

CS-5630 / CS-6630 Visualization

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...

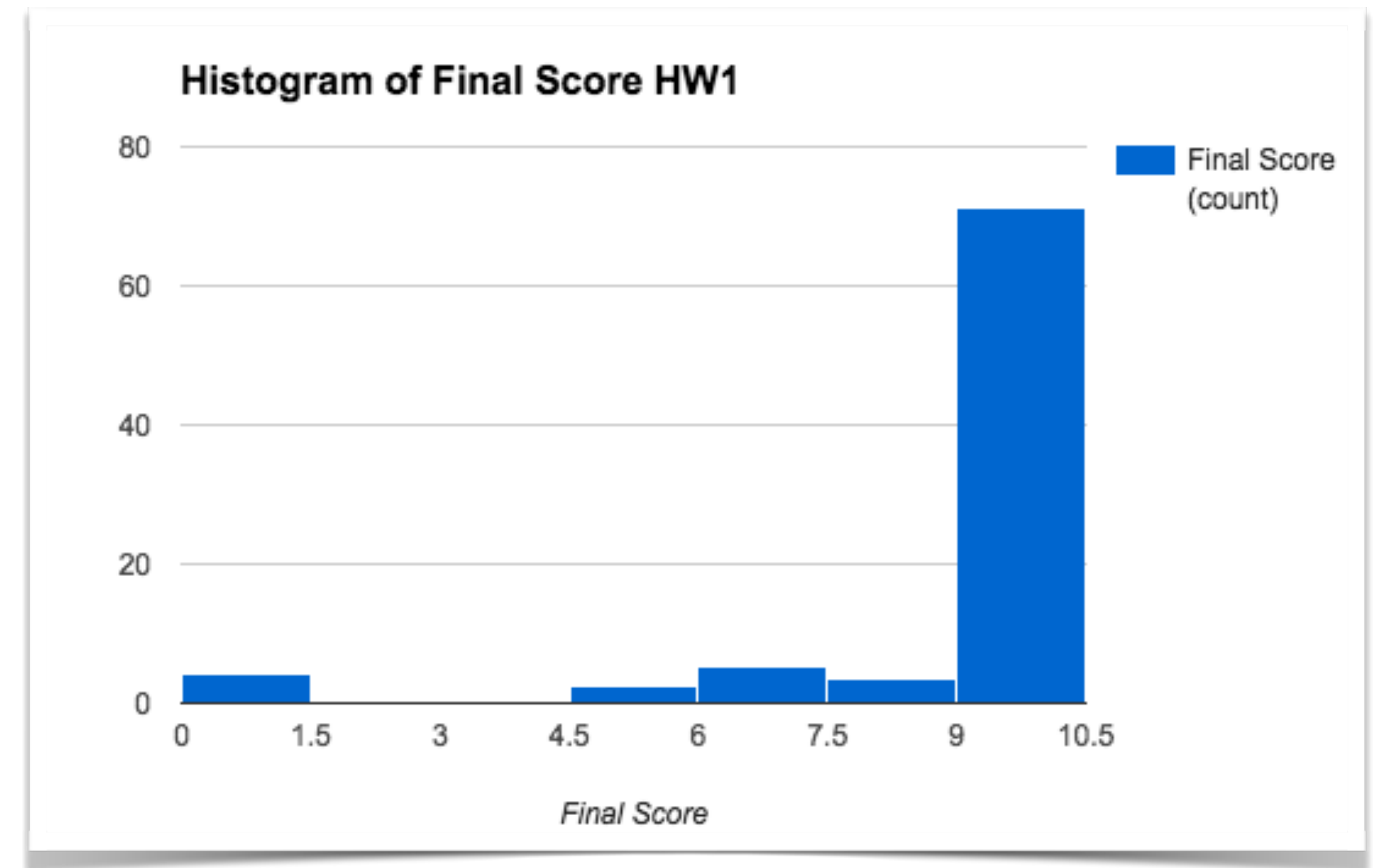
Administrativa

Homeworks 0 & 1

Grades are out!

HW 0 Average: 9.53

HW 1 Average: 8.72



Homework 3

Due Friday!

Use lecture resources and recommended readings.

Ask on Piazza.

Go to office hours.

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





perceptual hysteresis







we rely on priors



Pareidolia



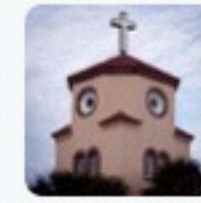
Faces in Things @FacesPics · Mar 9

These chairs have seen some terrible things pic.twitter.com/Gjlc9wuP47



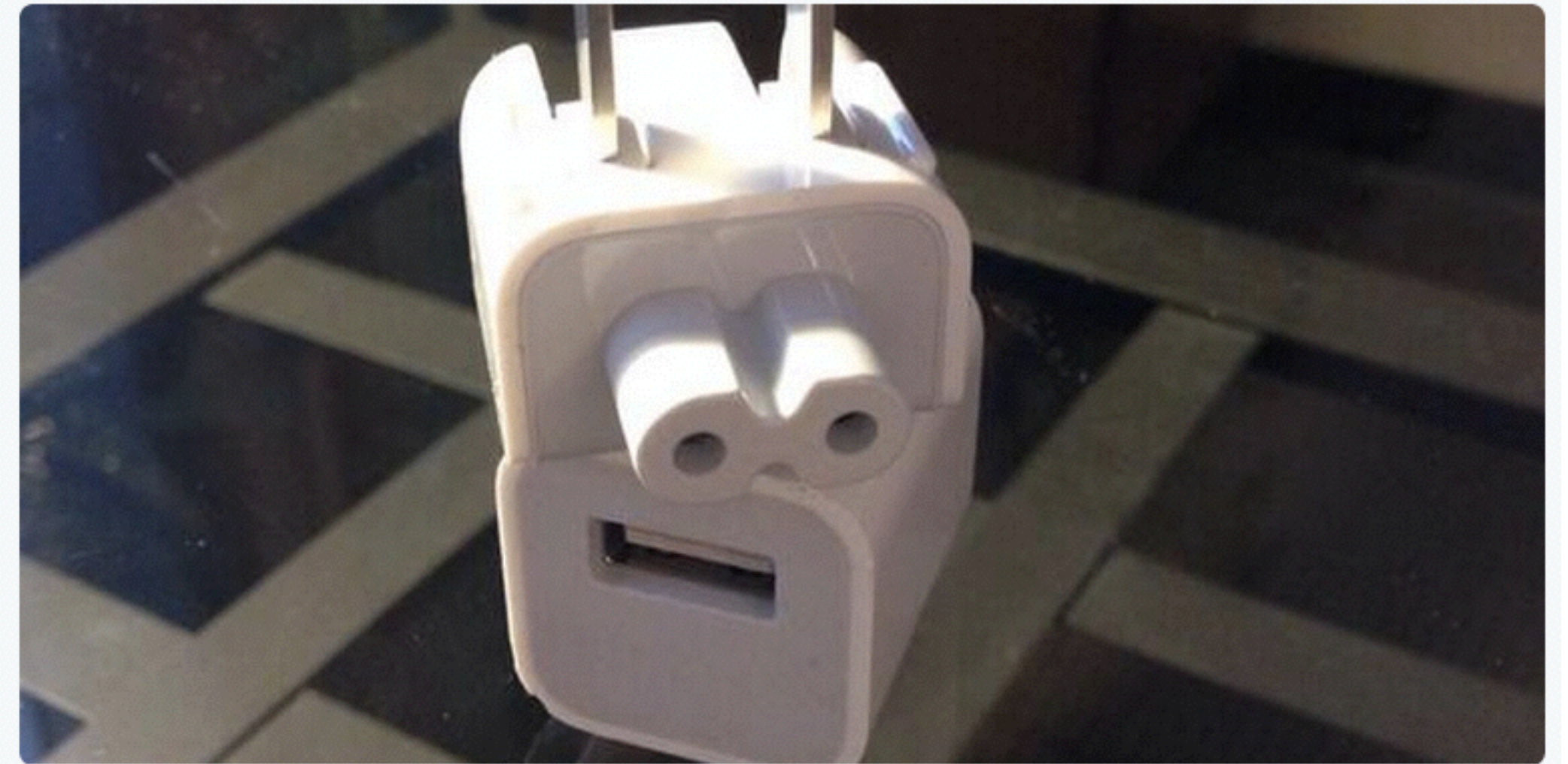
Faces in Things @FacesPics · Feb 14

Deep in thought Deep Fryer pic.twitter.com/1Qyqjmslka



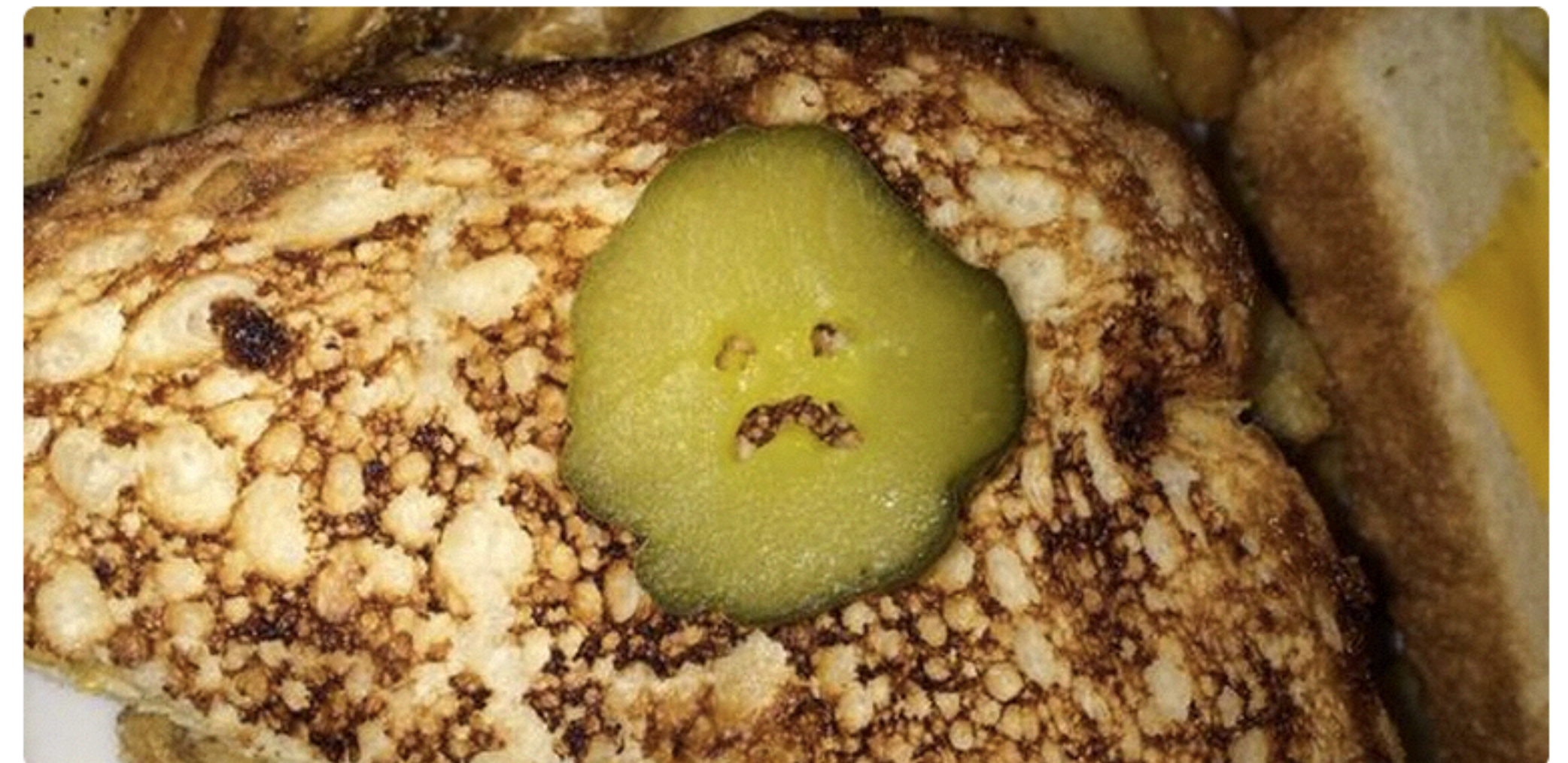
Faces in Things @FacesPics · Mar 22

Hey little guy! pic.twitter.com/nt2BgwZeTR



Faces in Things @FacesPics · Mar 10

A terrified pickle pic.twitter.com/Ffph1wzTyv



Take Home Point

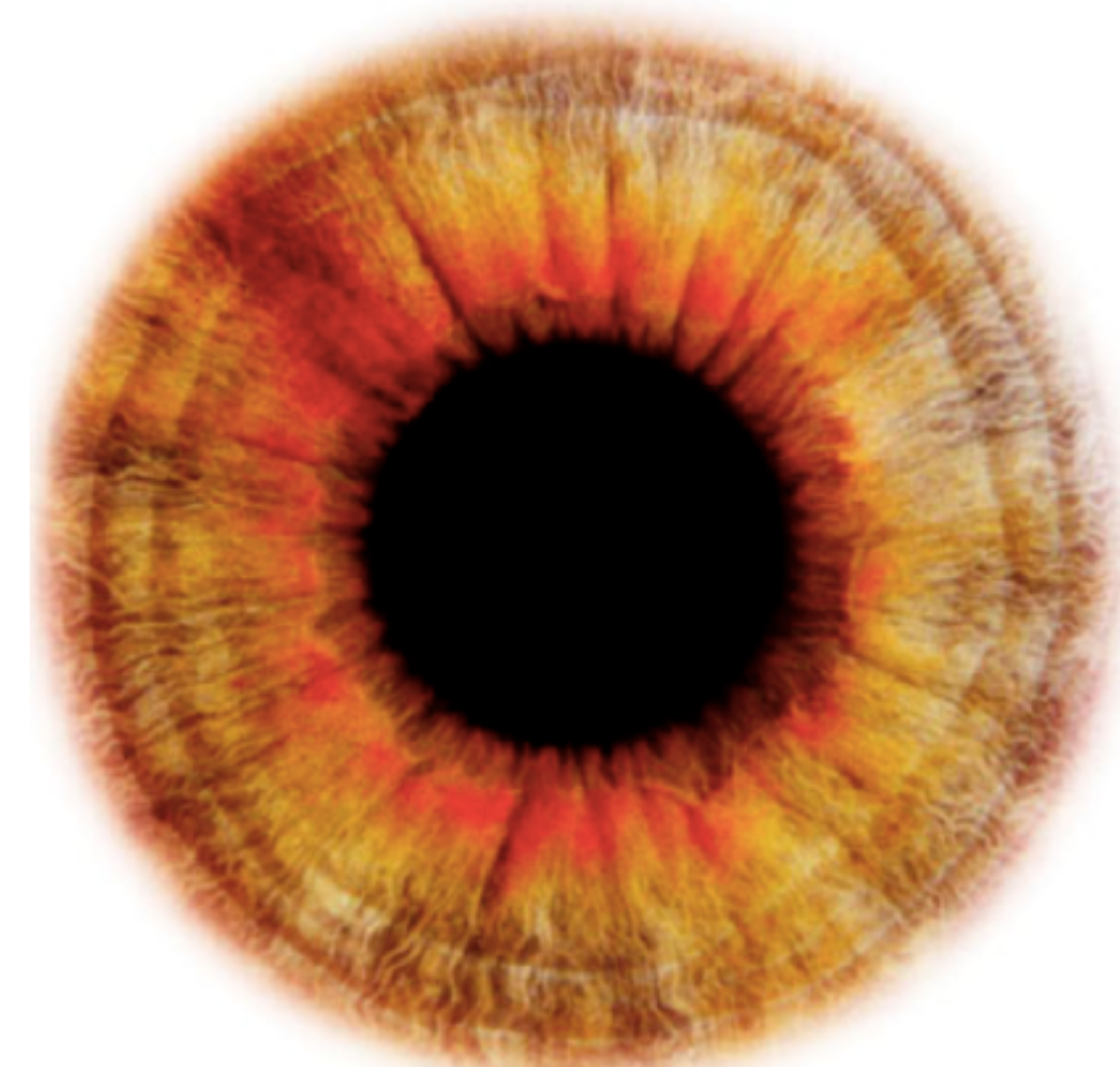
Vision is “constructed” top down from the input

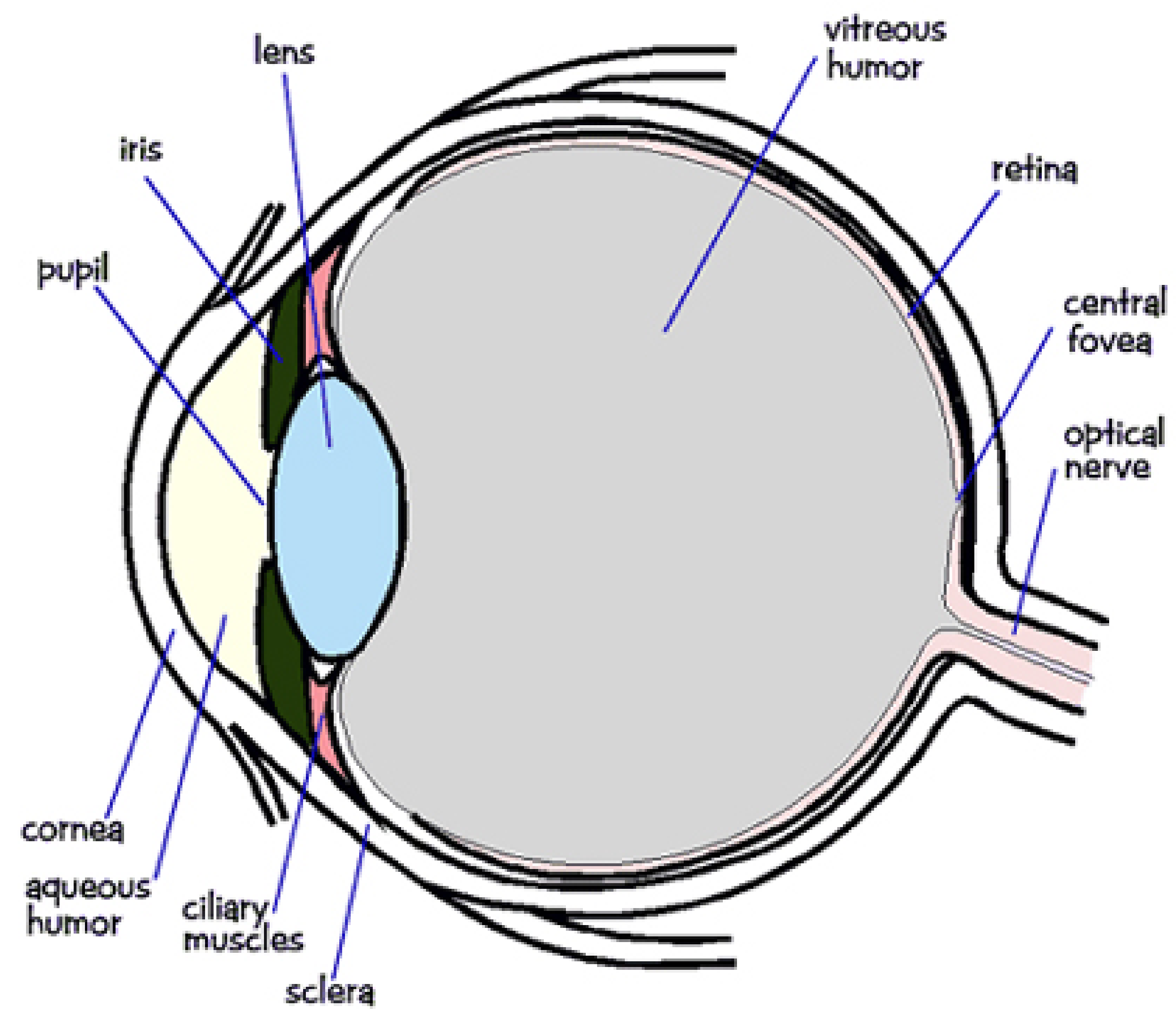
“What you see when you see a thing depends on what the thing is. What you see the thing as depends on what you know about what you are seeing.”

Zenon Pylyshyn
Canadian Cognitive Scientist
and Philosopher



The Eye





Human Visual System

5-6 mio cones

color vision

dense in the center

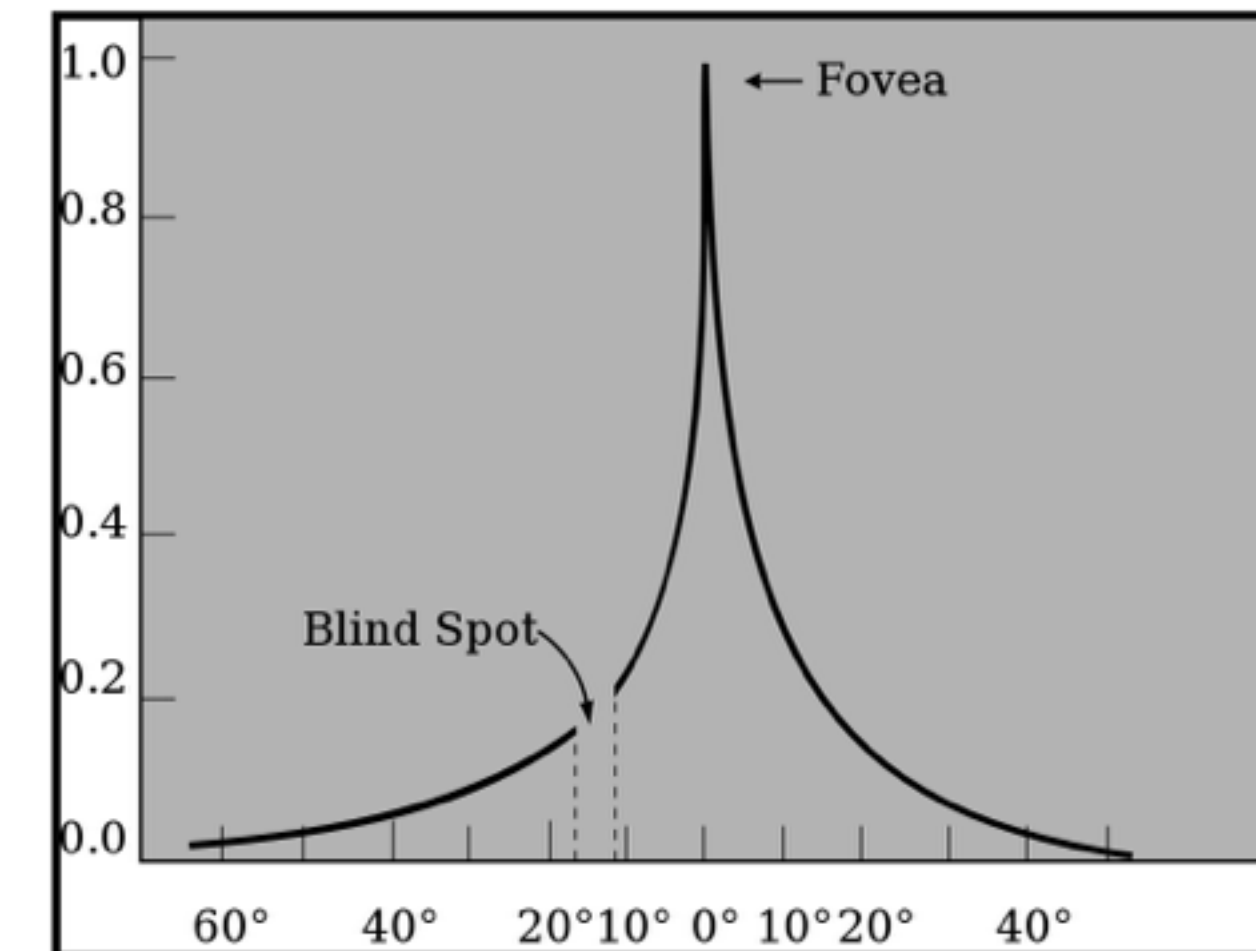
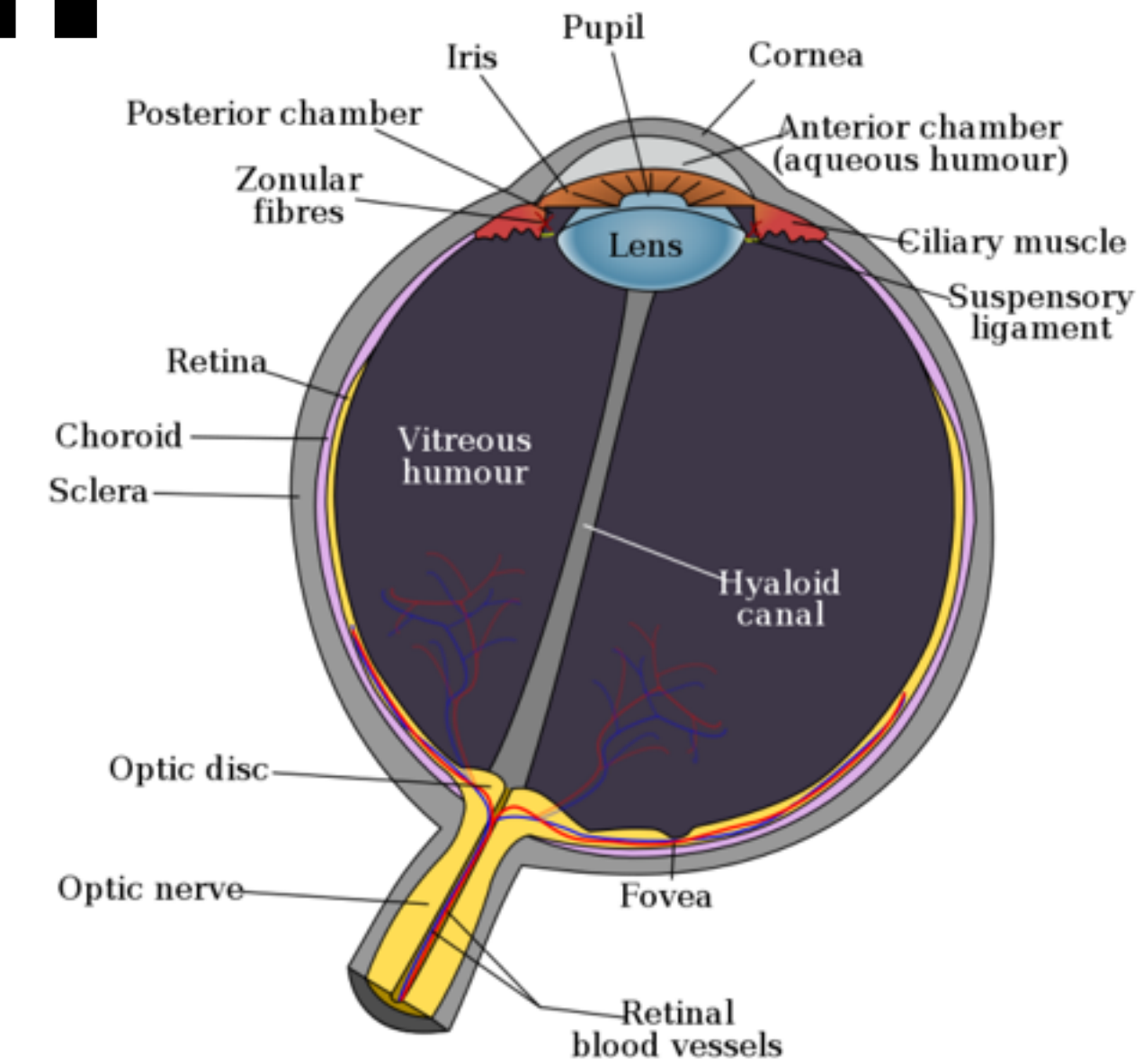
Fovea: 27 times the density

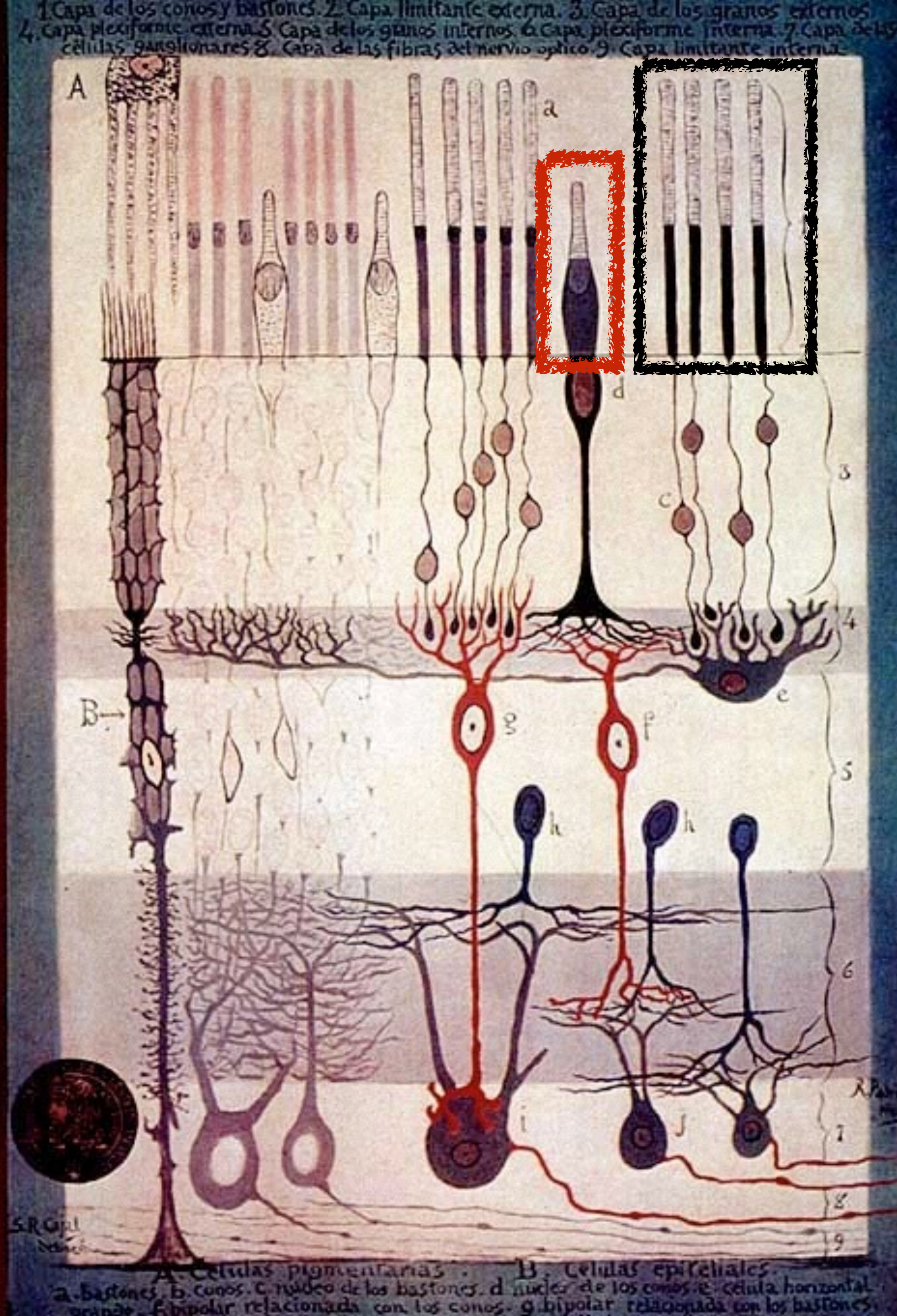
responsible for sharp central vision

only cone cells

~120 mio rods

black/white



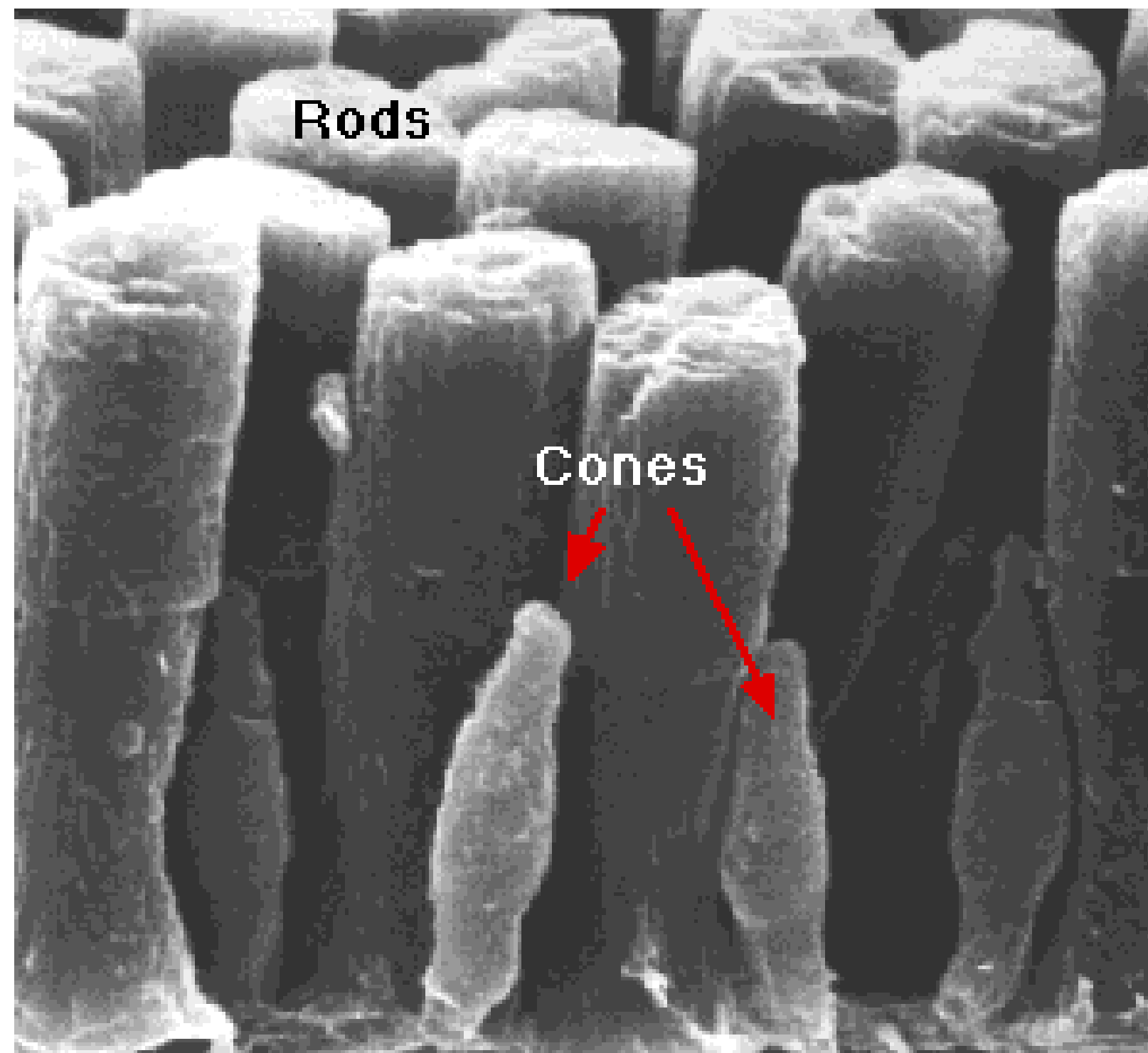


Rods - sensitive black and white

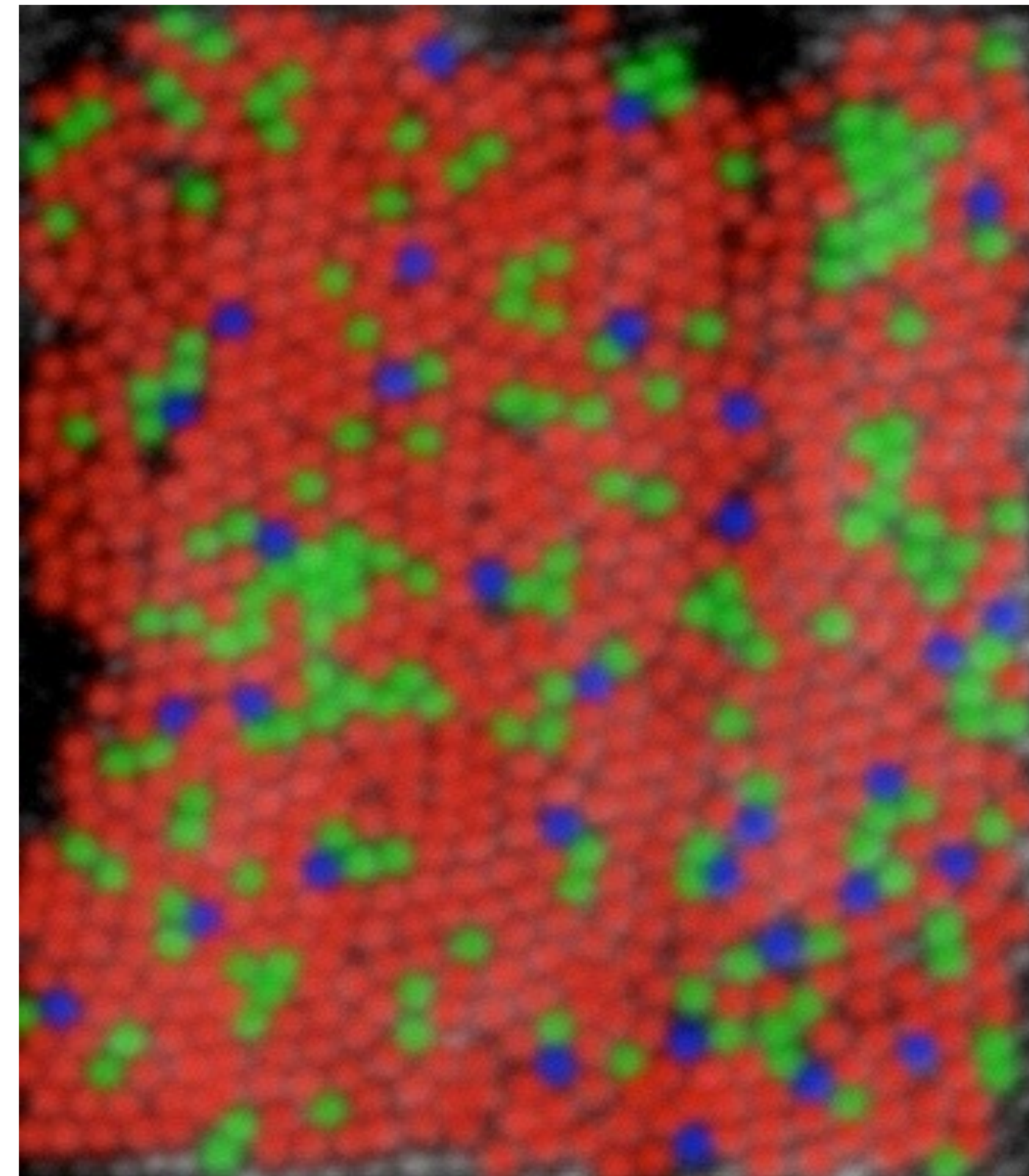
Cones - color vision

Ganglion Cells

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



~120 million rods
~5-6 million cones

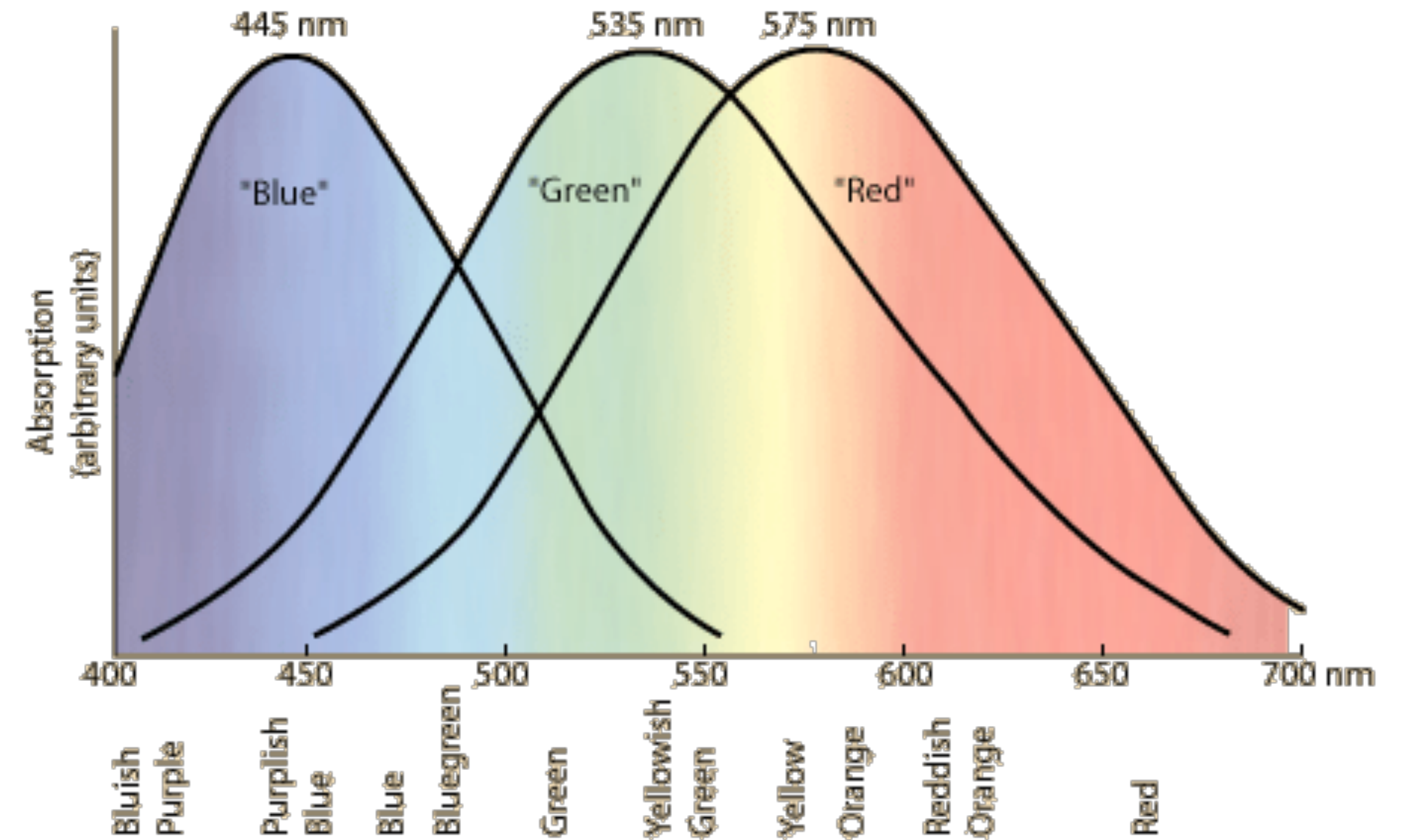
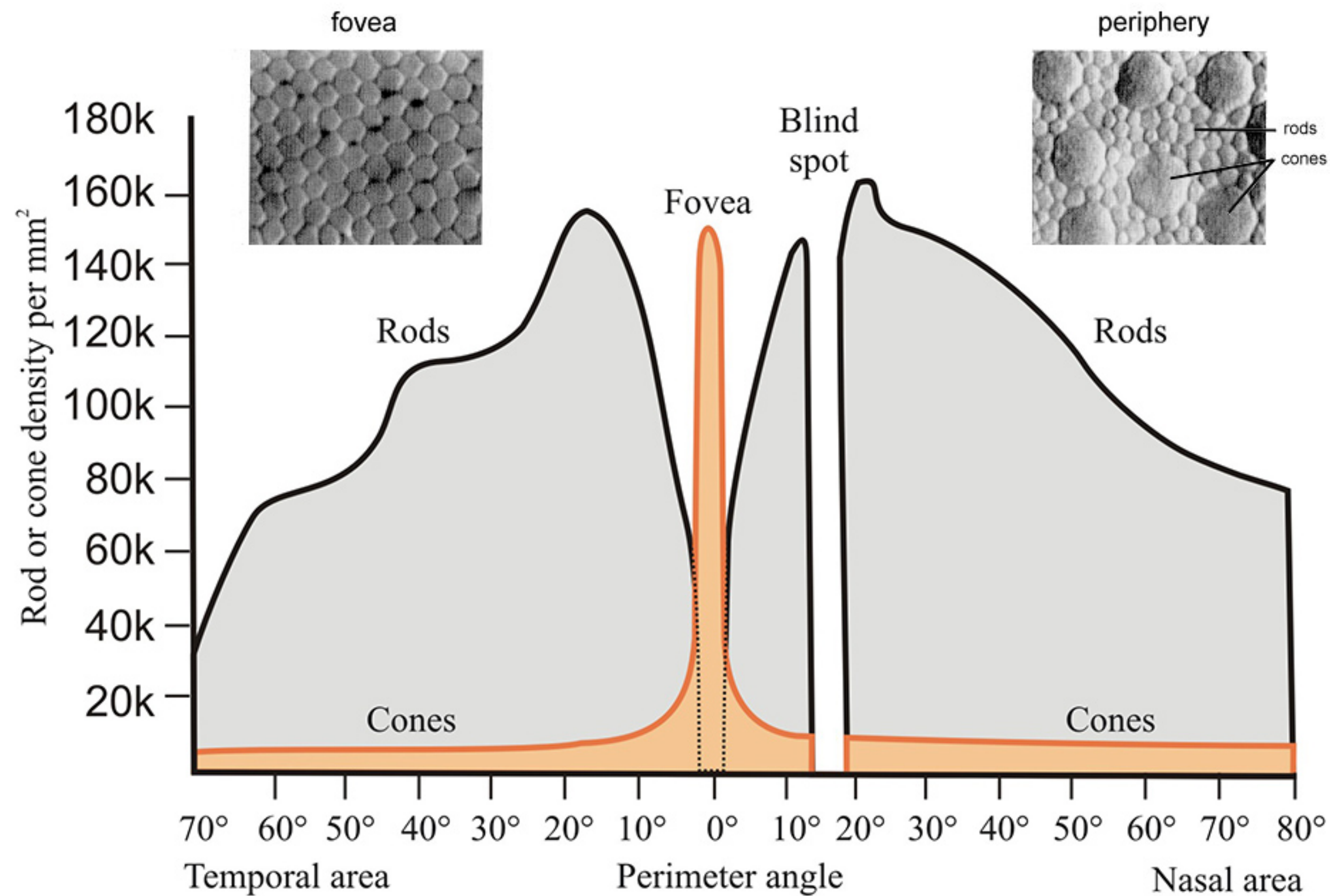


R 63% - G 31% - B 6%

Wandell, "Foundations of Vision" (left)

David R. Williams, Univ. of Rochester (right)

Cone Response



[illegible]

Human Visual System

VIDEO!

