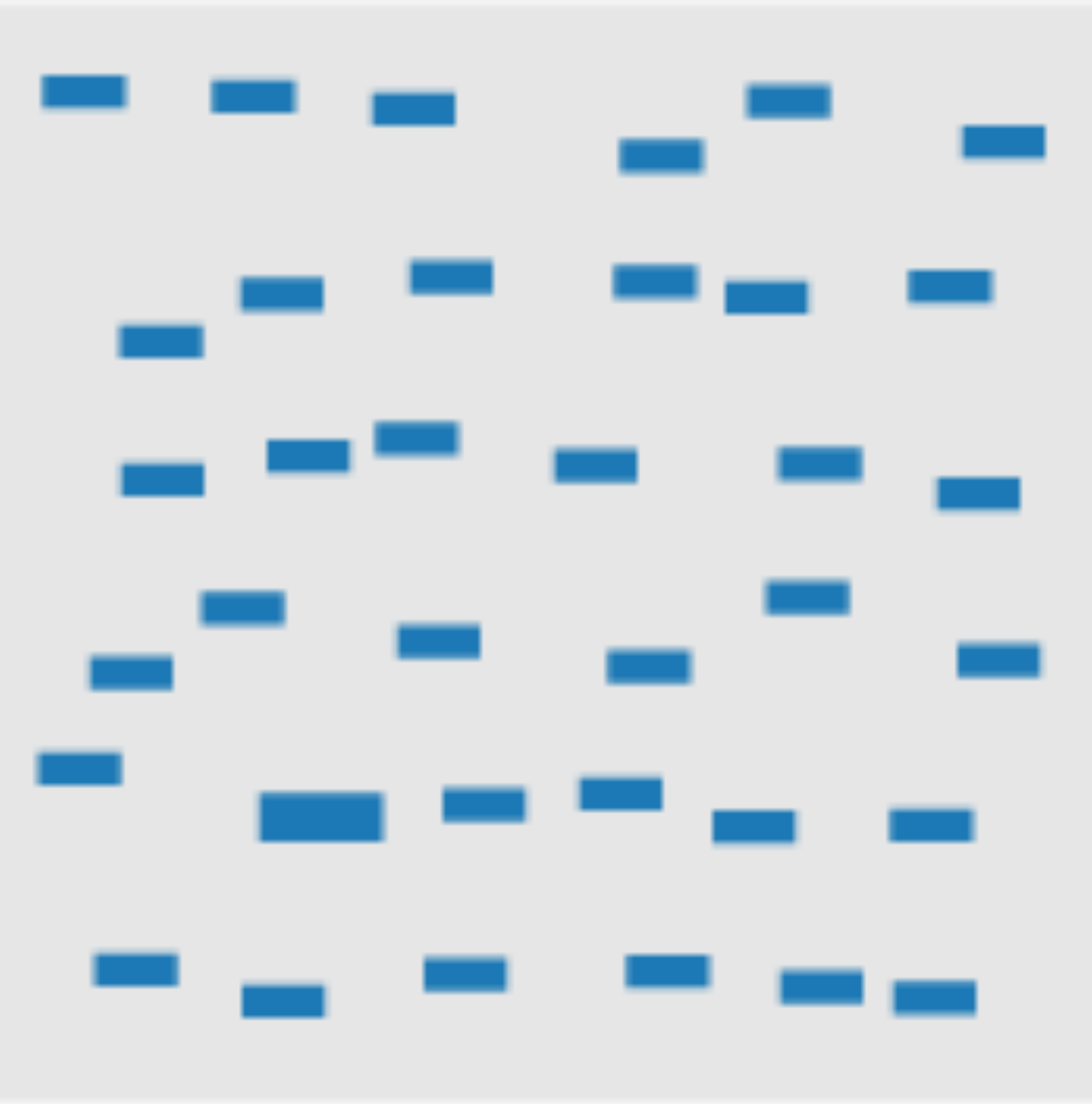
orientation



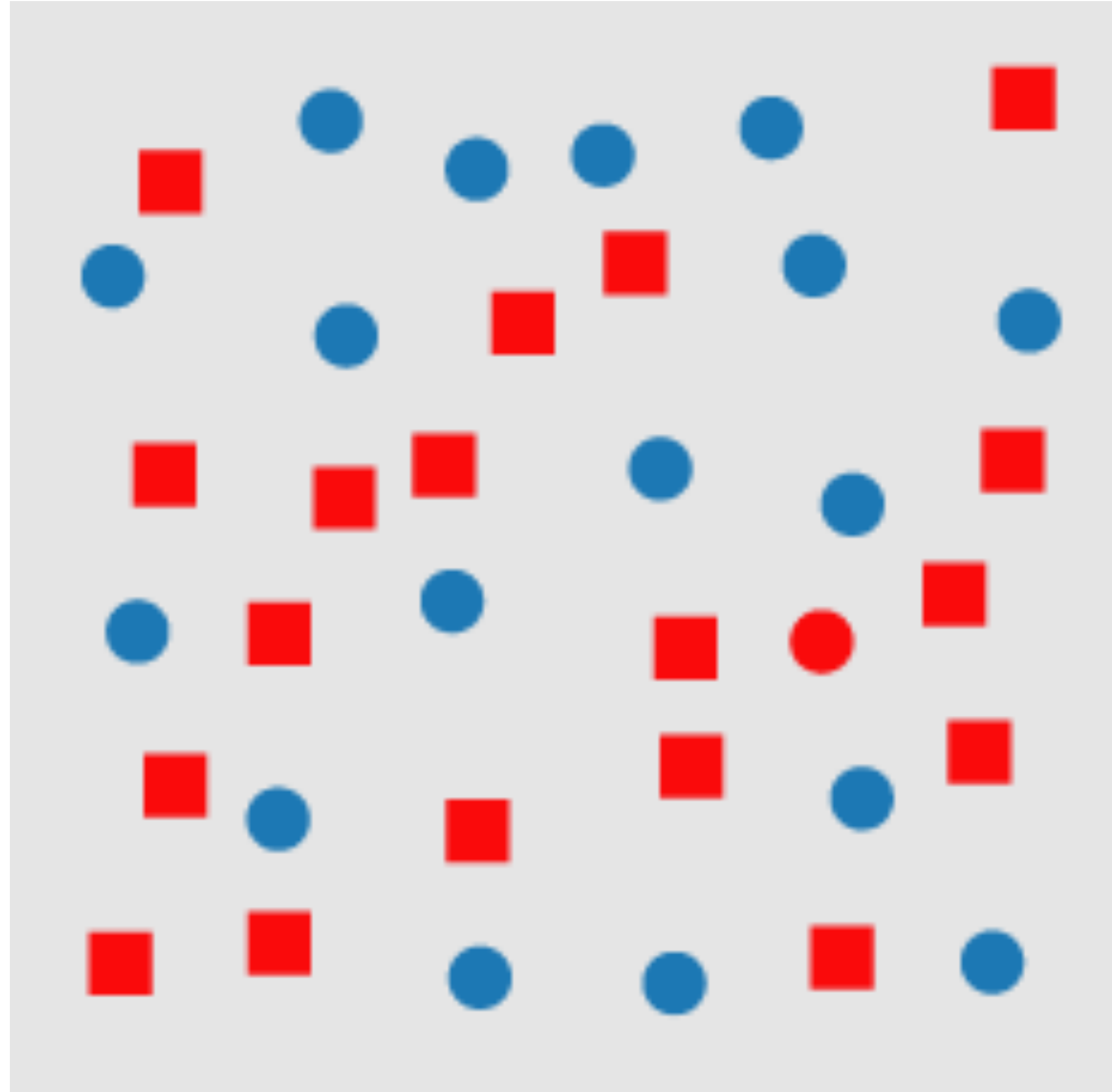
hue



closure

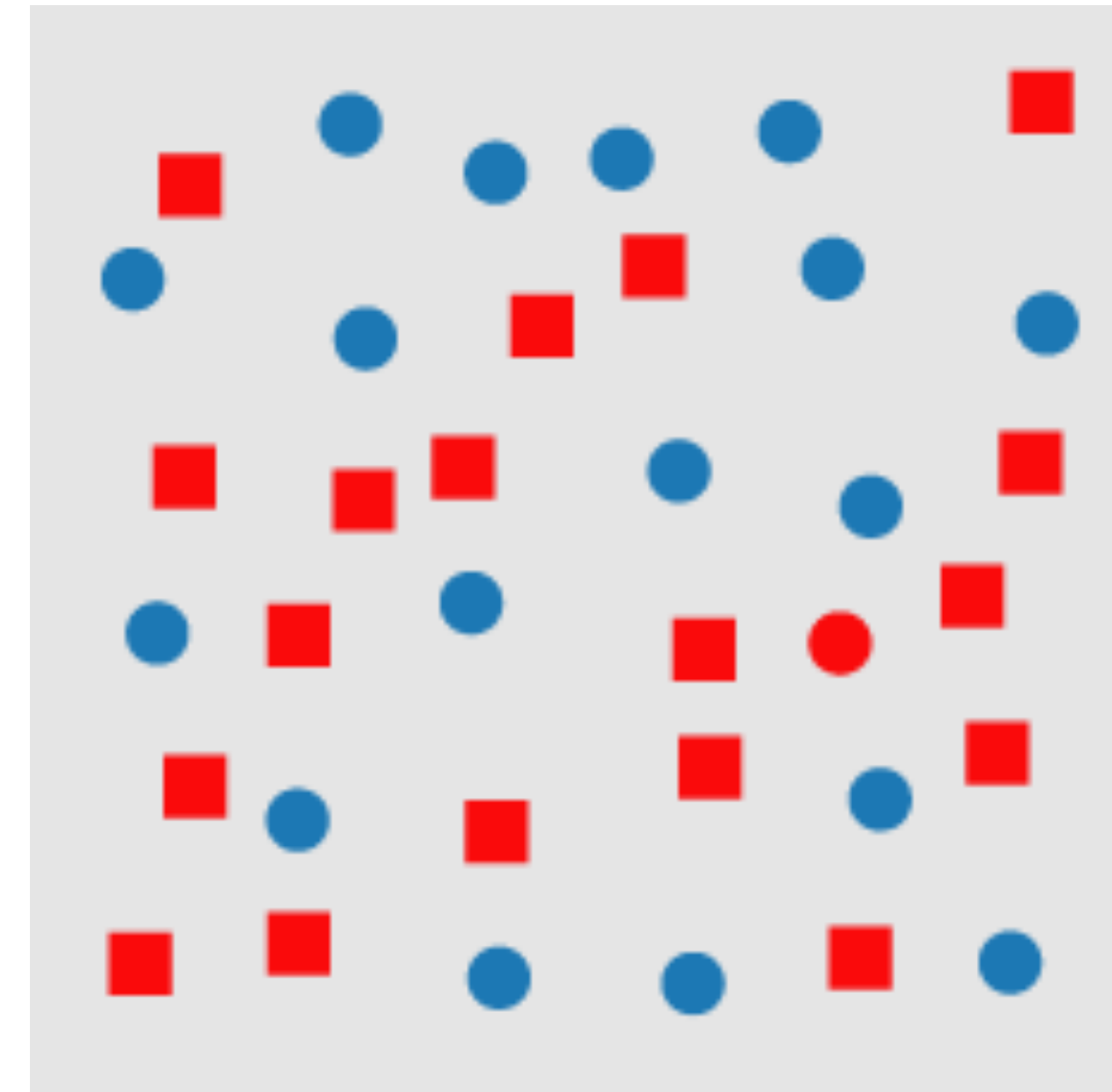
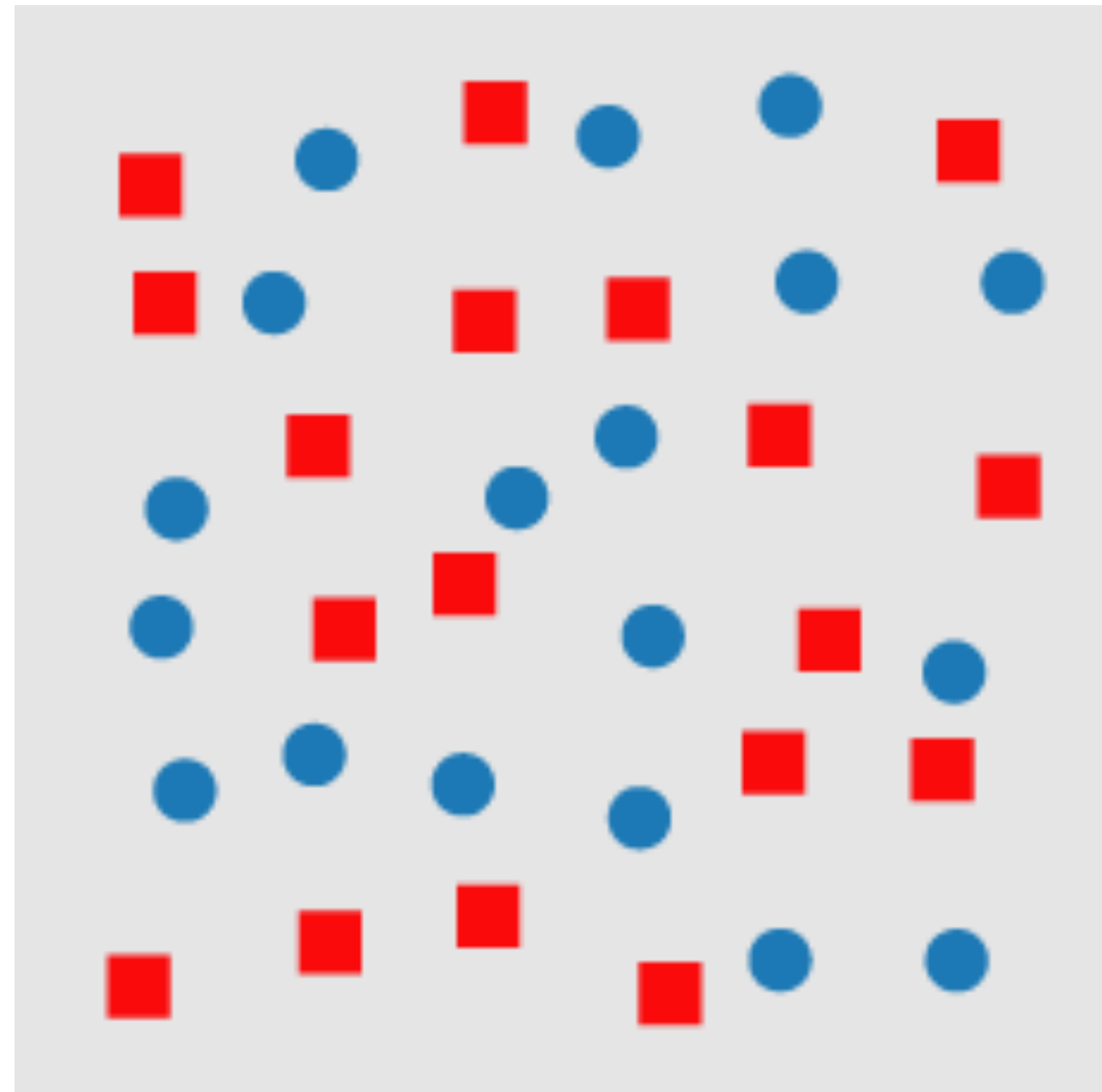


size



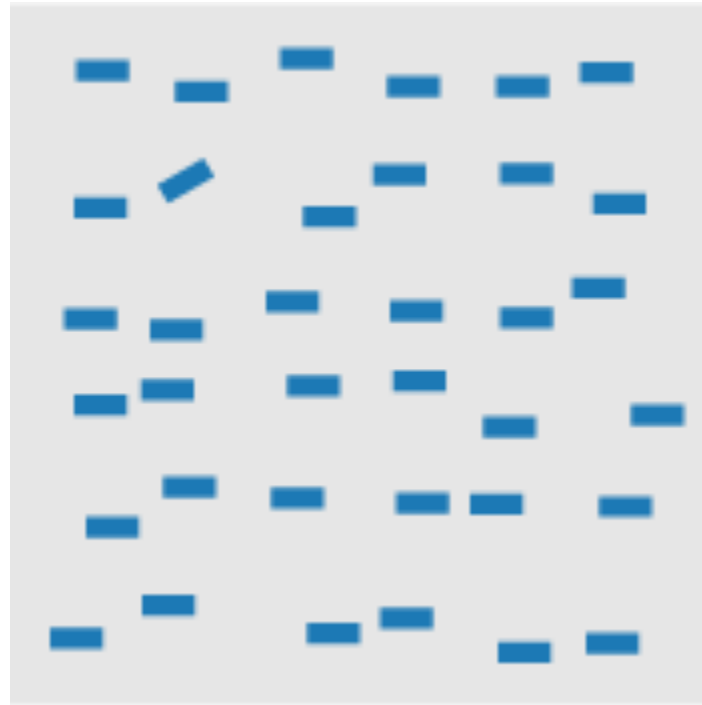
?

Not Valid for Combinations

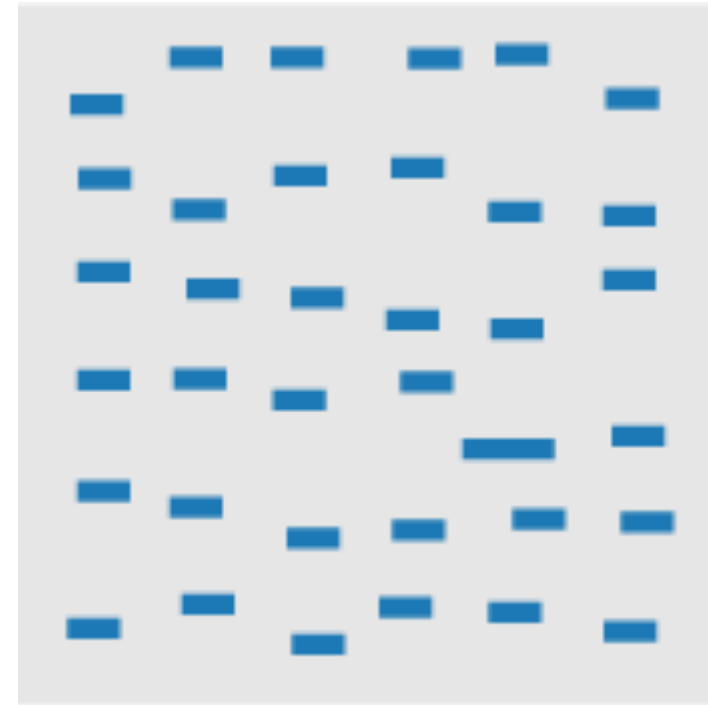


Conjunction Targets – no unique visual property
target: red, circle
distractor objects have both properties

