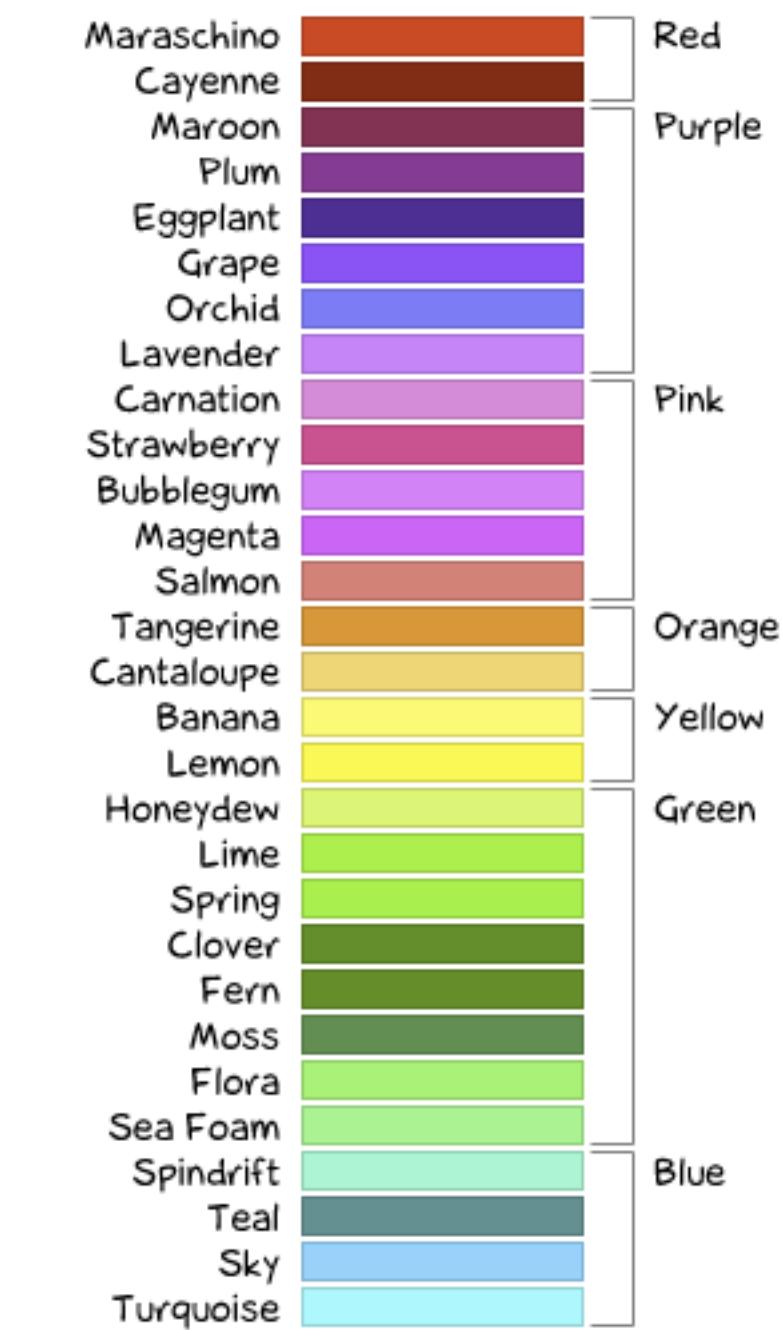


CS171 Visualization

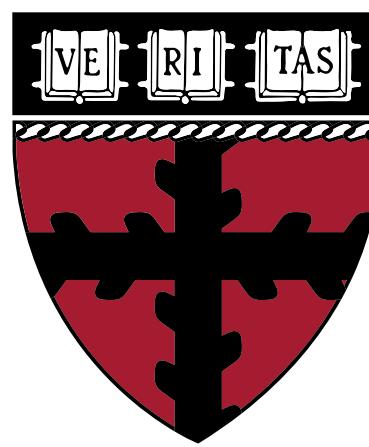
Alexander Lex
alex@seas.harvard.edu

Perception,
Cognition,
Color

Color names if
you're a girl...



Color names if
you're a guy...



HARVARD
School of Engineering
and Applied Sciences

Doghouse Diaries
"We take no as an answer."

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

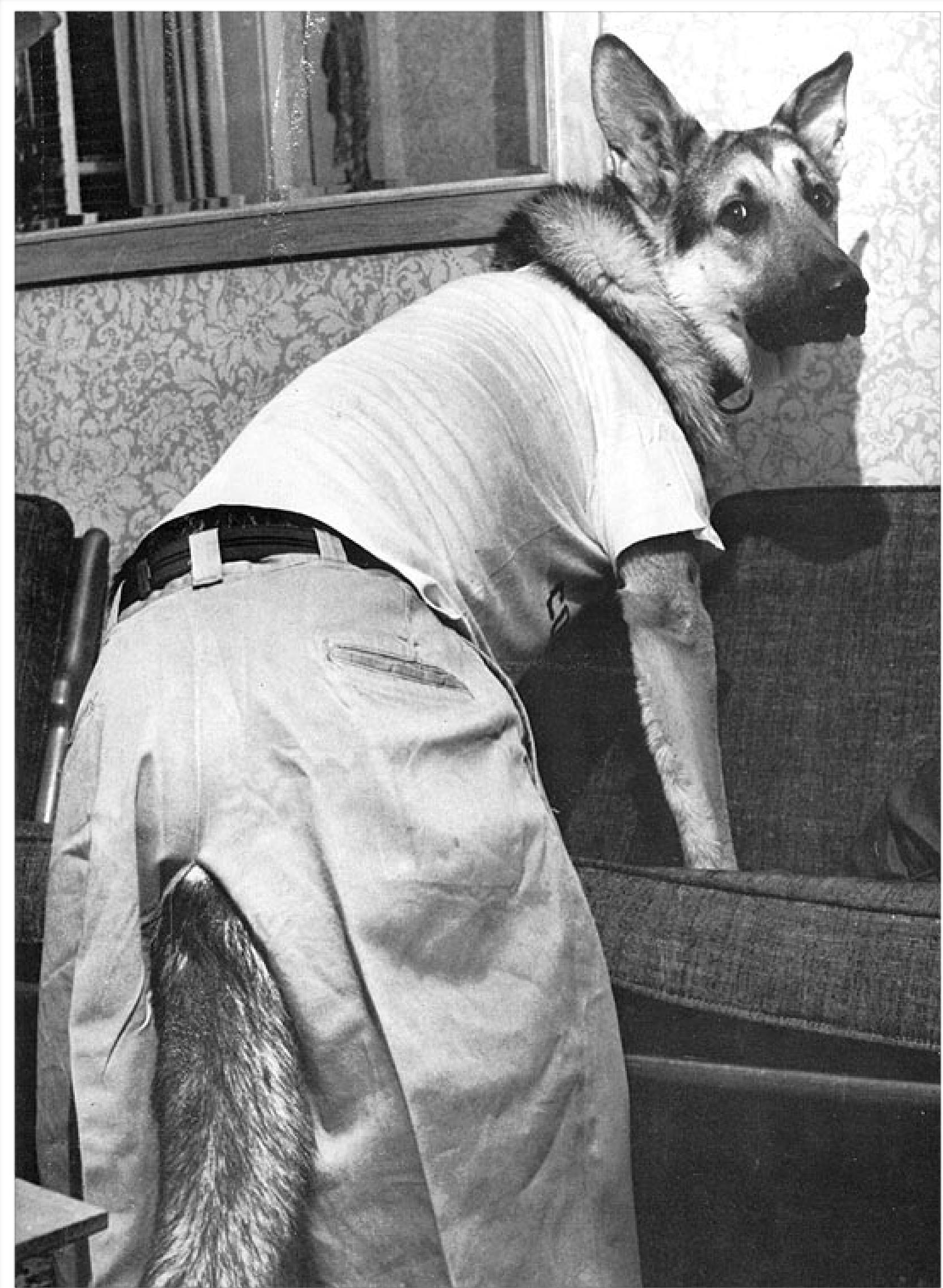


perceptual hysteresis





we rely on priors





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



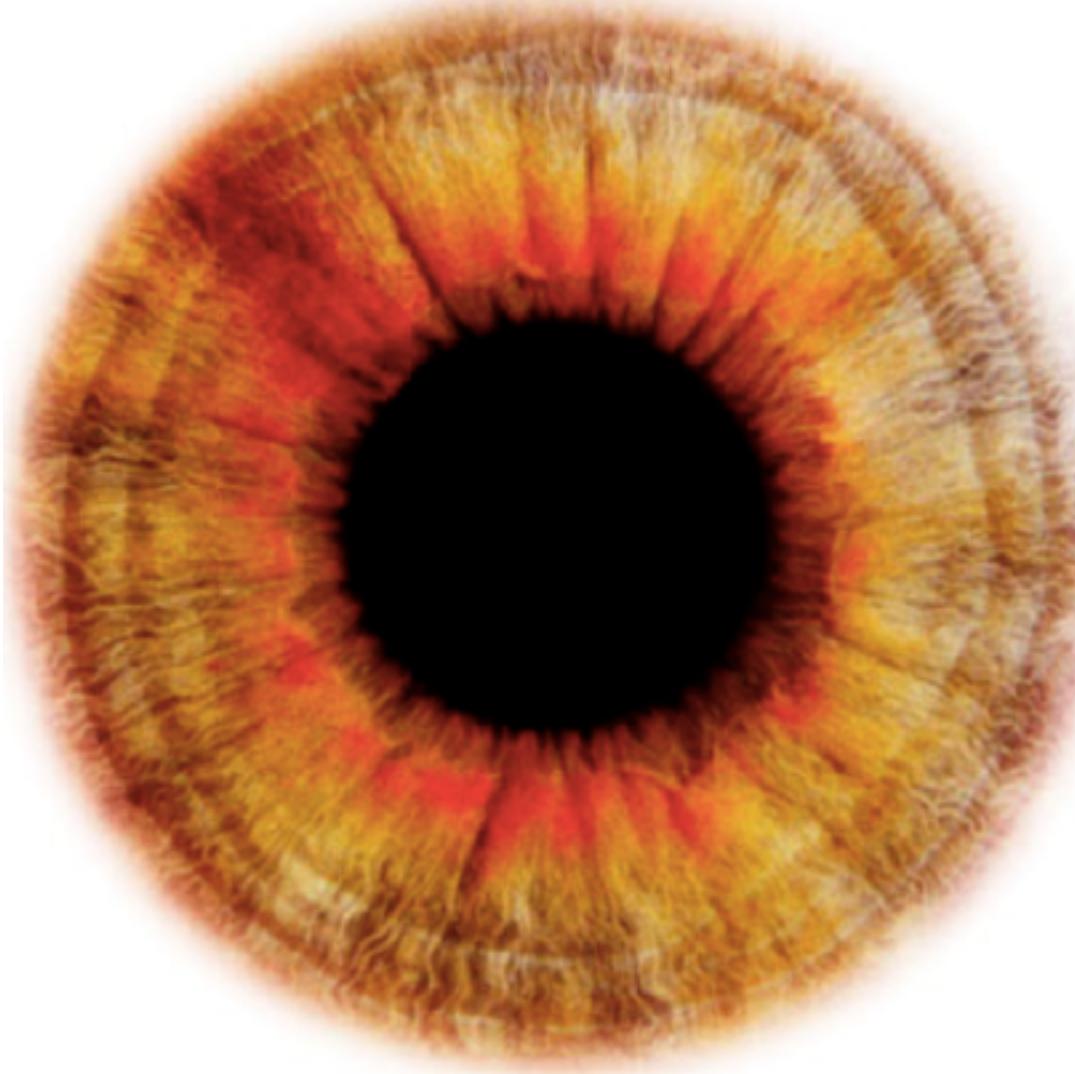
Take Home Point

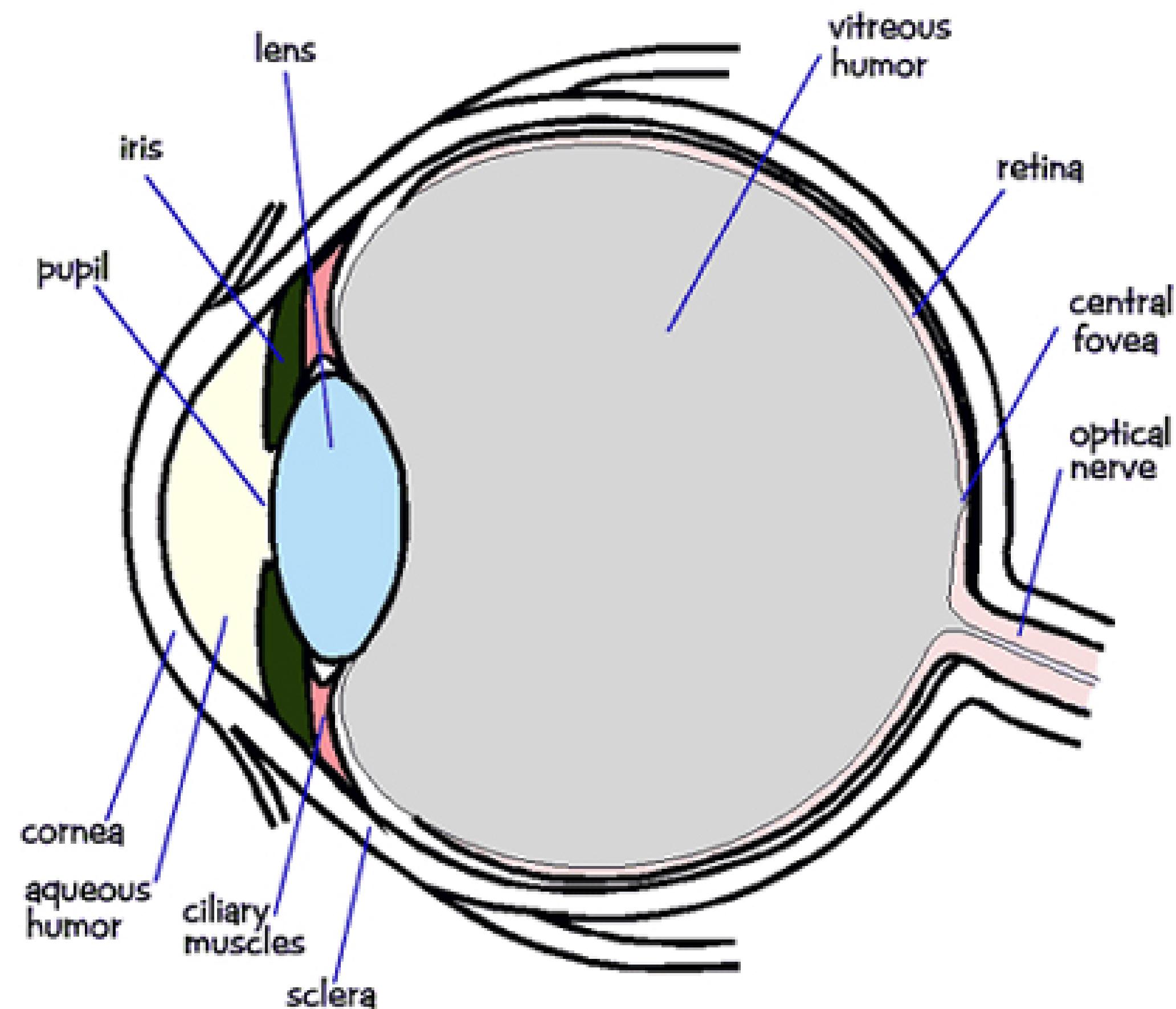
Vision is “constructed” top down from the input

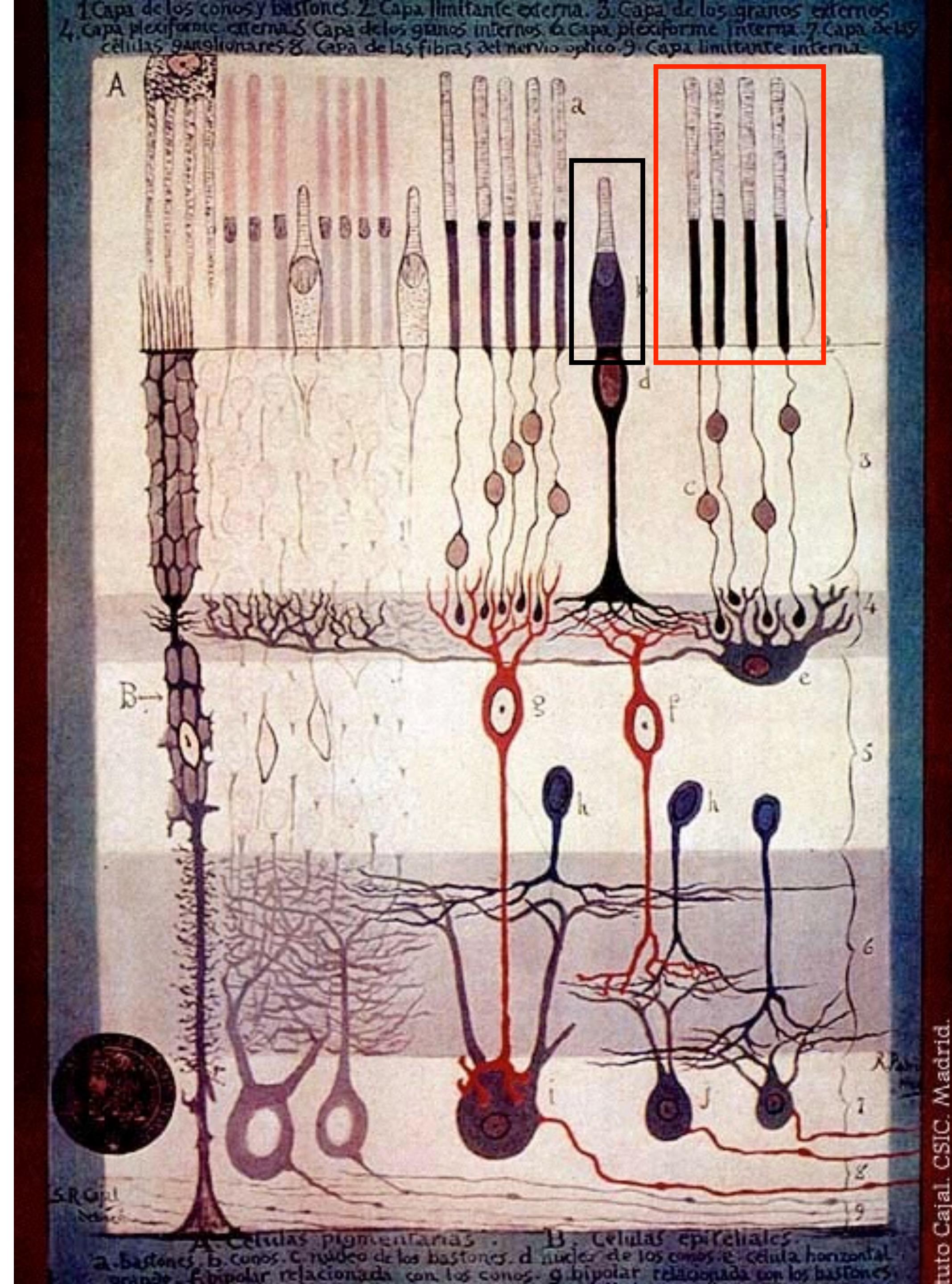
“What you see when you see a thing depends on what the thing is. What you see the thing as depends on what you know about what you are seeing.”

Zenon W. Pylyshyn
Canadian Cognitive Scientist
and Philosopher

The Eye



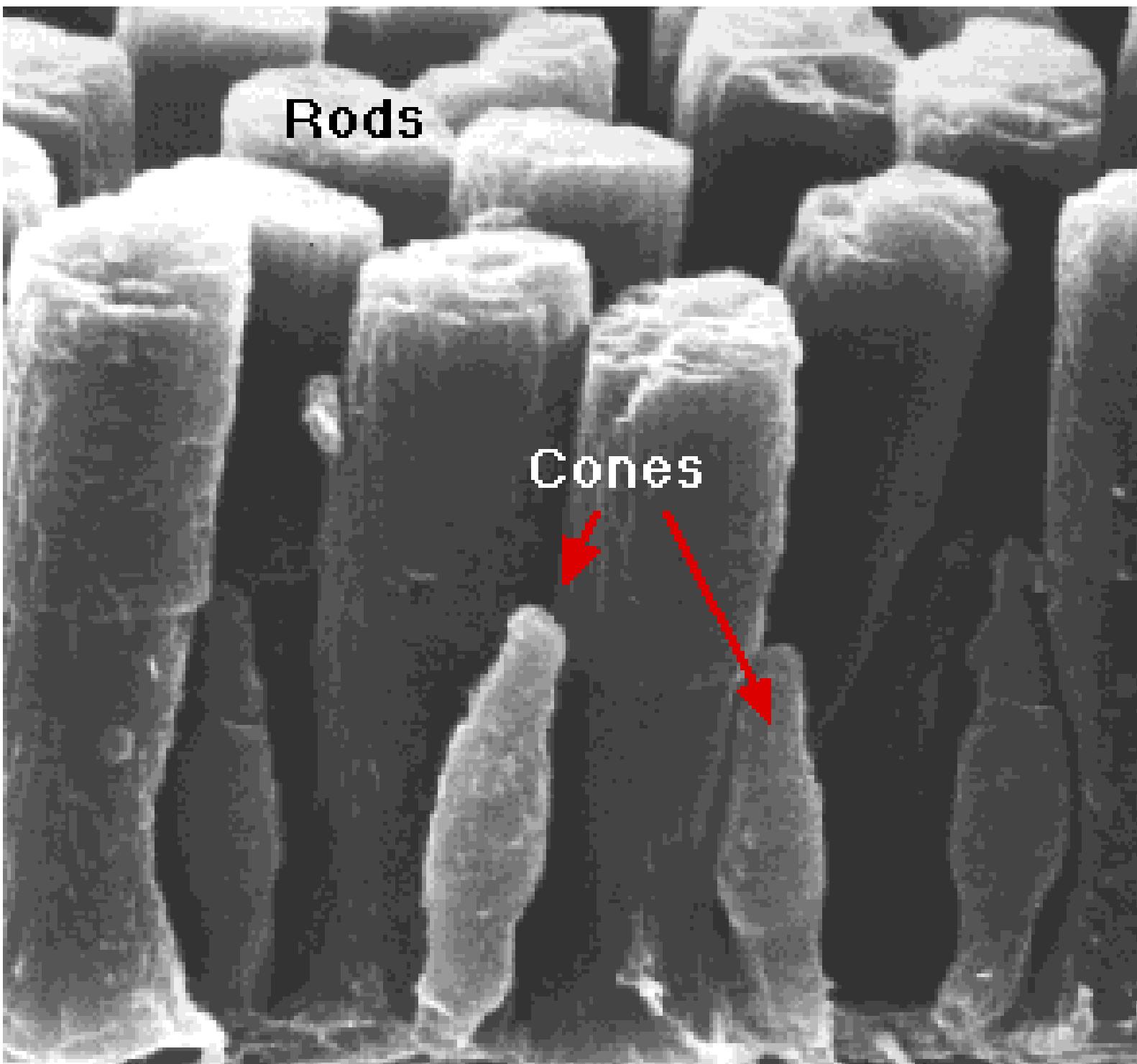




Rods

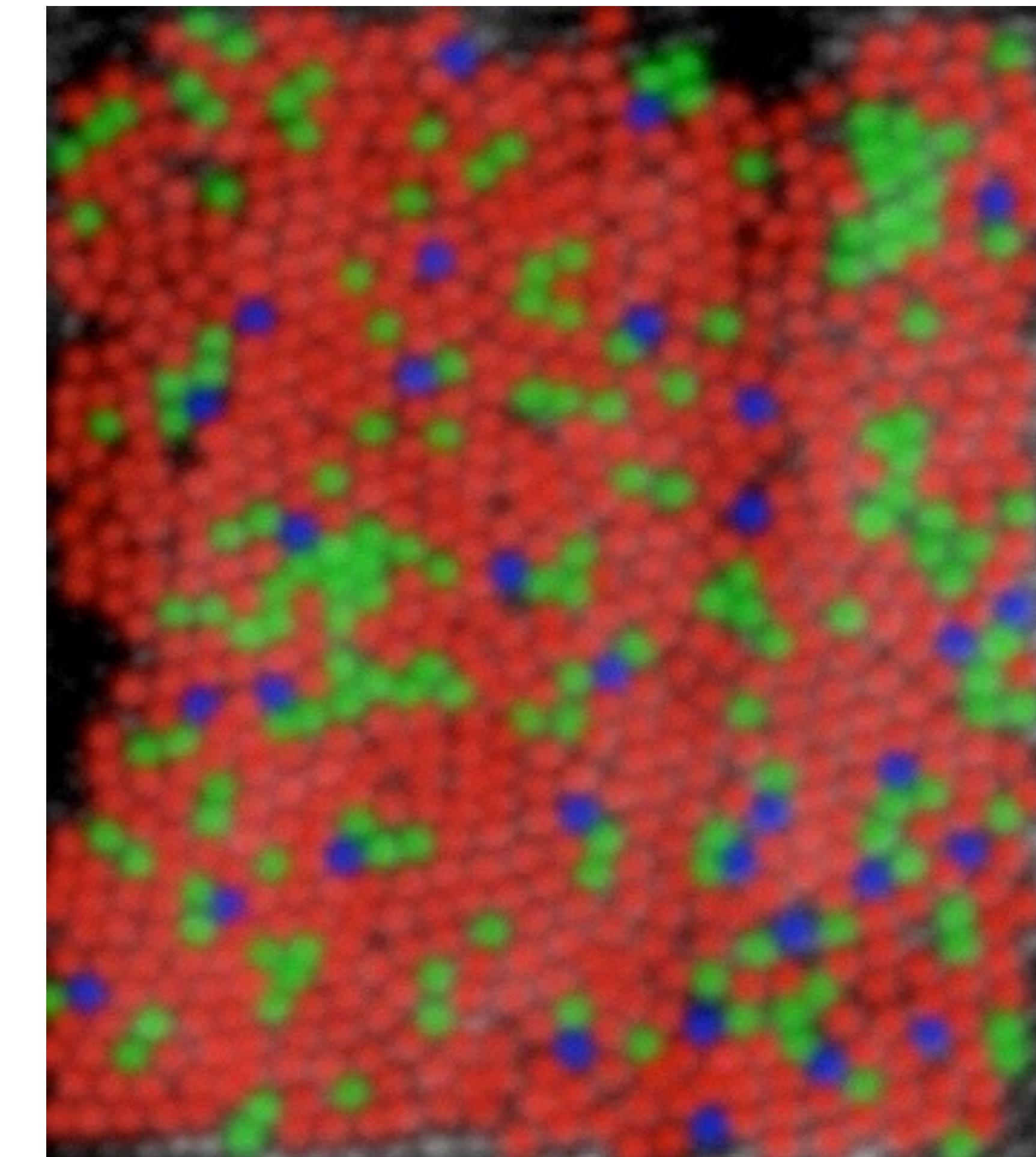
Cones

Ganglion Cells



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)

Human Visual System

6.5 mio cones

color vision

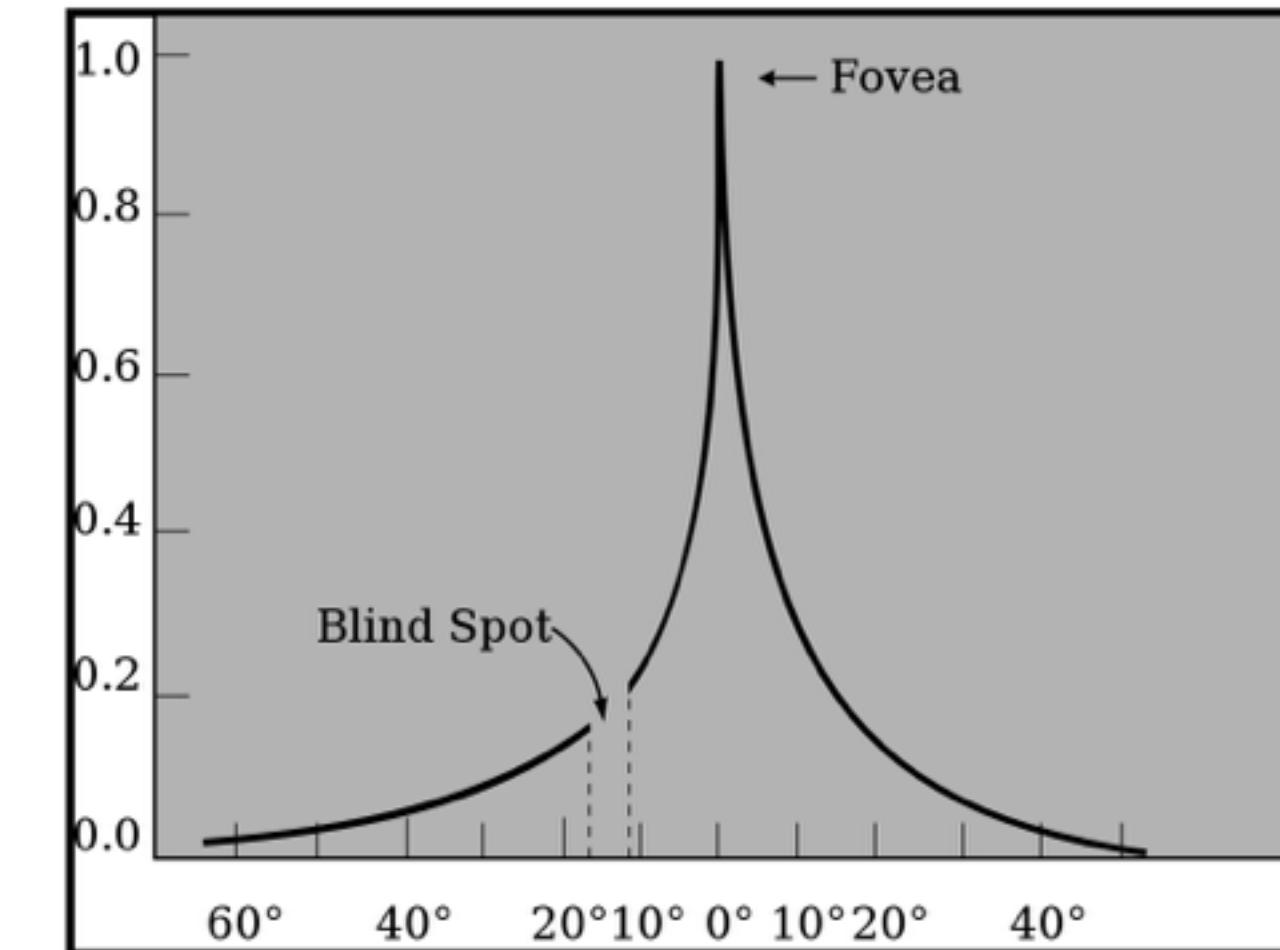
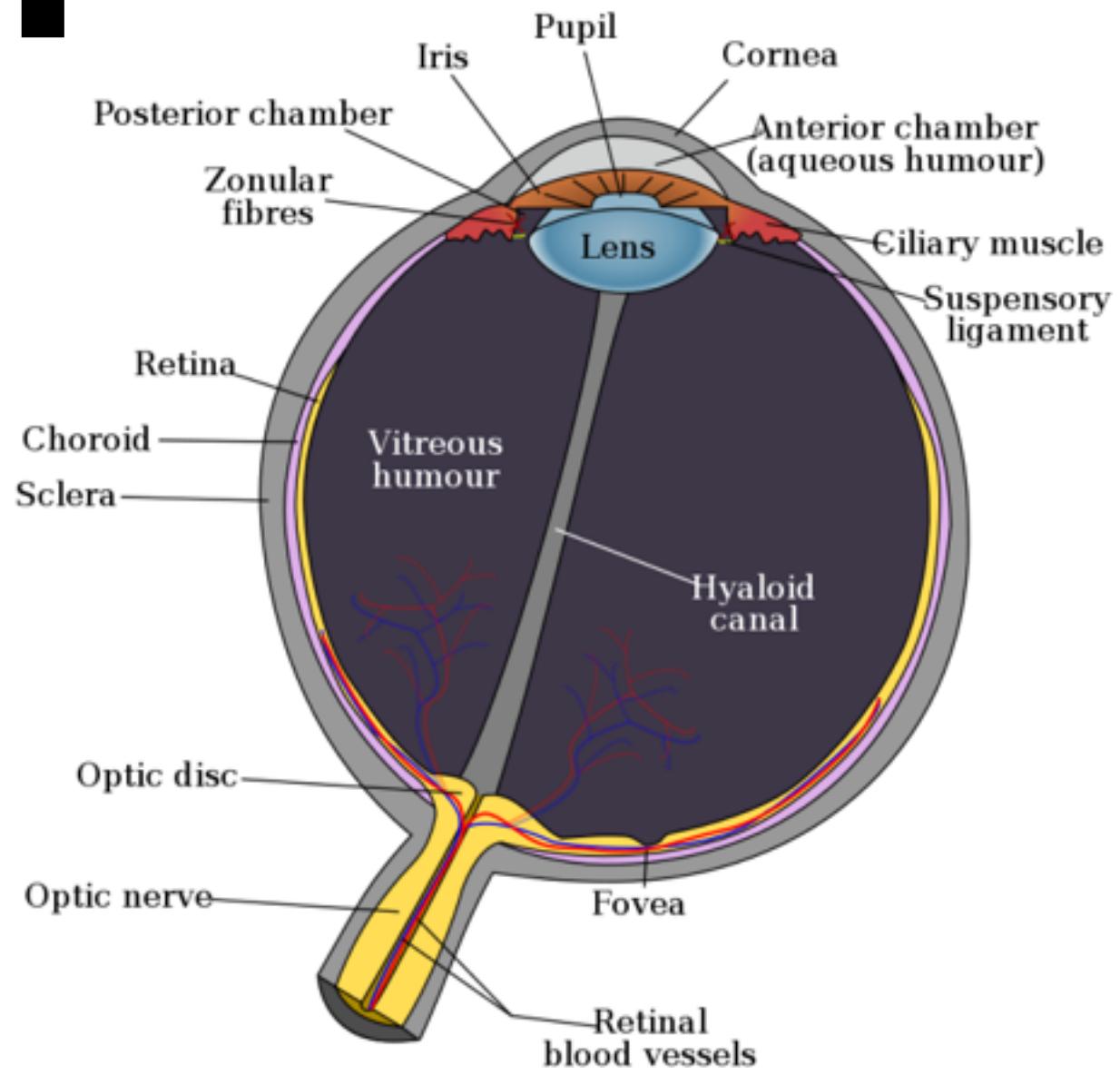
dense in the center

Fovea: 27 times the density

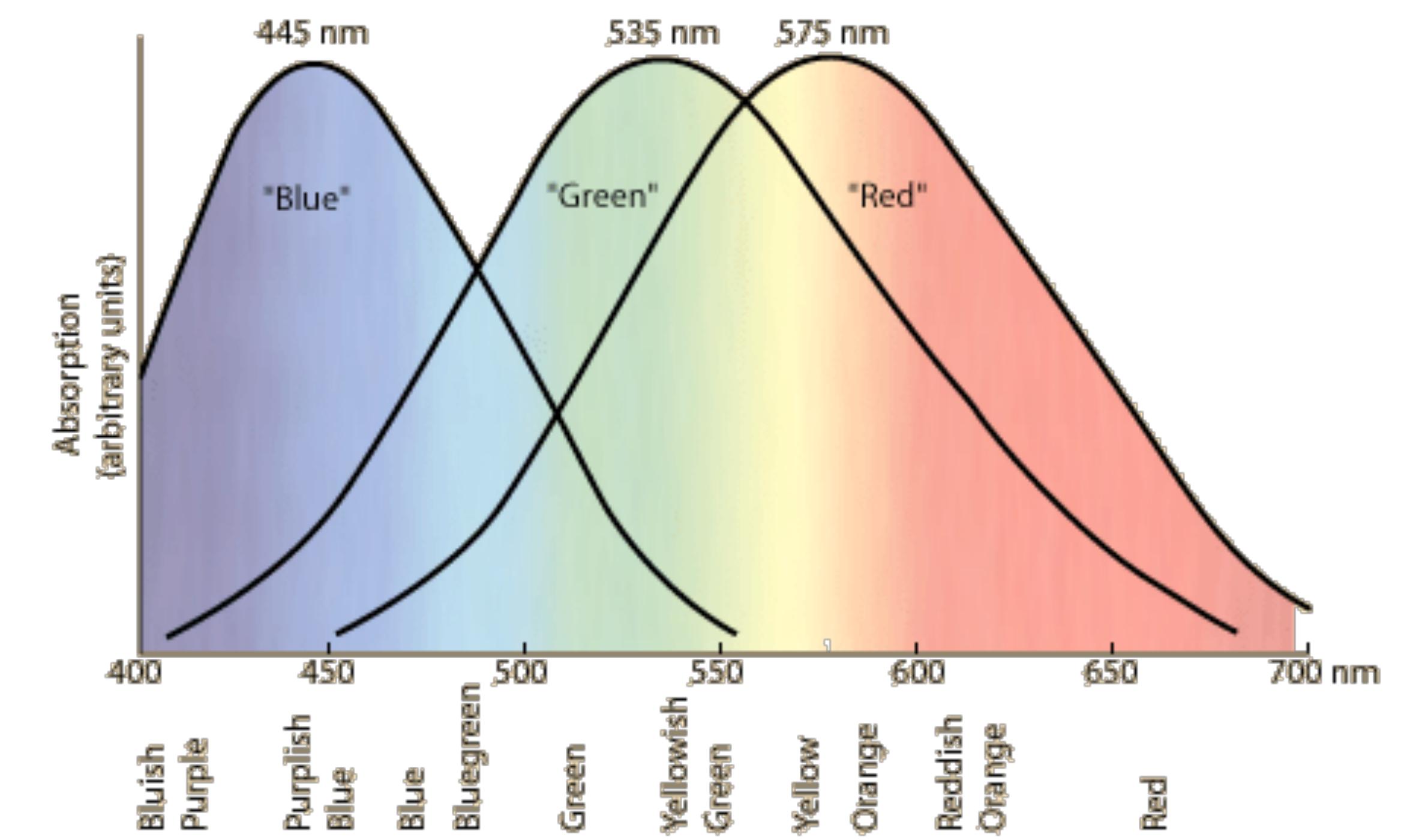
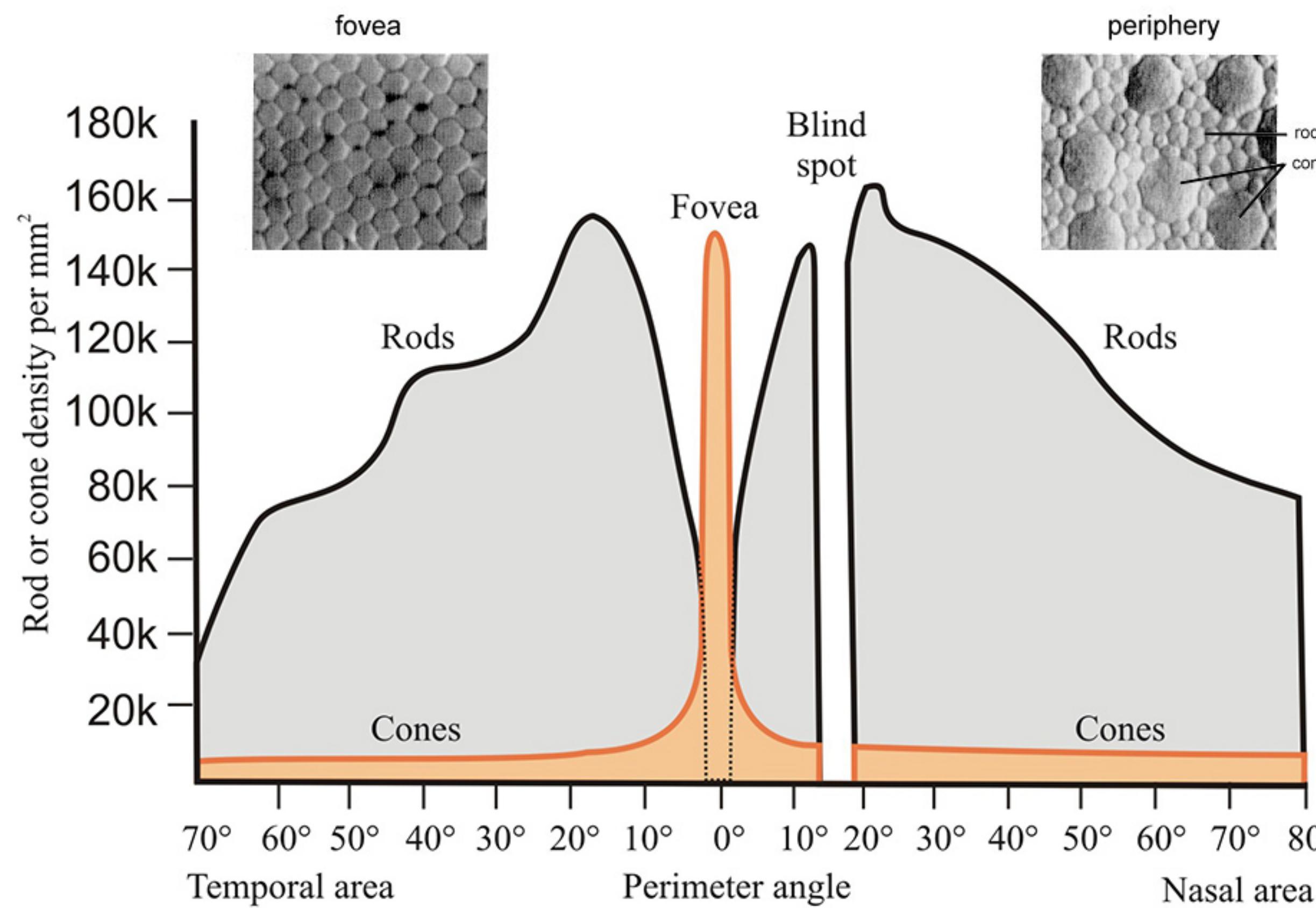
responsible for sharp central vision