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

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

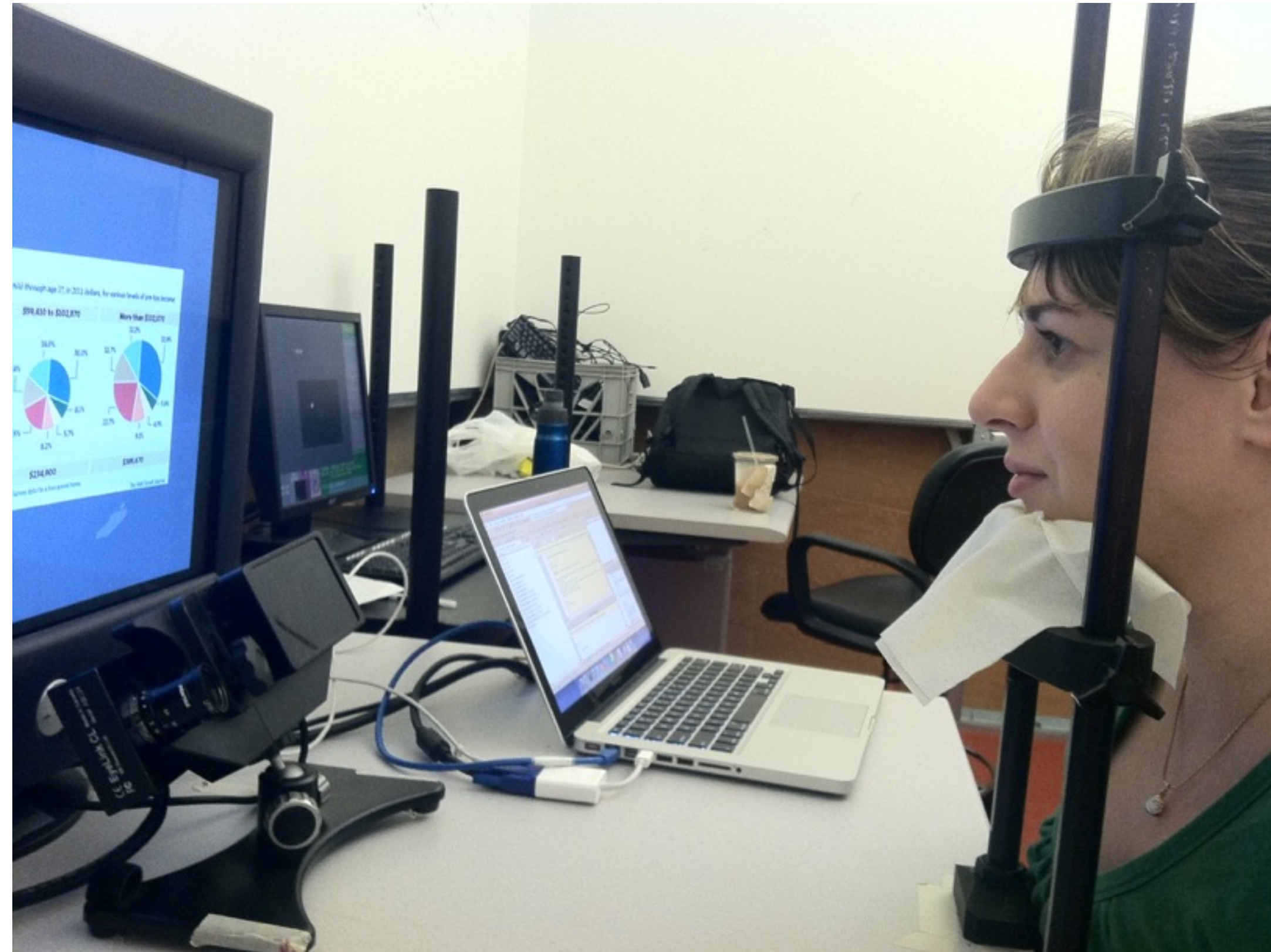
saccades: moving between different locations (20-100 ms)

Vision not similar to a camera

More similar to a dynamic and ongoing construction project



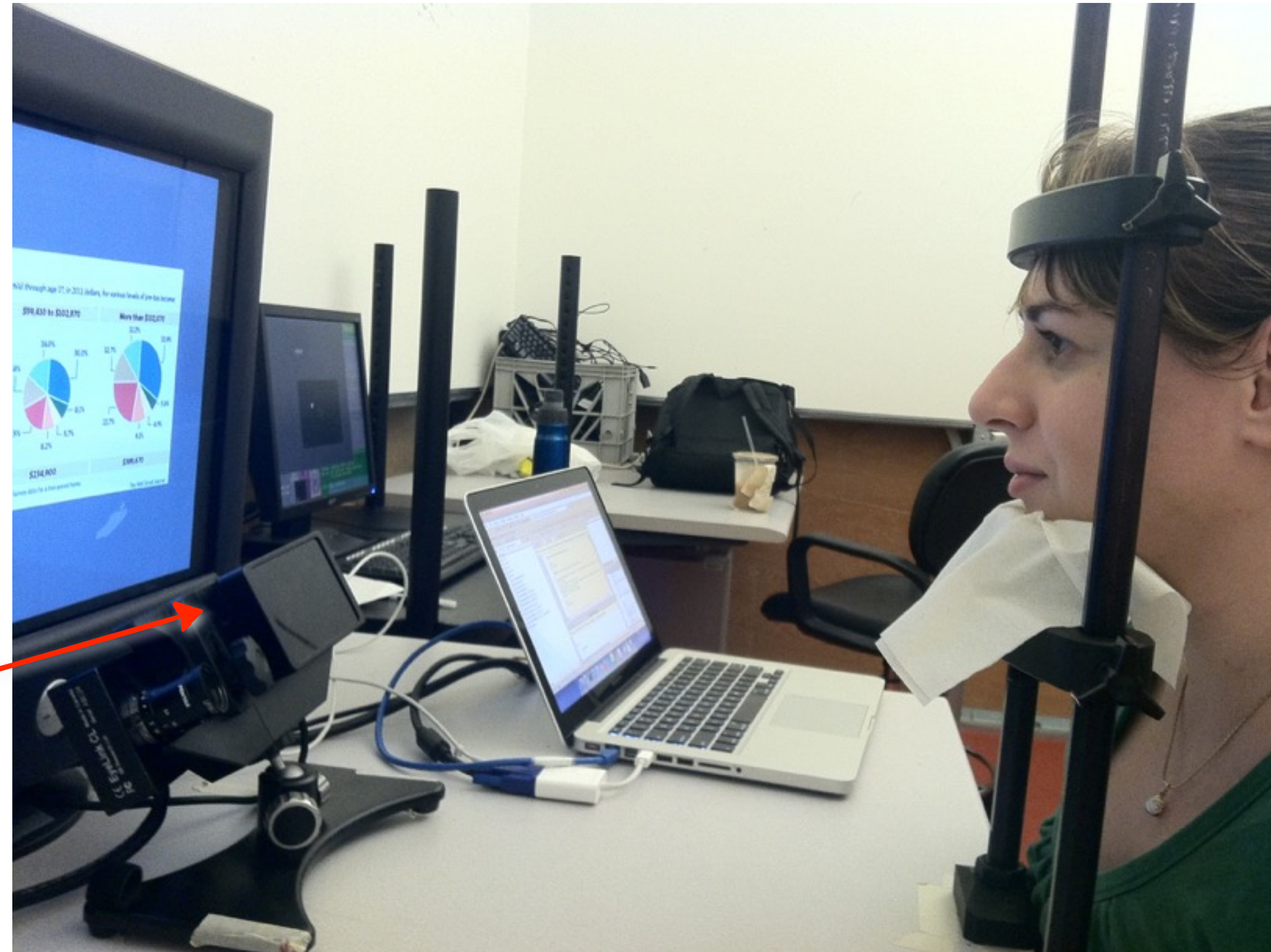
Eye-Tracking Experiment



Video!

Eye-Tracking Experiment

Infrared
camera

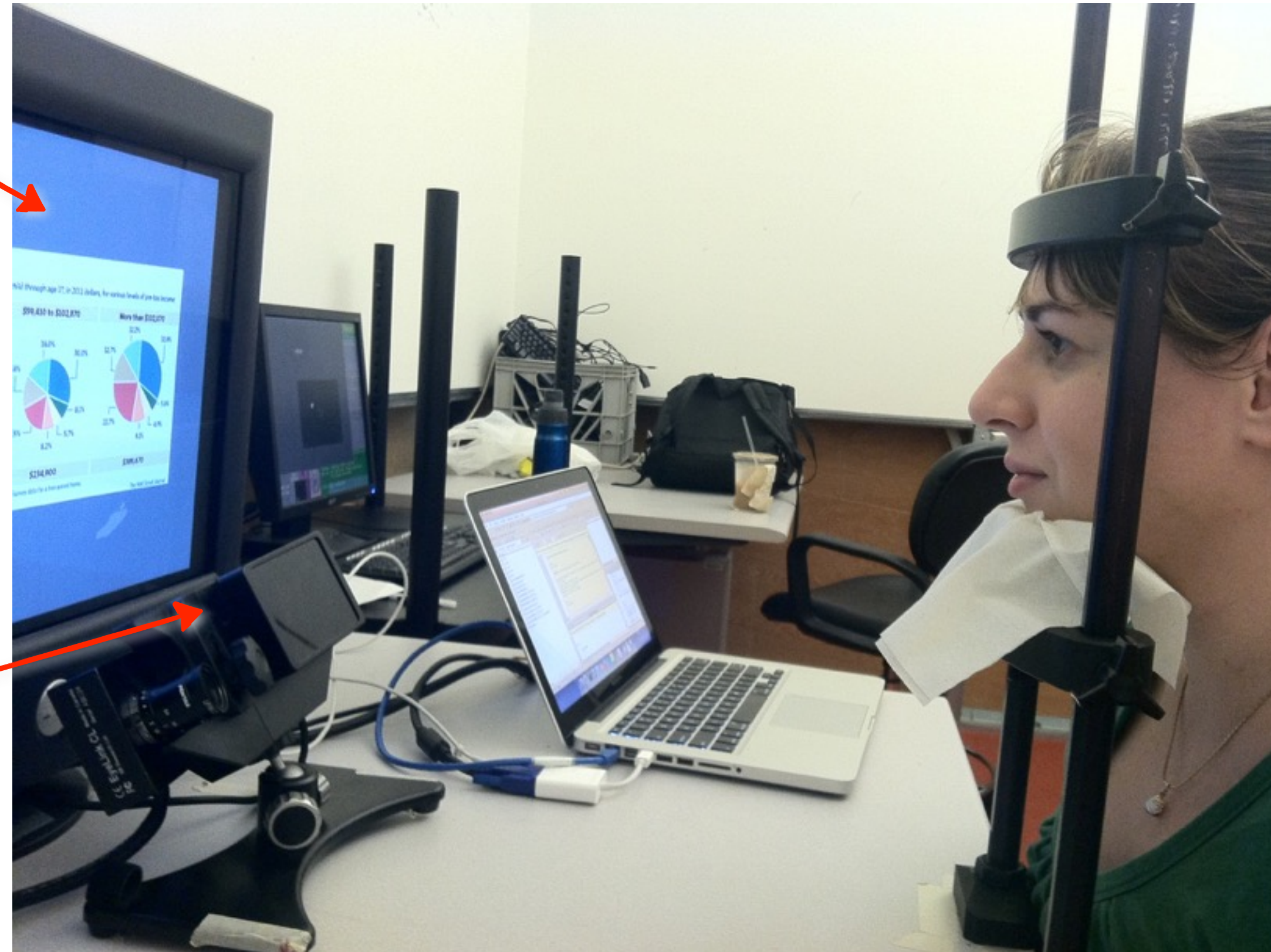


Video!

Eye-Tracking Experiment

Visualization
display

Infrared
camera



Video!

Eye-Tracking Experiment

Visualization
display

Eye-tracking control computer

Infrared
camera



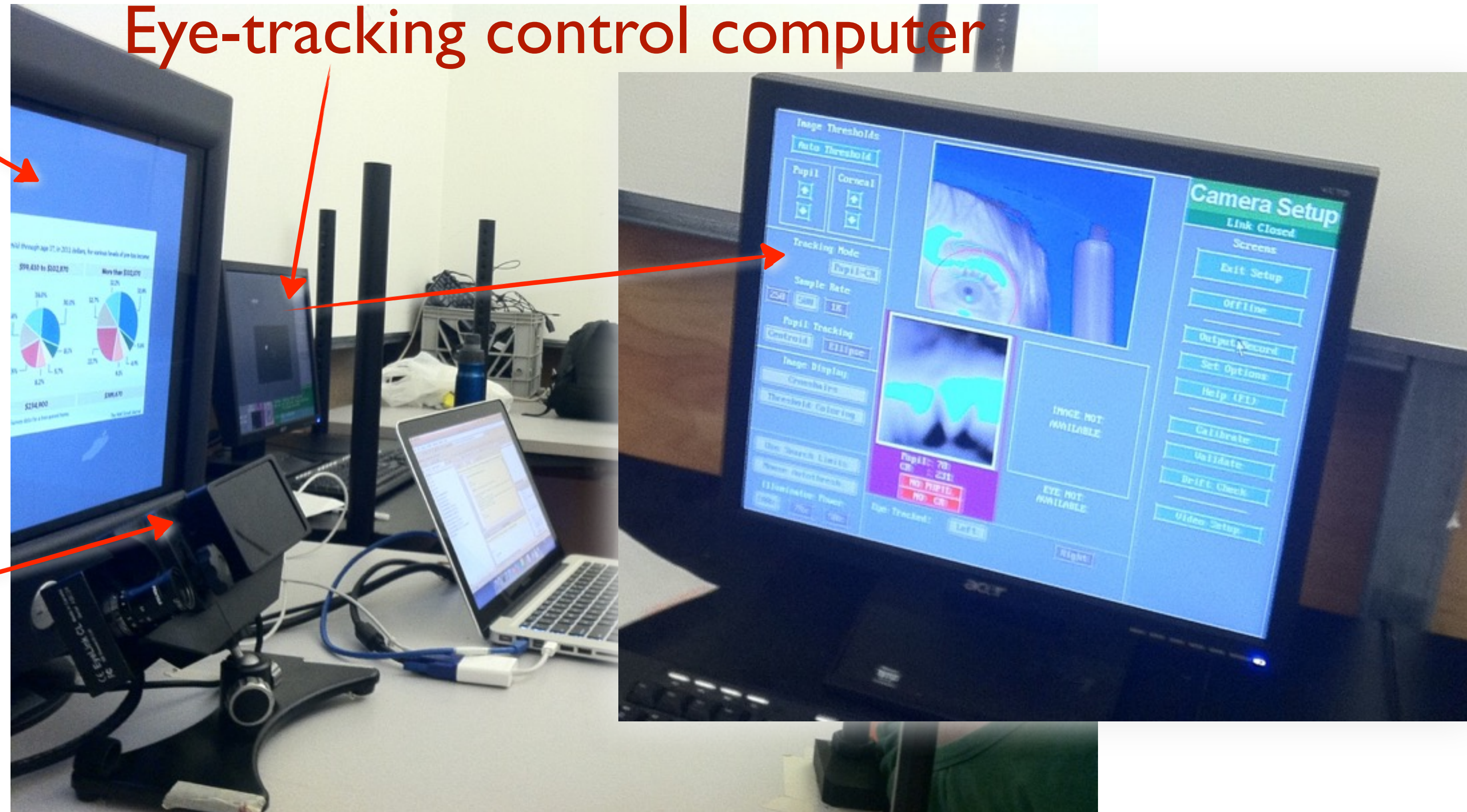
Video!

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

Human Visual System

VIDEO!

No general purpose vision

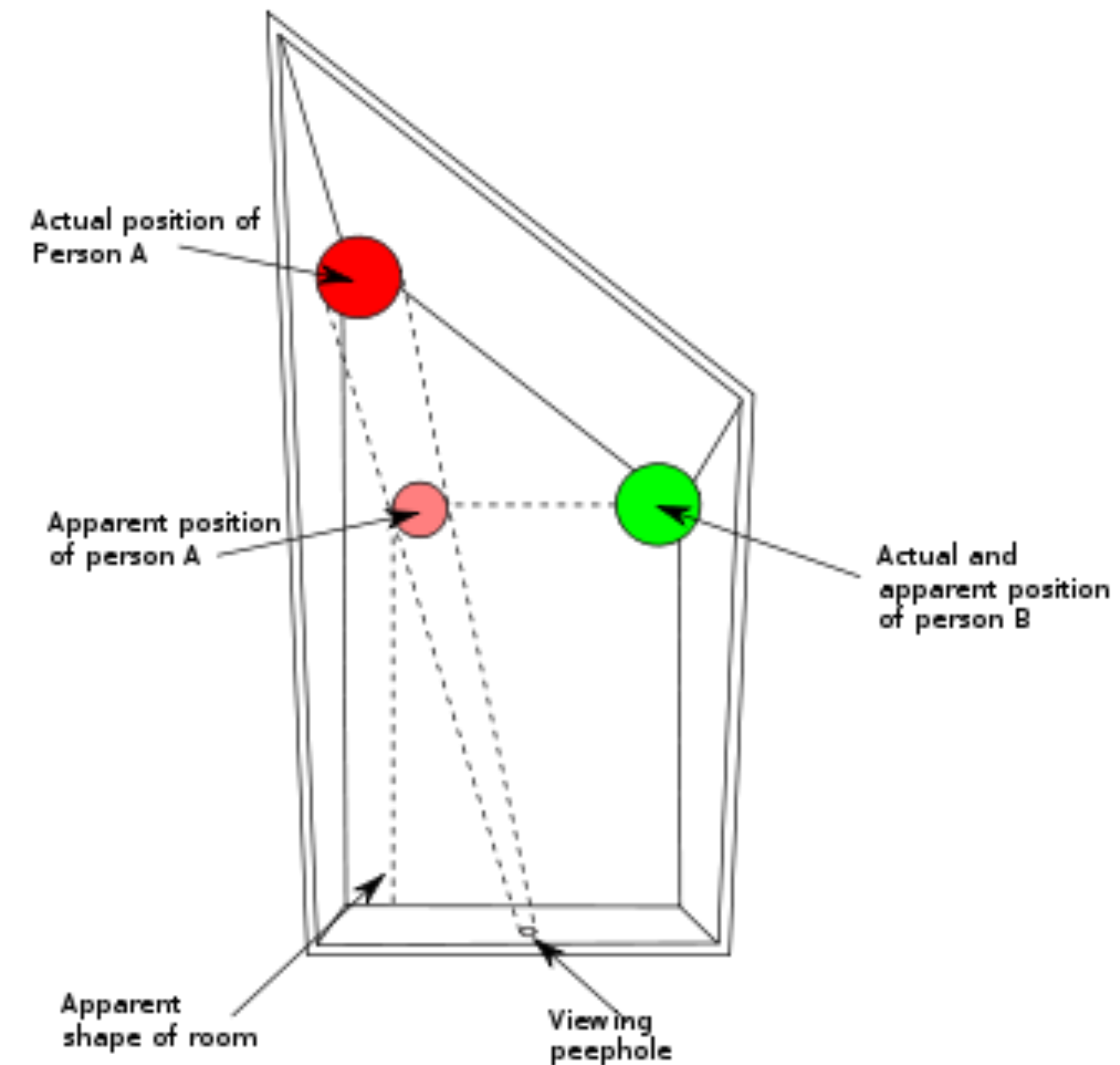
What we see depends on our goals and expectations

Relative judgments: strong

Absolute judgments: weak



Ames Room



Color

Color Basics

Visible part of the electromagnetic spectrum

390-750 nm

Spectral colors

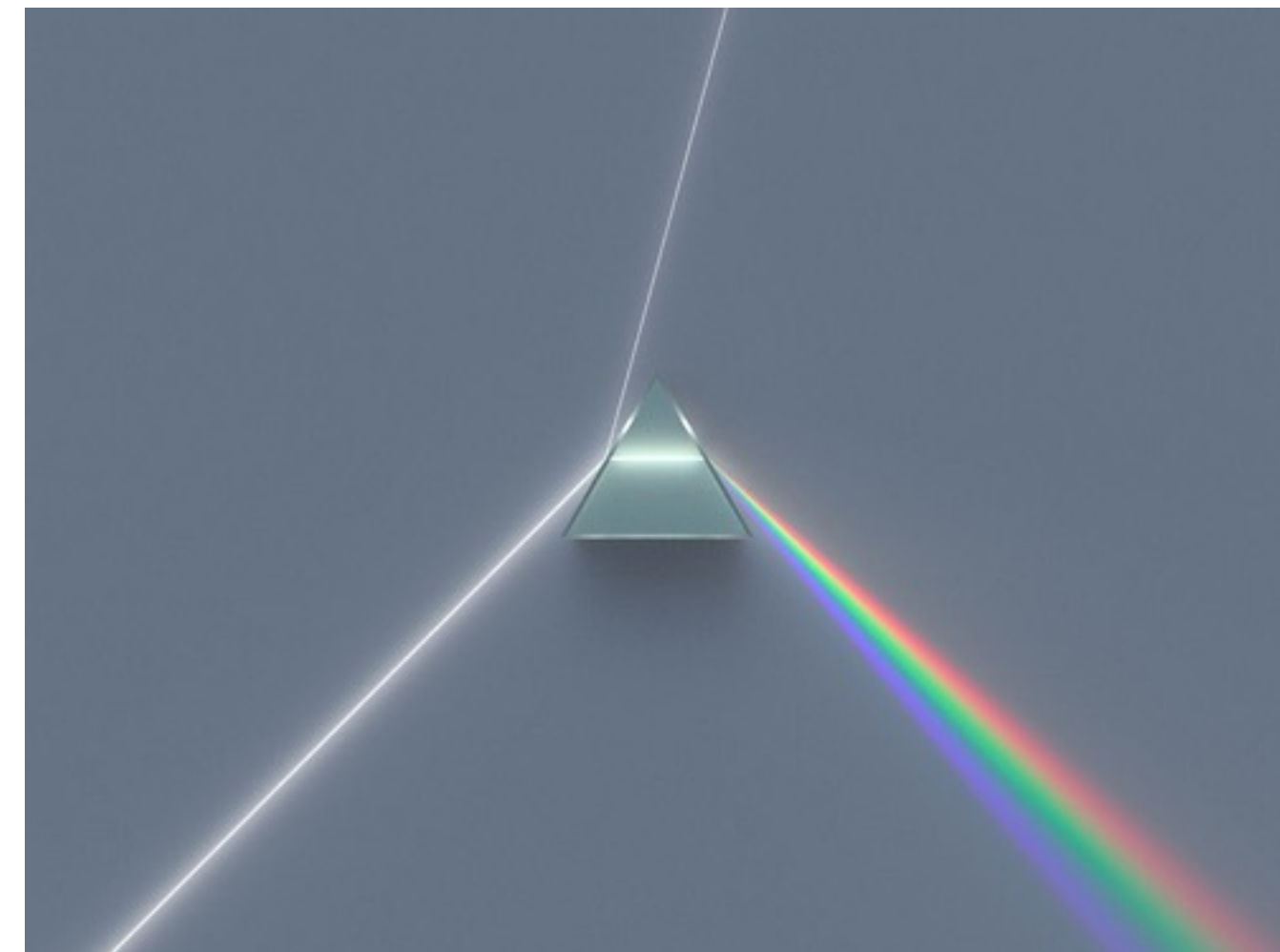
evoked by a single wavelength

Other colors: unsaturated colors

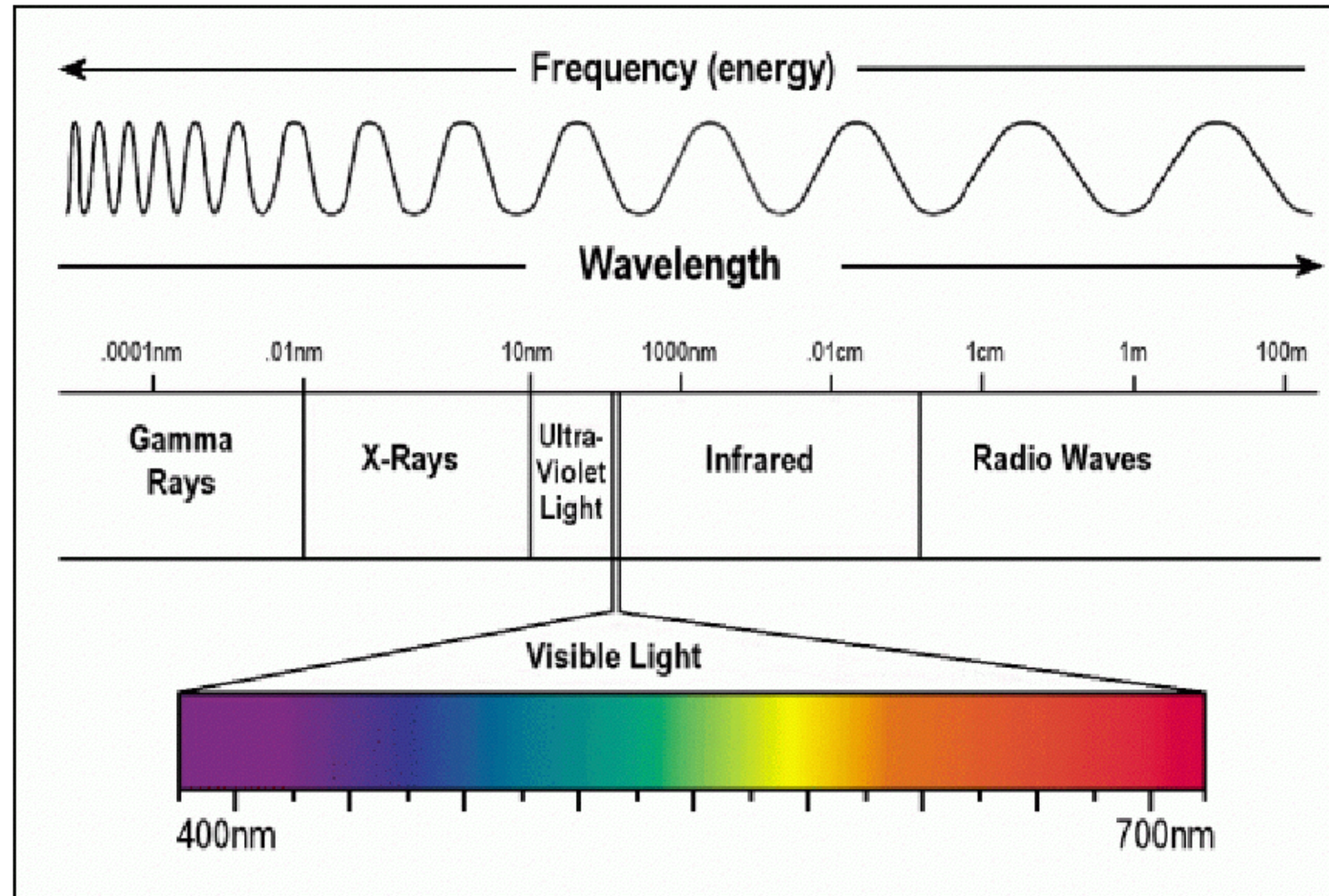
Gray scale (achromatic colors)

Mix of multiple wavelengths

e.g. purple, magenta



Visible Spectrum



Dimensions of Color

Hue



Saturation

The purity of a color



Different Saturation, medium Value

Value (Luminance, Brightness)

lightness or darkness of a color

high saturation colors have medium values
values



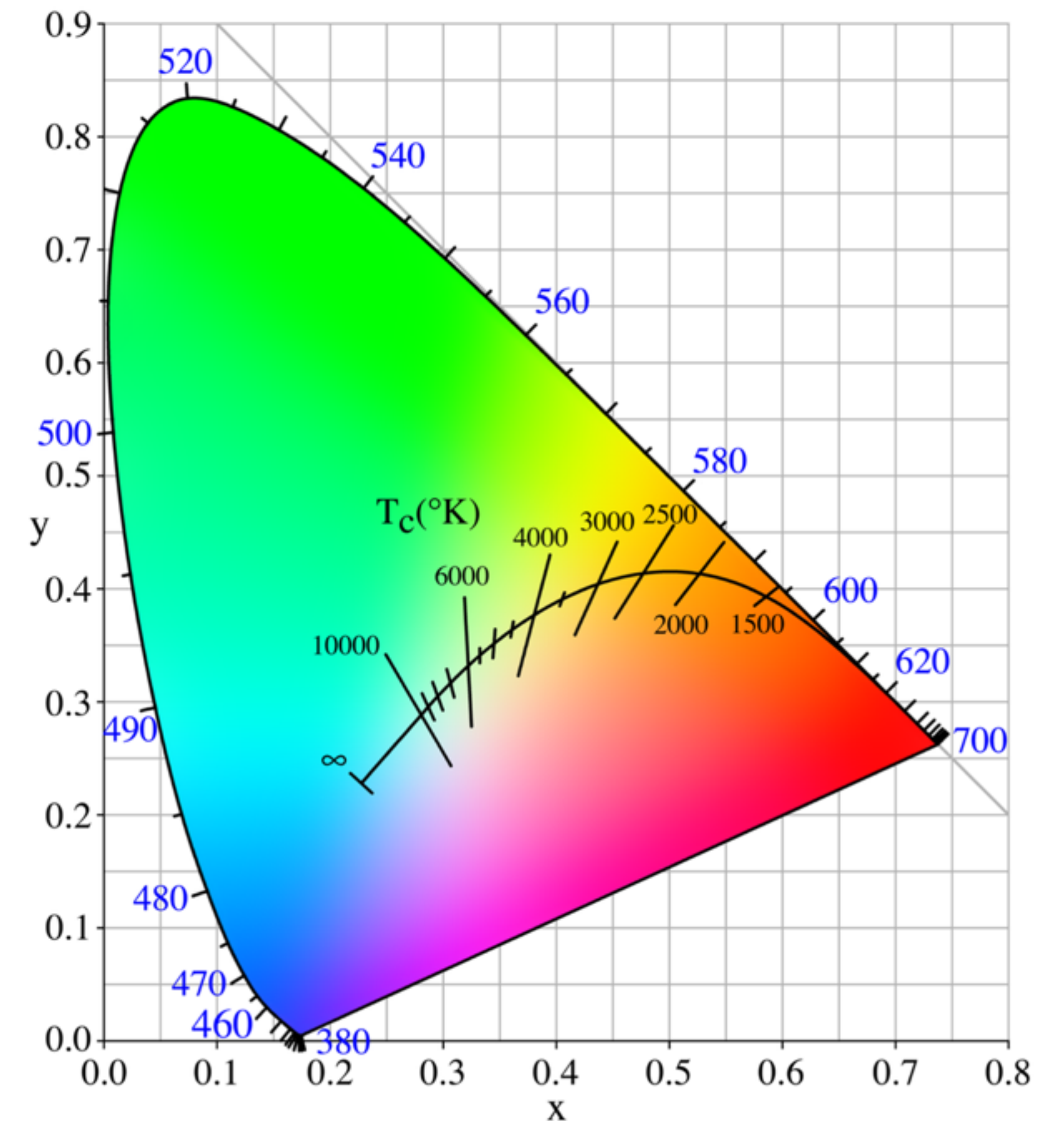
Different Values, low Saturation

CIE Color Model

Chromaticity Diagram

Specifies color by hue and saturation

Pure colors of visible spectrum along the curve (wavelength)

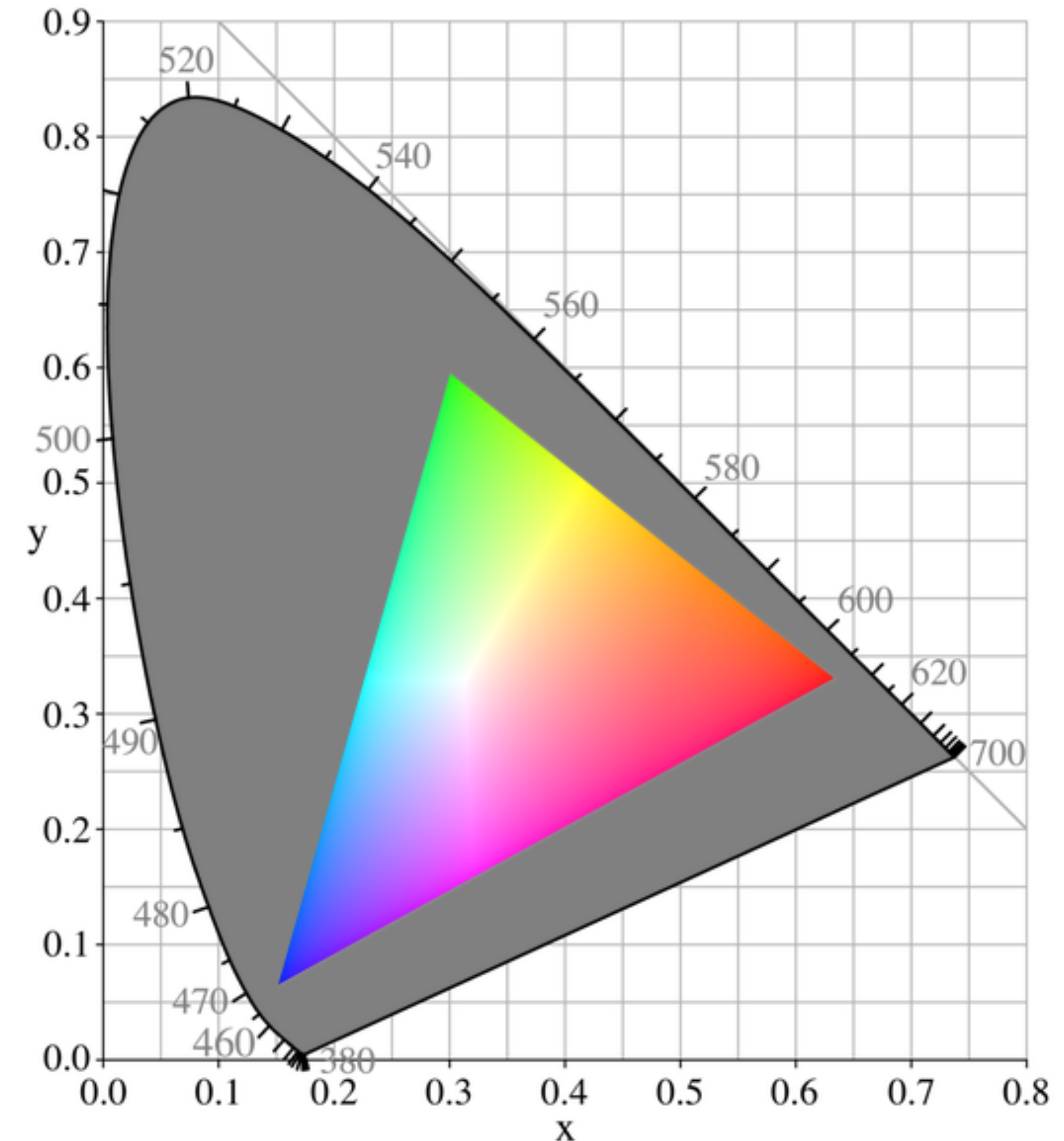
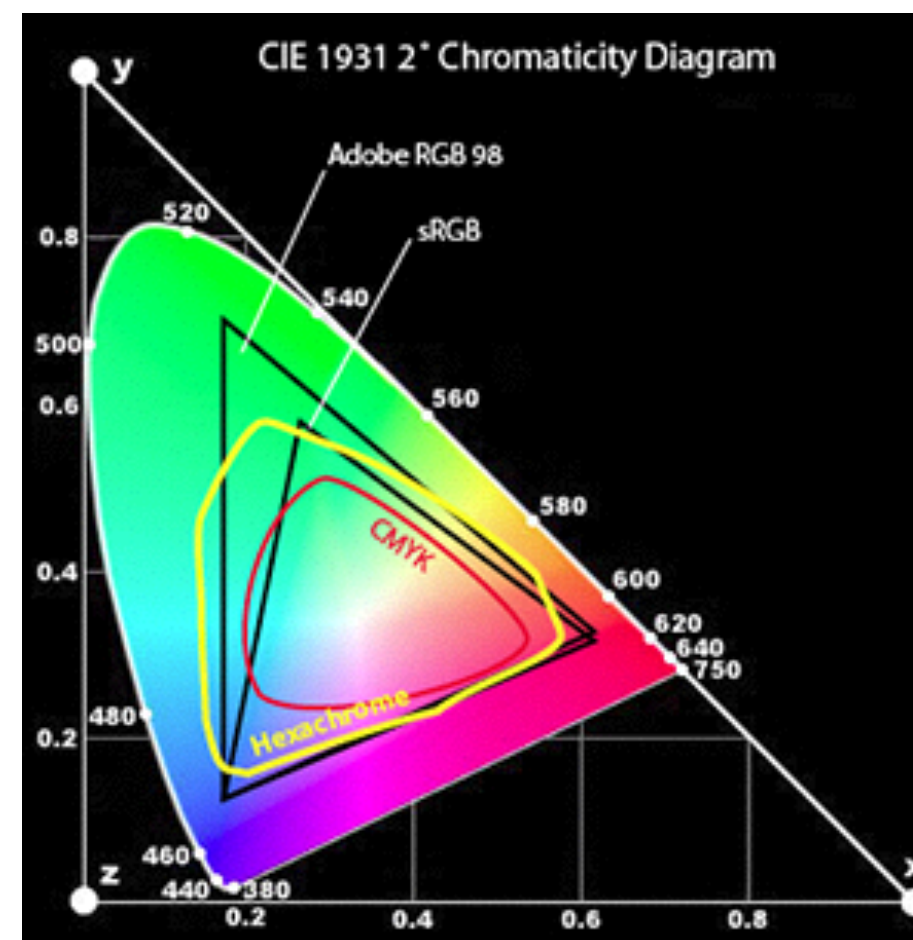


Gamut

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)

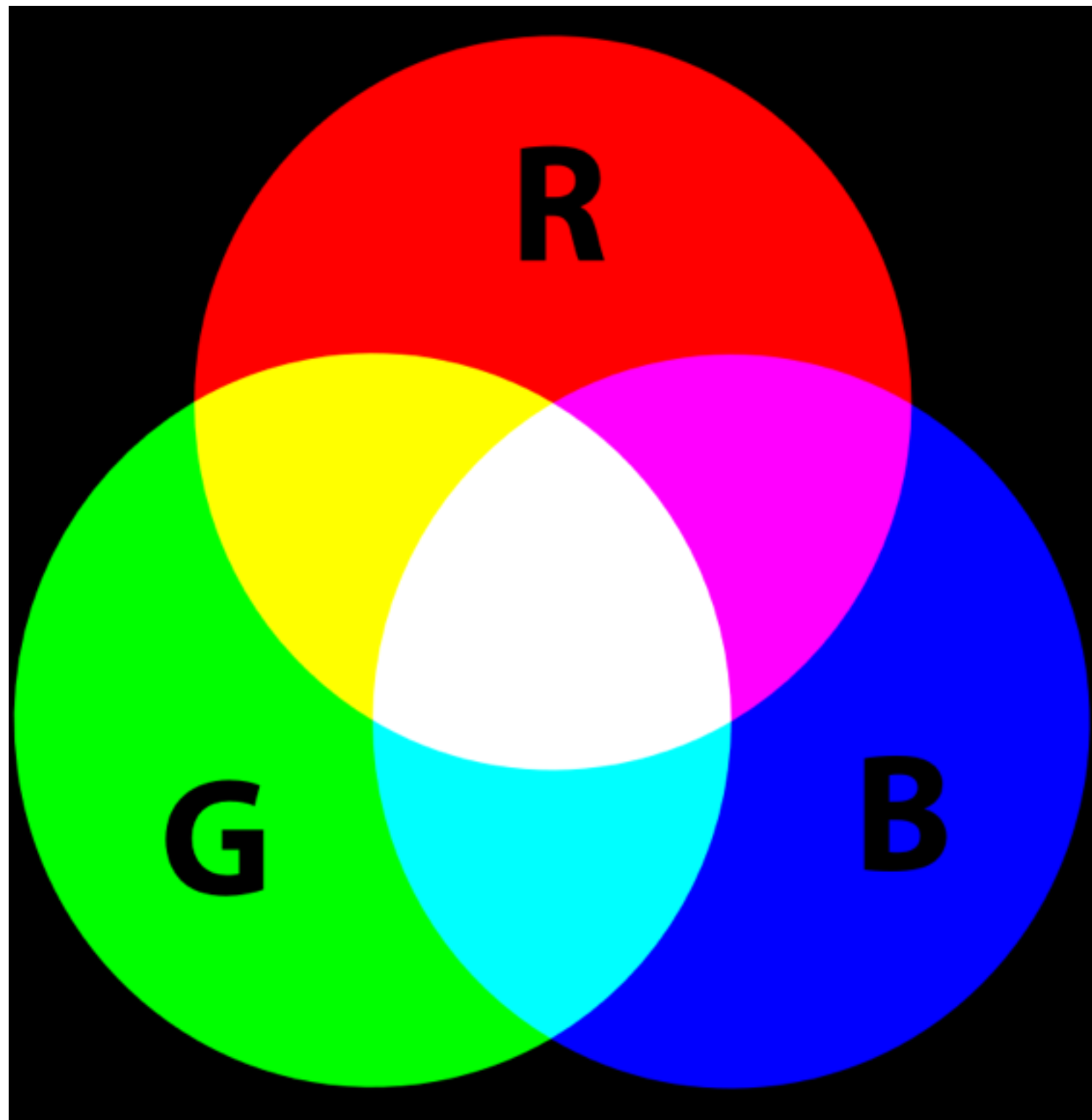
light

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

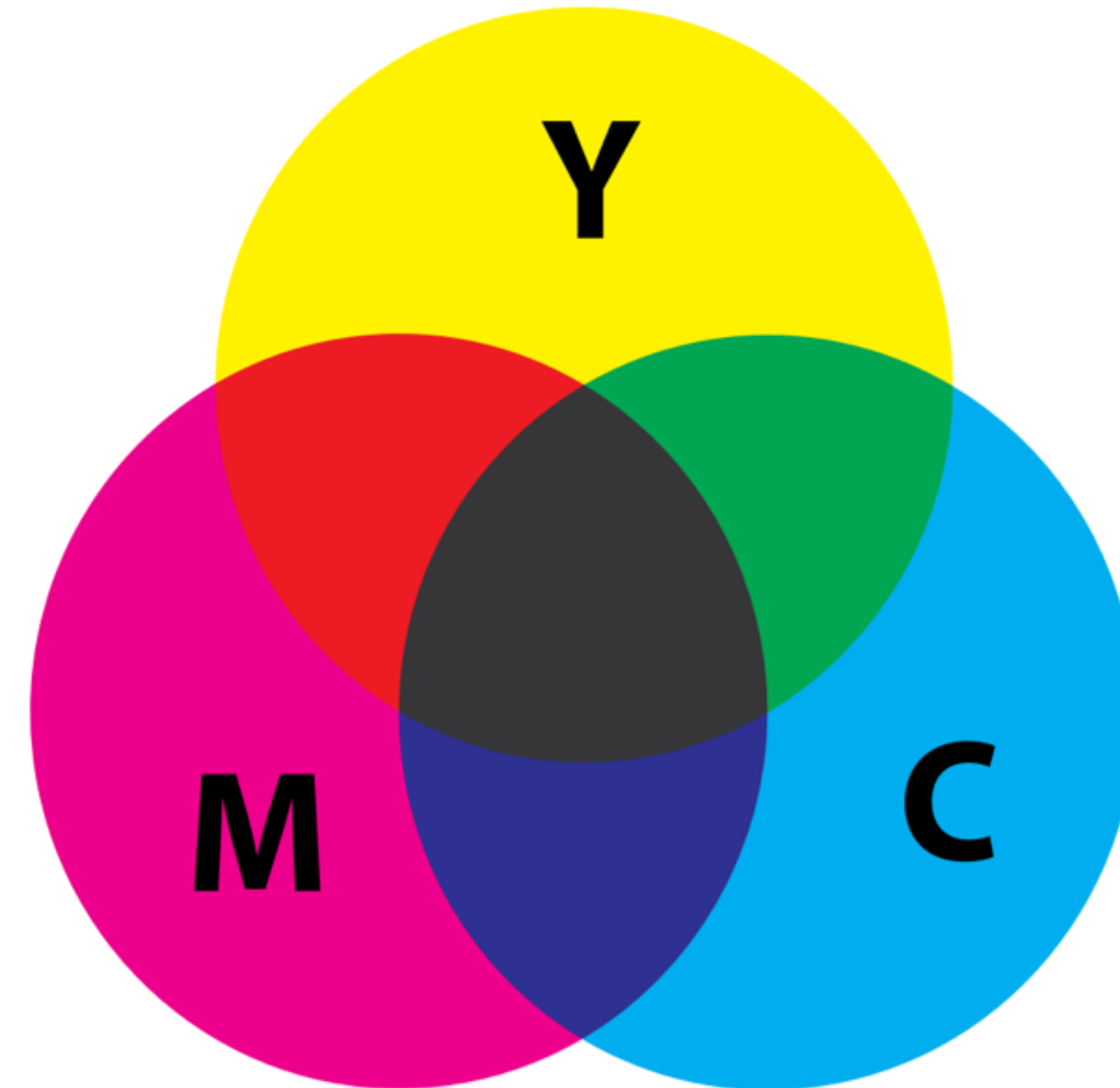
Subtractive

pigment (e.g., CMYK)

Additive / Subtractive Color

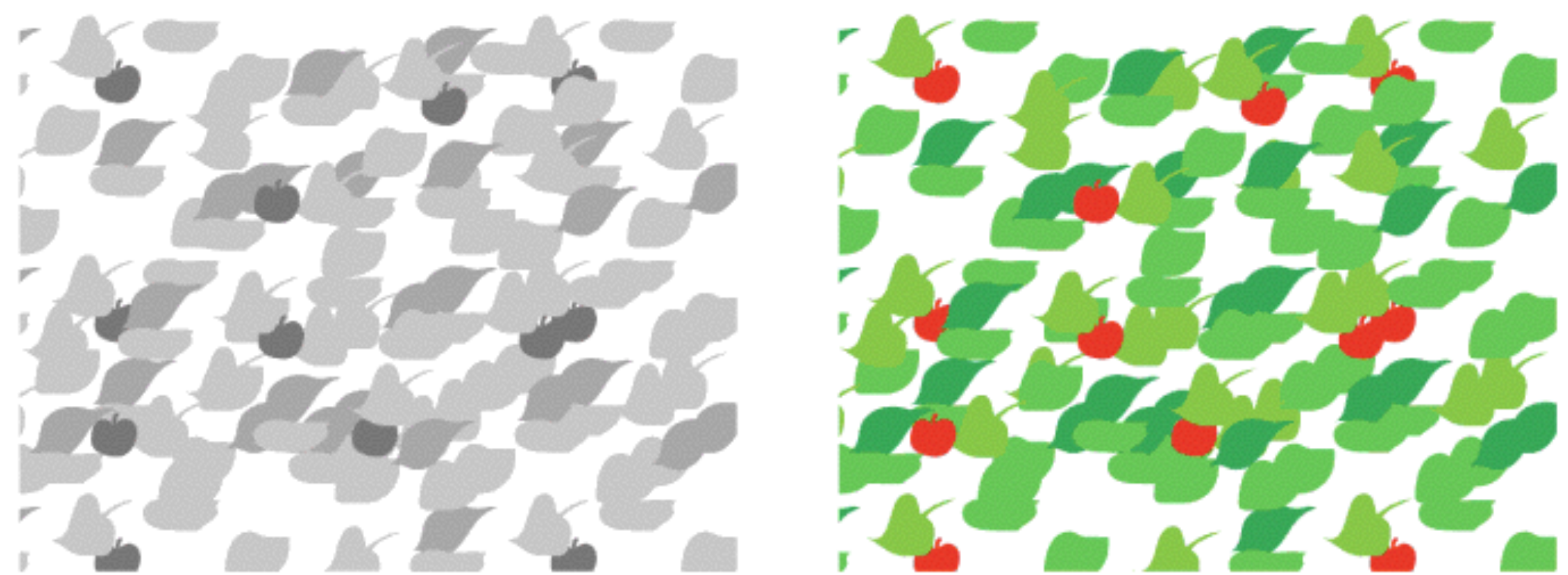


Add colors by adding light of certain wavelength



Subtract colors using pigments, inks by absorbing light

Color



Color vision is irrelevant to much of normal vision!