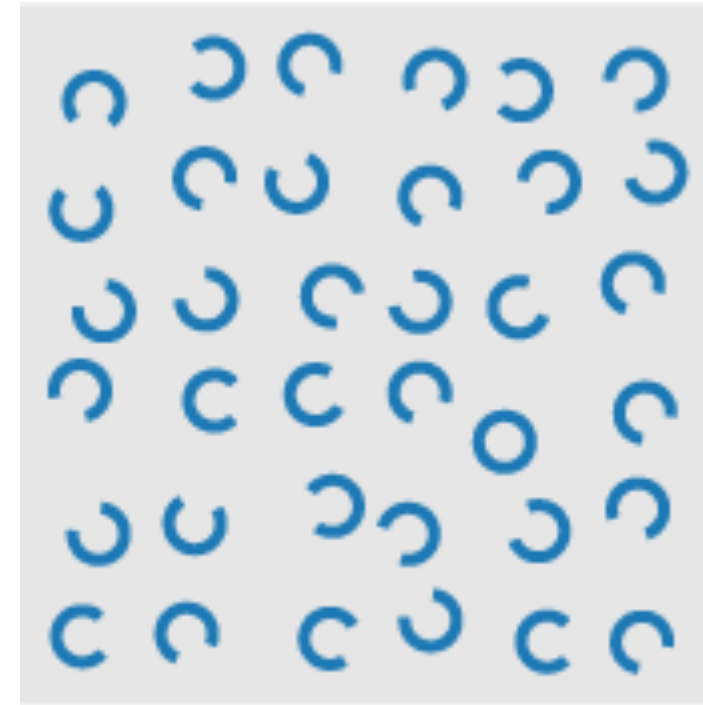
Some Preattentive Properties



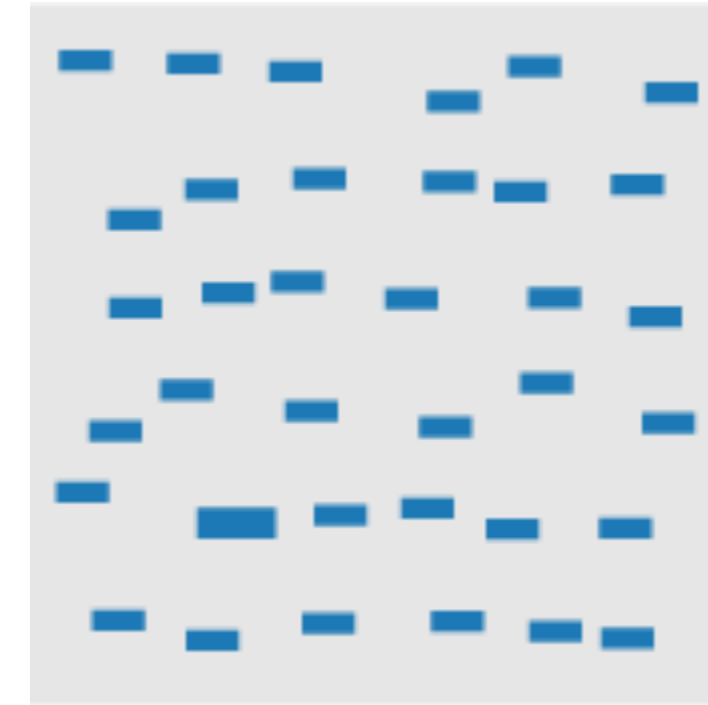
orientation



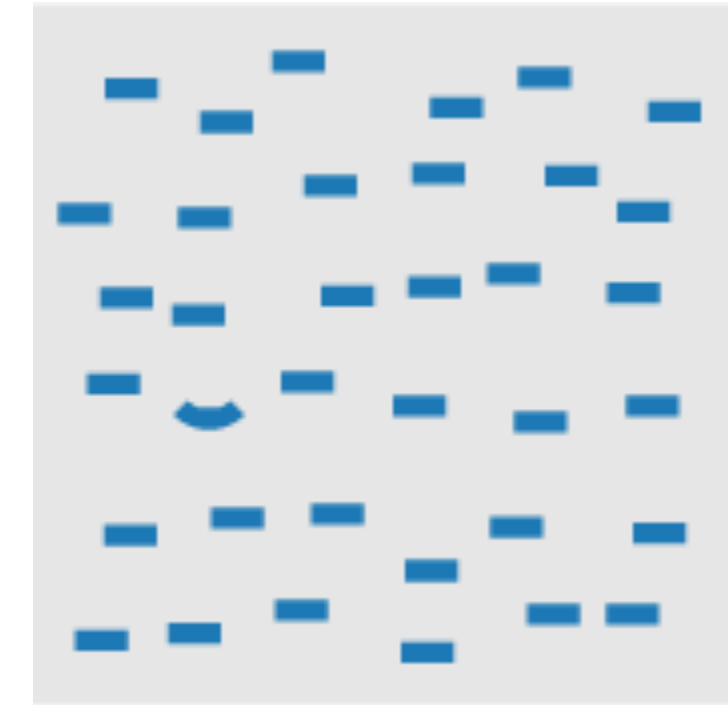
length



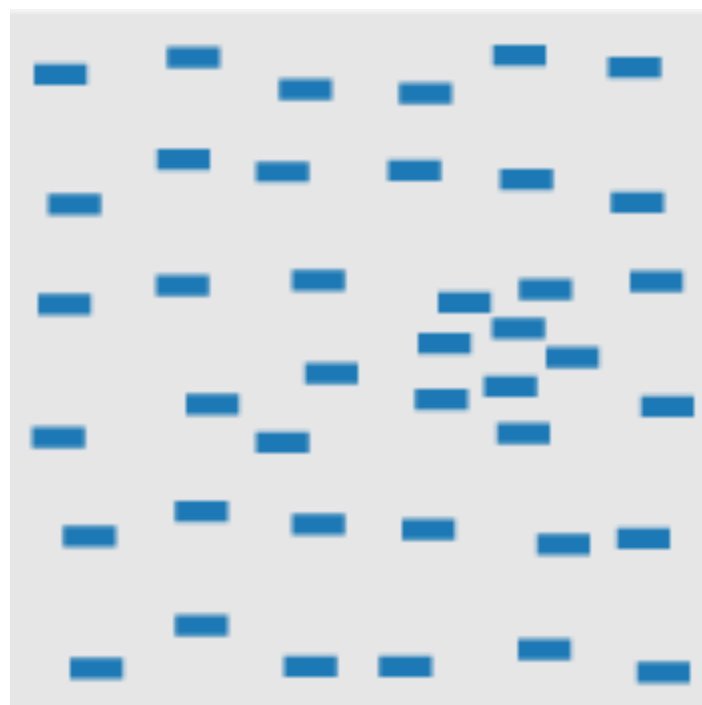
closure



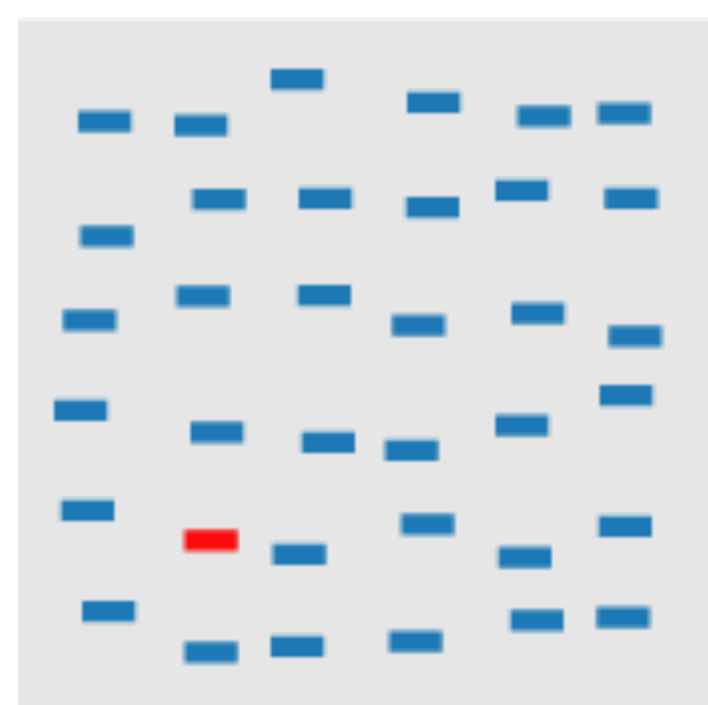
size



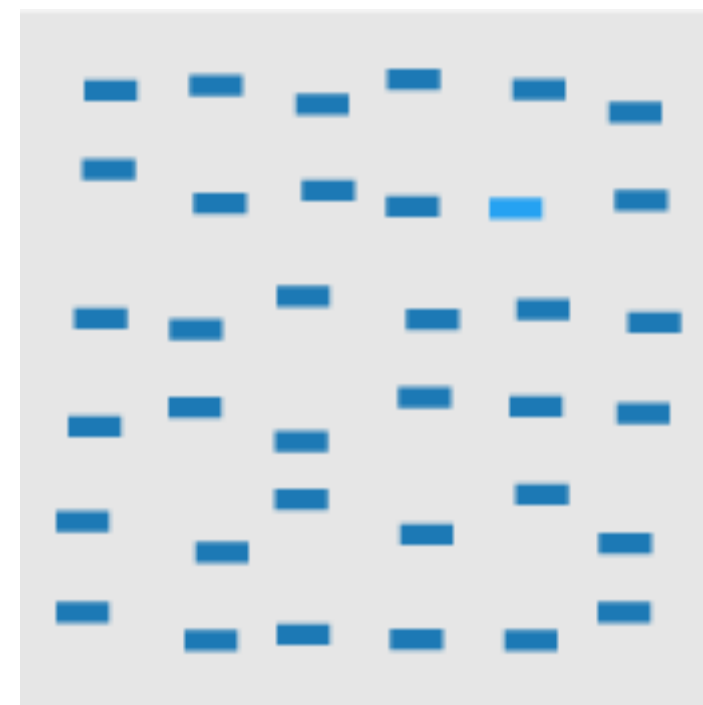
curvature



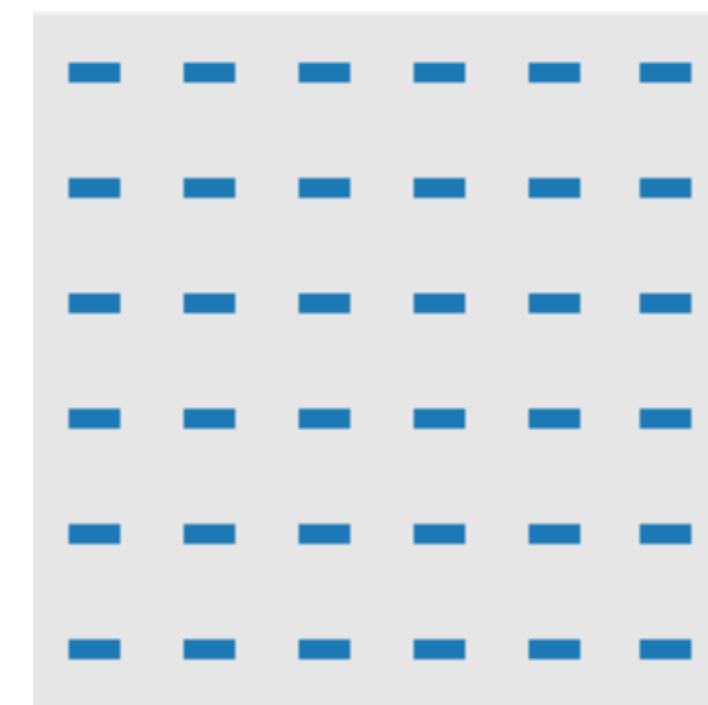
density



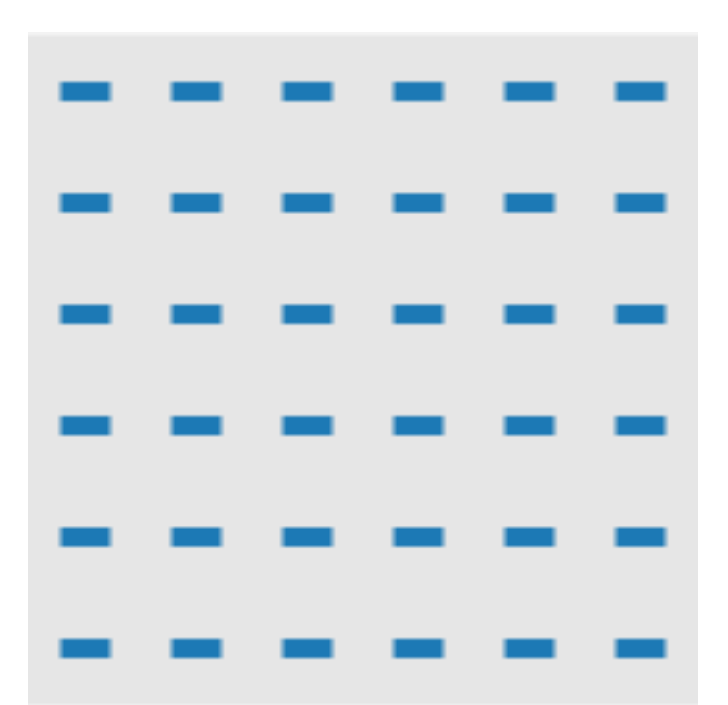
hue



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

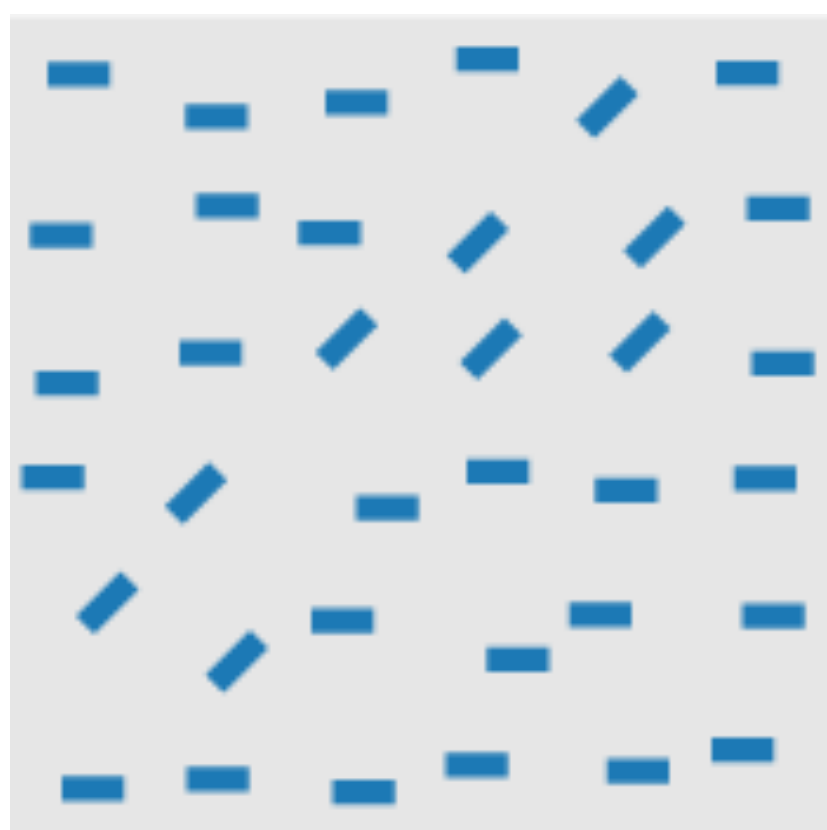
track one or more elements with a unique visual feature as they move in time and space

counting and estimation

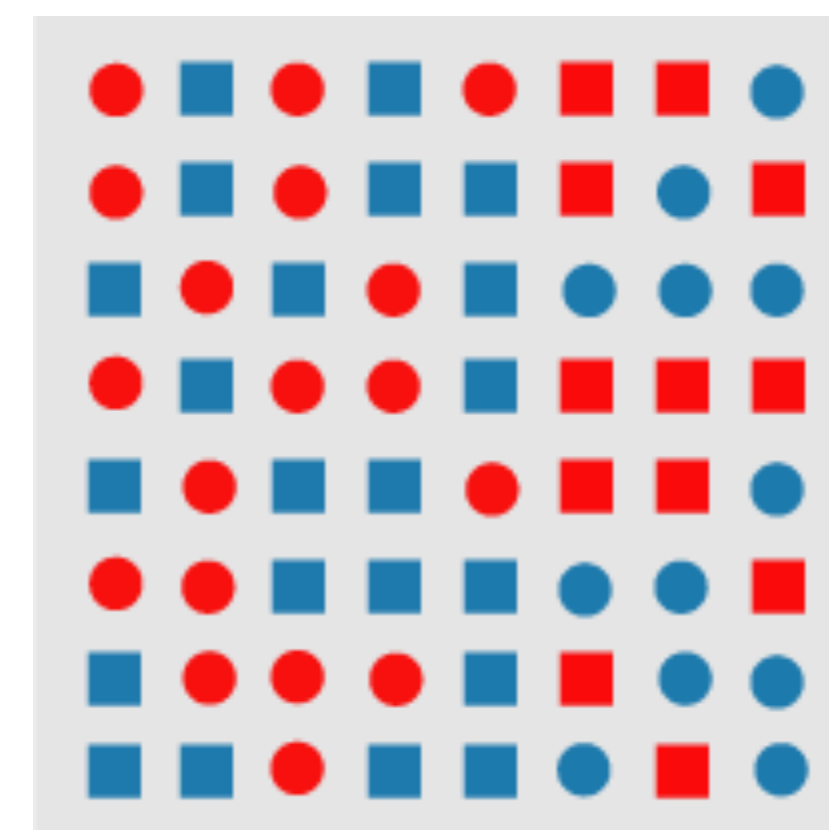
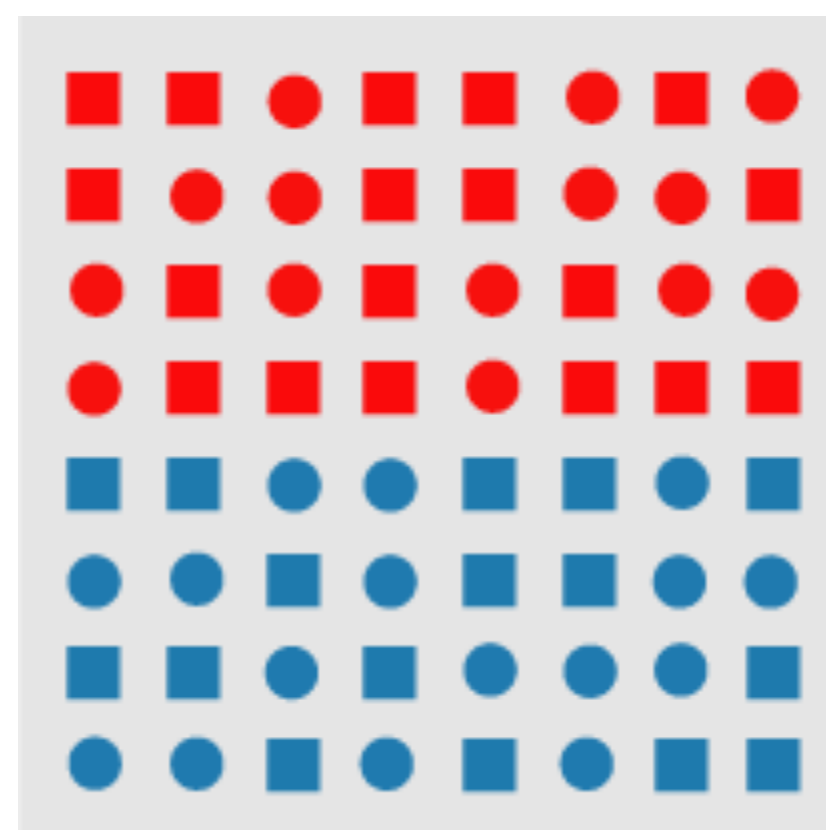
users count or estimate the number of elements with a unique visual feature.

Tasks

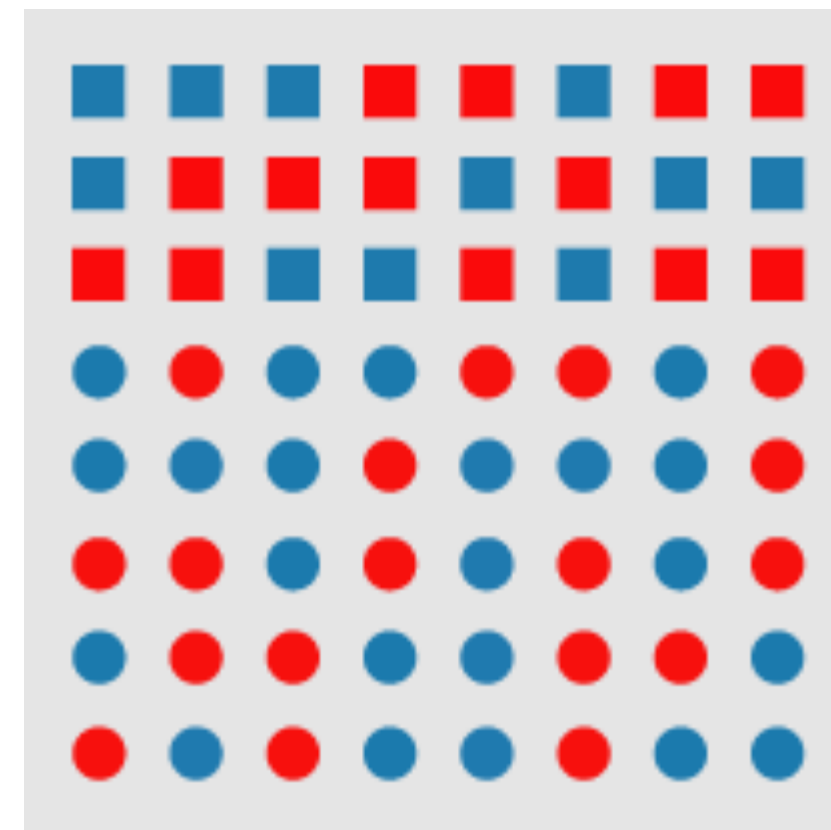
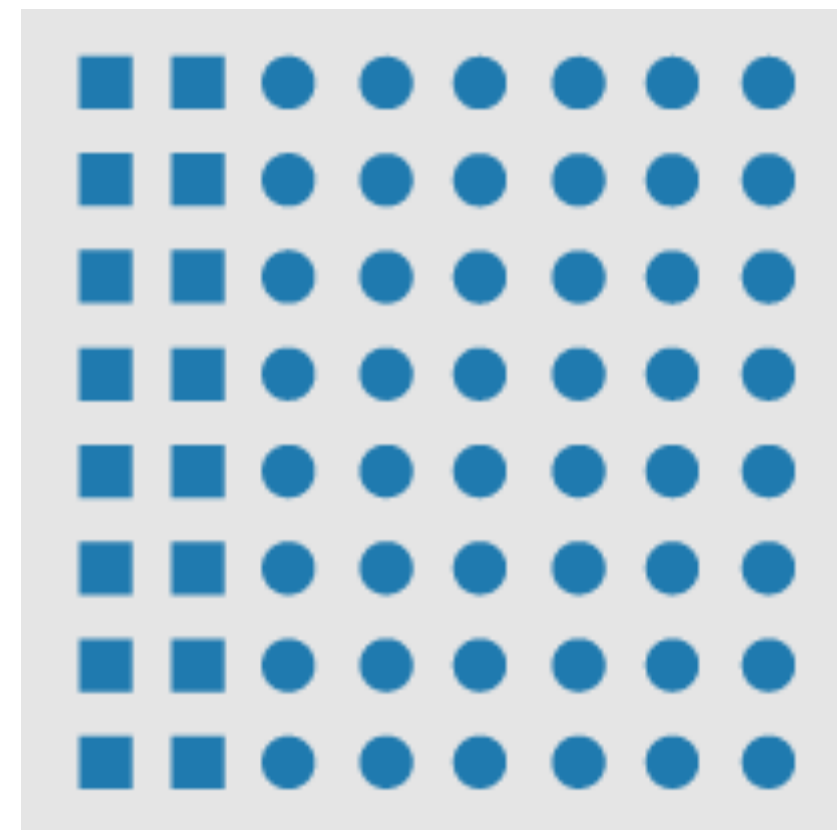
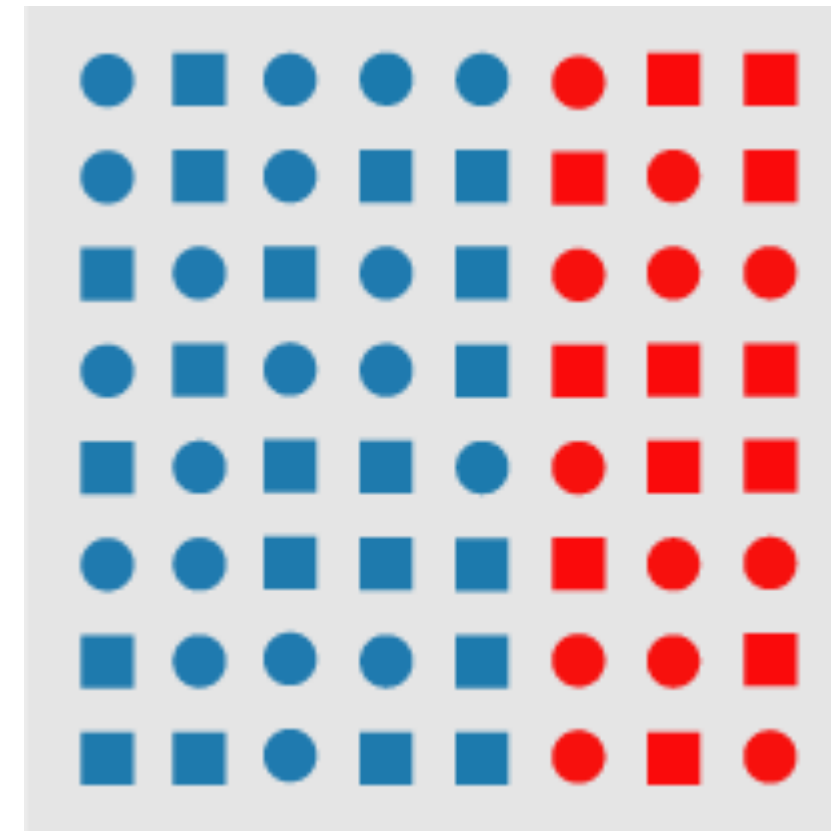
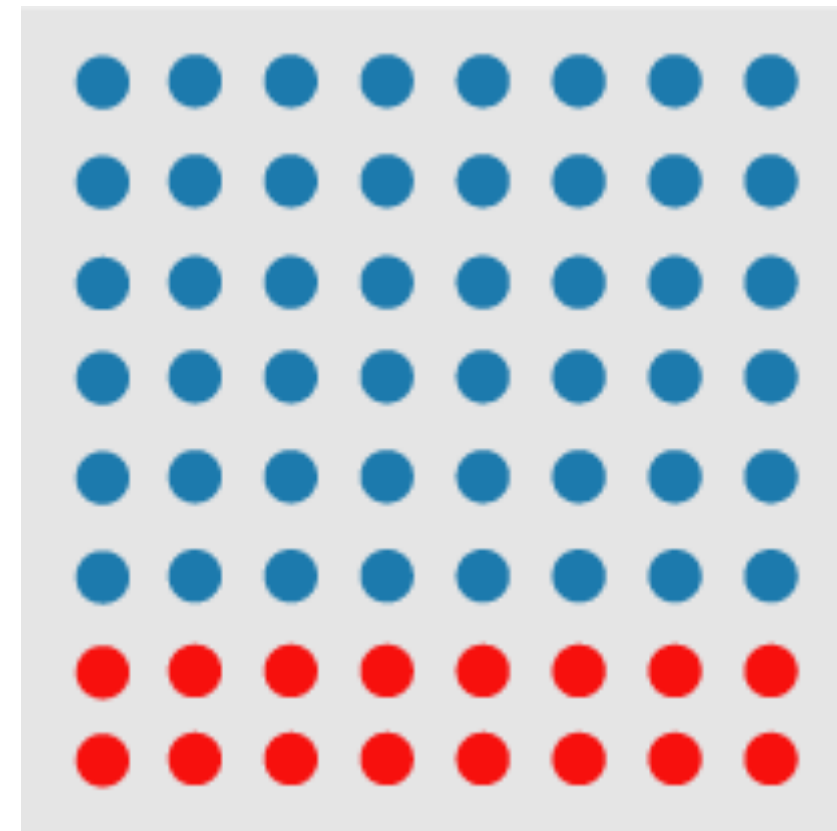
Number Estimation