118.5 mio rods

black/white



Cone Response



Category	Count	Percentage	Total
100-199	1,000	20.0%	5,000
200-299	1,800	36.0%	9,000
300-399	1,011,837	20.8%	4,874,900
400-499	29,112	24.9%	640,560
500-599	23,953	22.7%	63,184
600-699	30,652	24.5%	62,944
700-799	56,418	26.7%	416,081
800-899	5,278	17.3%	8,252
900-999	3,545	19.8%	13,930
1,000+	1,000	20.0%	5,000
Total	5,000	100.0%	25,000

Human Visual System

Vision works as sequence of fixations and saccades

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

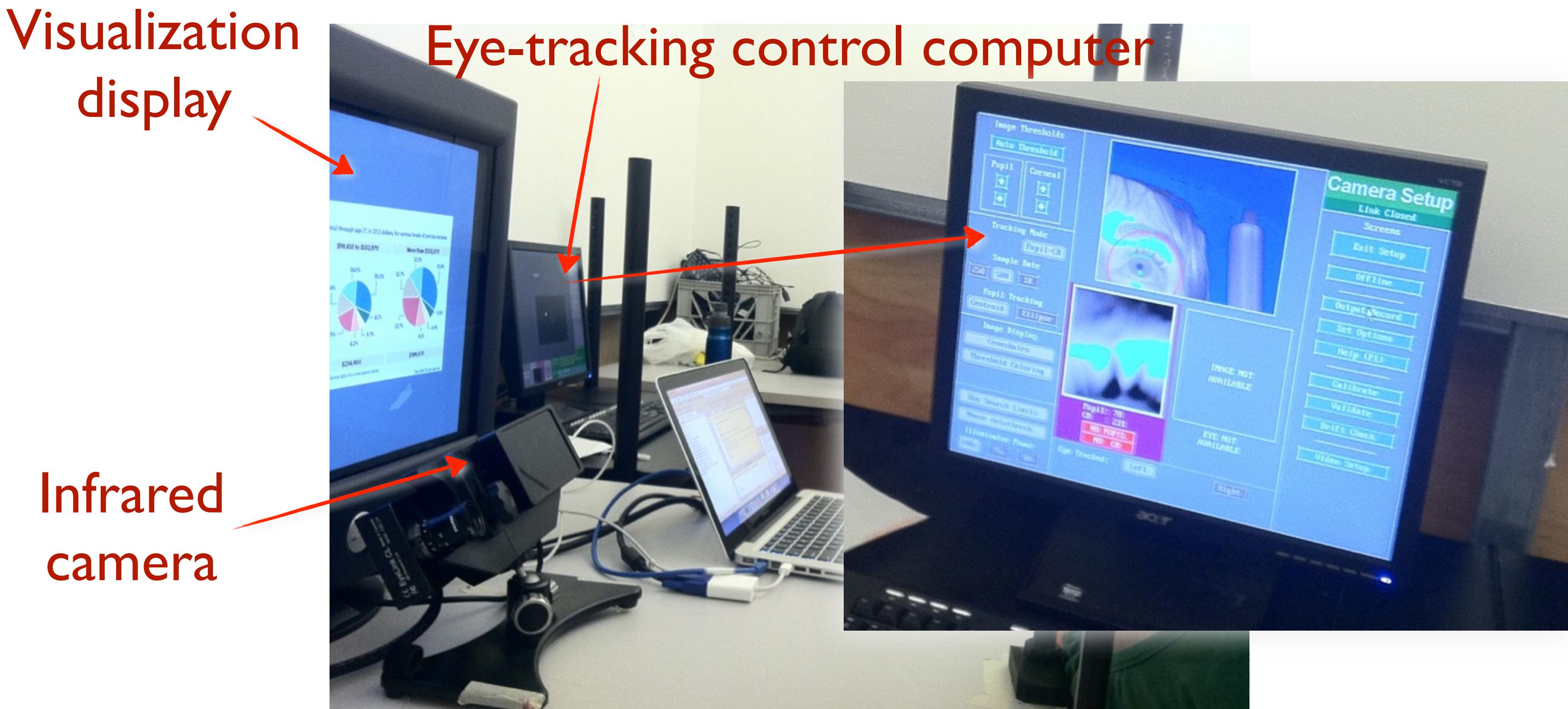
saccades: moving between different locations (20-100 ms)

Vision not similar to a camera

More similar to a dynamic and ongoing construction project



Eye-Tracking Experiment



Video!

Human Visual System

VIDEO!

No general purpose vision

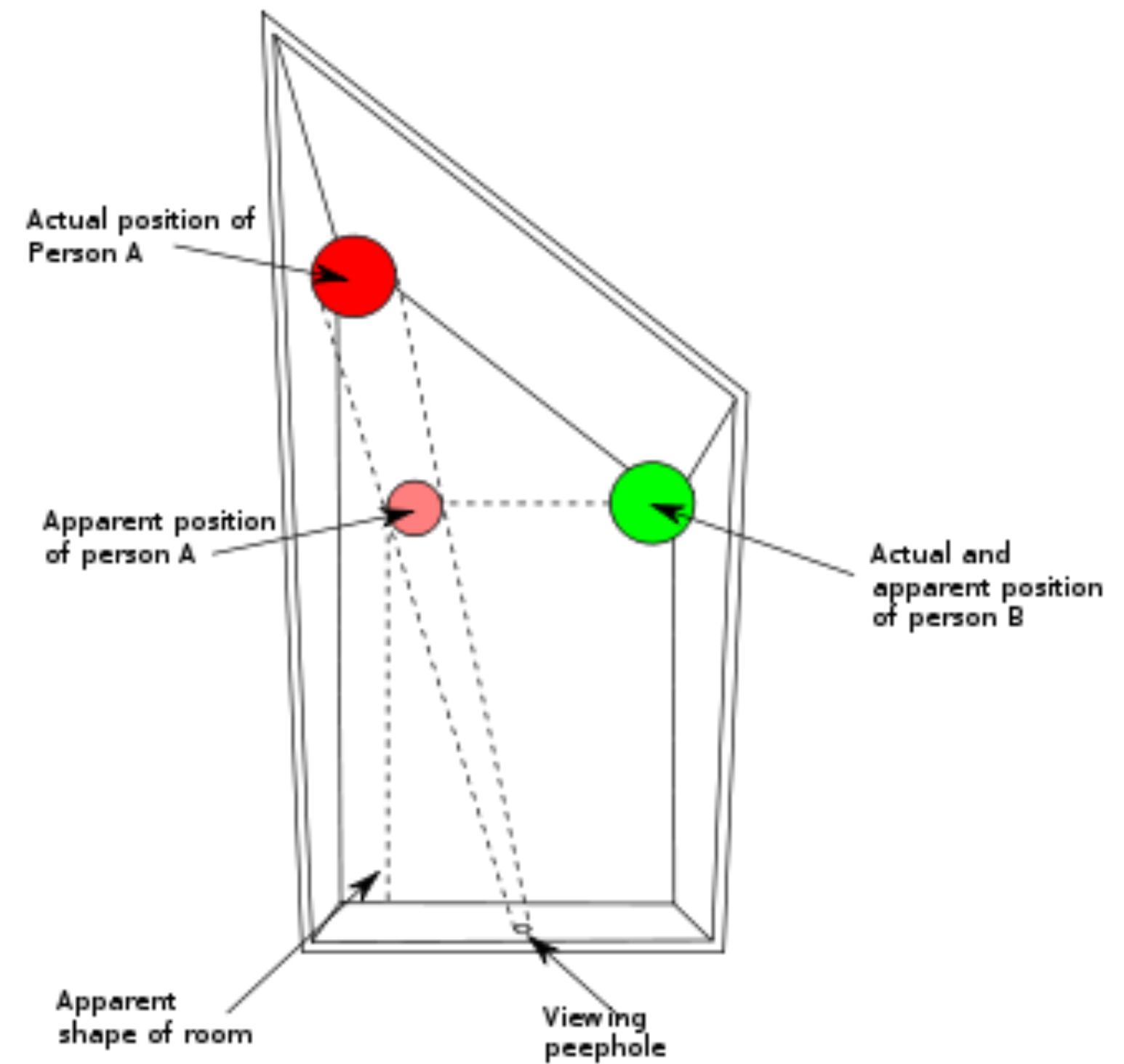
What we see depends on our goals and expectations

Relative judgments: strong

Absolute judgments: weak



Ames Room



Color

Color Basics

Visible part of the electromagnetic spectrum

390-750 nm

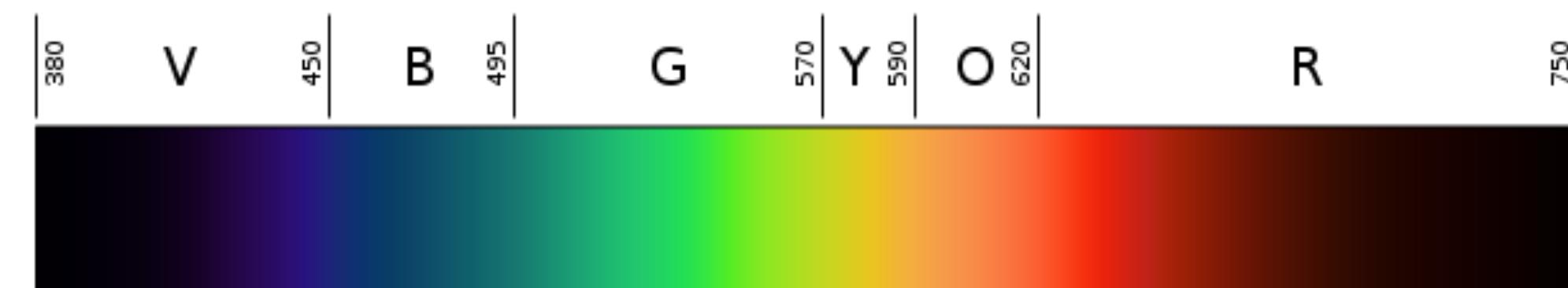
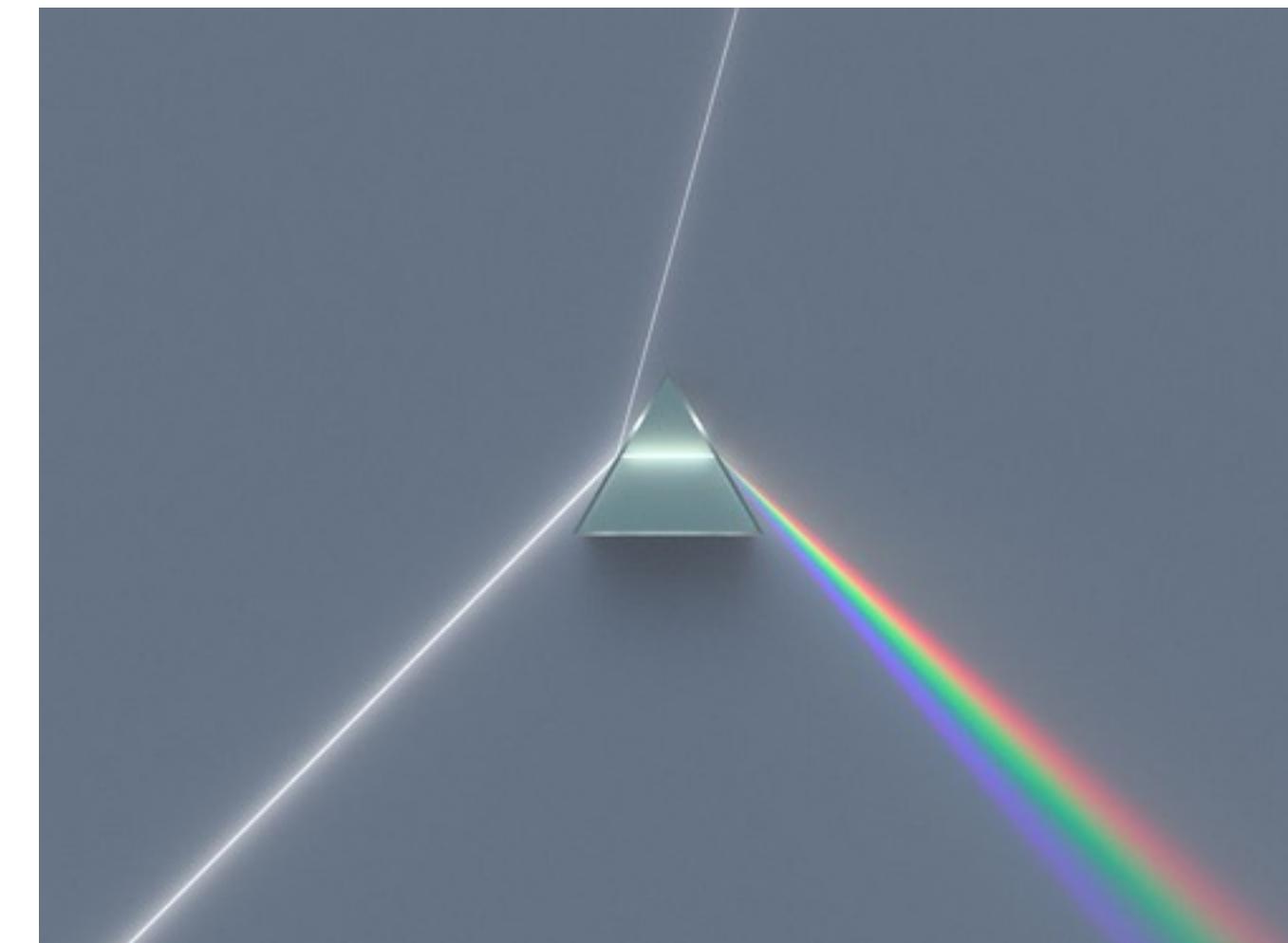
Spectral colors

evoked by a single wavelength

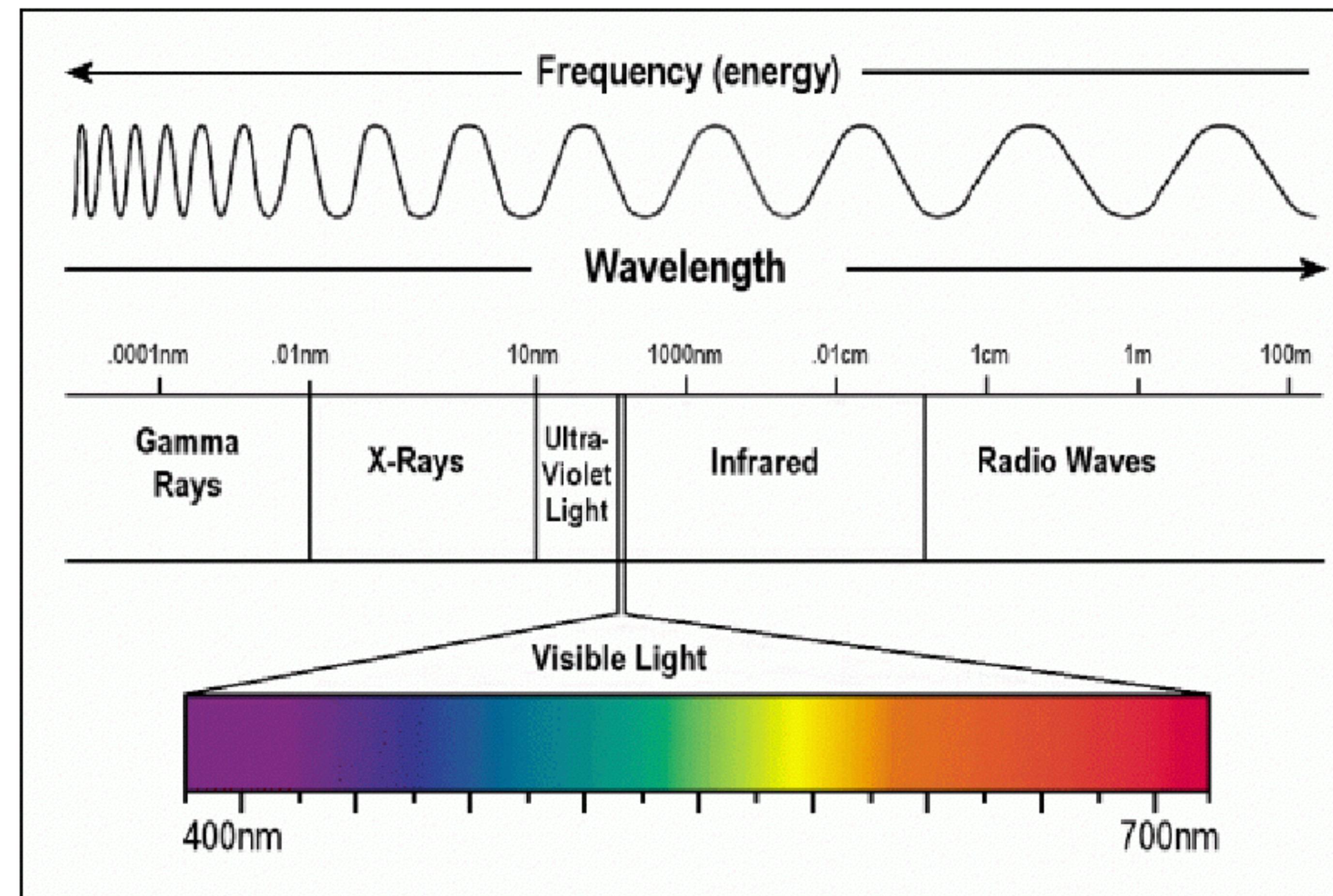
Other colors: unsaturated colors

Gray scale (achromatic colors)

Mix of multiple wavelengths
e.g. purple, magenta

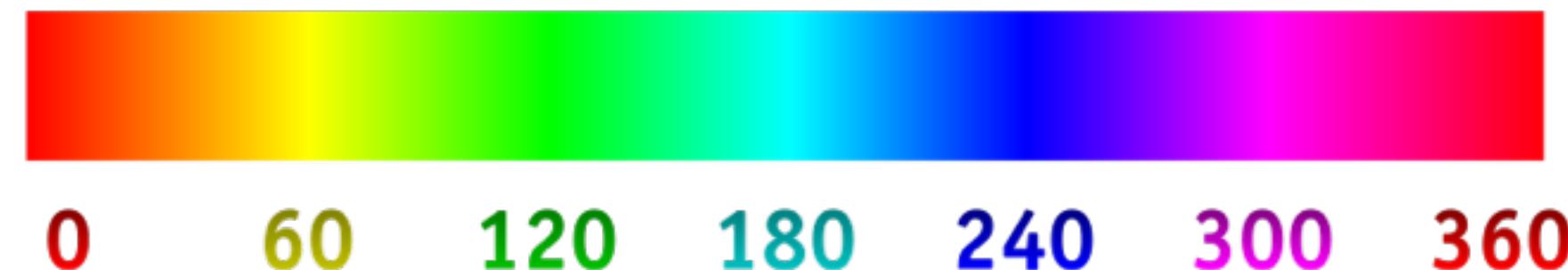


Visible Spectrum



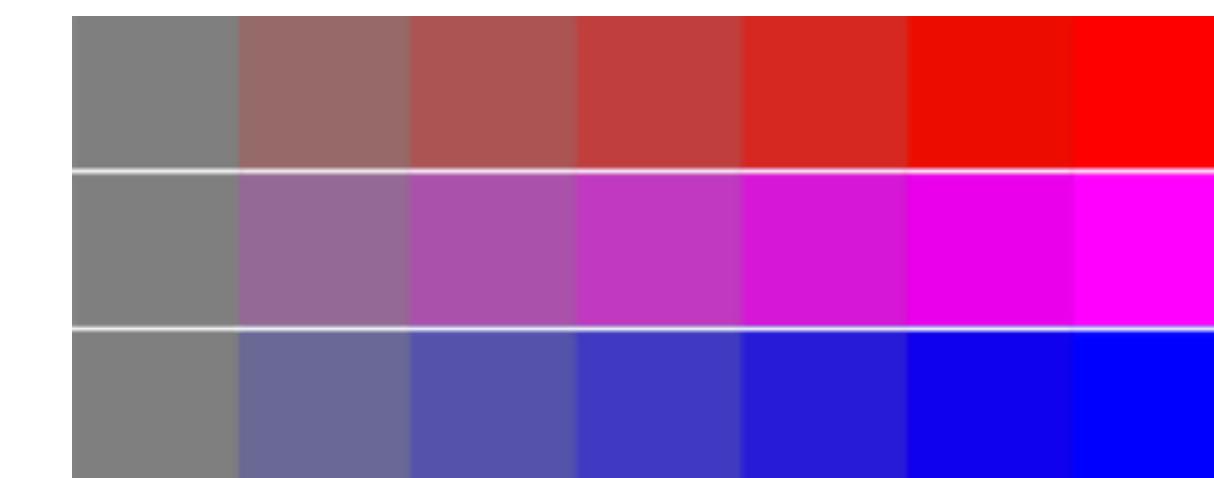
Dimensions of Color

Hue



Saturation

The purity of a color



Value (Luminance, Brightness)

lightness or darkness of a color

high saturation colors have medium values

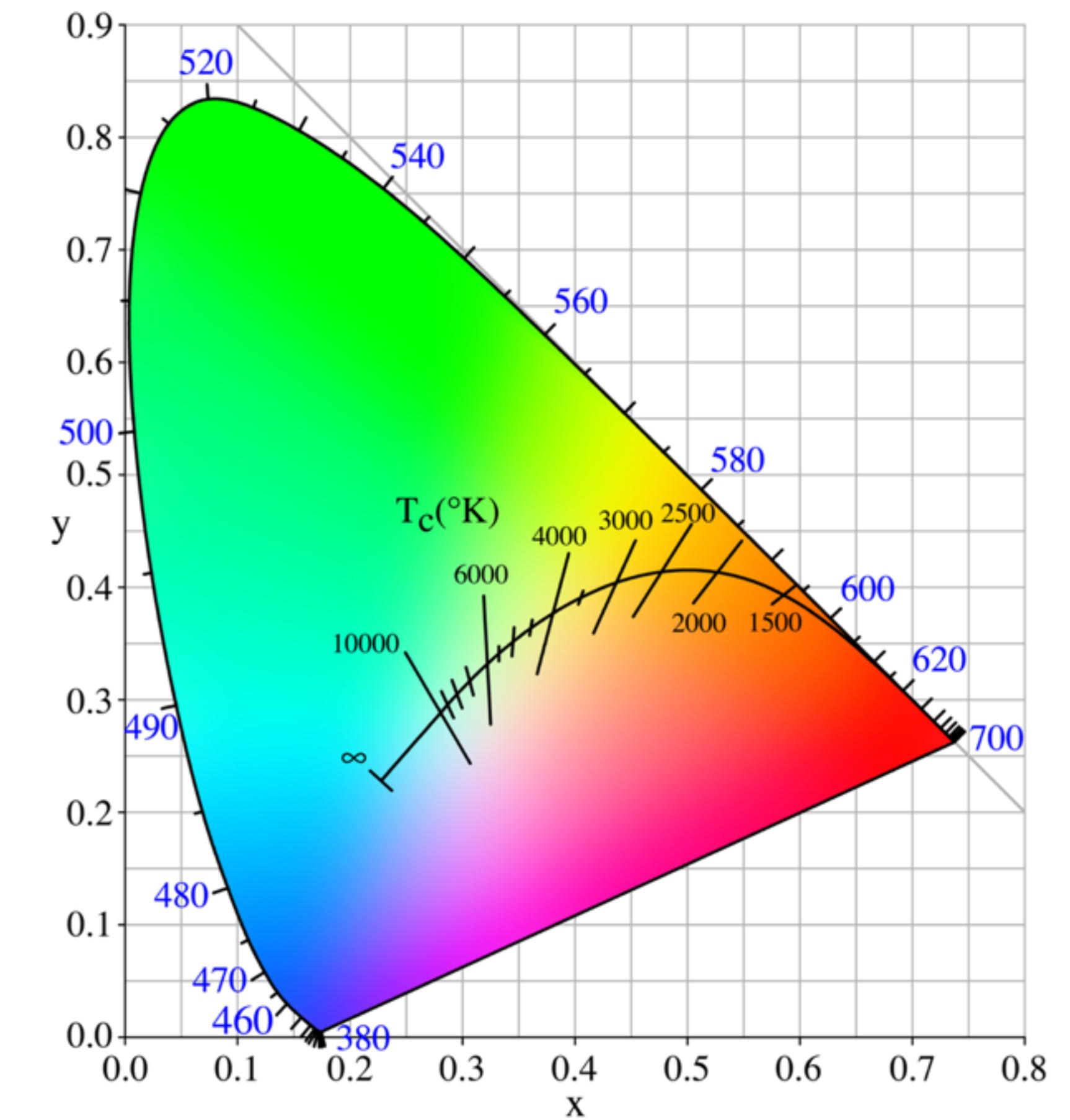


CIE Color Model

Chromaticity Diagram

Specifies color by hue and saturation

Pure colors of visible spectrum along
the curve (wavelength)

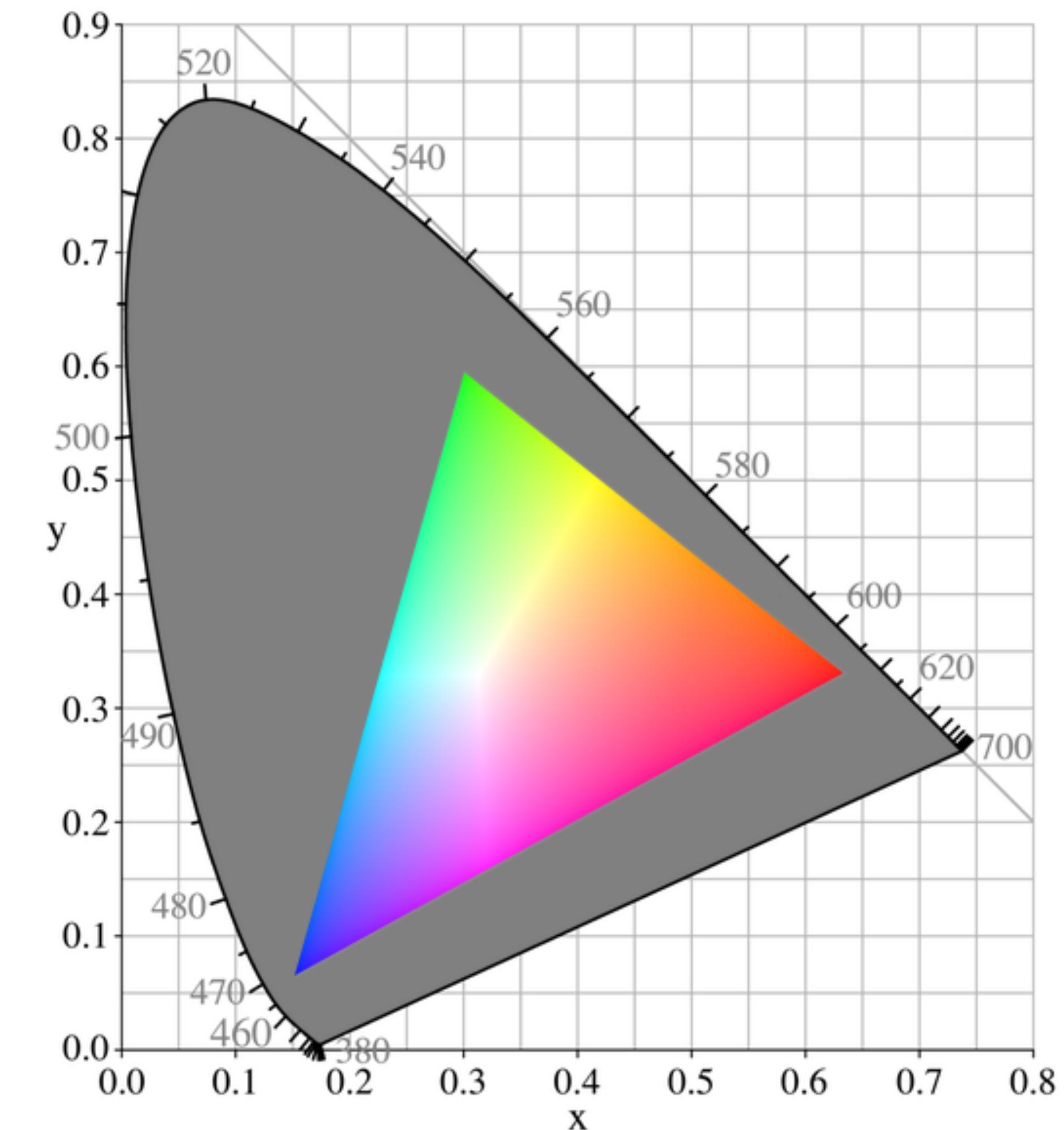
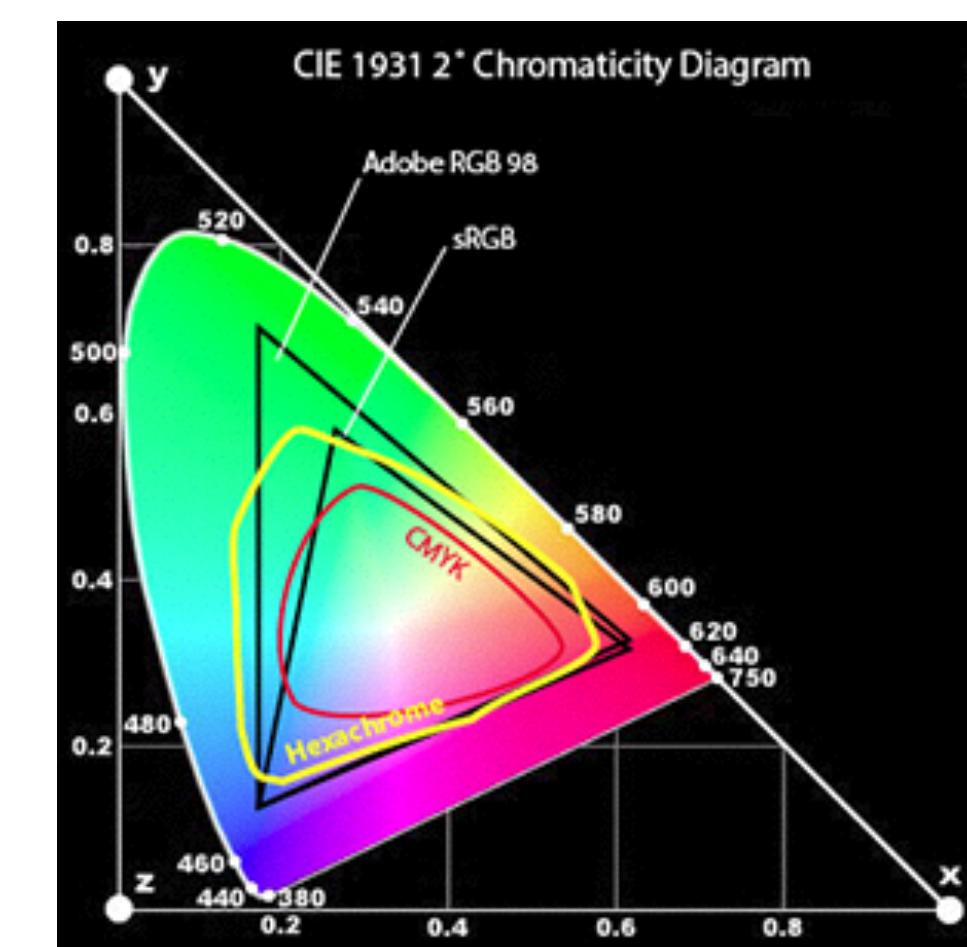


Gamut

Set of all colors that can be produced by a device

Area between the primary colors used can be shown

Primaries are arbitrary



Color Composition

Additive (e.g., RGB)

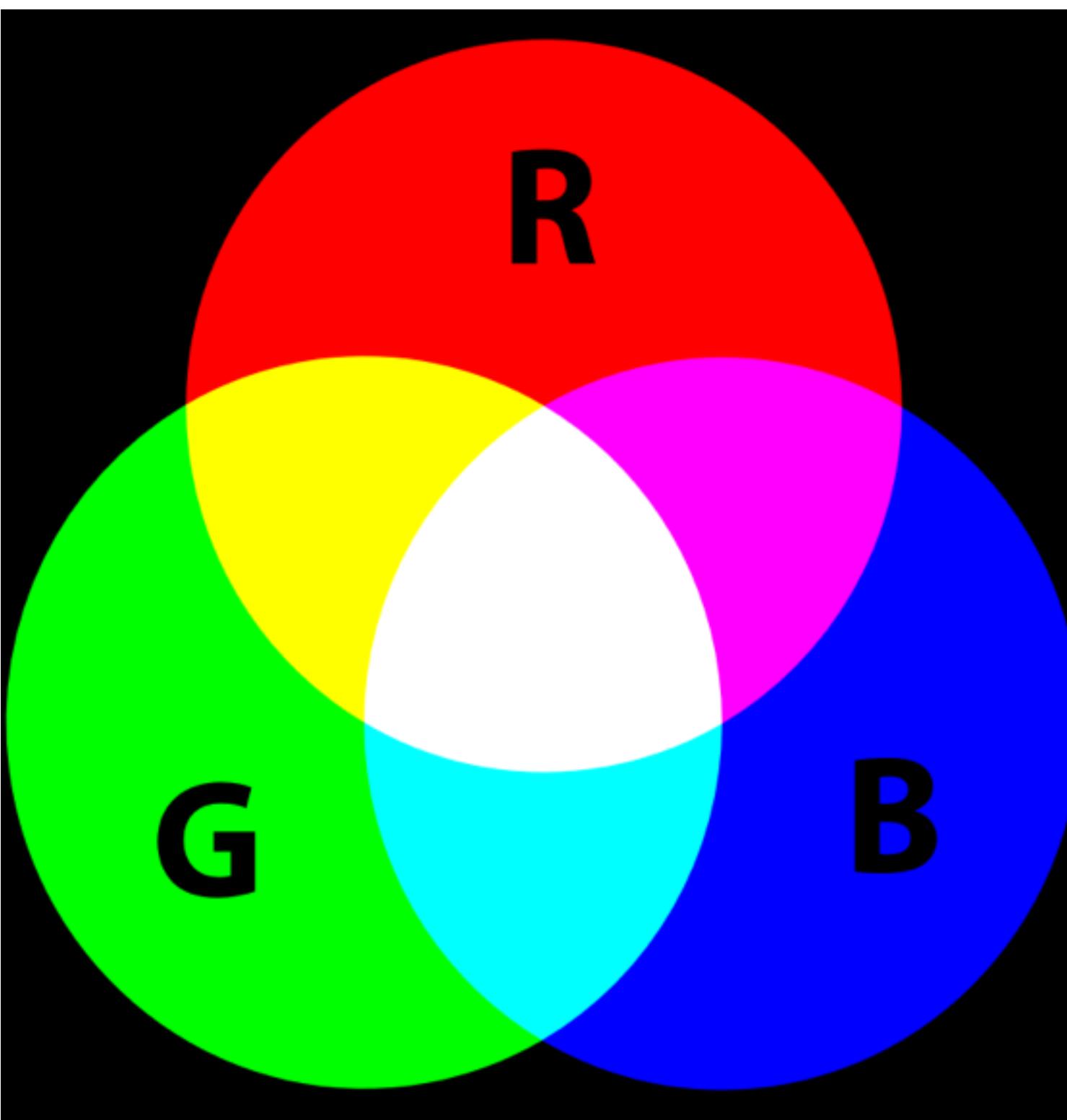
light

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

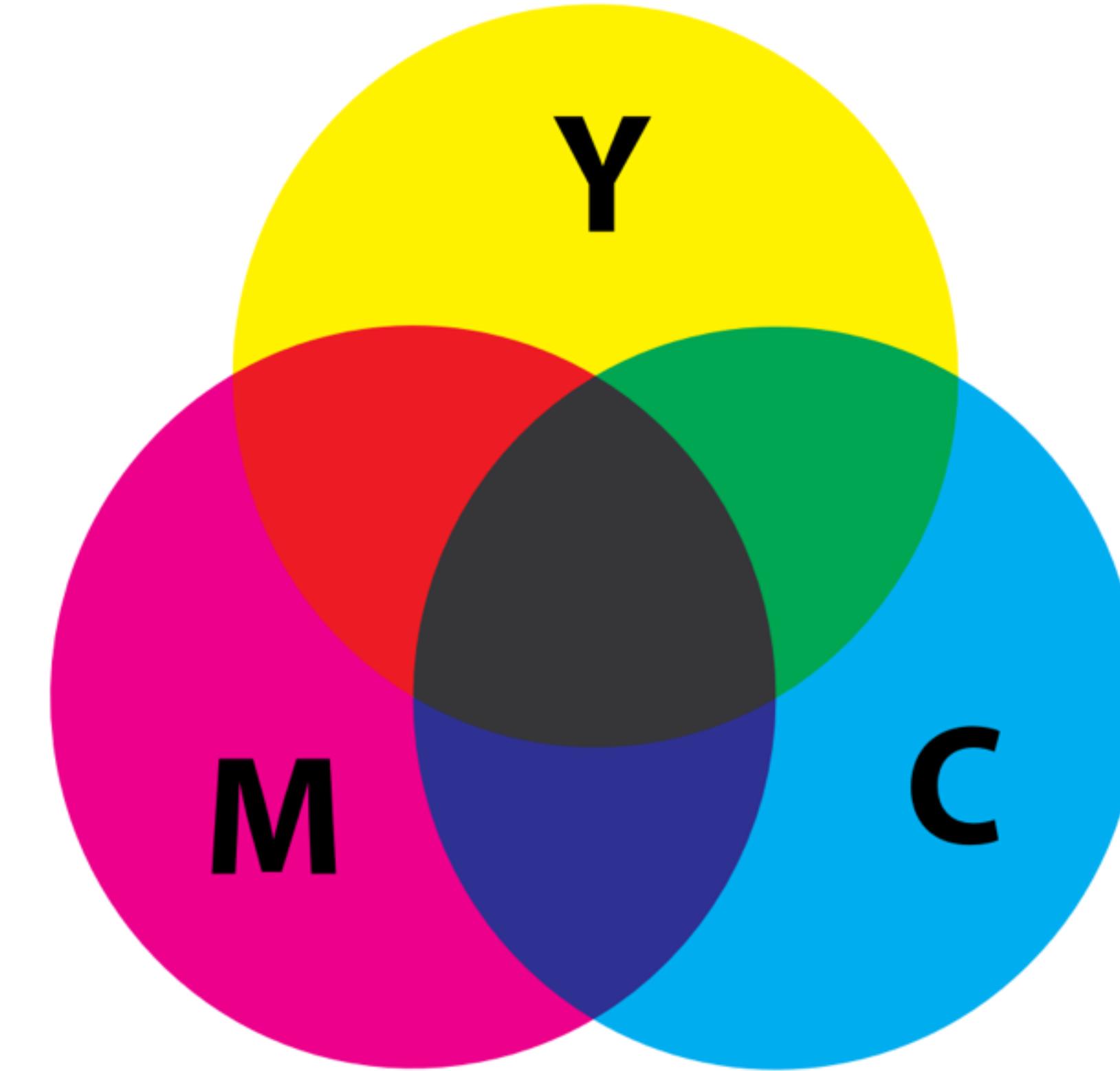
Subtractive

pigment (e.g., CMYK)