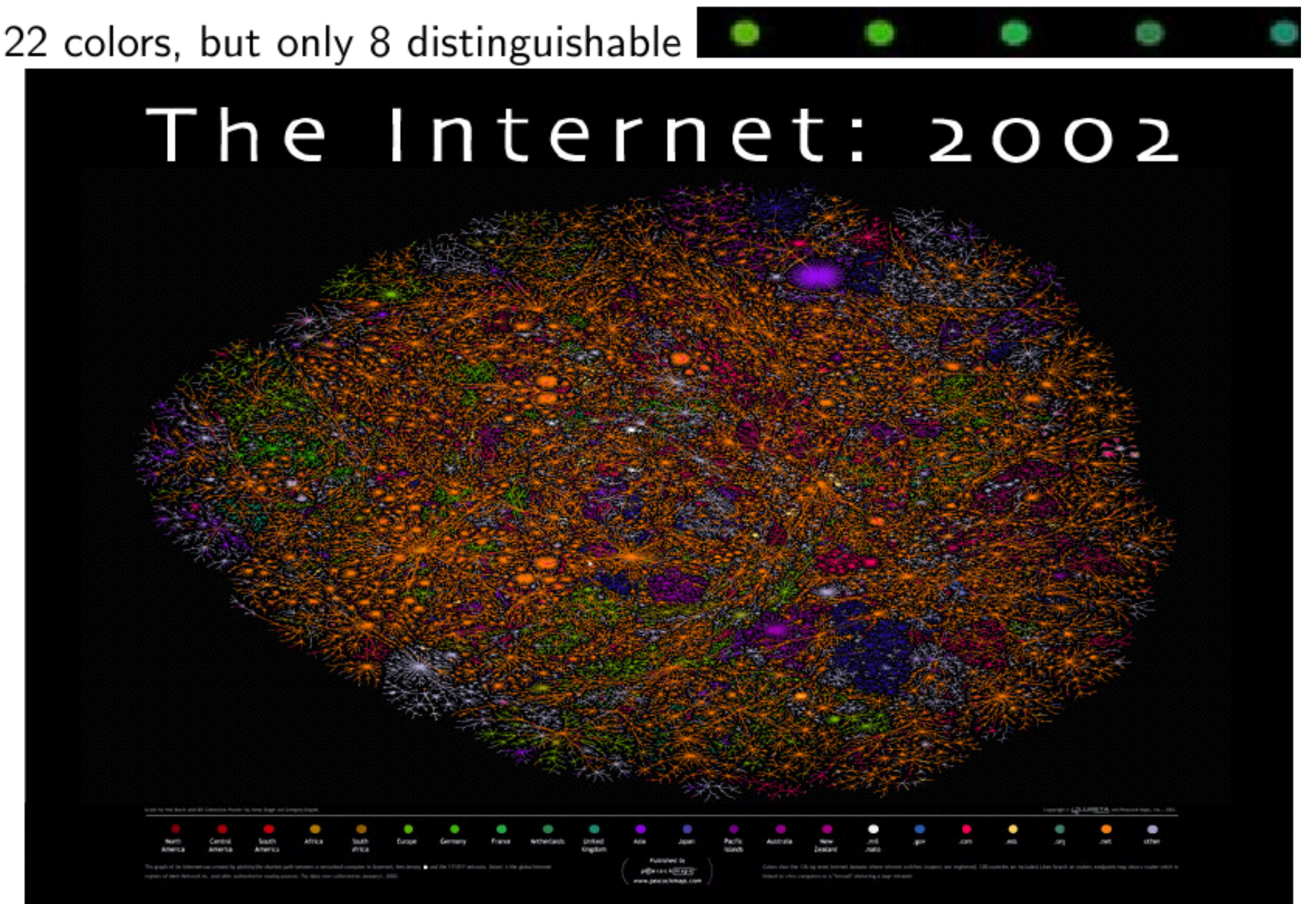
does not help to perceive layout of objects

how they are moving

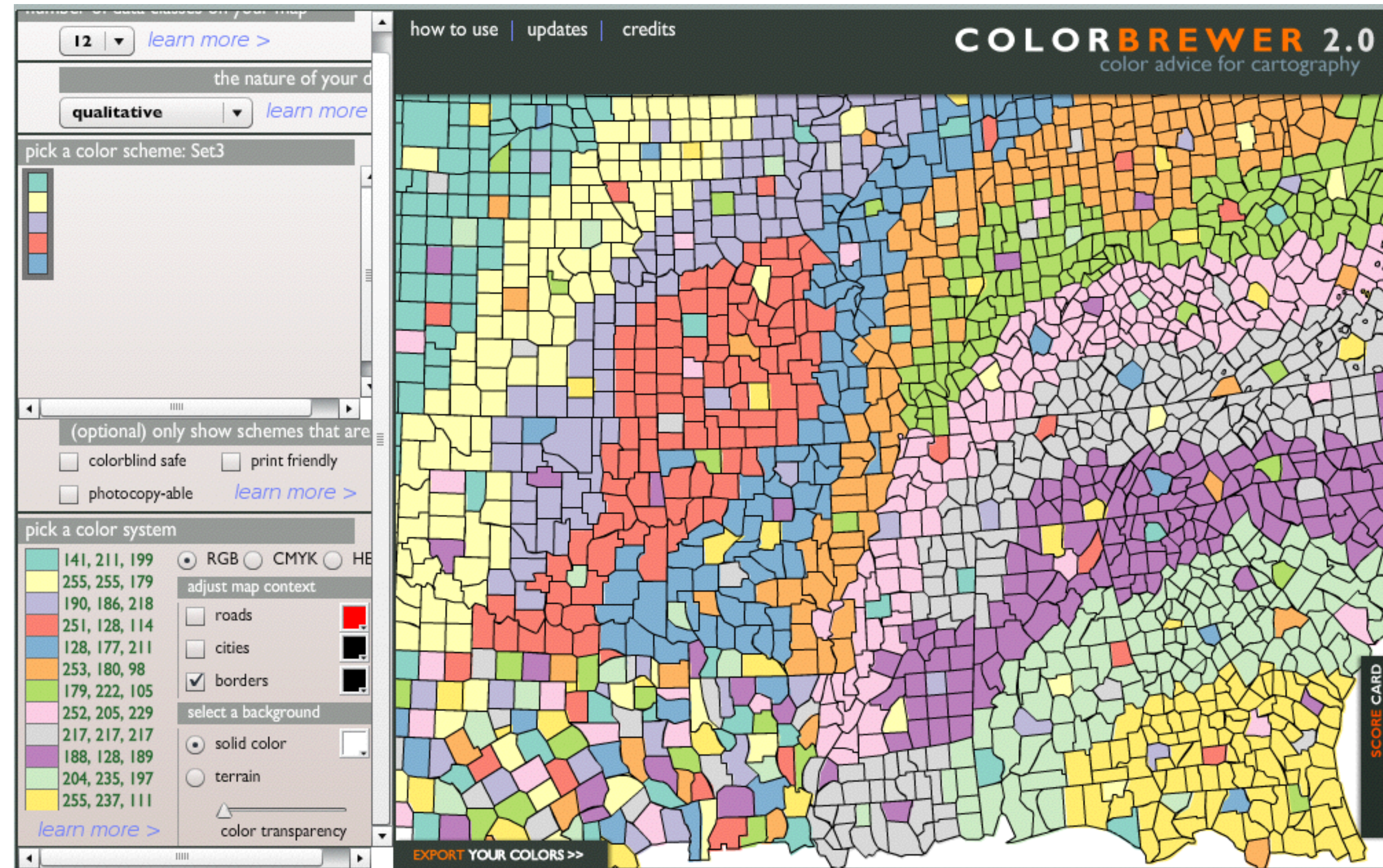
what shape they are

Color breaks camouflage

Tells about material properties (judging quality of food)



Application: Labeling



Carefully designed color scheme for 12 colors [colorbrewer]

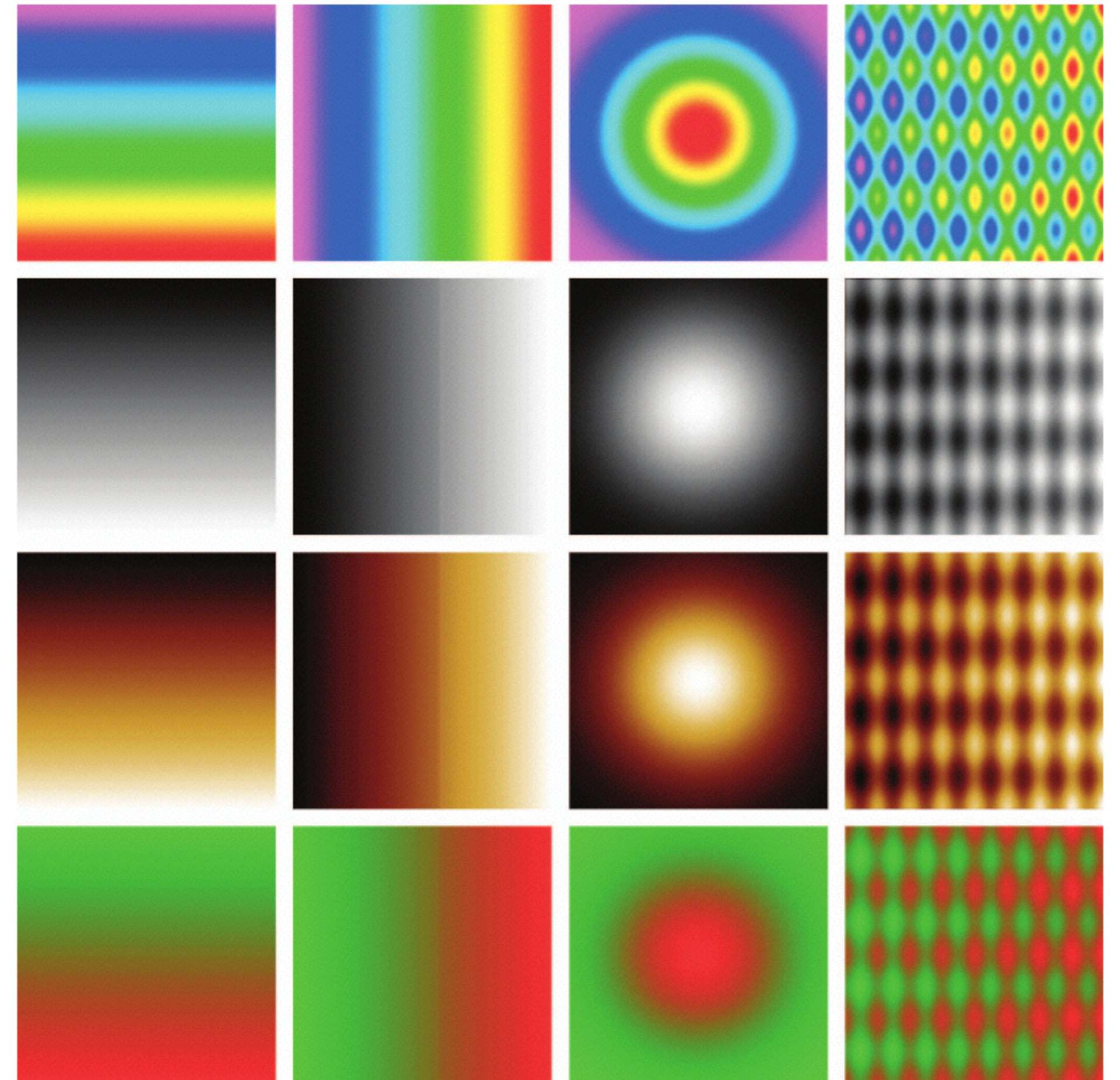
Quantitative Data Vis

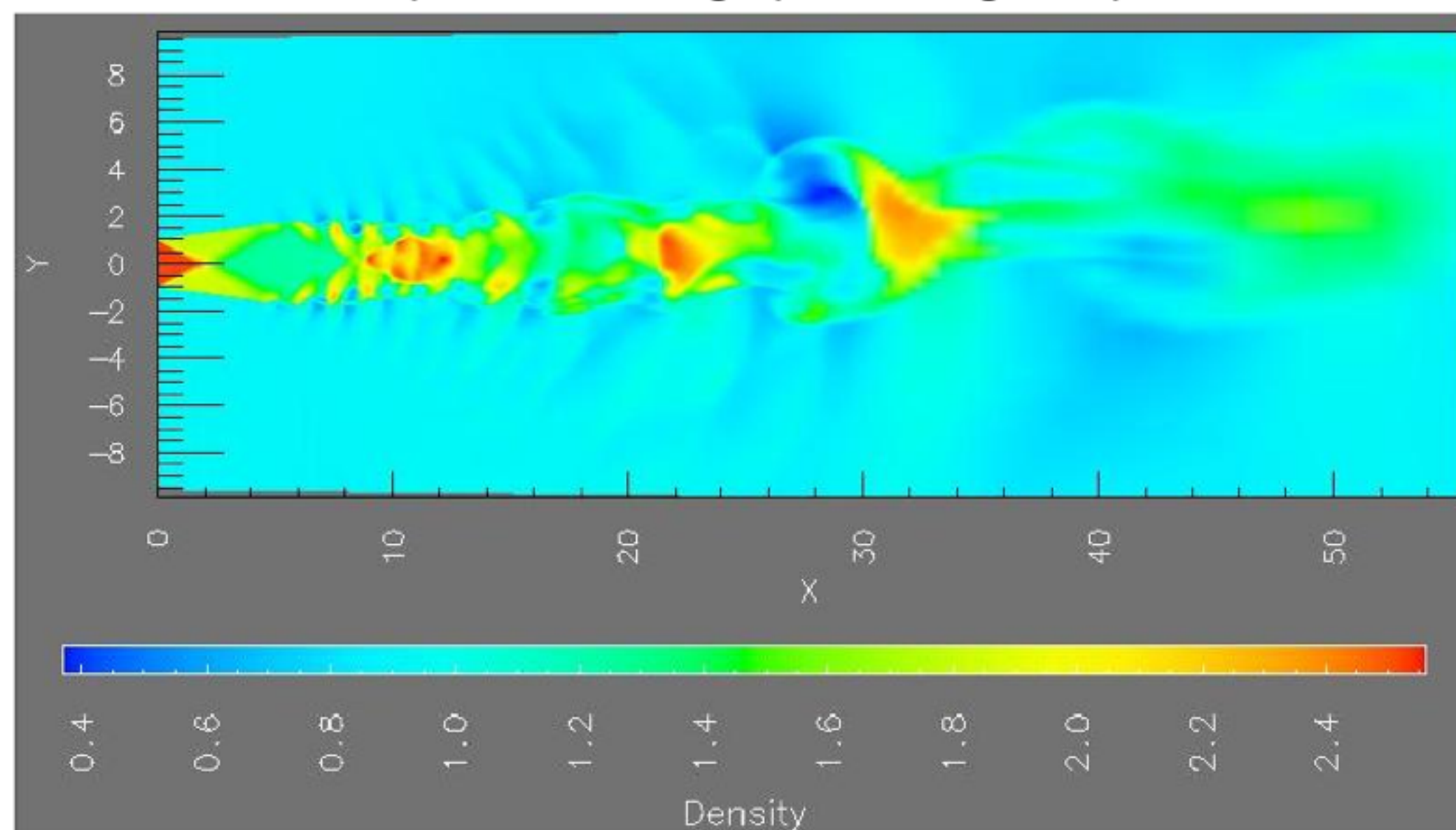
use value

saturation works but not as good

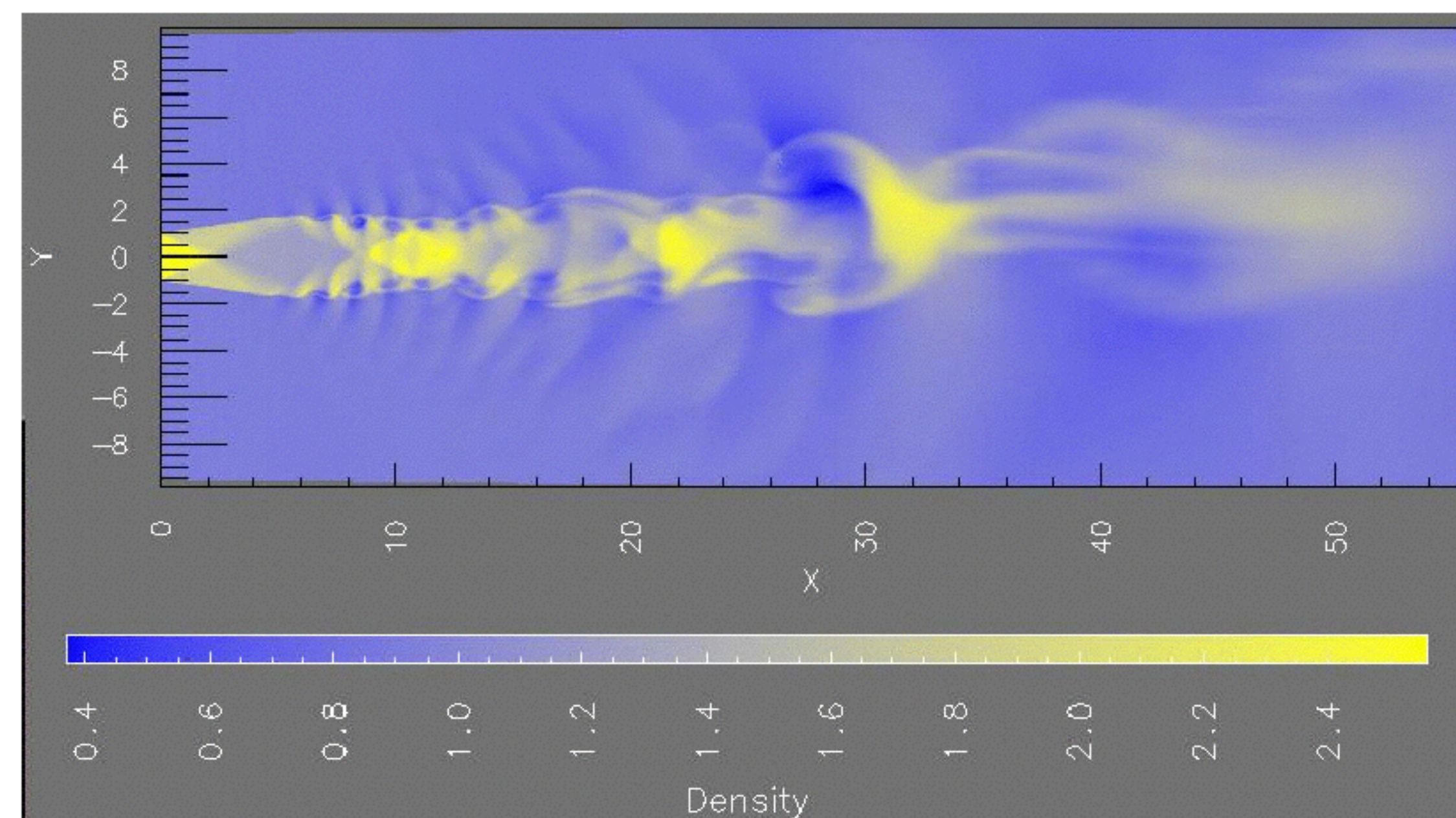
don't use hue!

Danger: rainbow color map



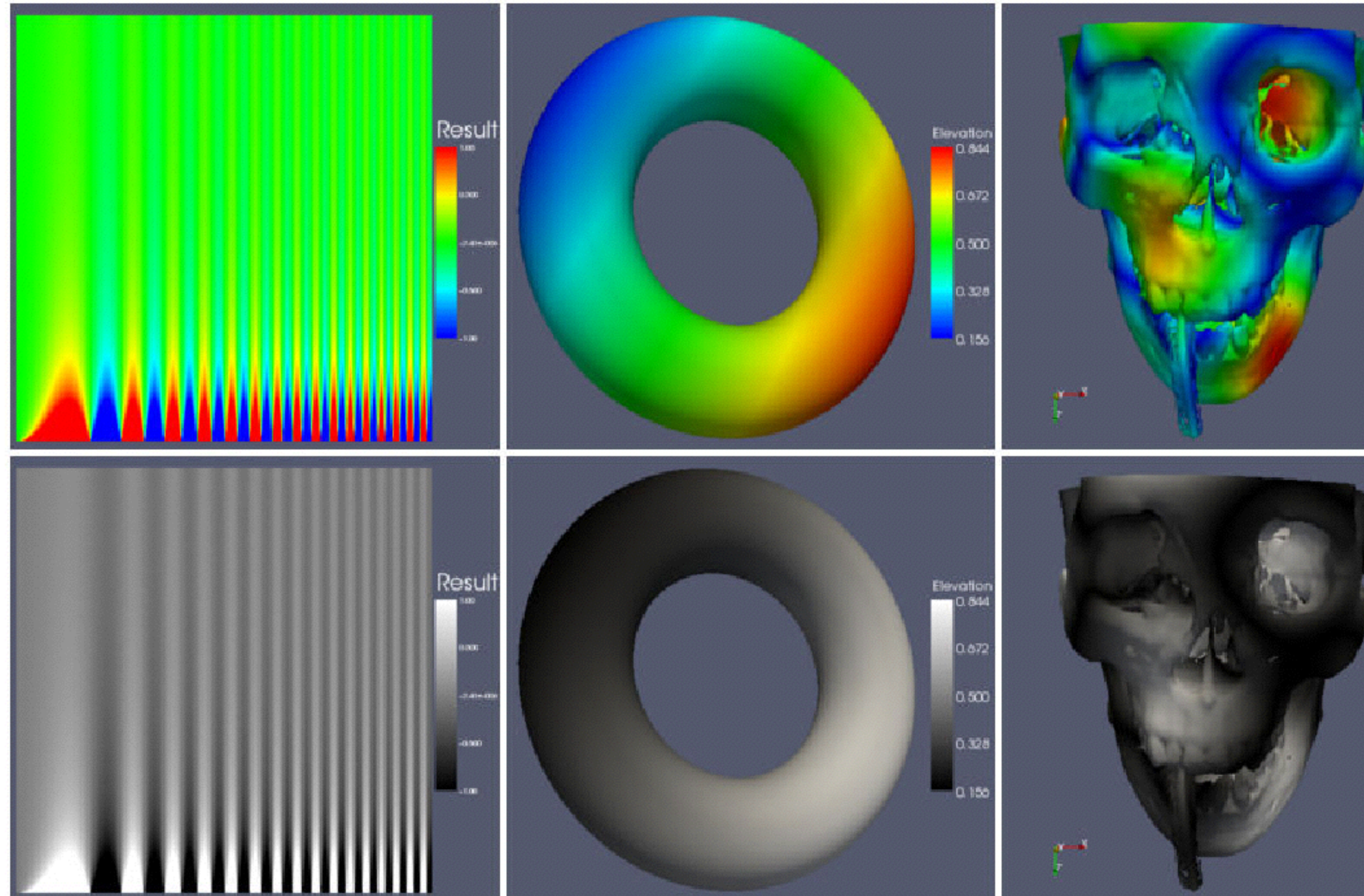


[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color? <http://www.research.ibm.com/people/l/lloyd/color/color.HTM>]

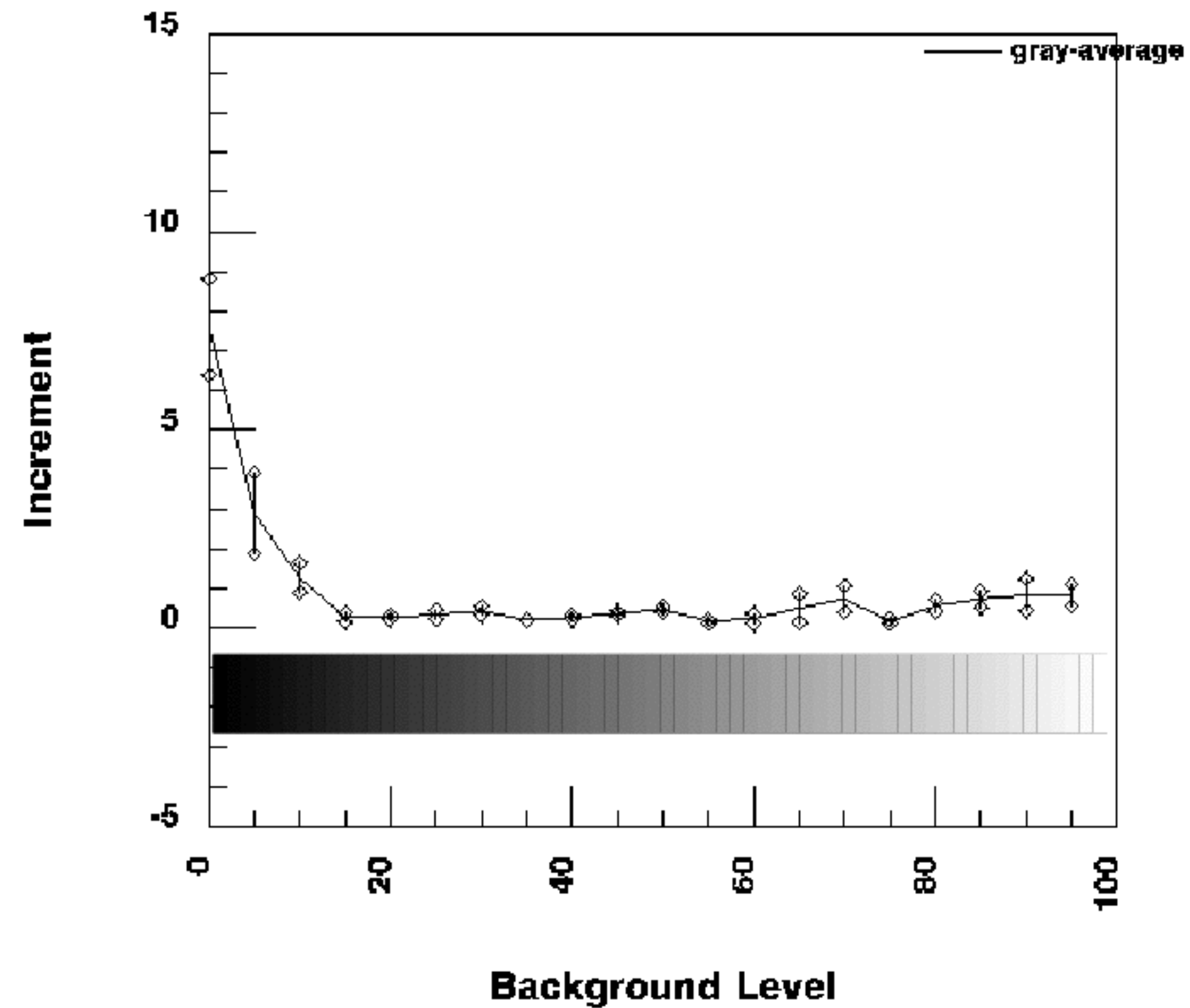
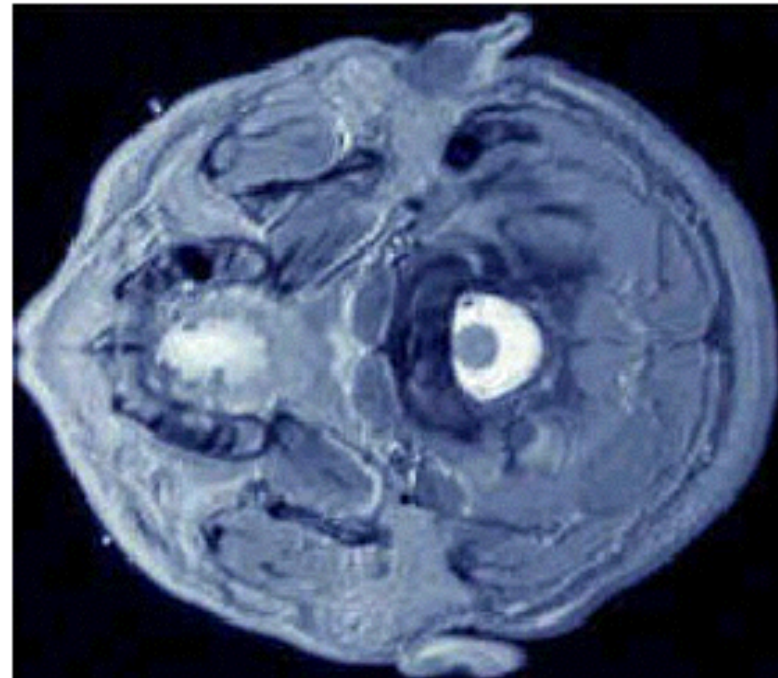


[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm]

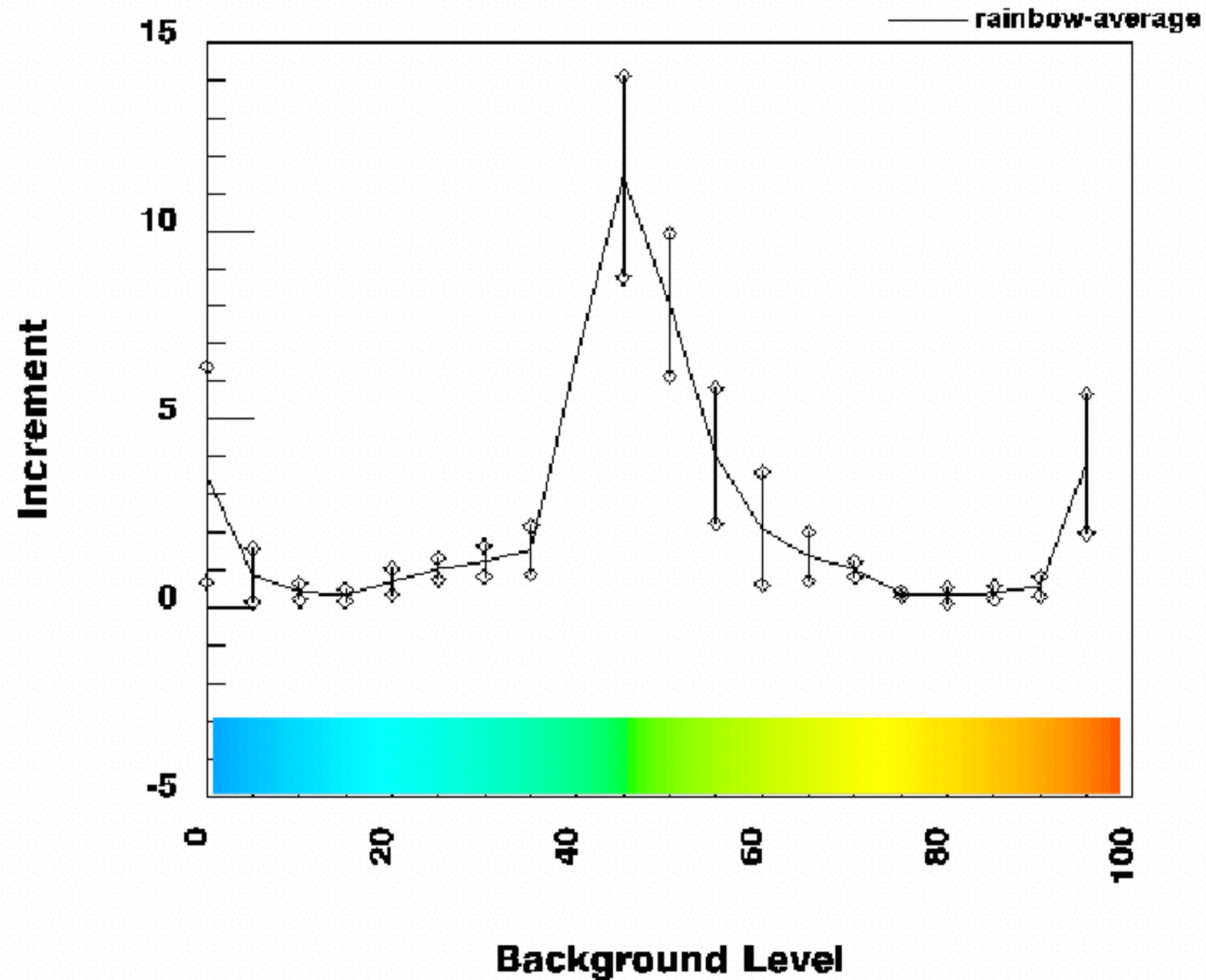
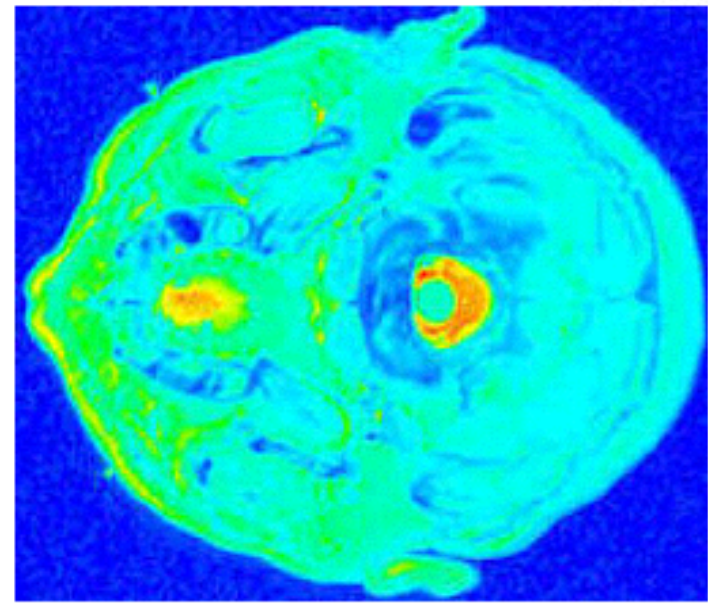
Rainbow vs. Value Color map



Increment Threshold Experiment: Luminance



Increment Threshold Experiment: Rainbow Color Scale



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)

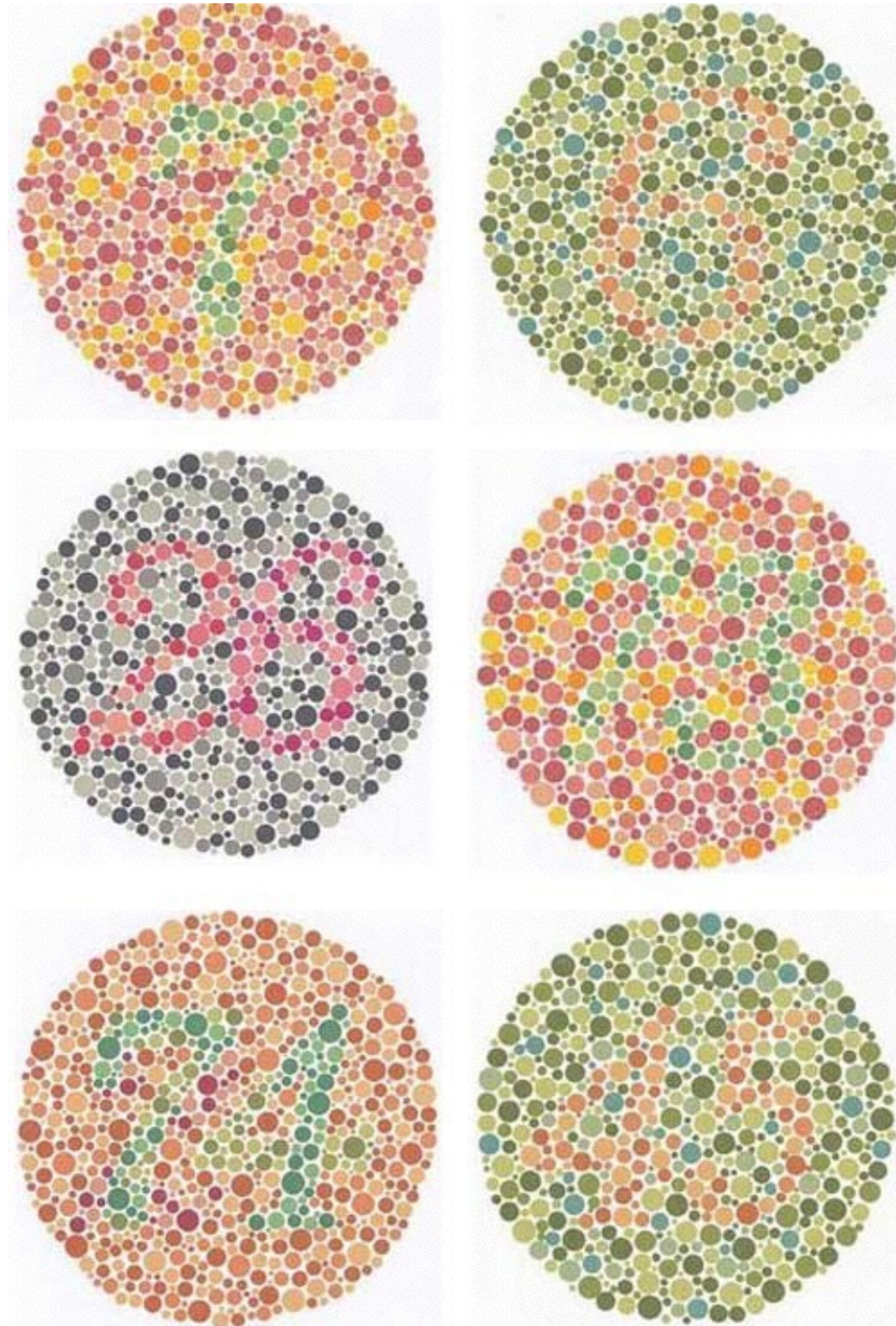


Normal Color Perception

Deuteranopia (no green receptors)

Protanopia (no red receptors)

Color Blindness Tests



Color Blindness



Protanope

No L cones

Red / green
deficiencies



Deuteranope

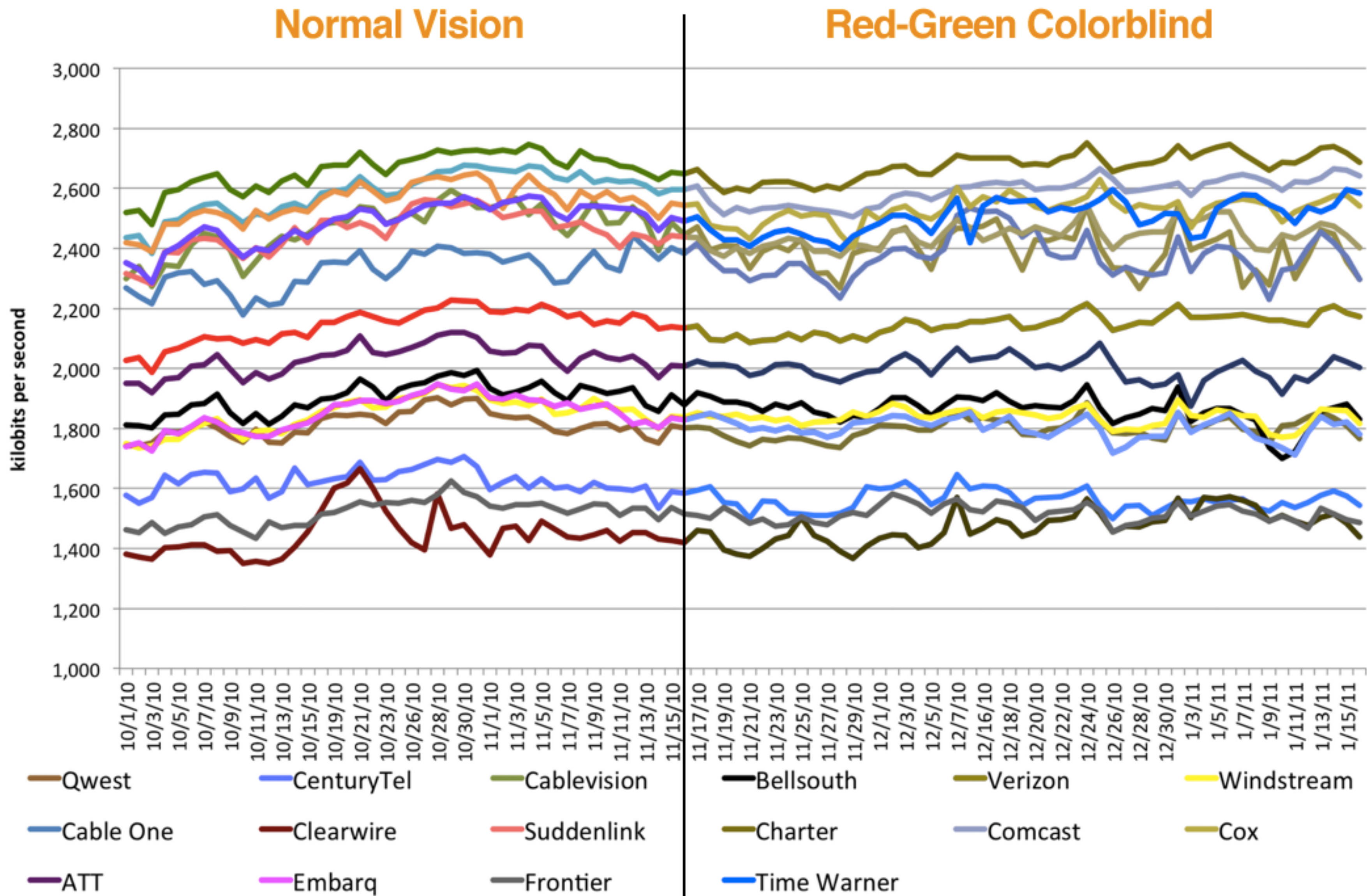
No M cones



Tritanope

No S cones

Blue / Yellow
deficiency





www.vischeck.com

Try Vischeck on a Webpage

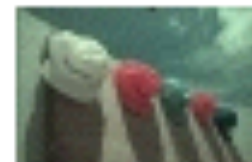
Select the type of color vision to simulate:



☒ Deuteranope (a form of red/green color deficit)



☐ Protanope (another form of red/green color deficit)



☐ Tritanope (a blue/yellow deficit- very rare)

Enter the URL of any webpage- eg. www.google.com.

URL:

Run Vischeck!

Luminance, Brightness, Lightness

Luminance

measured amount of light (luminous intensity per area)

Brightness

perceived amount of light

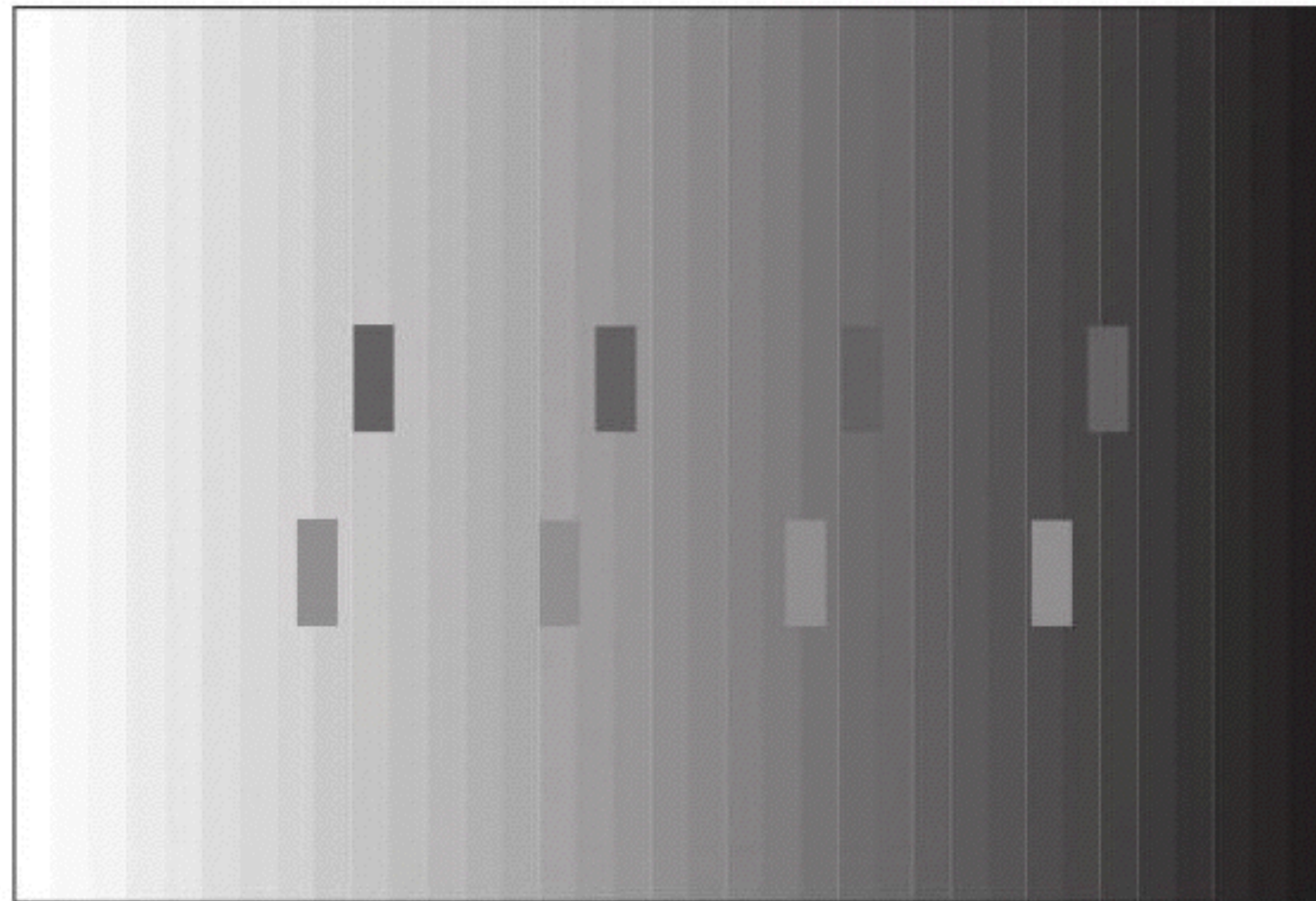
Lightness

perceived reflectance of a surface

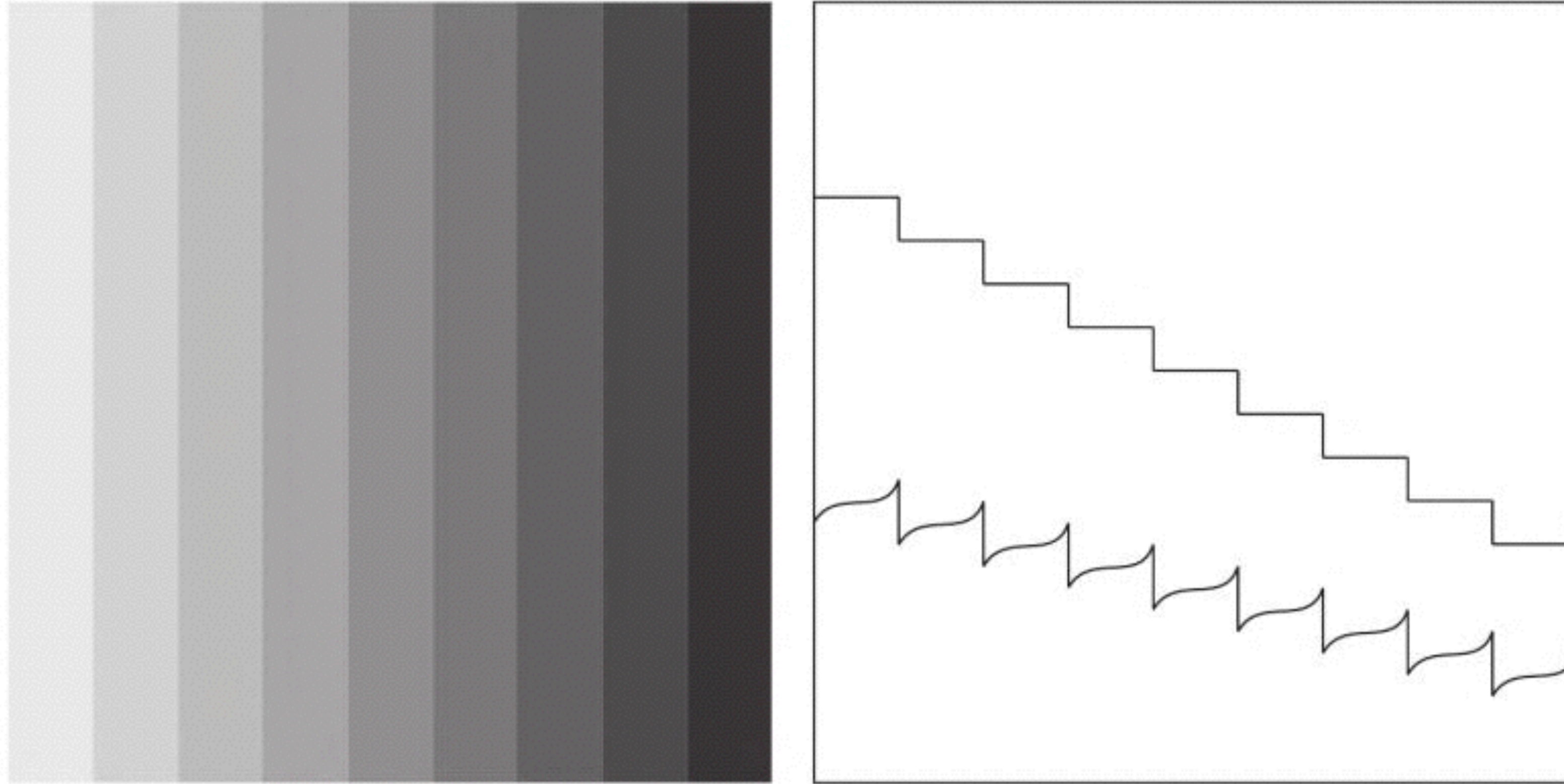
lightness of a color

Simultaneous Brightness Contrast

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



Chevreul Illusion



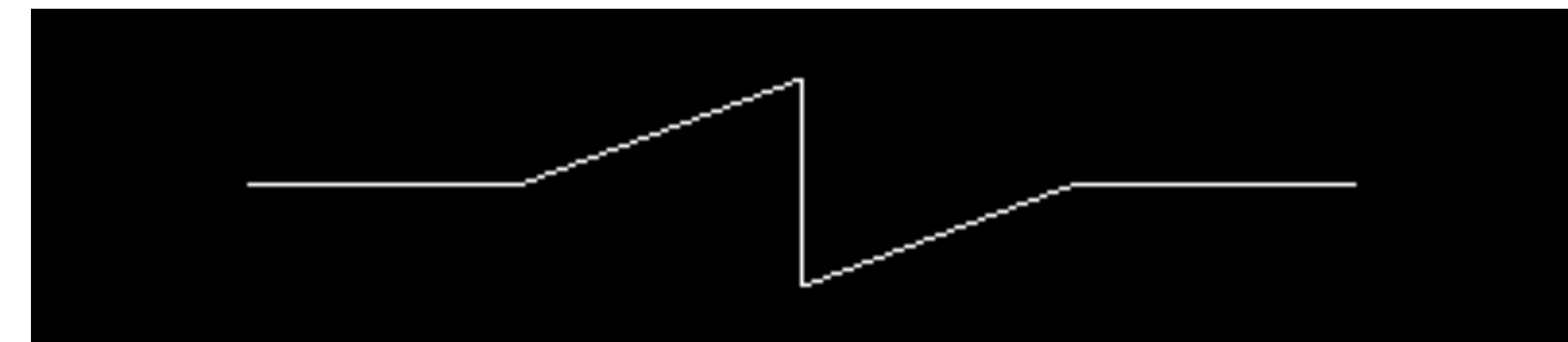
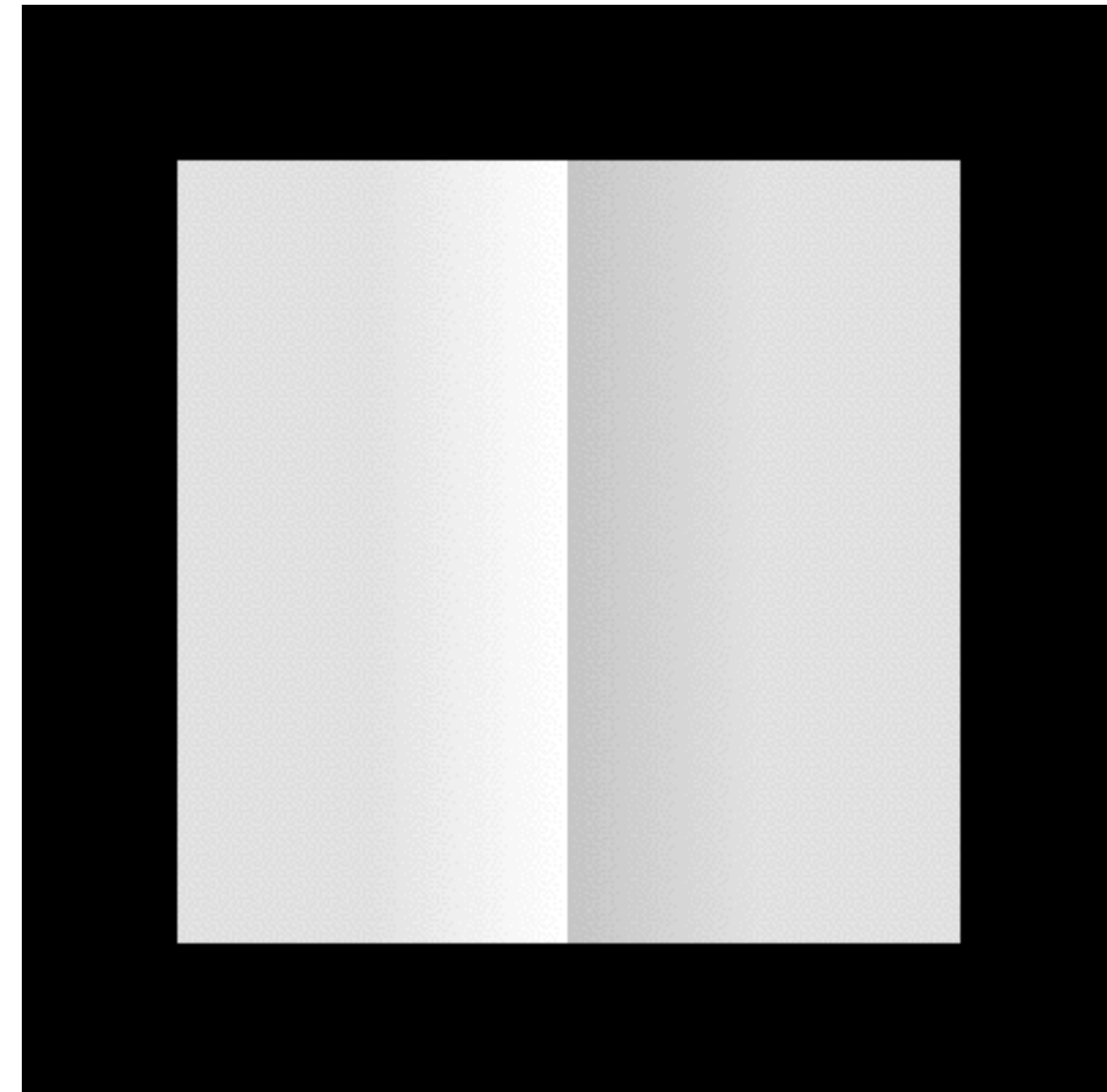
Edge Enhancement