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











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



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)

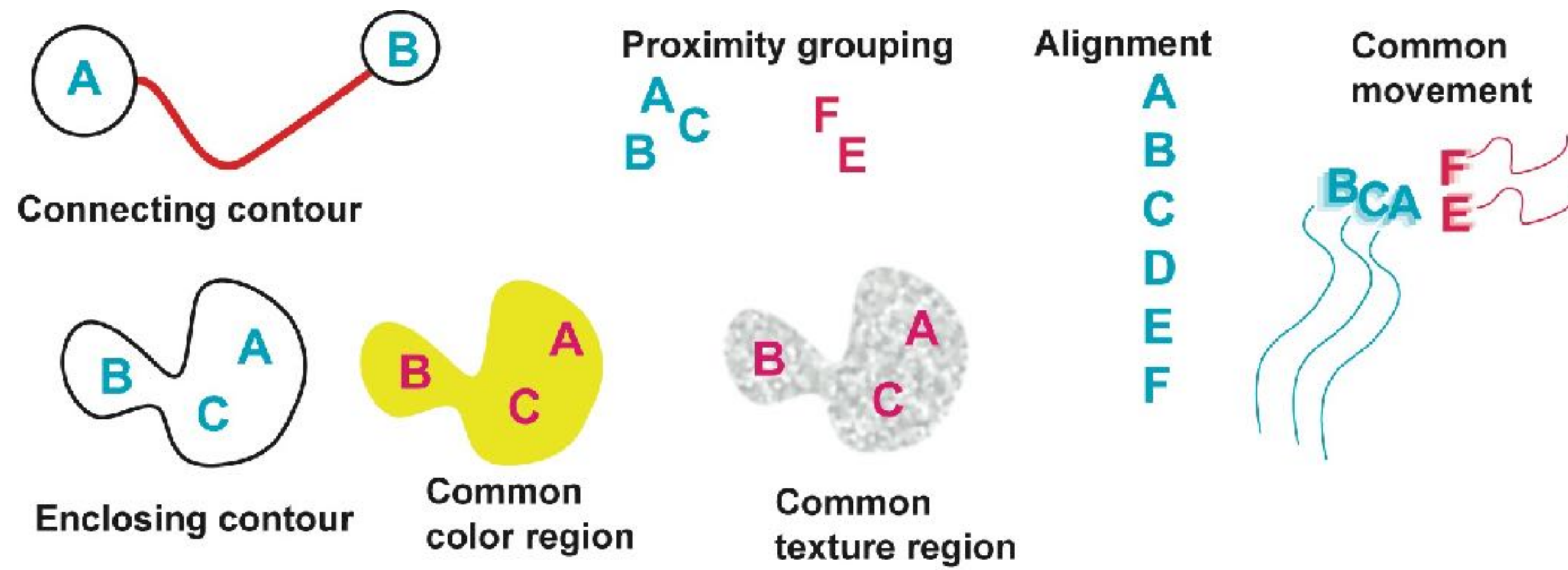
Attention is driven by preexisting knowledge, expectations, and goals stored in long-term memory

Gestalt Principles

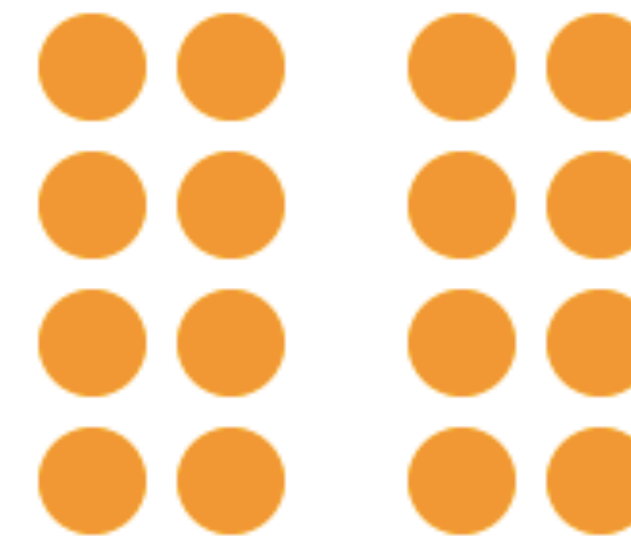
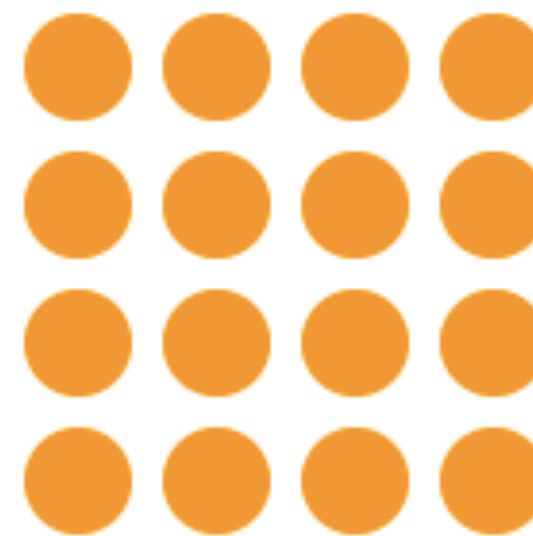
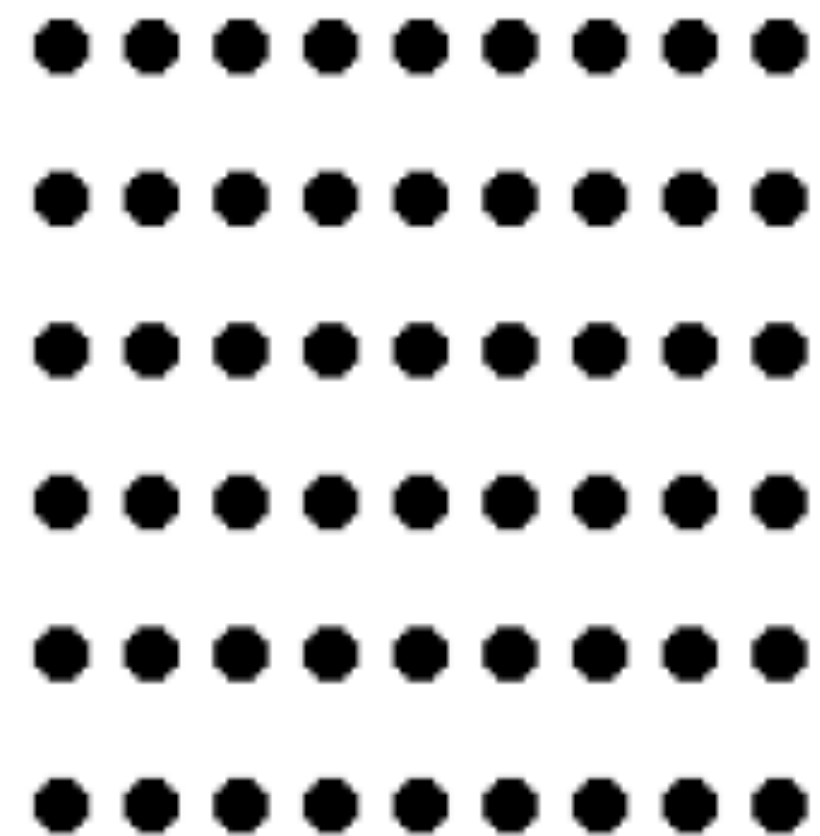
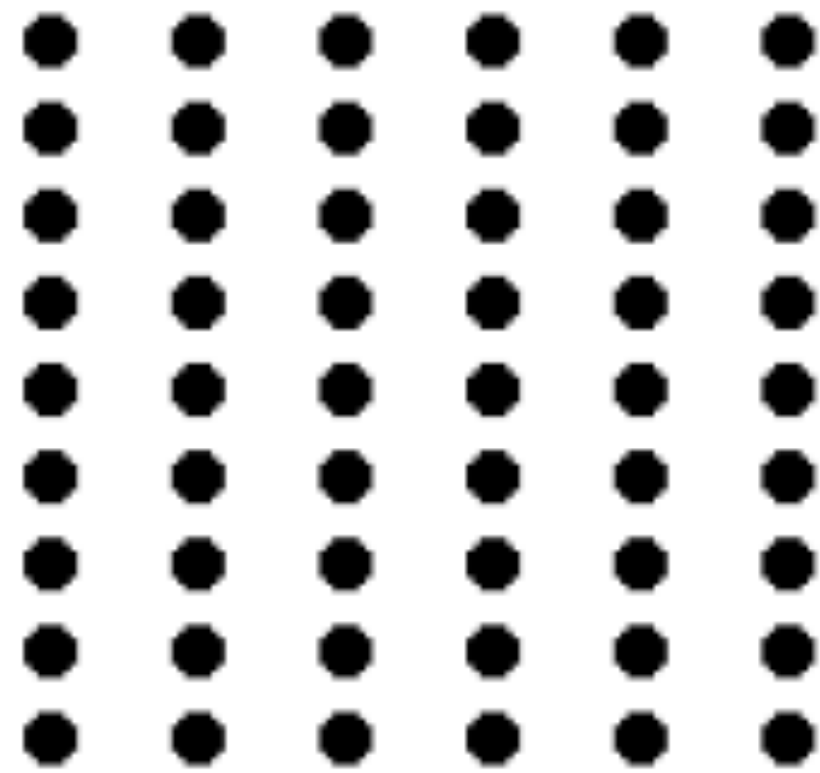
Wertheimer, 1923, and recent extensions