Additive / Subtractive Color

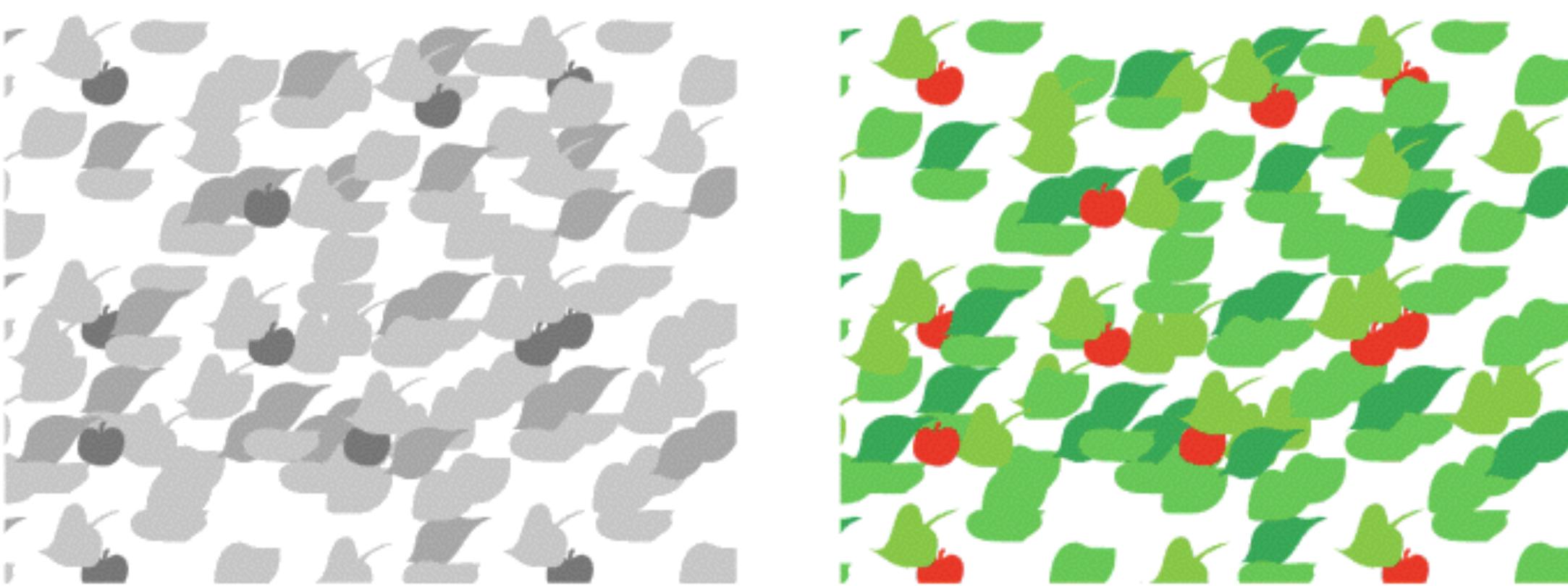


Add colors by adding light of certain wavelength



Subtract colors using pigments, inks by absorbing light

Color



Color vision is irrelevant to much of normal vision!

does not help to perceive layout of objects

how they are moving

what shape they are

Color breaks camouflage

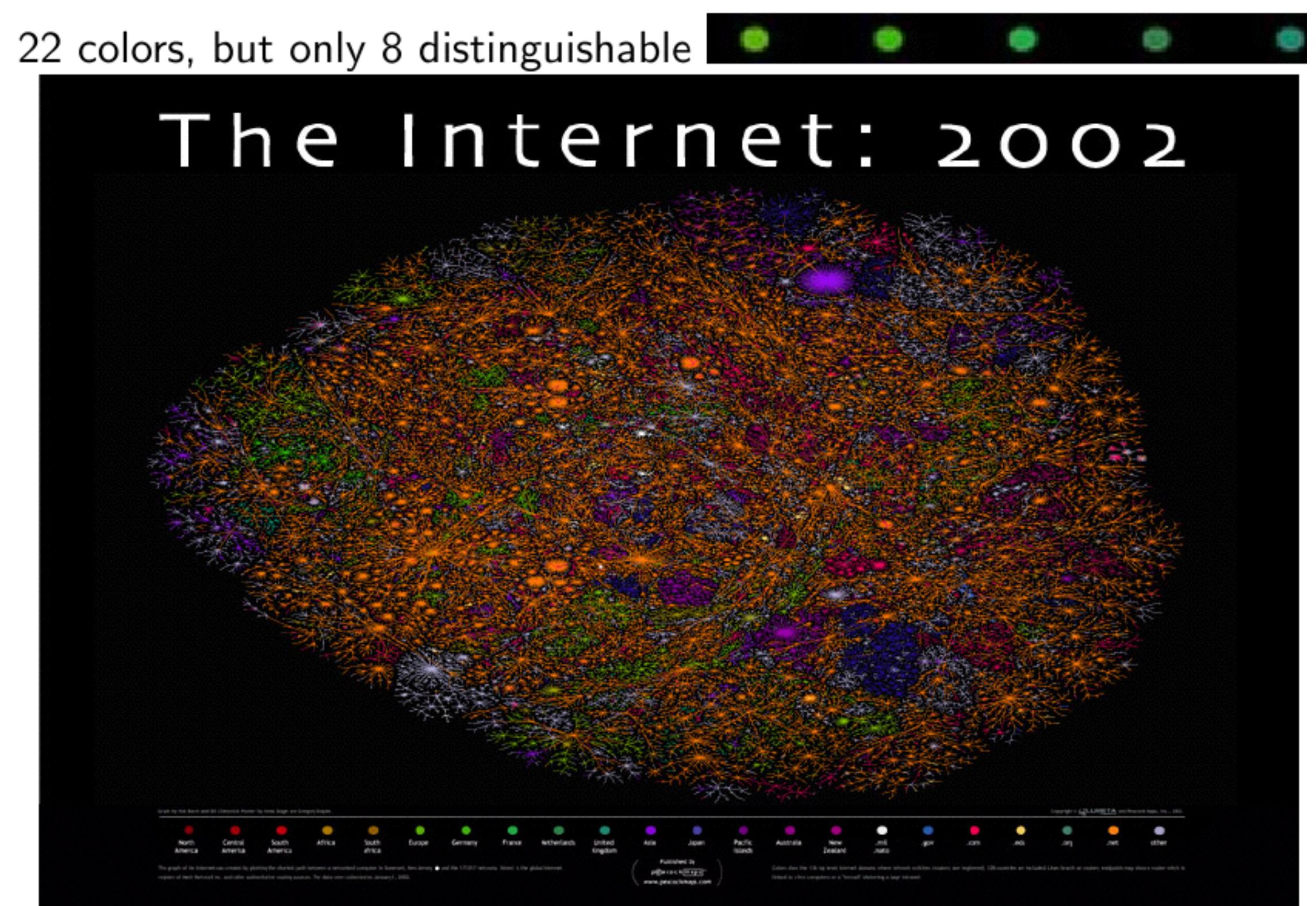
Tells about material properties (judging quality of food)

Qualitative Data Vis

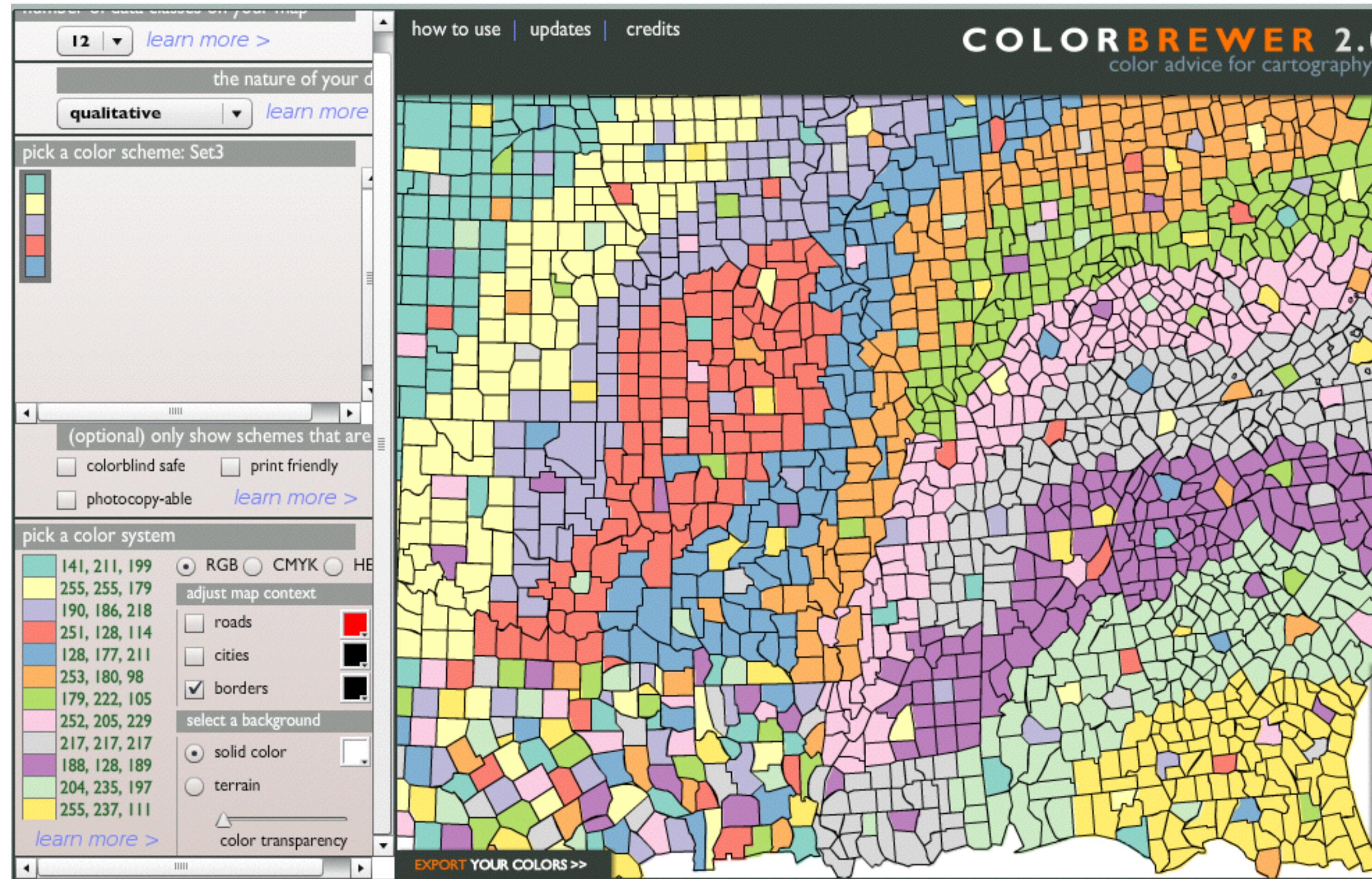
Color labeling (nominal information coding)

recommended: about 6, no more than 10

22 colors, but only 8 distinguishable



Application: Labeling



Carefully designed color scheme for 12 colors [colorbrewer]

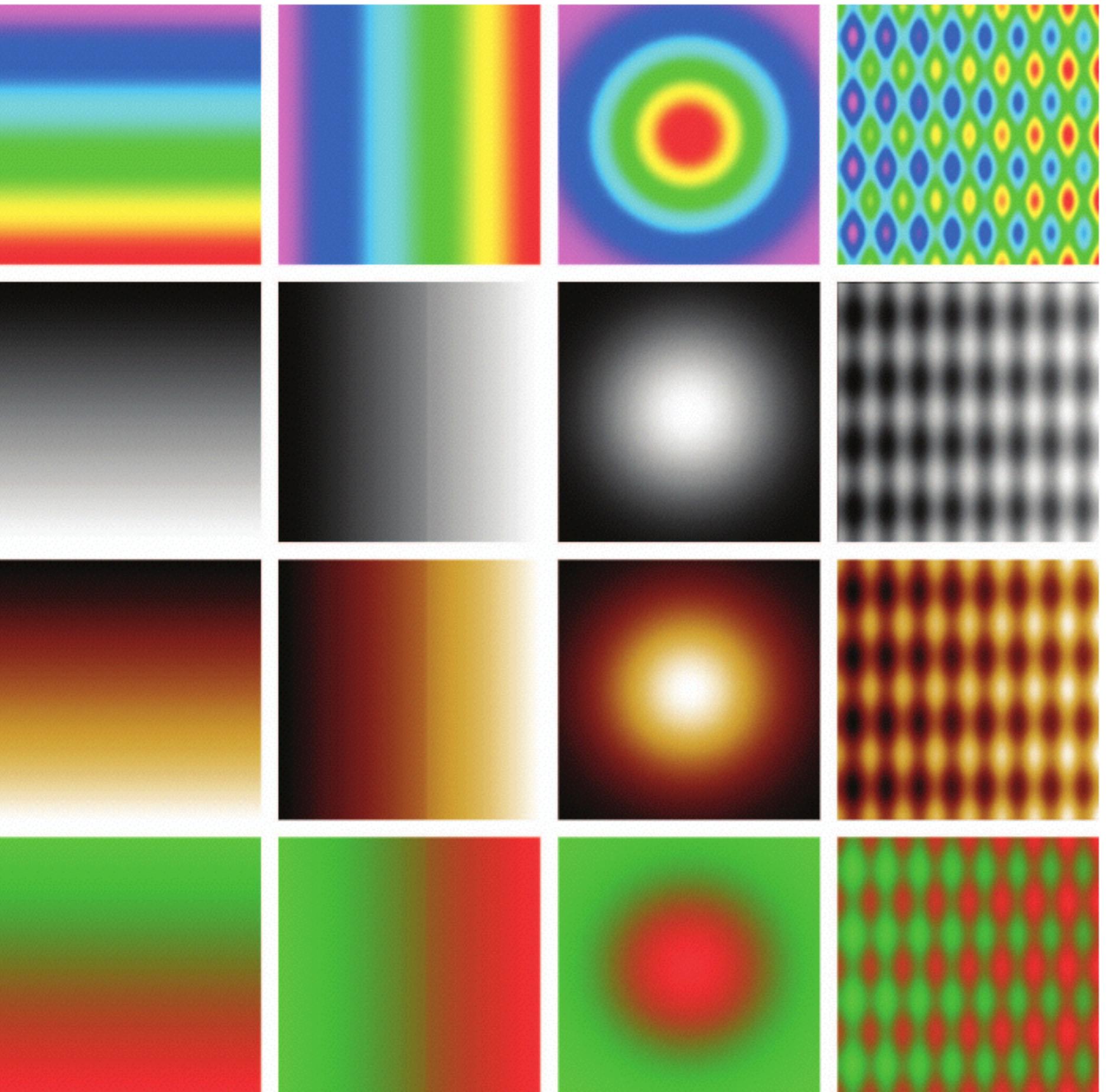
Quantitative Data Vis

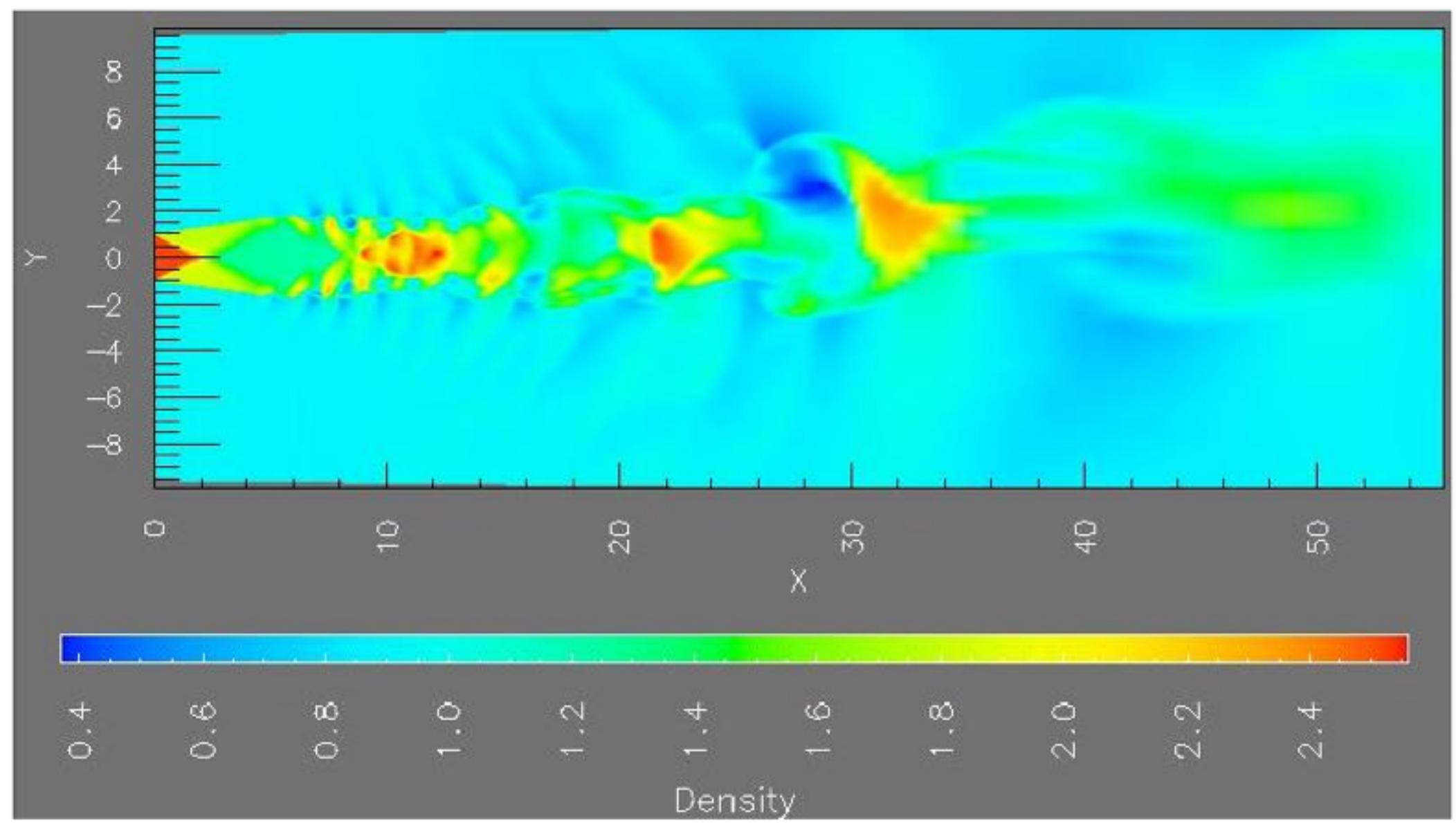
use value

saturation works but not as good

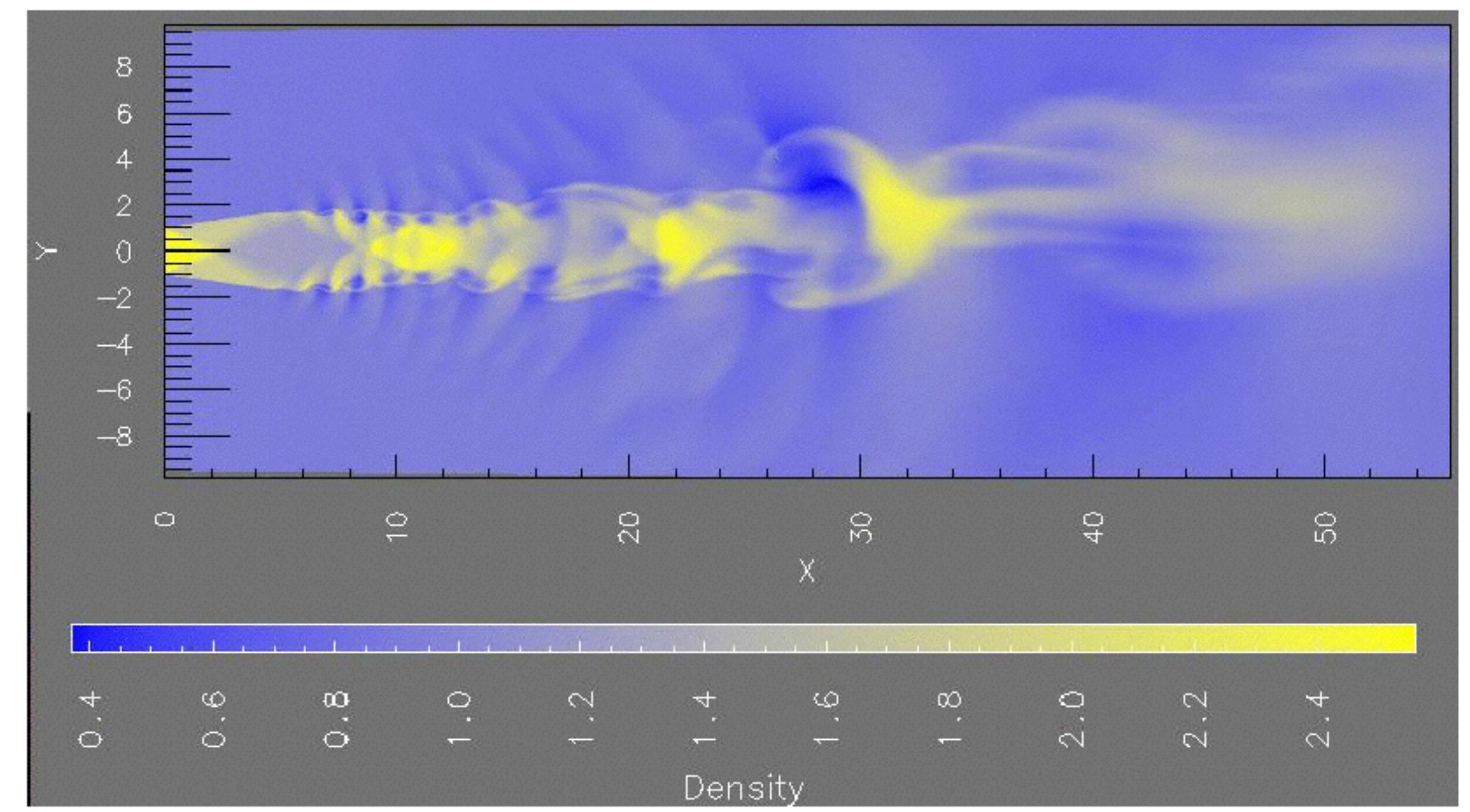
don't use hue!

Danger: rainbow color map



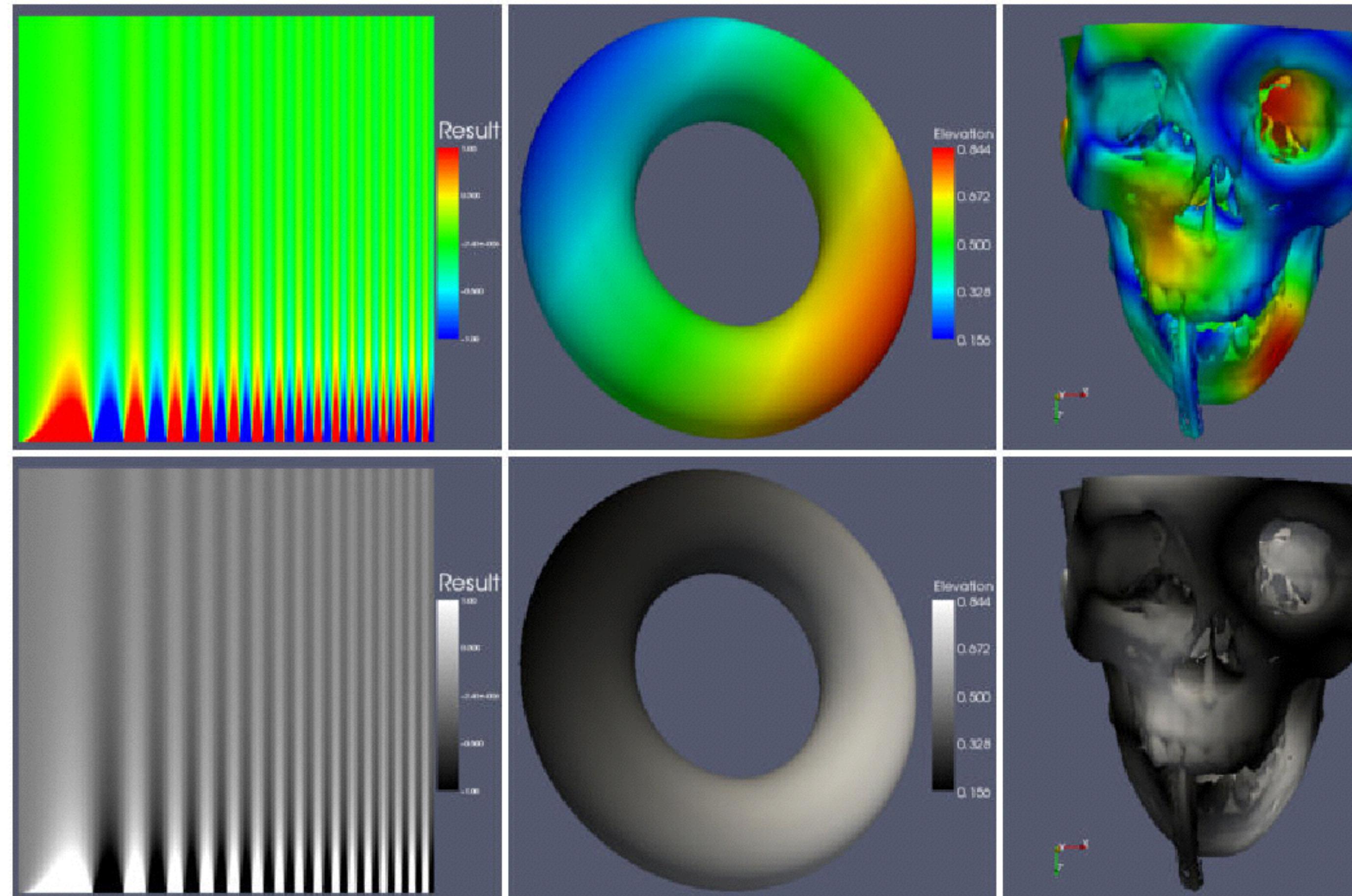


[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color? <http://www.research.ibm.com/people/l/lloydt/color/color.HTM>]

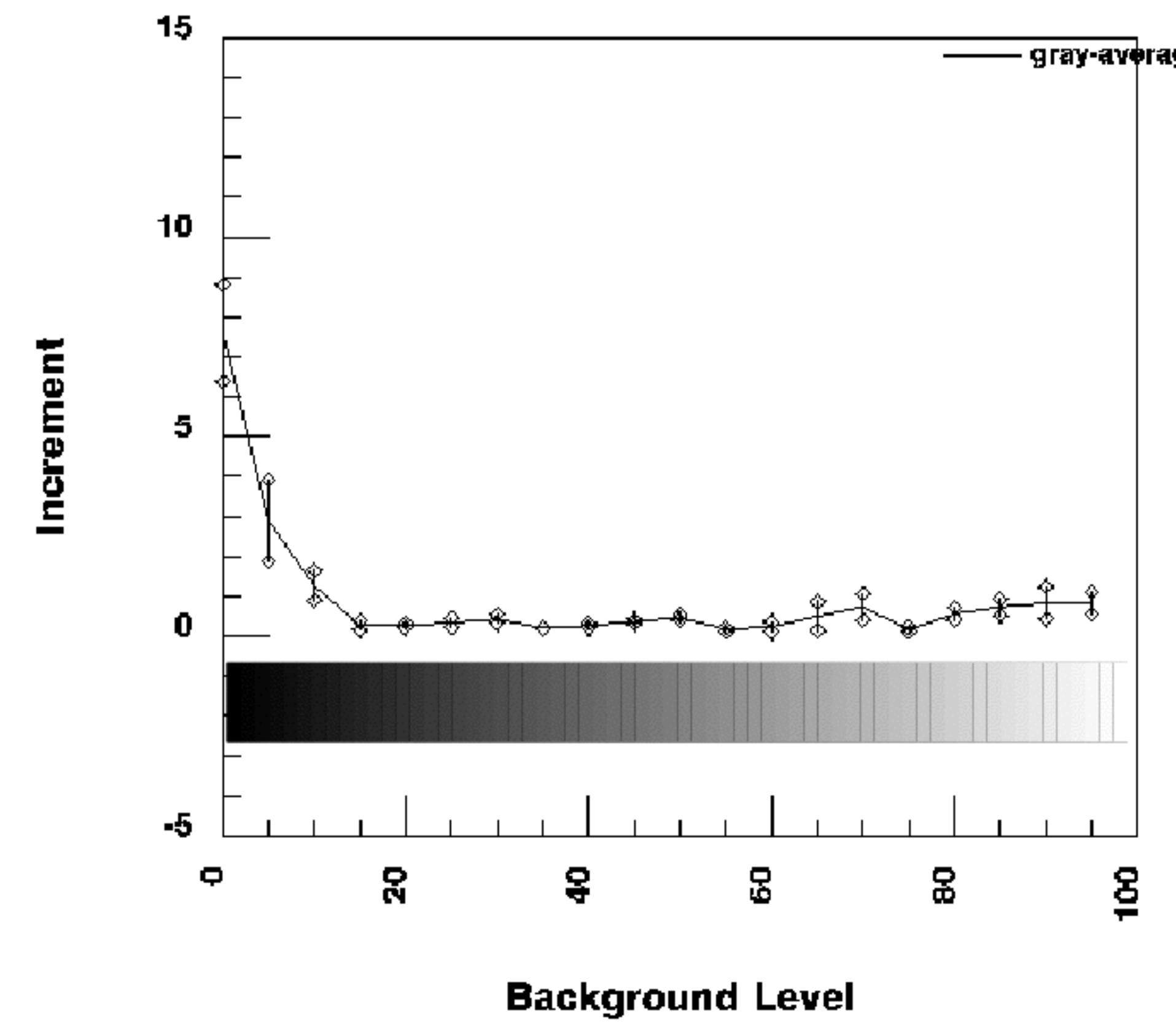
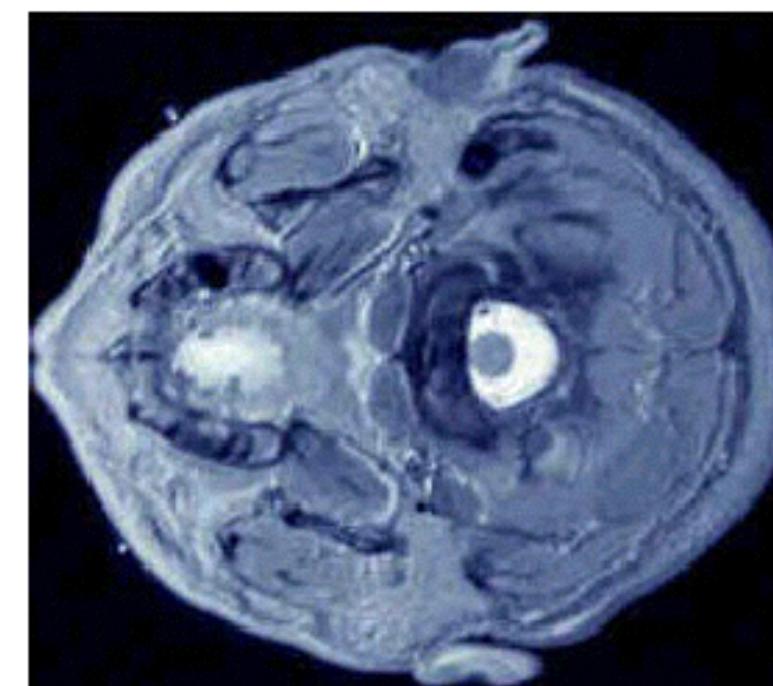


[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm]

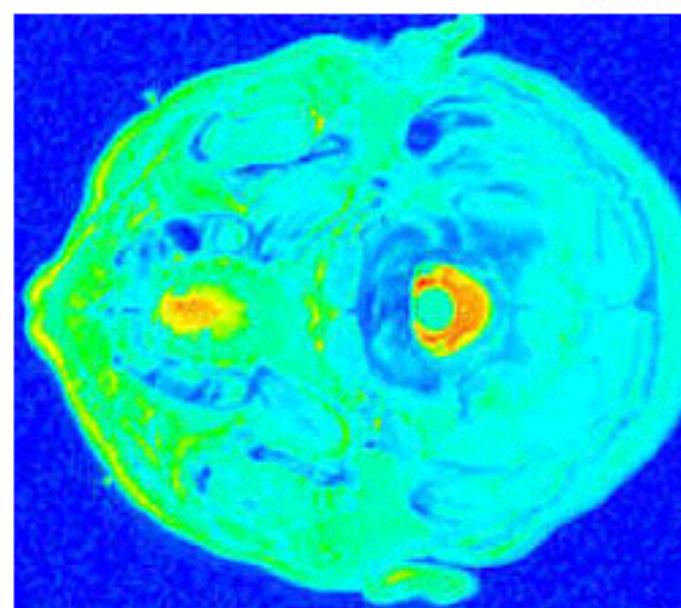
Rainbow vs. Value Color map



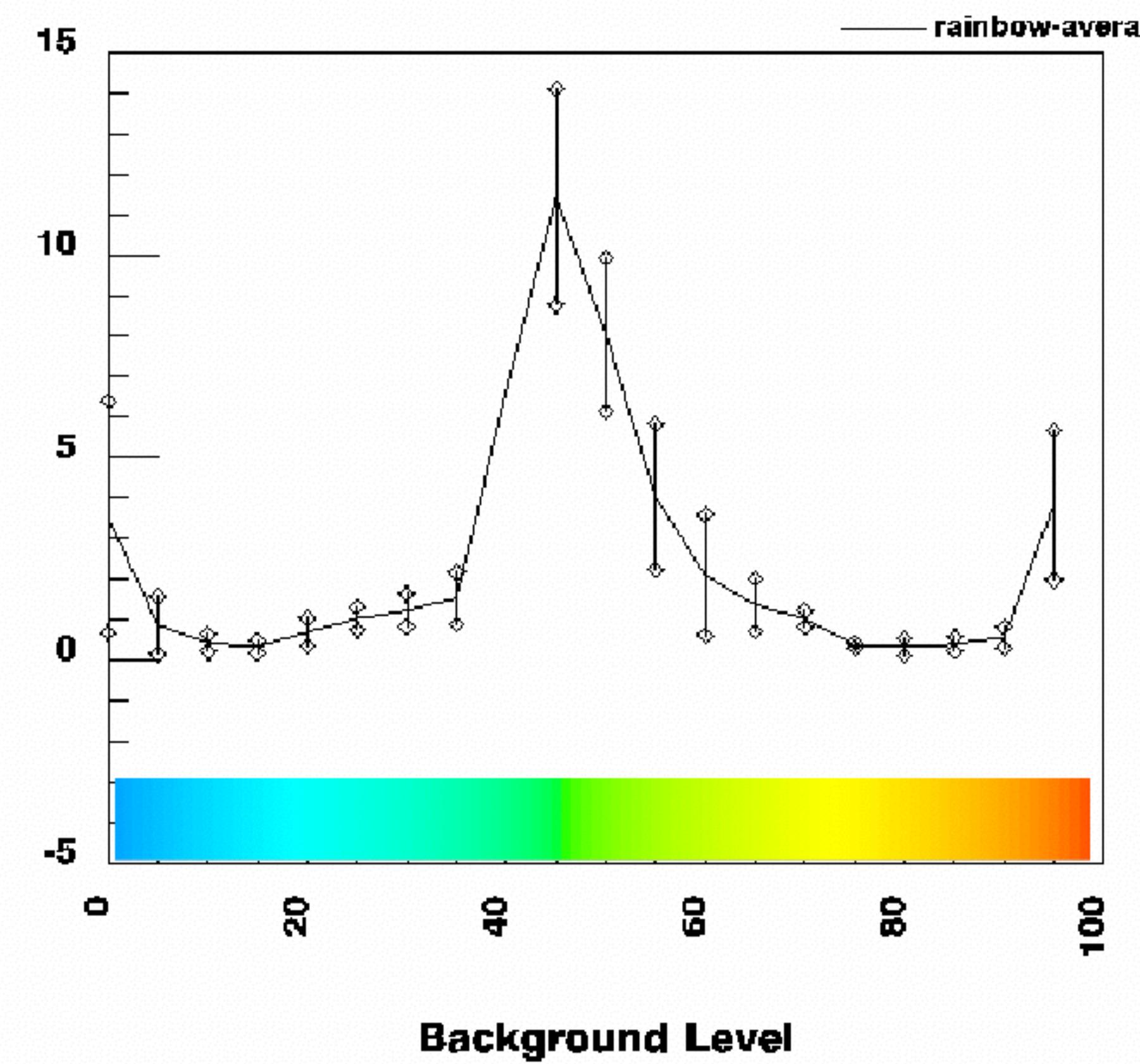
Increment Threshold Experiment: Luminance