Cornsweet effect

Make objects more distinct



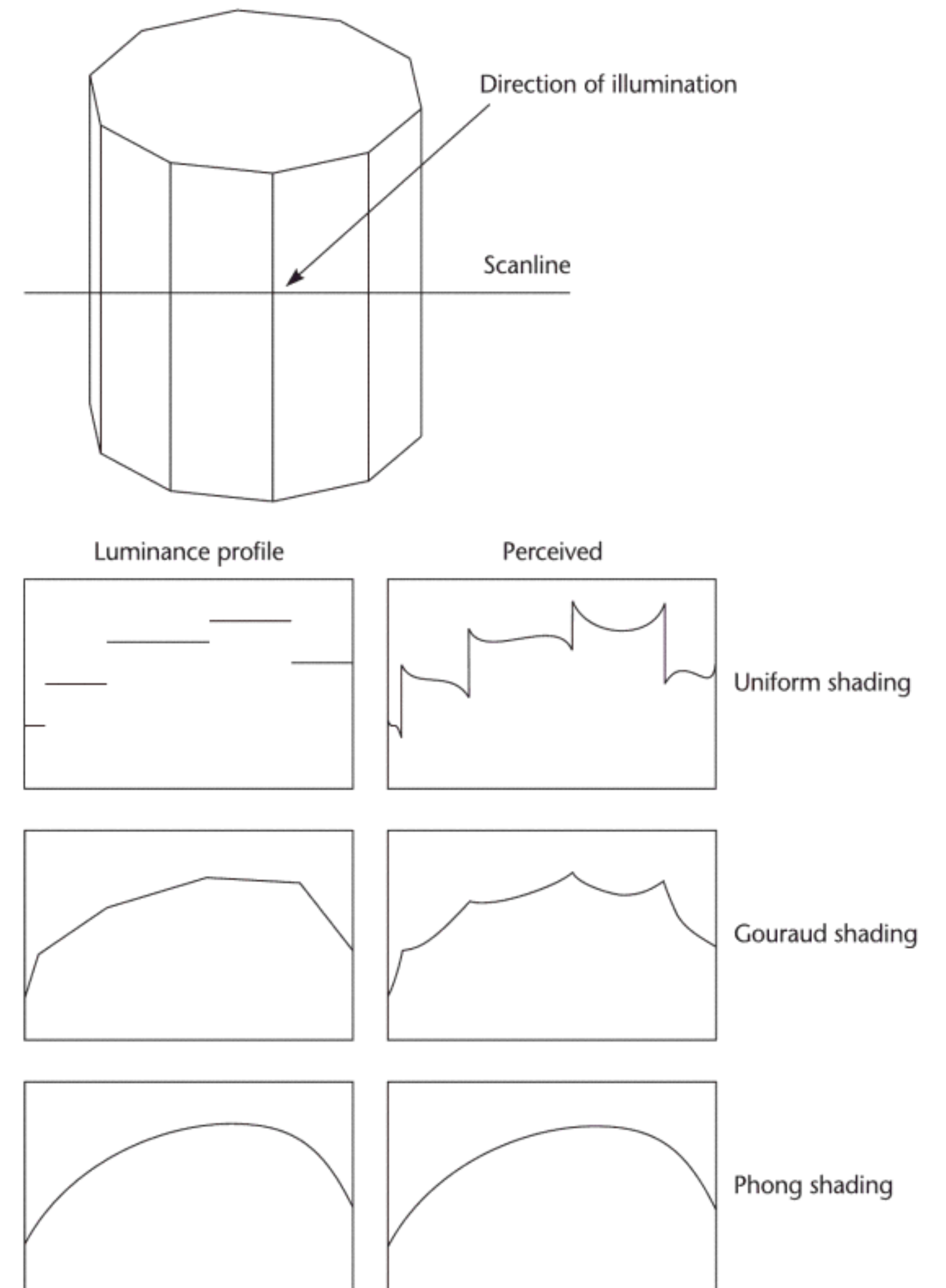
Seurat's Bathers



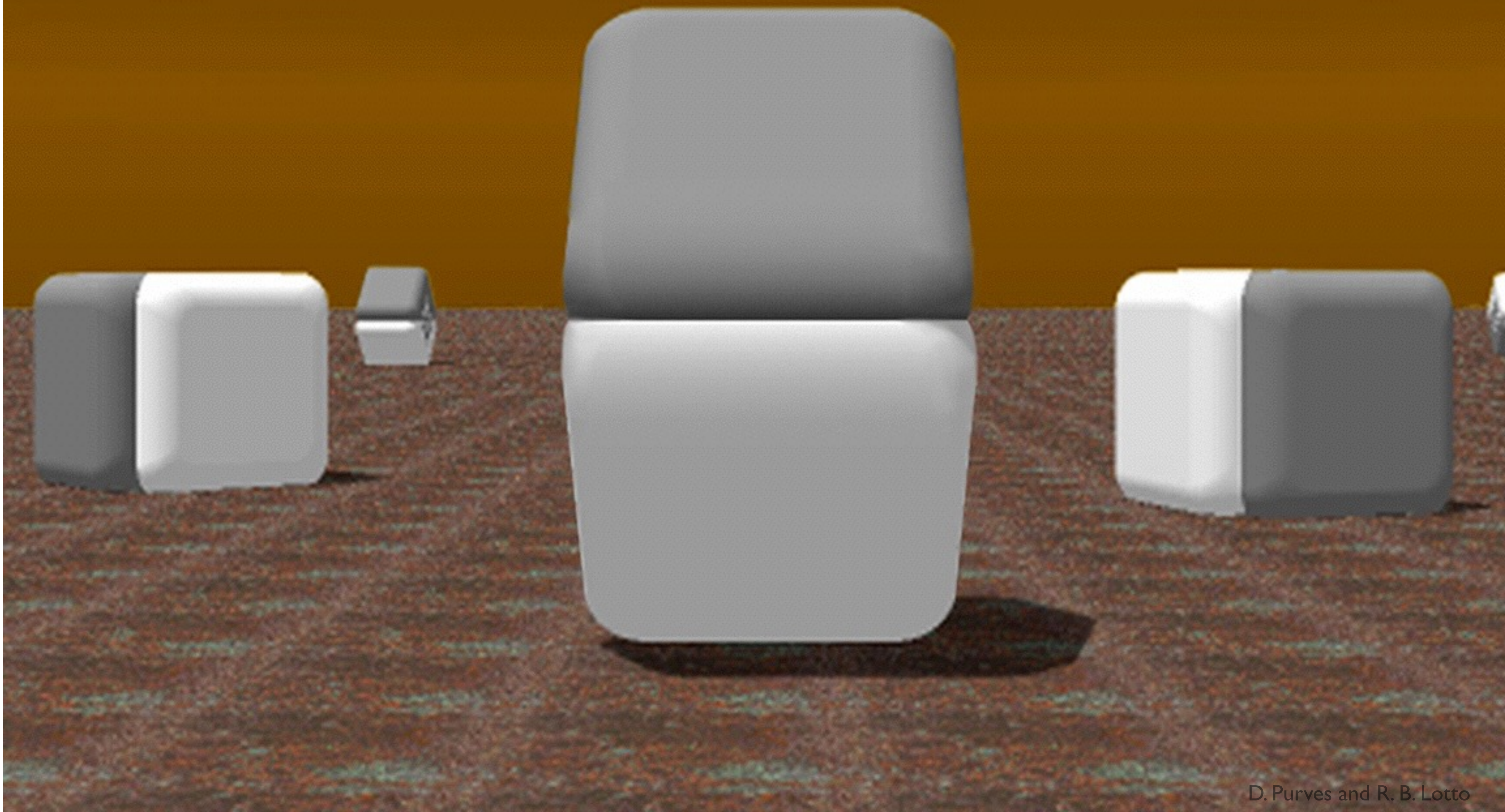
Why is this an issue?

Can result in large errors of judgment

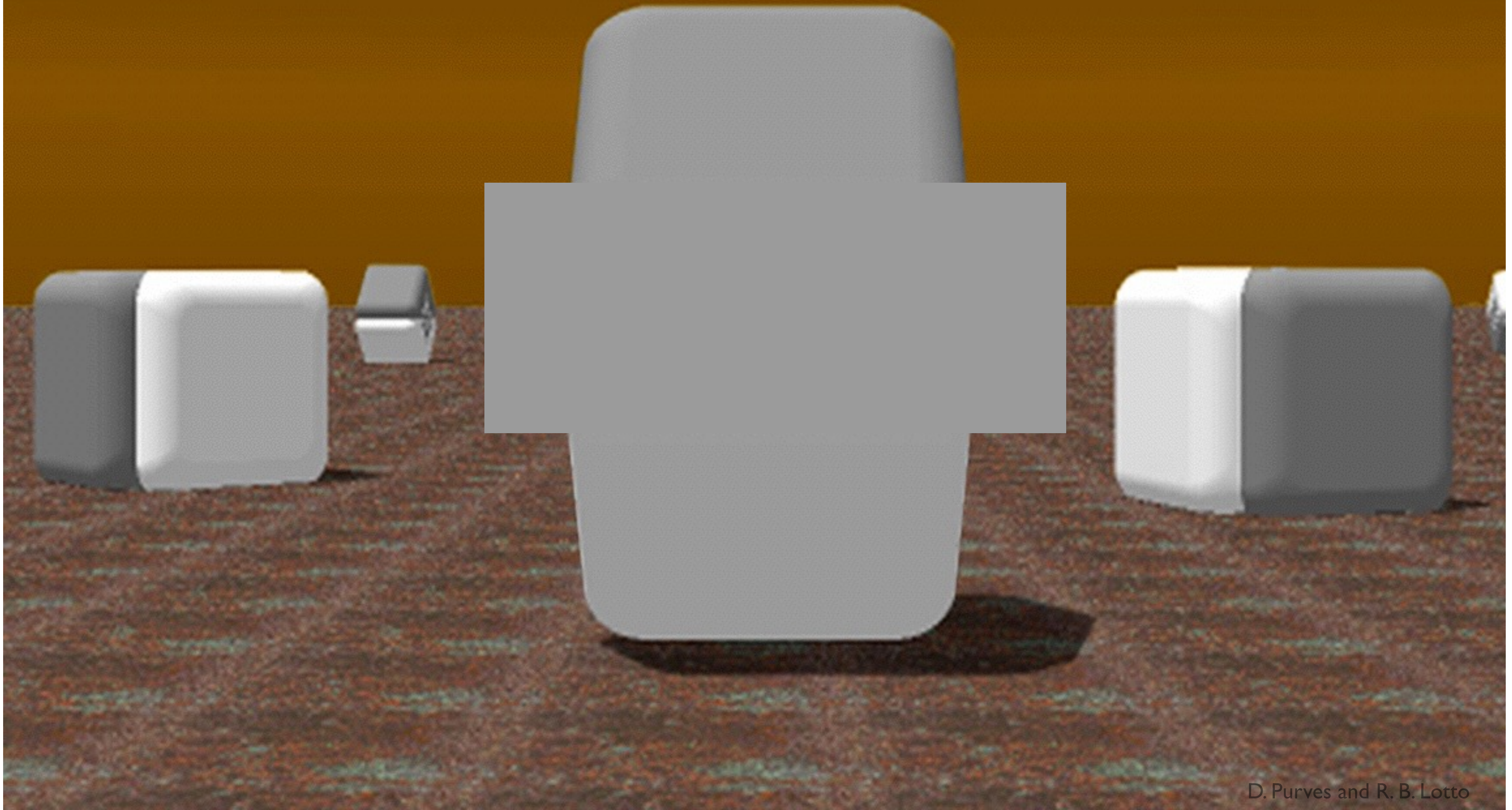
Amplifies artifacts in computer graphics shading



Cornsweet Illusion



Cornsweet Illusion



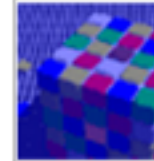
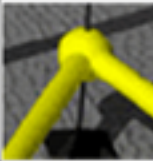
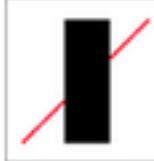
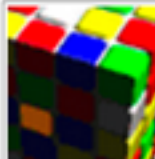
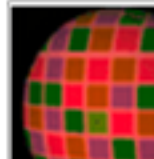
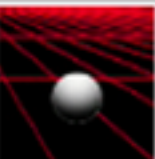
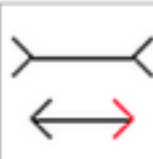
Demo

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

purves-lab

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

MAINNEWSPEOPLERESEARCHPUBLICATIONSRESOURCESSEE FOR YOURSELFCONTACT

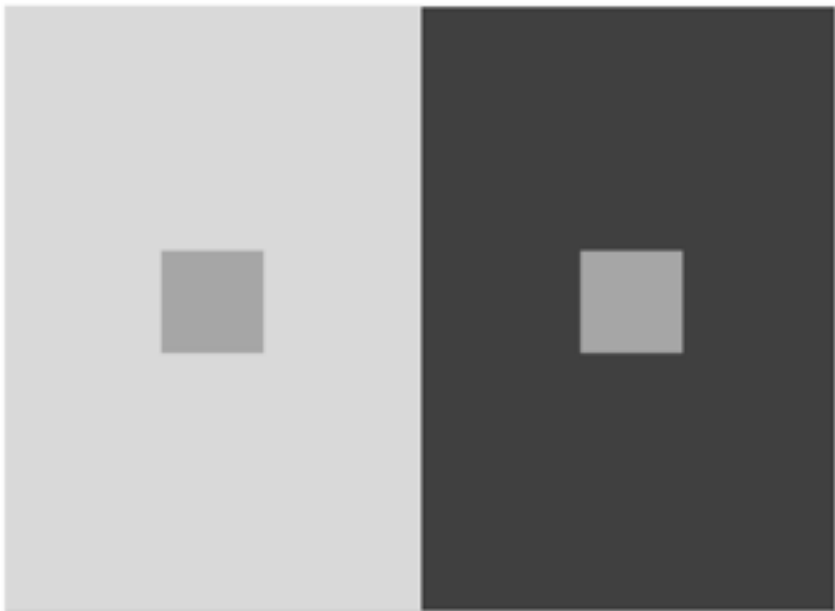
Lightness/Brightness	Color	Lines and Angles	Motion	Sound and Music
   	 	 	 	 
   	 	 	 	 
   	 	 	 	 

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](#)

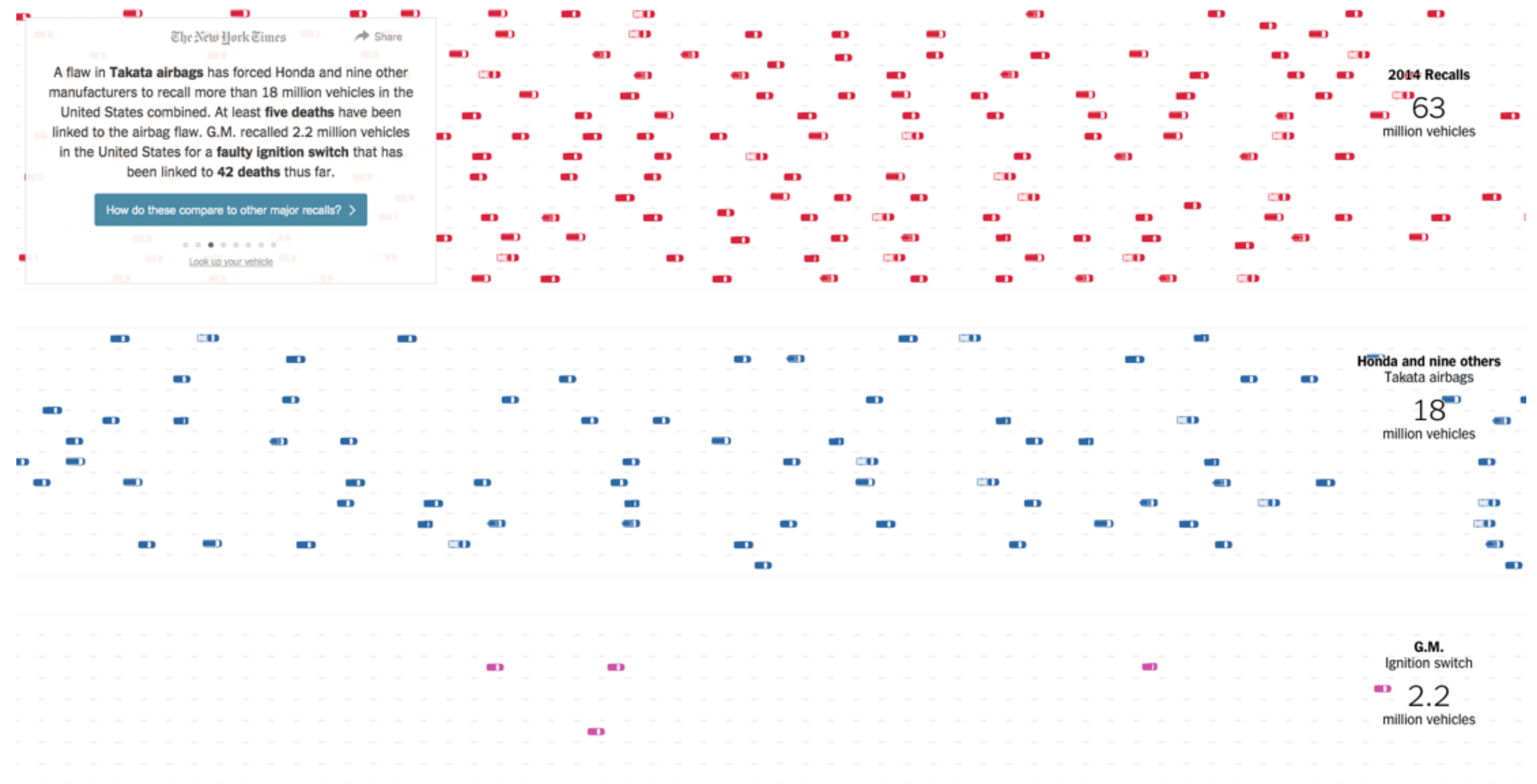
[» Download high resolution images](#)





Design Critique

A Record Year for Auto Recalls



<https://goo.gl/DYpvvr>

NY Times: <http://goo.gl/tDVISB>

Preattentive Processing

Preattentive Processing

Properties detected by the low-level visual system

- very rapid - 200-250 milliseconds

- very accurate

- processed in parallel

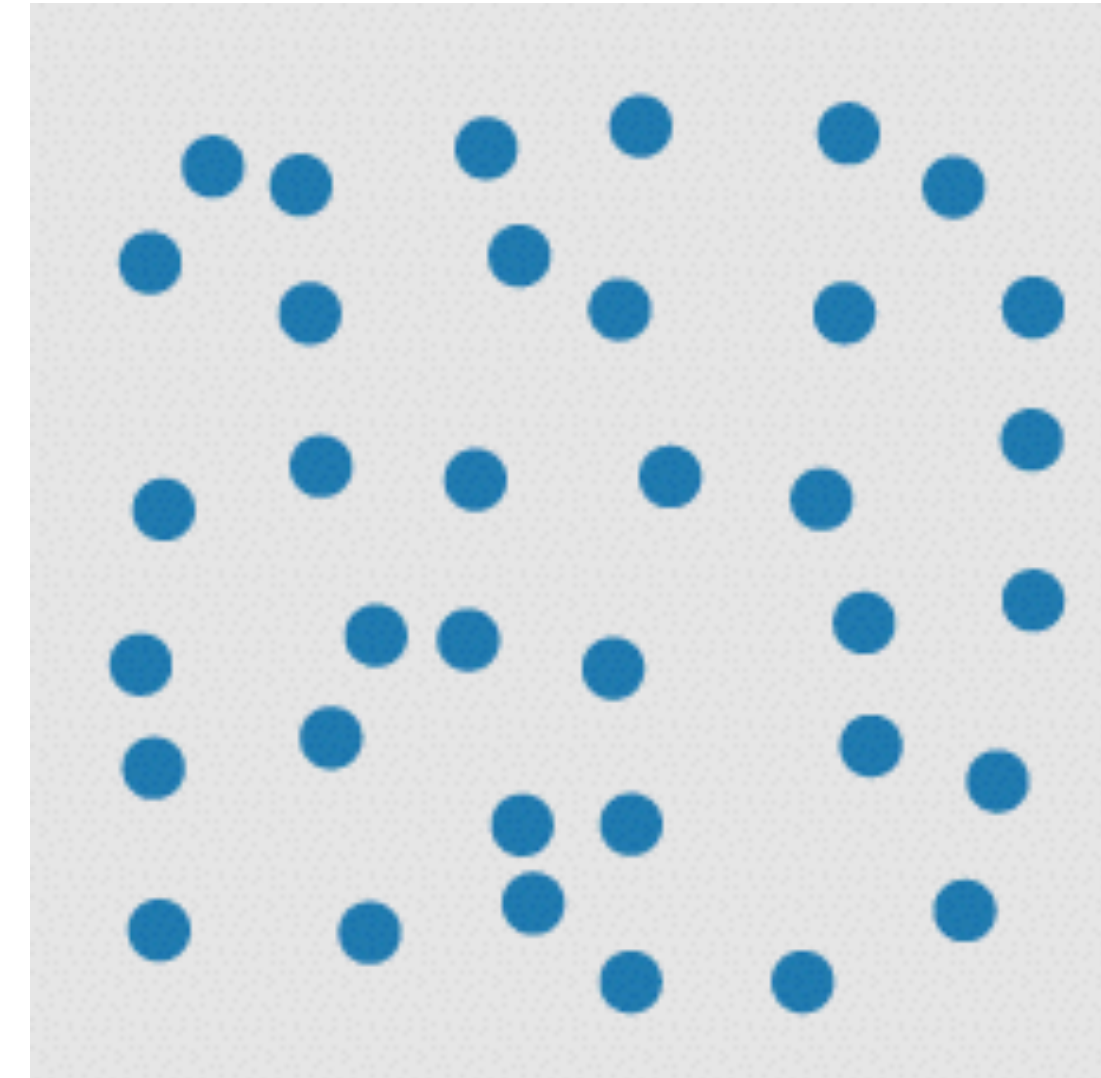
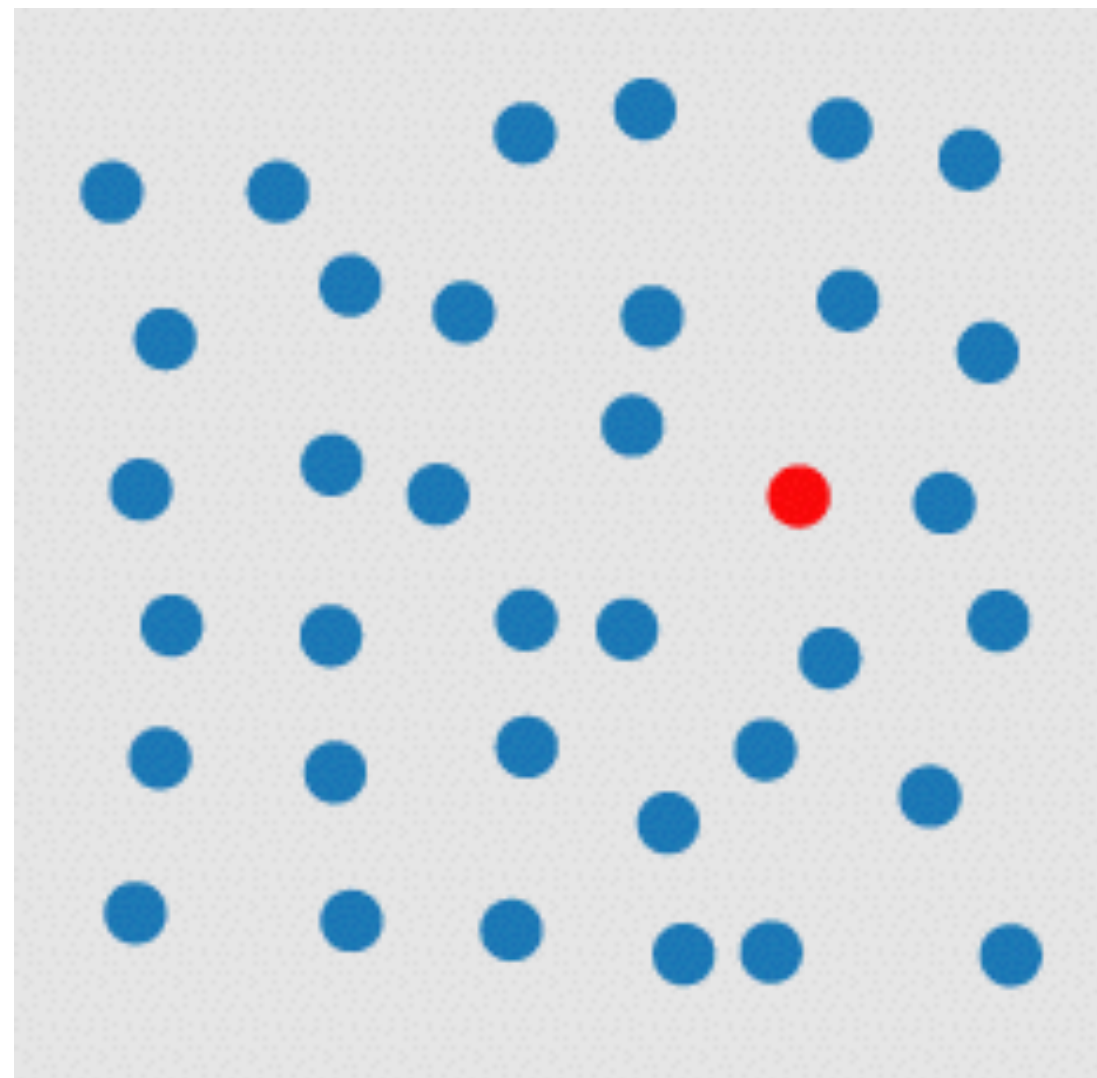
happens before focused attention -> „pre“attentive

attention is very important for cognition

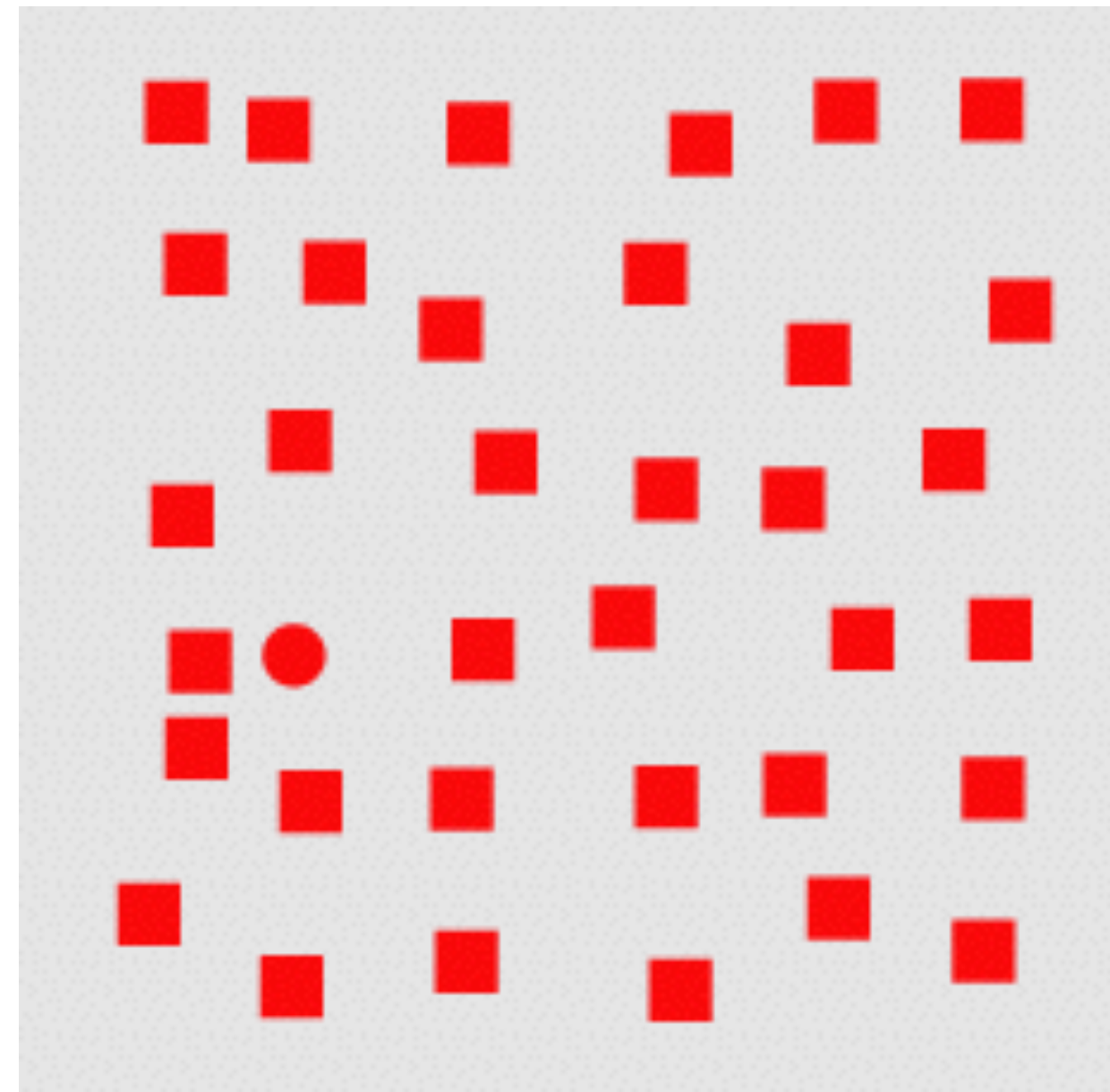
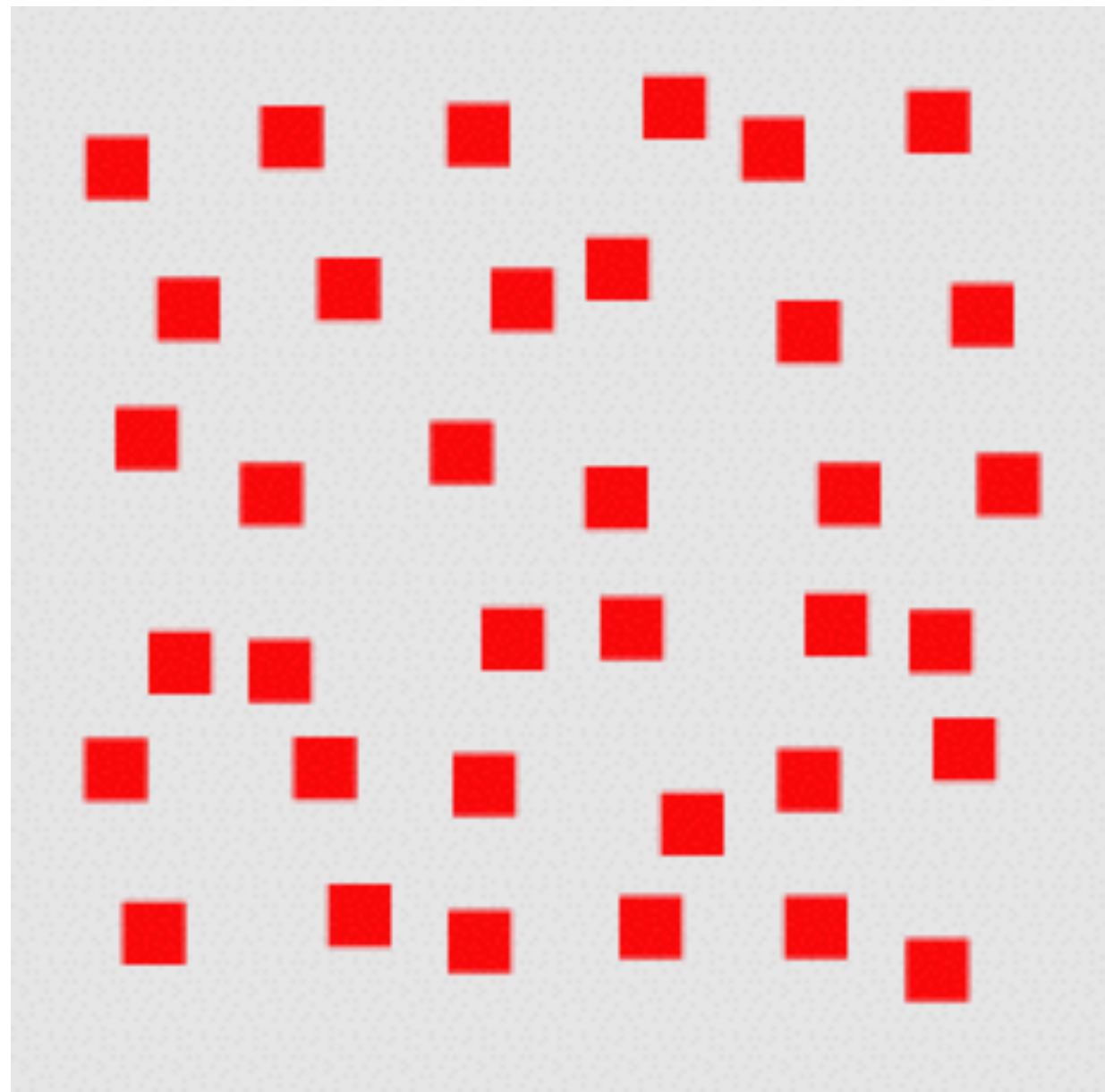
Independent of the number of distractors!

Opposite: sequential search (processed serially)

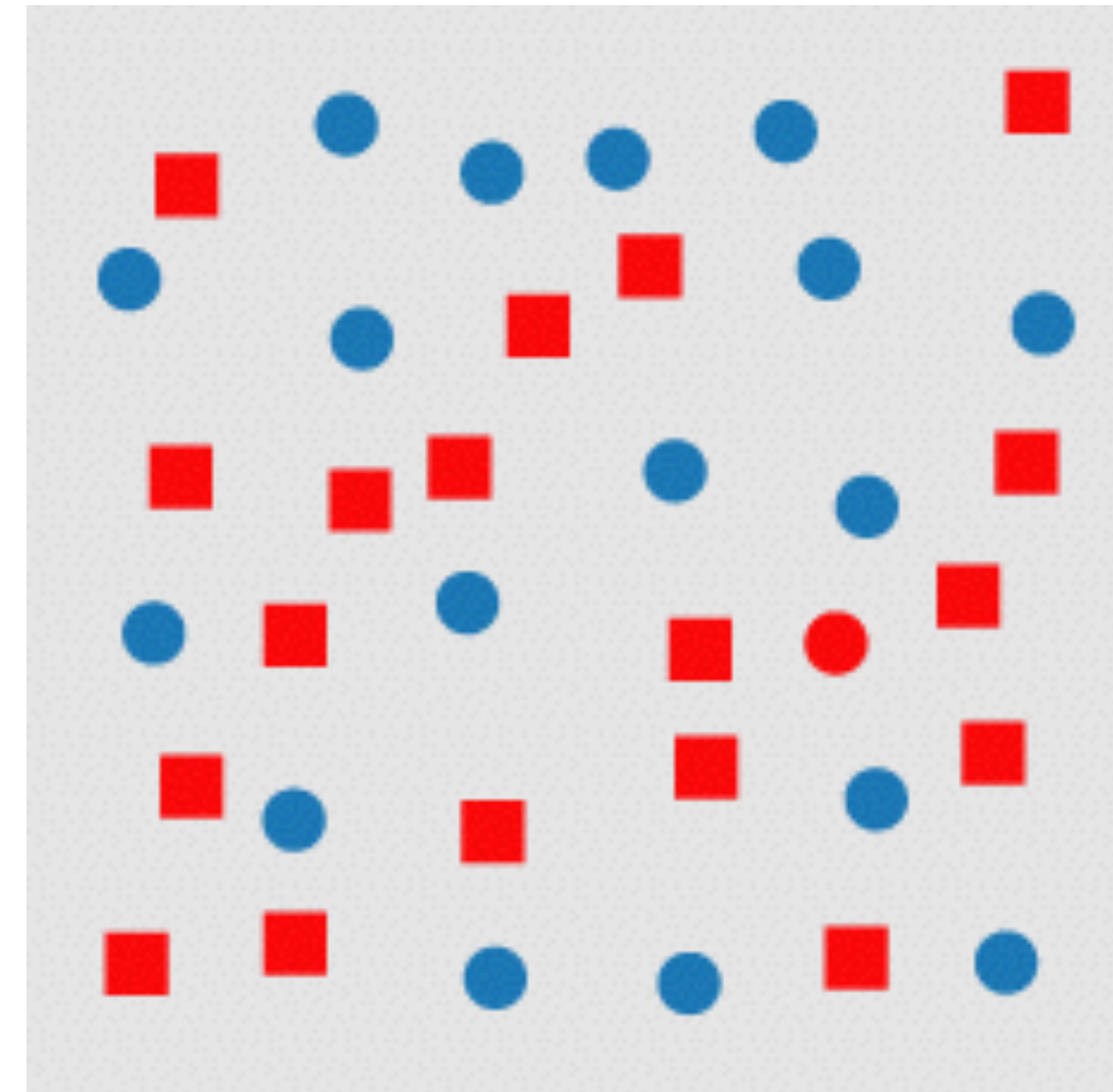
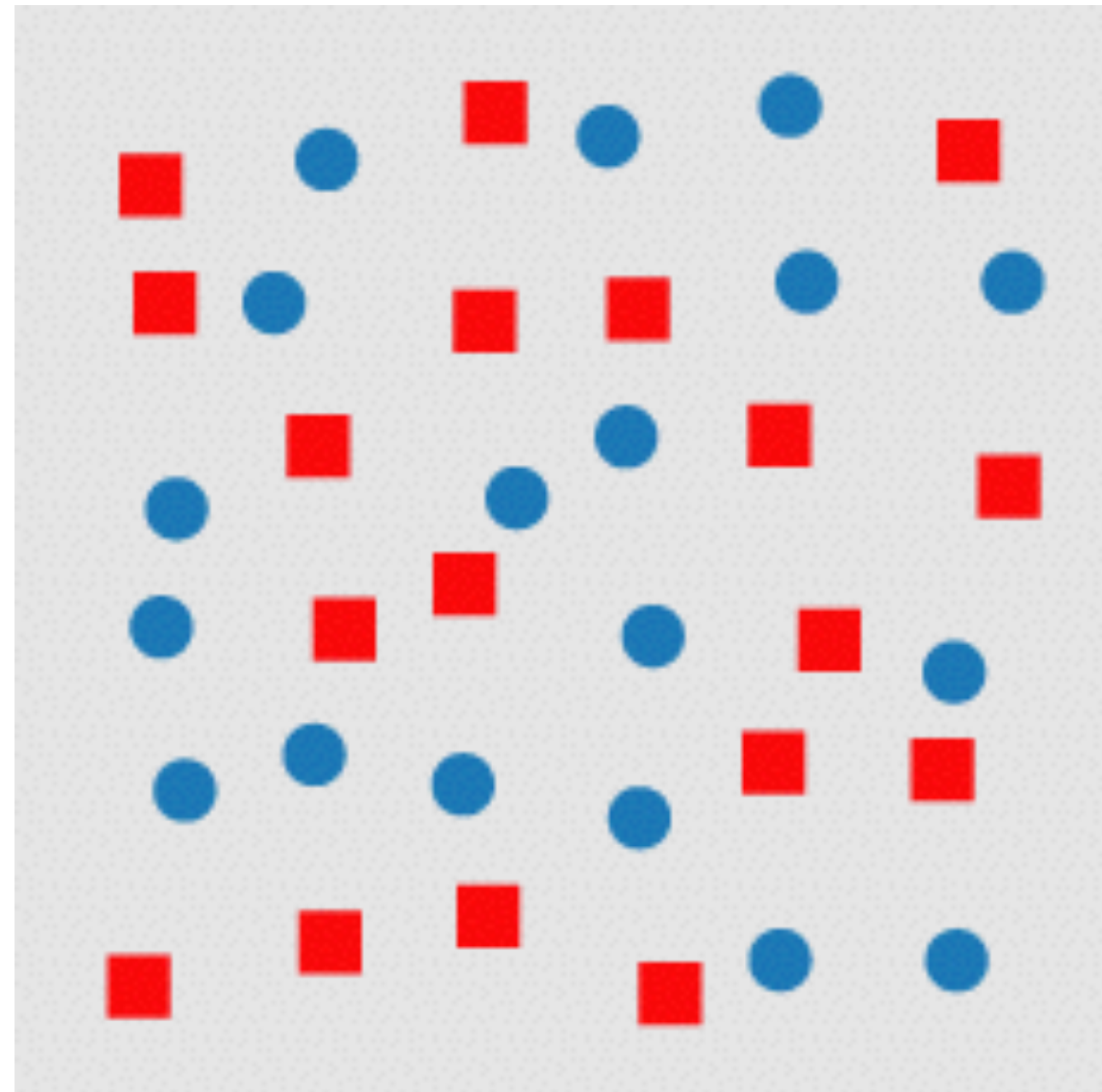
Difference in Hue



Difference in Curvature / Form

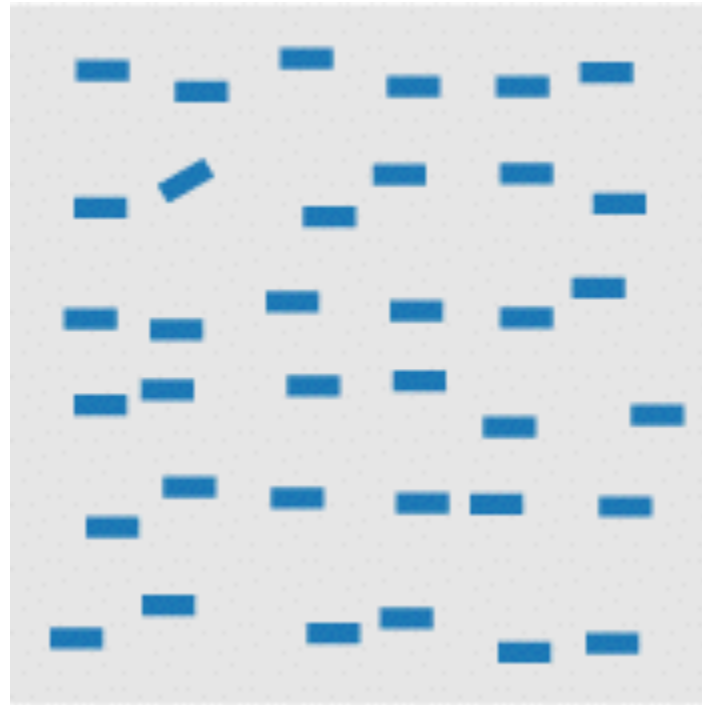


Not Valid for Combinations

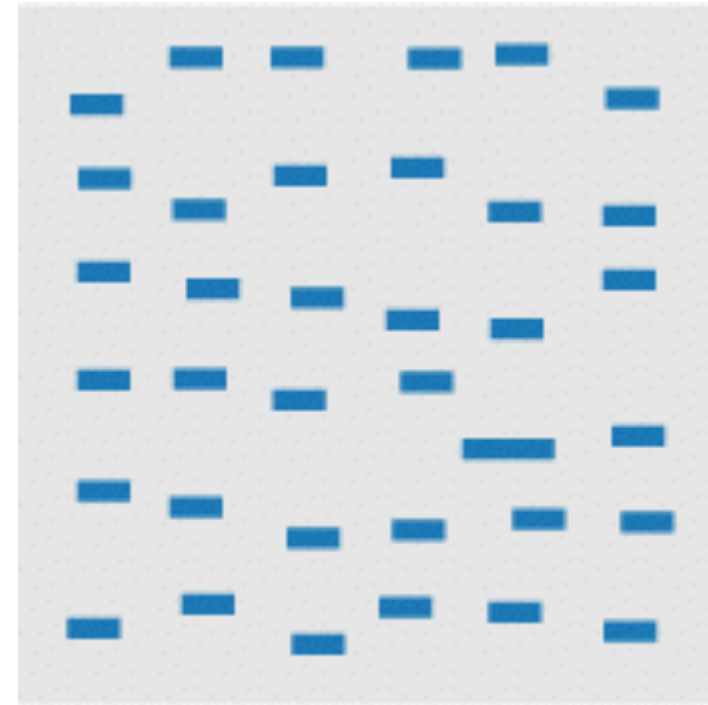


Conjunction Targets – no unique visual property
target: red, circle
distractor objects have both properties