Gestalt Principles

Patterns that transcend the visual stimuli that produced them

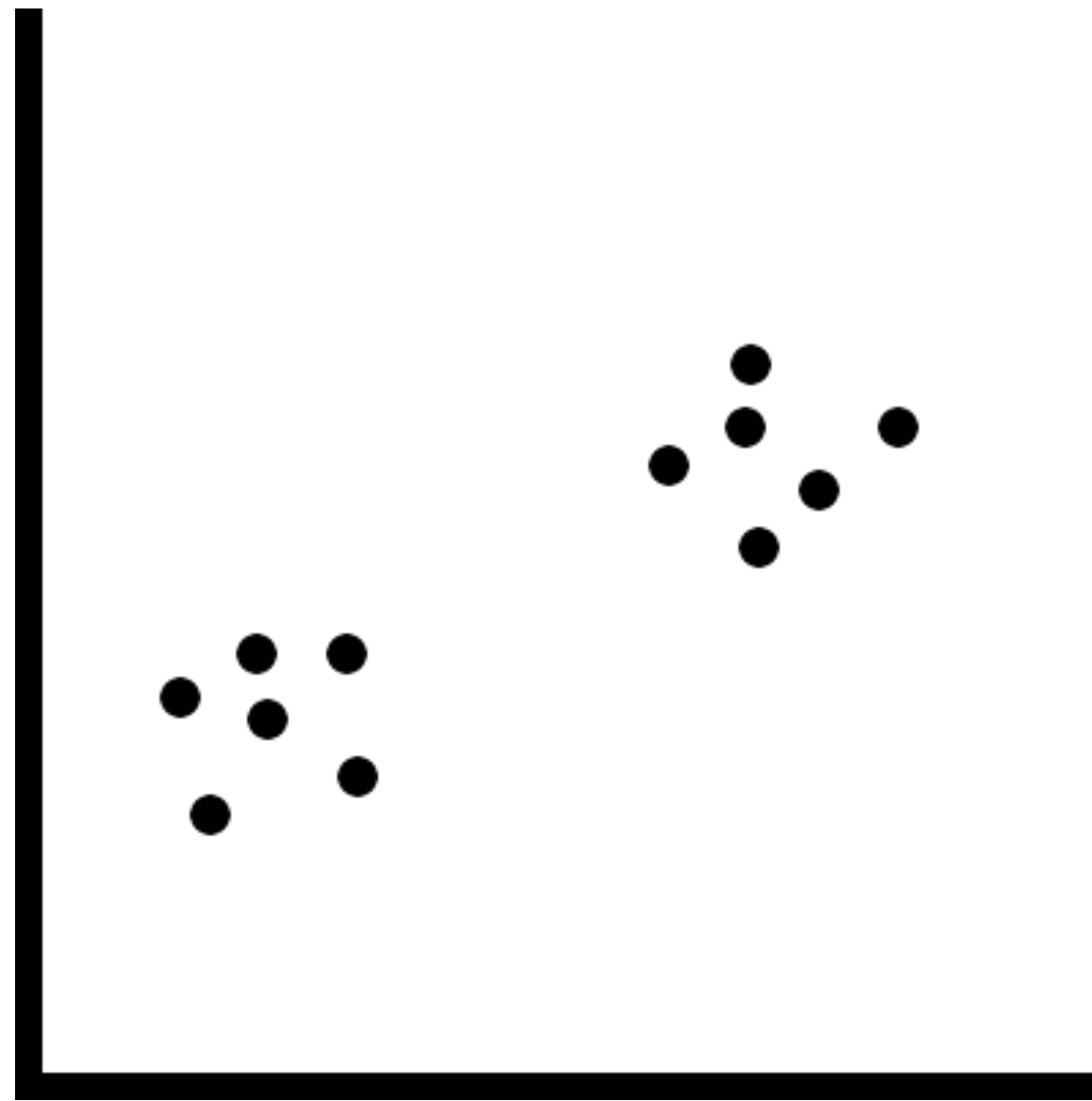


Proximity



Proximity

Grouping/linking by placing entities in close proximity



Similarity

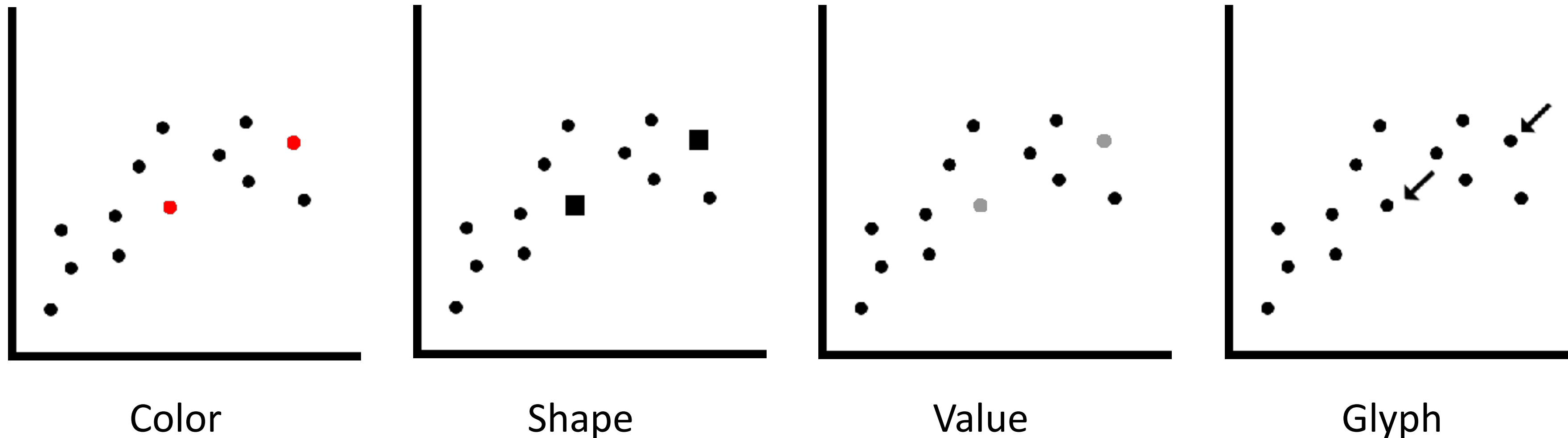


Similarity

Co-modulation of a **channel**

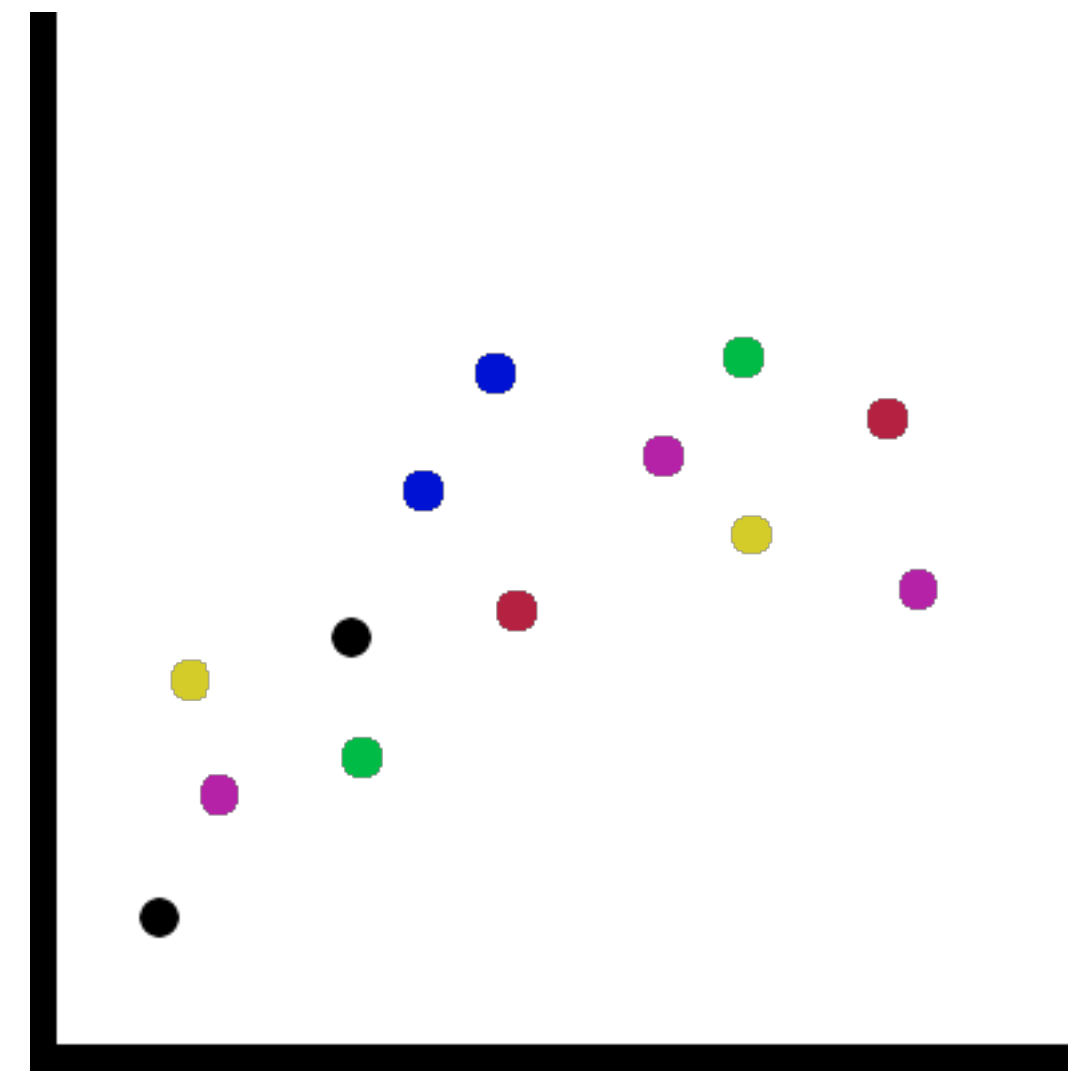
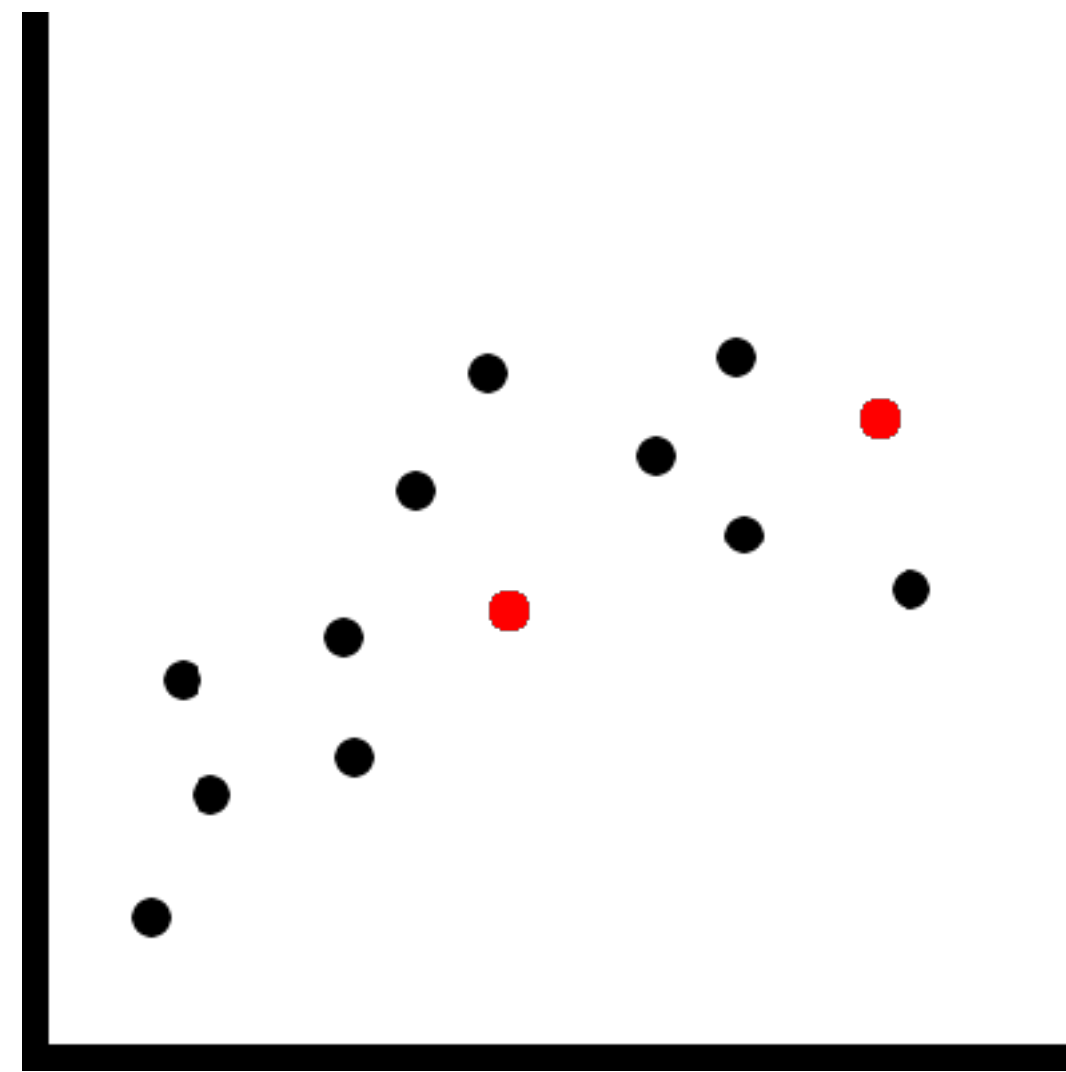
color, shape, size, value, orientation, texture, ...

Adding a glyph, label, frame, background



Color – Perception Issues (1/2)

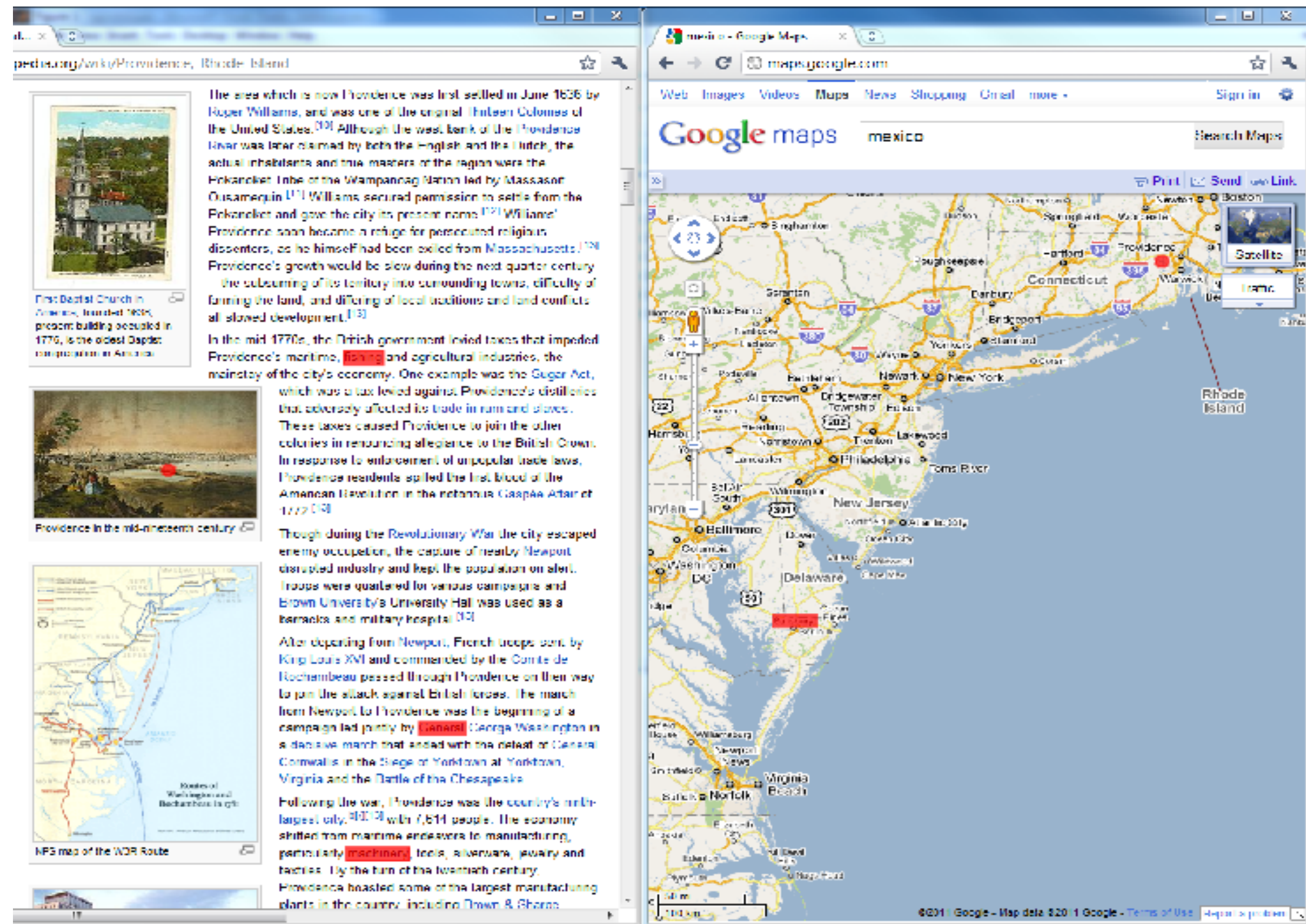
Preattentive properties: Very good for 1-2 simultaneous,
serial search for more



Color – Perception Issues (2/2)

Slower in a cluttered environment

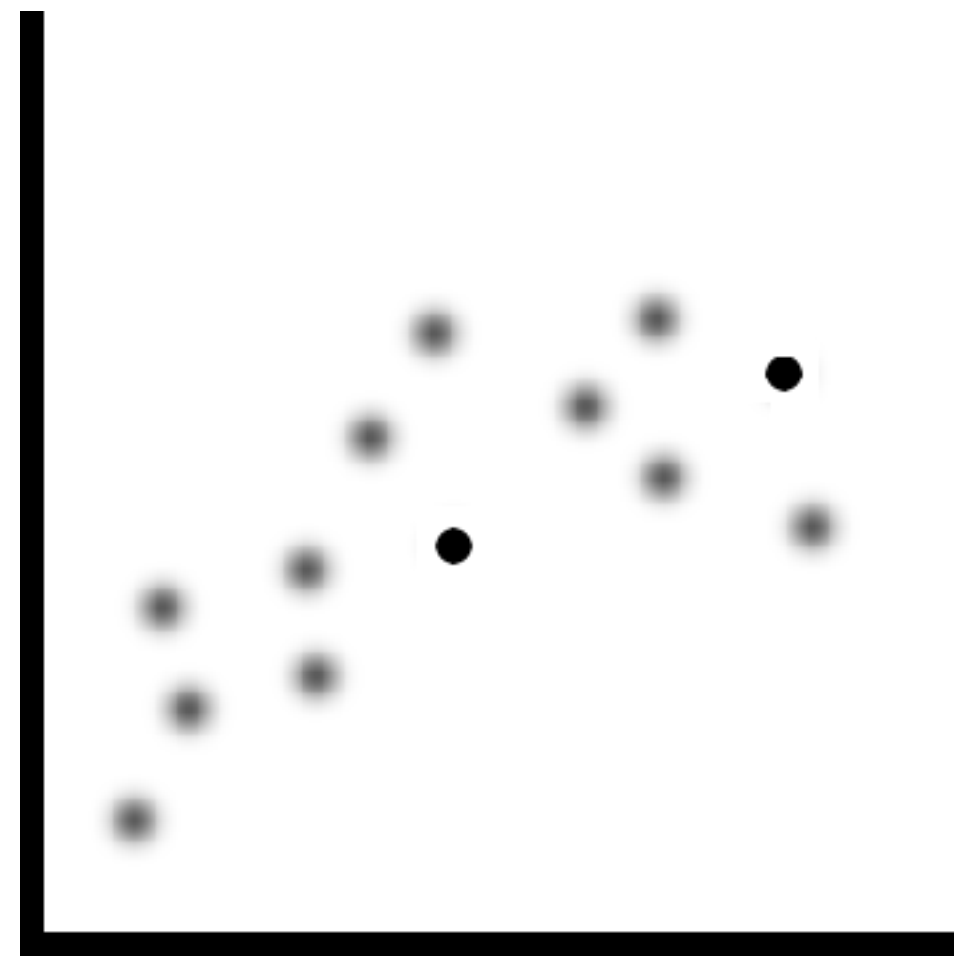
Size of colored object relevant.



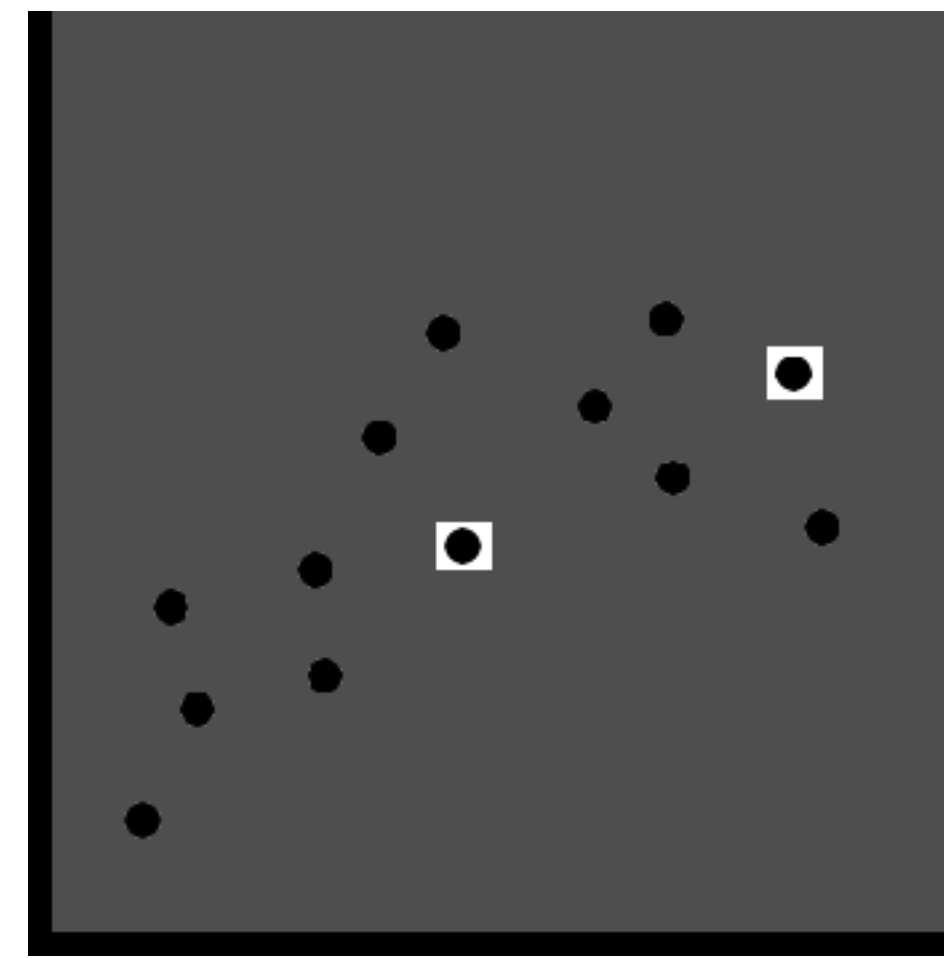
Similarity

Modulate everything else

Blurring, darkening, desaturating, etc.



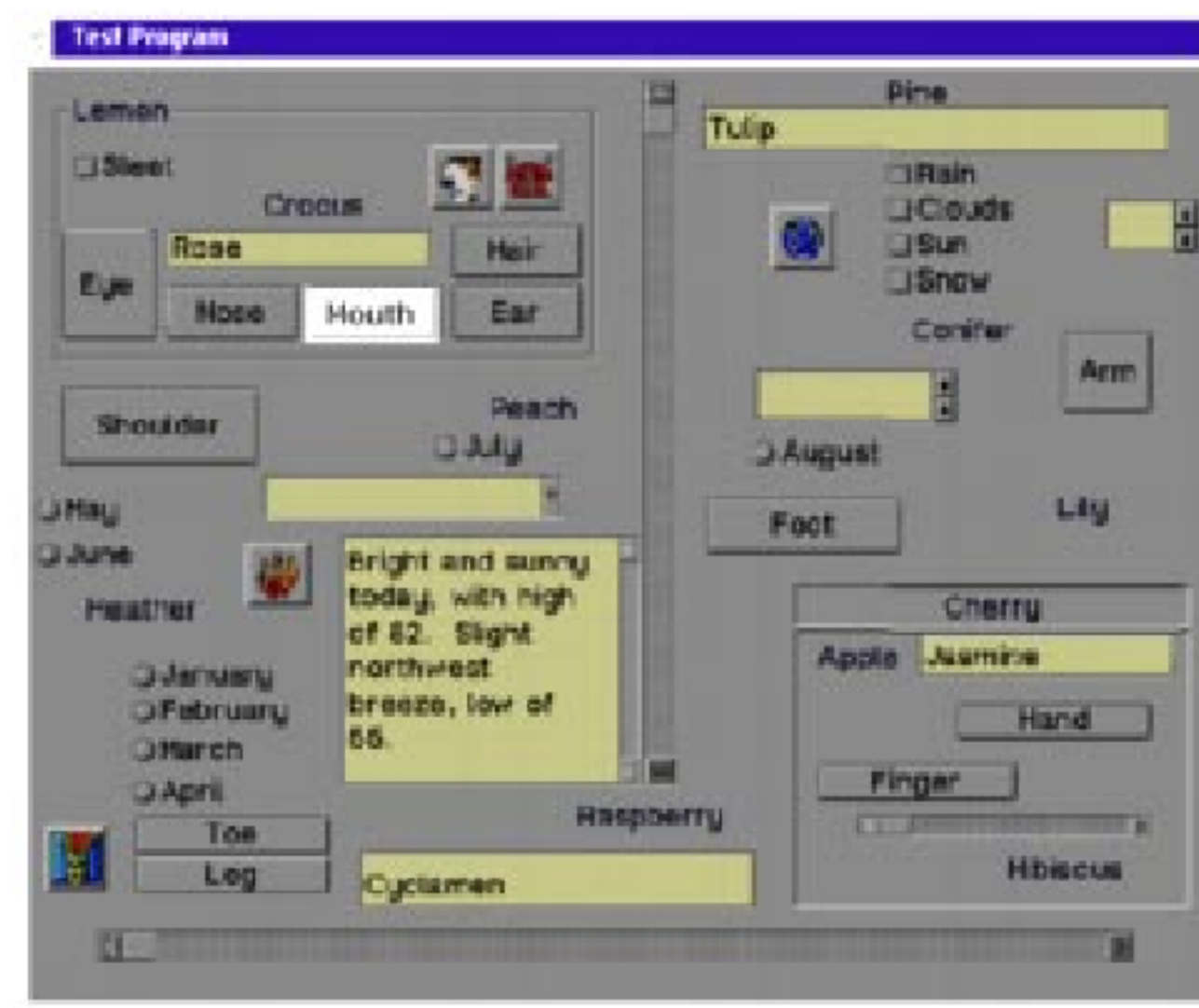
Blur



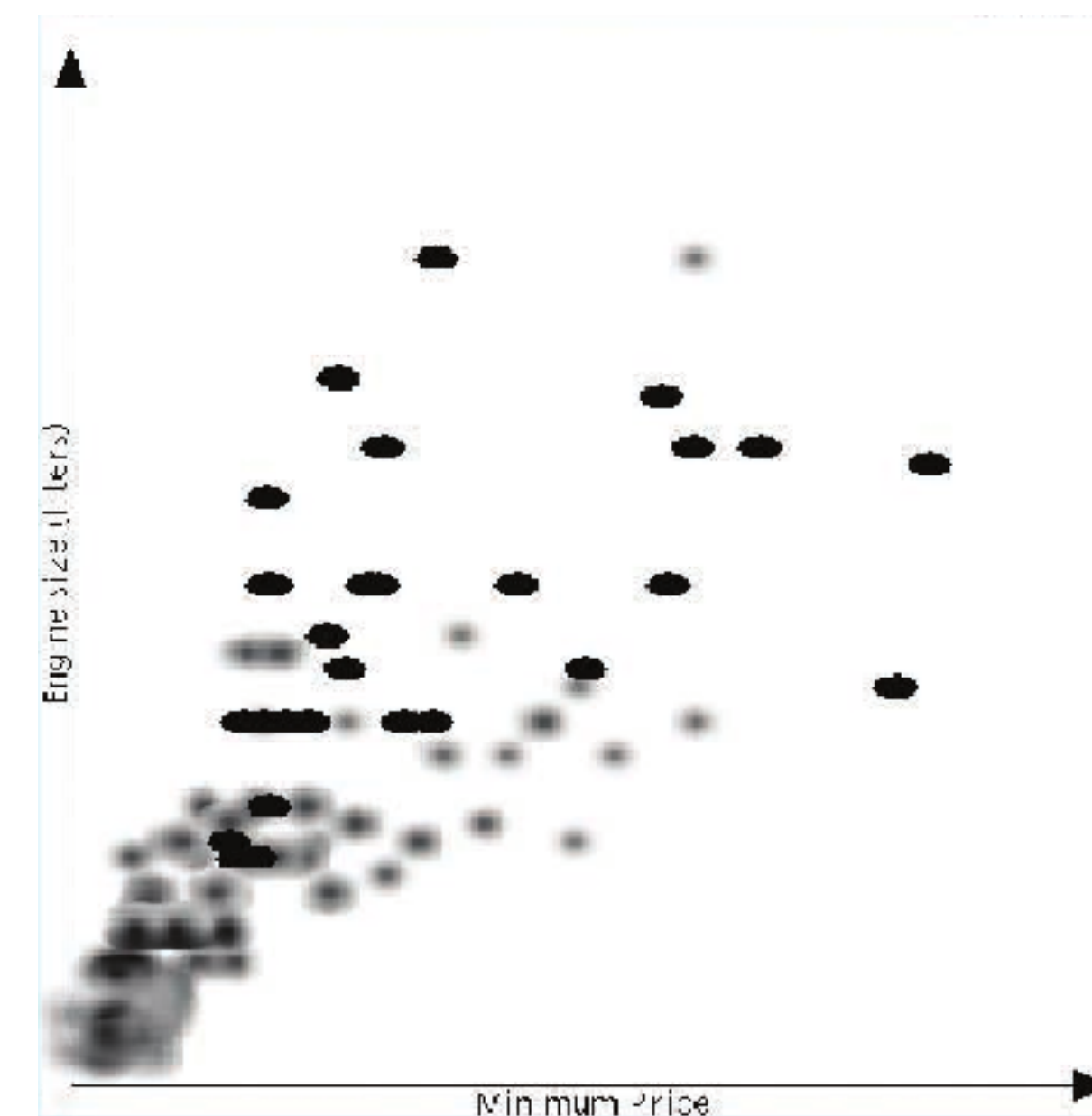
Darkening

Modulating Everything Else: Recommendation, Example

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

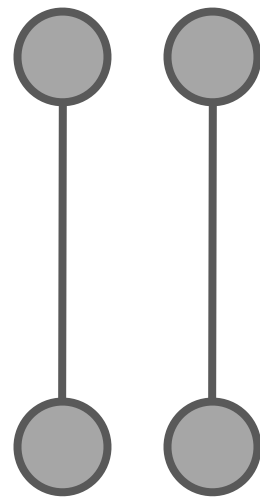


[Zhai et al., 1997]

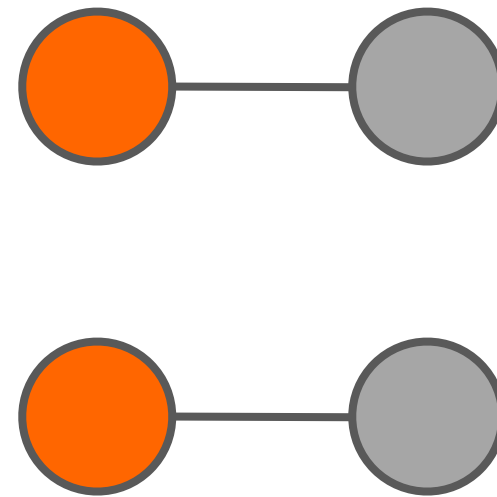


[Kosara et al., 2002]

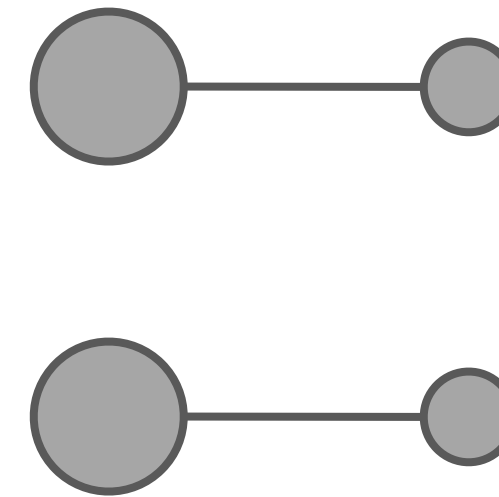
A Little Experiment...