Increment Threshold Experiment: Rainbow Color Scale



Increment



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)

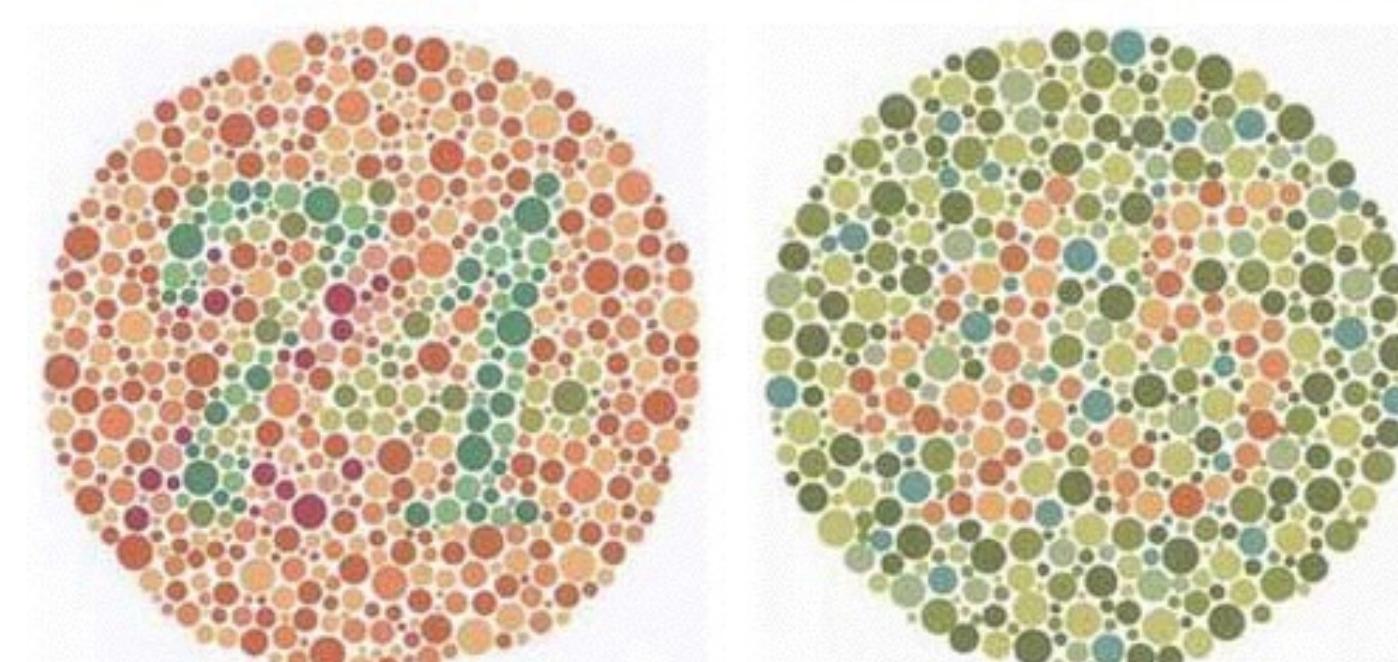
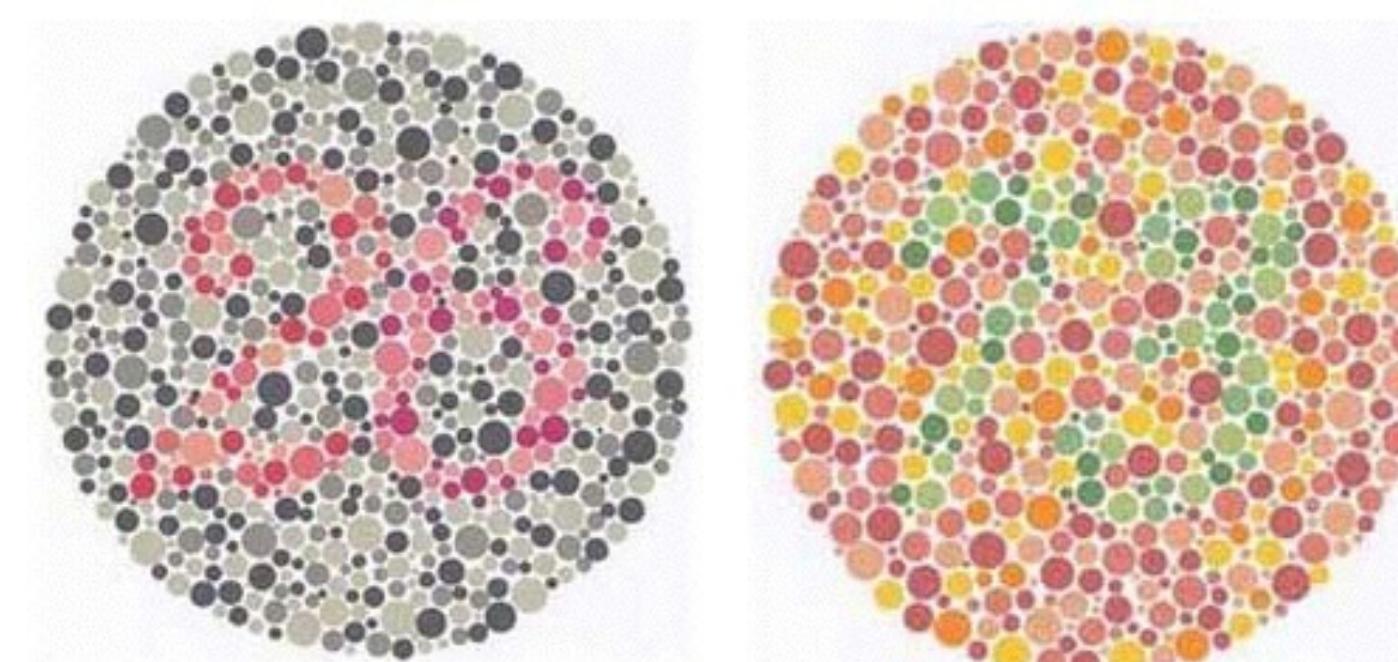
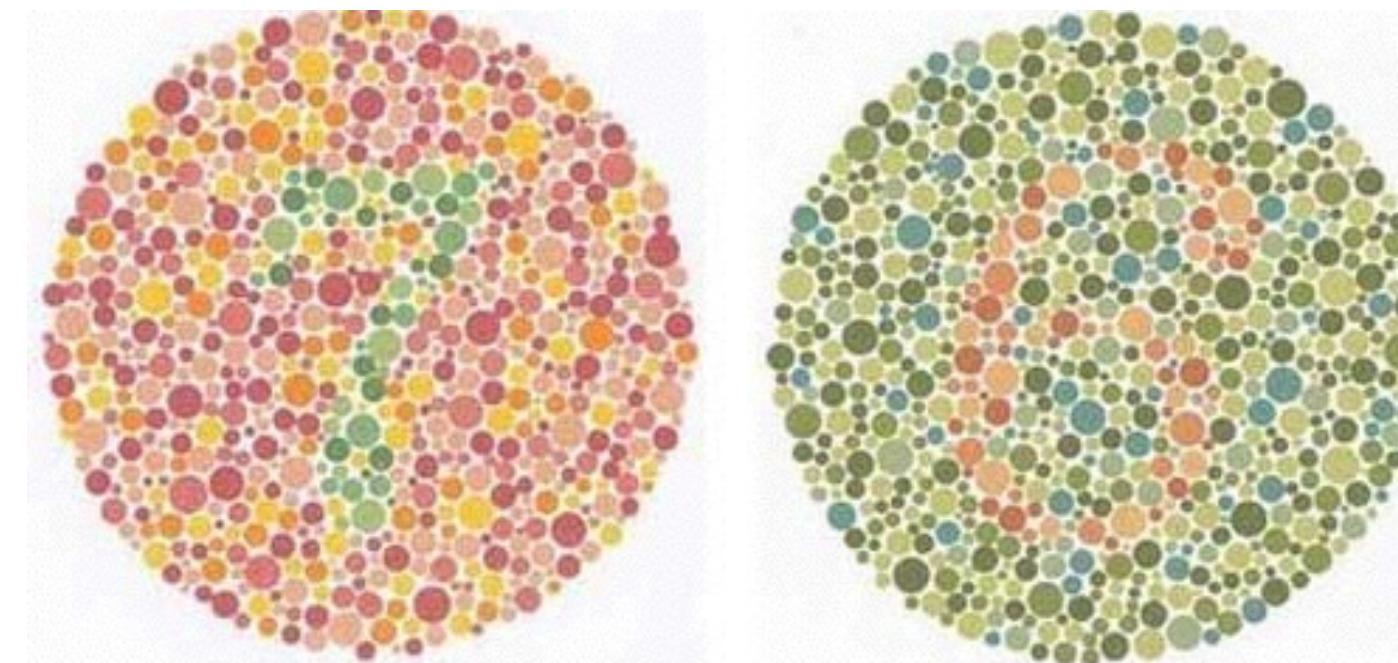


Normal Color Perception

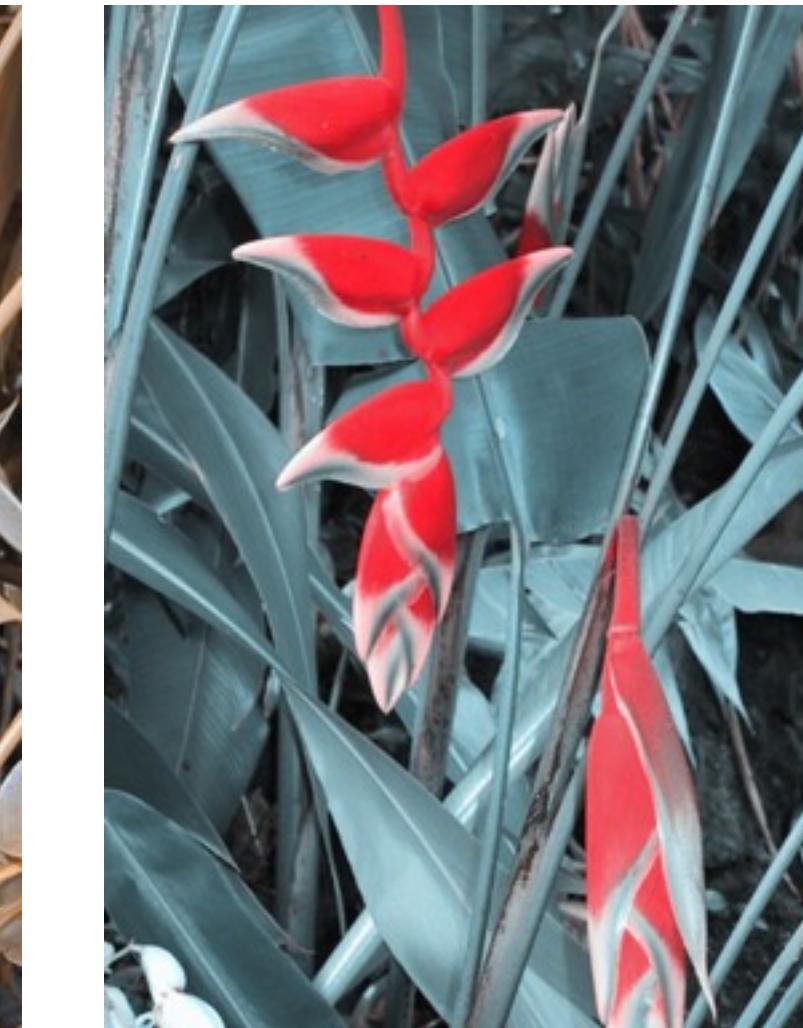
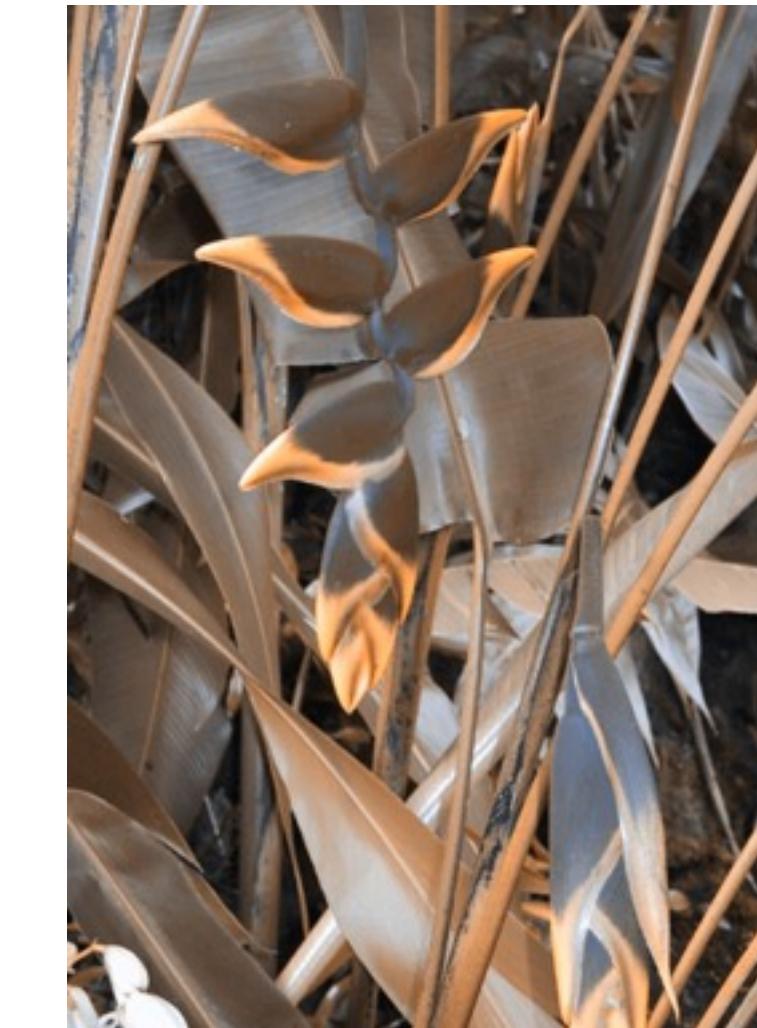
Deutanopia (no green receptors)

Protanopia (no red receptors)

Color Blindness Tests



Color Blindness



Protanope

No L cones

Red / green
deficiencies

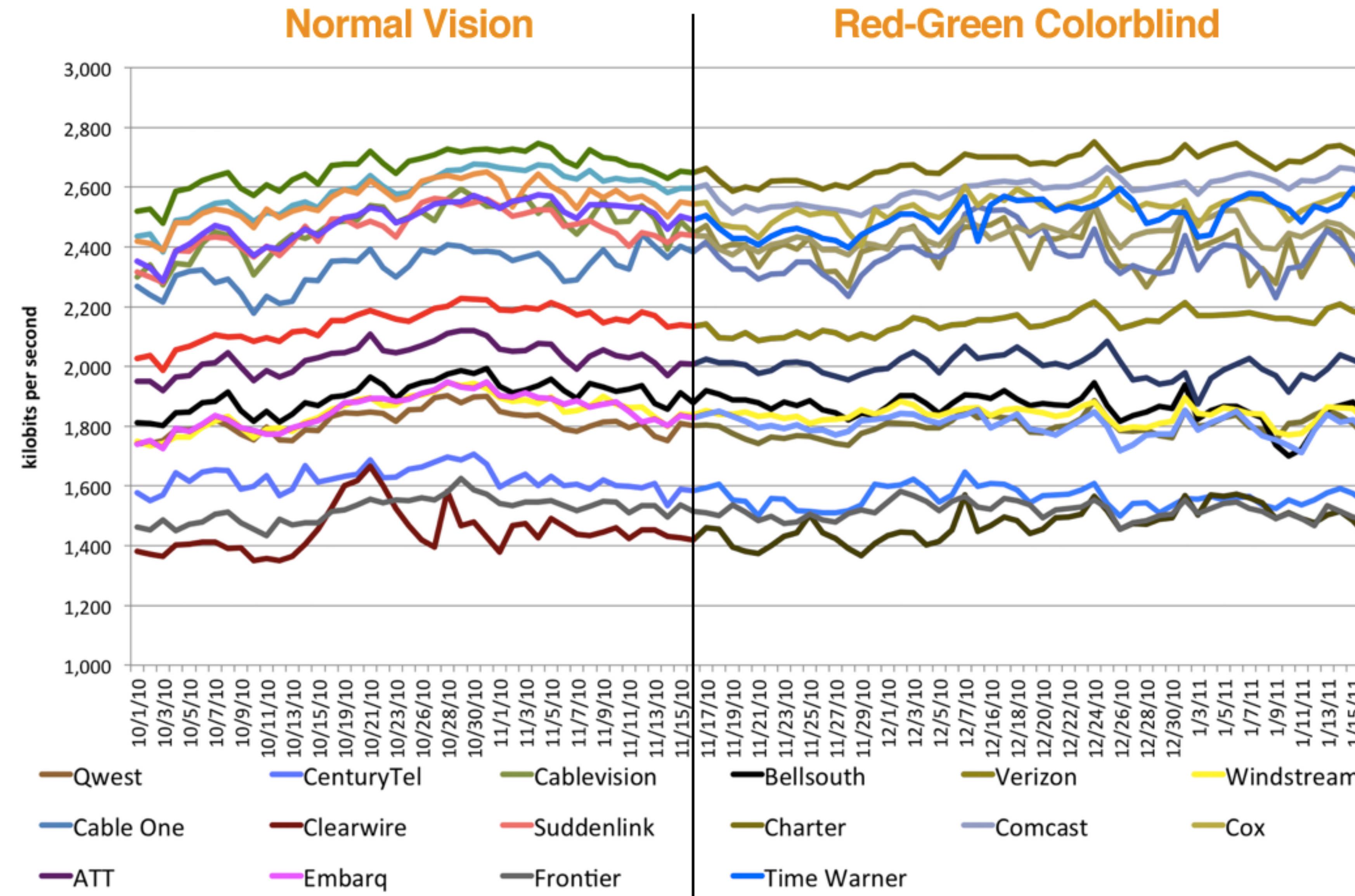
Deuteranope

No M cones

Tritanope

No S cones

Blue / Yellow
deficiency



Andy Baio

All Spending Types of Spending Changes Department Totals

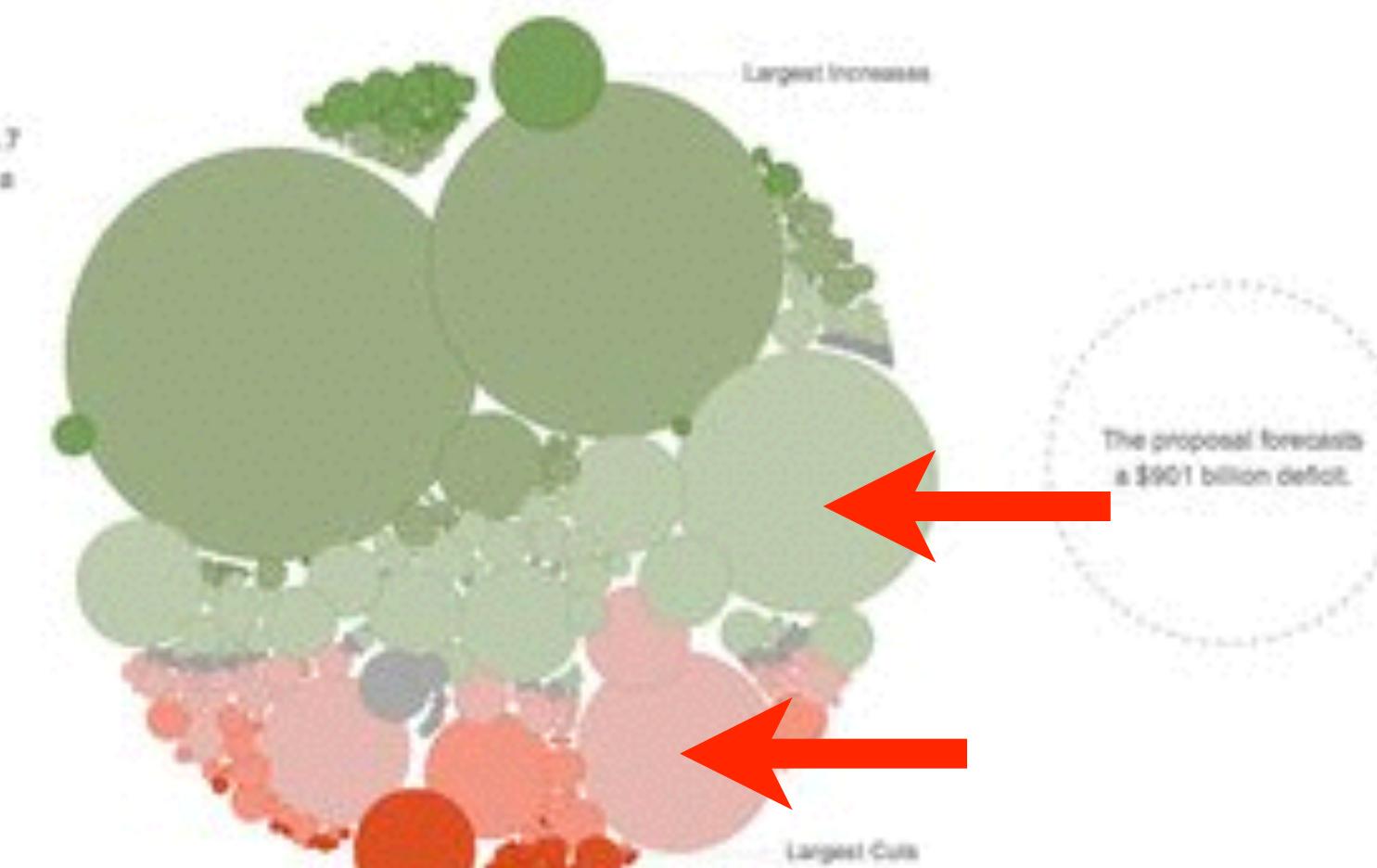
How \$3.7 Trillion Is Spent

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

Circles are sized according to the proposed spending.



Color shows amount of cut or increase from 2012.



All Spending Types of Spending Changes Department Totals

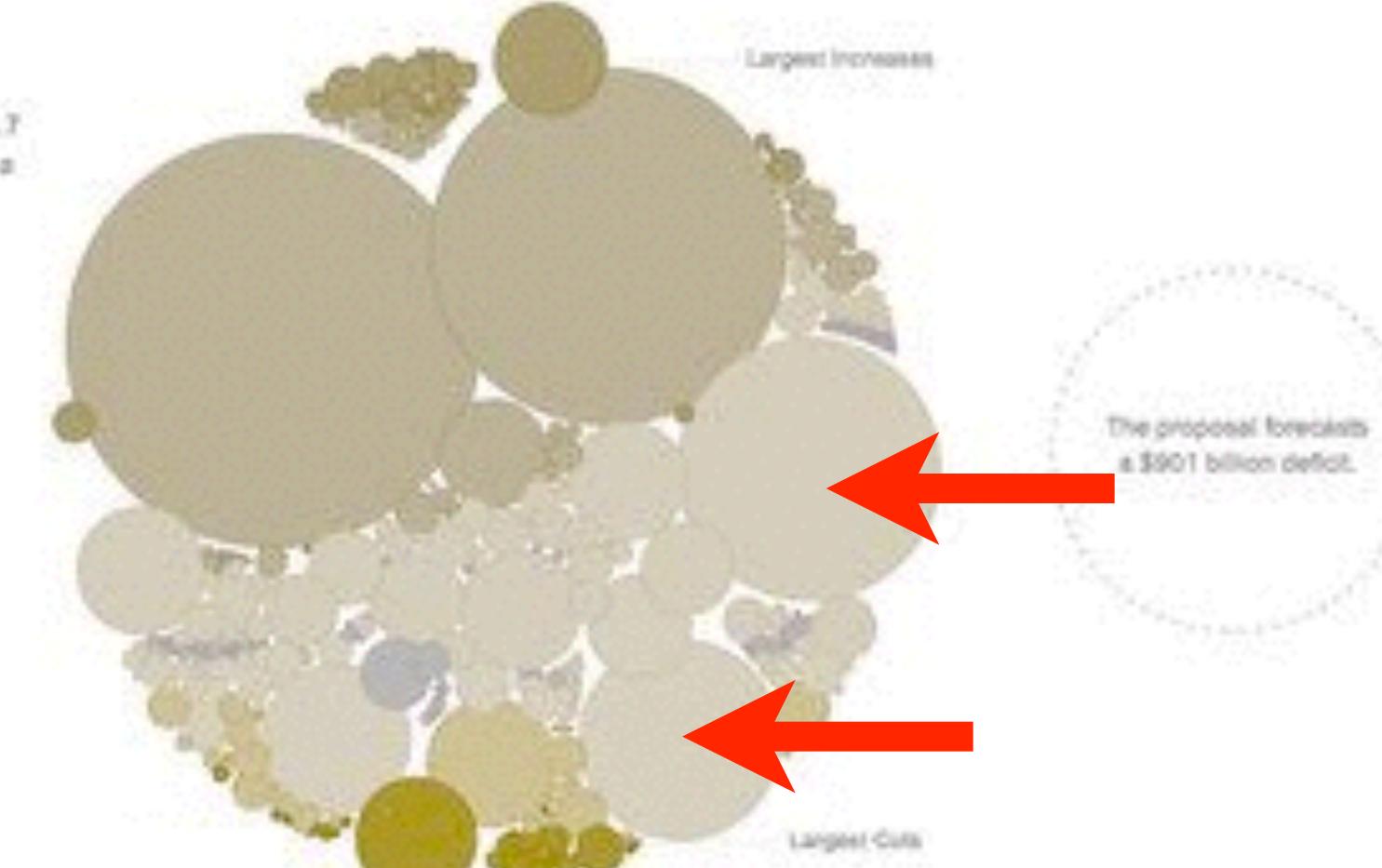
How \$3.7 Trillion Is Spent

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Circles are sized according to the proposed spending.



Color shows amount of cut or increase from 2012.



www.vischeck.com

Try Vischeck on a Webpage

Select the type of color vision to simulate:



Deutanope (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

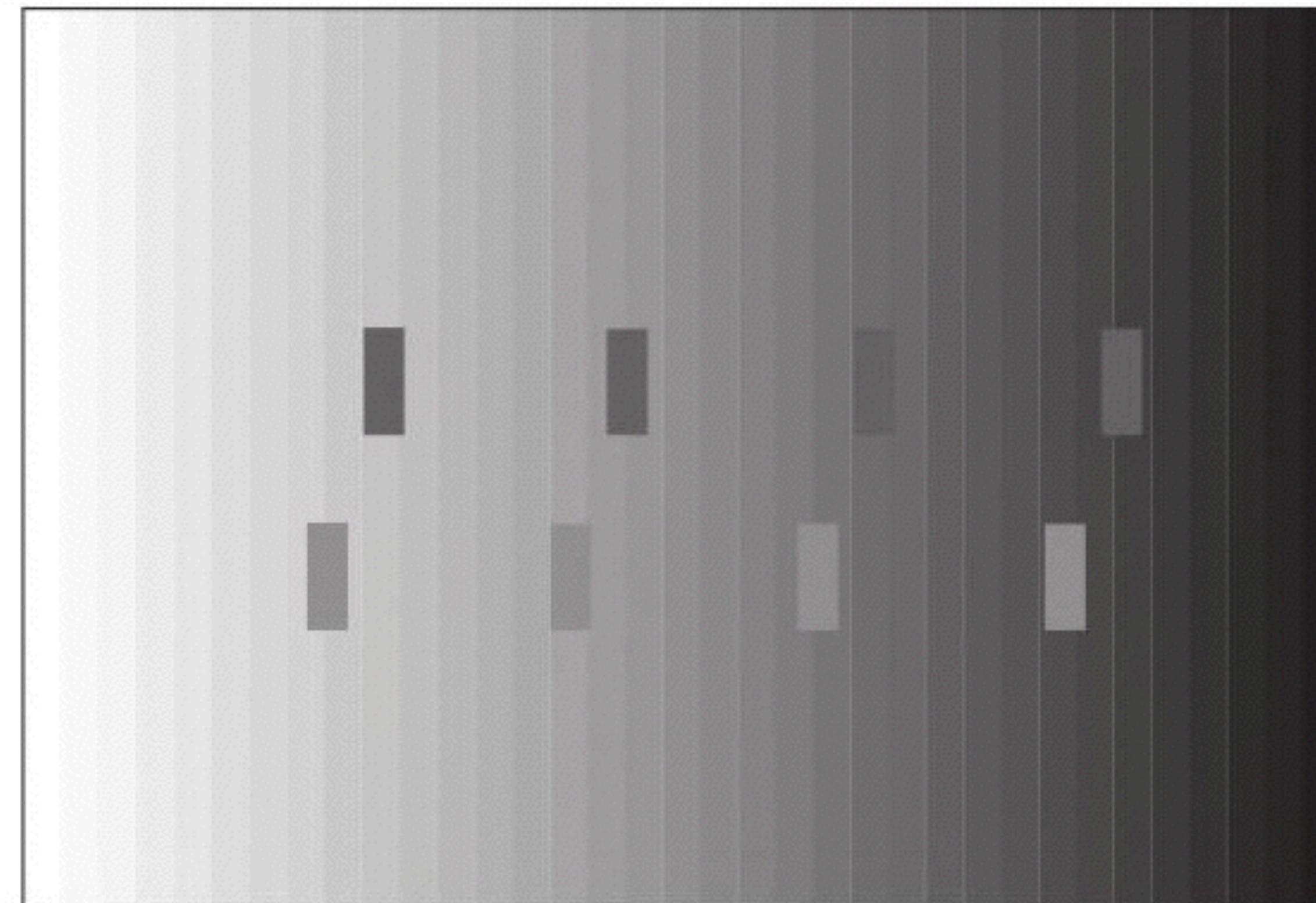
Lightness

perceived reflectance of a surface

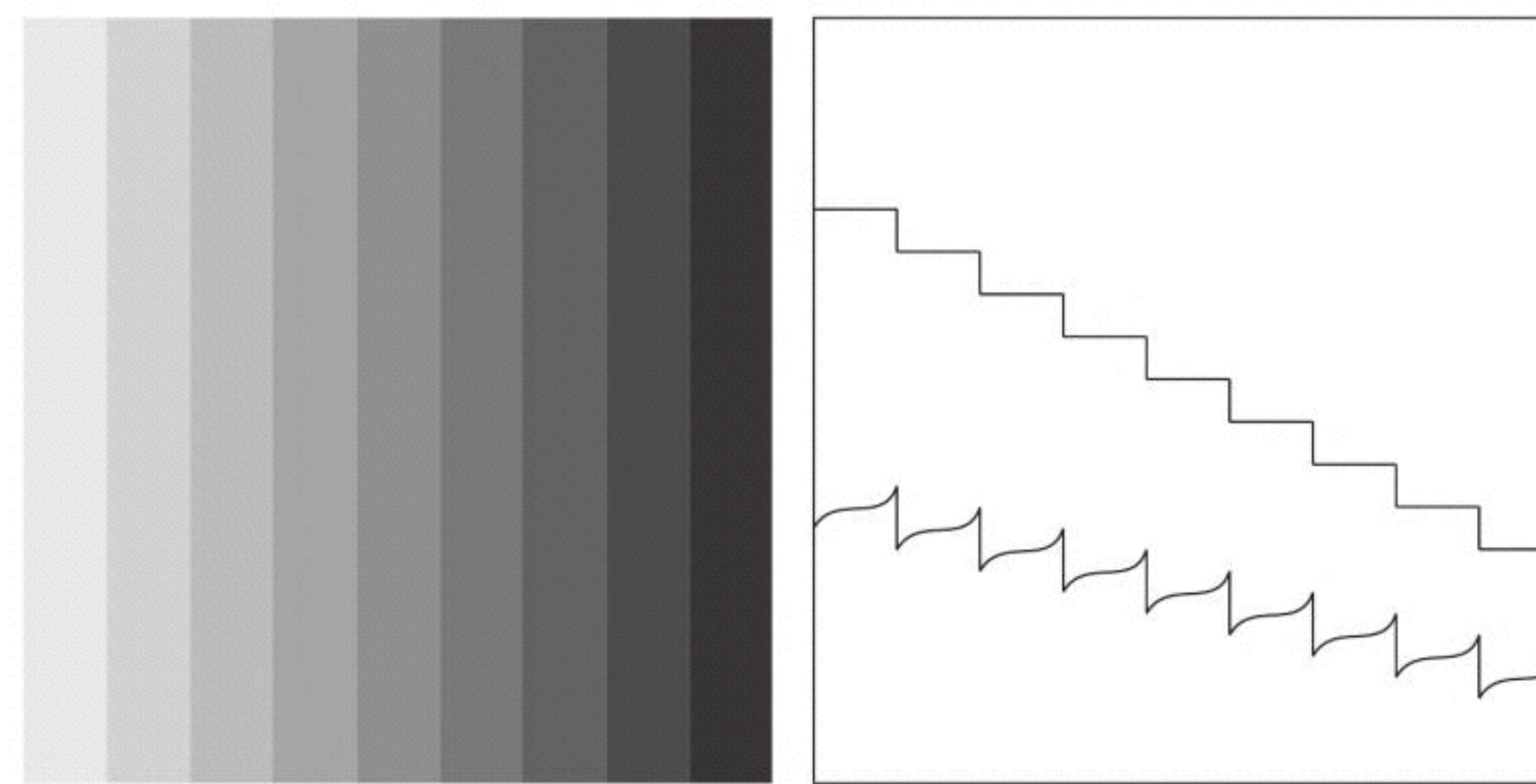
lightness of a color

Simultaneous Brightness Contrast

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



Chevreul illusion



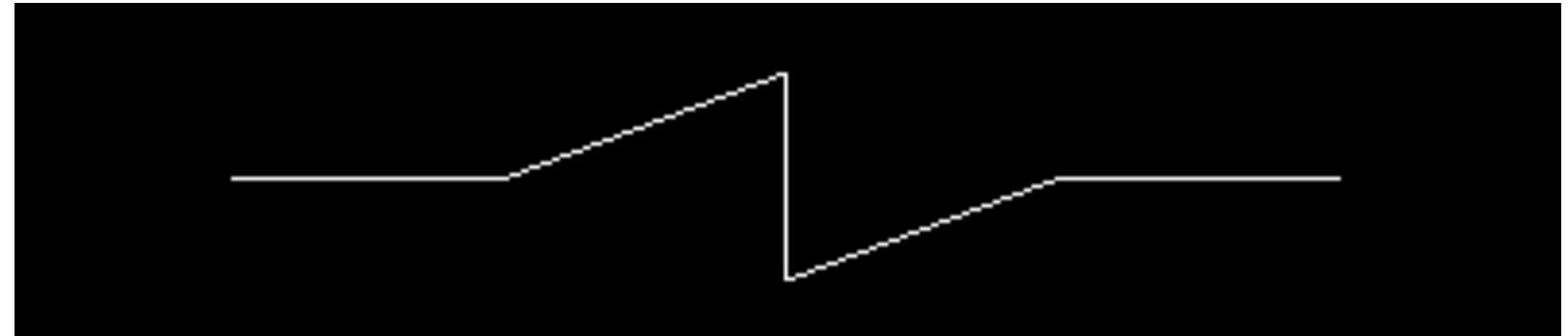
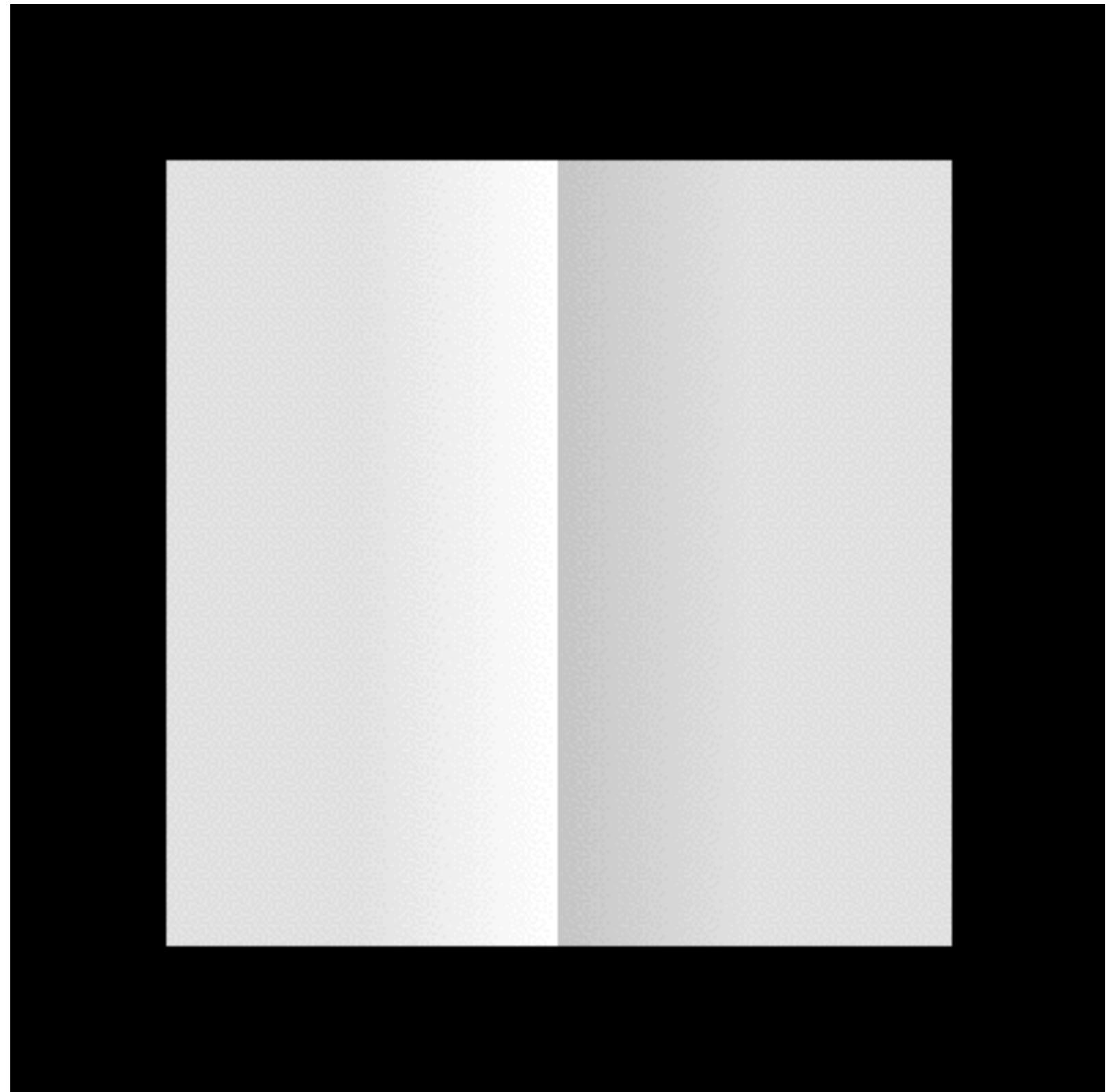
Edge Enhancement