Some Preattentive Properties



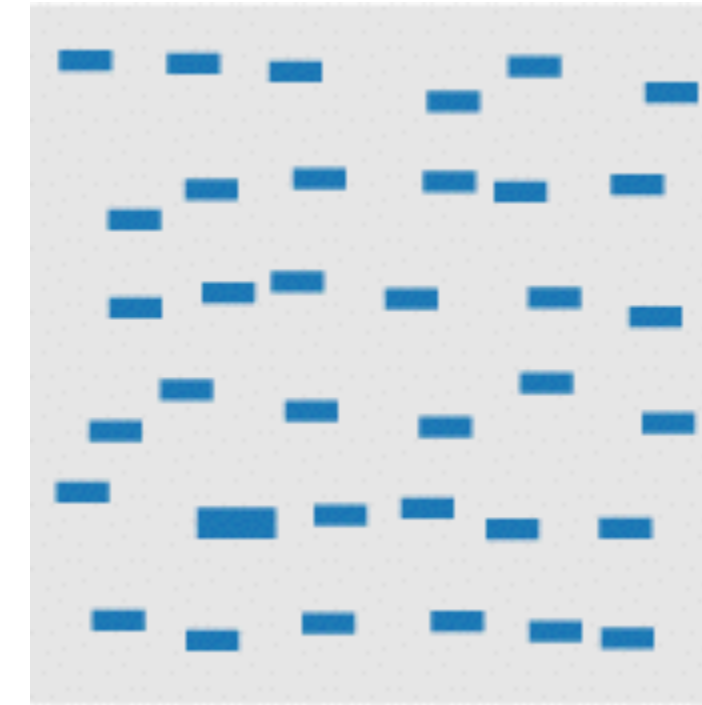
orientation



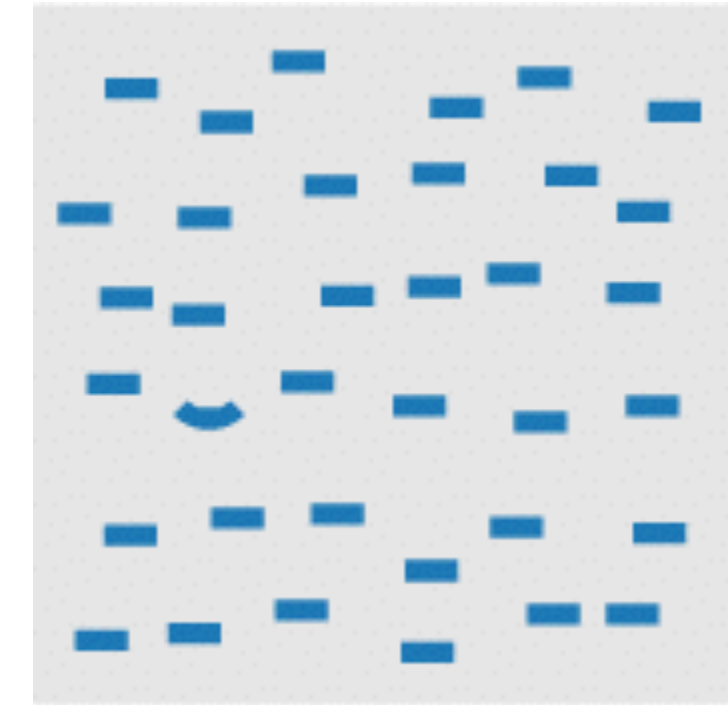
length



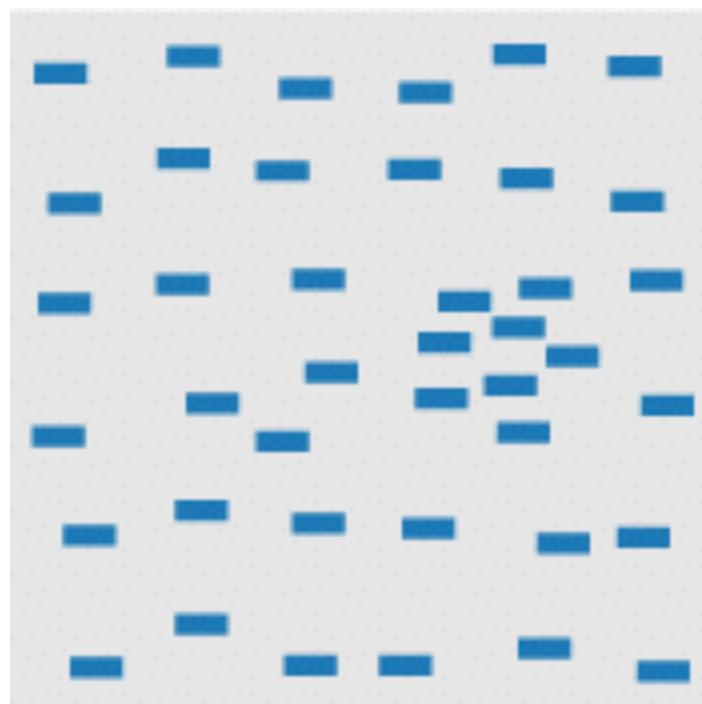
closure



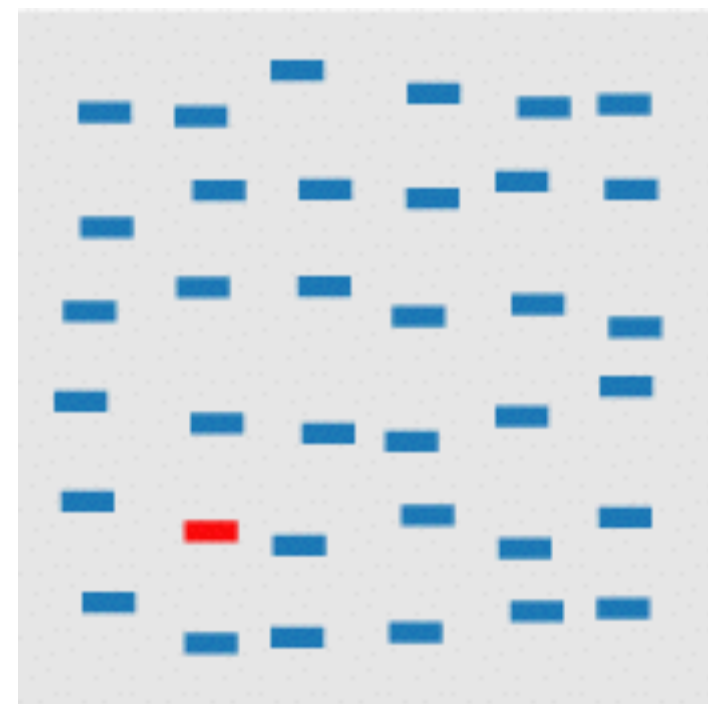
size



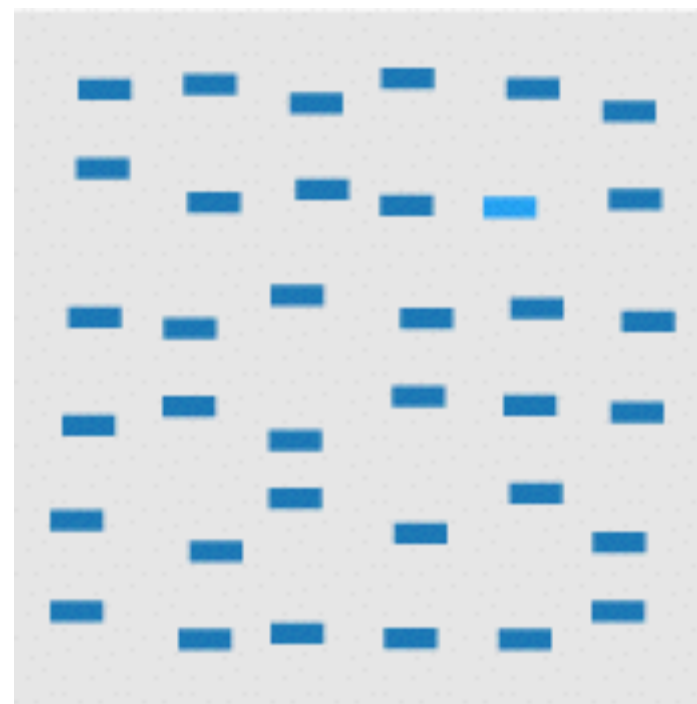
curvature



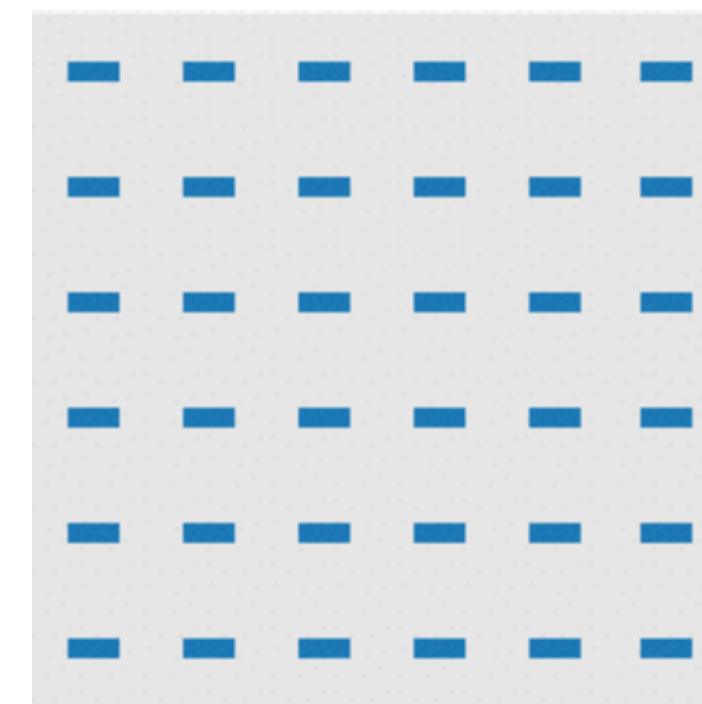
density



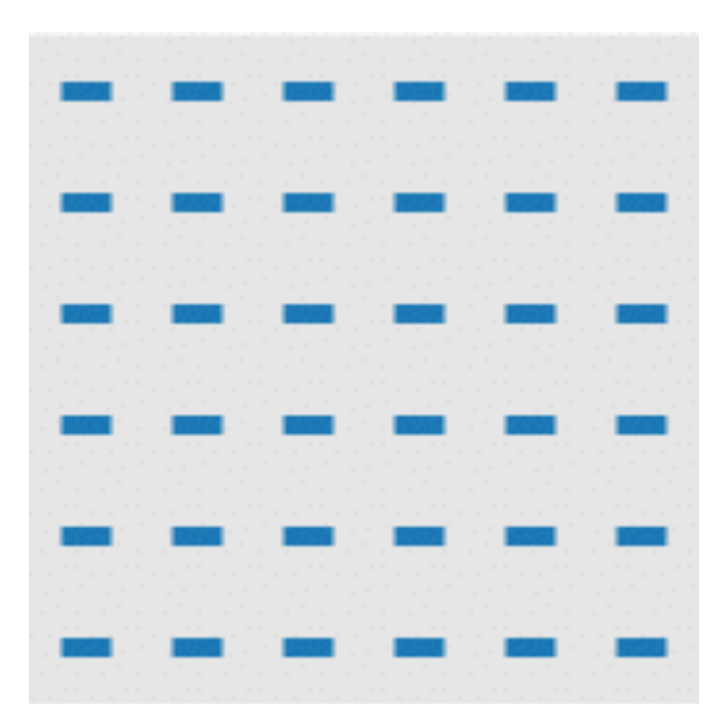
hue



hue

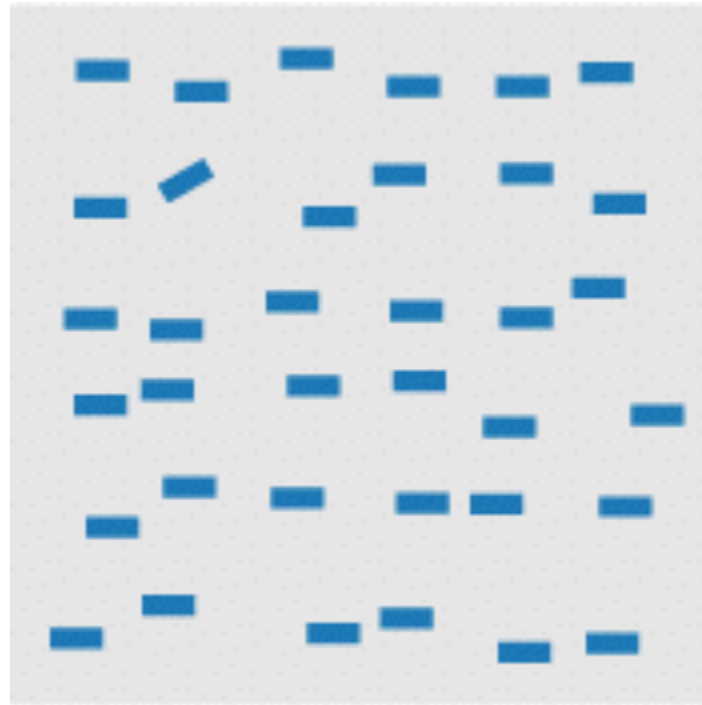


flicker

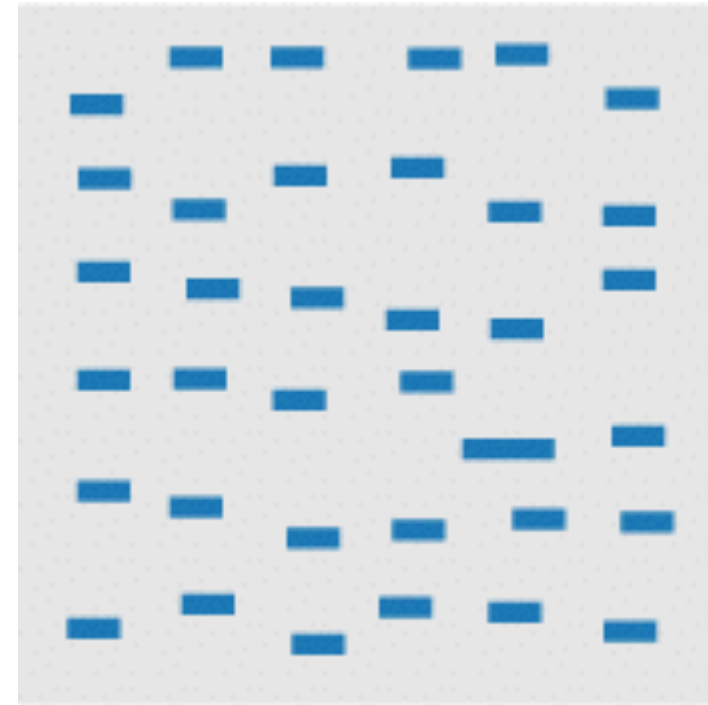


direction of motion

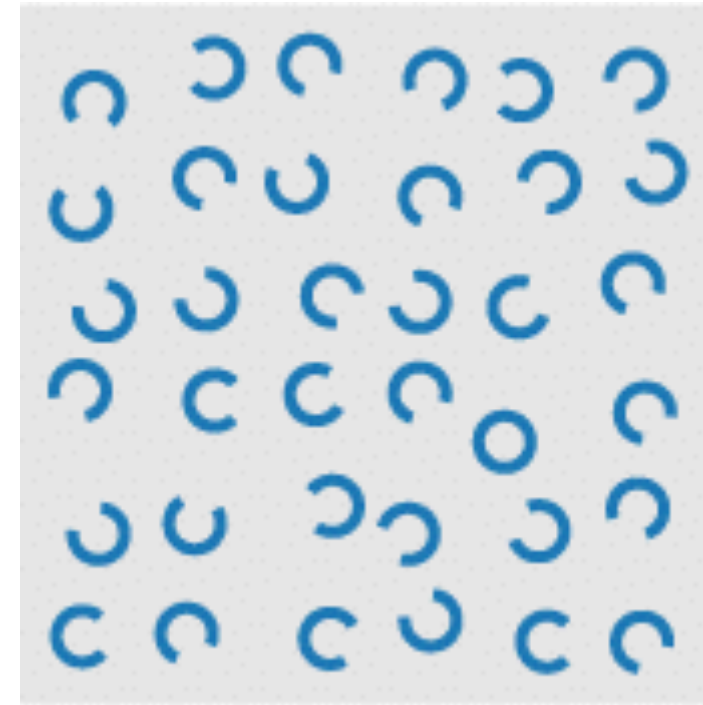
Some Preattentive Properties



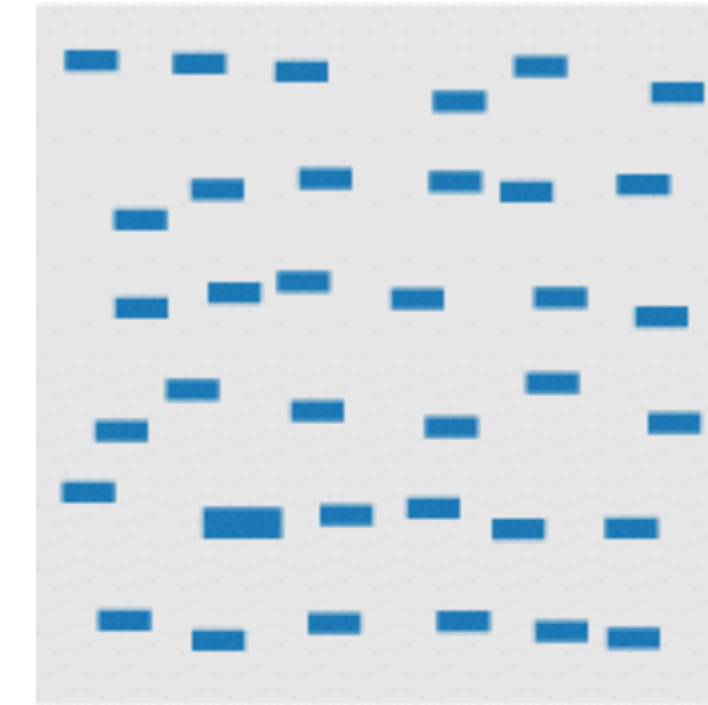
orientation



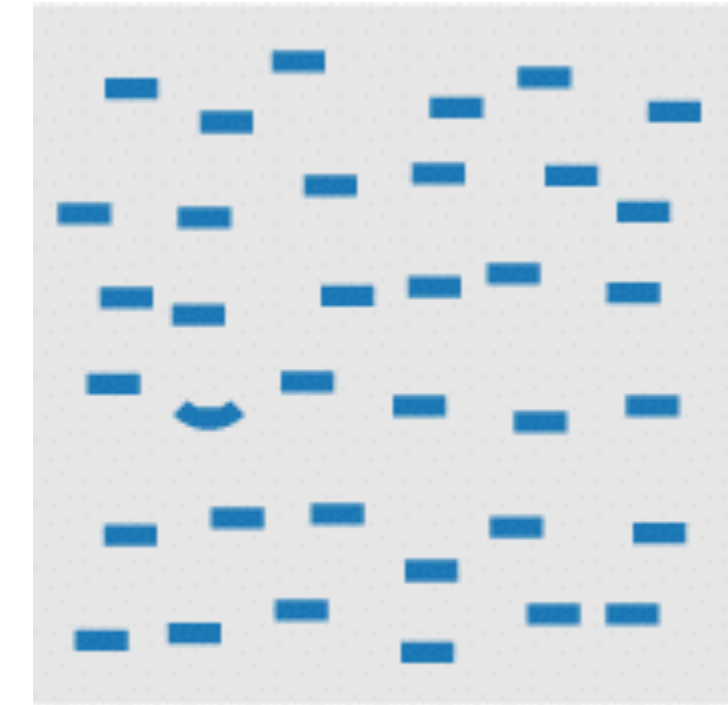
length



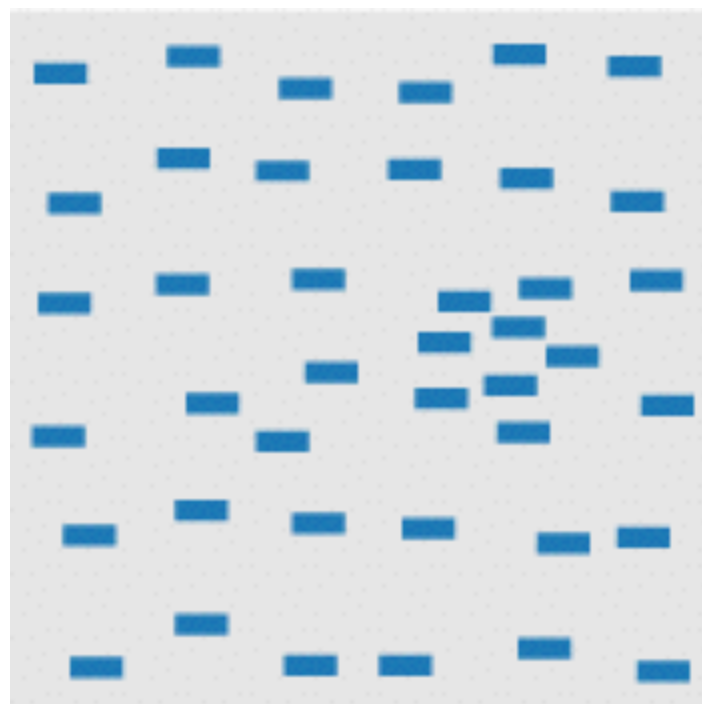
closure



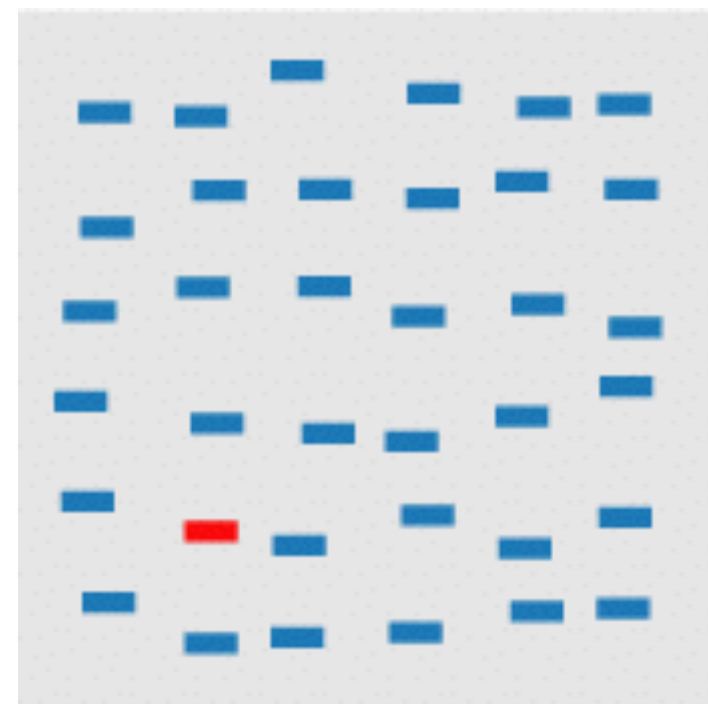
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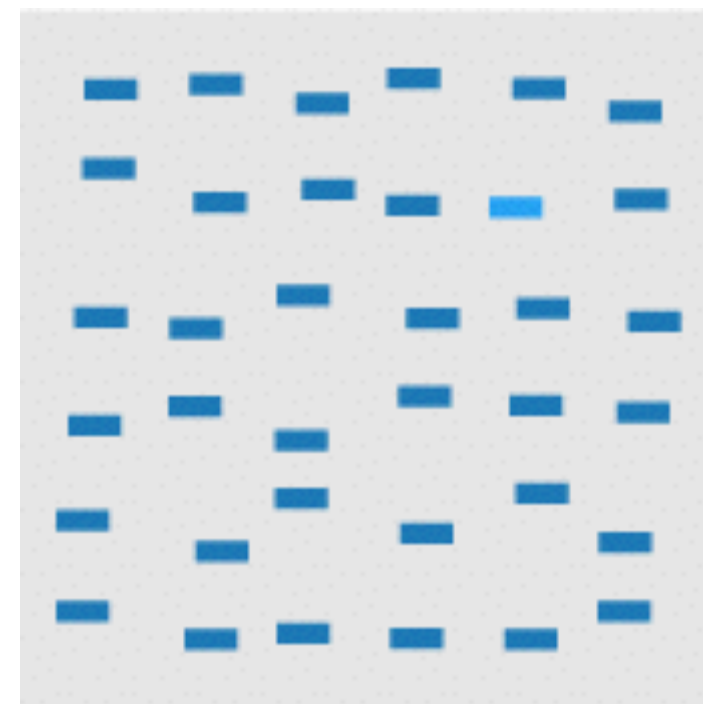
curvature



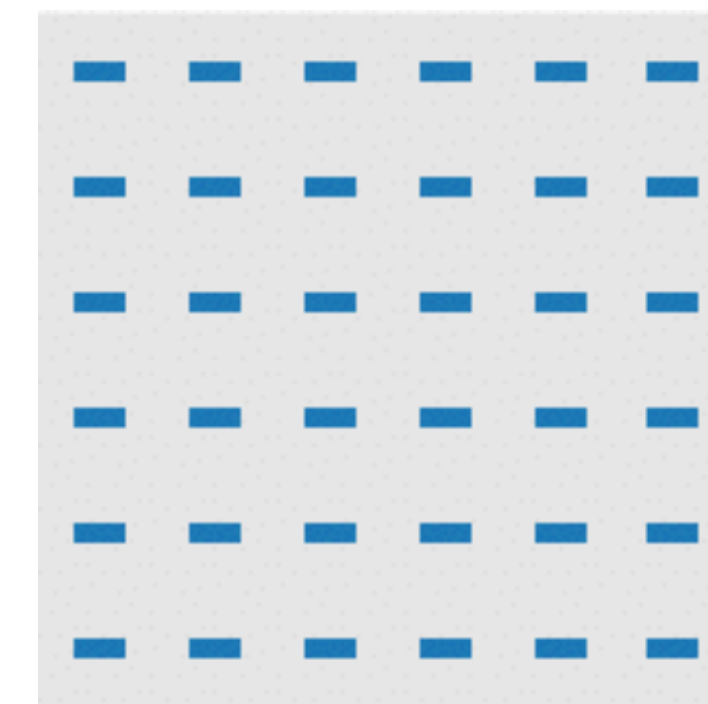
density



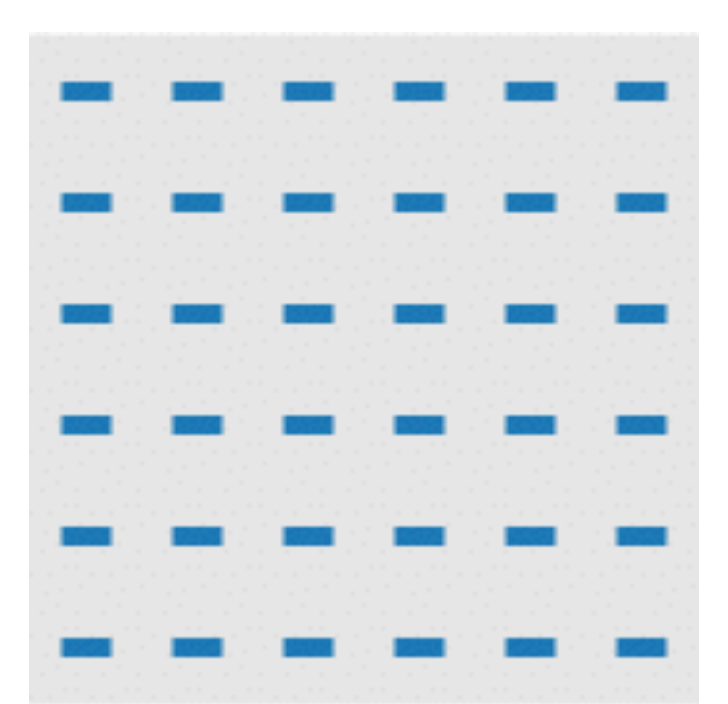
hue



hue

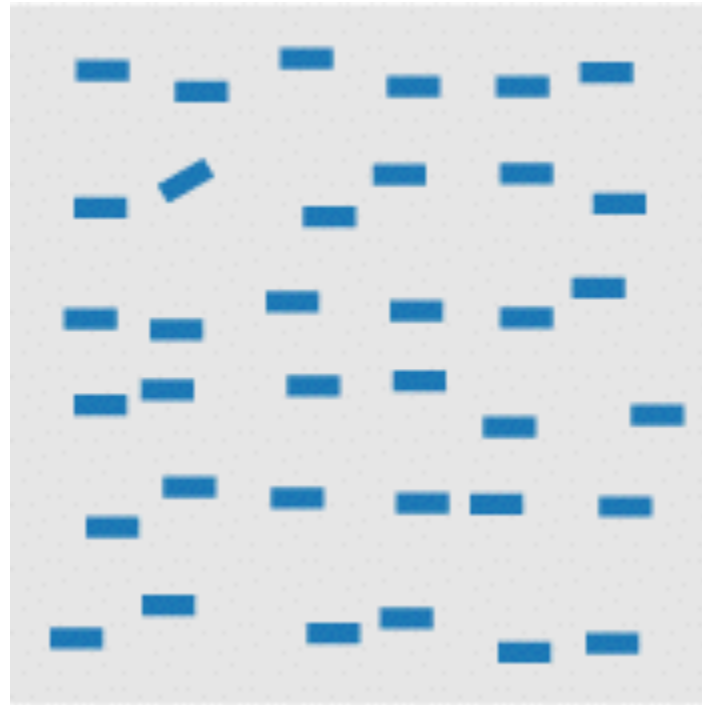


flicker

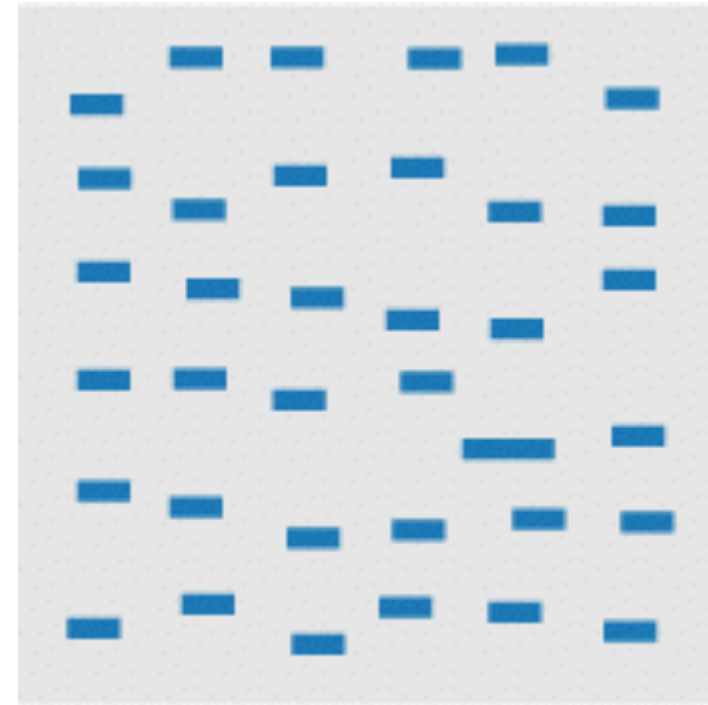


direction of motion

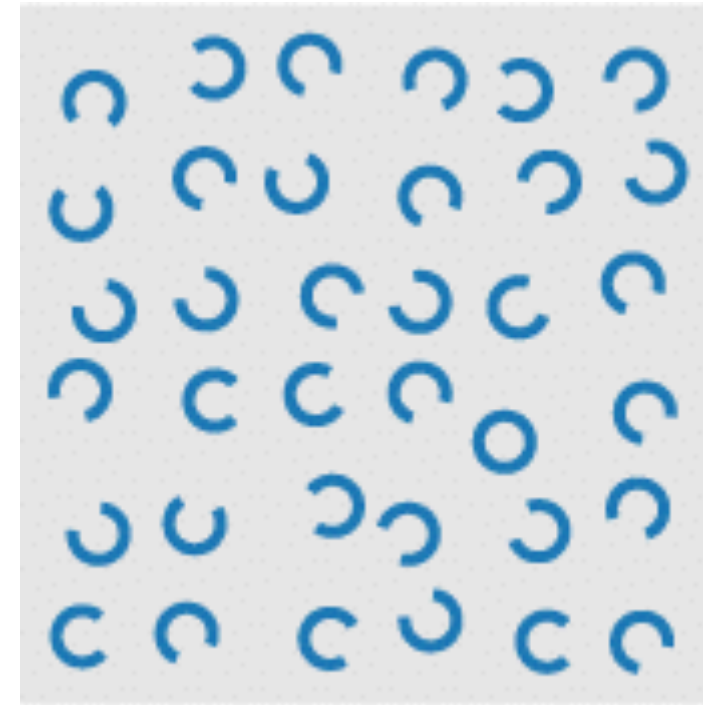
Some Preattentive Properties



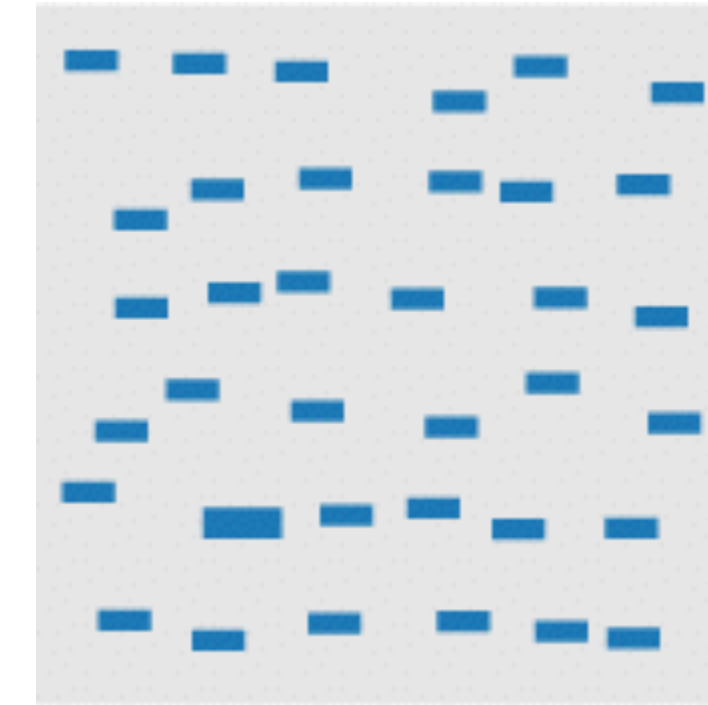
orientation



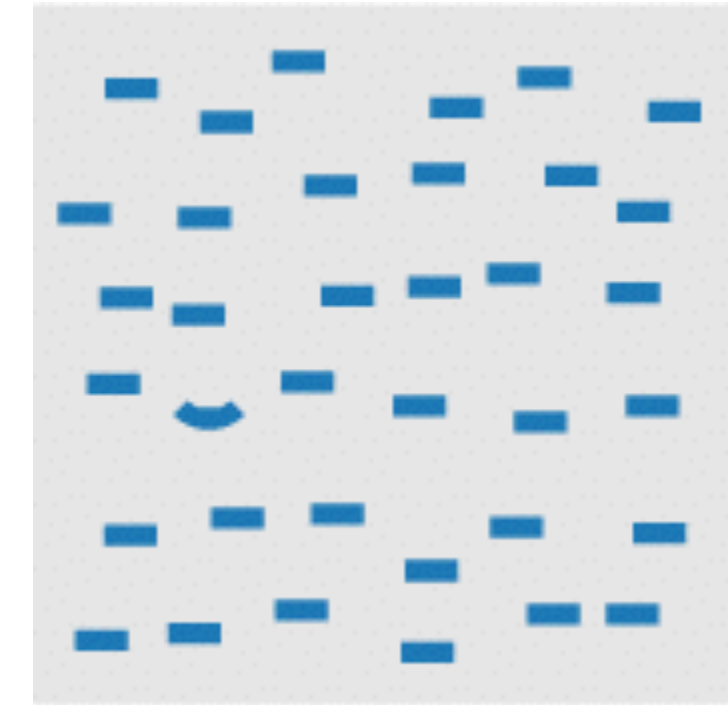
length



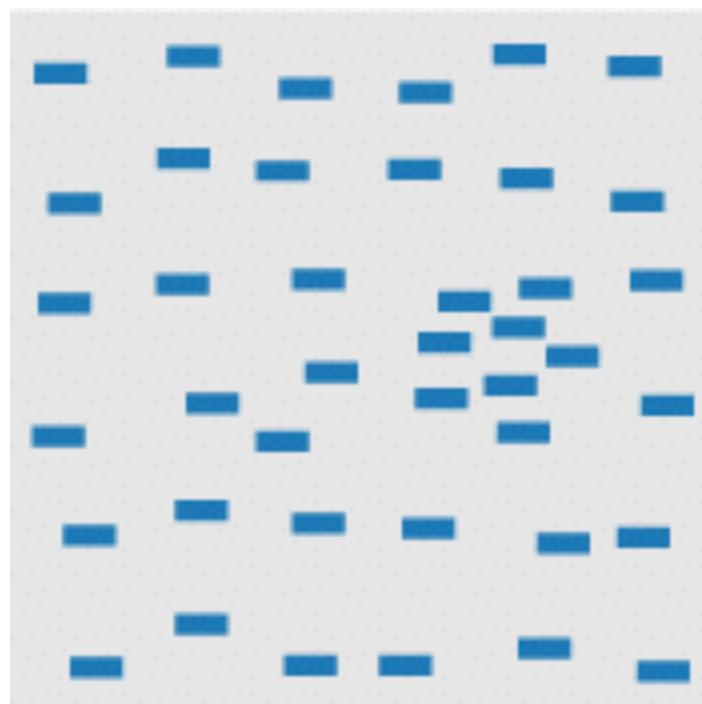
closure



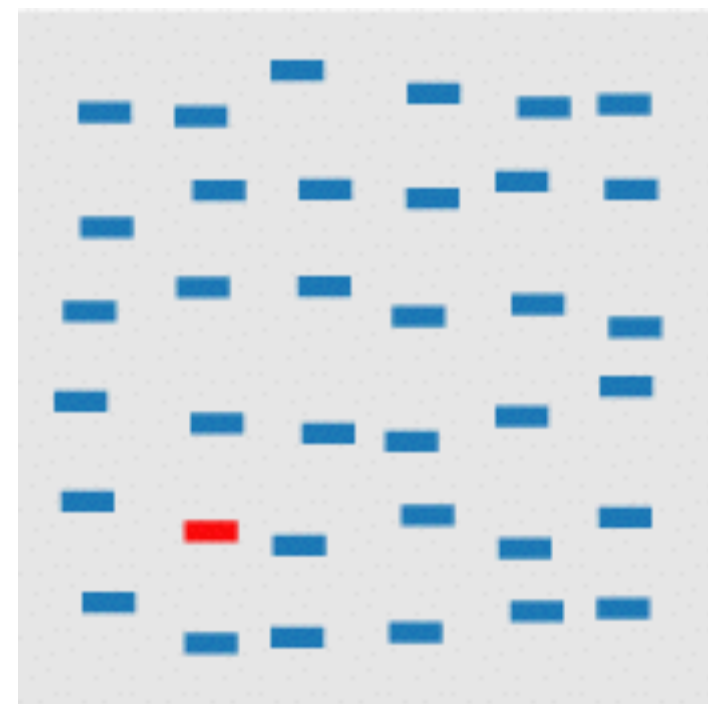
size



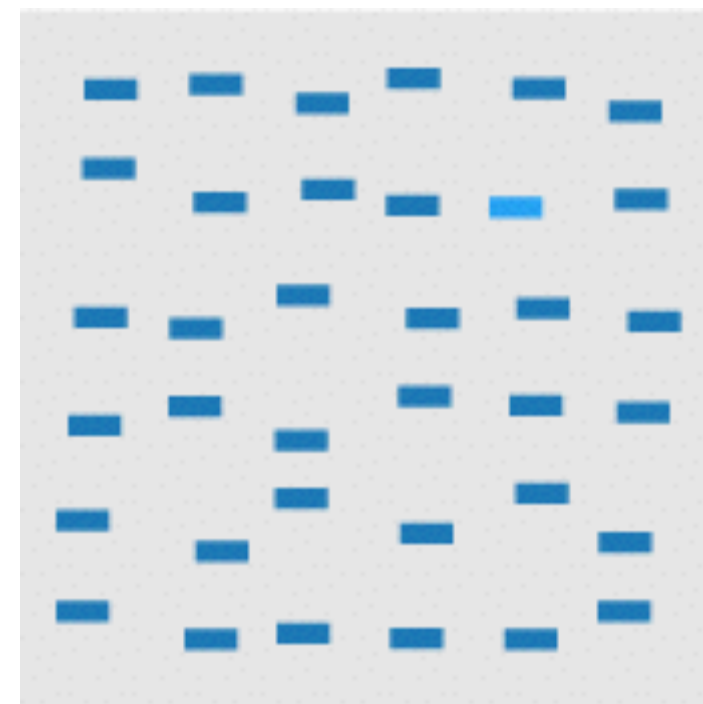
curvature



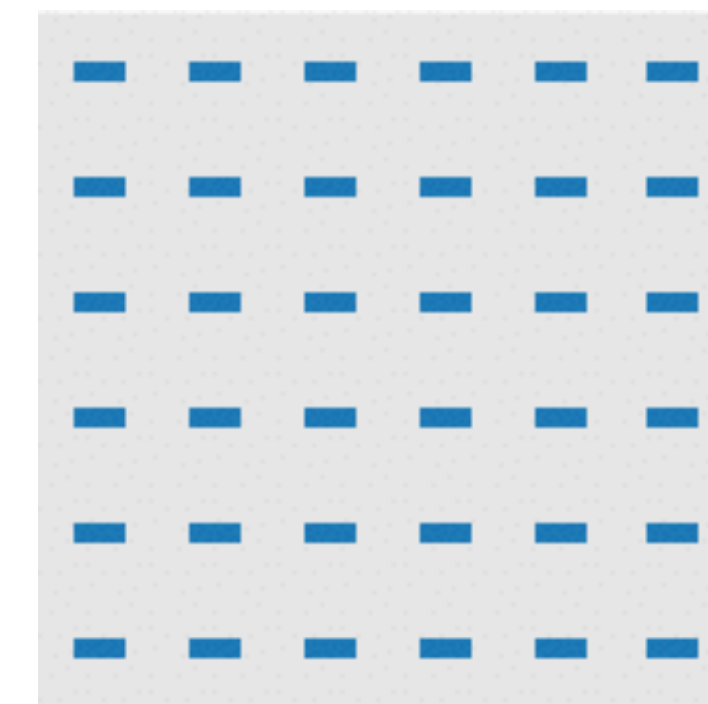
density



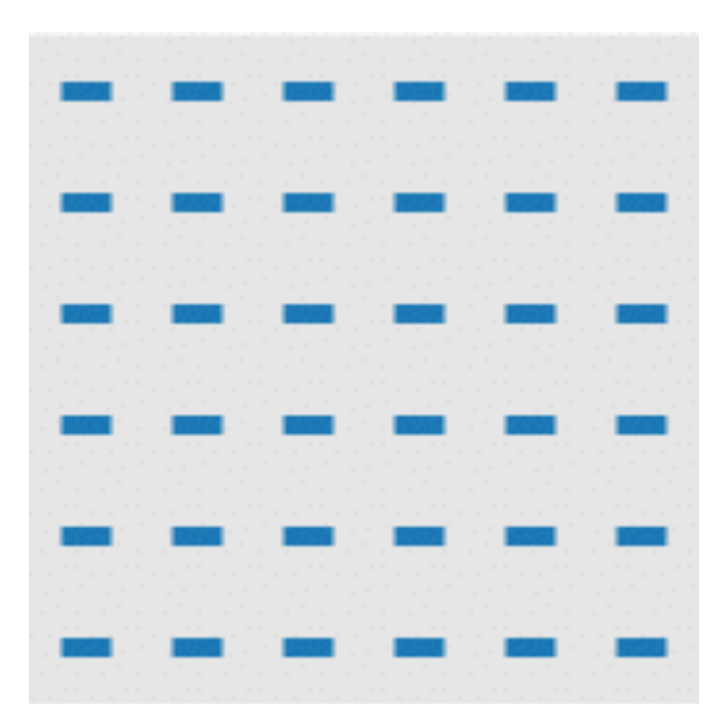
hue



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

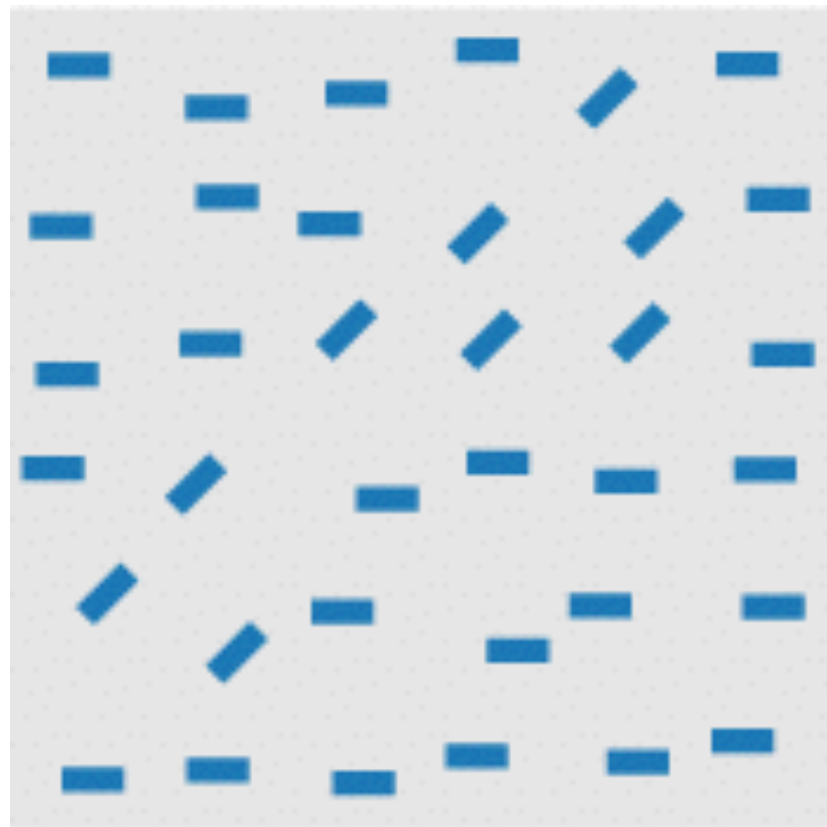
track one or more elements with a unique visual feature as they move in time and space

counting and estimation

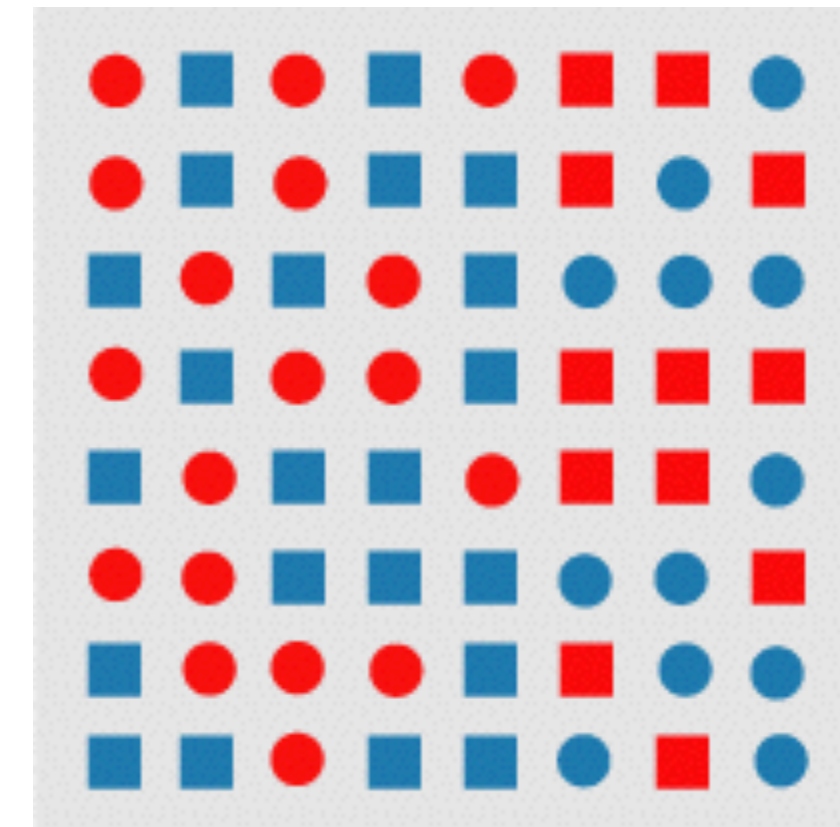
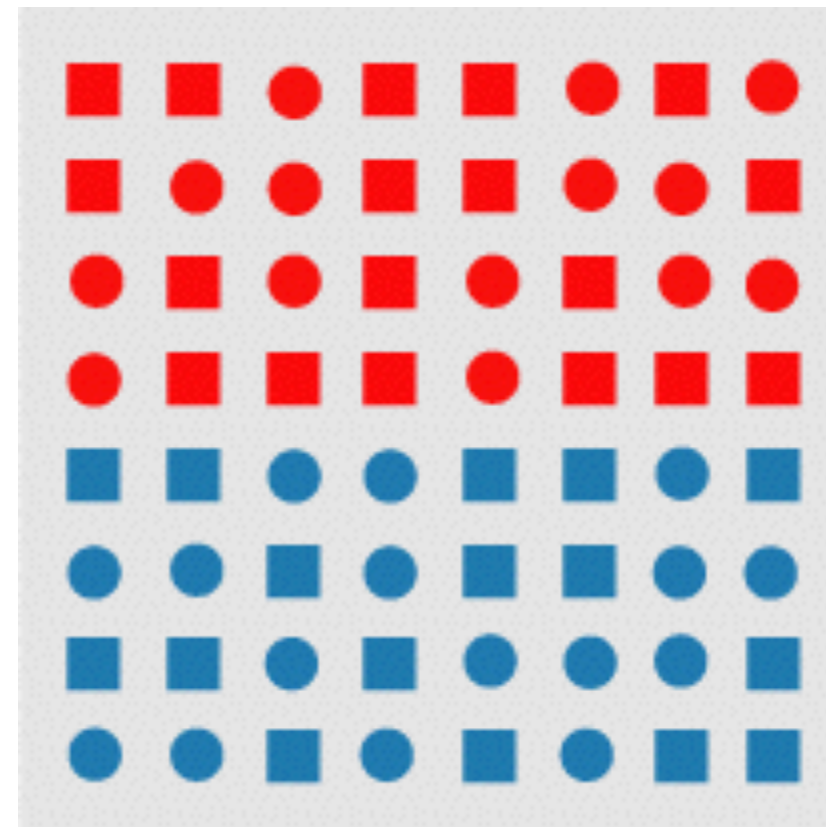
users count or estimate the number of elements with a unique visual feature.