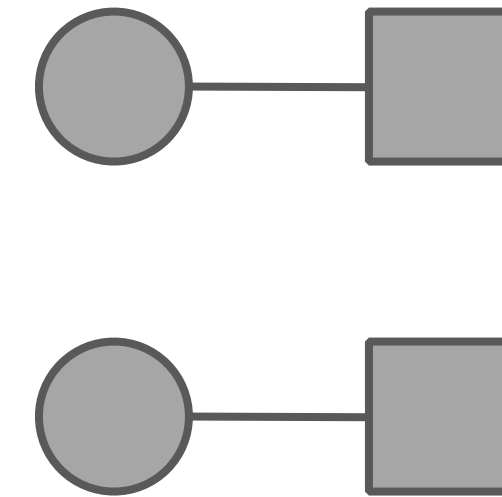
Proximity



Color



Size

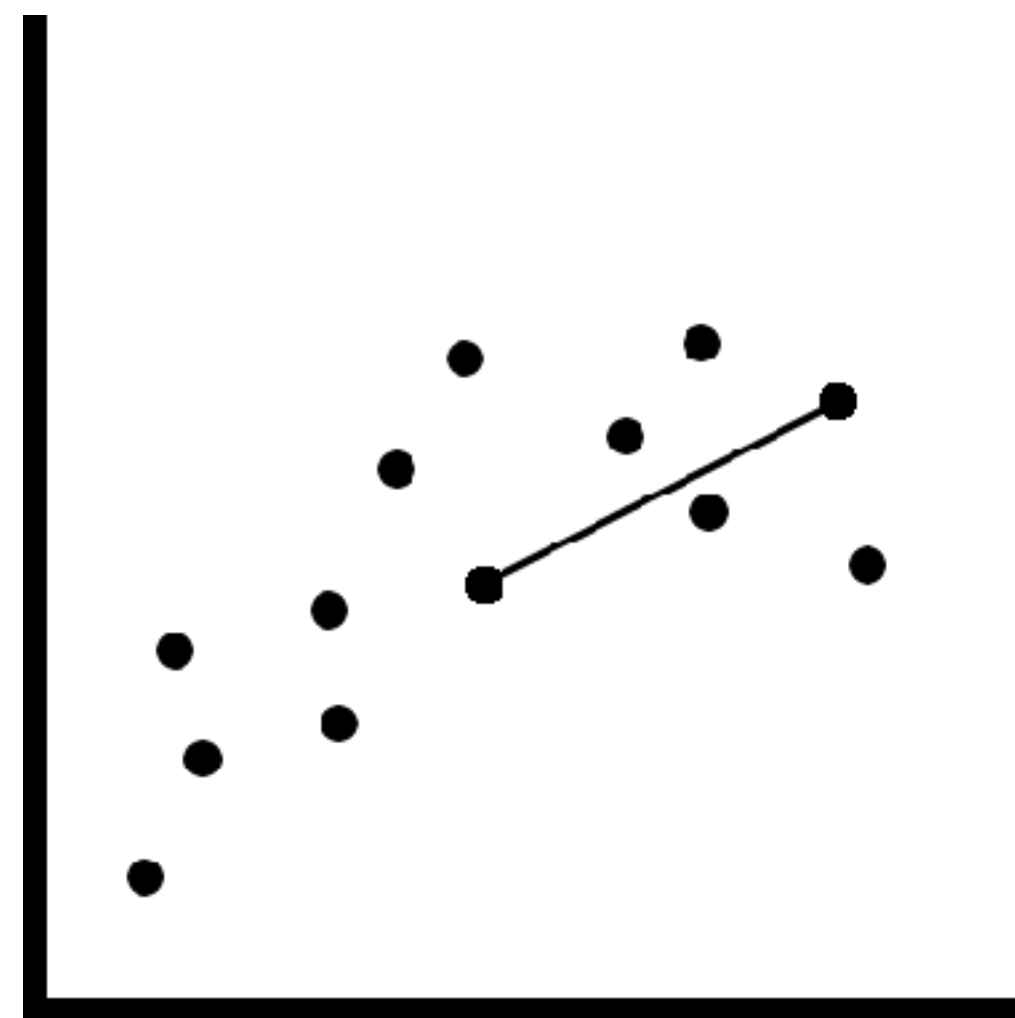


Shape

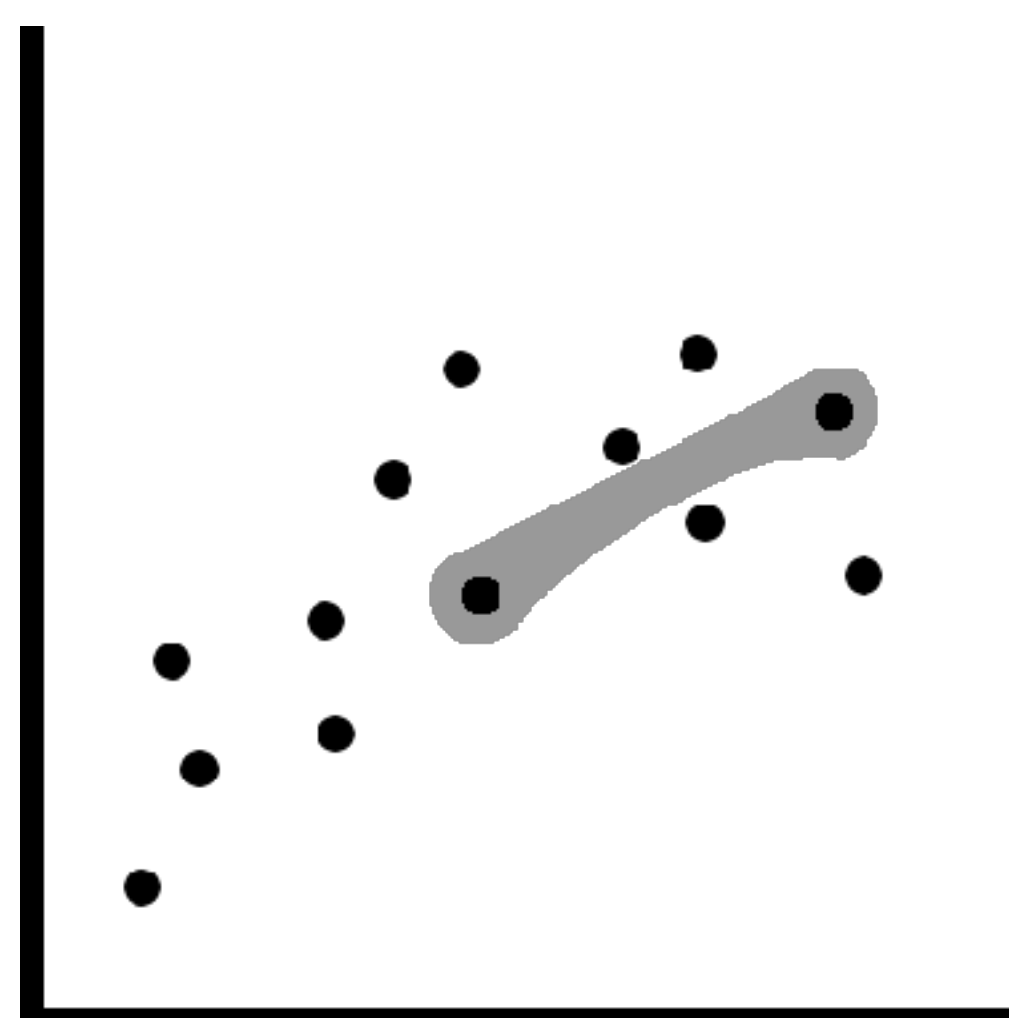
Connectedness and Common Region

Connected items with a line or curve

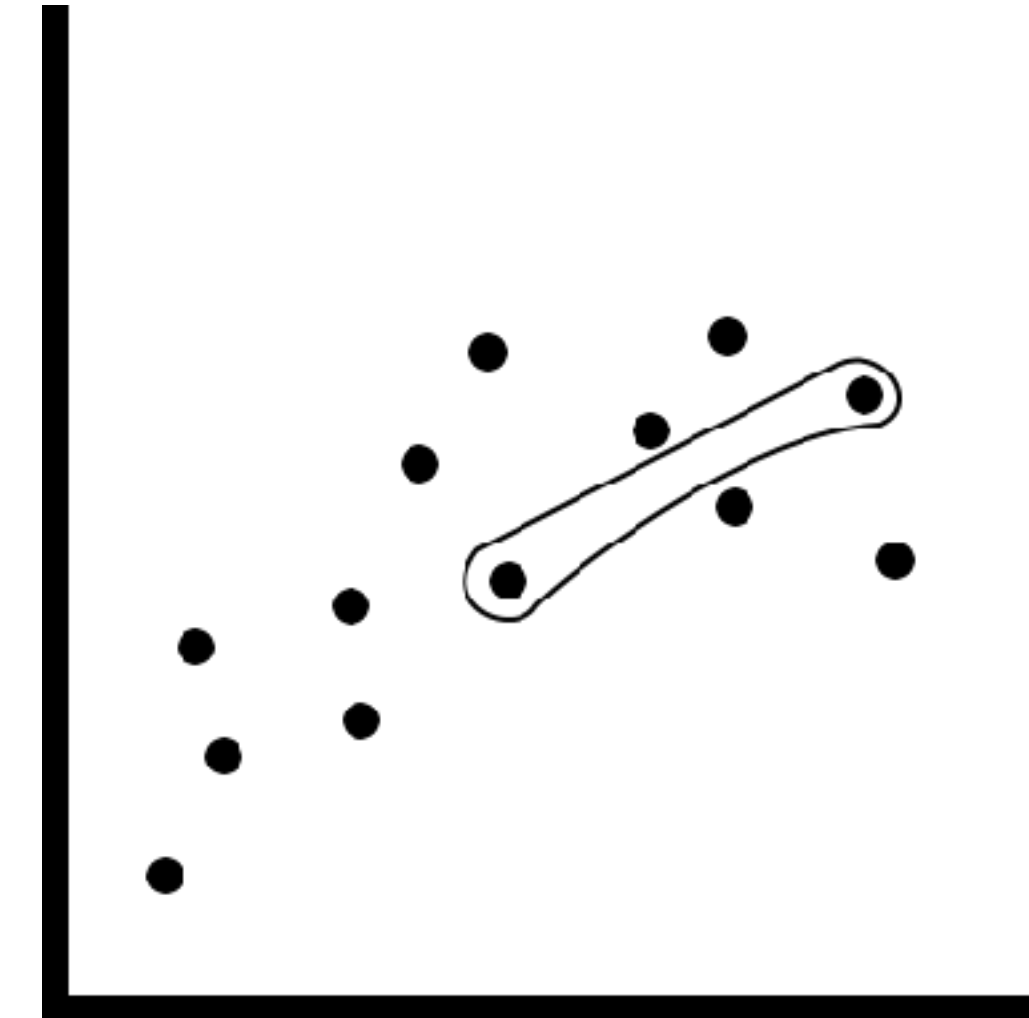
Surround items with a outline, surface, volume