Cornsweet effect

Make objects more distinct



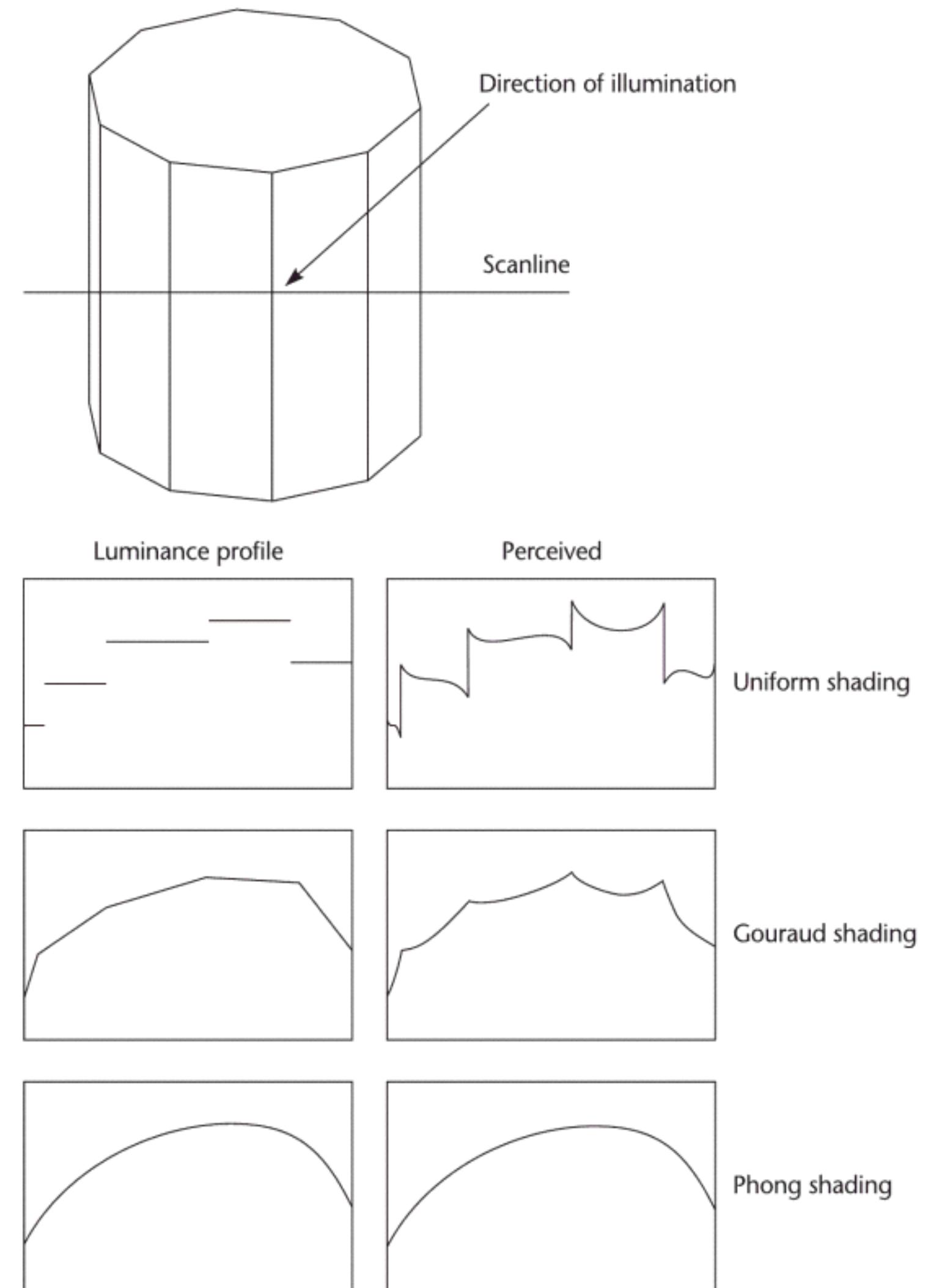
Seurat's Bathers



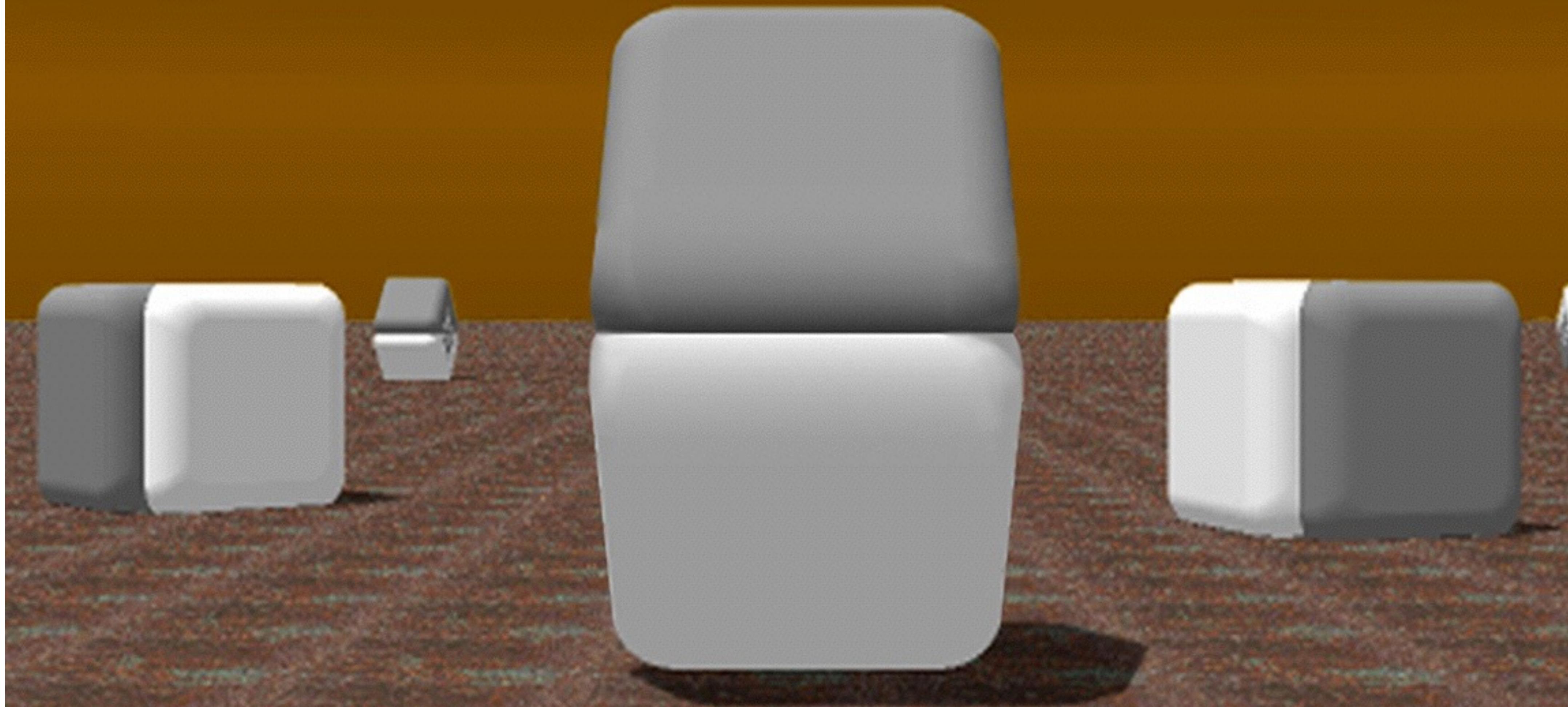
Why is this an issue?

Can result in large errors of judgment

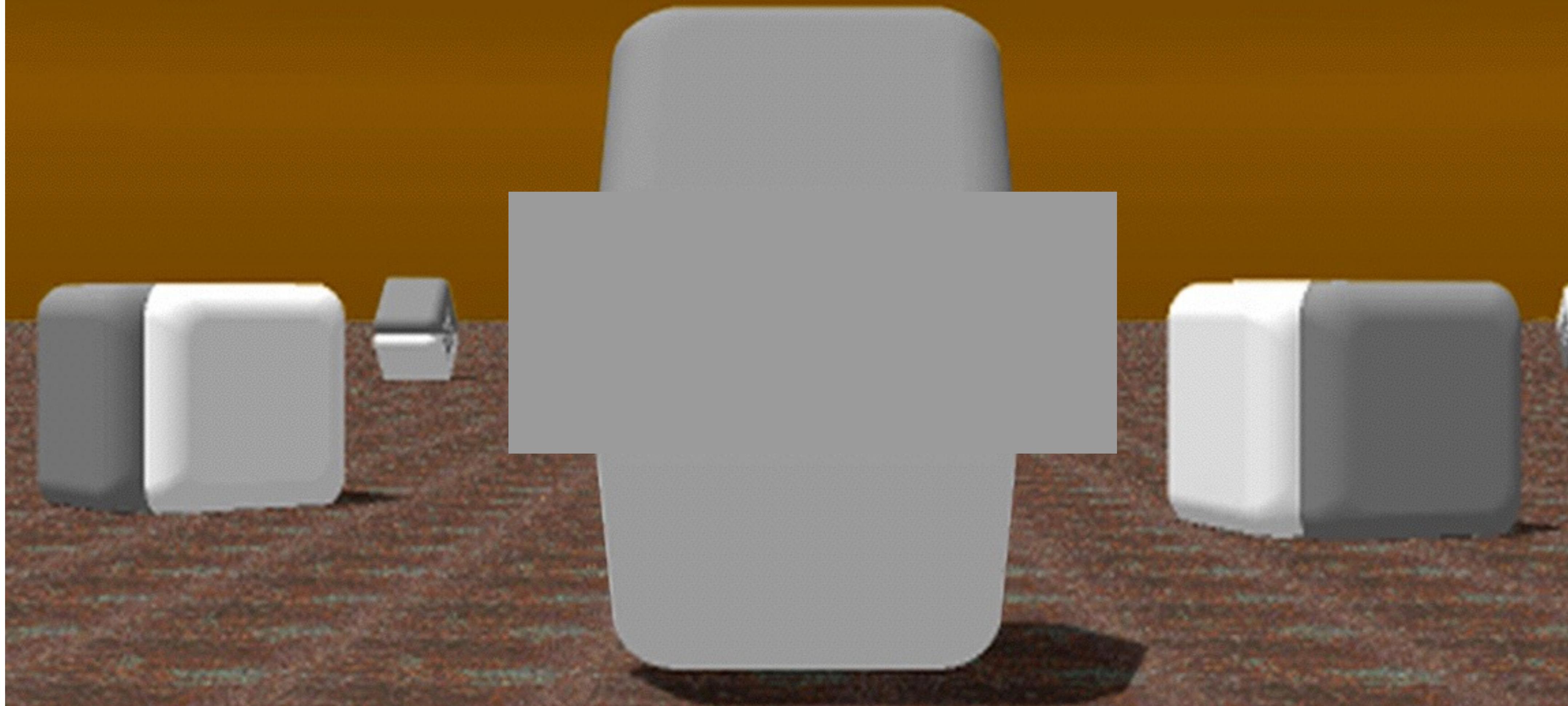
Amplifies artifacts in computer graphics shading



Cornsweet Illusion



Cornsweet Illusion



Demo

<http://www.purveslab.net/seeforyourself/index.html?0.00>

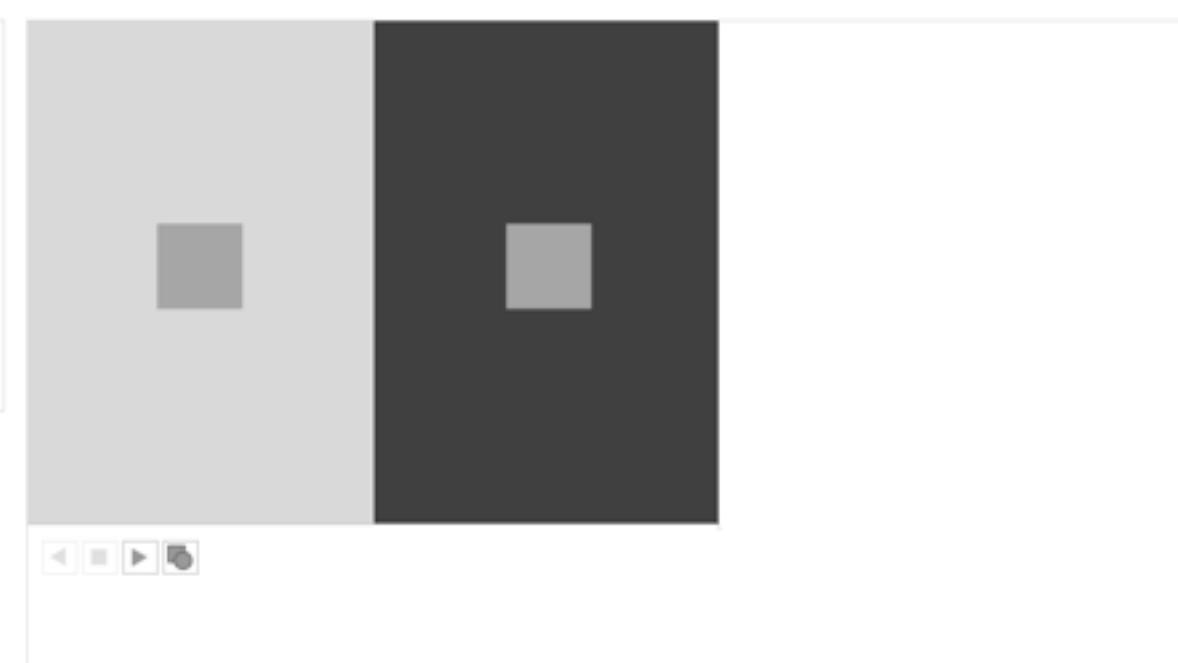
purves-lab Laboratory of Dale Purves, M.D. Center for Cognitive Neuroscience Duke University

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

Lightness/Brightness	Color	Lines and Angles	Motion	Sound and Music

Brightness contrast: standard
In viewing this stimulus, people invariably perceive the square on the brighter surround (left) to be darker than the square on the darker surround (right). Click on the "Play" button to convince yourself that the squares are equiluminant or click on the "Move mask" button to manually position the mask over the squares.

[» Read the empirical explanation](#)
[» Download high resolution images](#)



< > ○

Preattentive Processing

Preattentive Processing

Properties detected by the low-level visual system

very rapid - 200-250 milliseconds

very accurate

processed in parallel

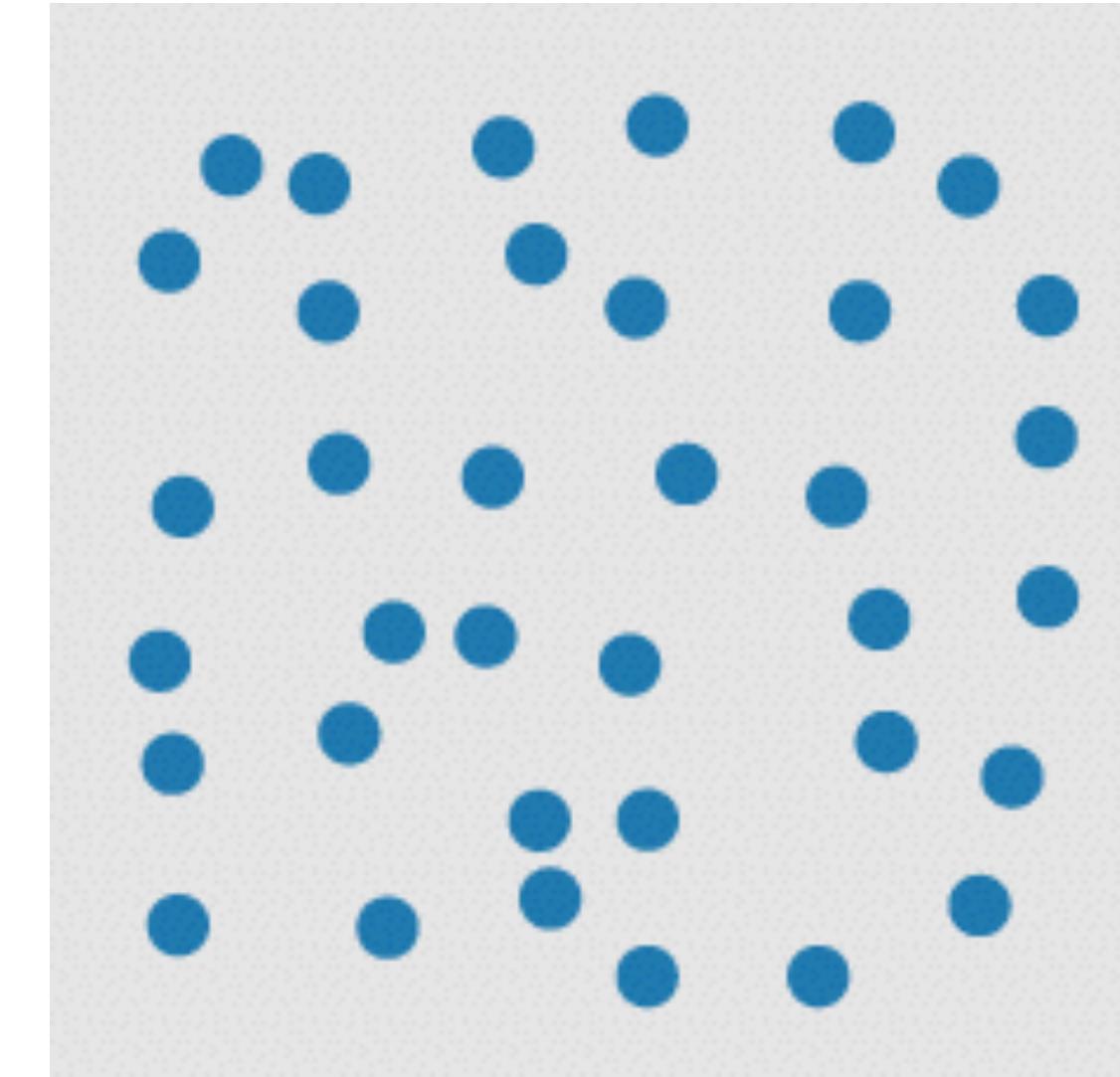
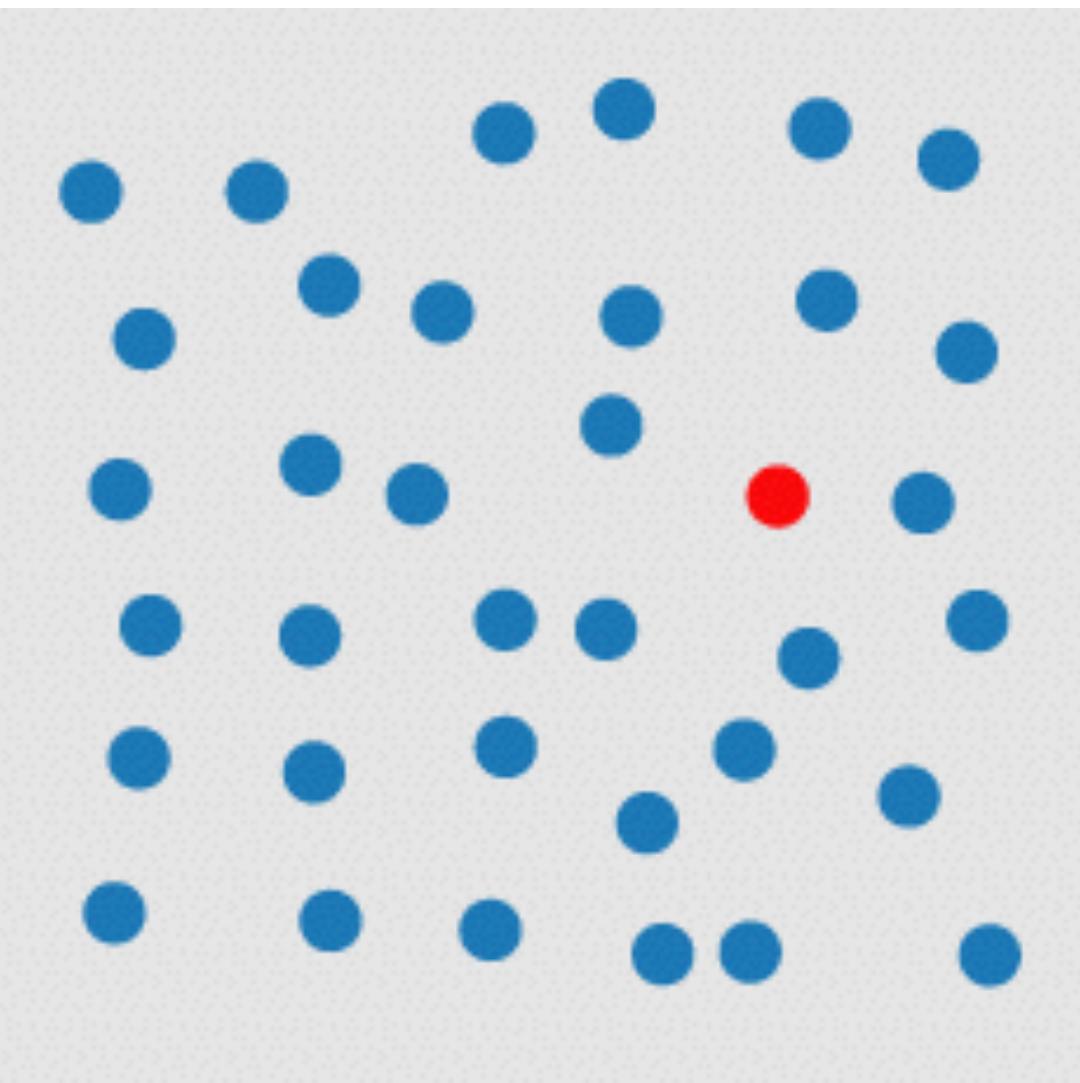
happens before focused attention -> „pre“attentive

attention is very important for cognition

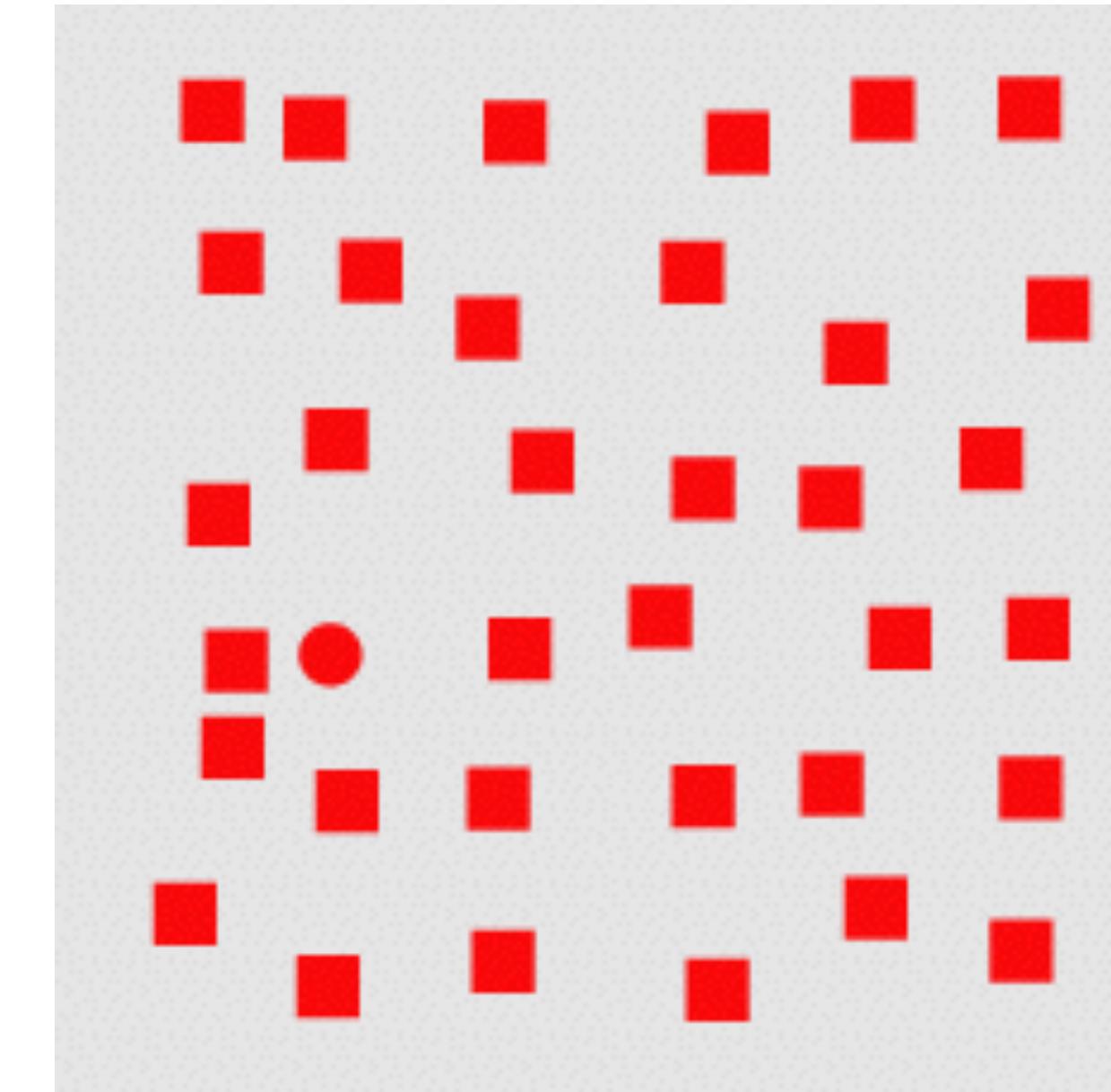
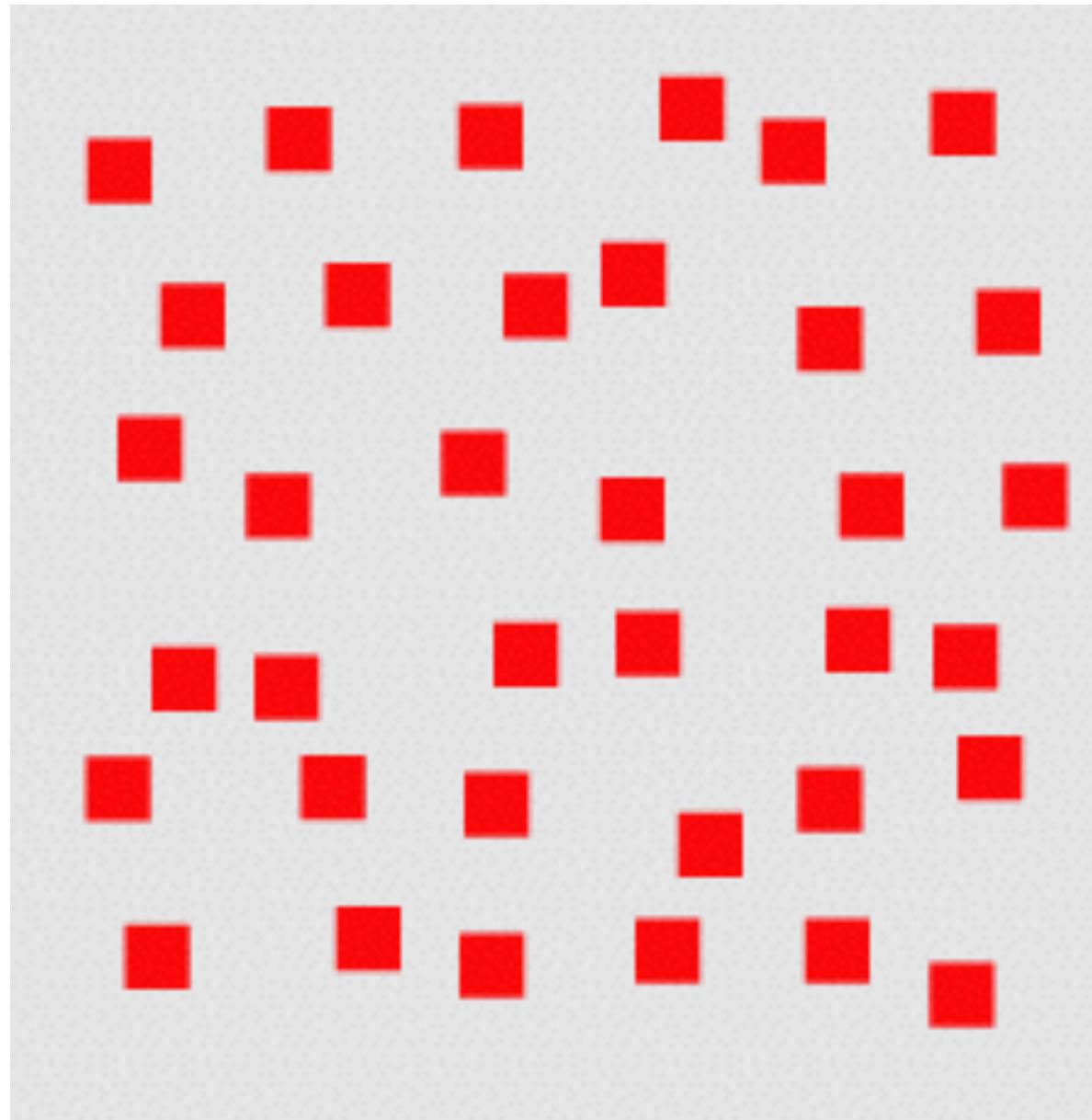
Independent of the number of distractors!

Opposite: sequential search (processed serially)

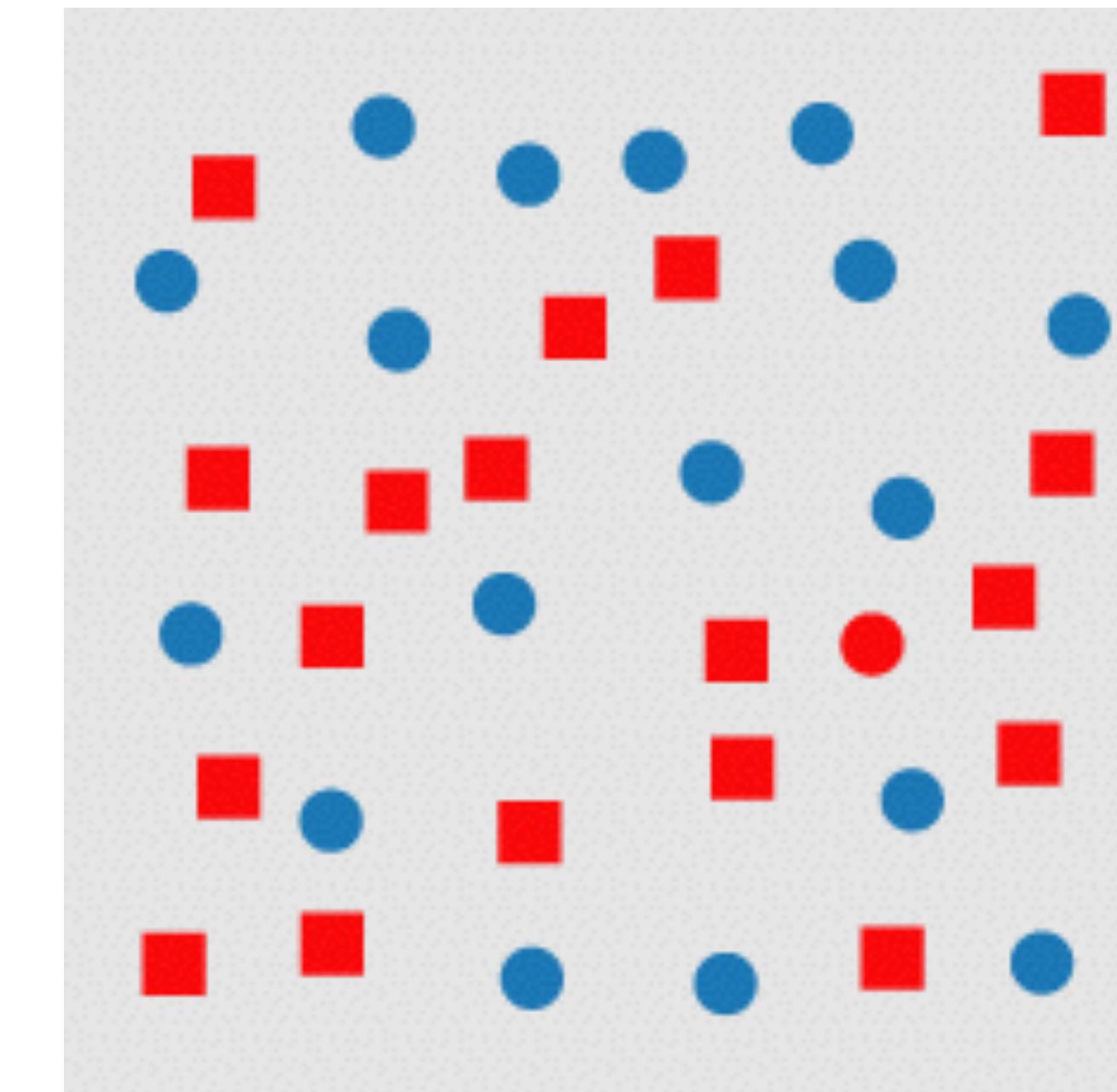
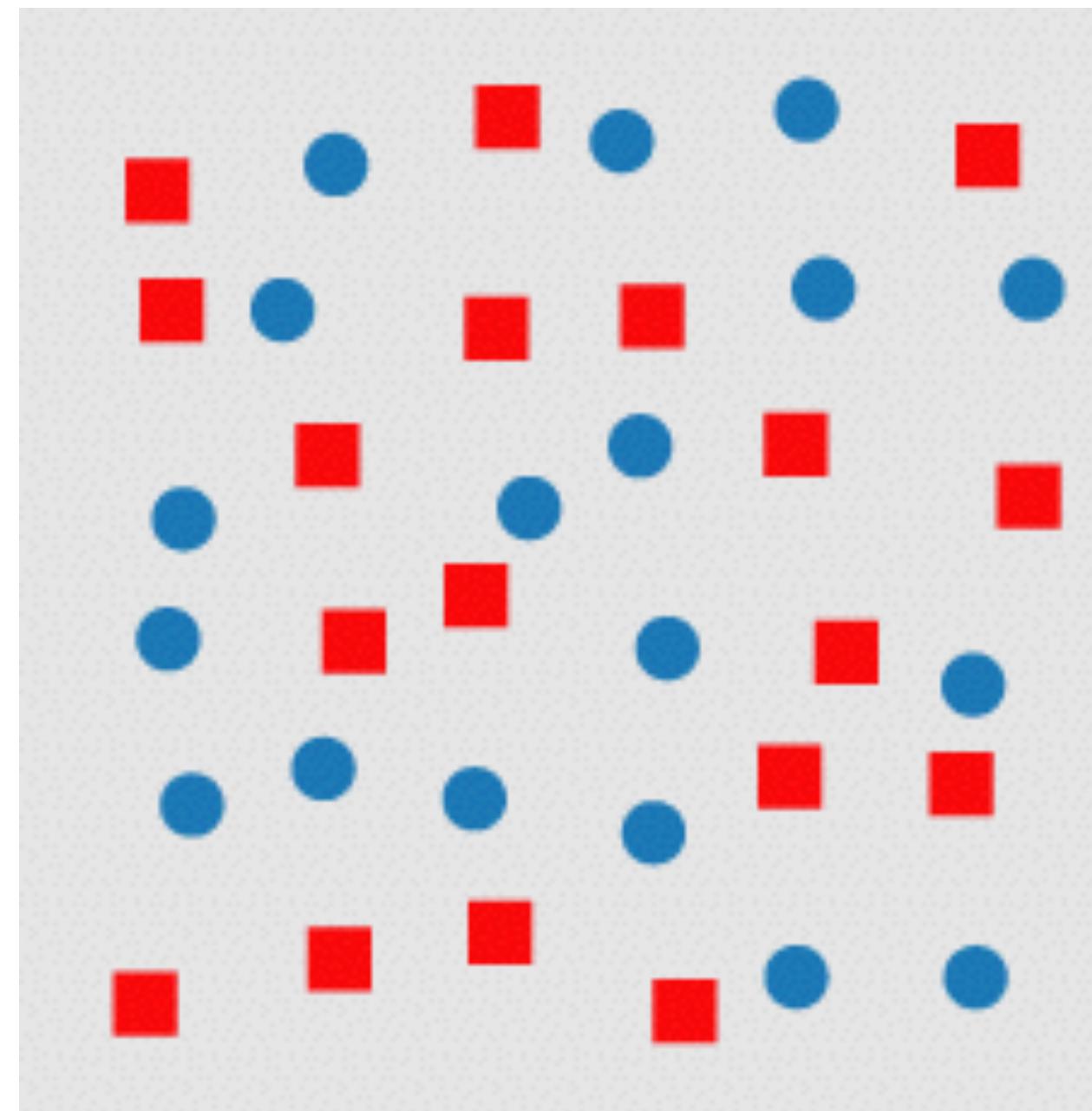
Difference in Hue



Difference in Curvature / Form

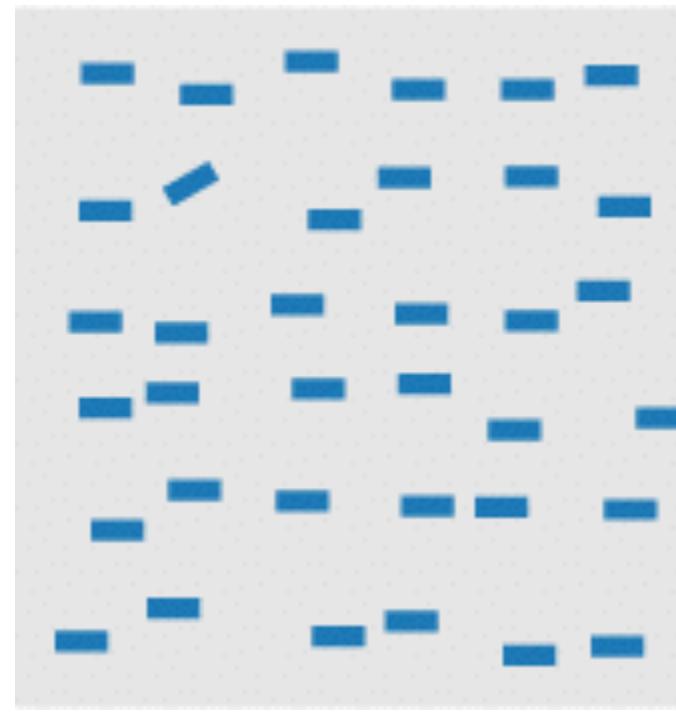


Not Valid for Combinations

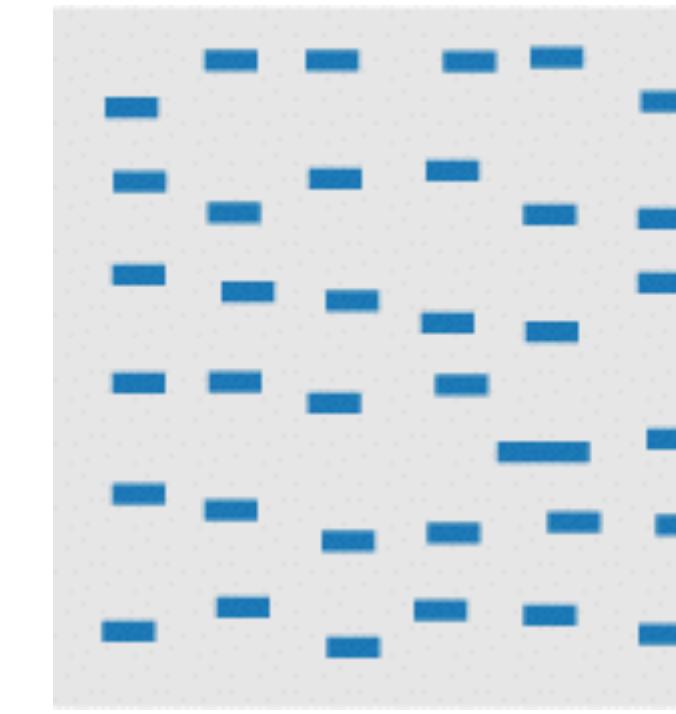


Conjunction Targets – no unique visual property
target: red, circle
distractor objects have both properties