Tasks

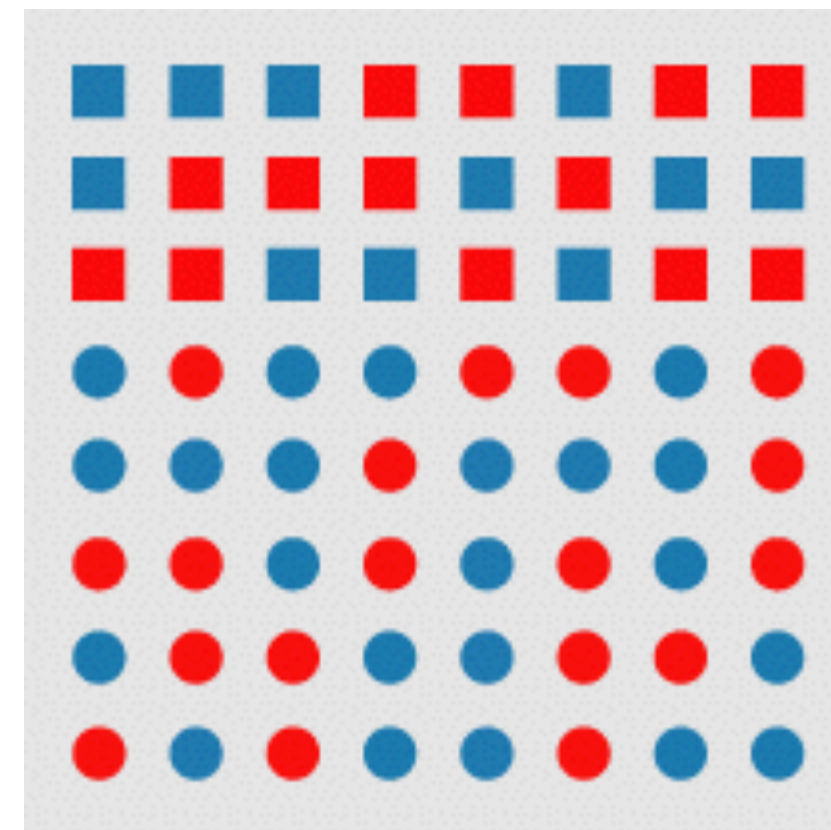
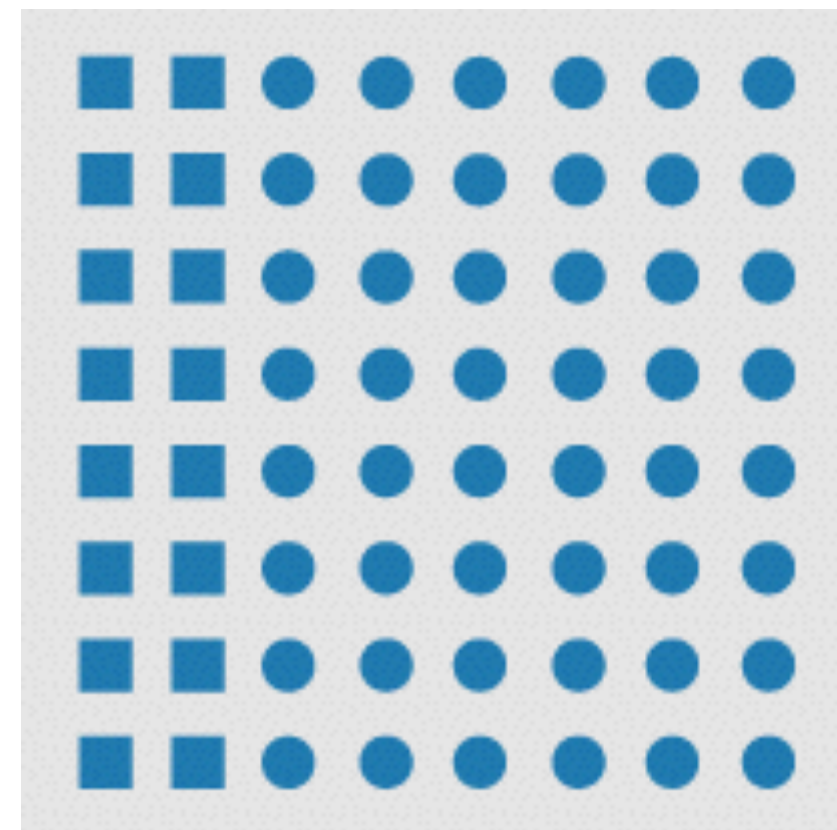
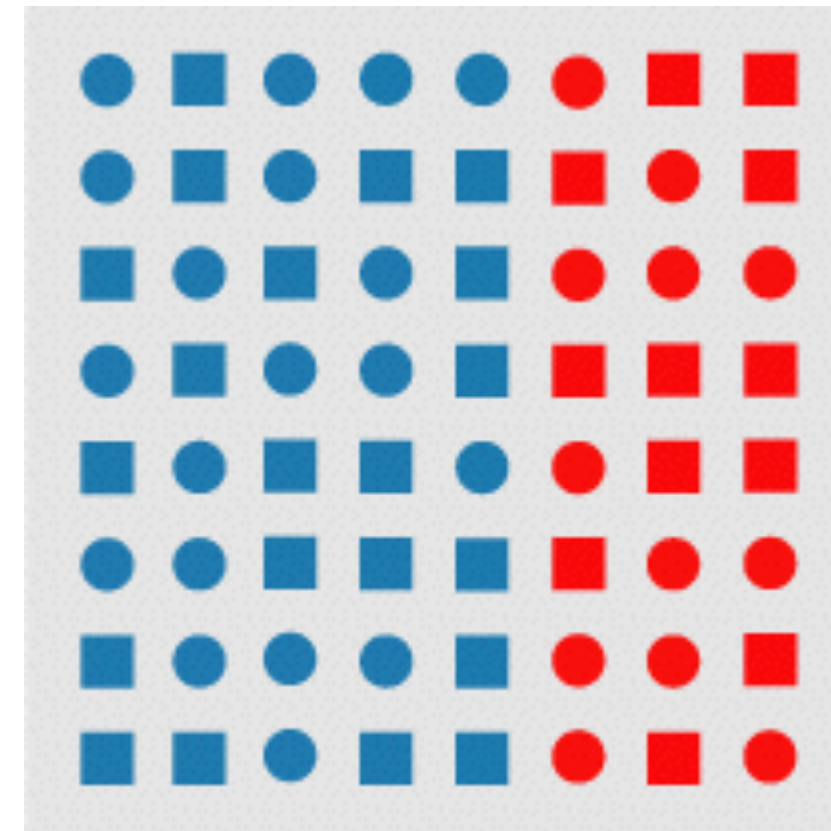
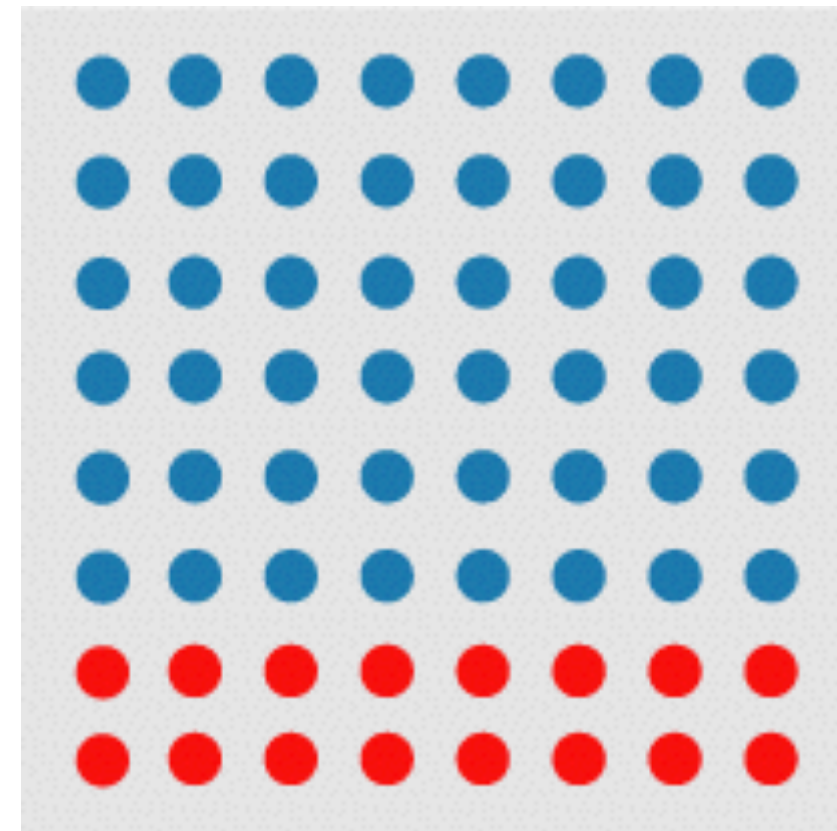
Number Estimation



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

No failure of vision system, failure based on 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

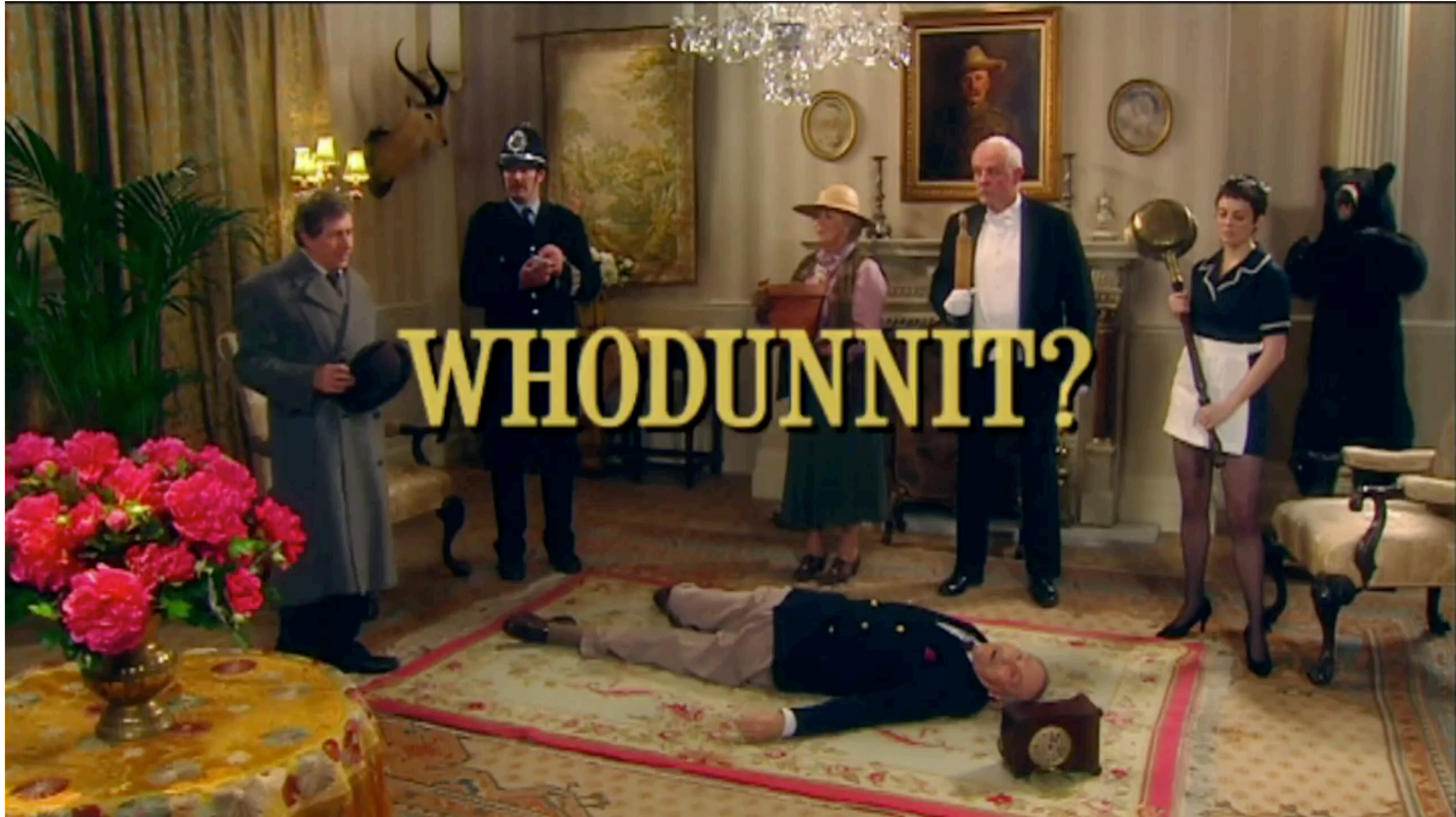
expectation (knowing something will change)

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)

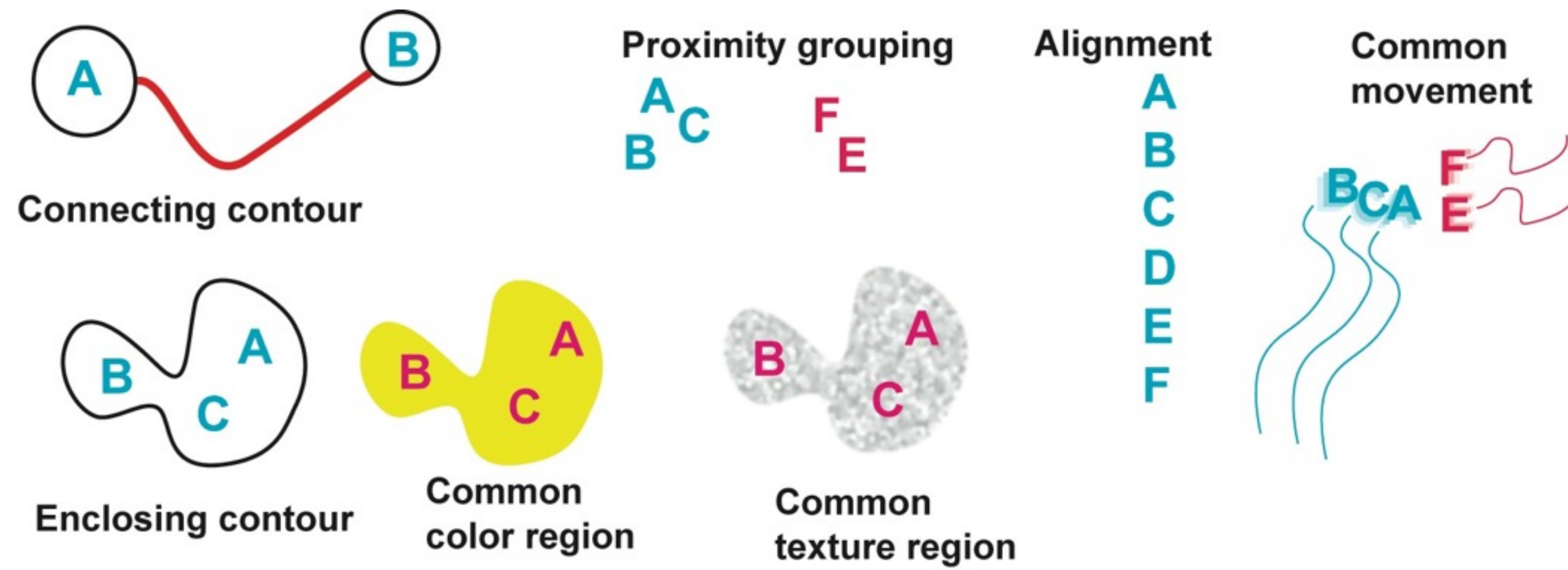
Attention is driven by preexisting knowledge, expectations, and goals stored in long-term memory

Gestalt Principles

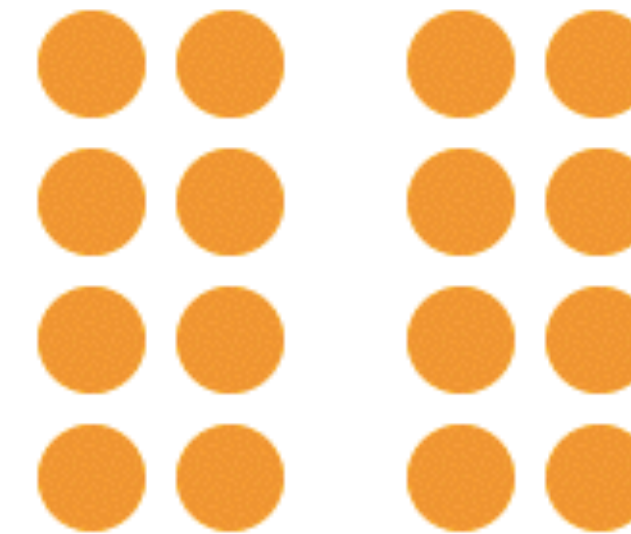
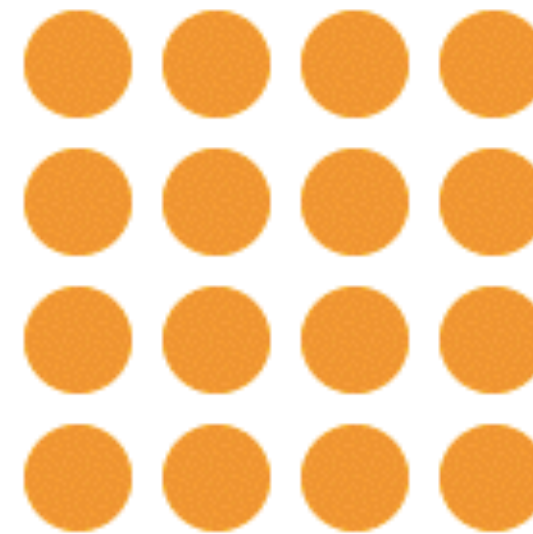
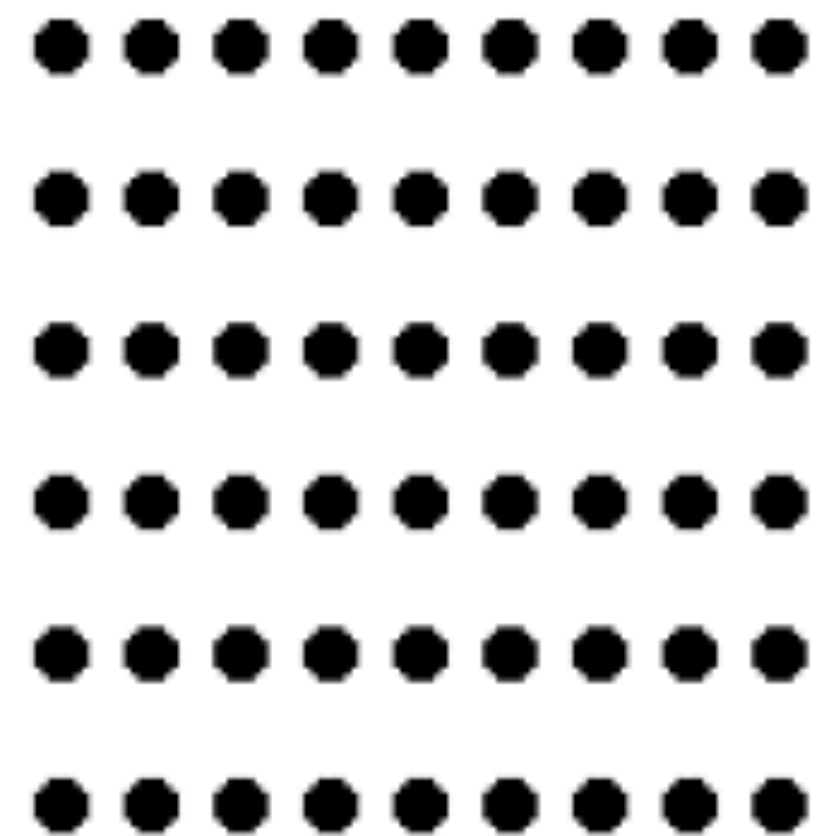
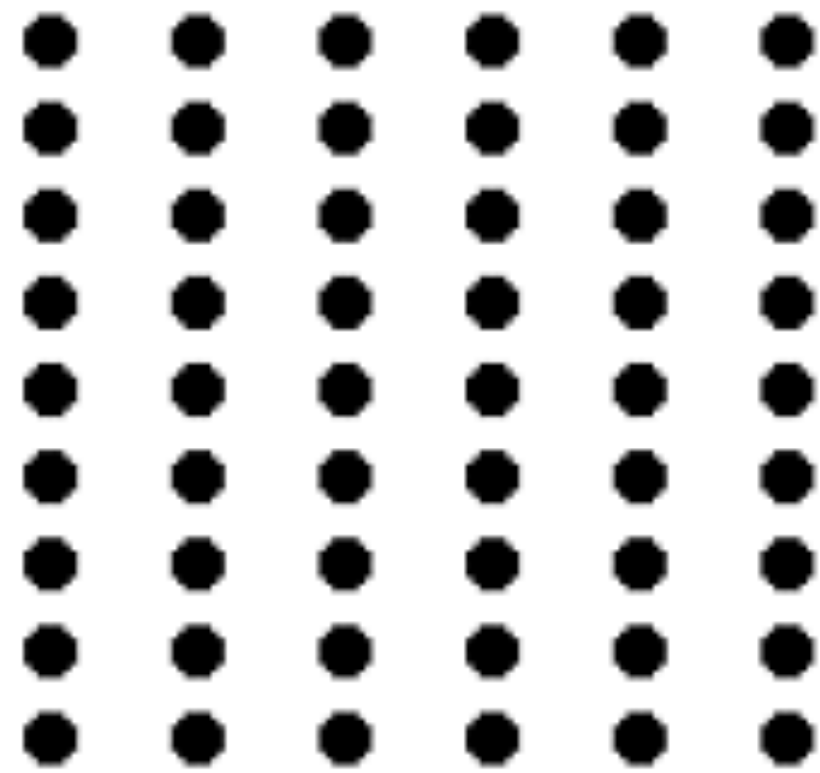
Wertheimer, 1923, and recent extensions

Gestalt Principles

Patterns that transcend the visual stimuli that produced them

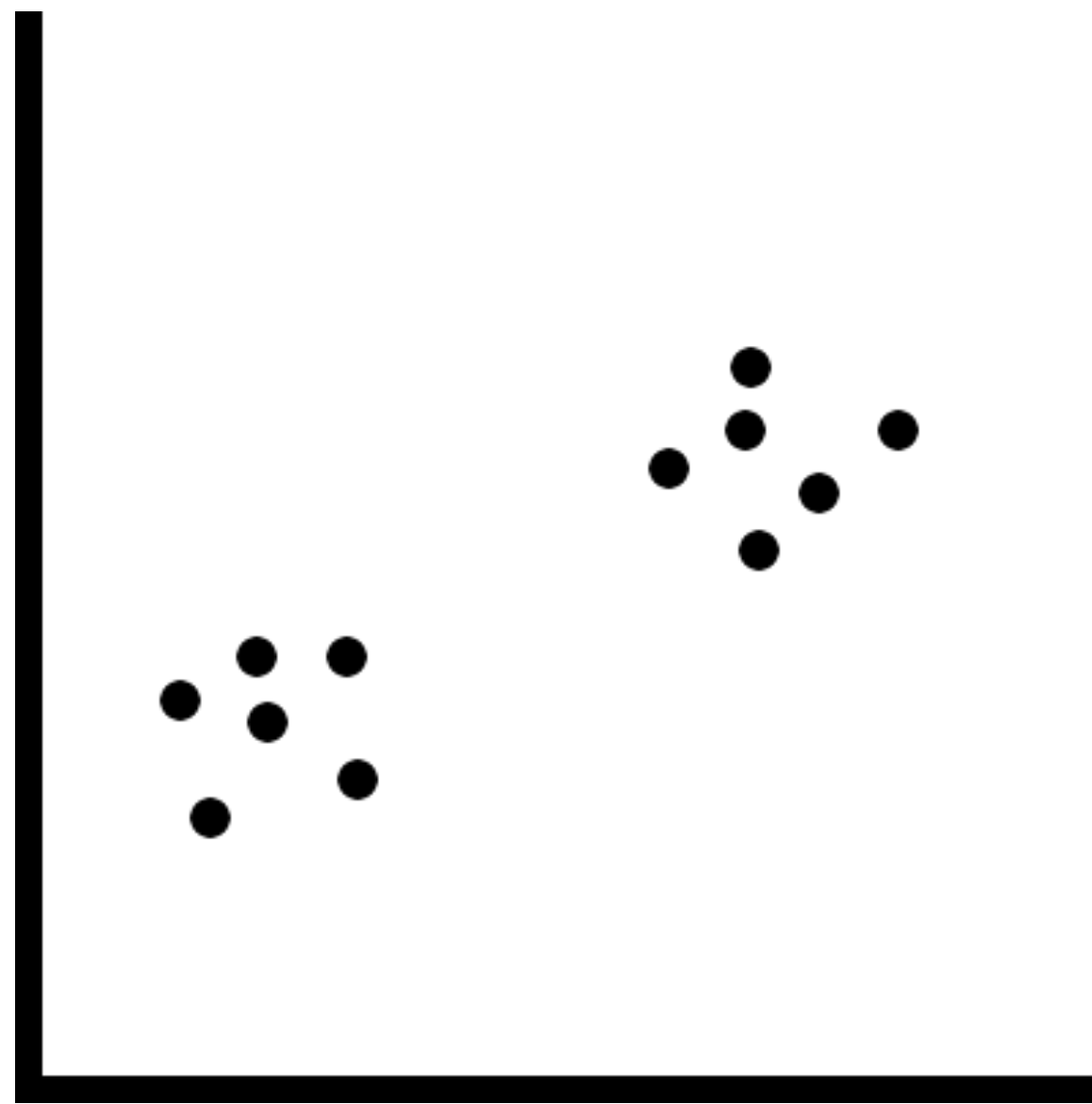


Proximity

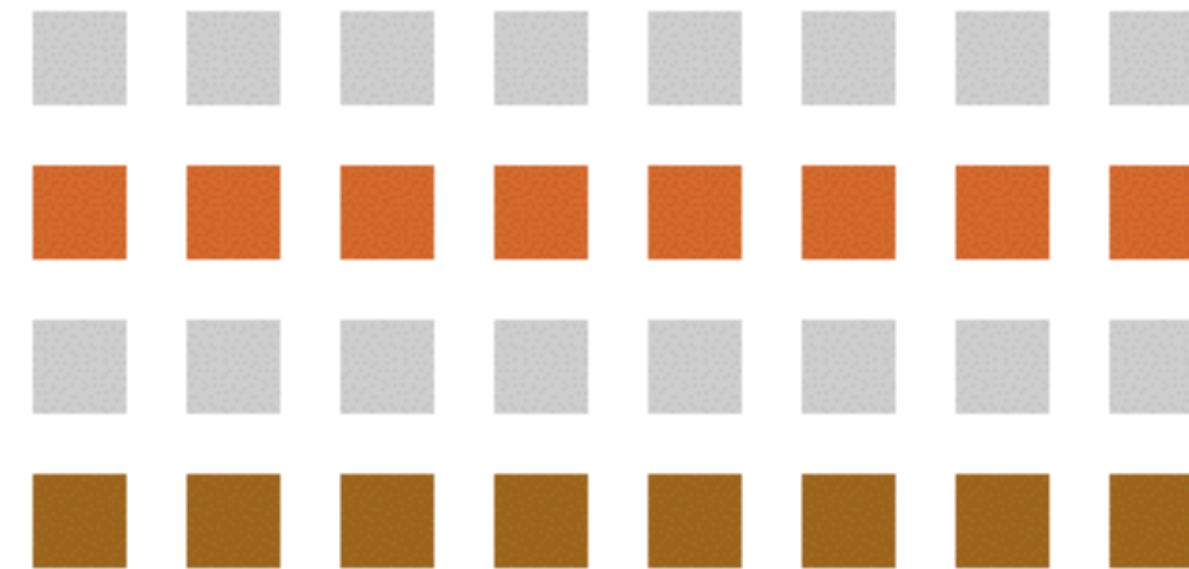


Proximity

Grouping/linking by placing entities in close proximity



Similarity

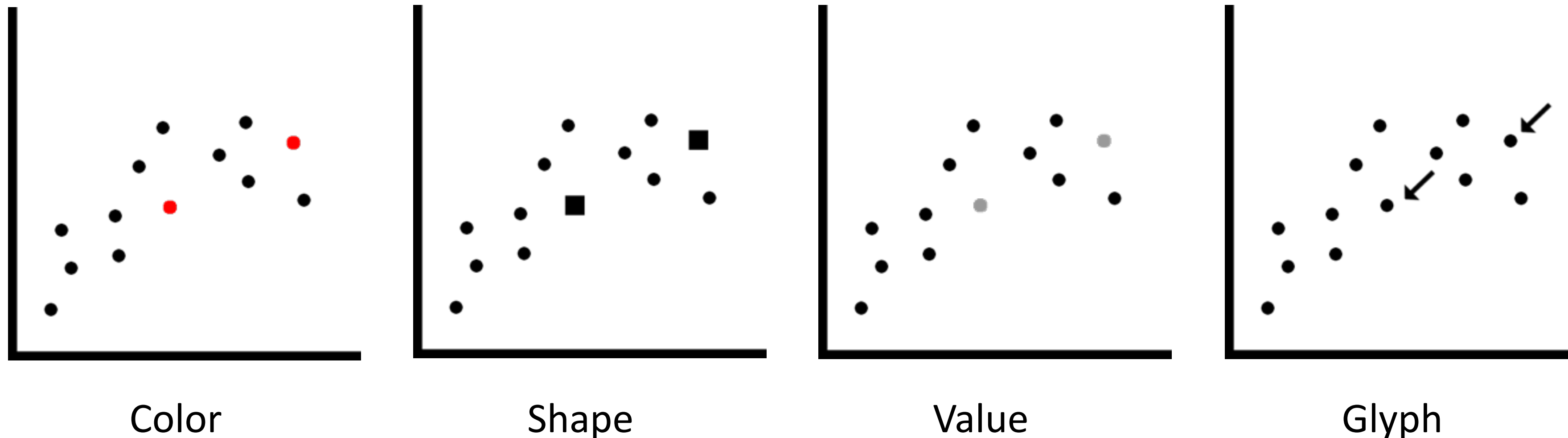


Similarity

Co-modulation of a **channel**

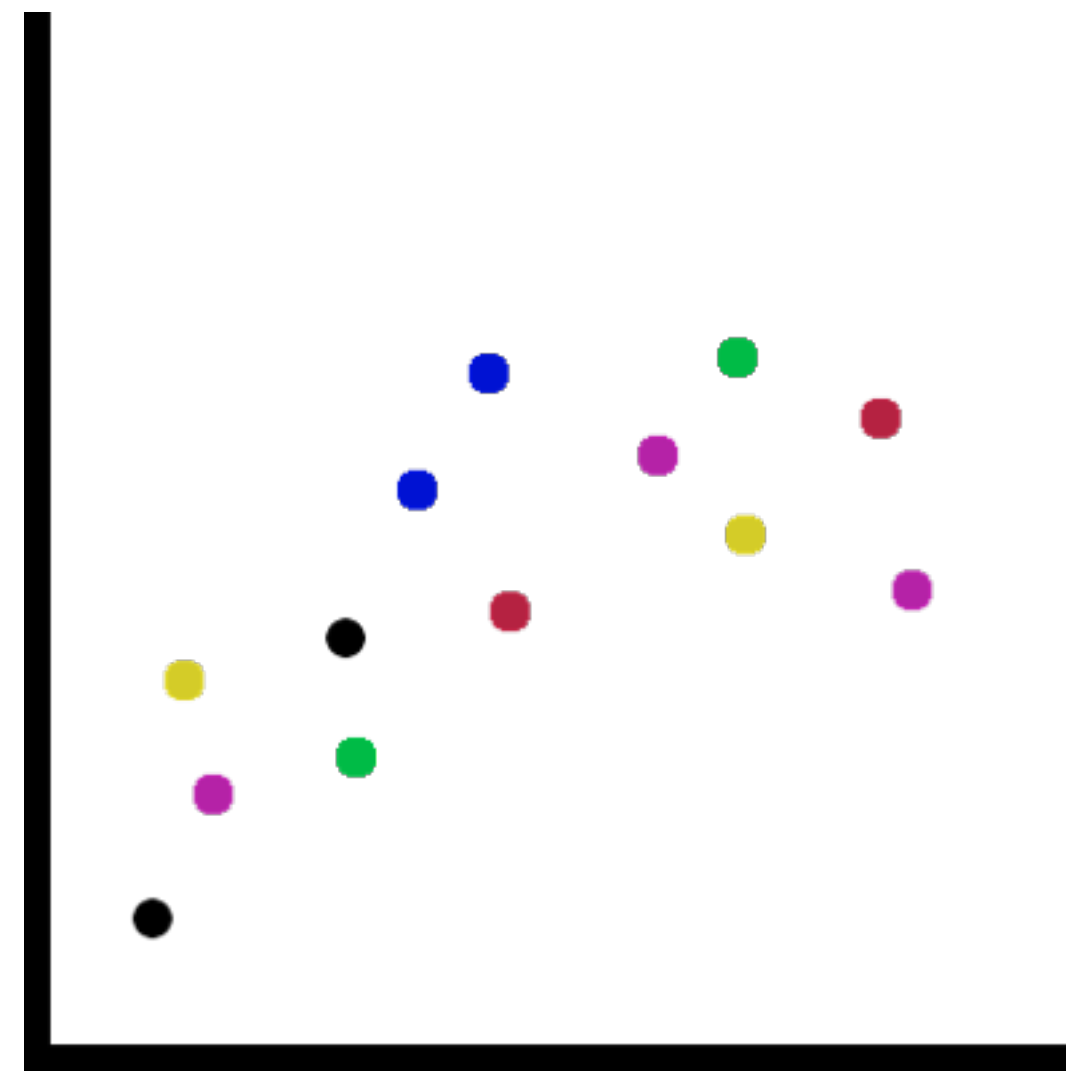
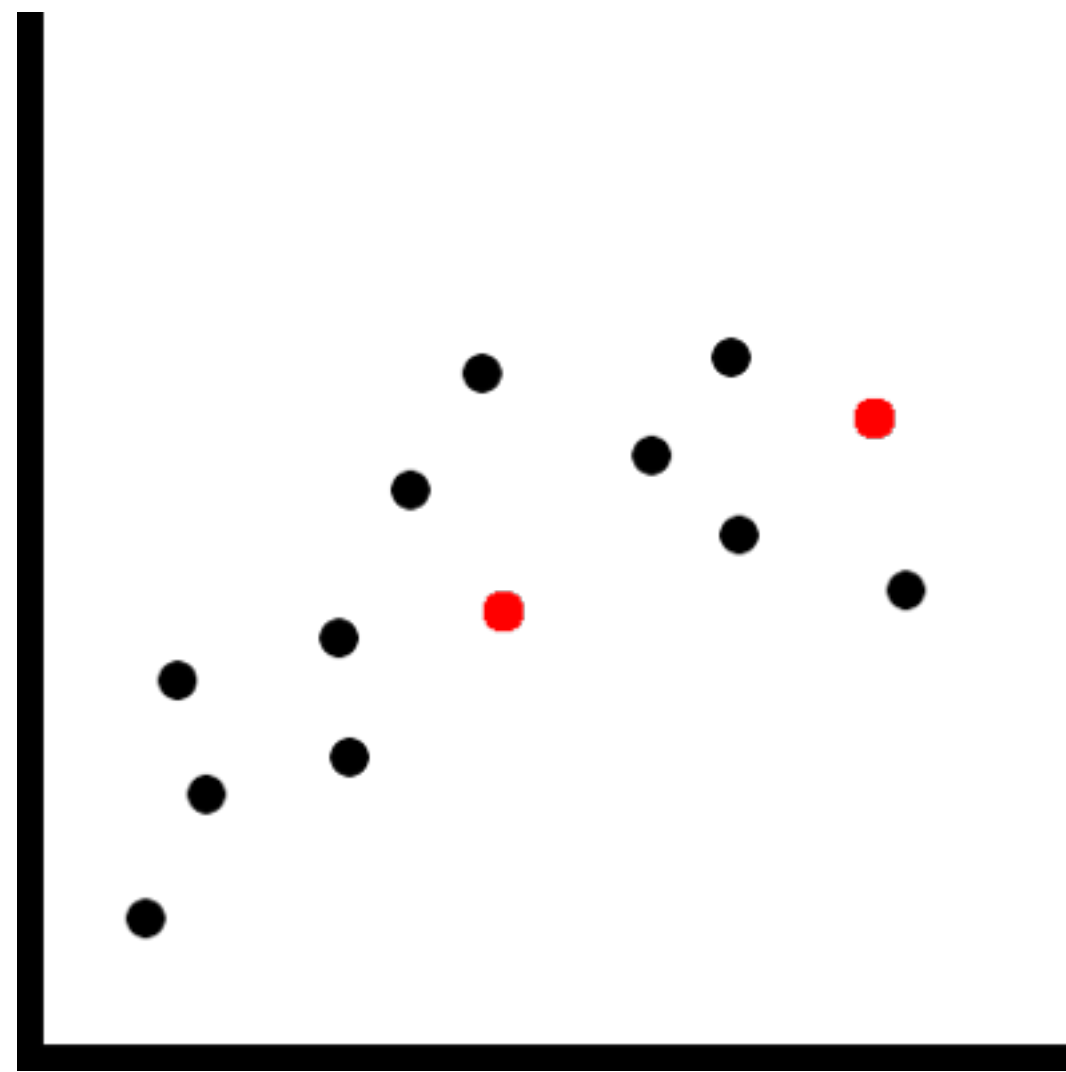
color, shape, size, value, orientation, texture, ...

Adding a glyph, label, frame, background



Color – Perception Issues (1/2)

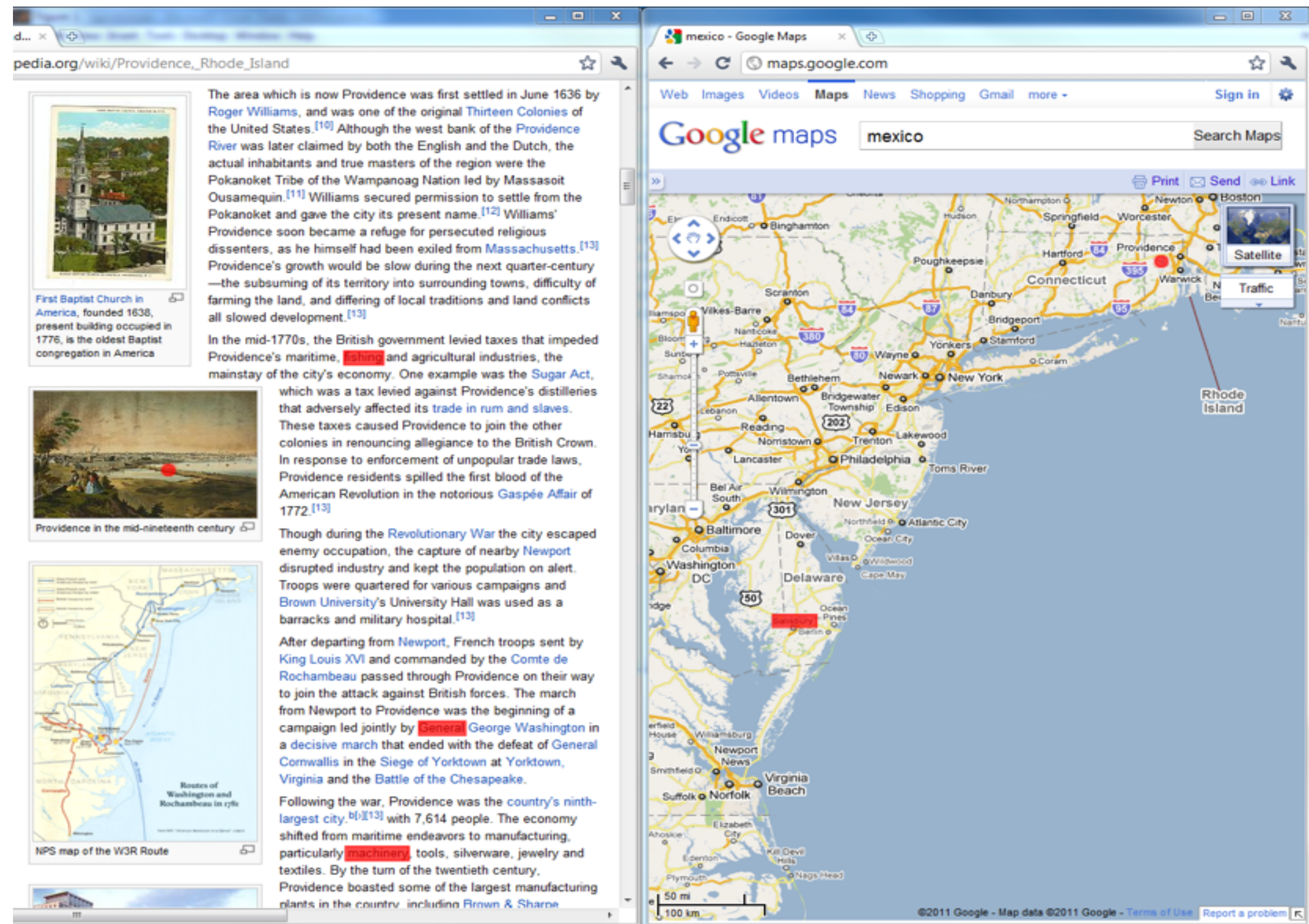
Preattentive properties: Very good for 1-2 simultaneous,
serial search for more



Color – Perception Issues (2/2)

Slower in a cluttered environment

Size of colored object relevant.



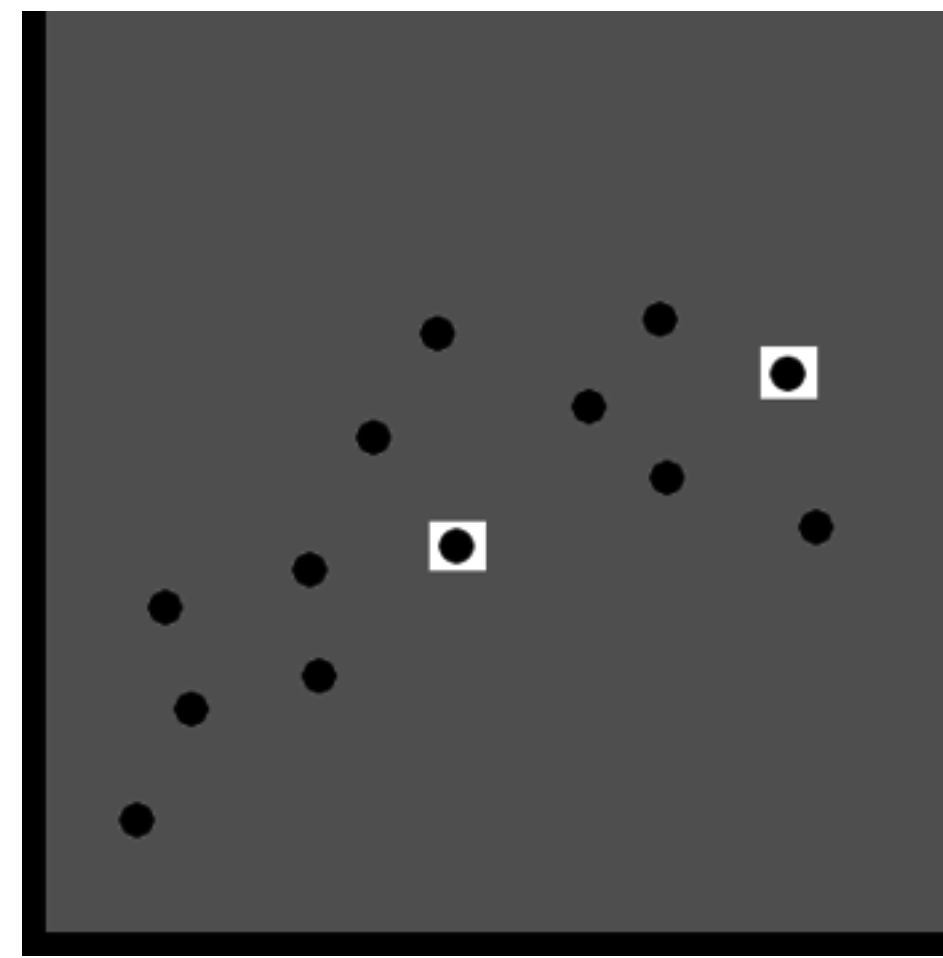
Similarity

Modulate everything else

Blurring, darkening, desaturating, etc.



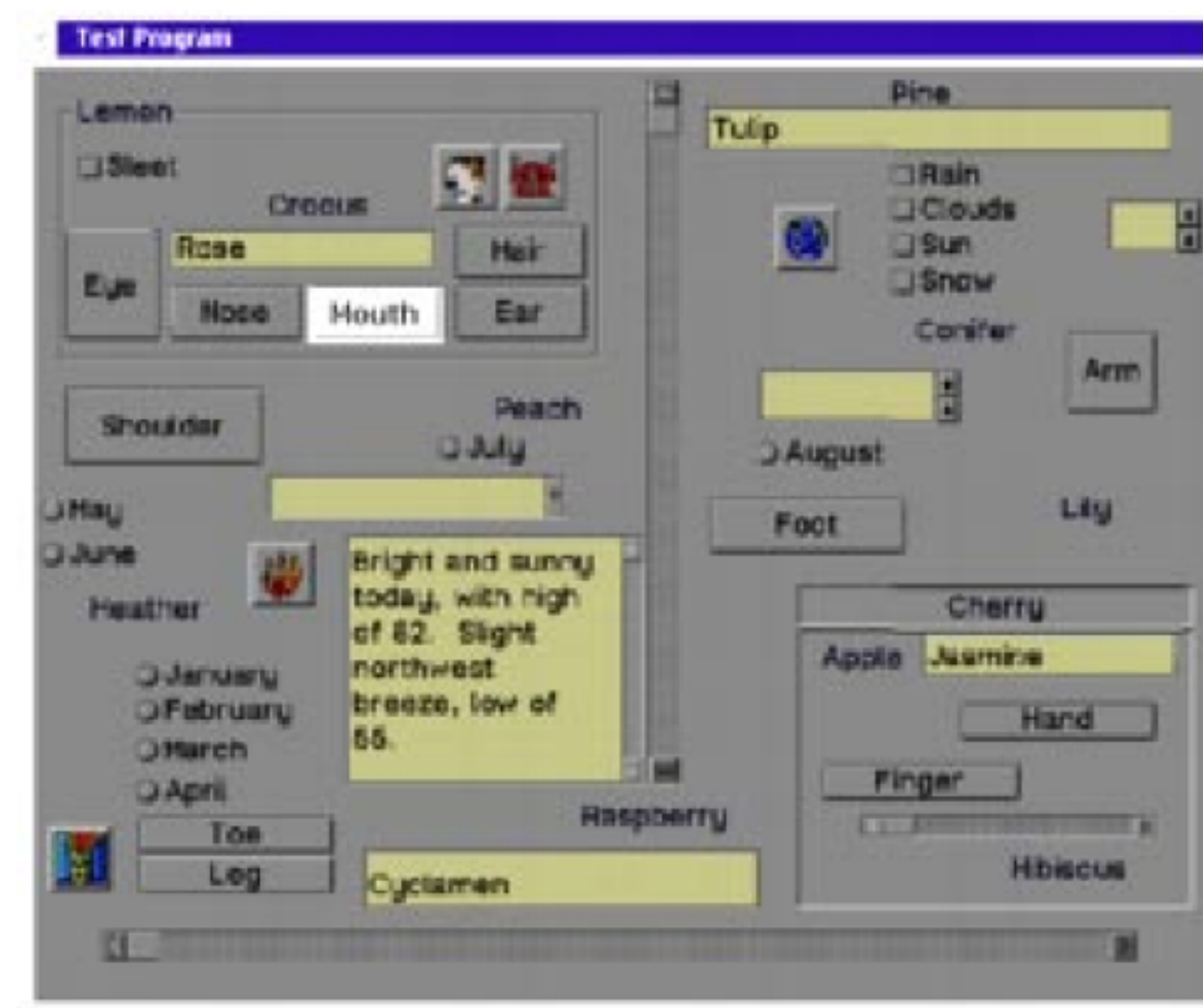
Blur



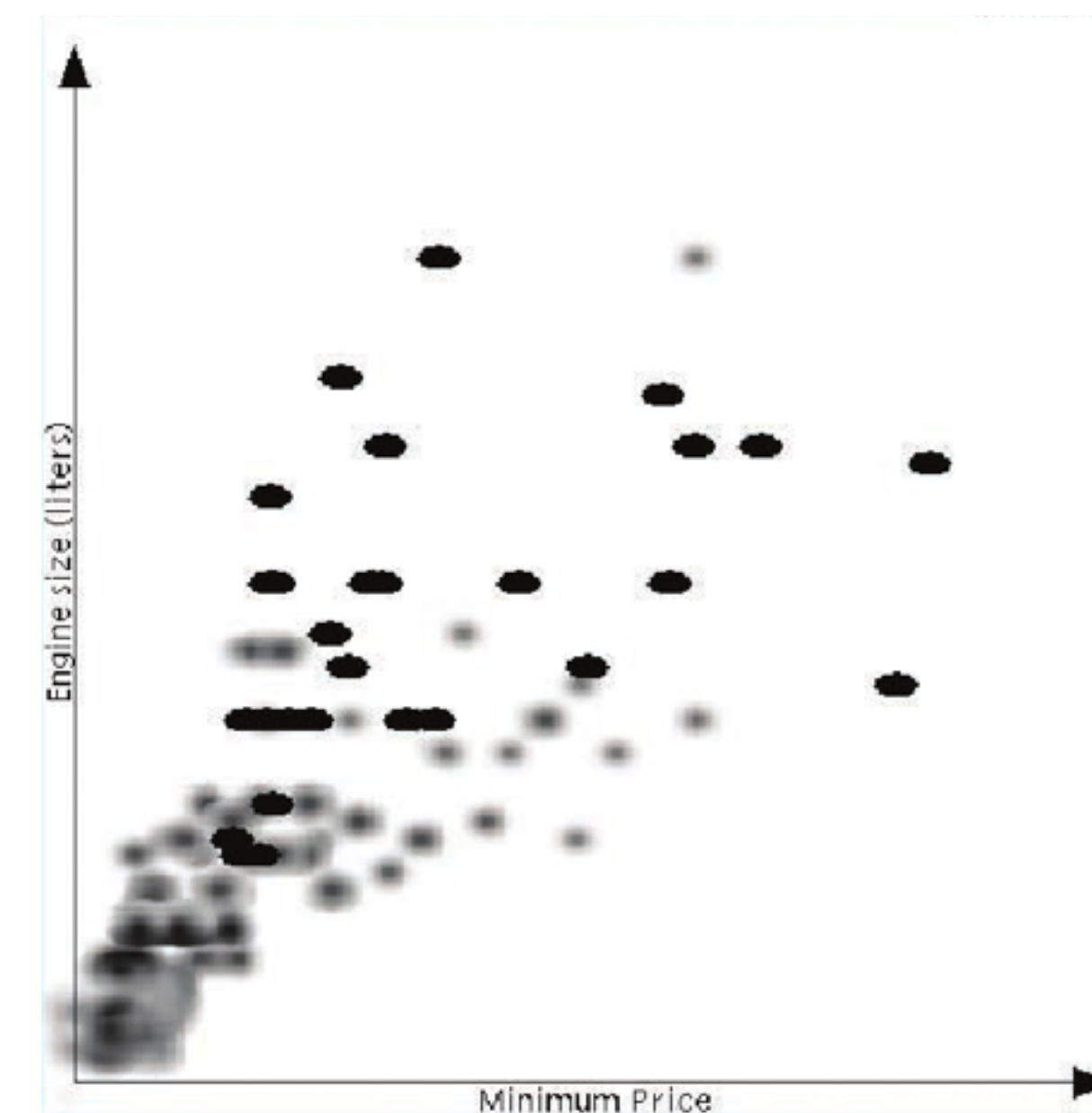
Darkening

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...