Connectedness



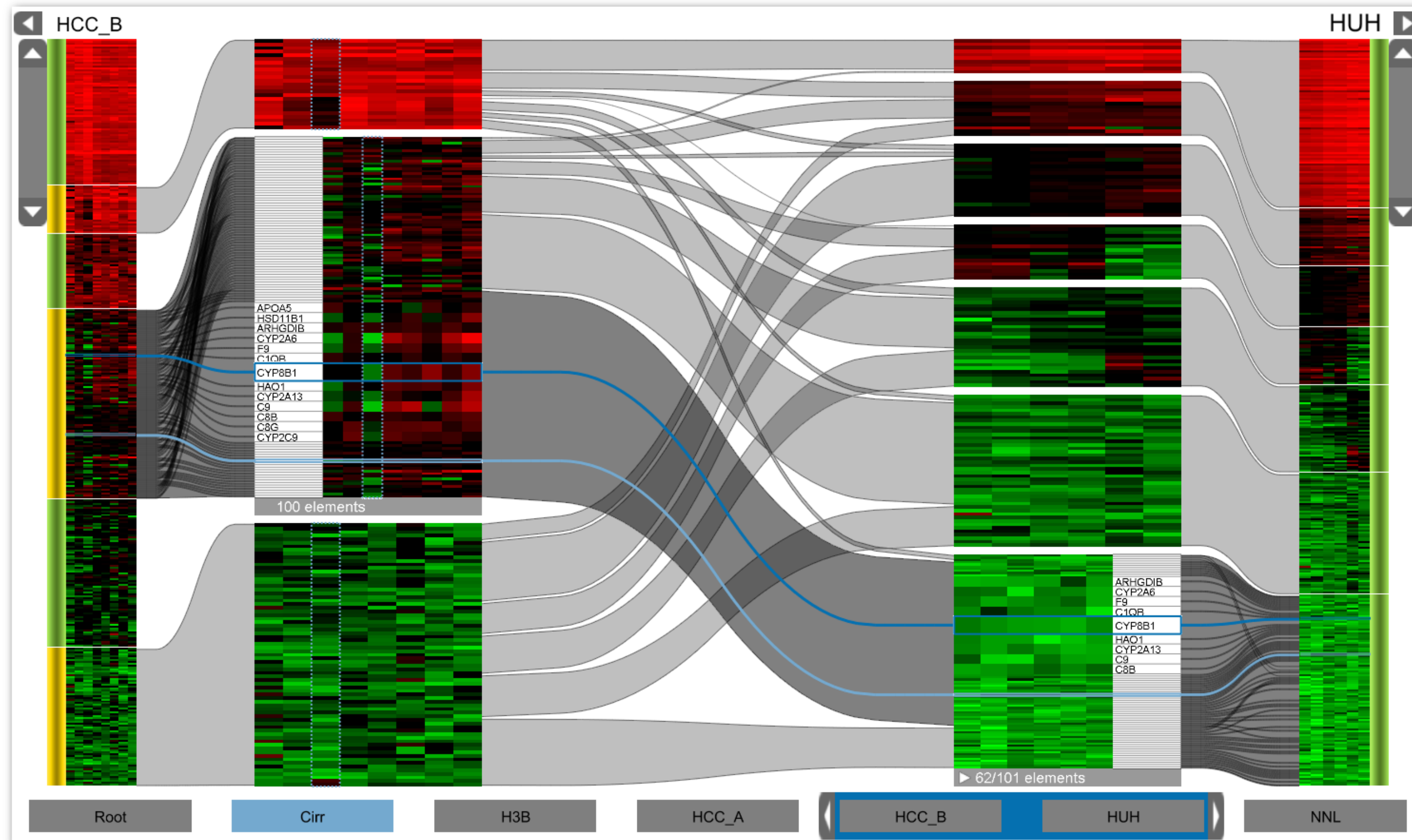
Surface



Outline

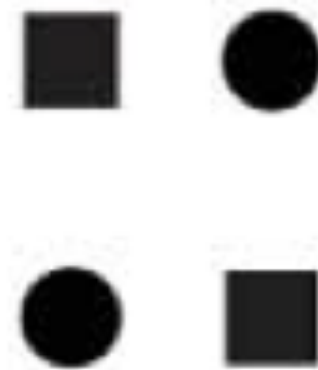
Common Region

Connection

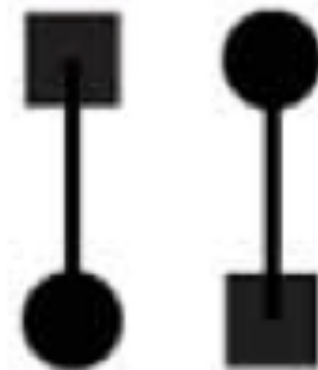


Enclosure

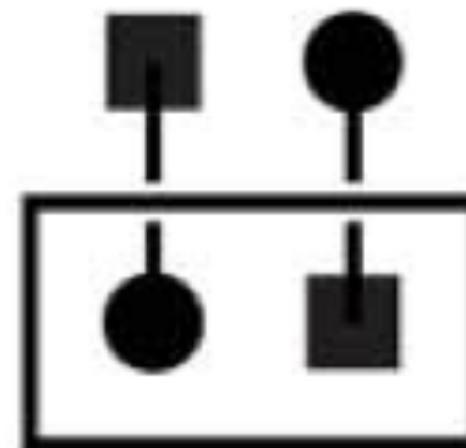
Similarity



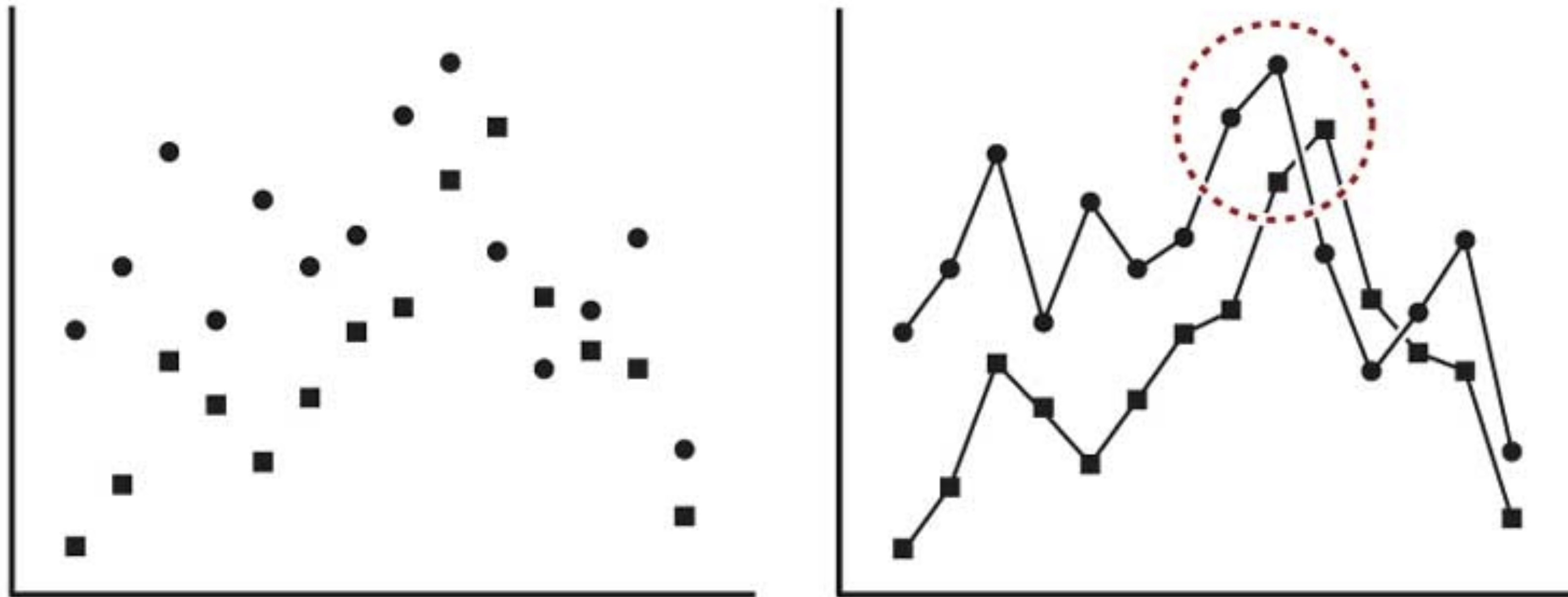
Connection



Enclosure



Enclosure



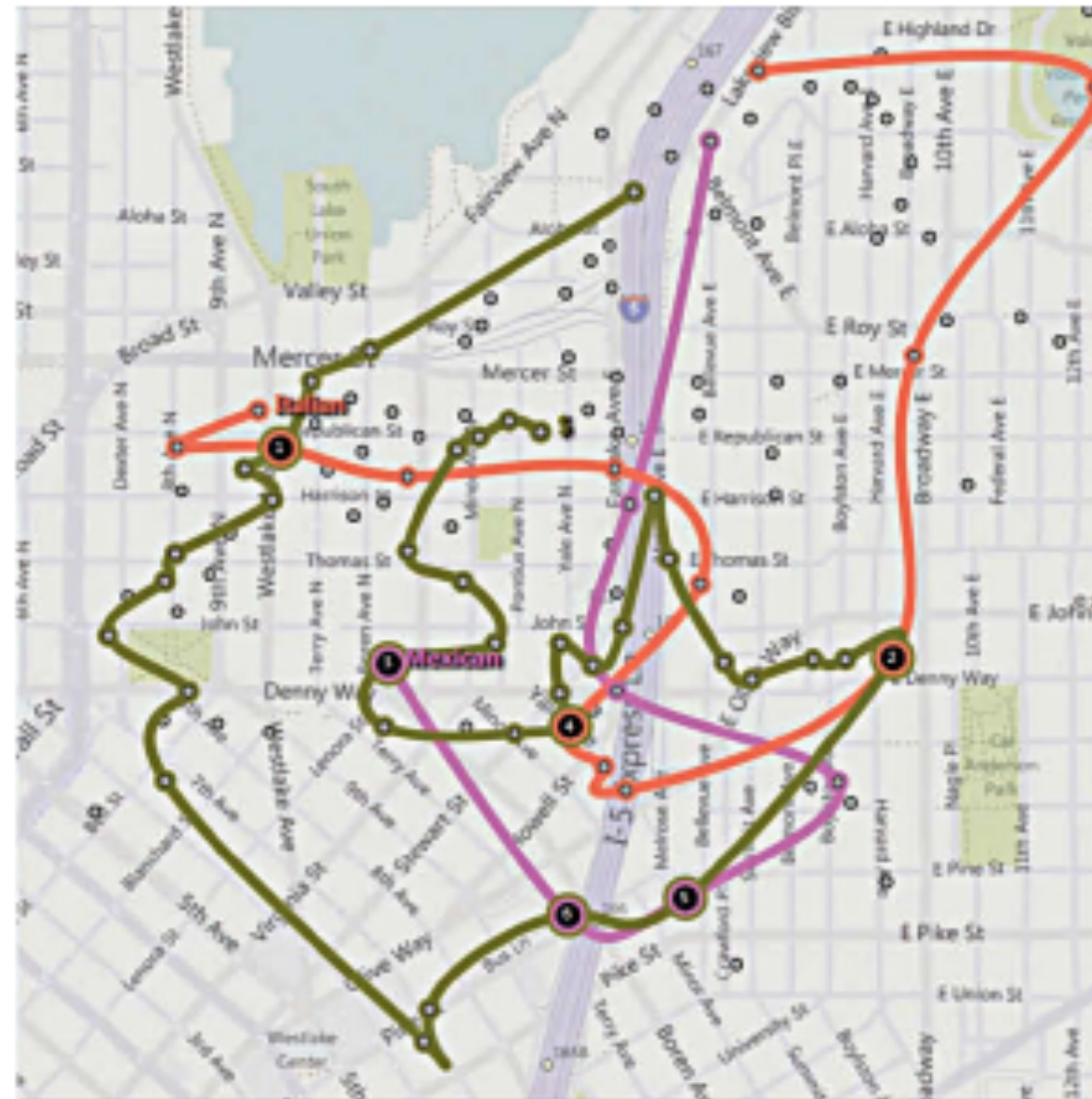
Connectedness Varieties

Bubble Sets



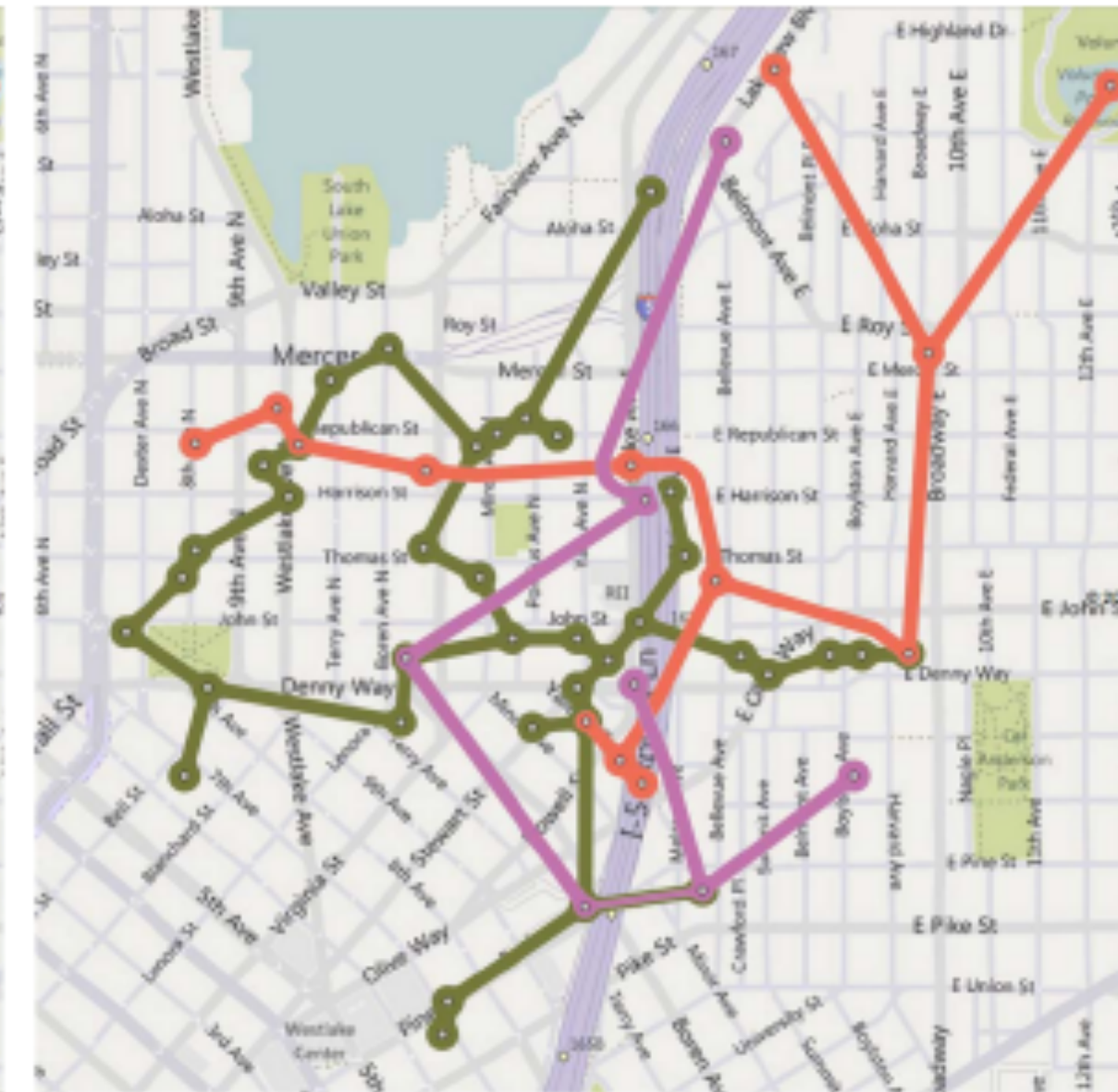
Image by [Dinkla et al., 2011]
Technique by [Collins et al., 2009]

Line Sets



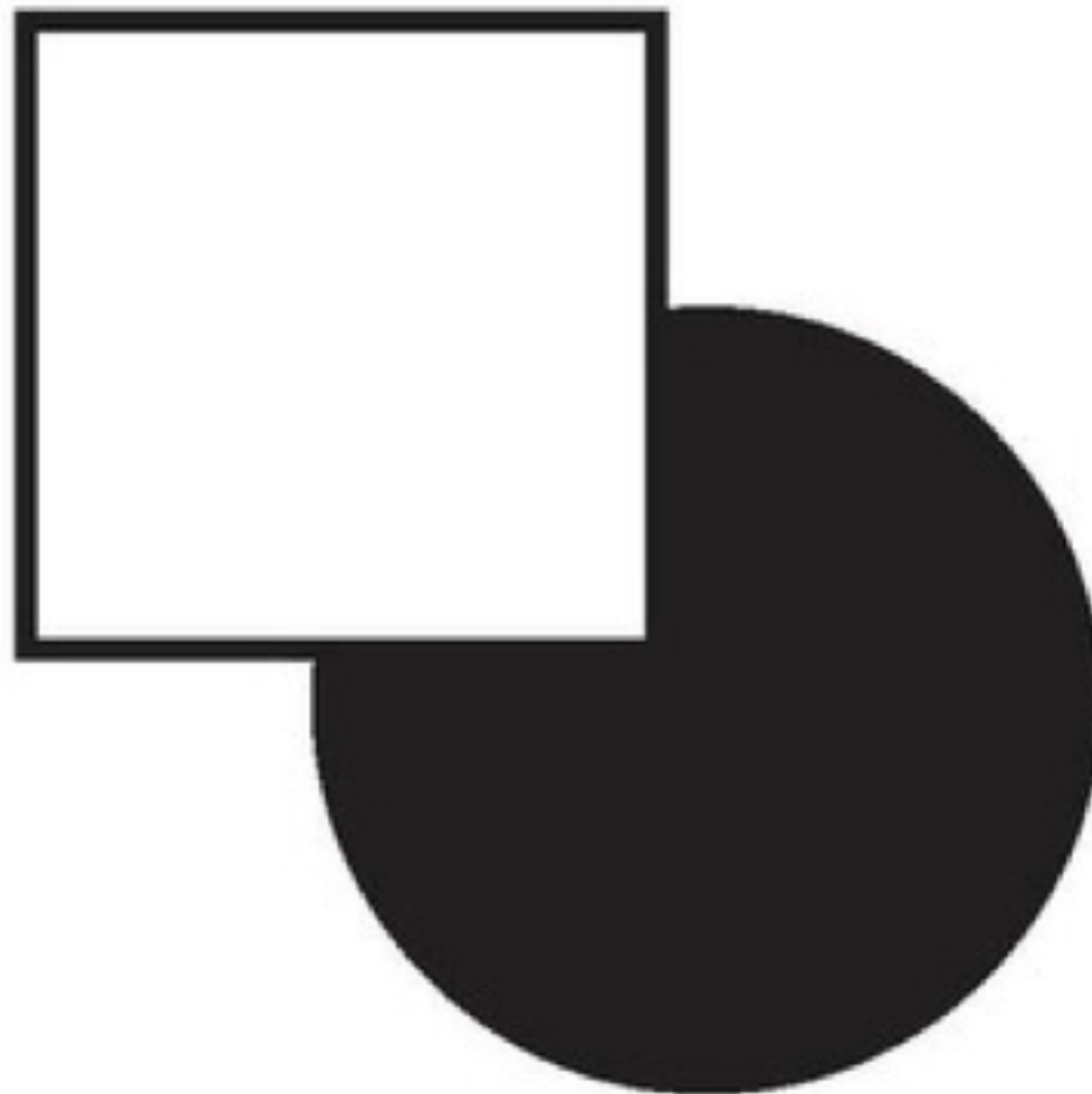
[Alper et al., 2011]

Kelp Diagrams

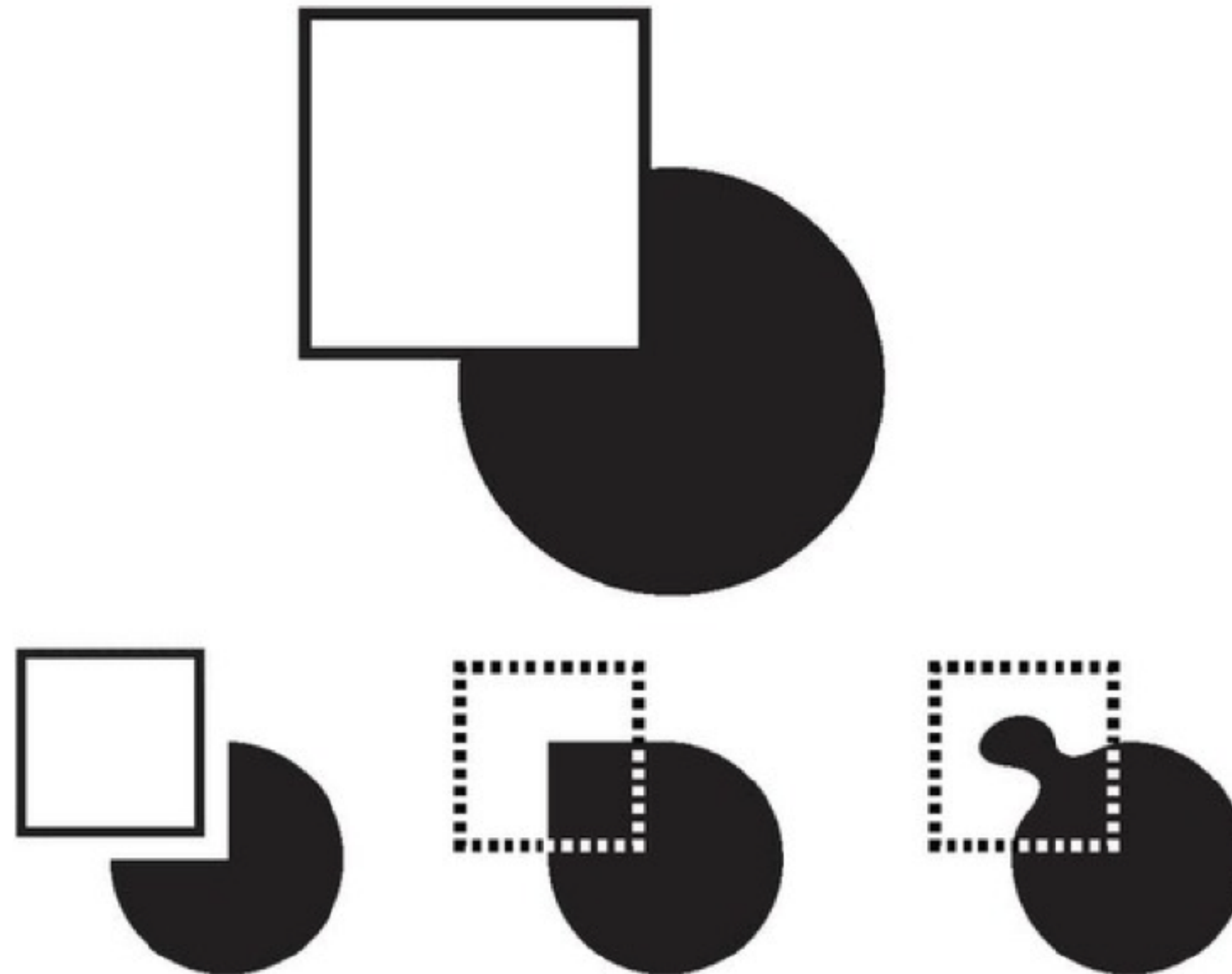


[Dinkla et al., 2012]

Continuity

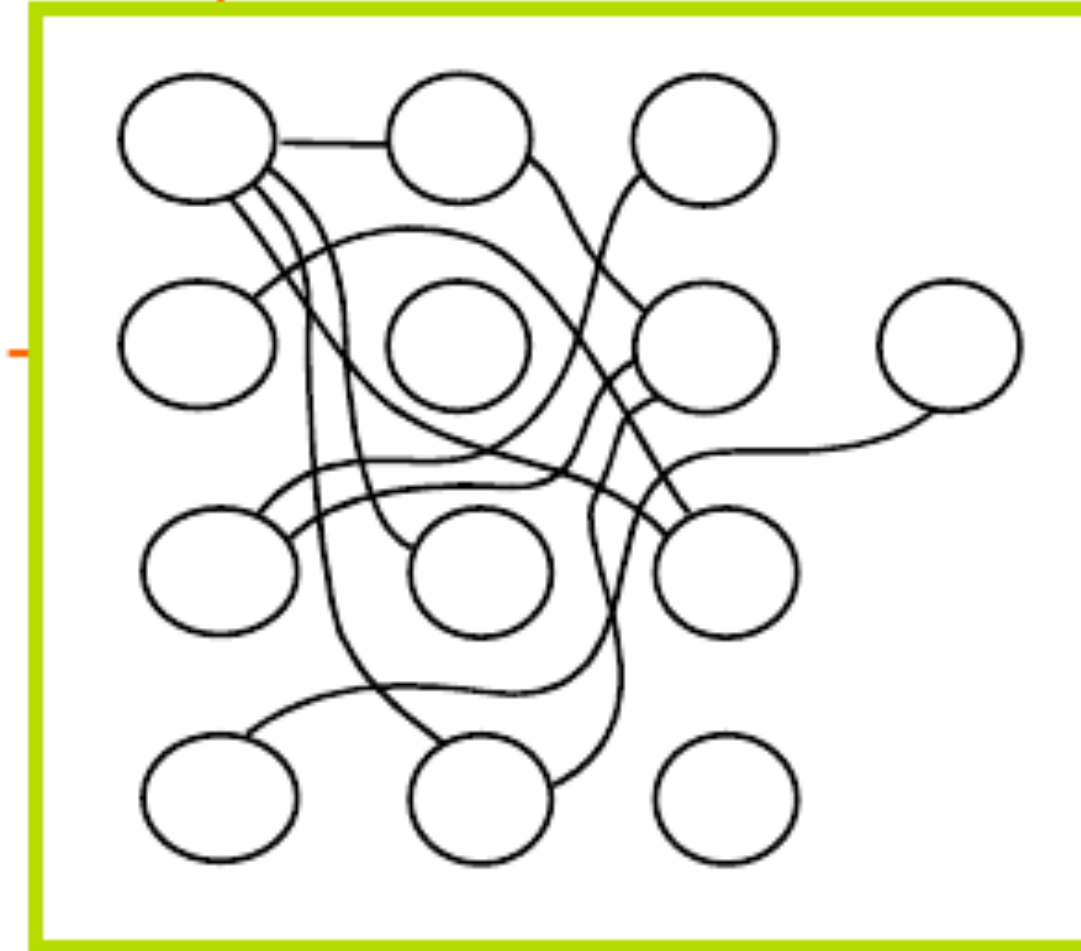
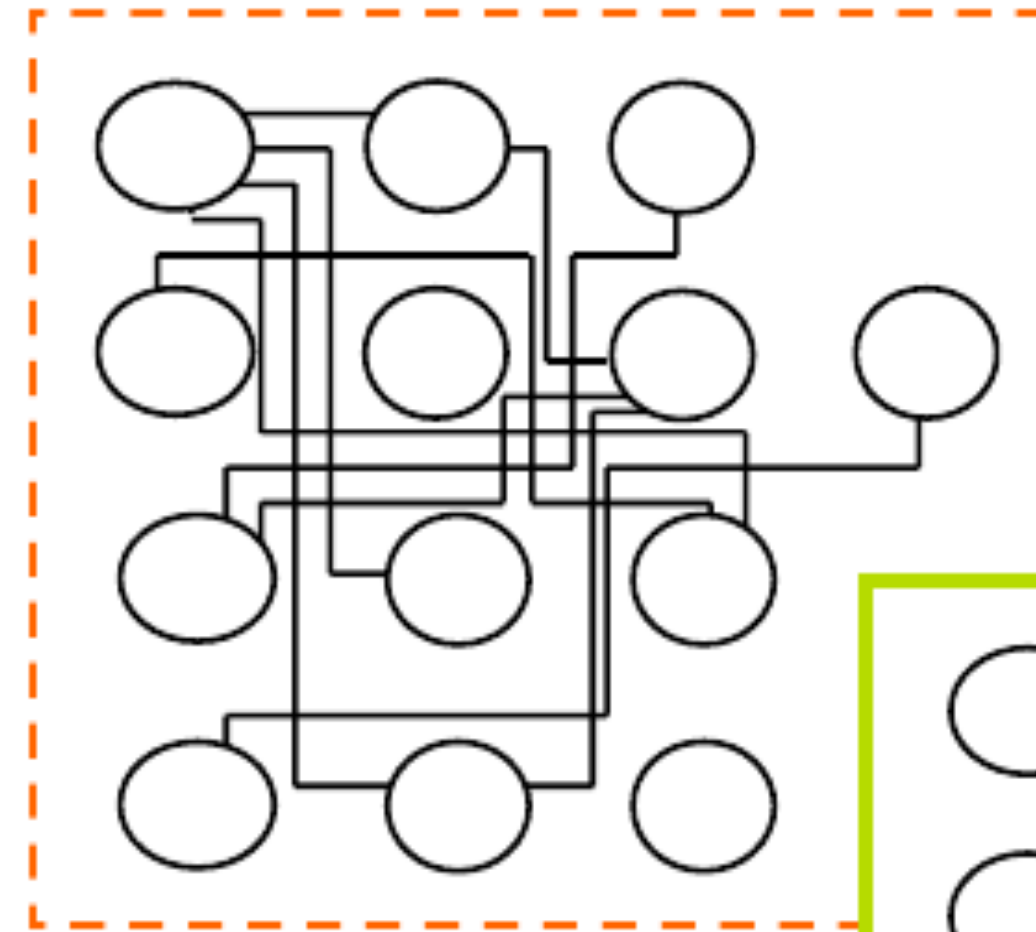
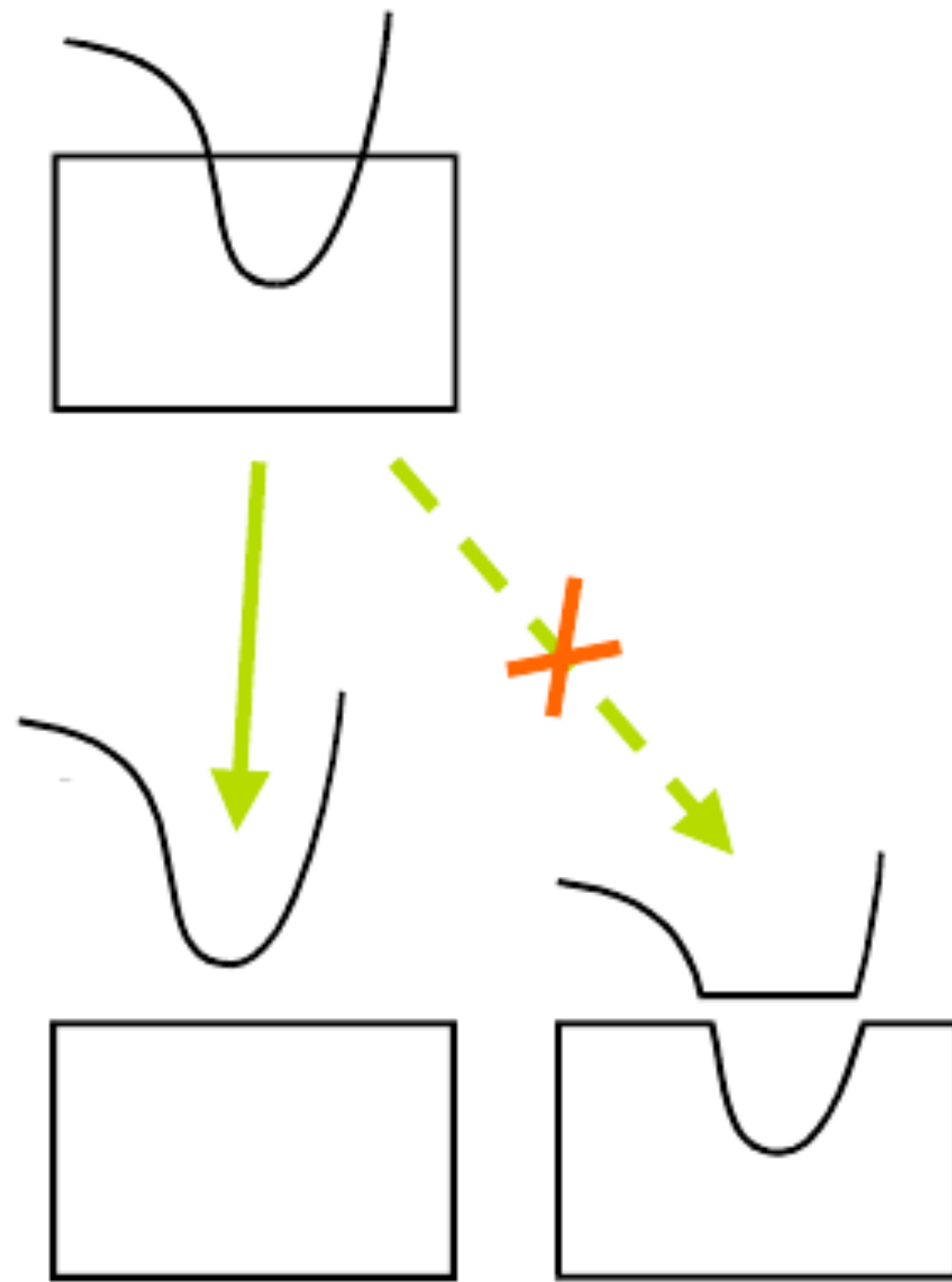