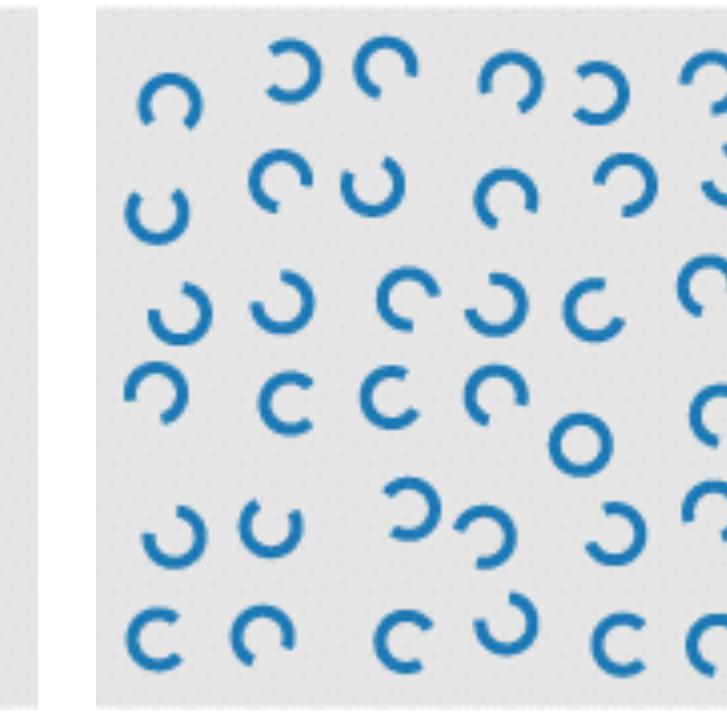
Some Preattentive Properties



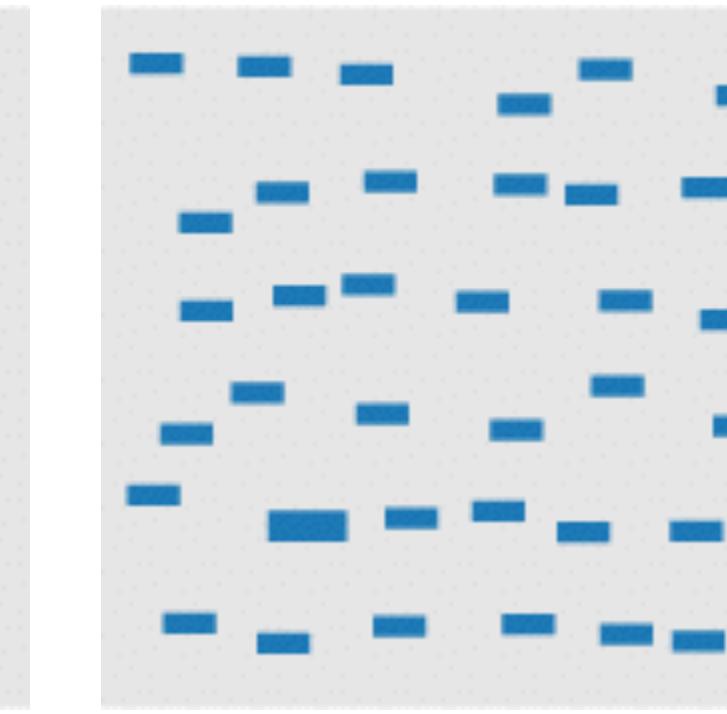
orientation



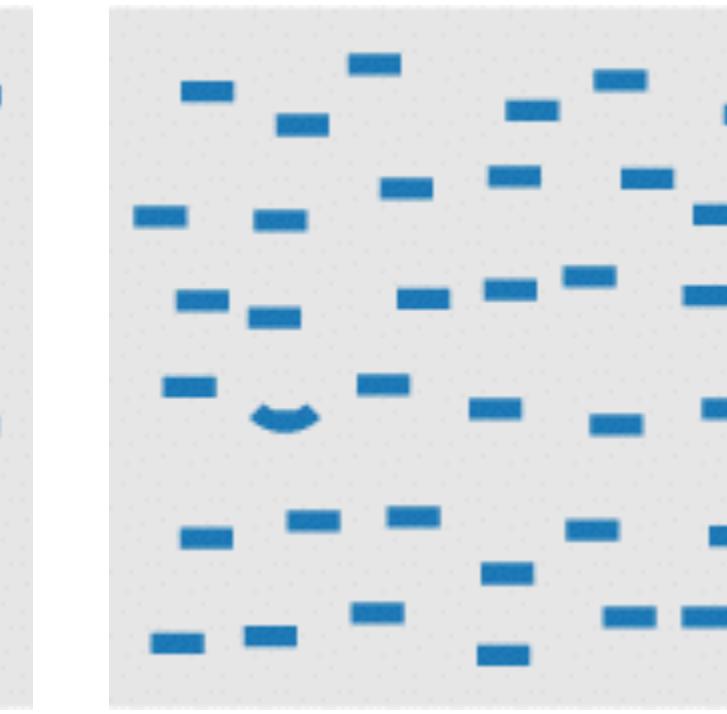
length



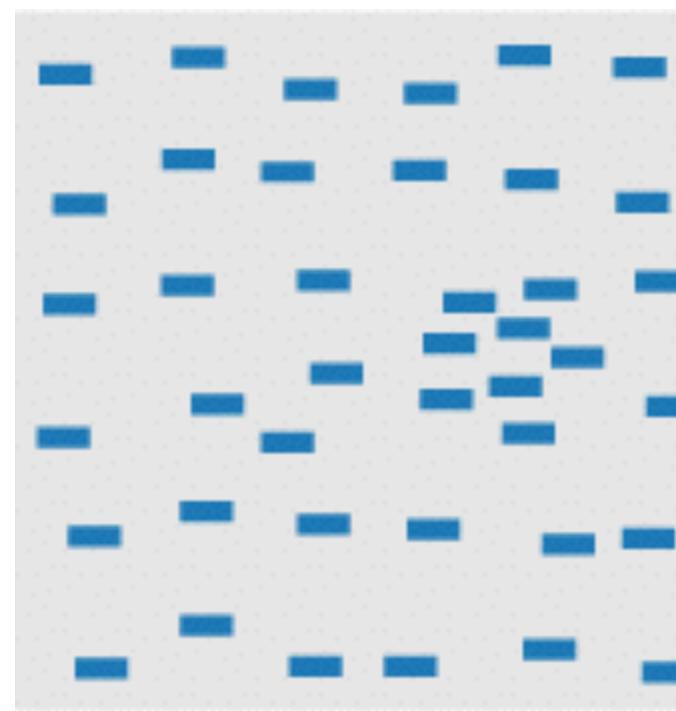
closure



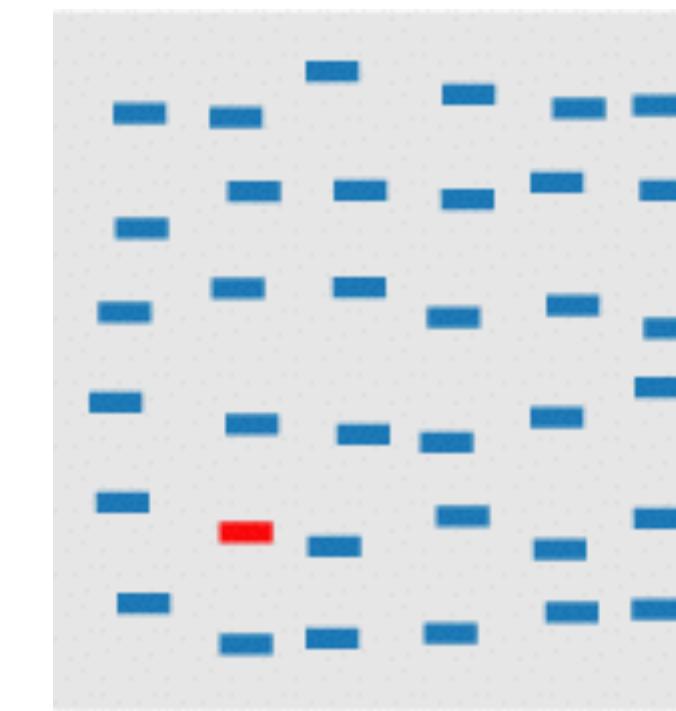
size



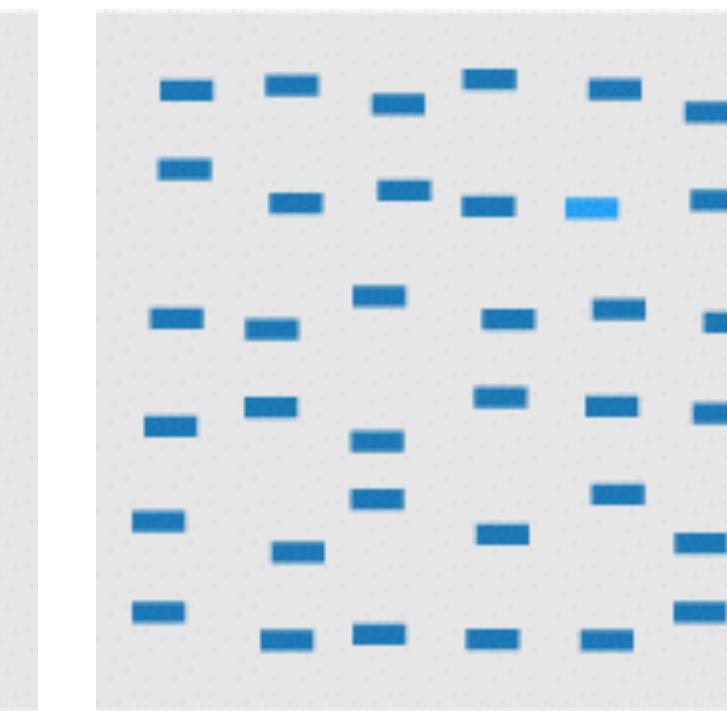
curvature



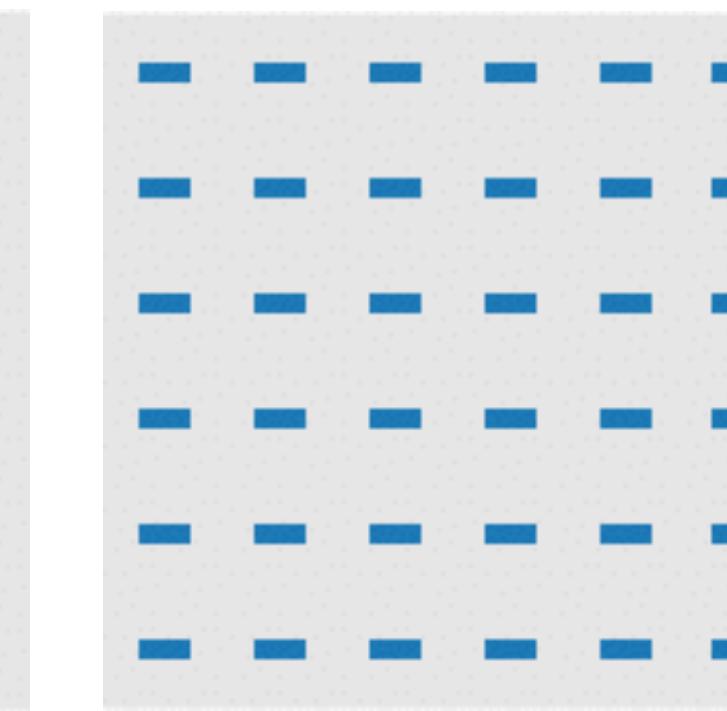
density



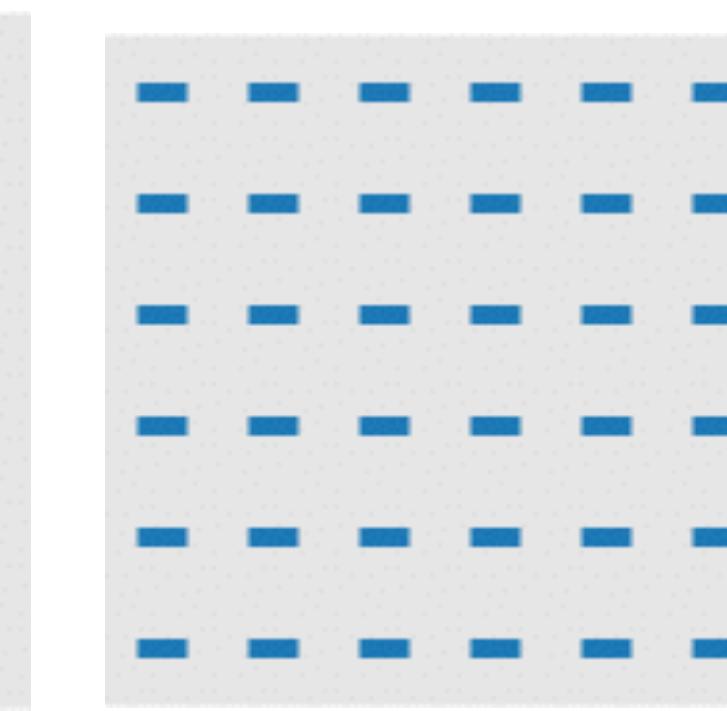
hue



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

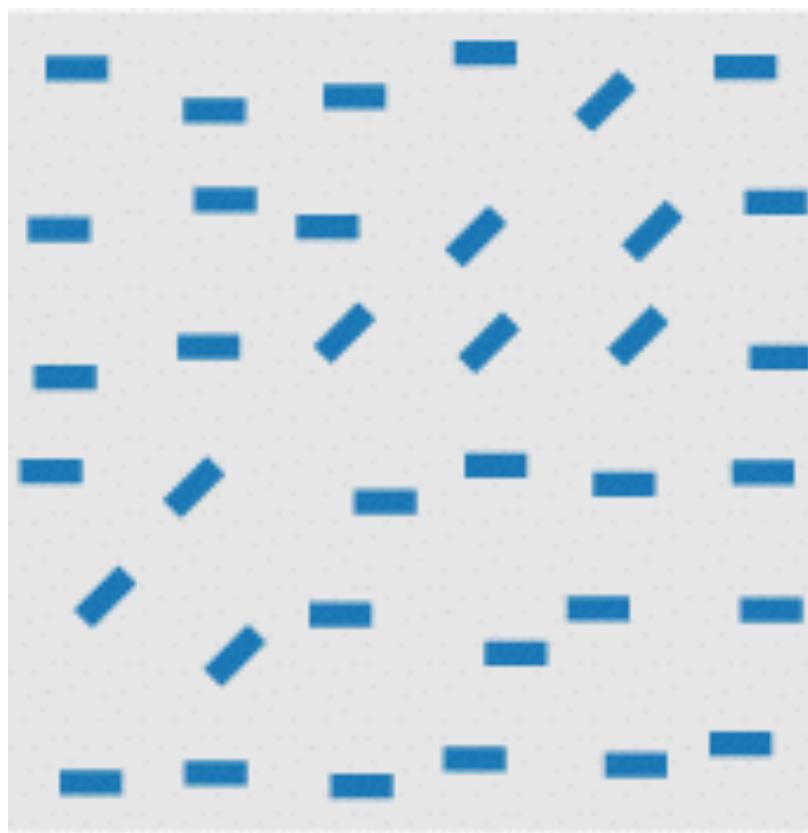
track one or more elements with a unique visual feature as they move in time and space

counting and estimation

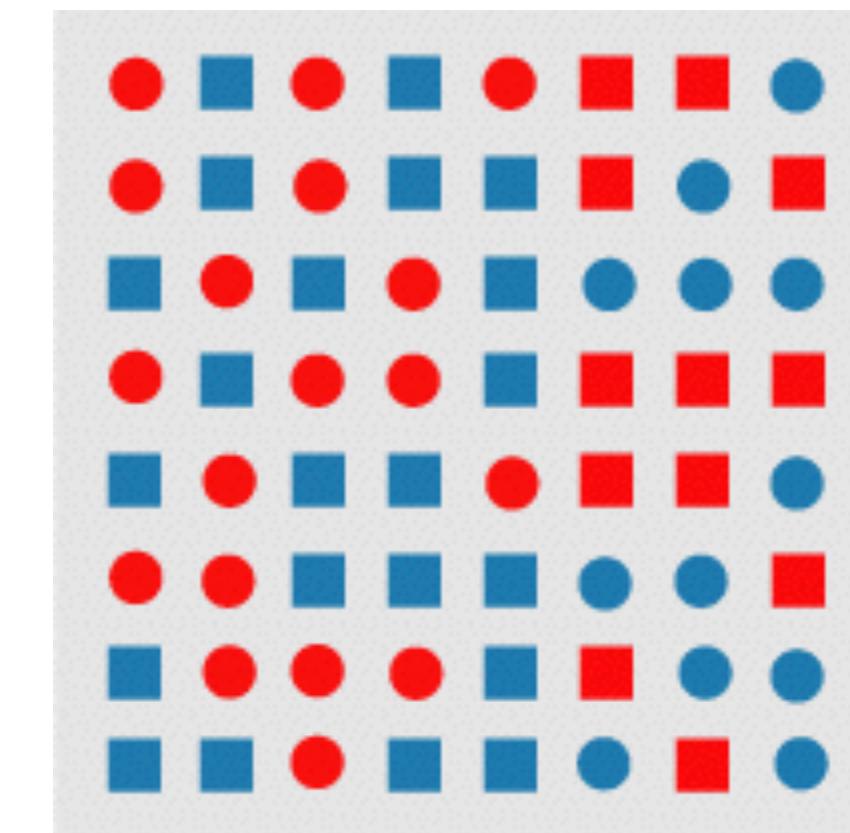
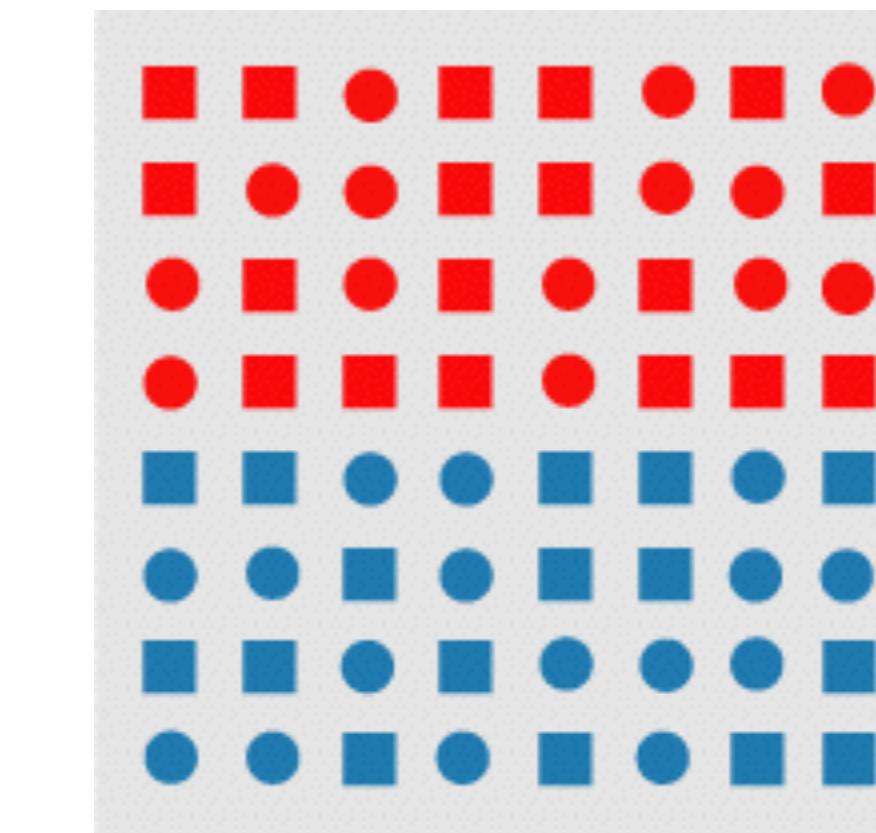
users count or estimate the number of elements with a unique visual feature.

Tasks

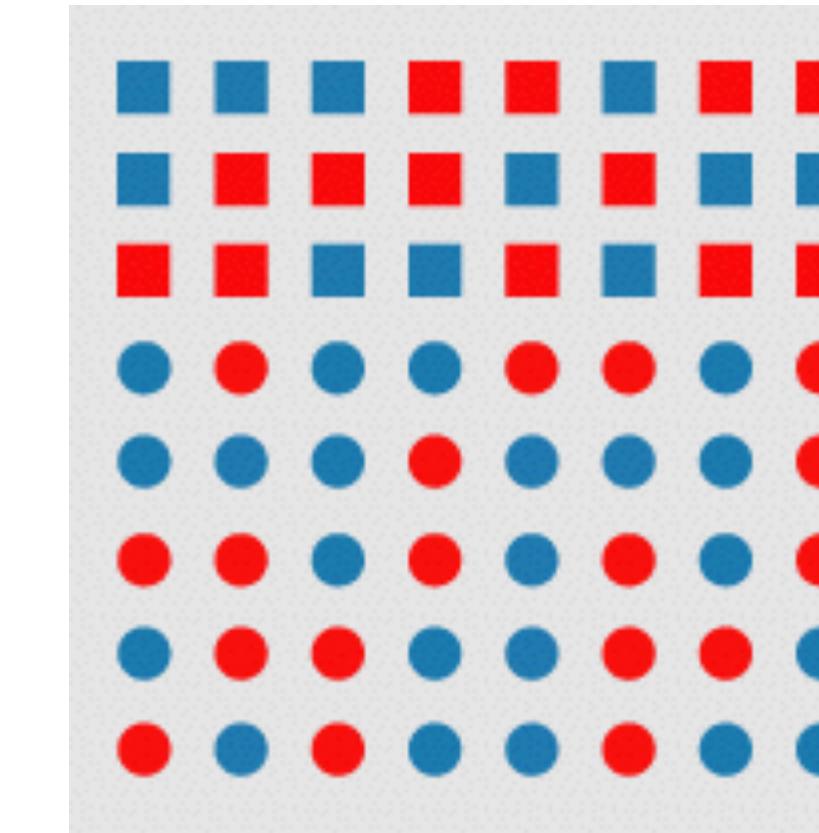
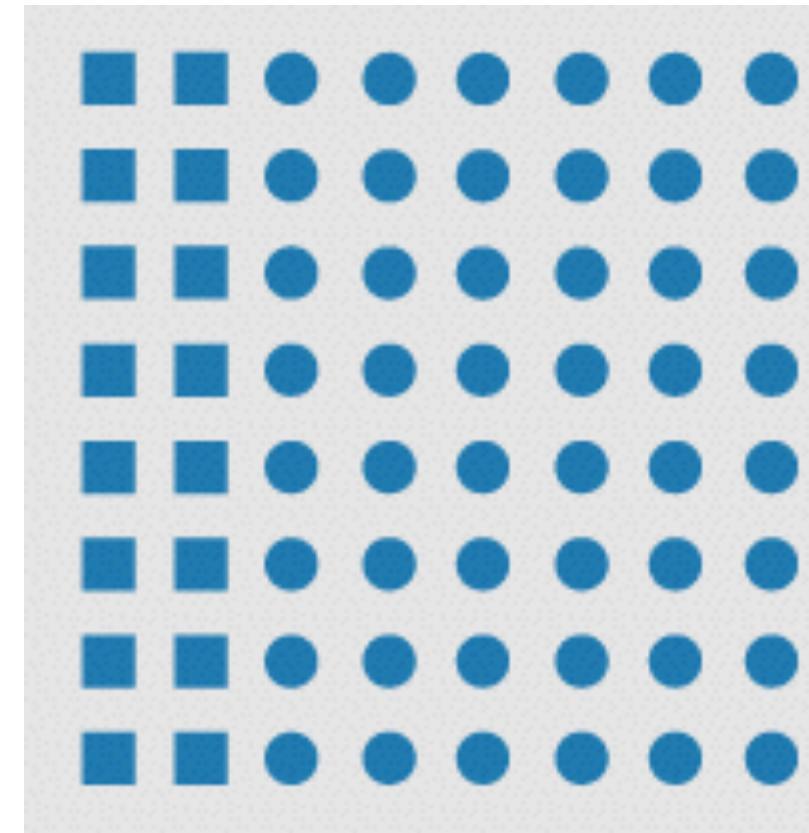
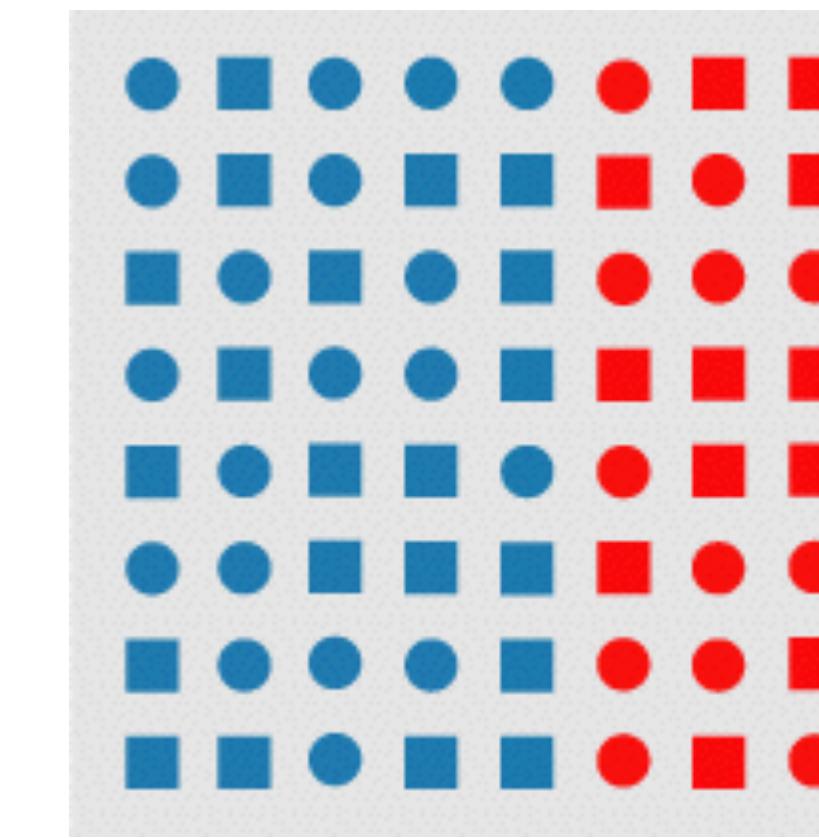
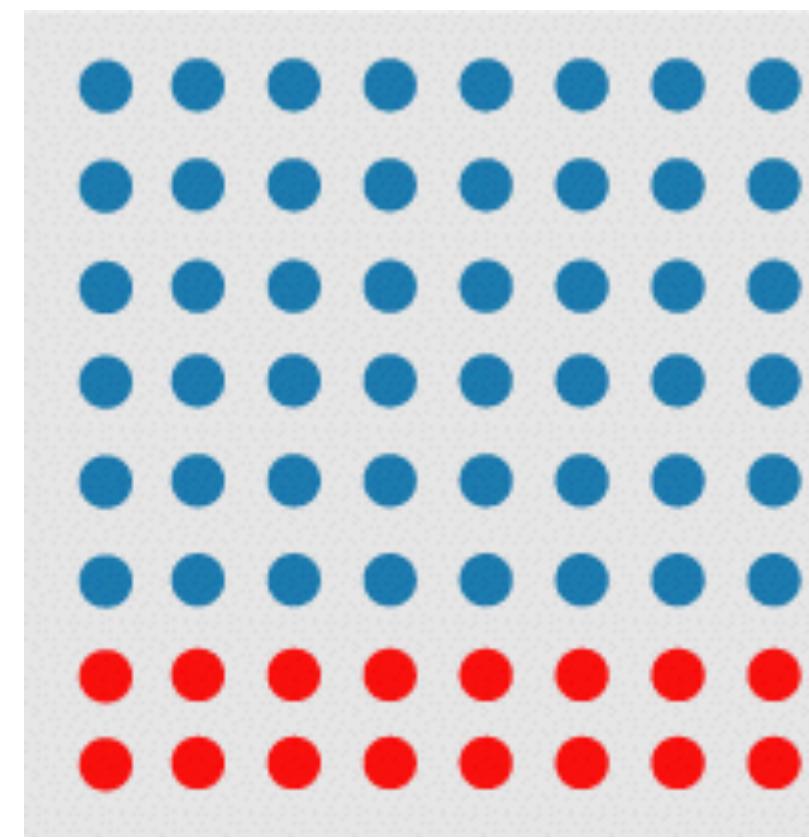
Number Estimation



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

No failure of vision system, failure based on inappropriate attentional guidance





Ron Rensink 2002



Ron Rensink 2002



Ron Rensink 2002



Ron Rensink 2002

Change Blindness

Various theories about causes

Overwriting: Information that was not abstracted is lost

First Impression: Only initial view is abstracted

Nothing is Stored: Only abstract concepts are committed to memory

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

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

Influencing factors

attention

expectation (knowing something will change)

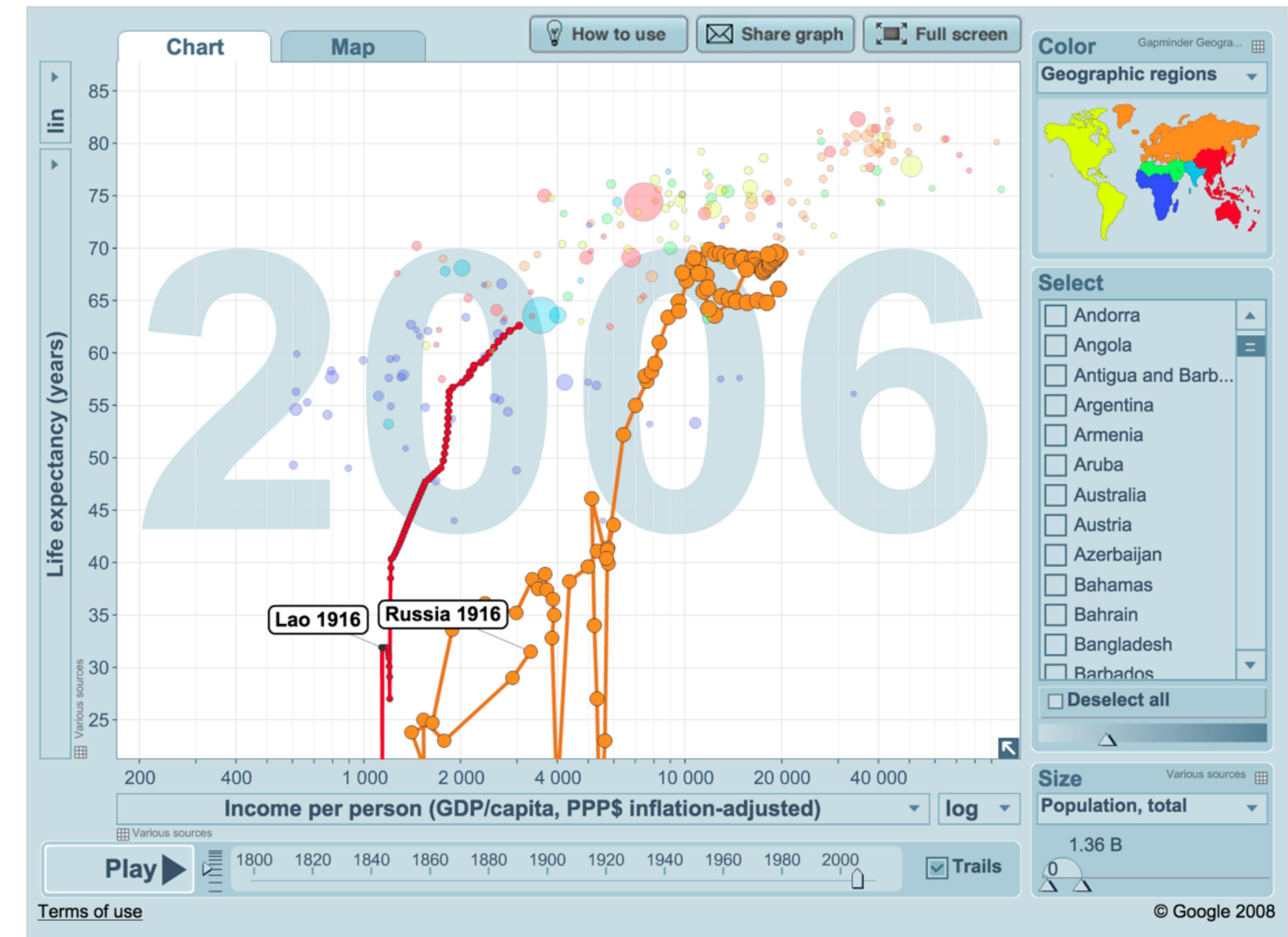
semantic importance of changed object

low level object properties overlooked more easily

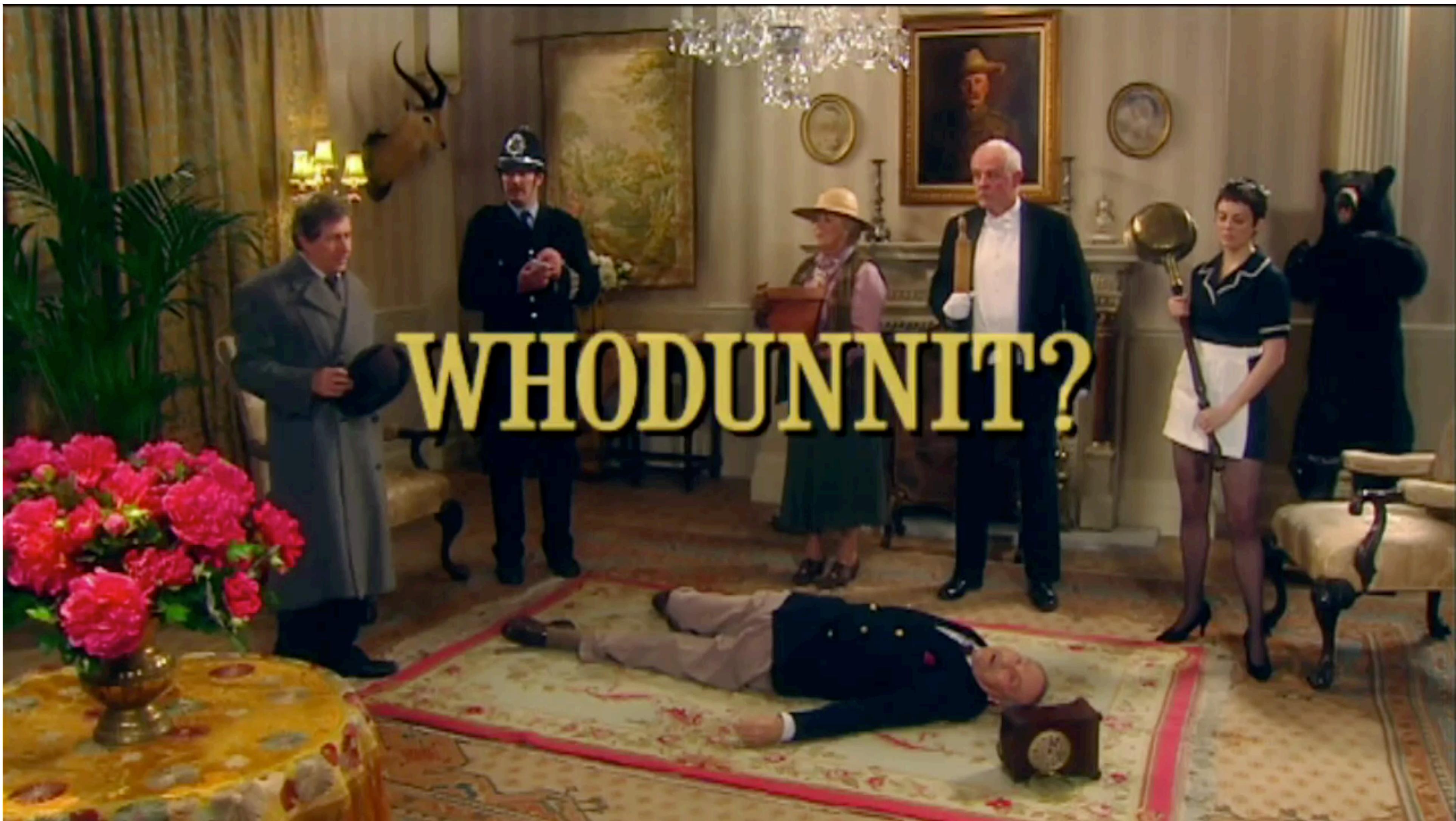
Design Critique

GapMinder

<http://goo.gl/FqbQ3P>



Attention Blindness



Transport for London

Other Videos

Take Home Points

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

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

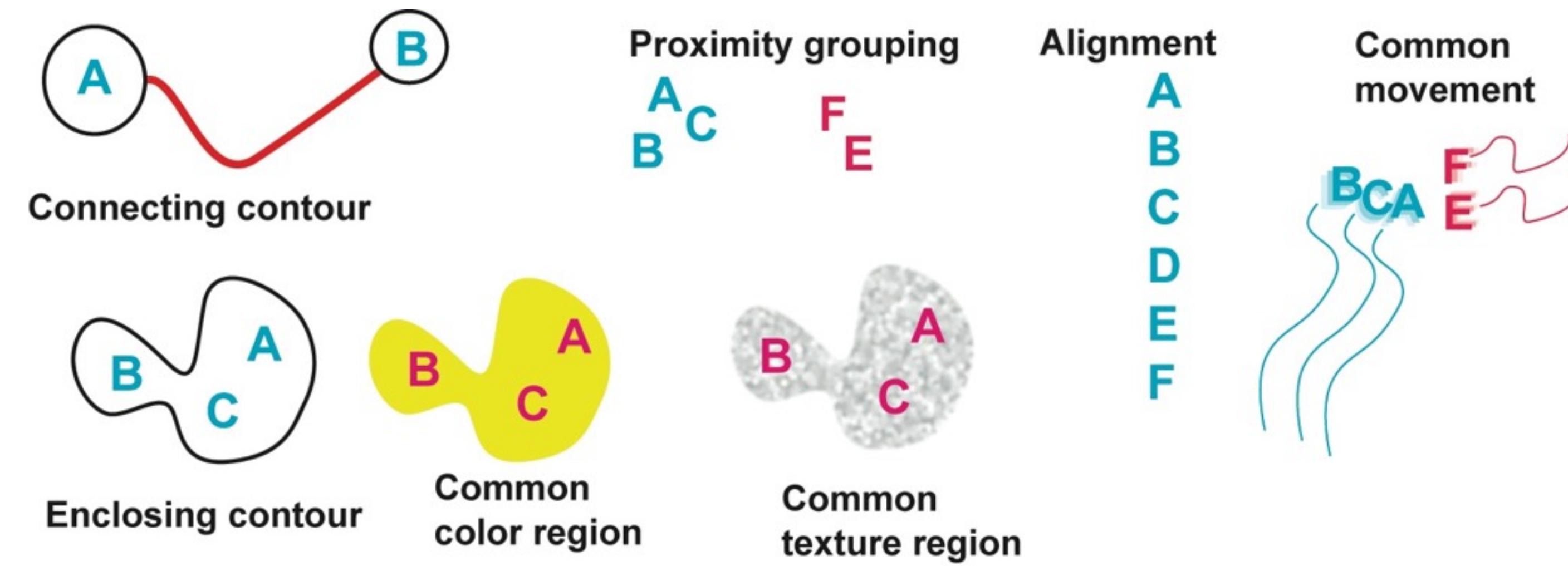
Attention is driven by preexisting knowledge, expectations, and goals stored in long-term memory