A Little Experiment...

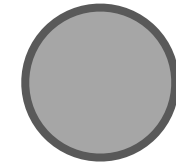
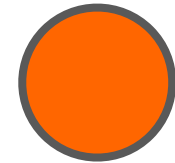
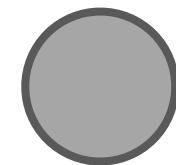
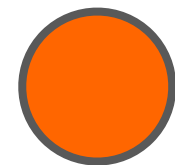


Proximity

A Little Experiment...



Proximity

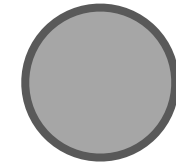
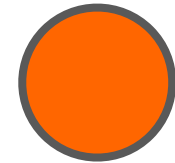
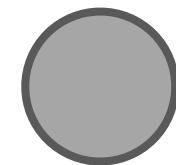
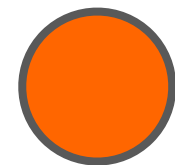


Color

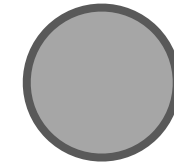
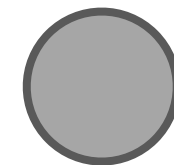
A Little Experiment...



Proximity



Color

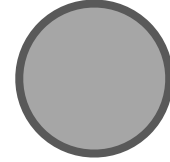
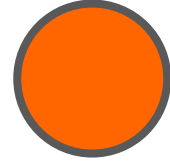
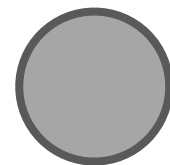
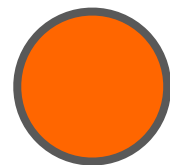


Size

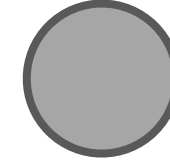
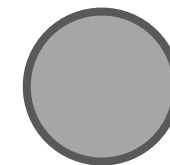
A Little Experiment...



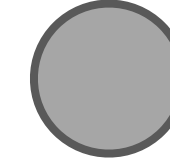
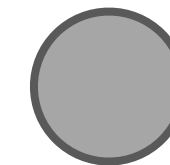
Proximity



Color

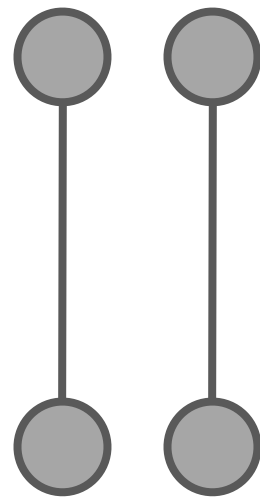


Size

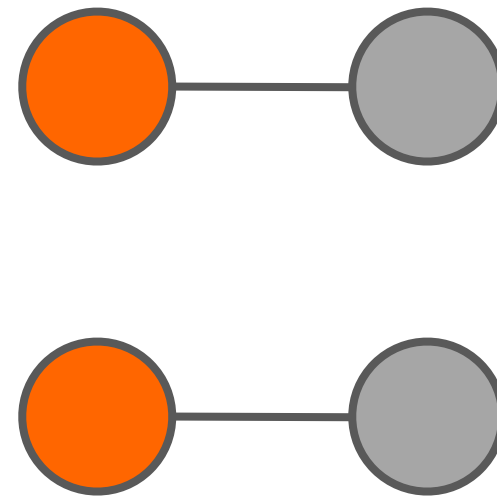


Shape

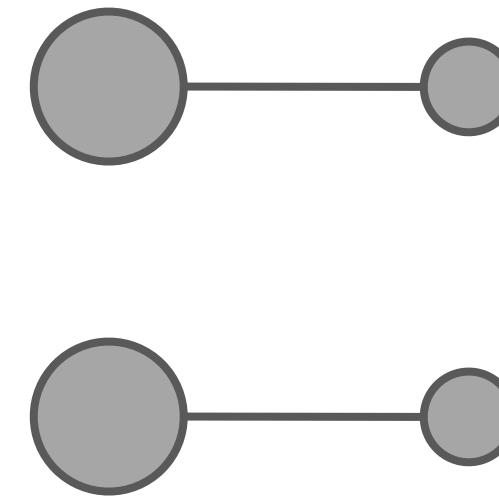
A Little Experiment...



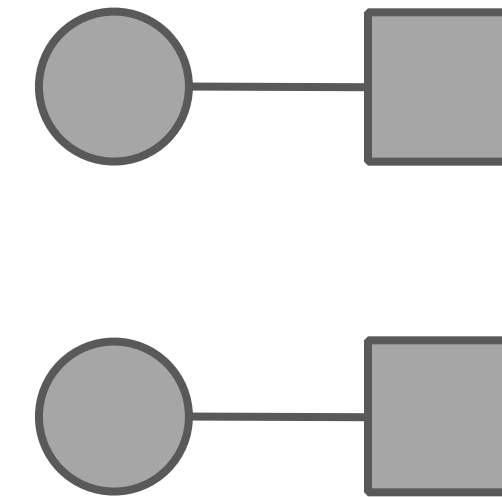
Proximity



Color



Size

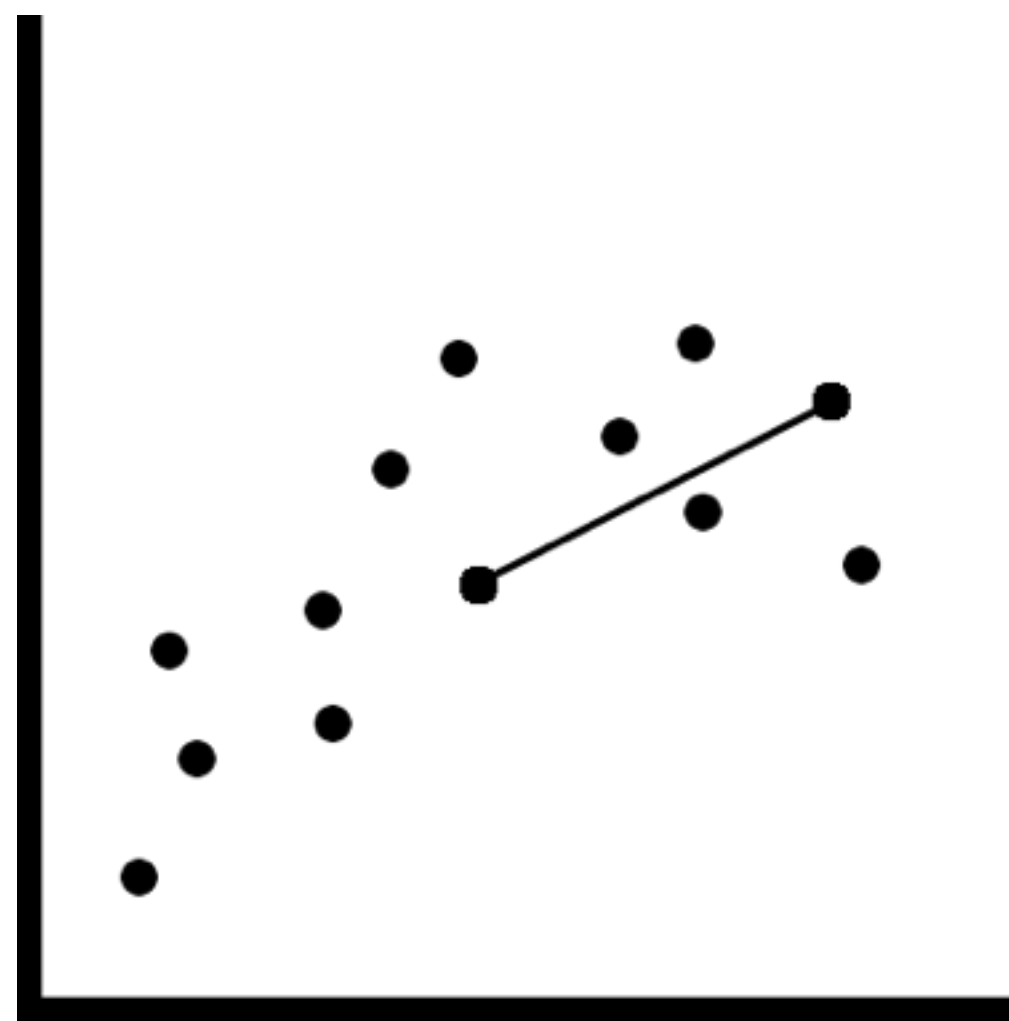


Shape

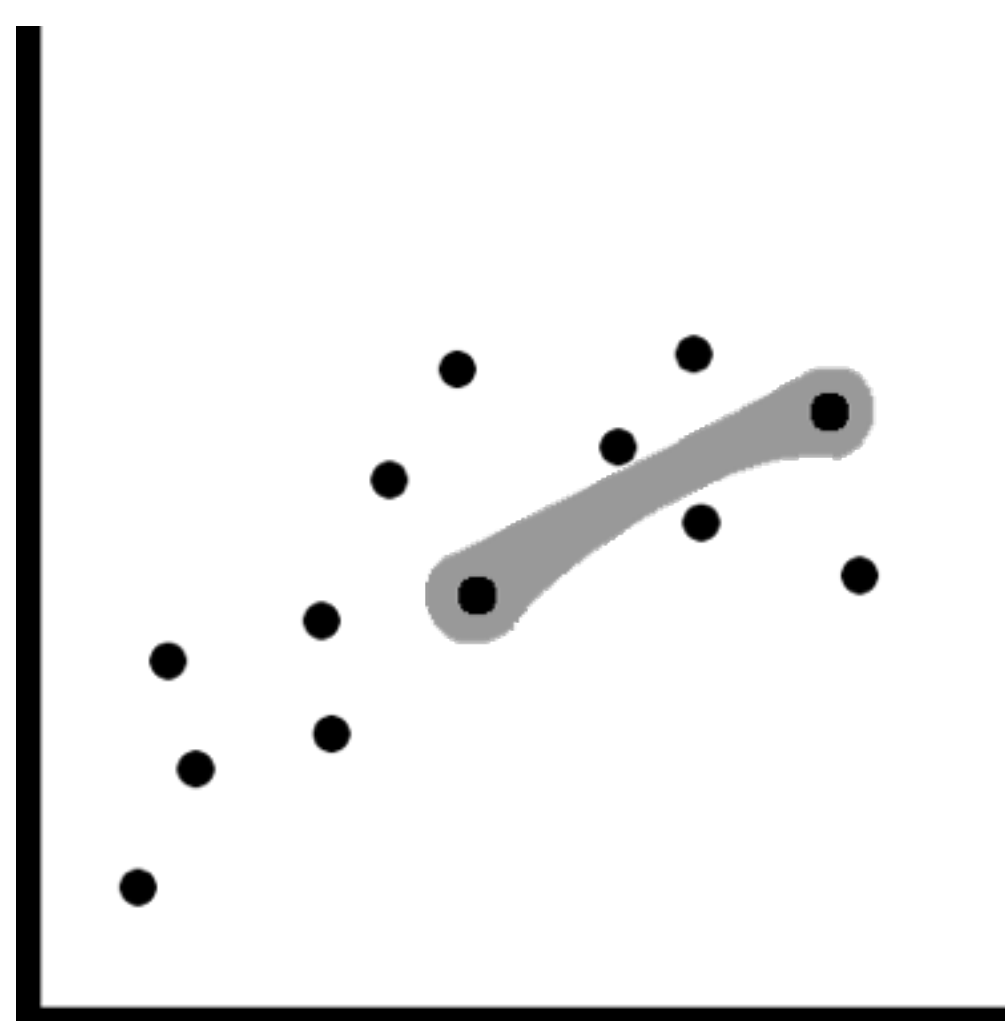
Connectedness and Common Region

Connected items with a line or curve

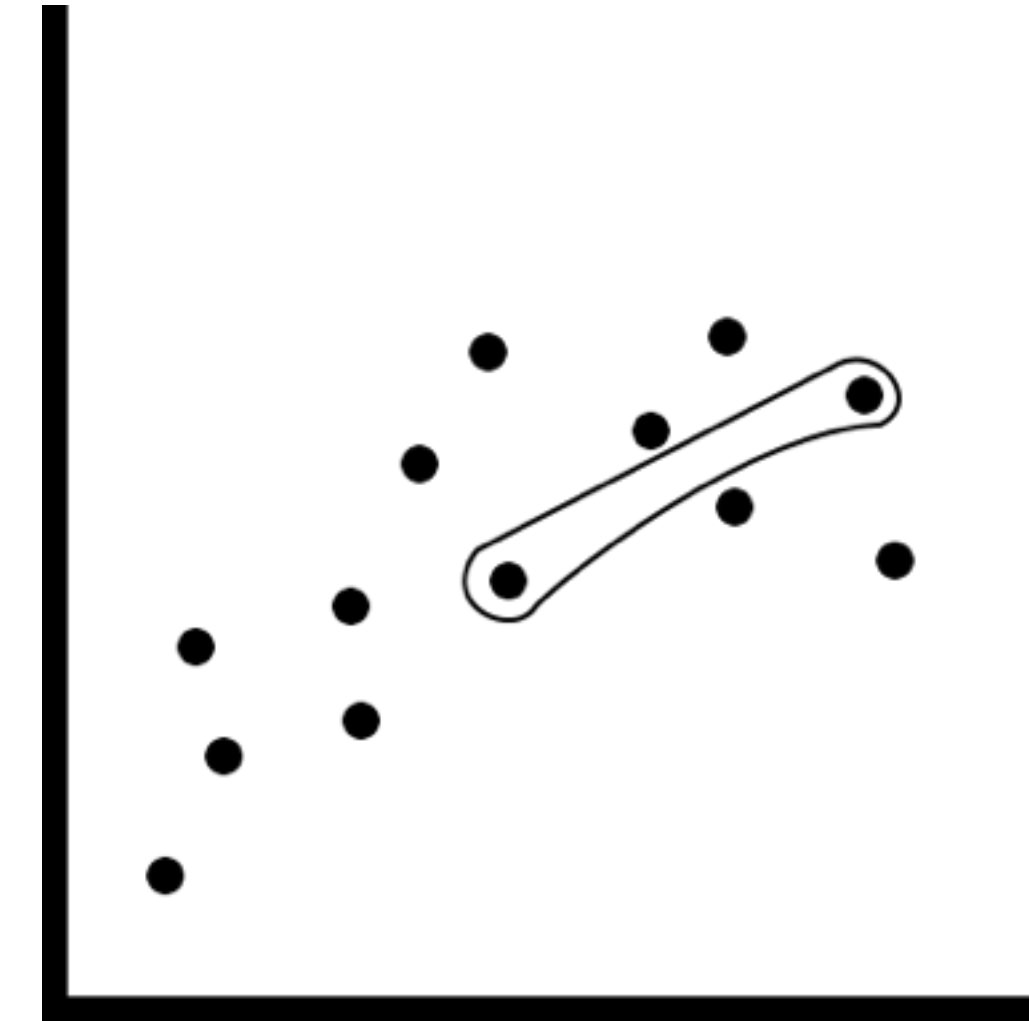
Surround items with a outline, surface, volume



Connectedness



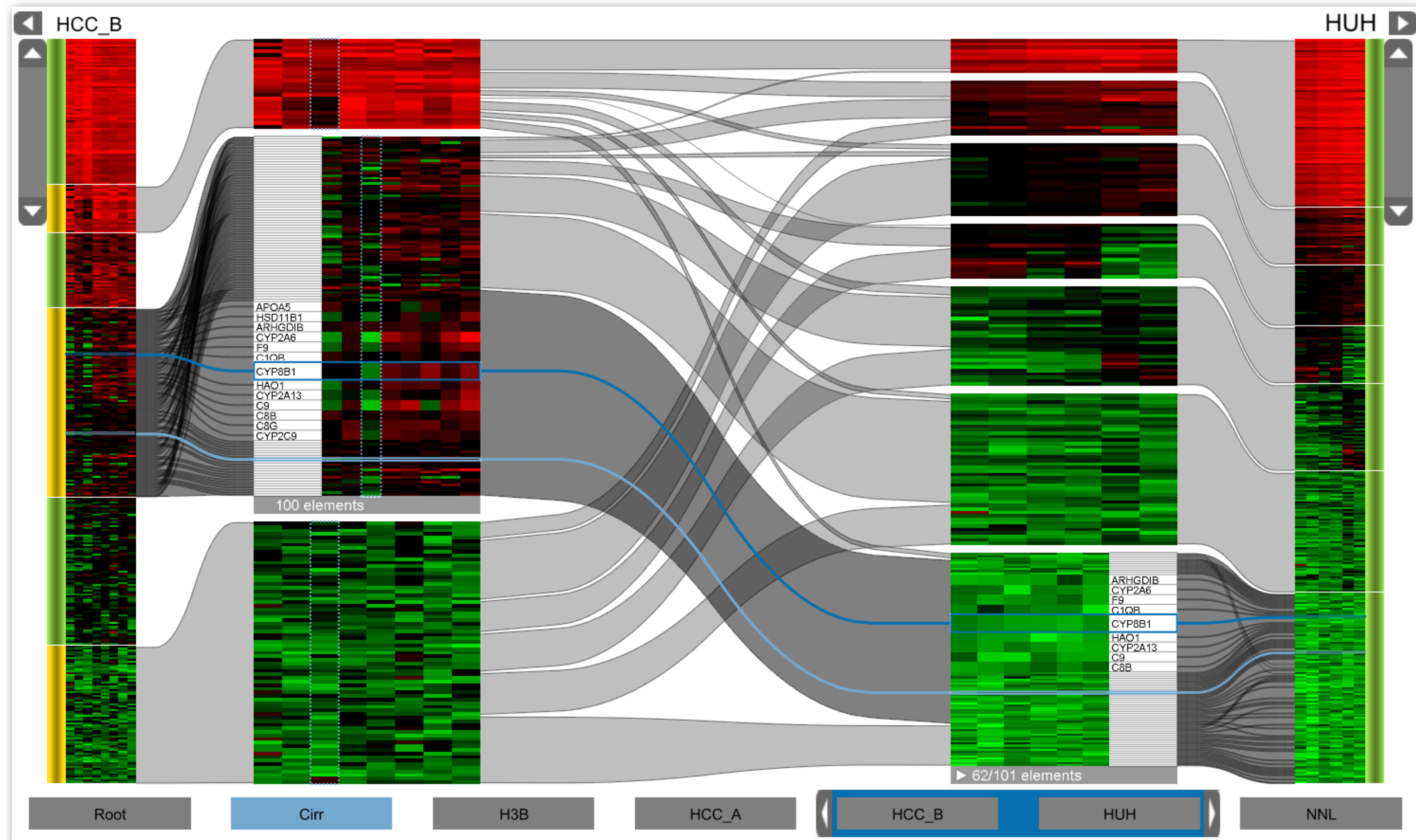
Surface



Outline

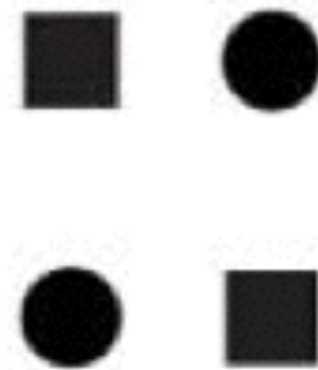
Common Region

Connection

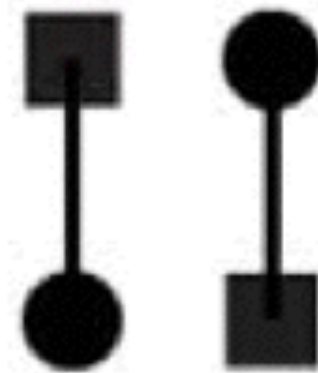


Enclosure

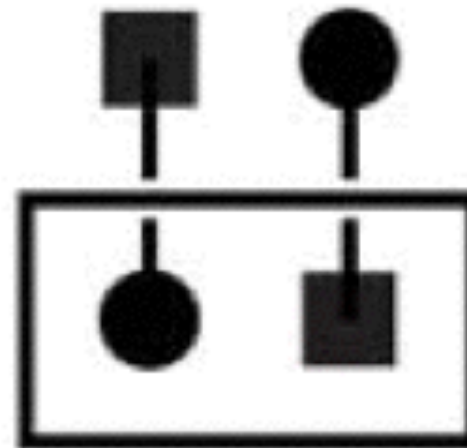
Similarity



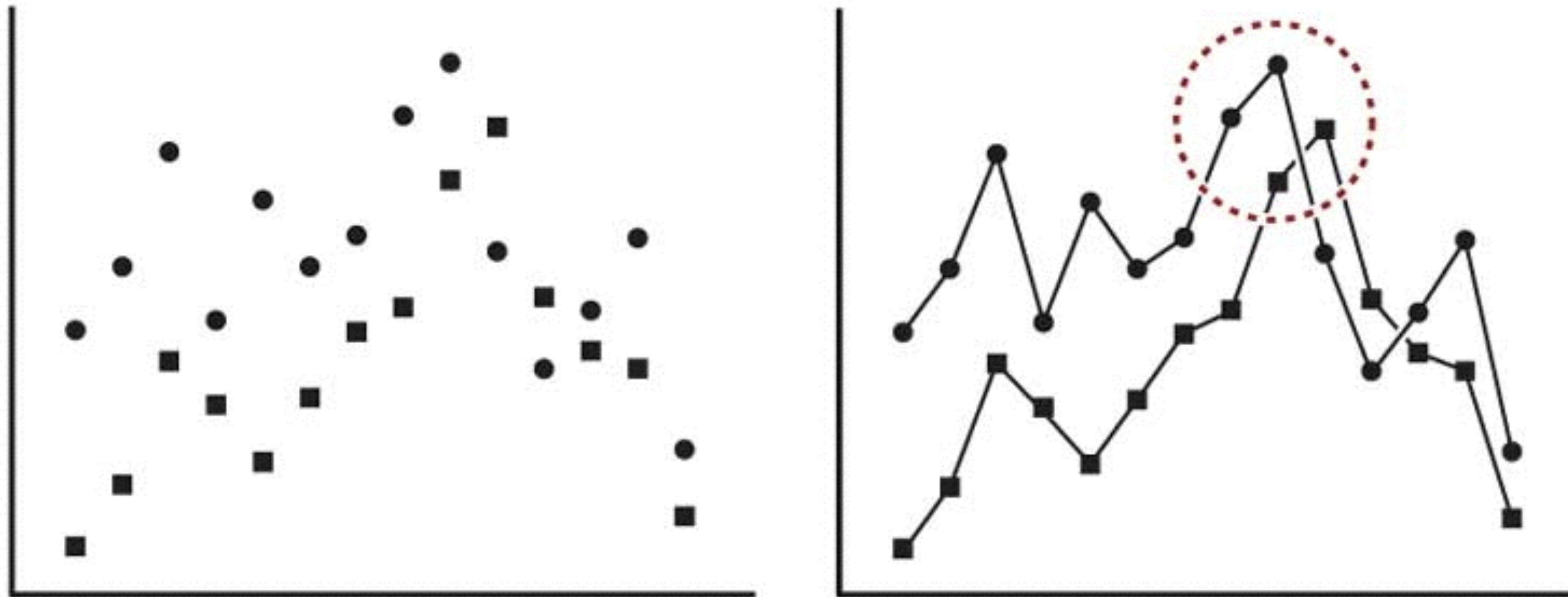
Connection



Enclosure



Enclosure



Connectedness Varieties

Bubble Sets

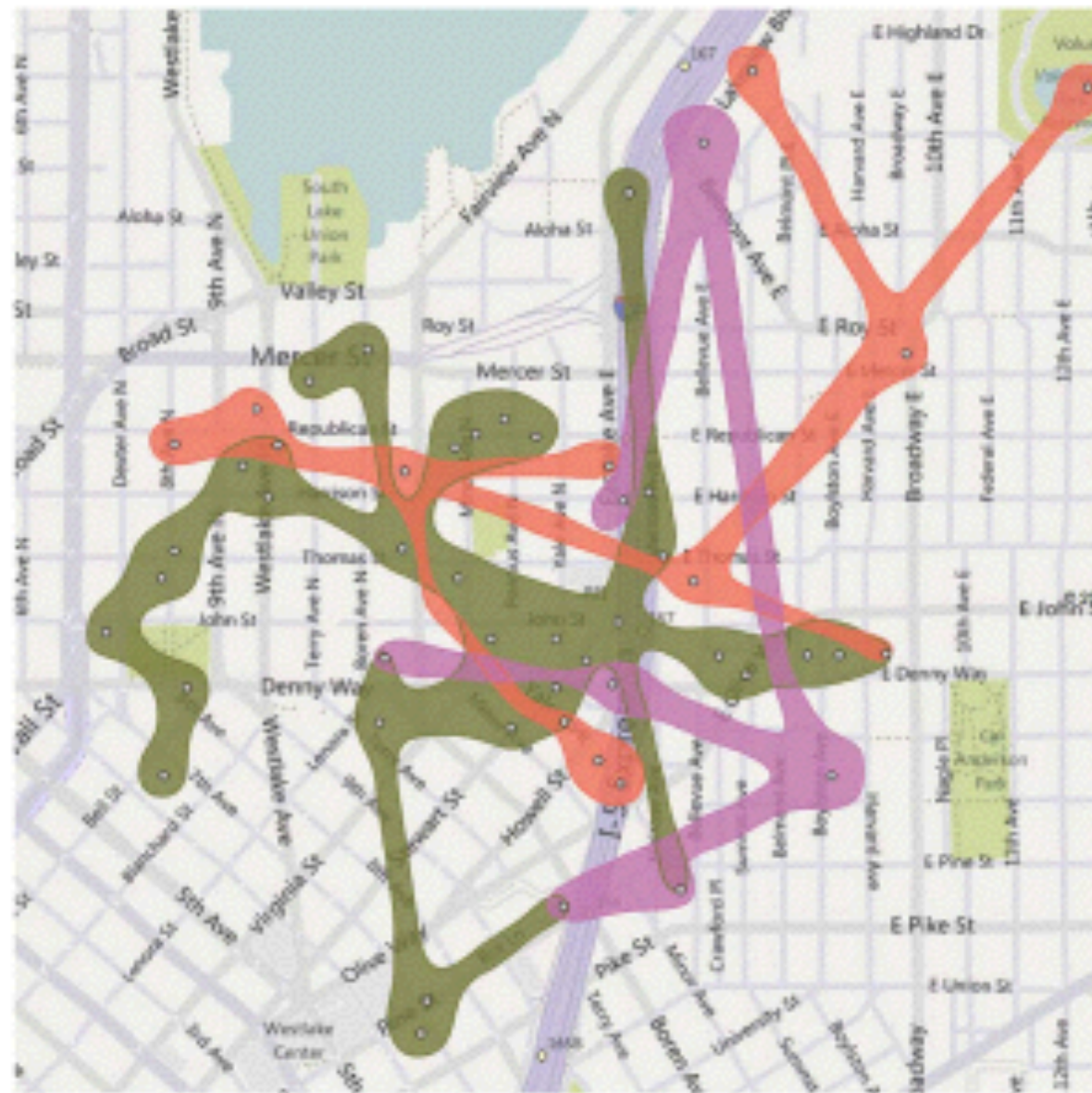
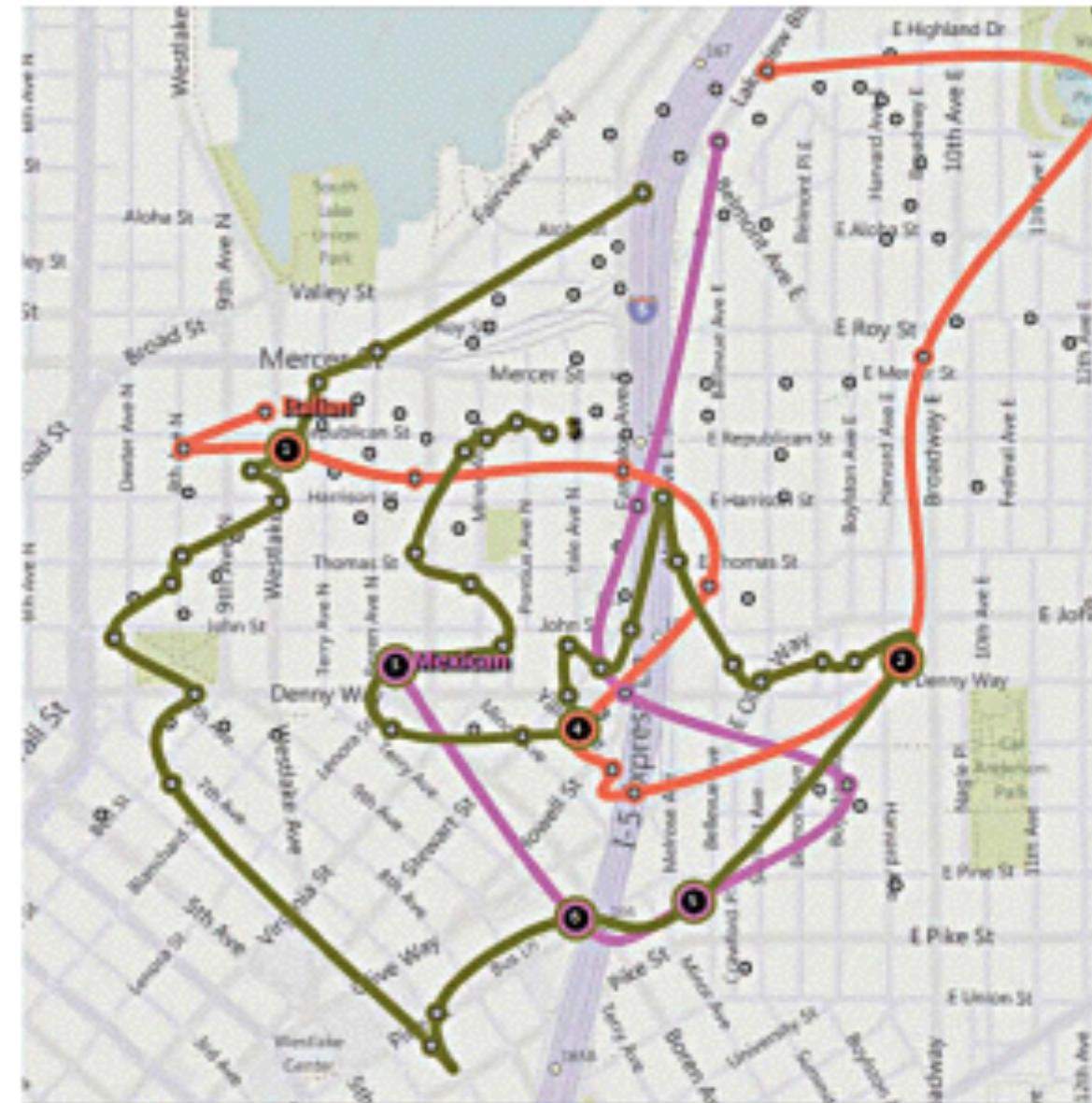


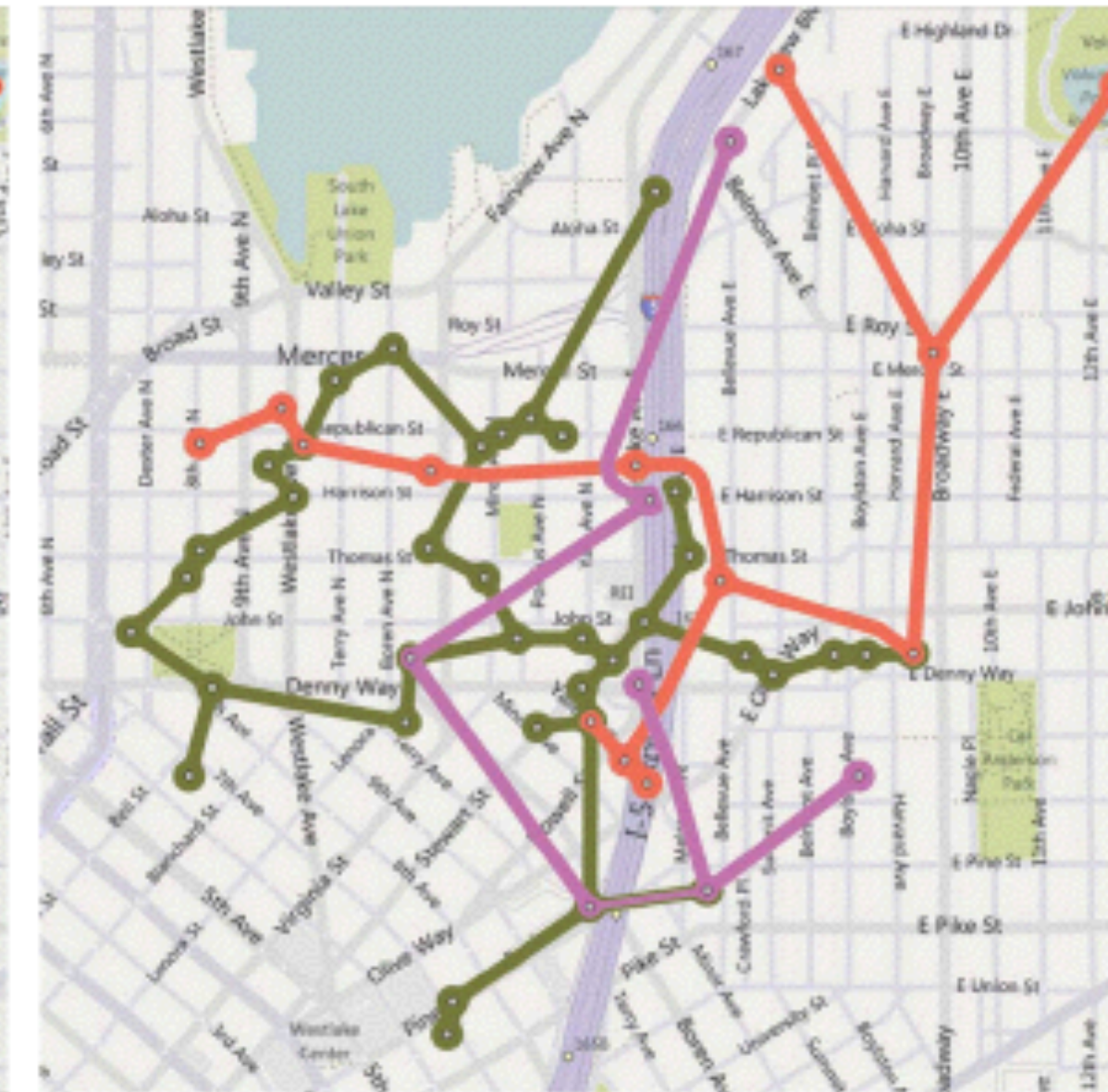
Image by [Dinkla et al., 2011]
Technique by [Collins et al., 2009]

Line Sets



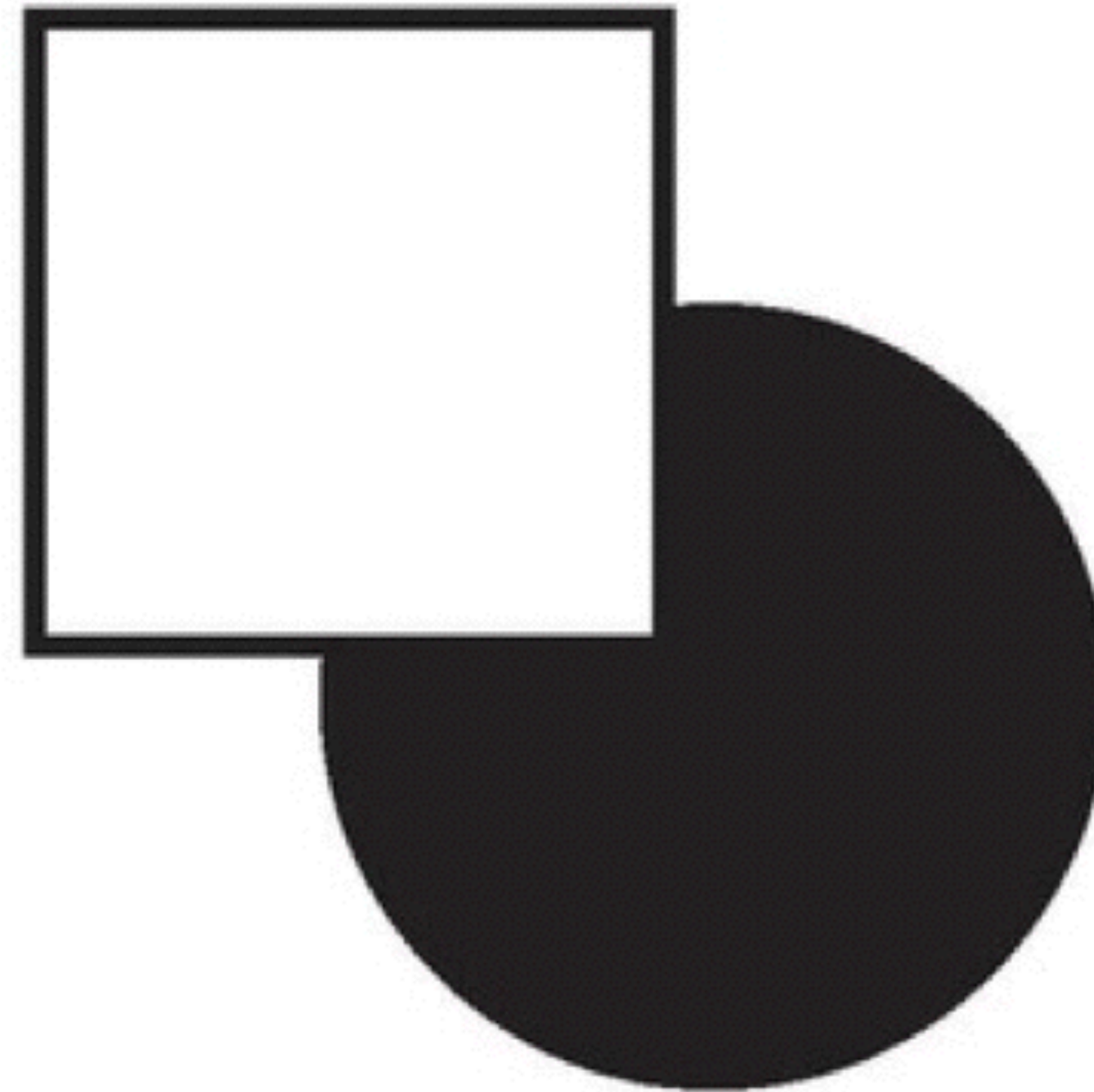
[Alper et al., 2011]

Kelp Diagrams

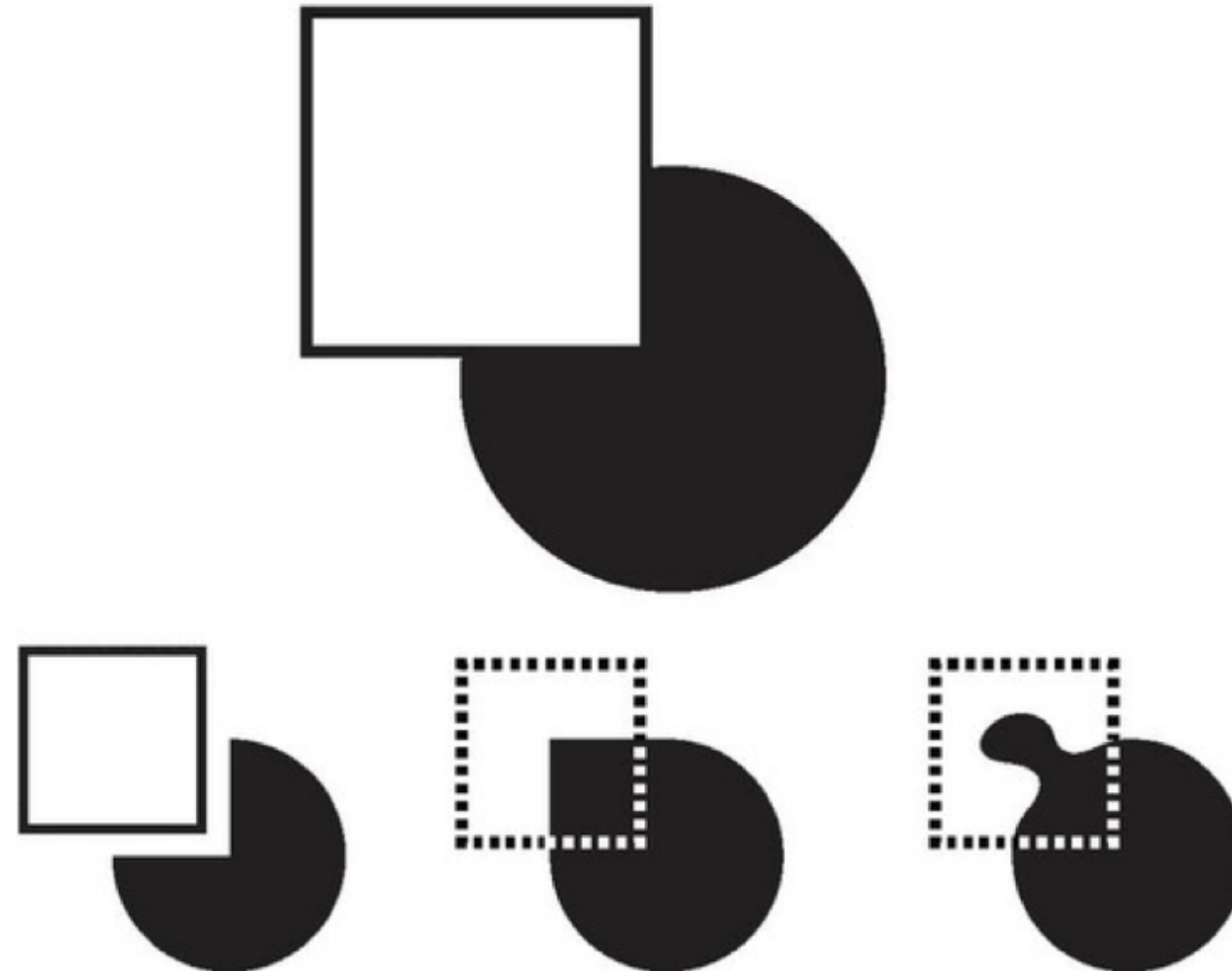


[Dinkla et al., 2012]

Continuity

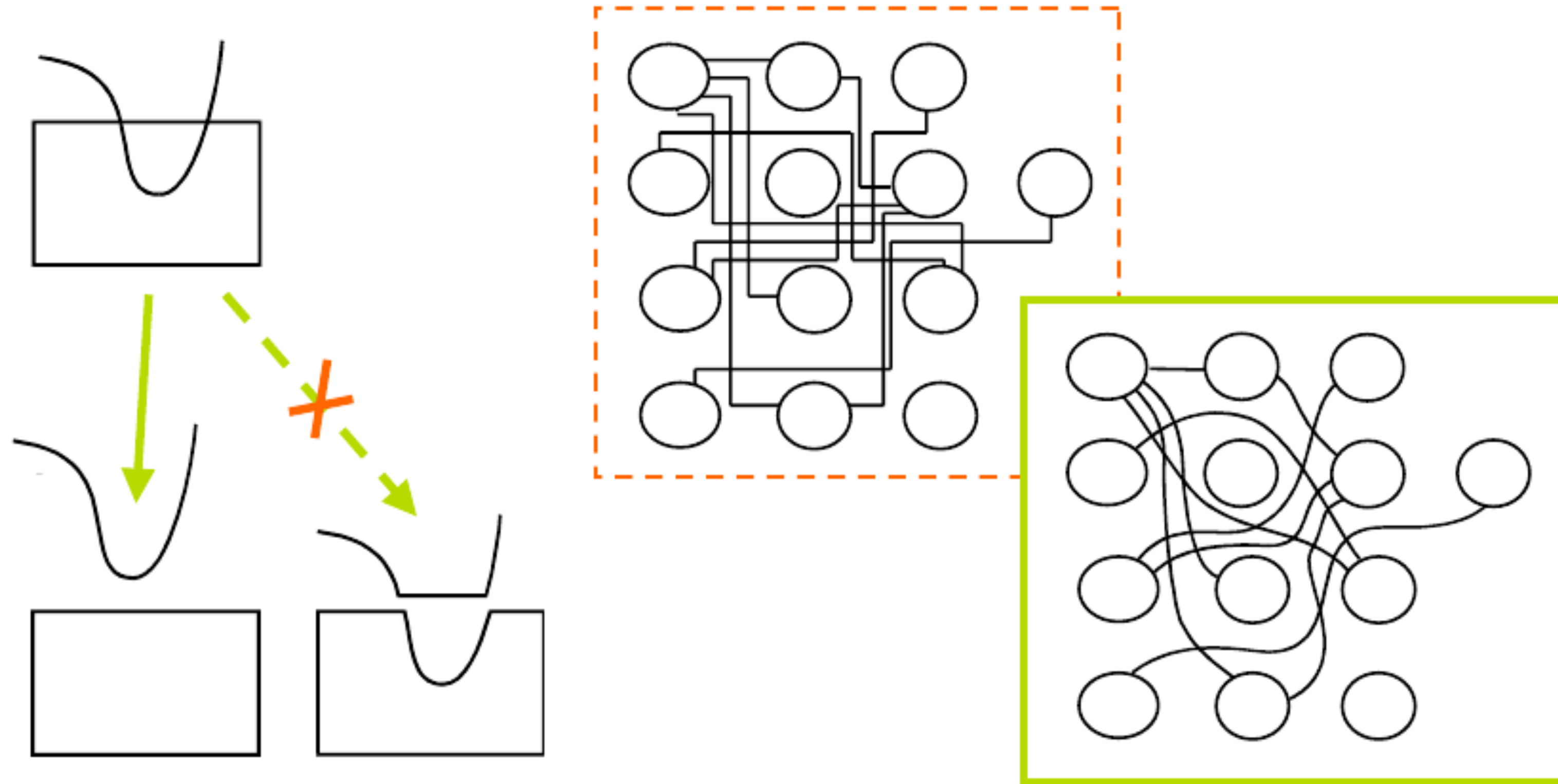


Continuity

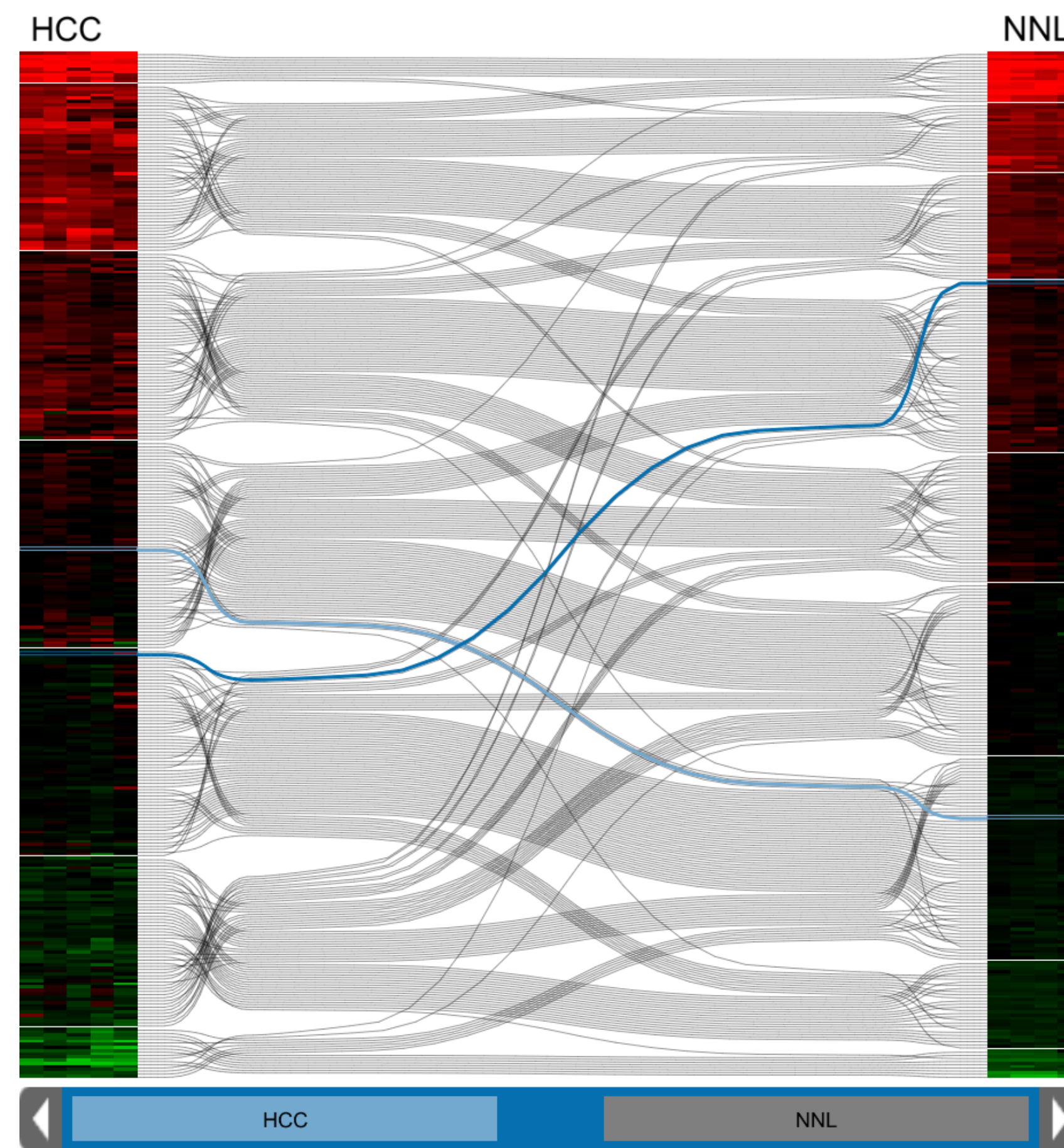
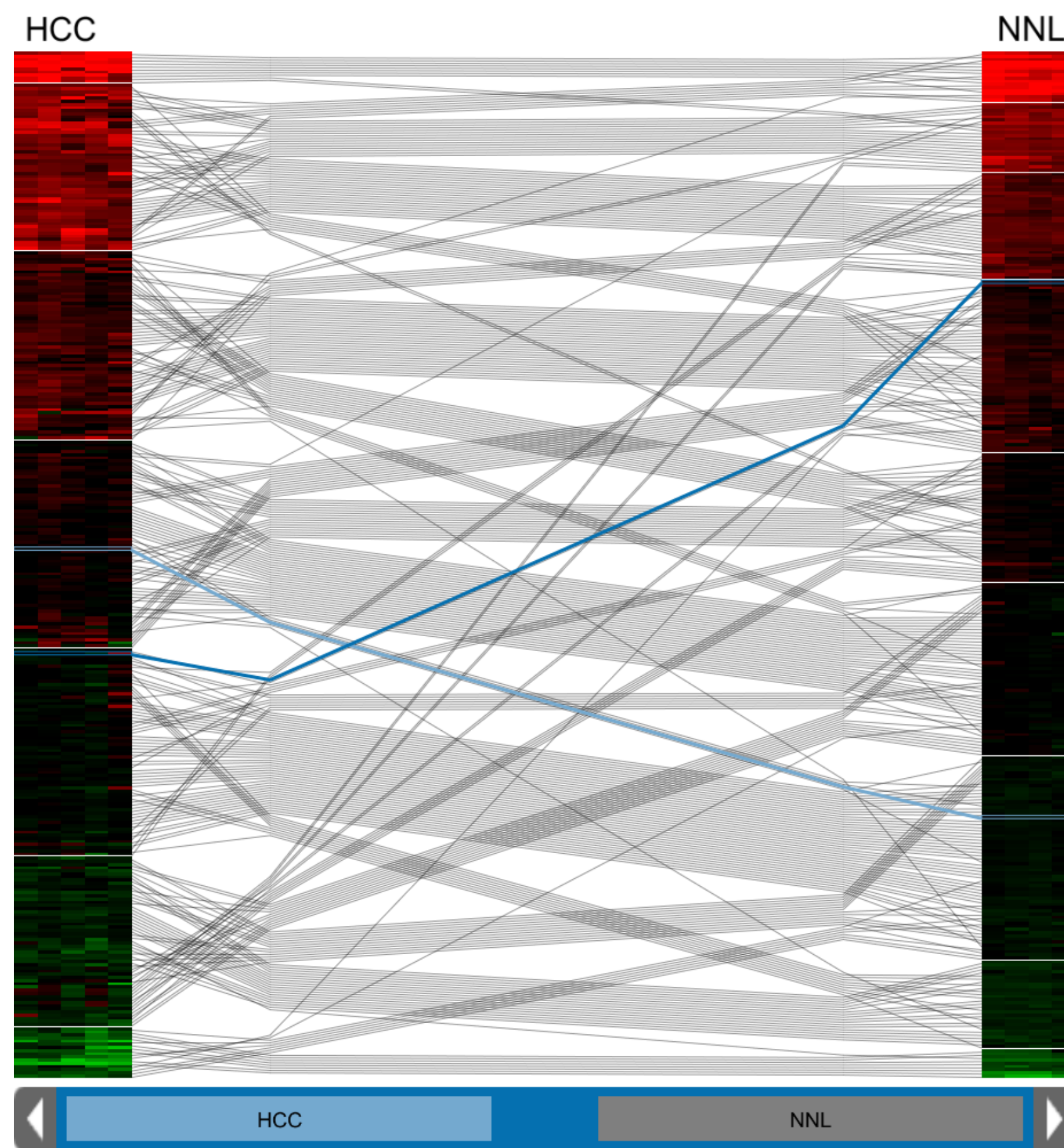