Continuity

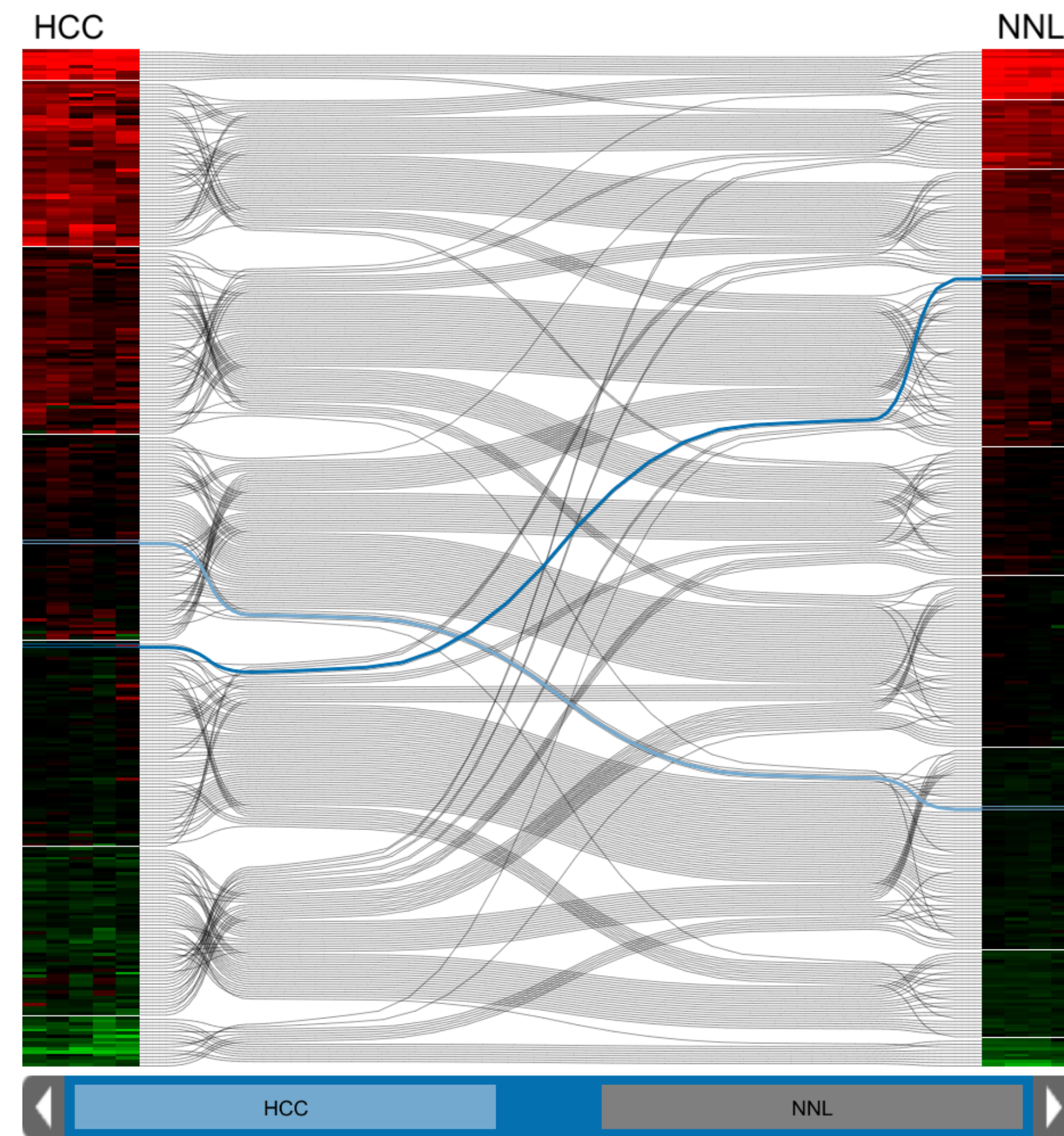
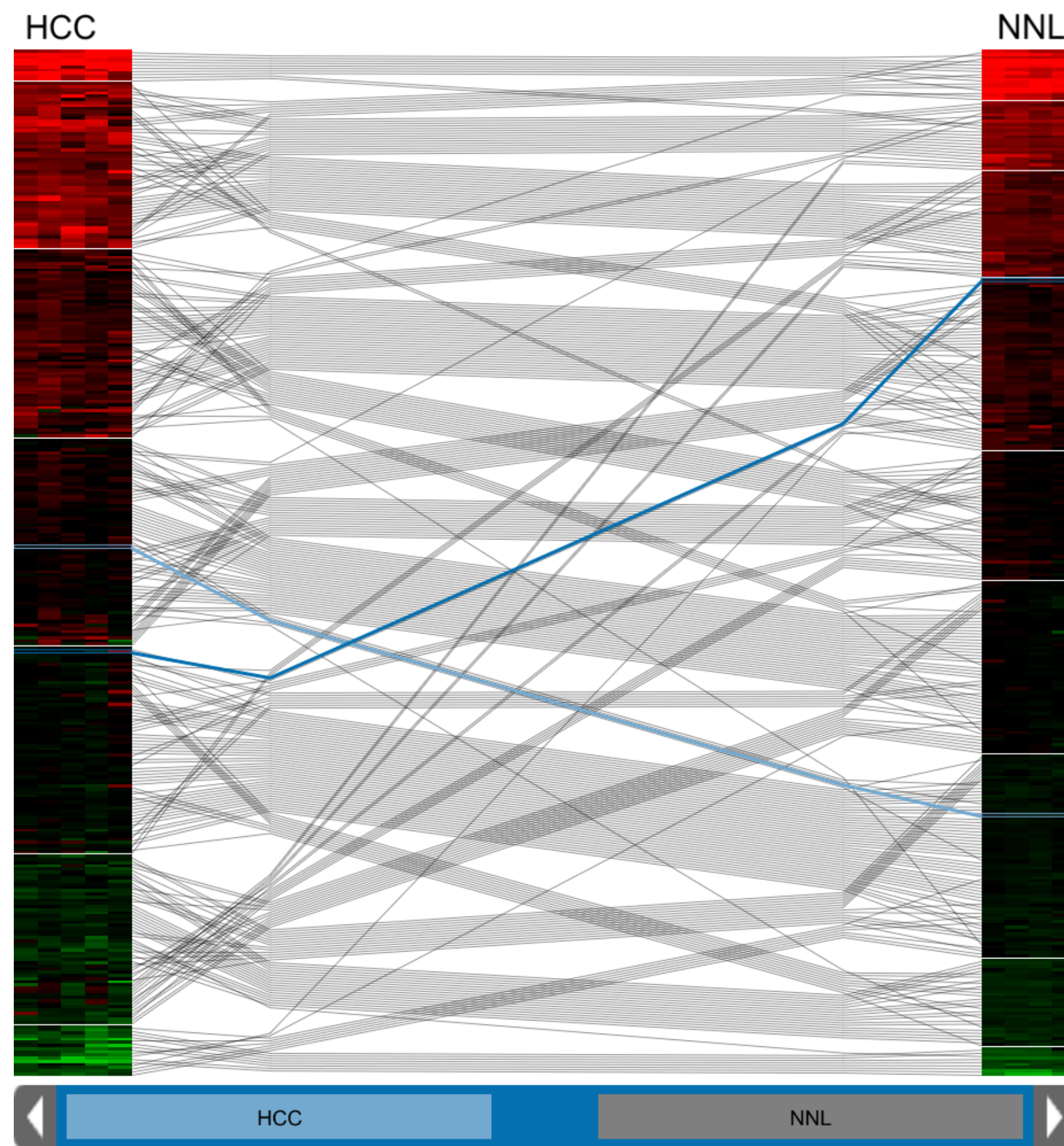


Continuity

Things: smooth & continuous



Continuity



Closure

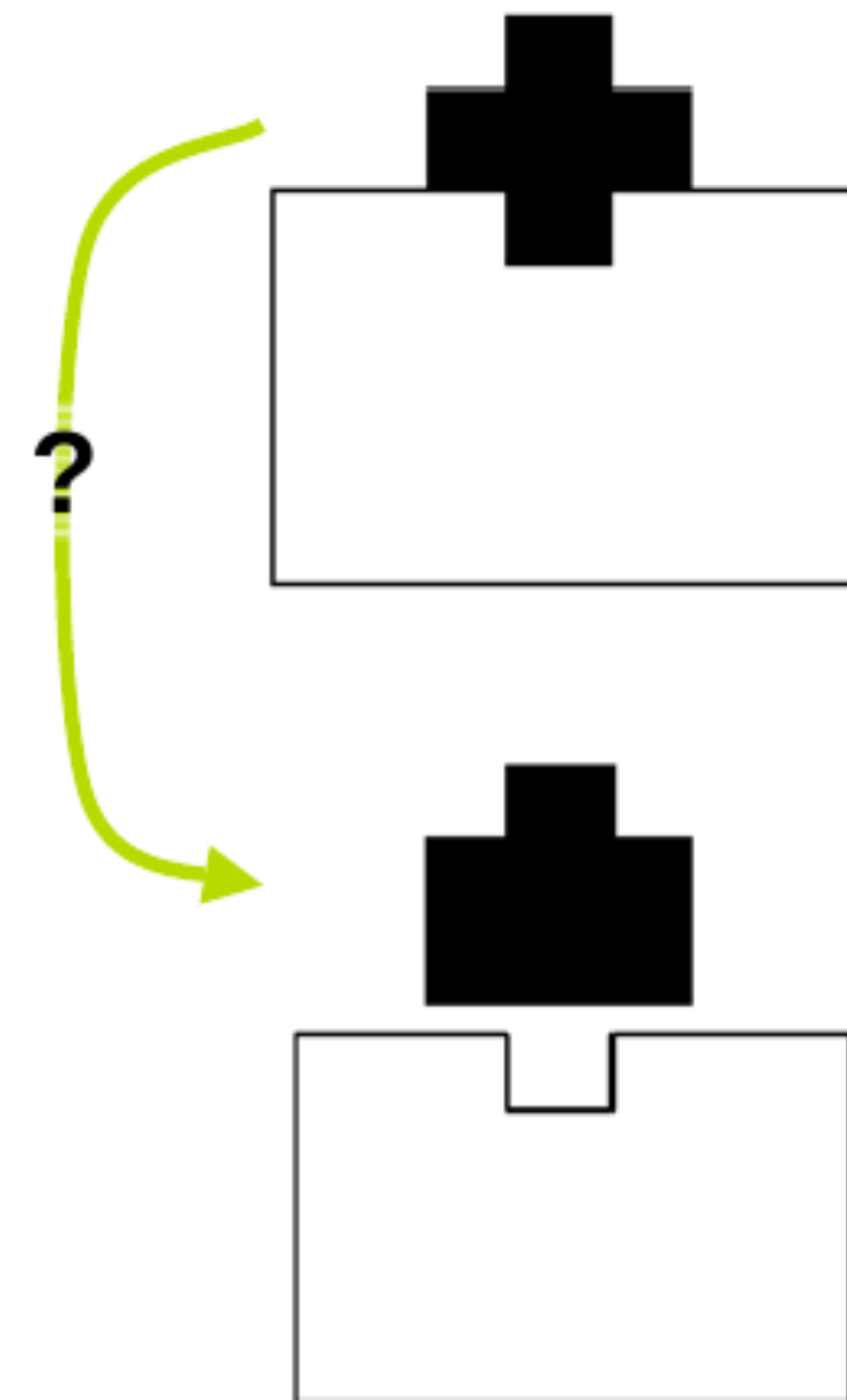
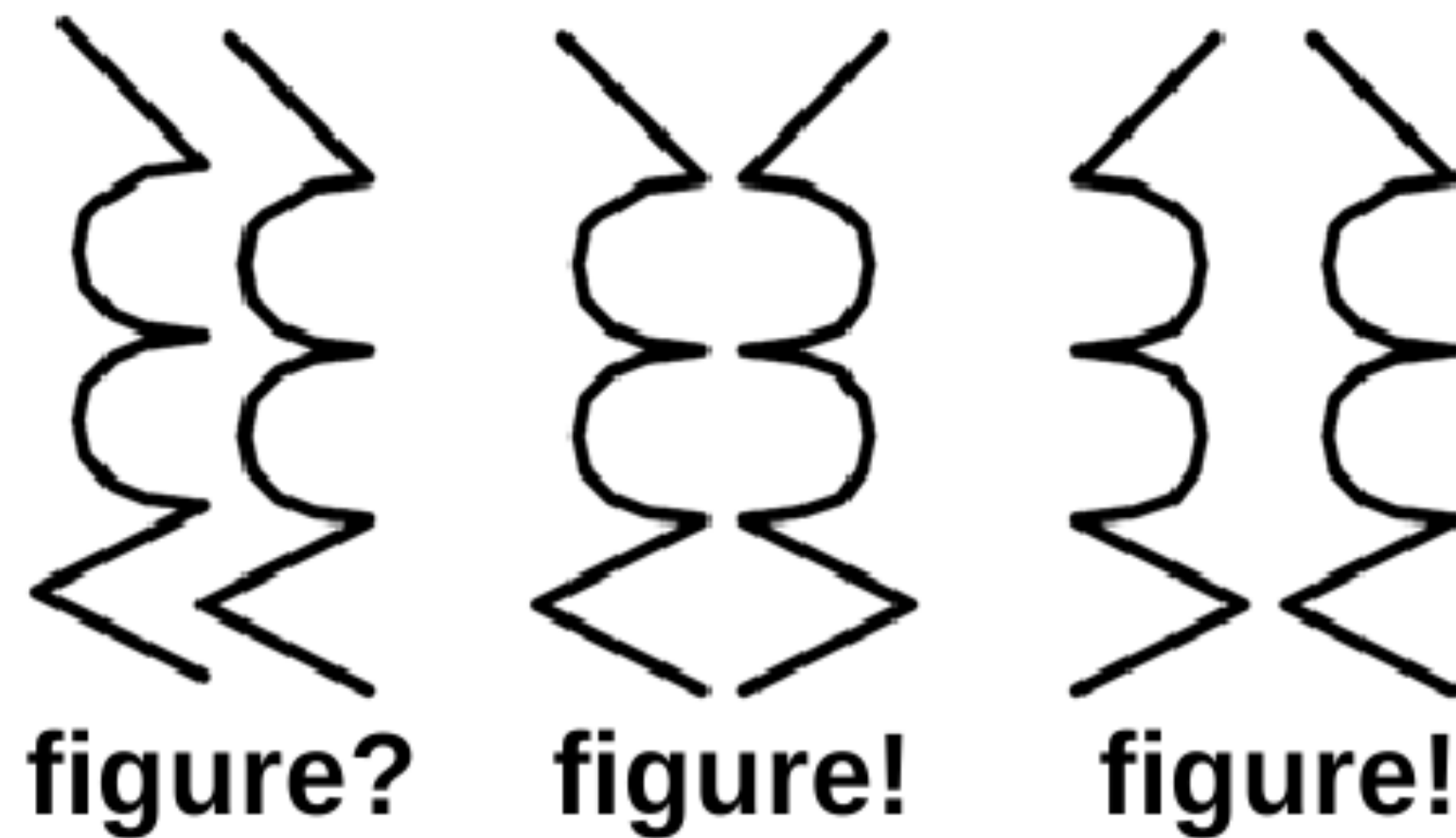