Gestalt Principles

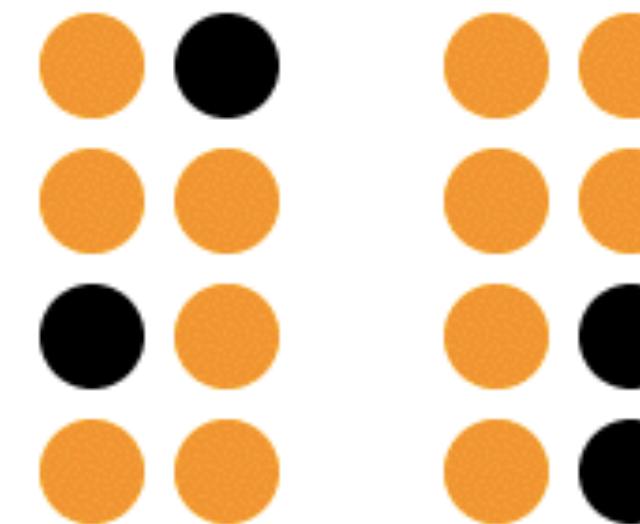
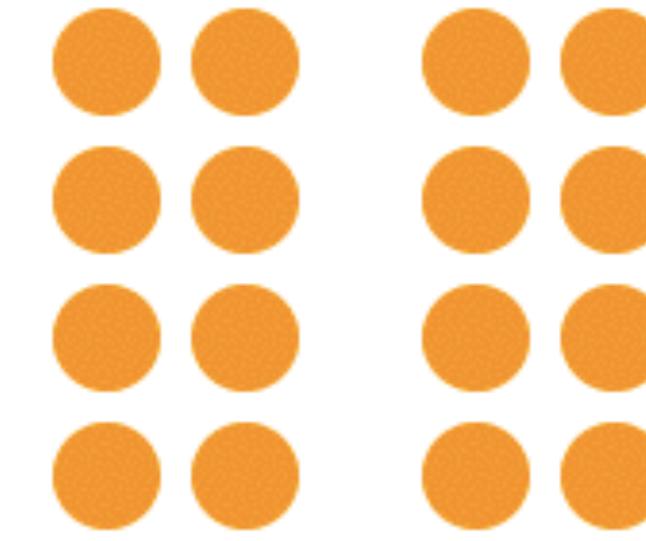
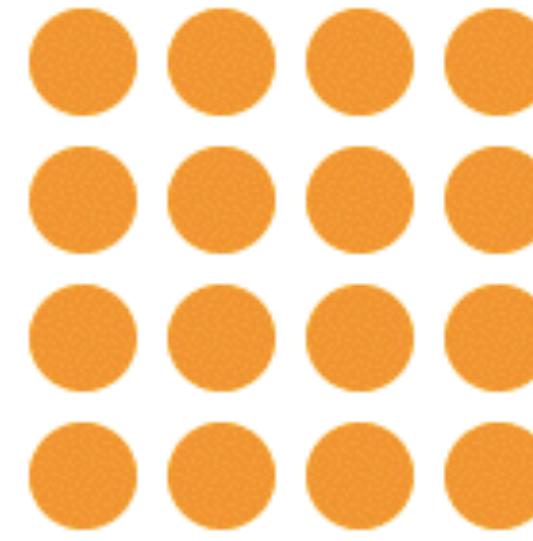
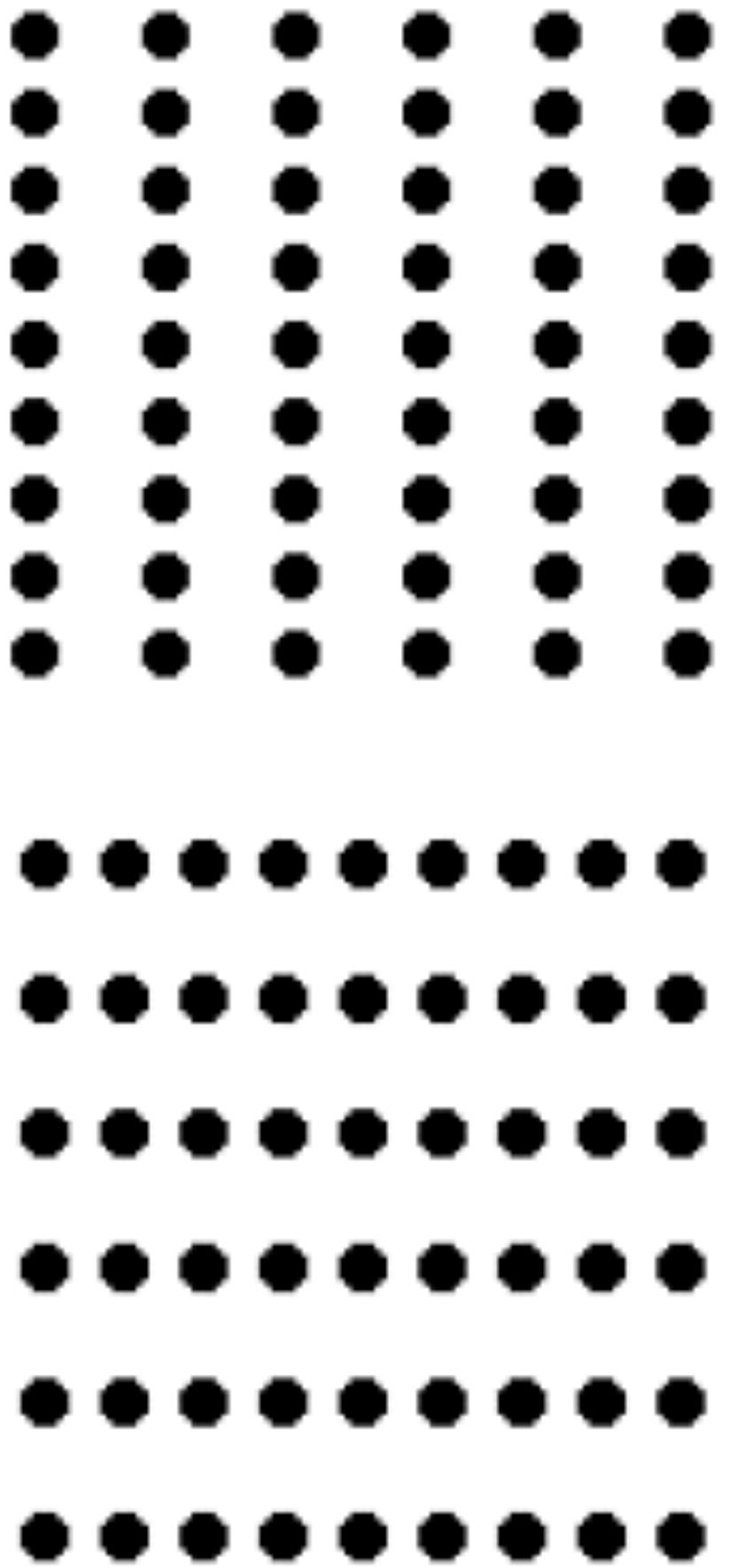
Wertheimer, 1923, and recent extensions

Gestalt Principles

Patterns that transcend the visual stimuli that produced them

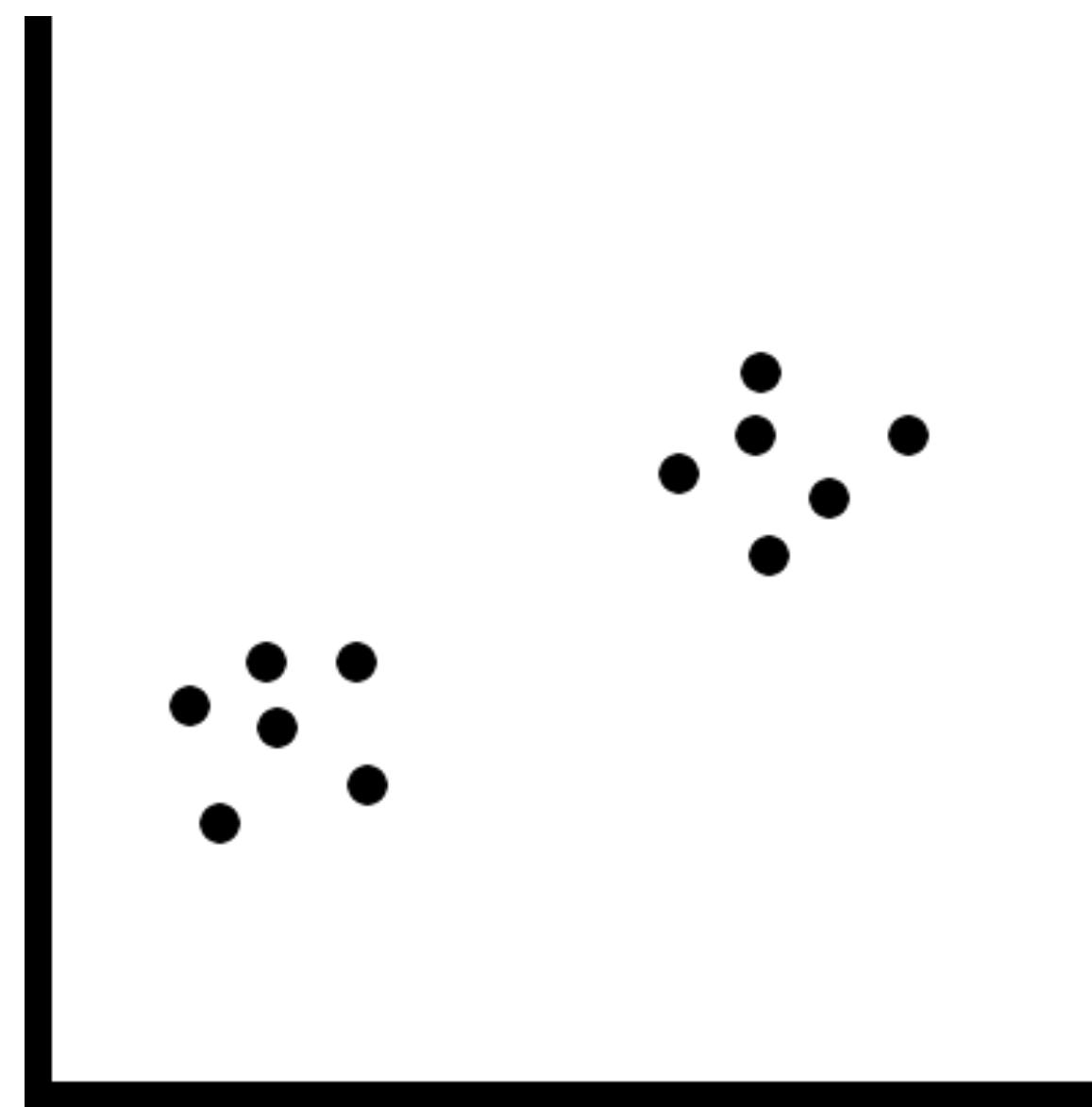


Proximity

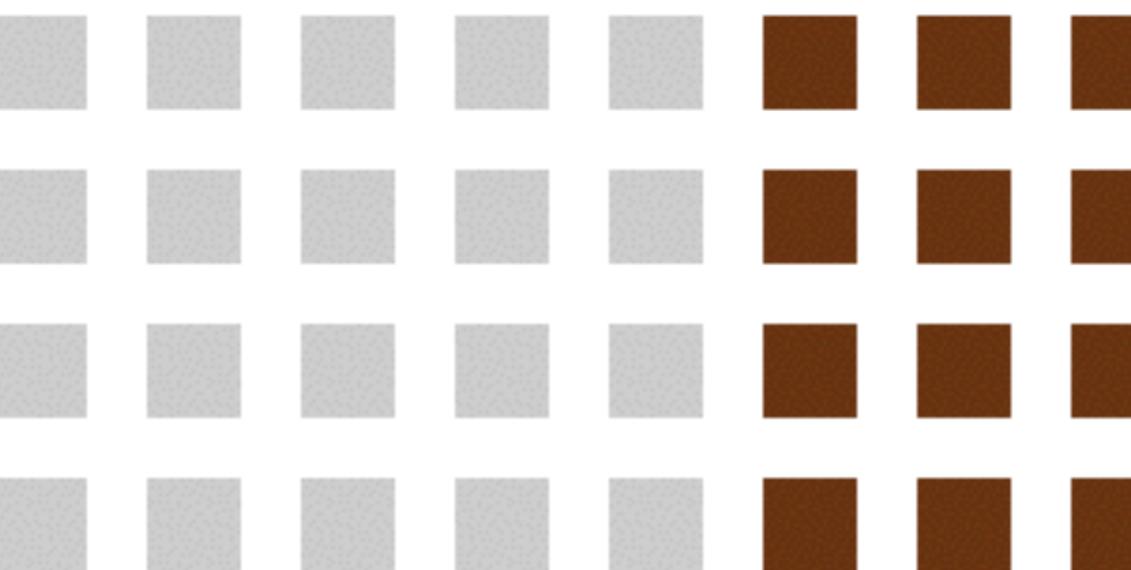
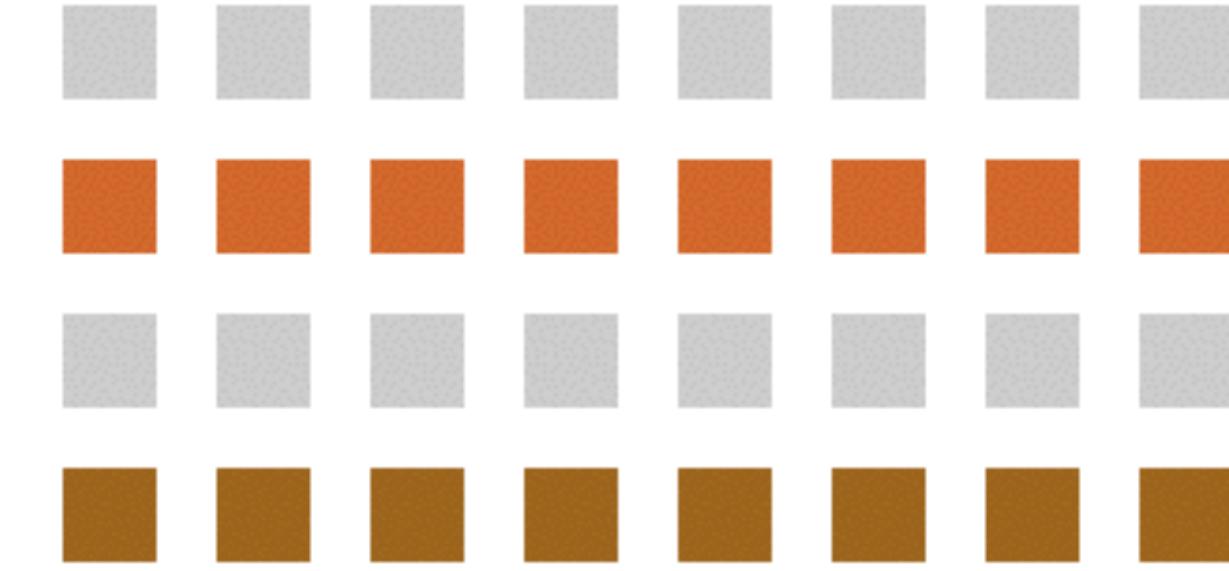


Proximity

Grouping/linking by placing entities in close proximity



Similarity

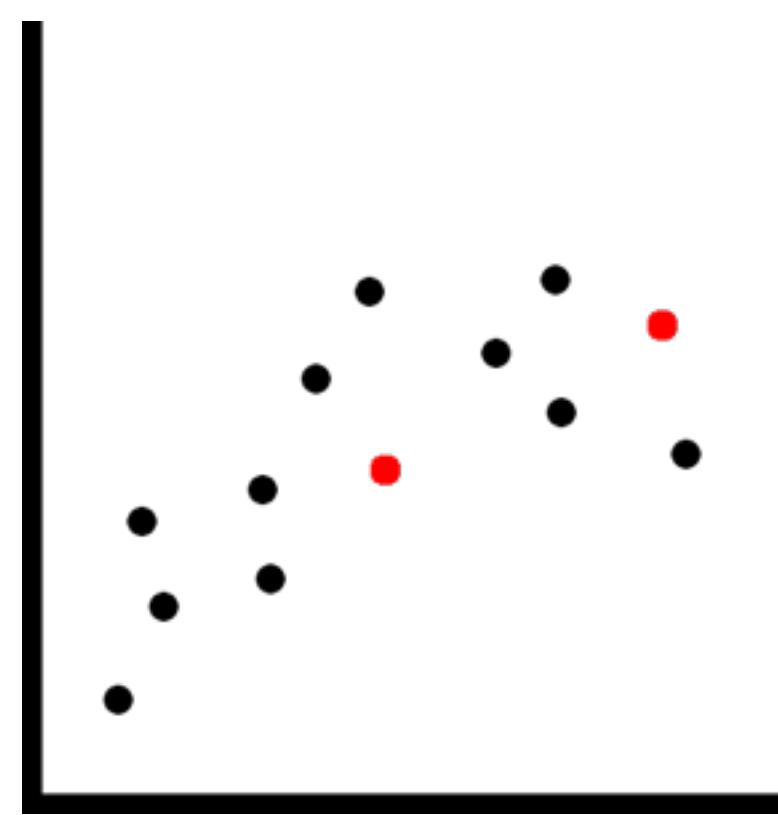


Similarity

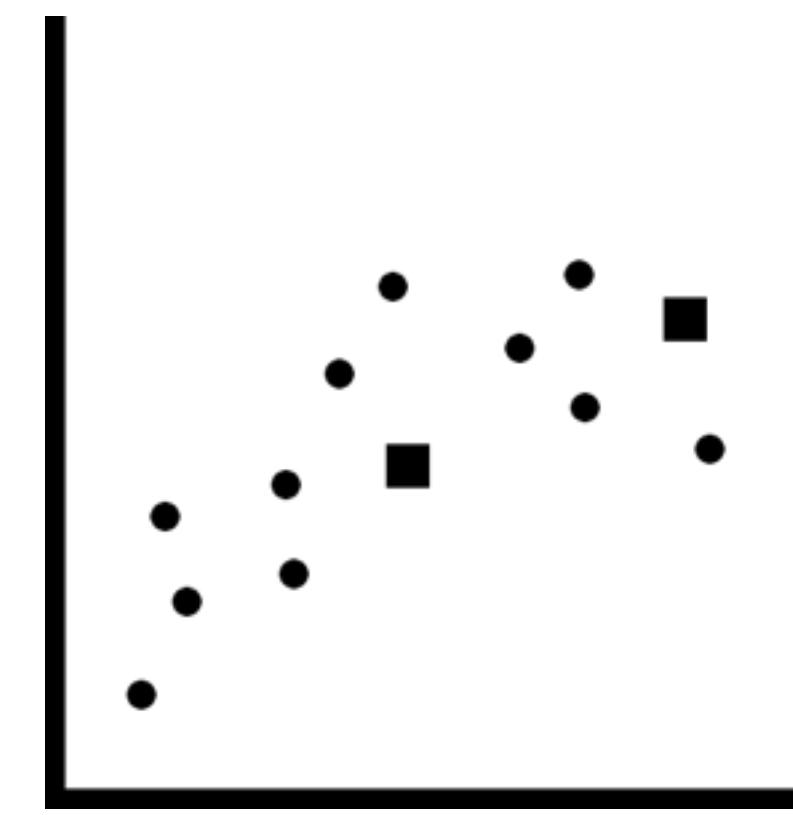
Co-modulation of a **channel**

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

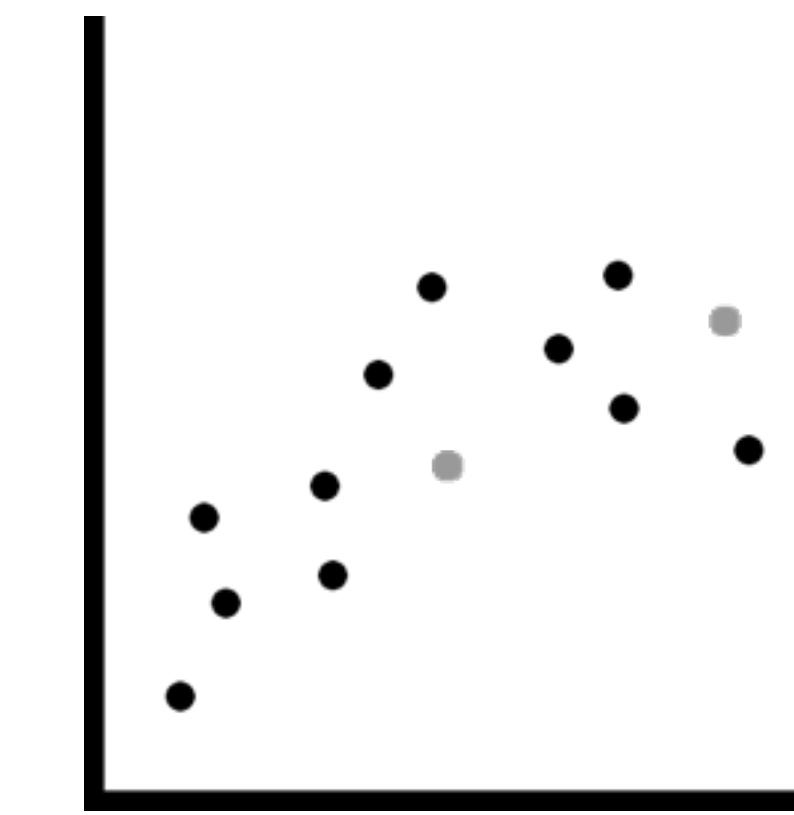
Adding a glyph, label, frame, background



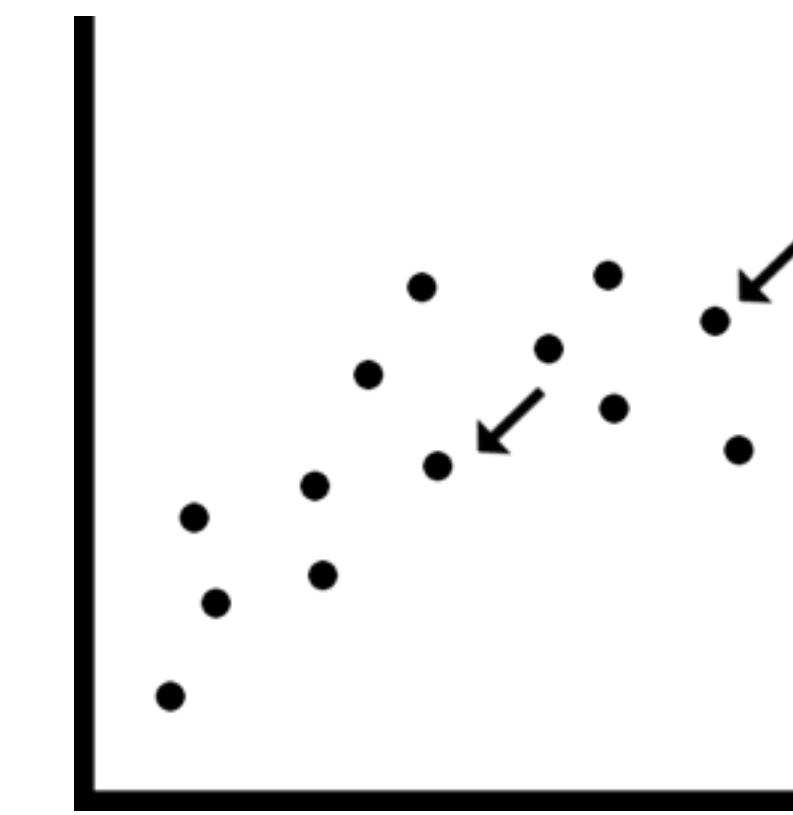
Color



Shape



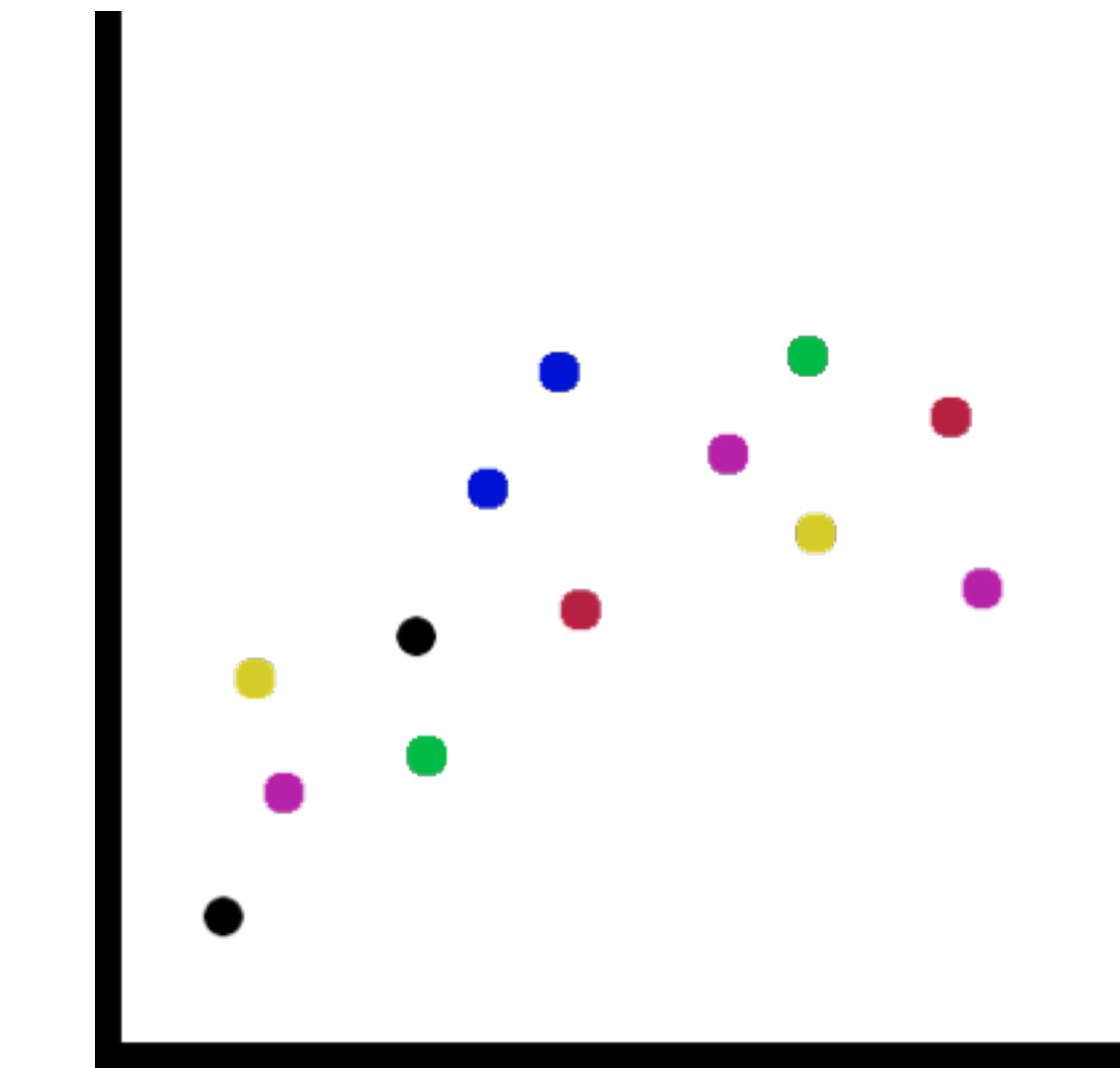
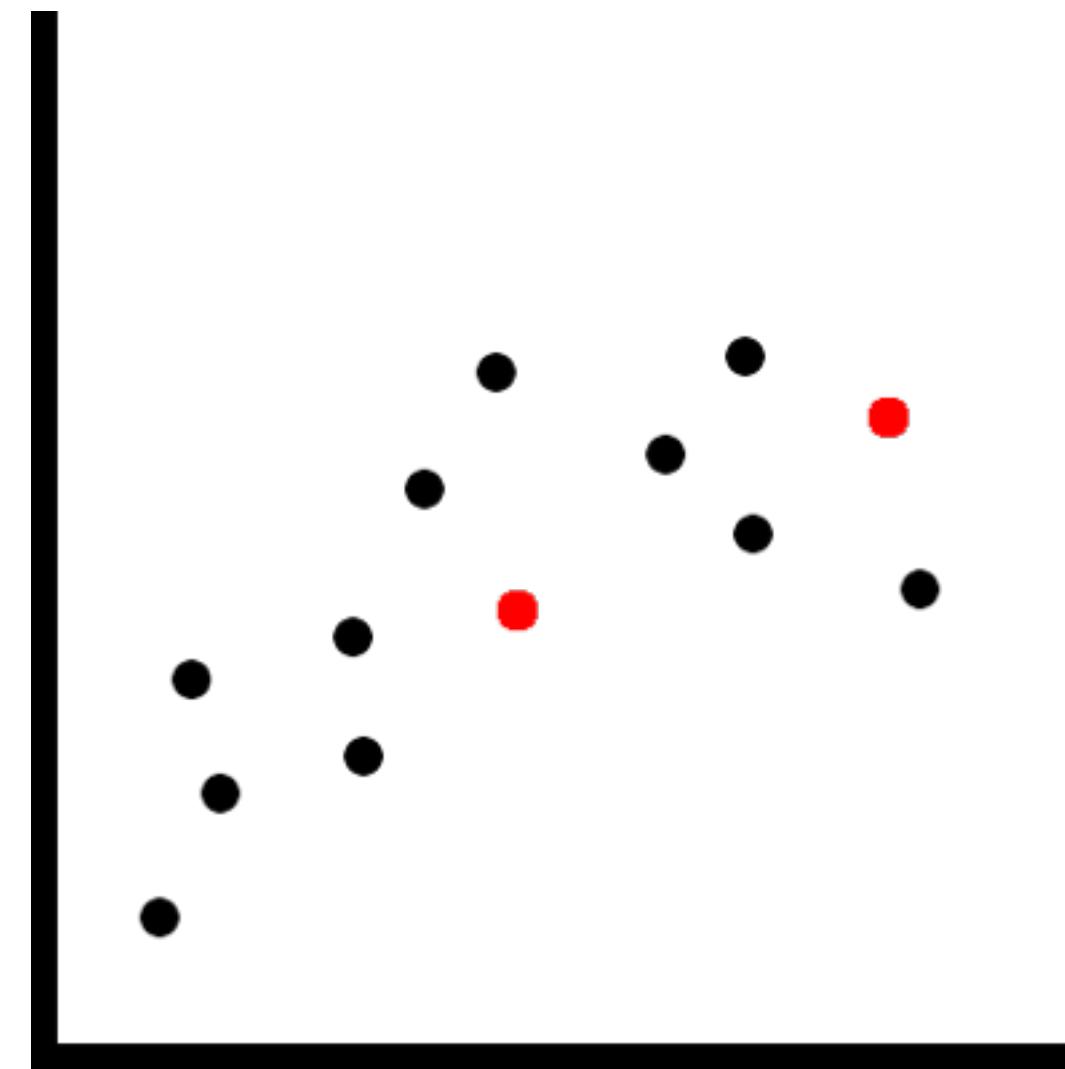
Value



Glyph

Color - Perception Issues (1/2)

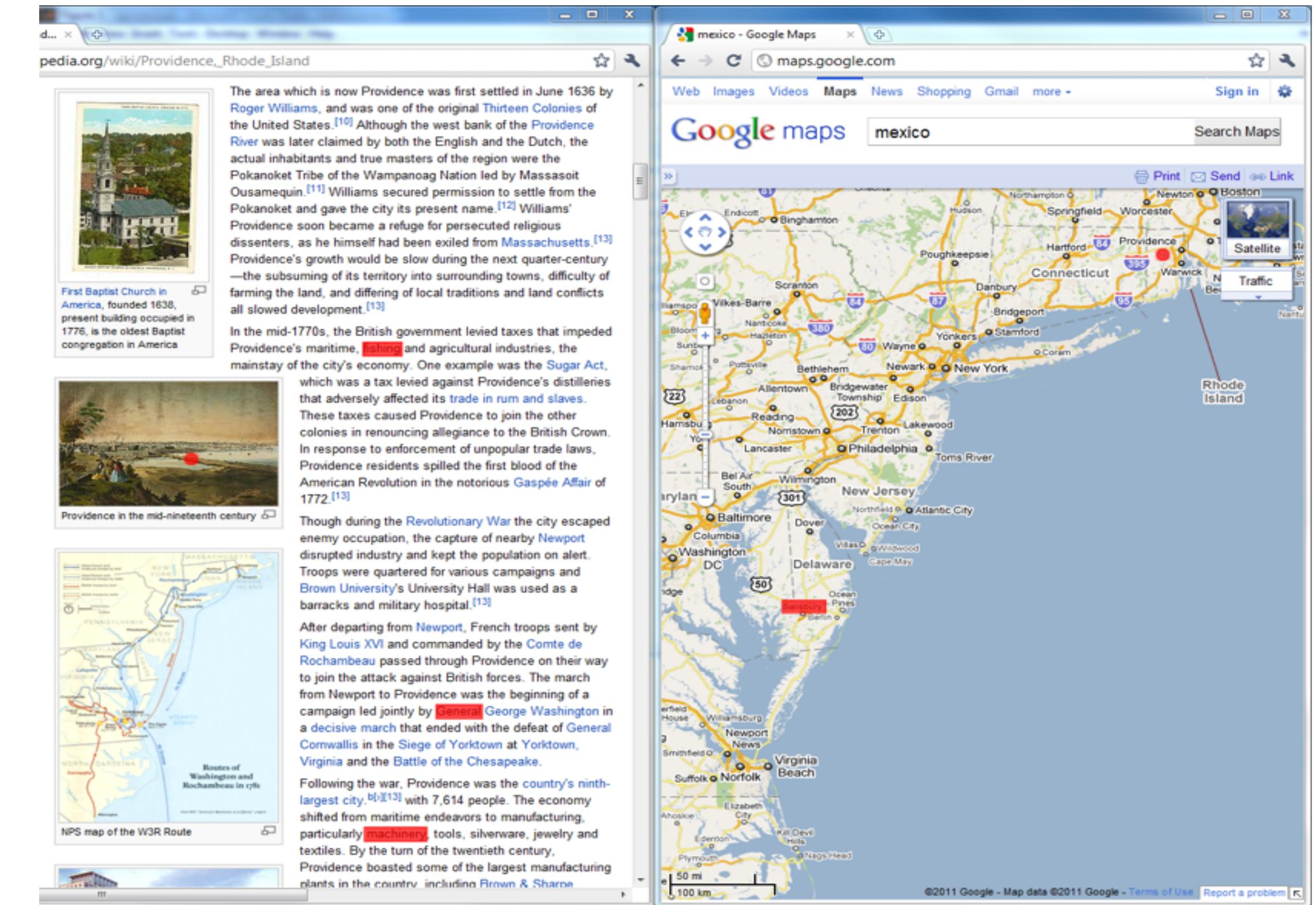
Preattentive properties: Very good for 1-2 simultaneous,
serial search for more



Color - Perception Issues (2/2)

Slower in a cluttered environment

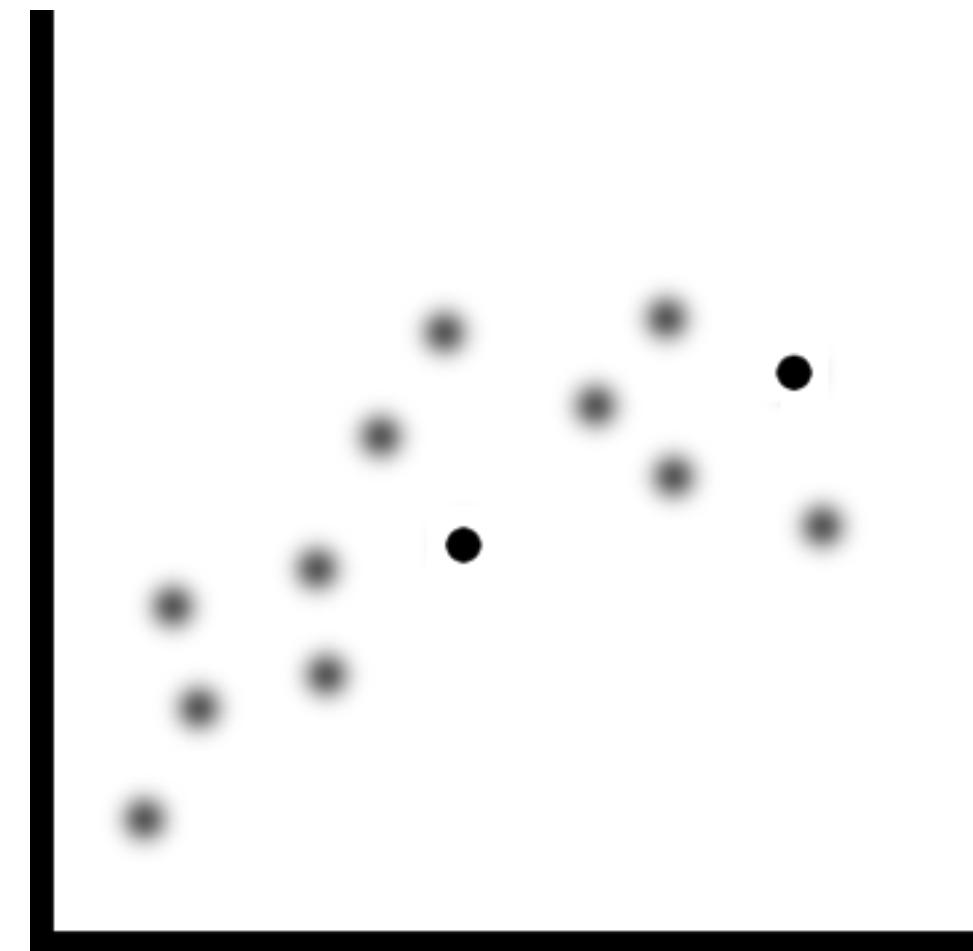
Size of colored object relevant.