Continuity

Things: smooth & continuous



Continuity



Closure

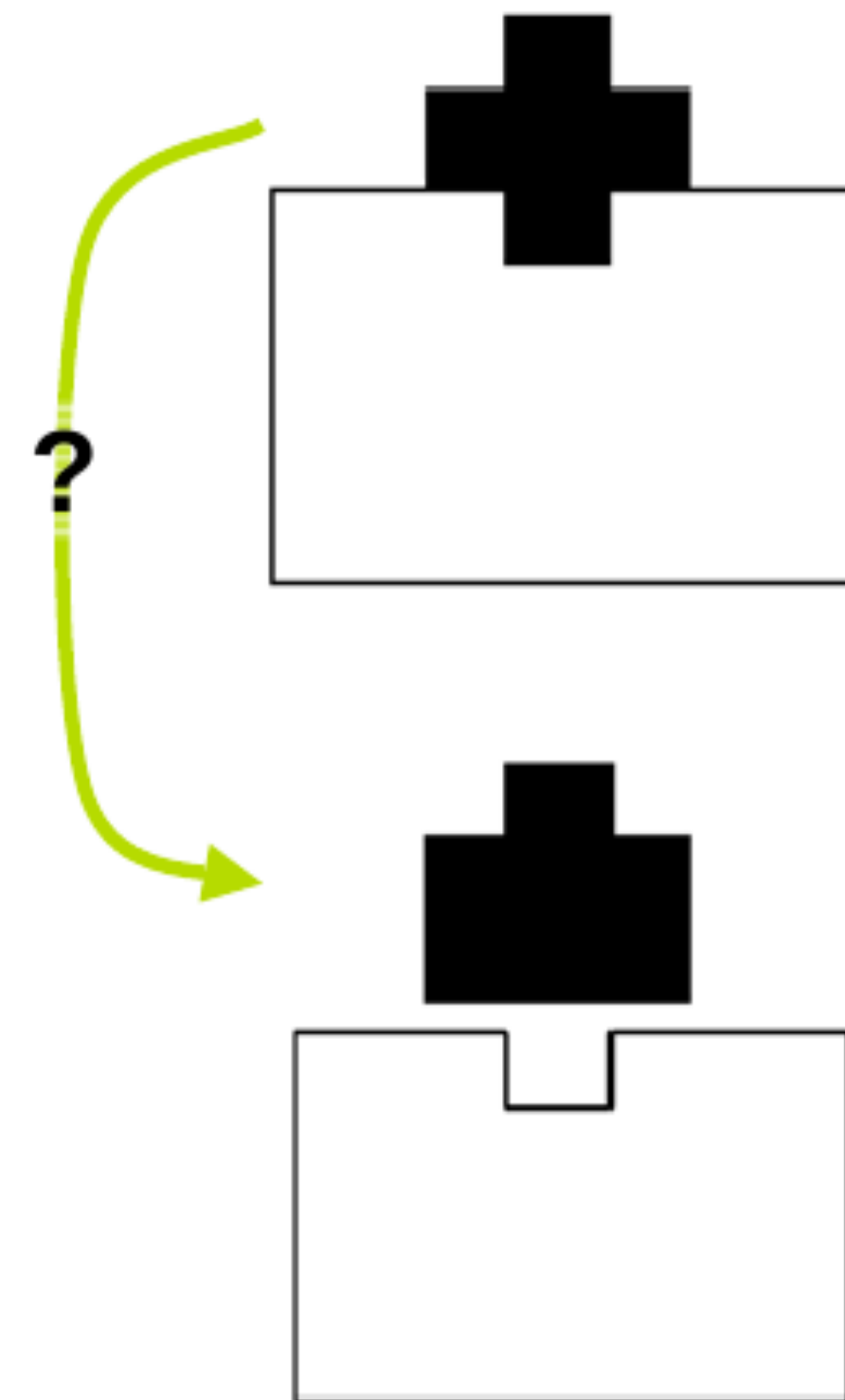
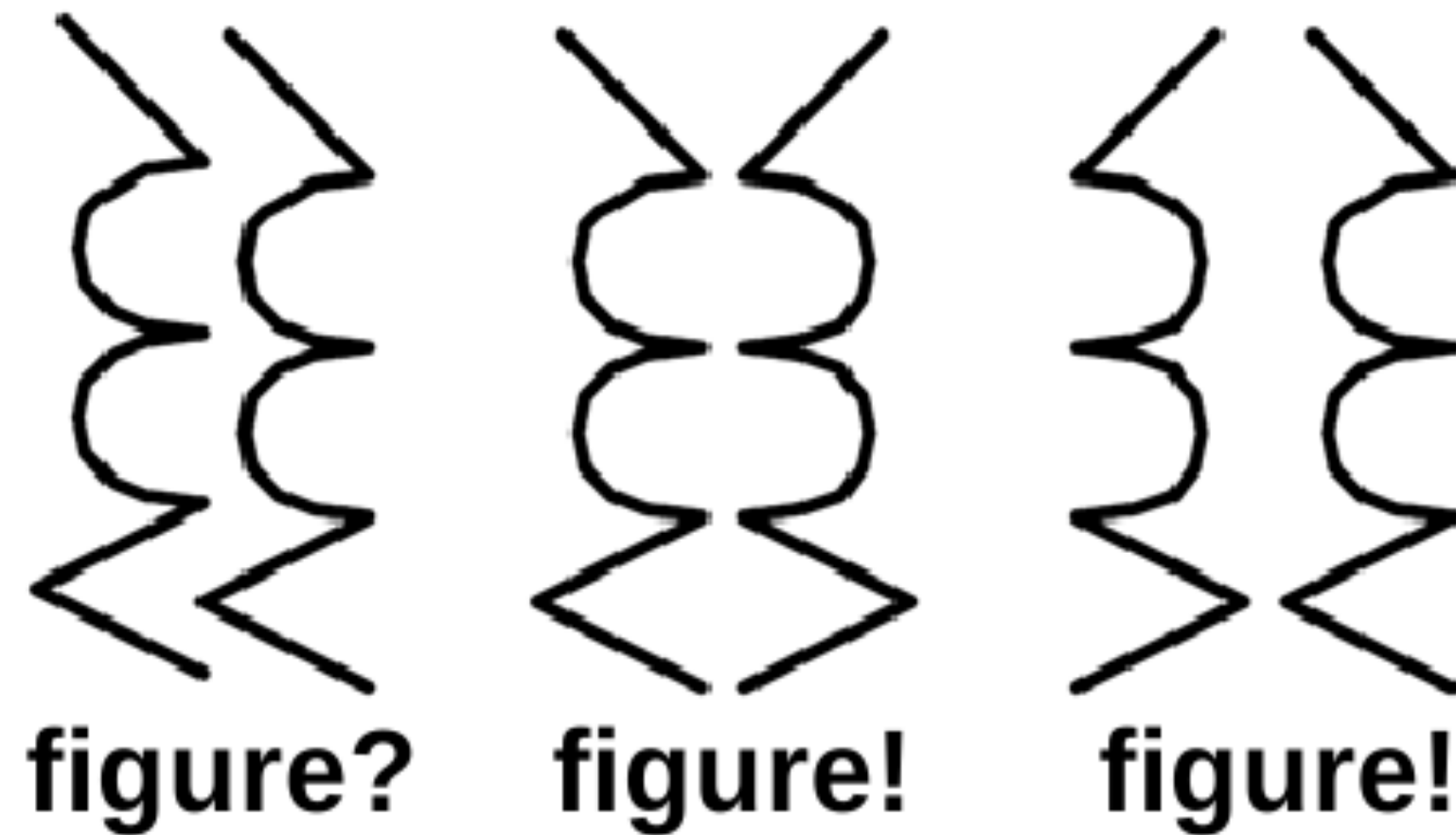


Closure



Symmetry

Things: symmetric



Population Pyramid

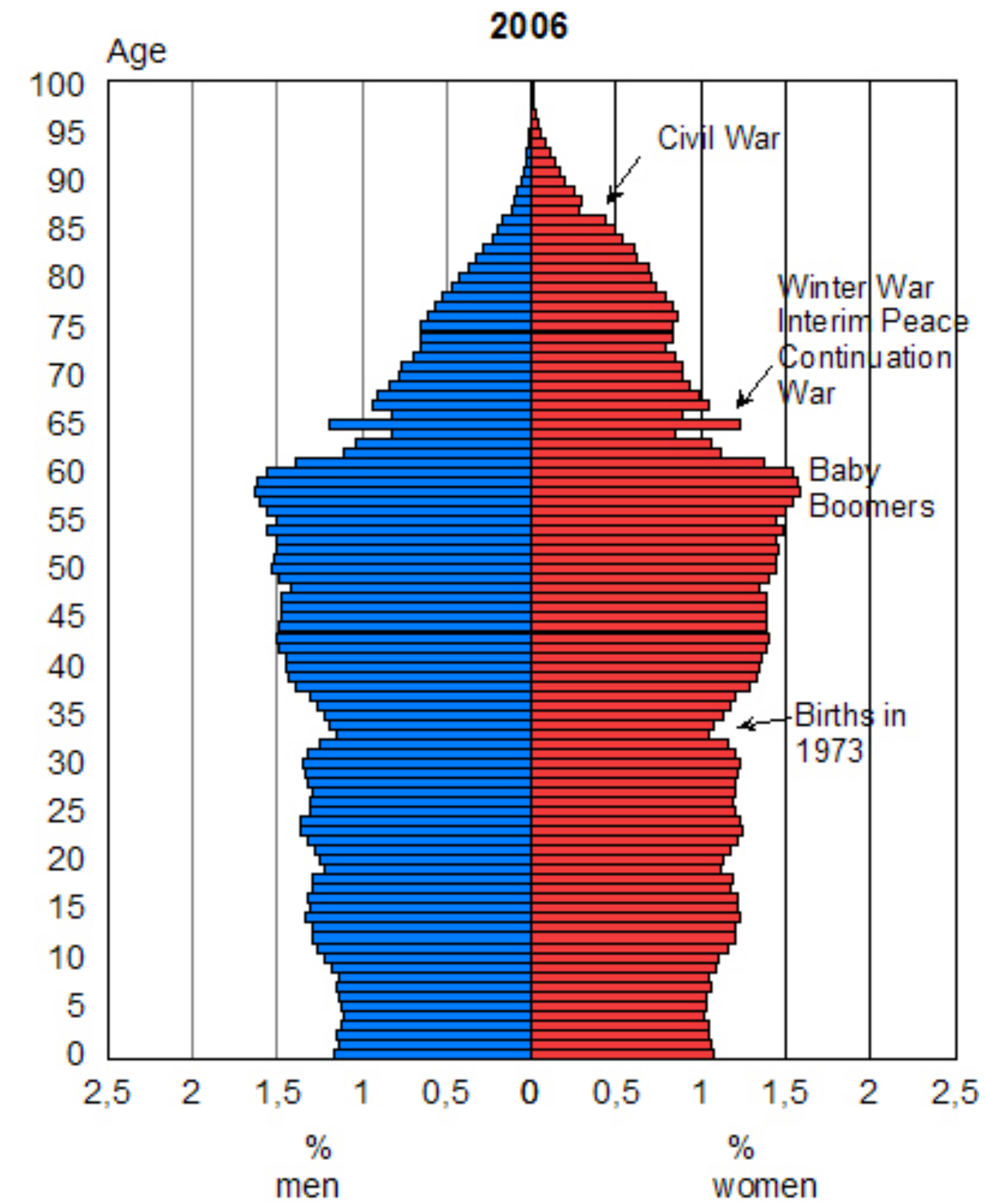
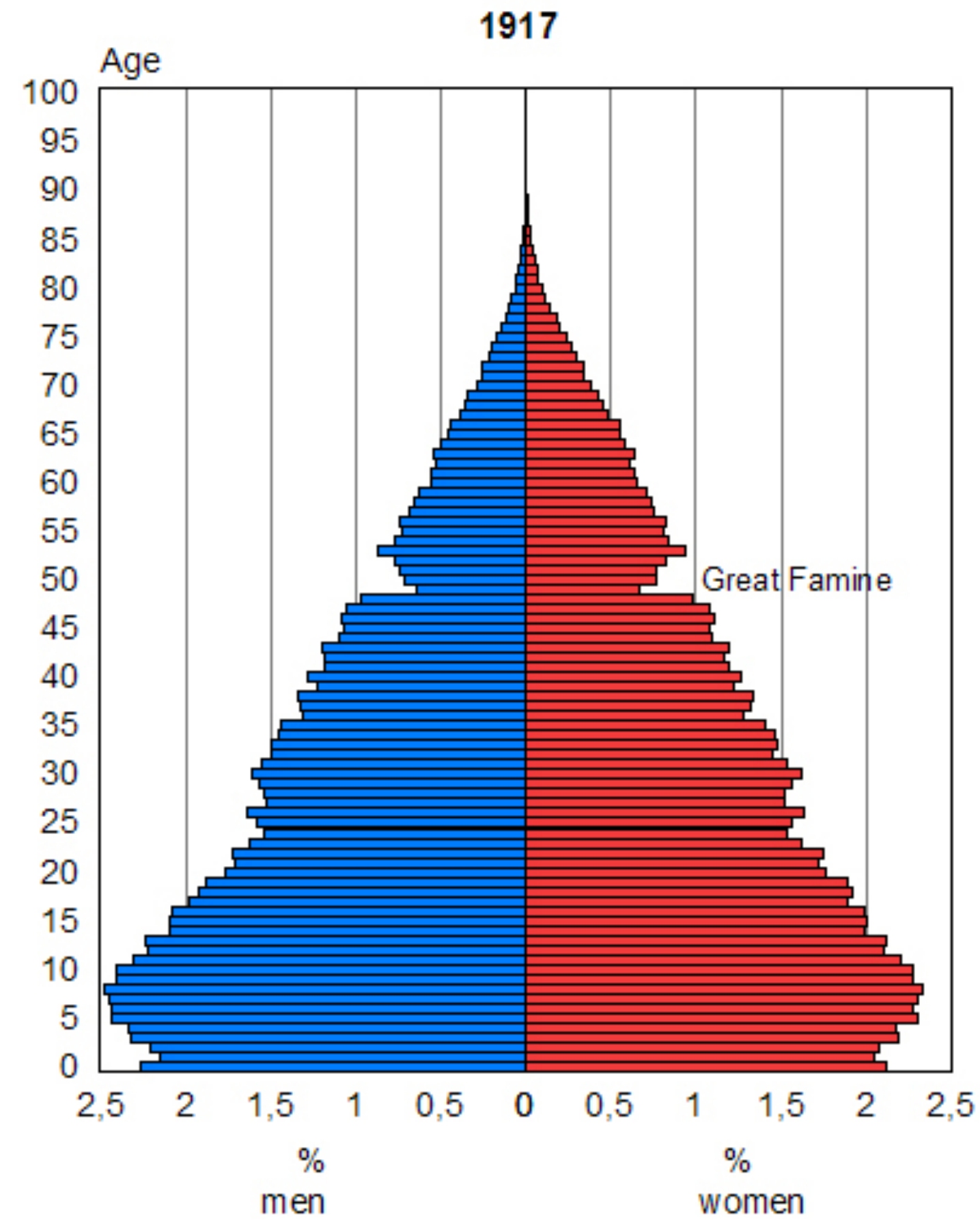
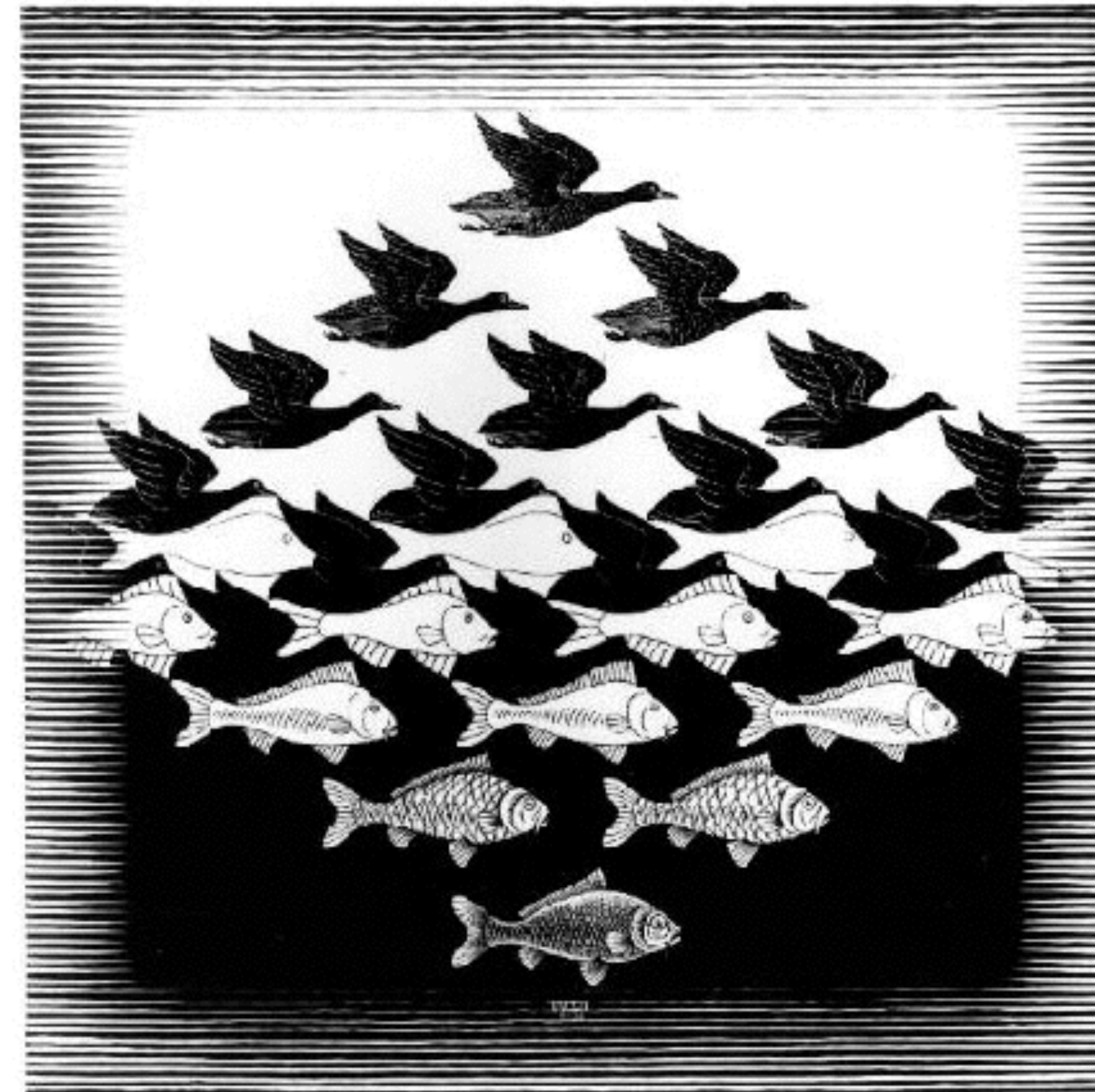


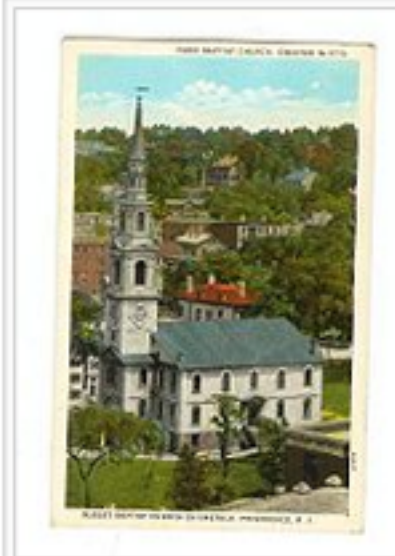
Figure / Ground



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

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Providence in the mid-nineteenth century



NPS map of the W3R Route



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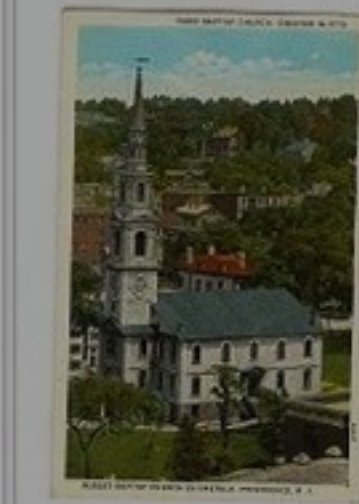
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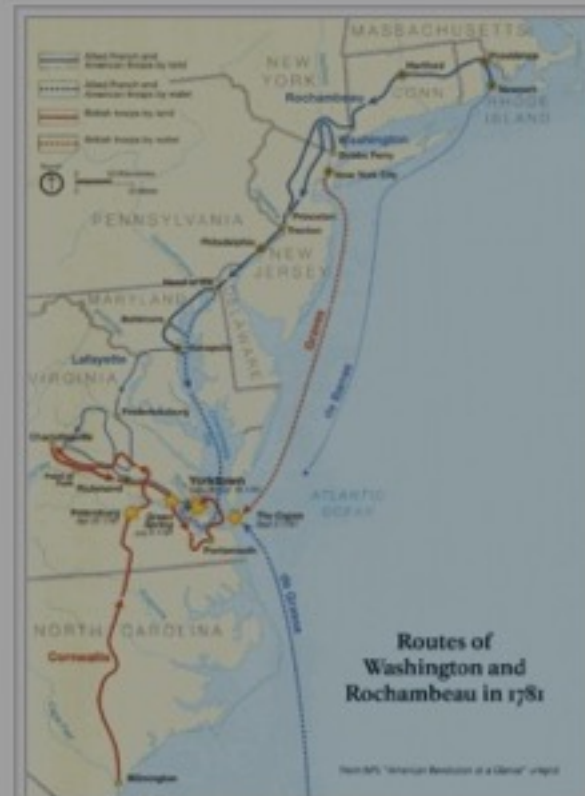
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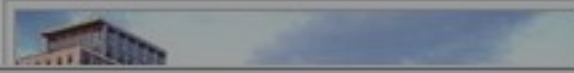
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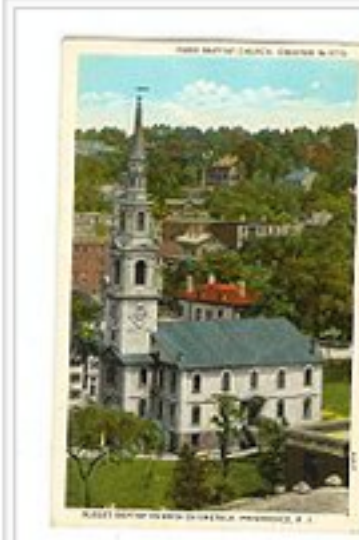
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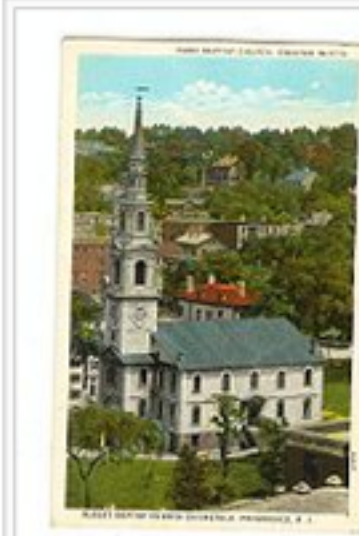
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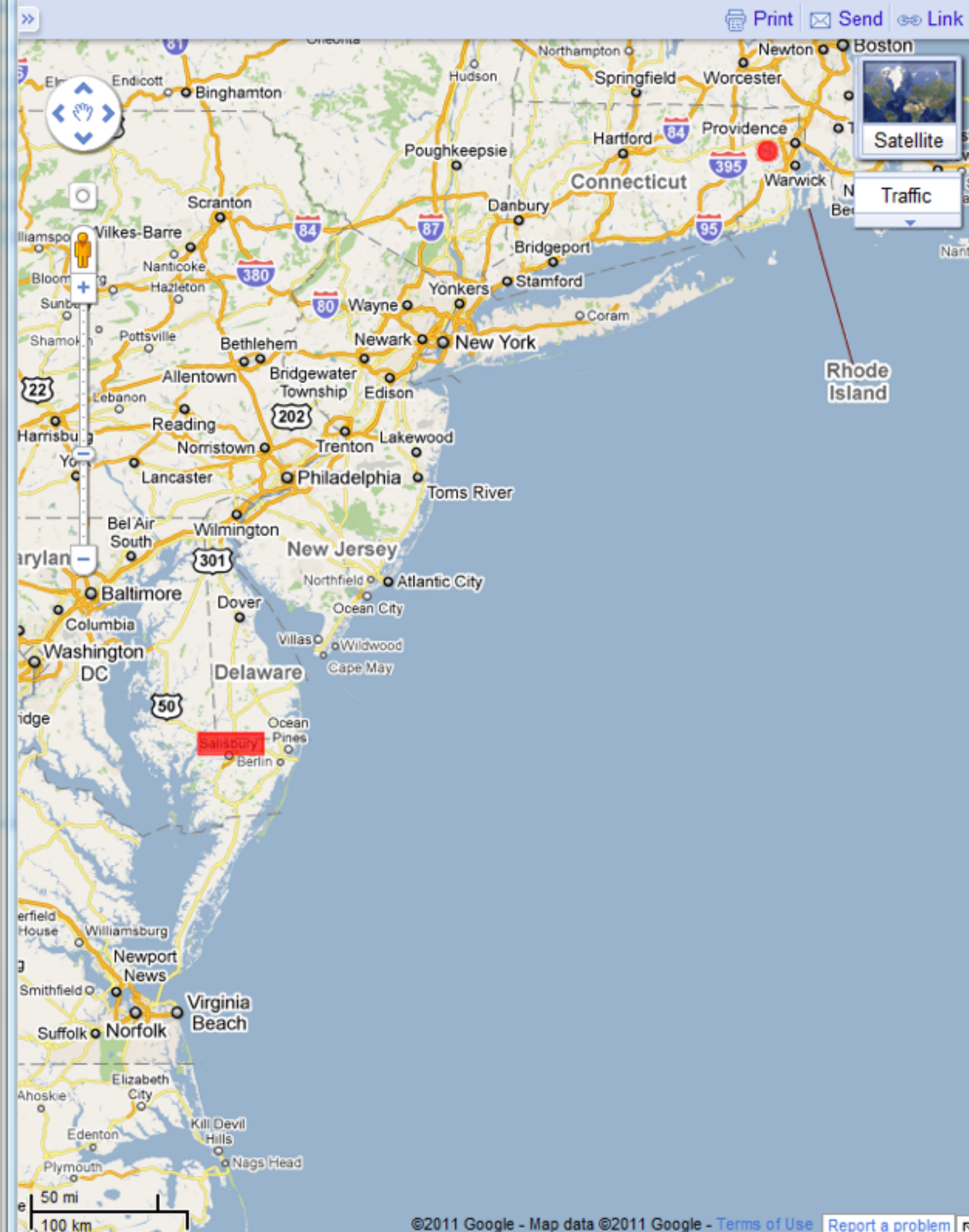
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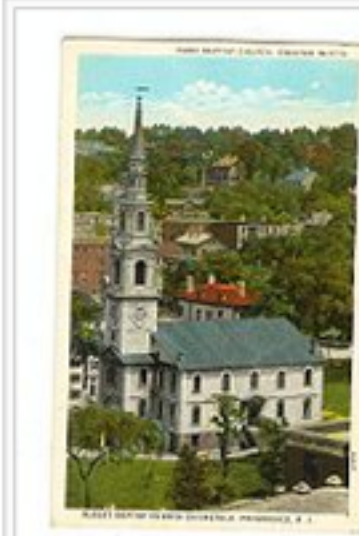
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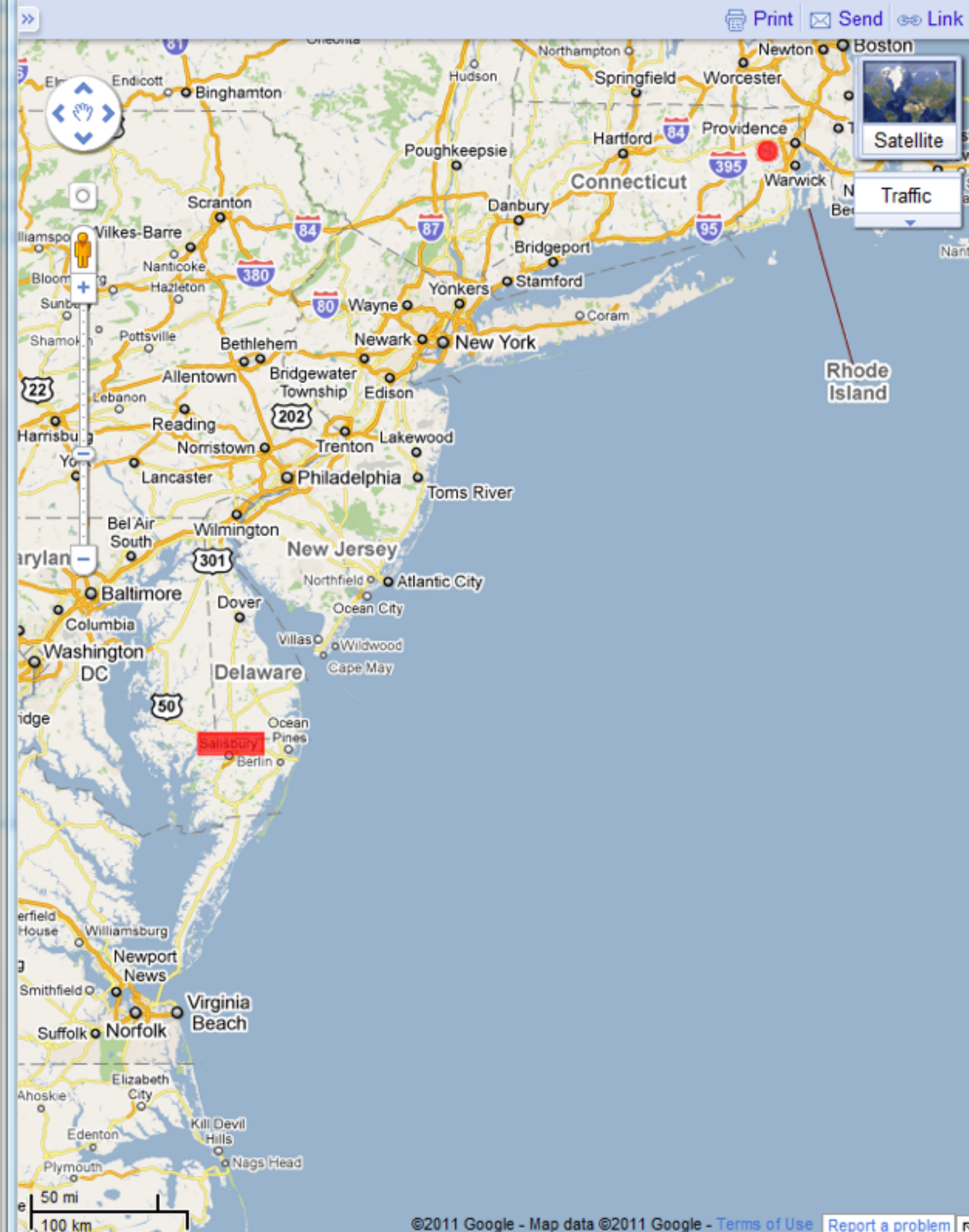
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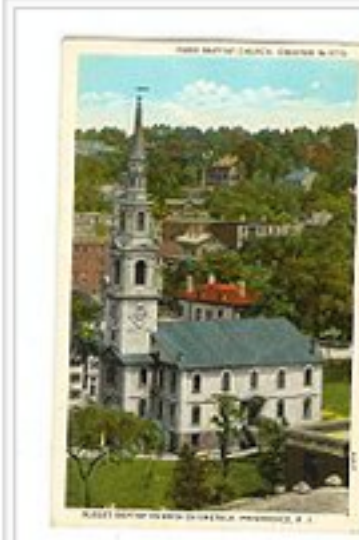
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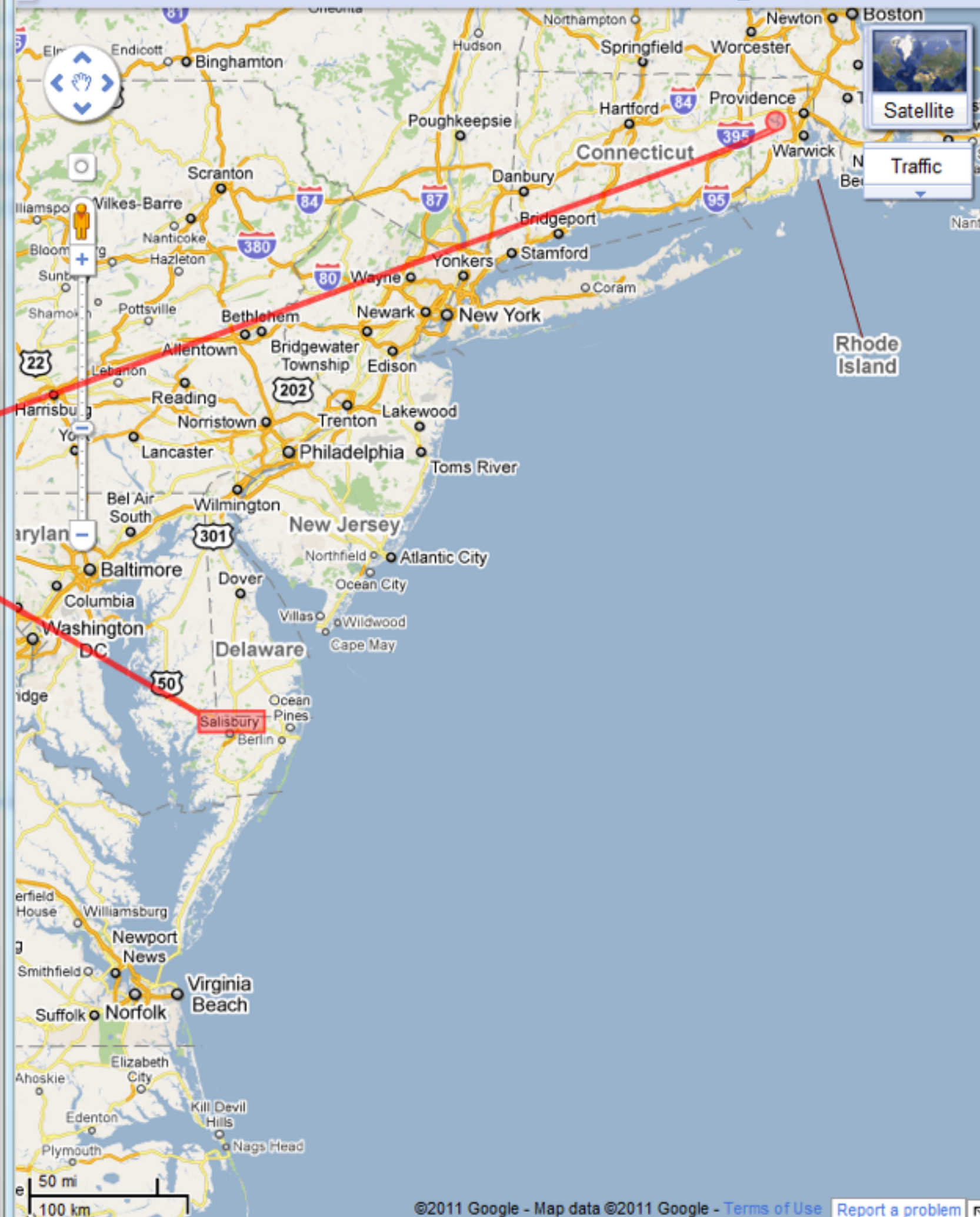
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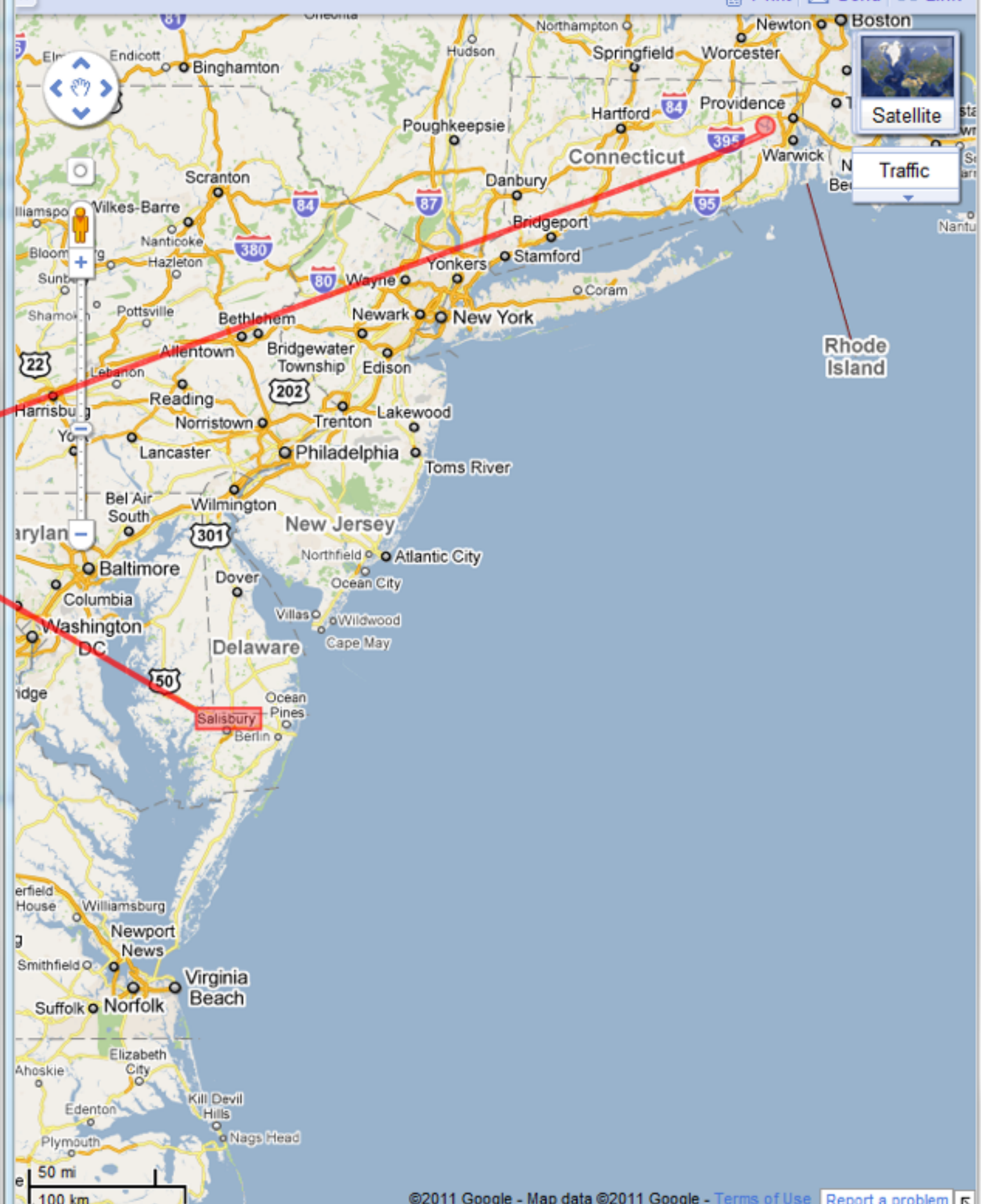
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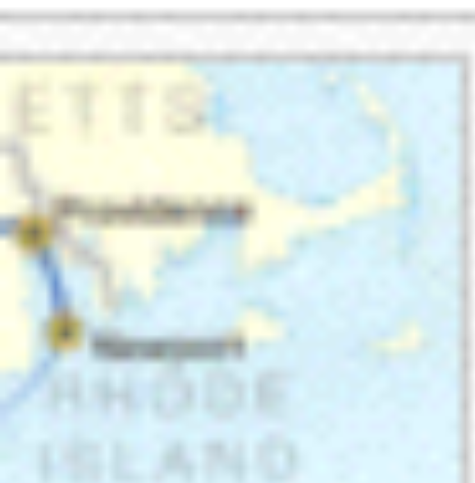
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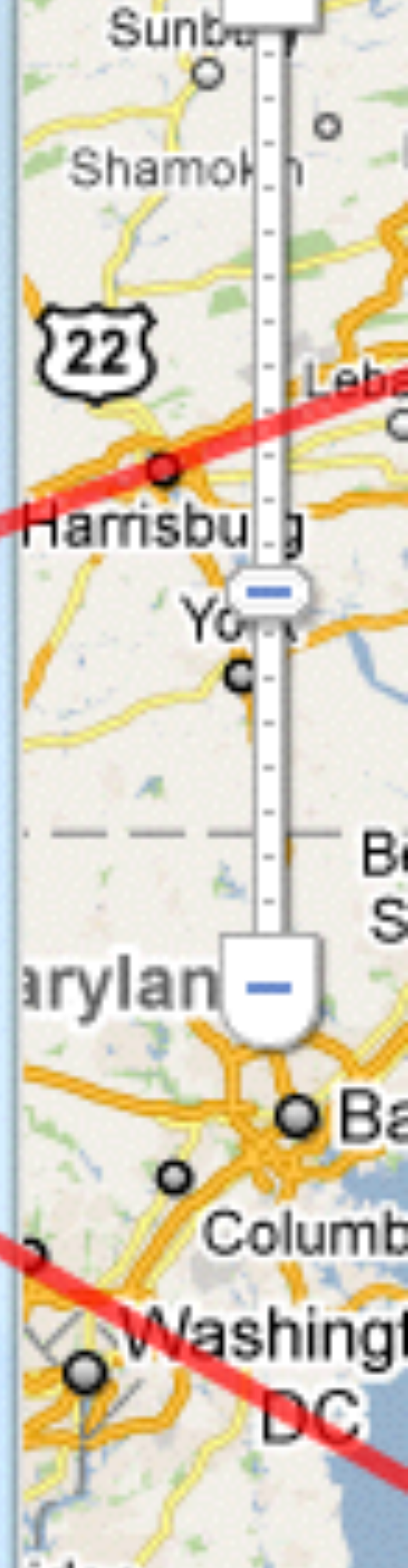


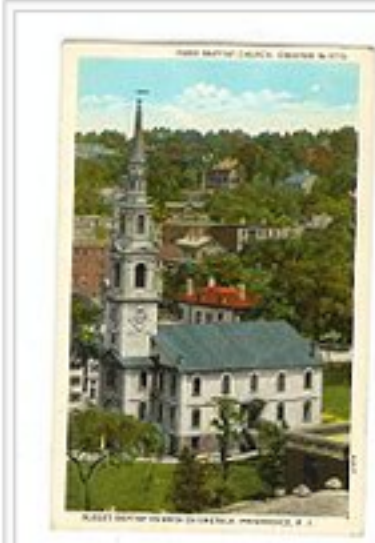
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In the mid-1770s, the British government levied taxes that impeded Providence's maritime, [fishing](#) and agricultural industries, the mainstay of the city's economy. One example was the [Sugar Act](#), which was a tax levied against Providence's distilleries that adversely affected its [trade in rum and slaves](#). These taxes caused Providence to join the other colonies in renouncing allegiance to the British Crown. In response to enforcement of unpopular trade laws, Providence residents spilled the first blood of the American Revolution in the notorious [Gaspée Affair](#) of 1772.^[13]

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]

After departing from [Newport](#), French troops sent by [King Louis XVI](#) and commanded by the [Comte de Rochambeau](#) passed through Providence on their way to join the attack against British forces. The march from Newport to Providence was the beginning of a campaign led jointly by [General George Washington](#) in a [decisive march](#) that ended with the defeat of [General Cornwallis](#) in the [Siege of Yorktown](#) at [Yorktown, Virginia](#) and the [Battle of the Chesapeake](#).

Following the war, Providence was the [country's ninth-largest city](#).^{b6}^[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](#)

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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