Closure



Symmetry

Things: symmetric



Population Pyramid

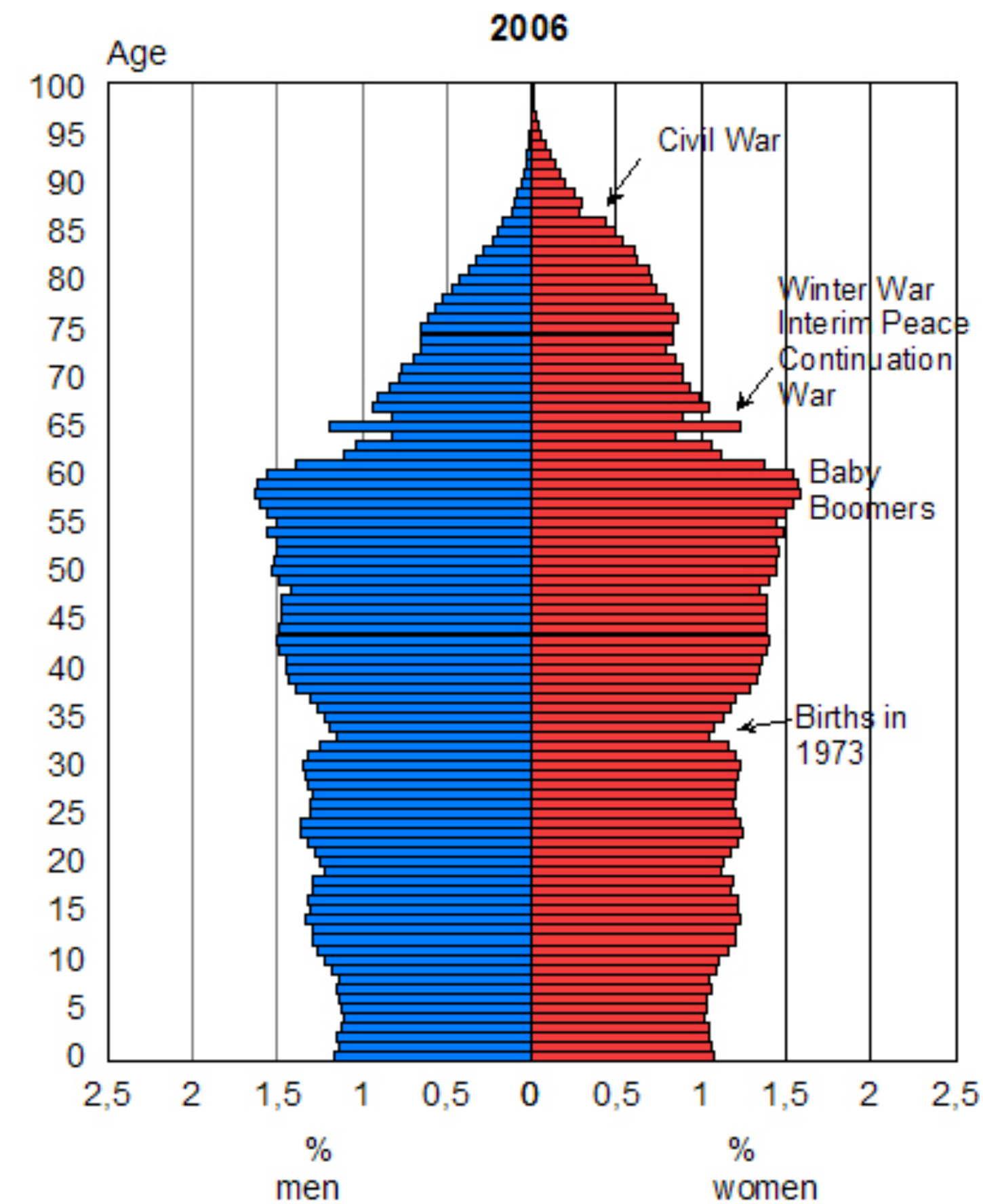
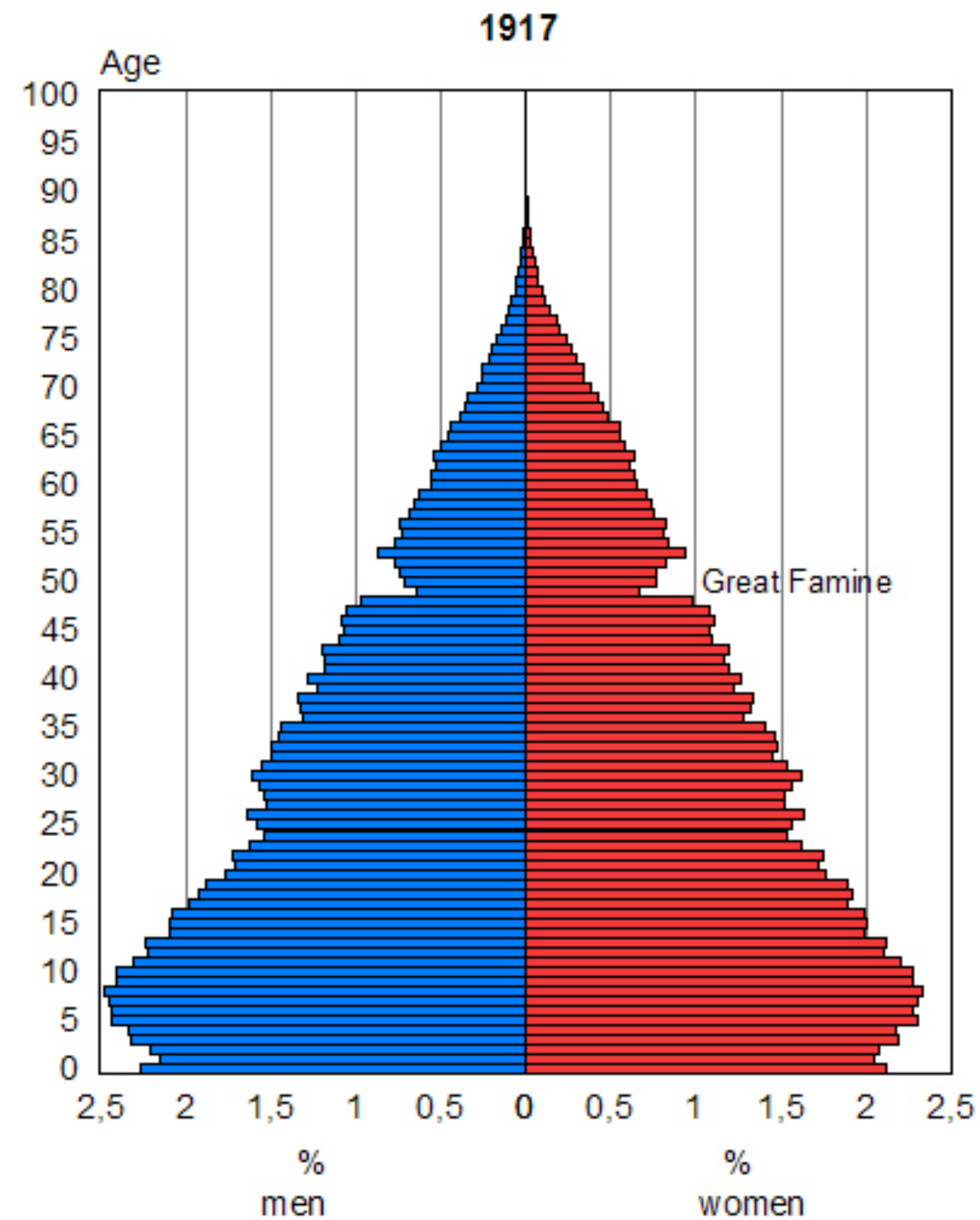
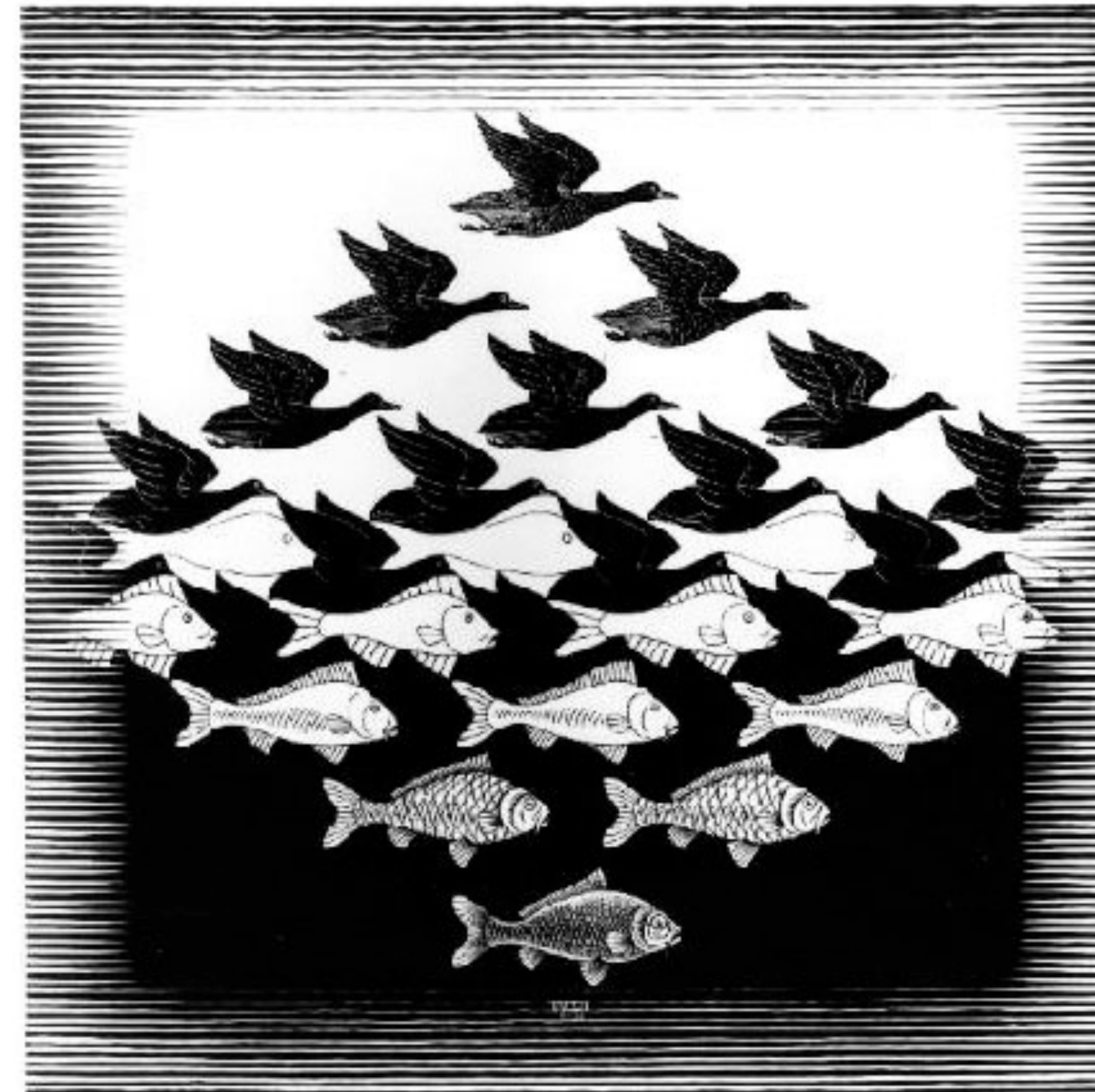


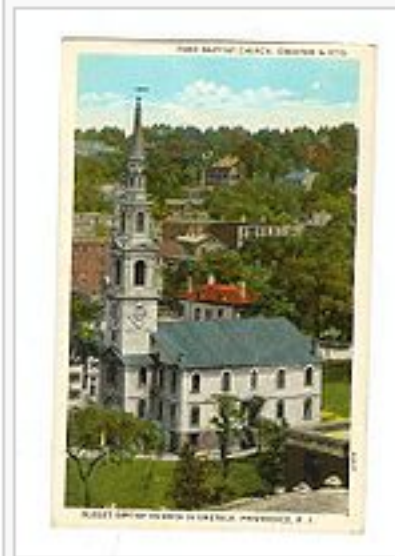
Figure / Ground



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

Applications in Vis

edia.org/wiki/Providence,_Rhode_Island



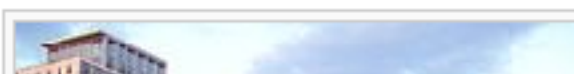
First Baptist Church in America, founded 1638, present building occupied in 1776, is the oldest Baptist congregation in America



Providence in the mid-nineteenth century



NPS map of the W3R Route



The area which is now Providence was first settled in June 1536 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 Inbe 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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Providence in the mid-nineteenth century



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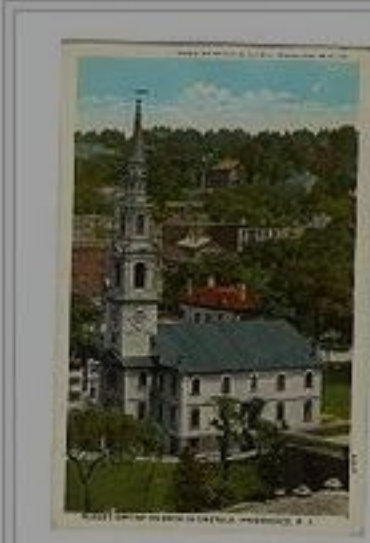
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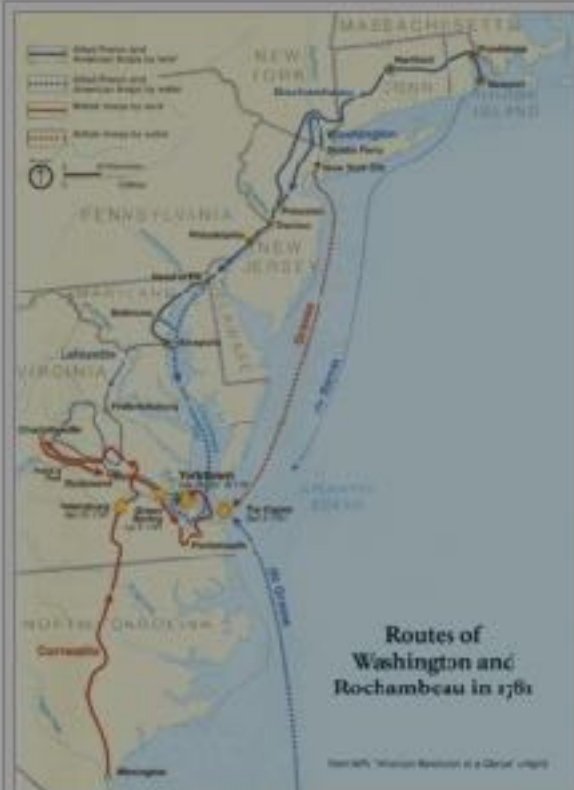




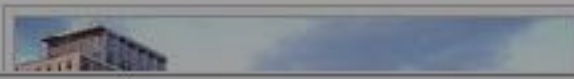
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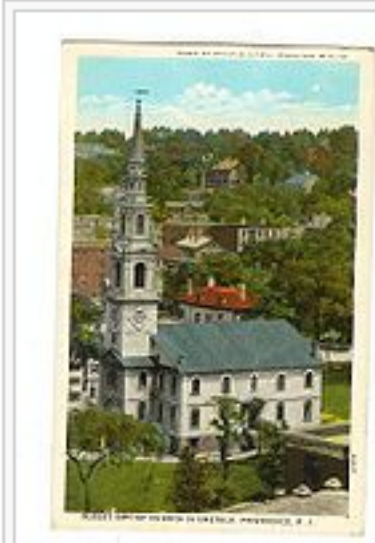
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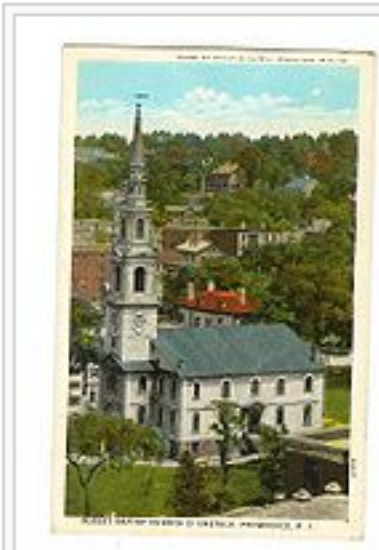
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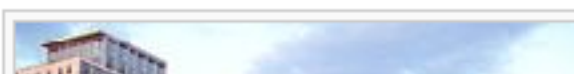
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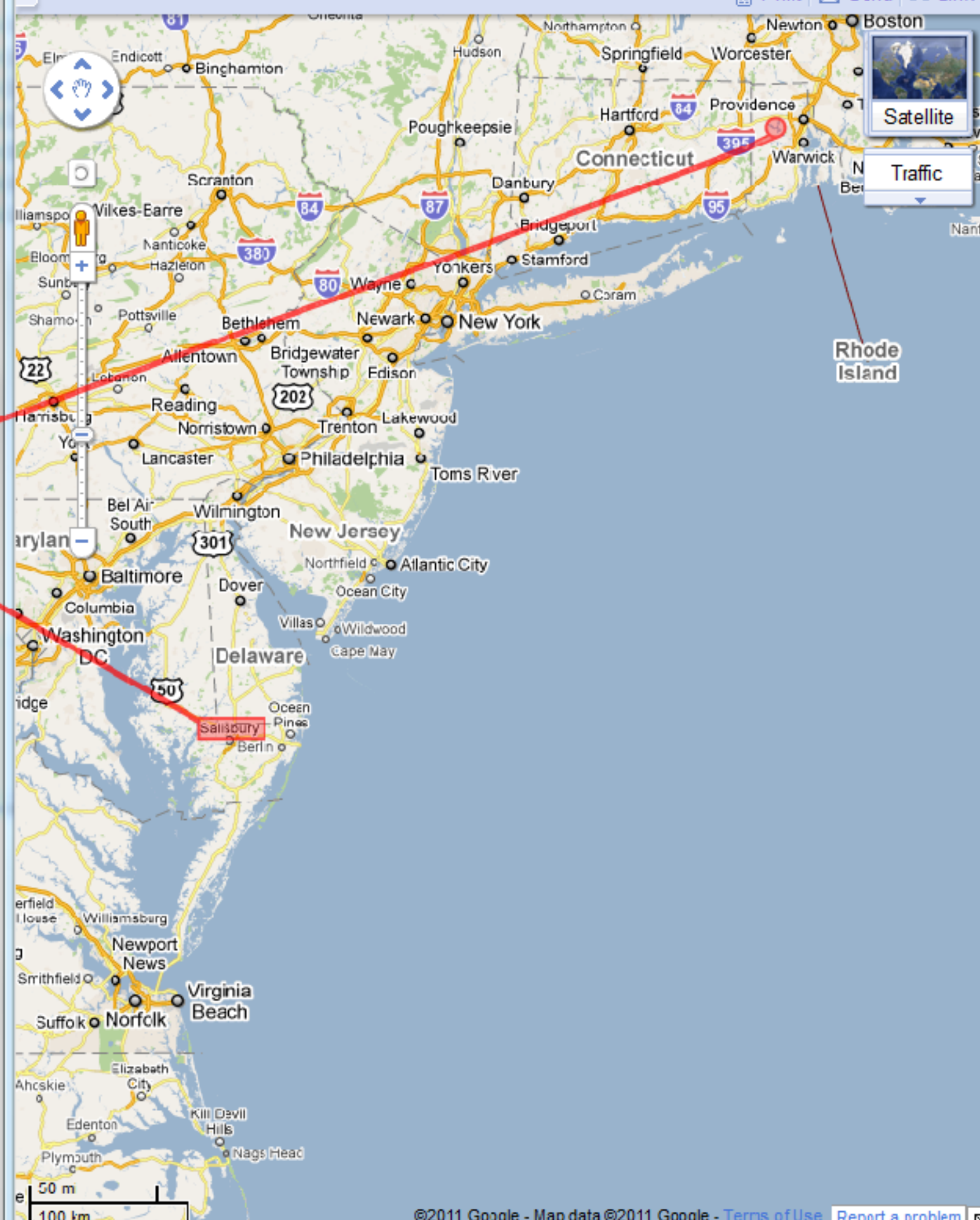
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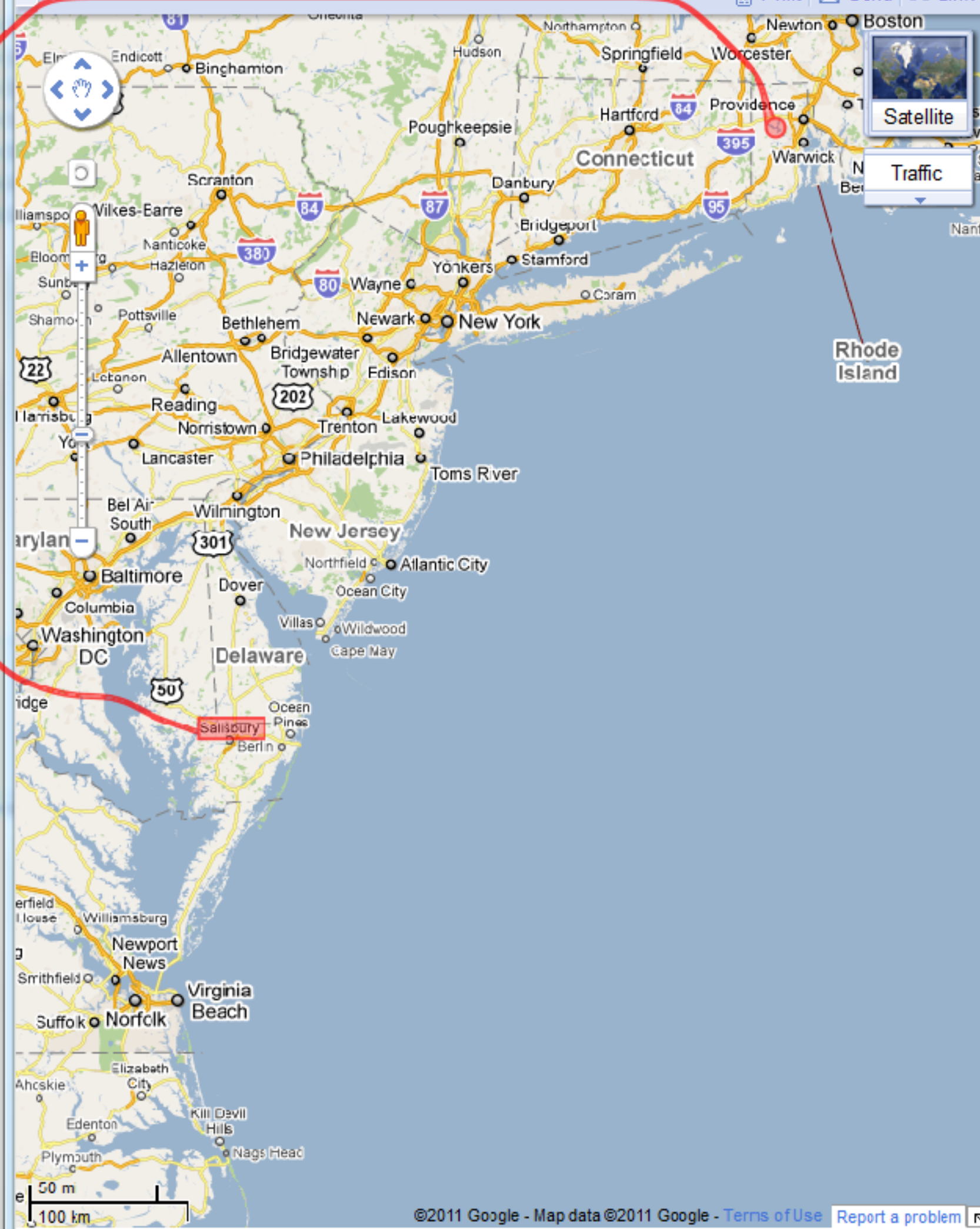
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Knowing about Perception is important for Vis and UI design

- How to choose your colors

- How to show relationships

- How to draw attention

- How to minimize risk of overlooking