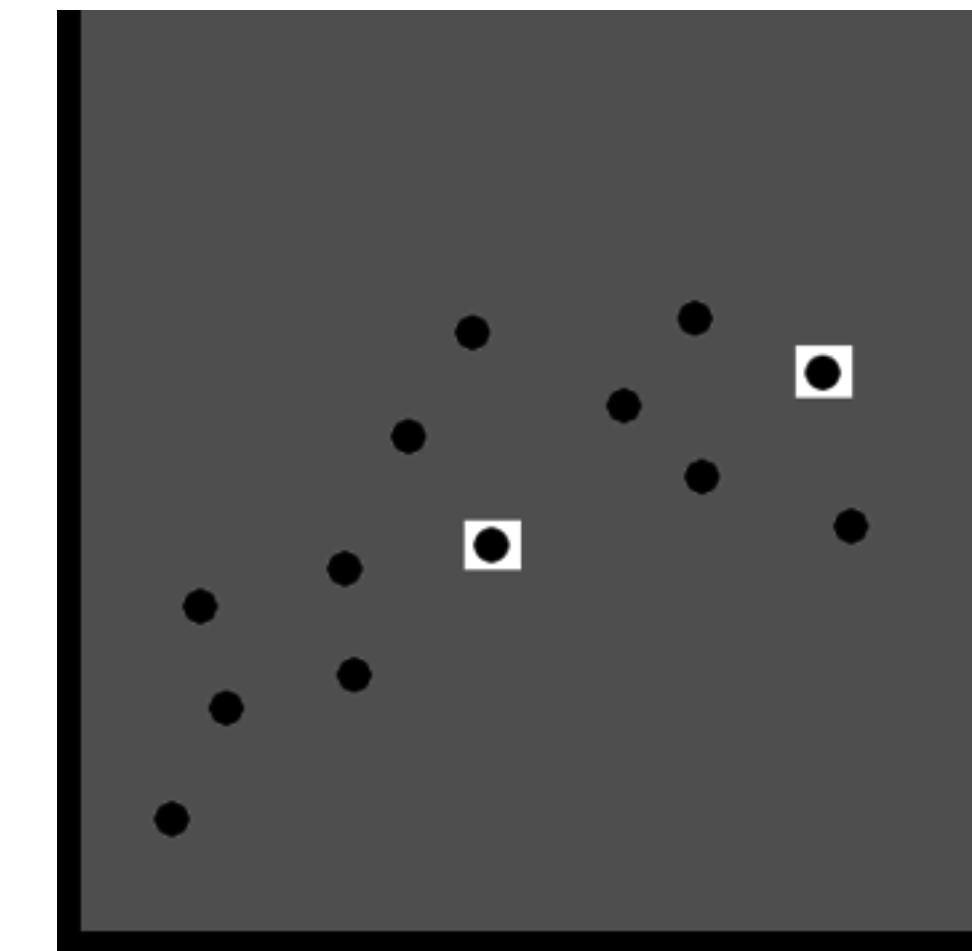
Similarity

Modulate everything else

Blurring, darkening, desaturating, etc.



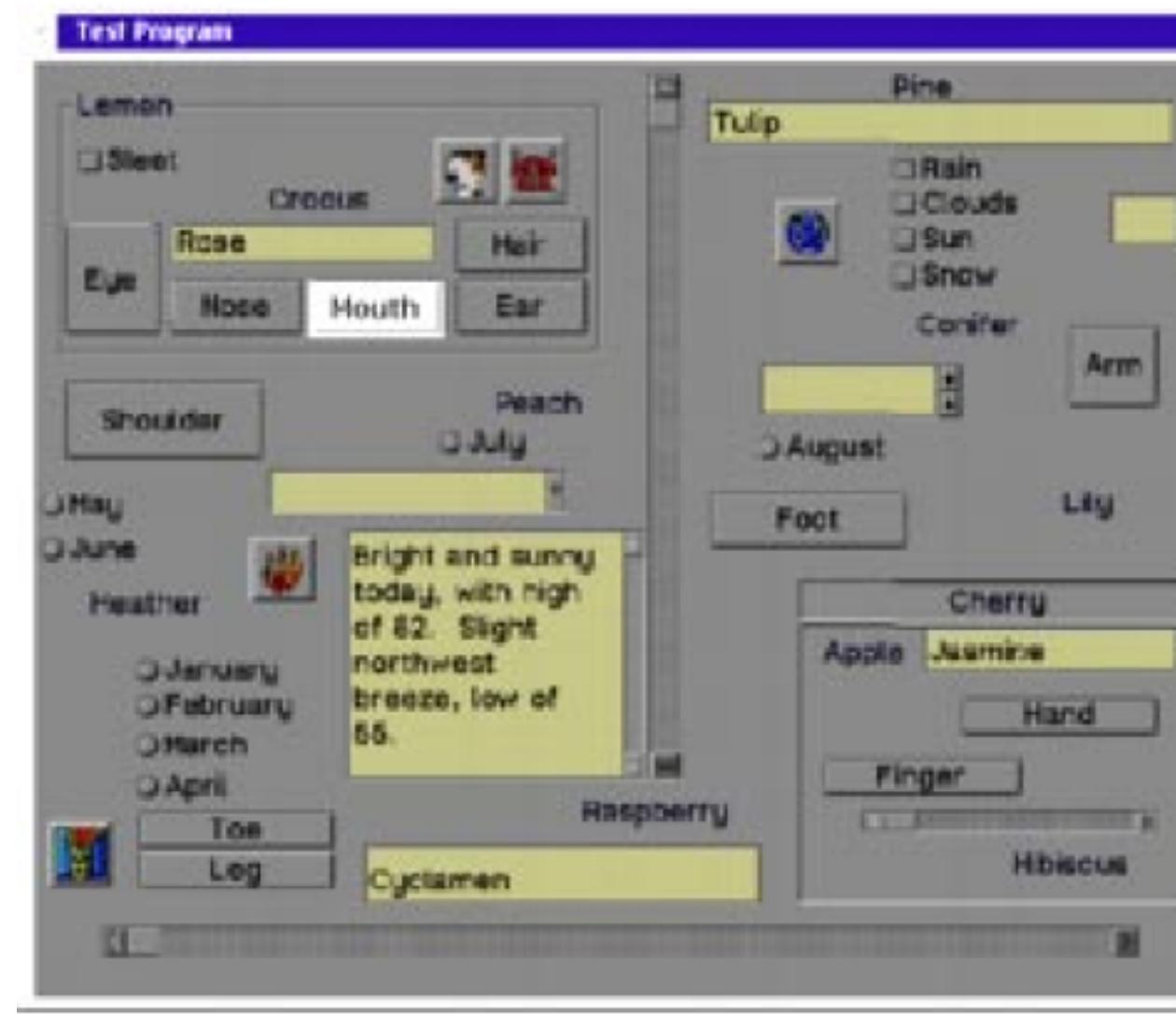
Blur



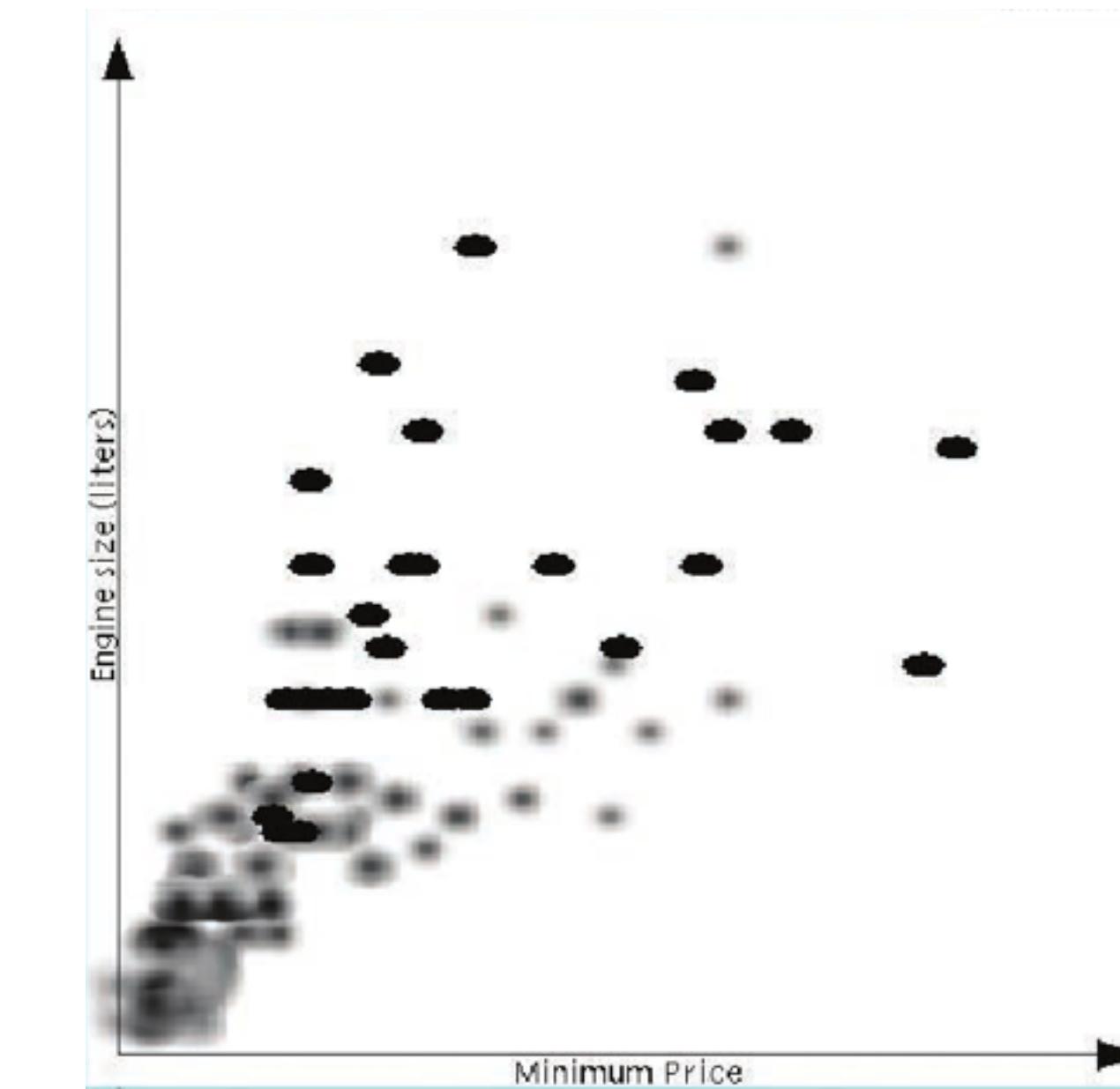
Darkening

Modulating Everything Else: Recommendation, Example

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

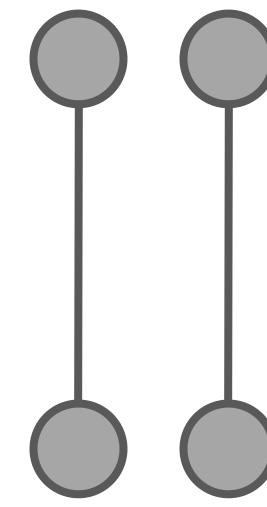


[Zhai et al., 1997]

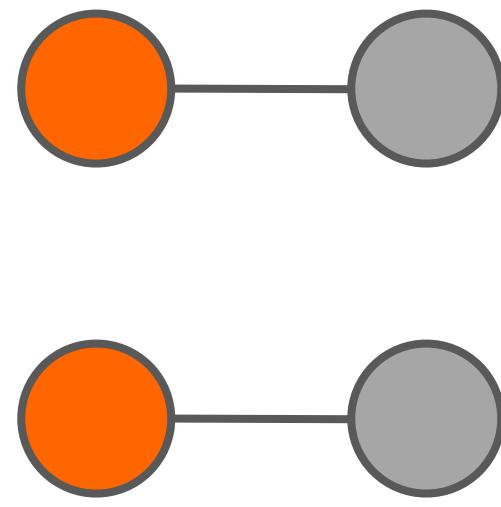


[Kosara et al., 2002]

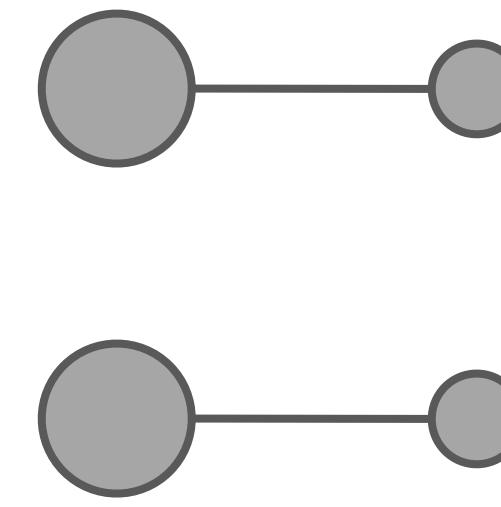
A Little Experiment...



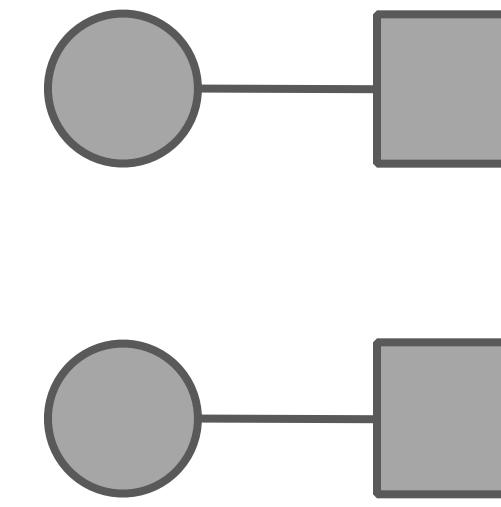
Proximity



Color



Size

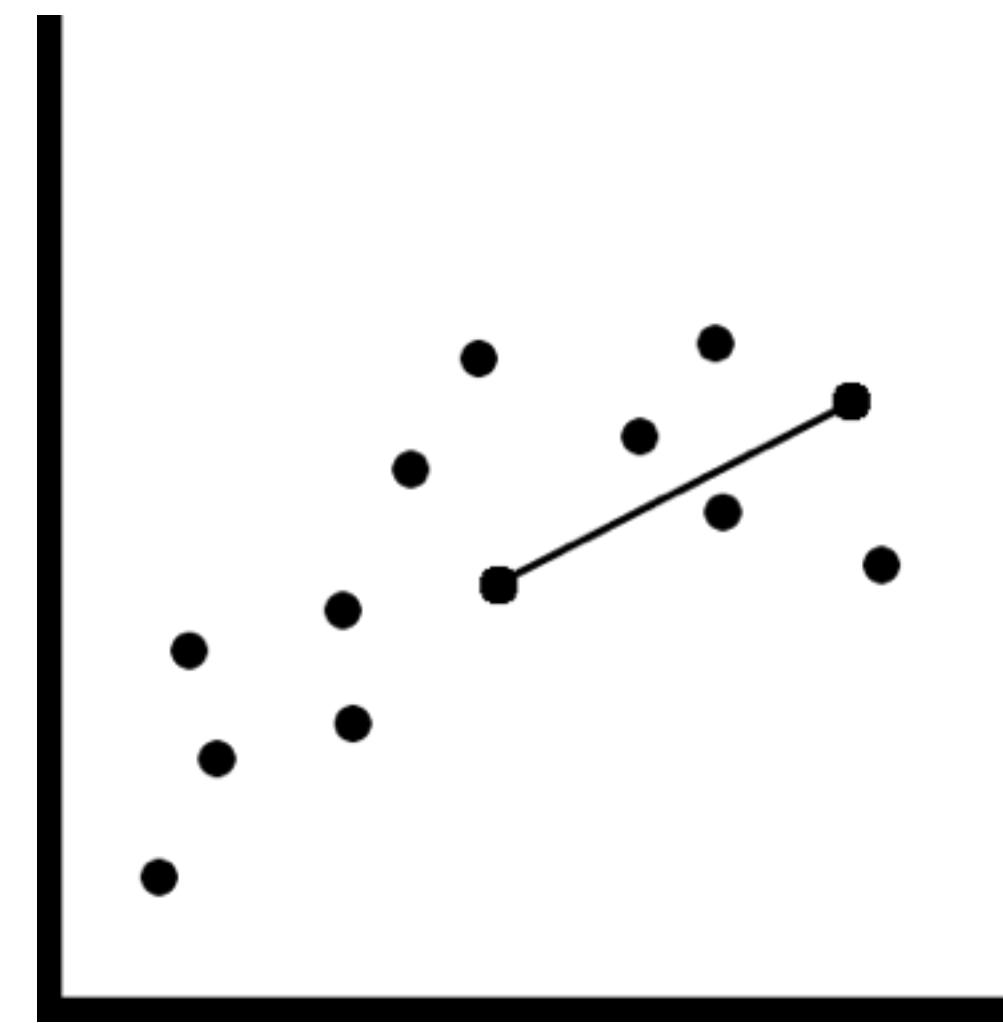


Shape

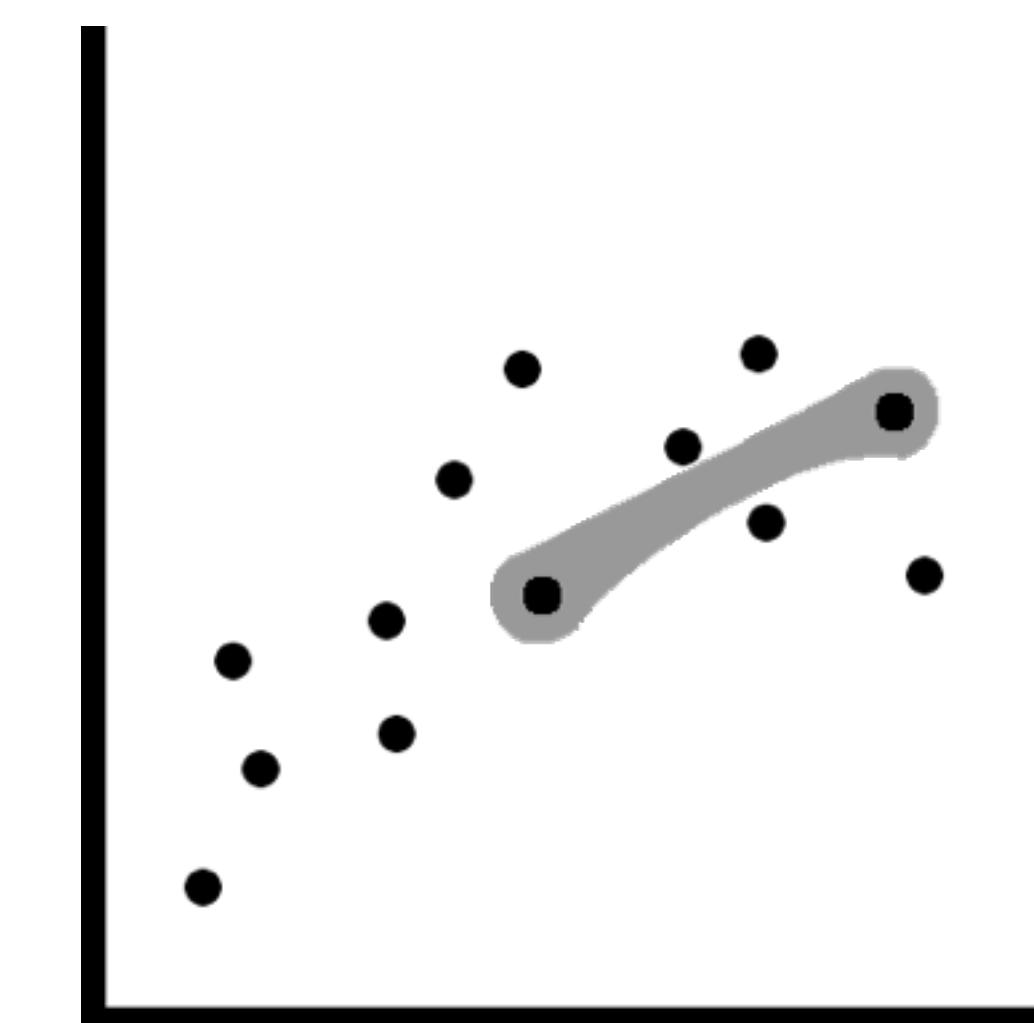
Connectedness and Common Region

Connected items with a line or curve

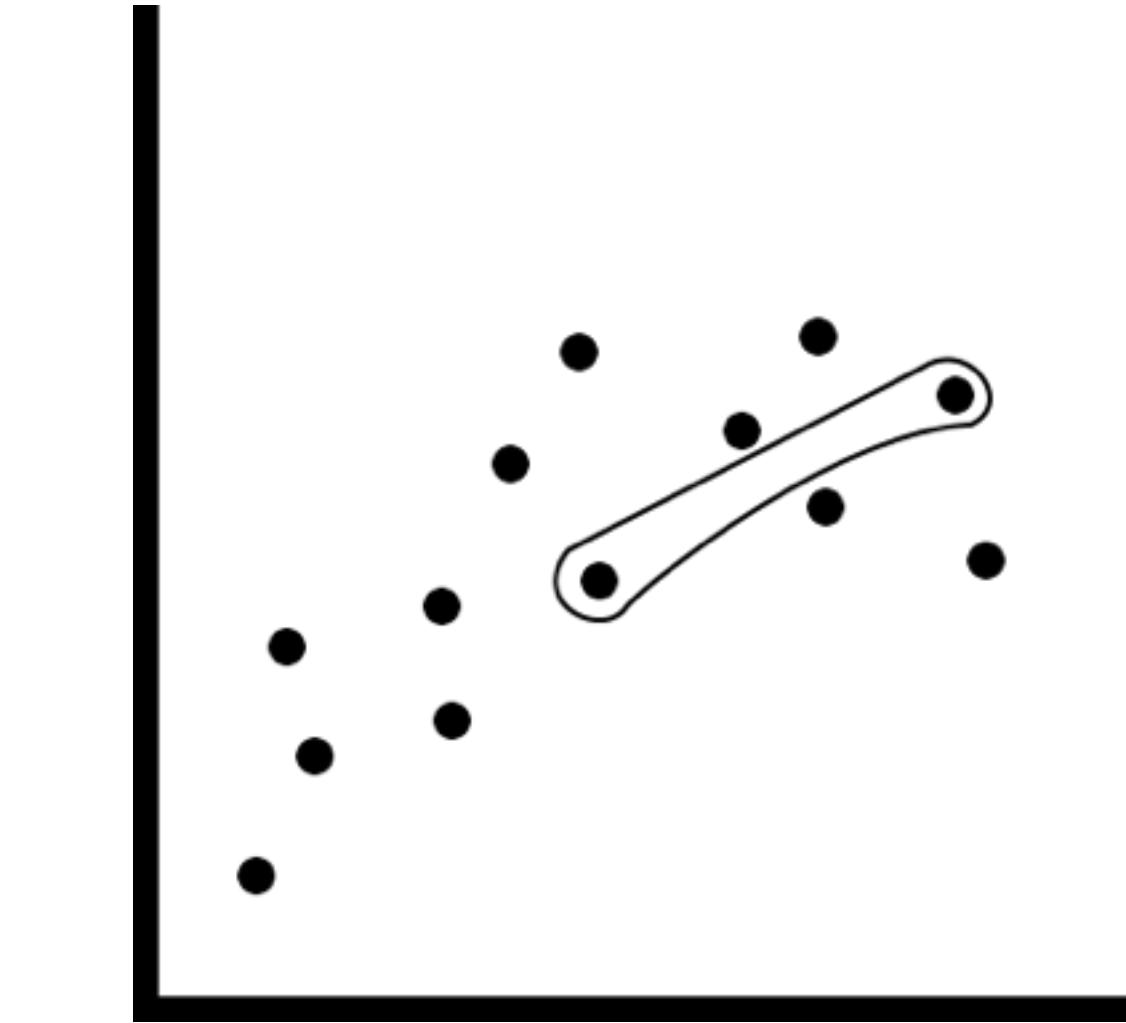
Surround items with a outline, surface, volume



Connectedness



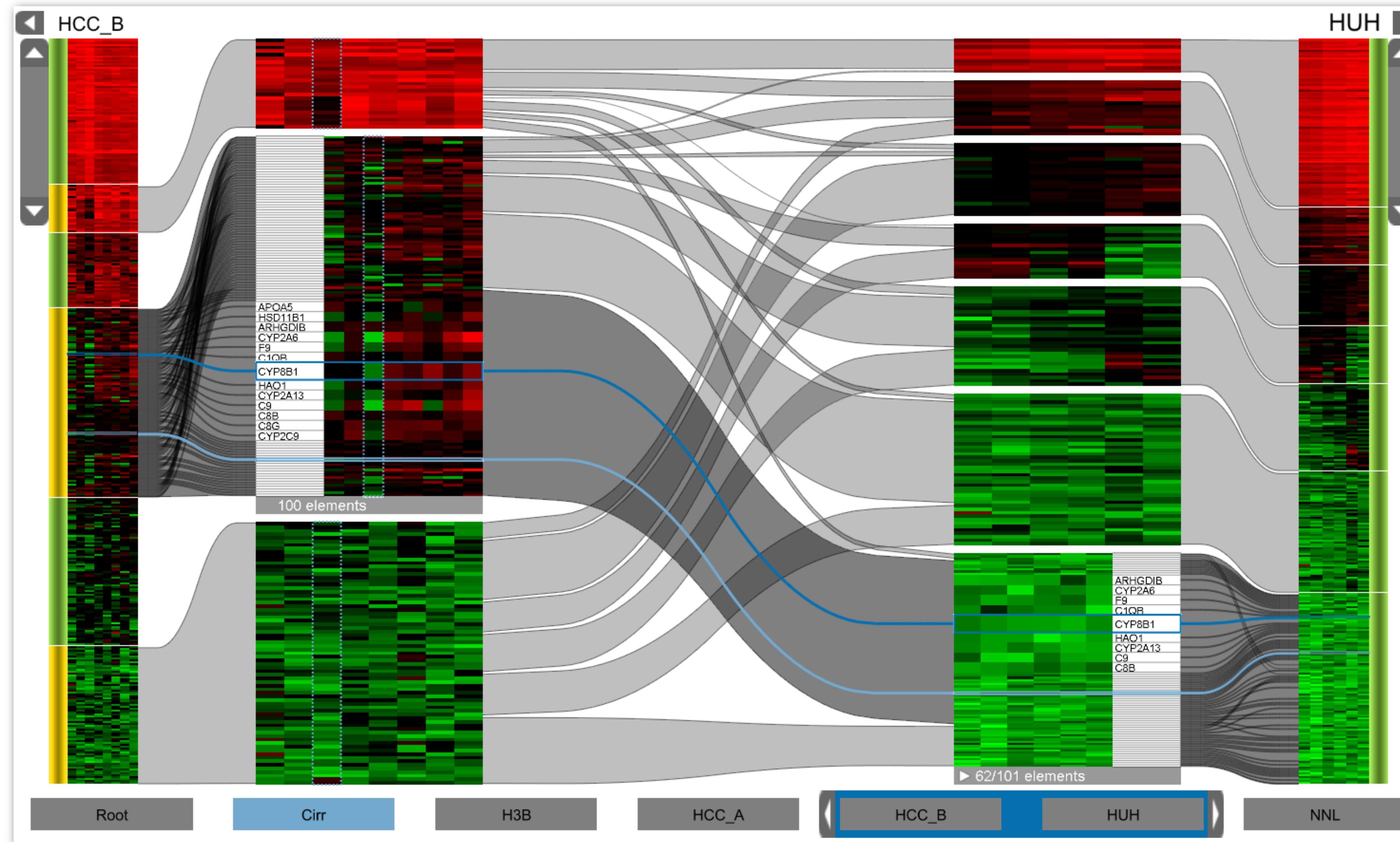
Surface



Common Region

Outline

Connection



Enclosure

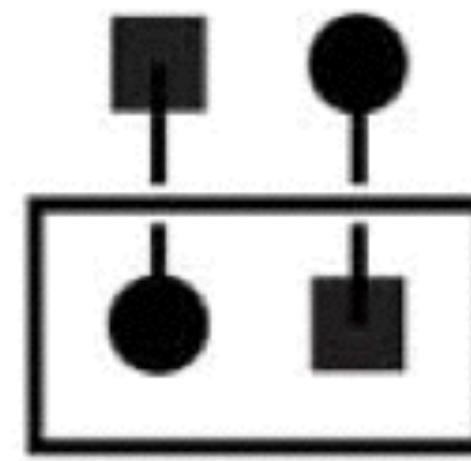
Similarity



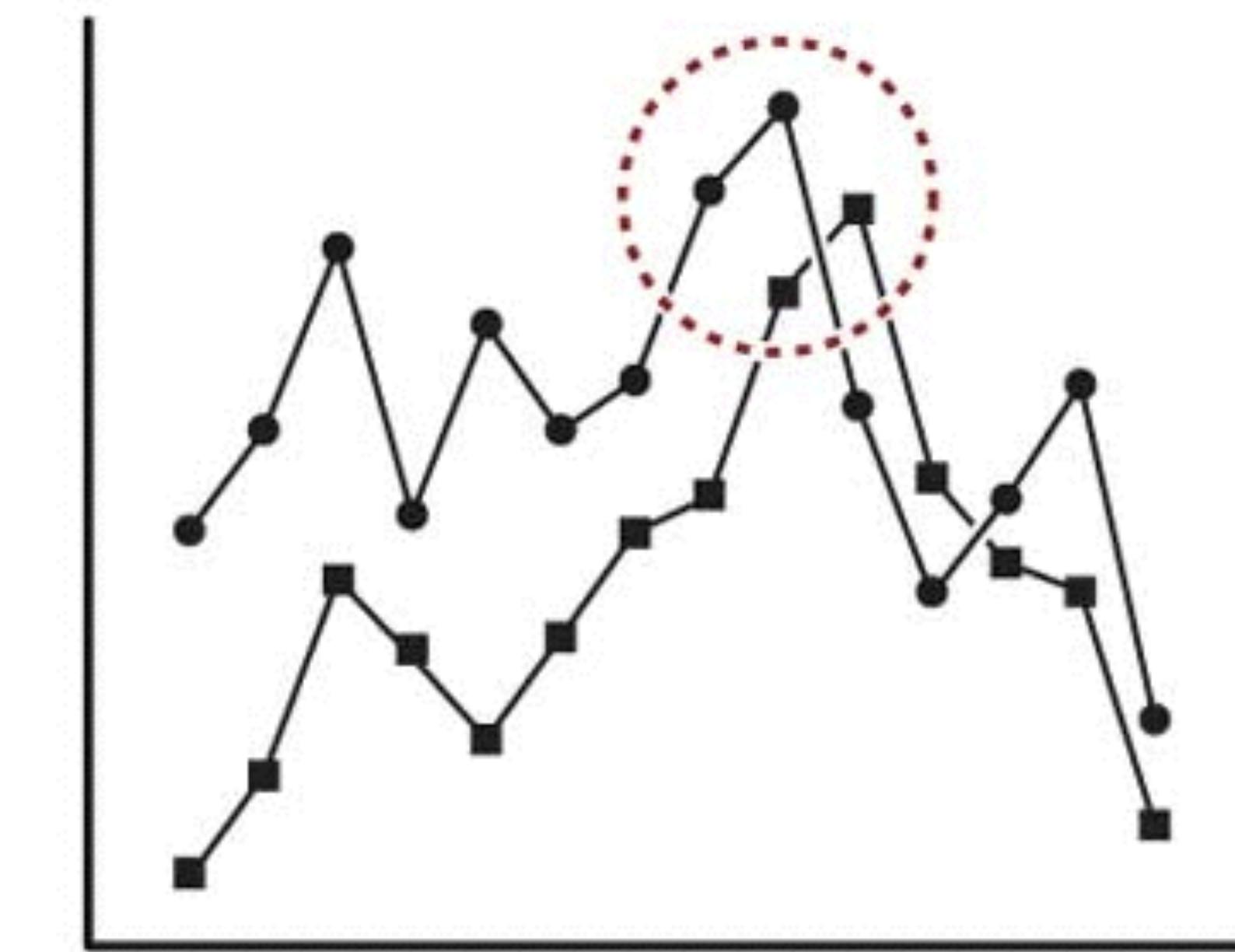
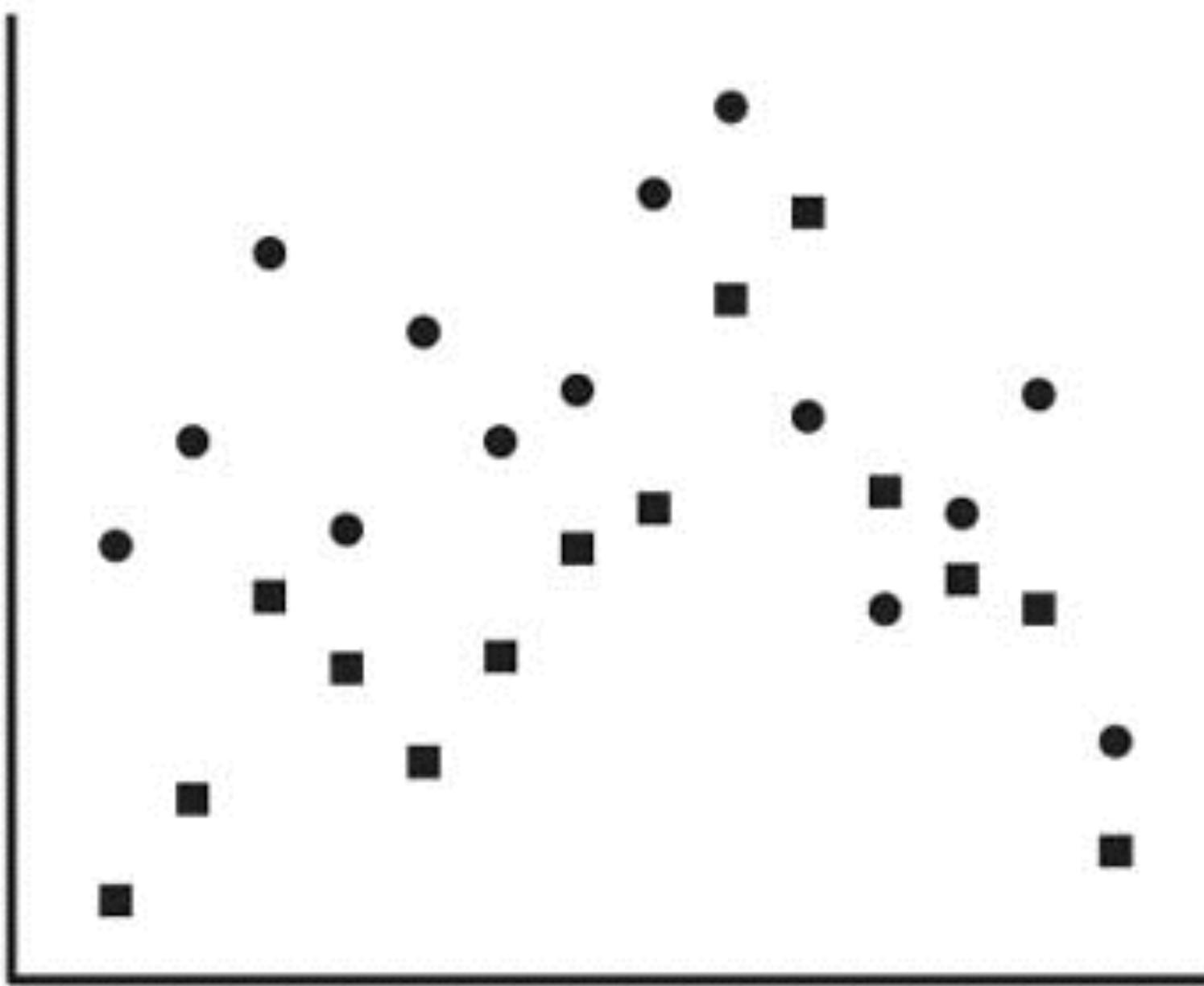
Connection



Enclosure



Enclosure



Connectedness Varieties

Bubble Sets

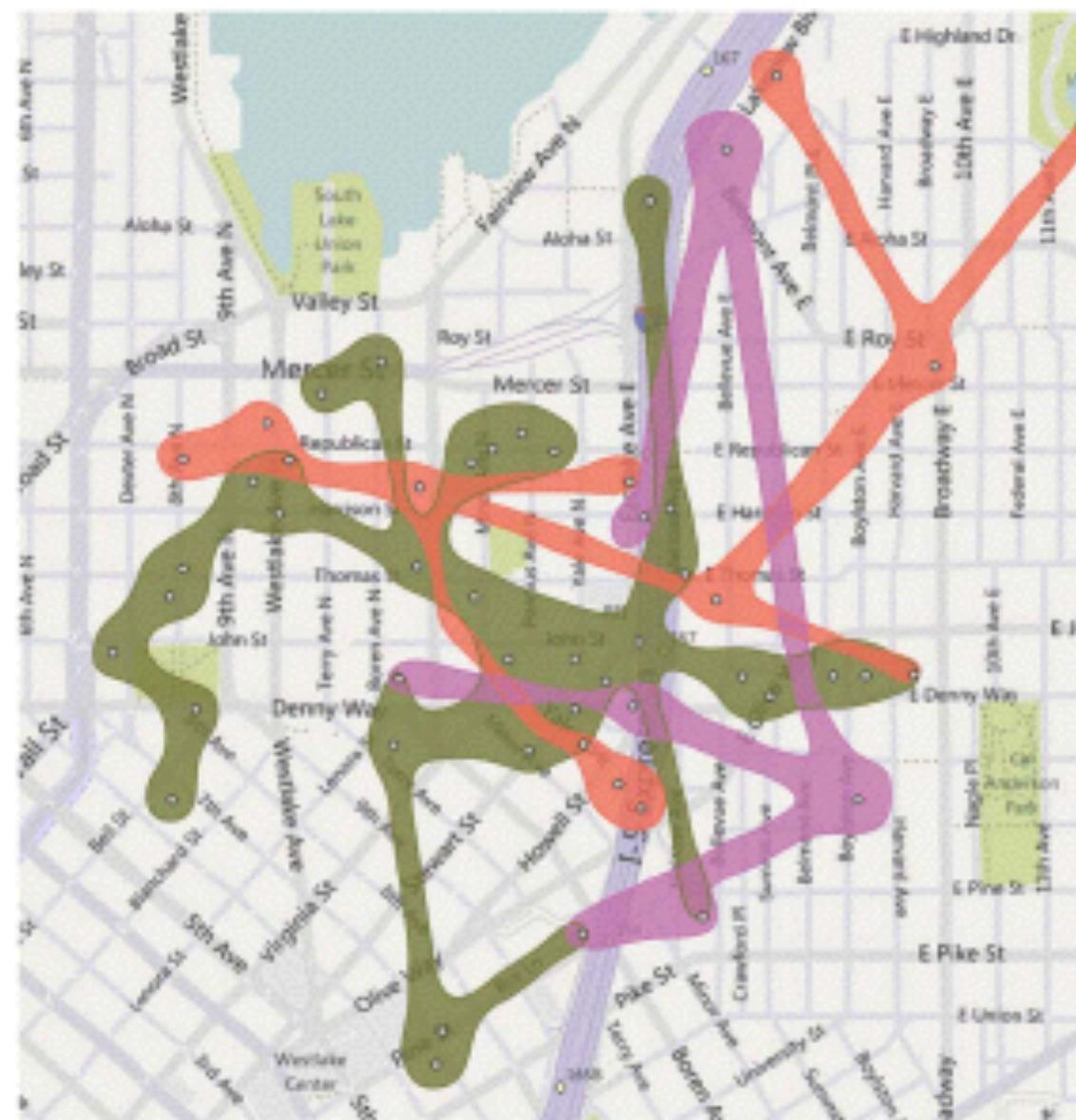
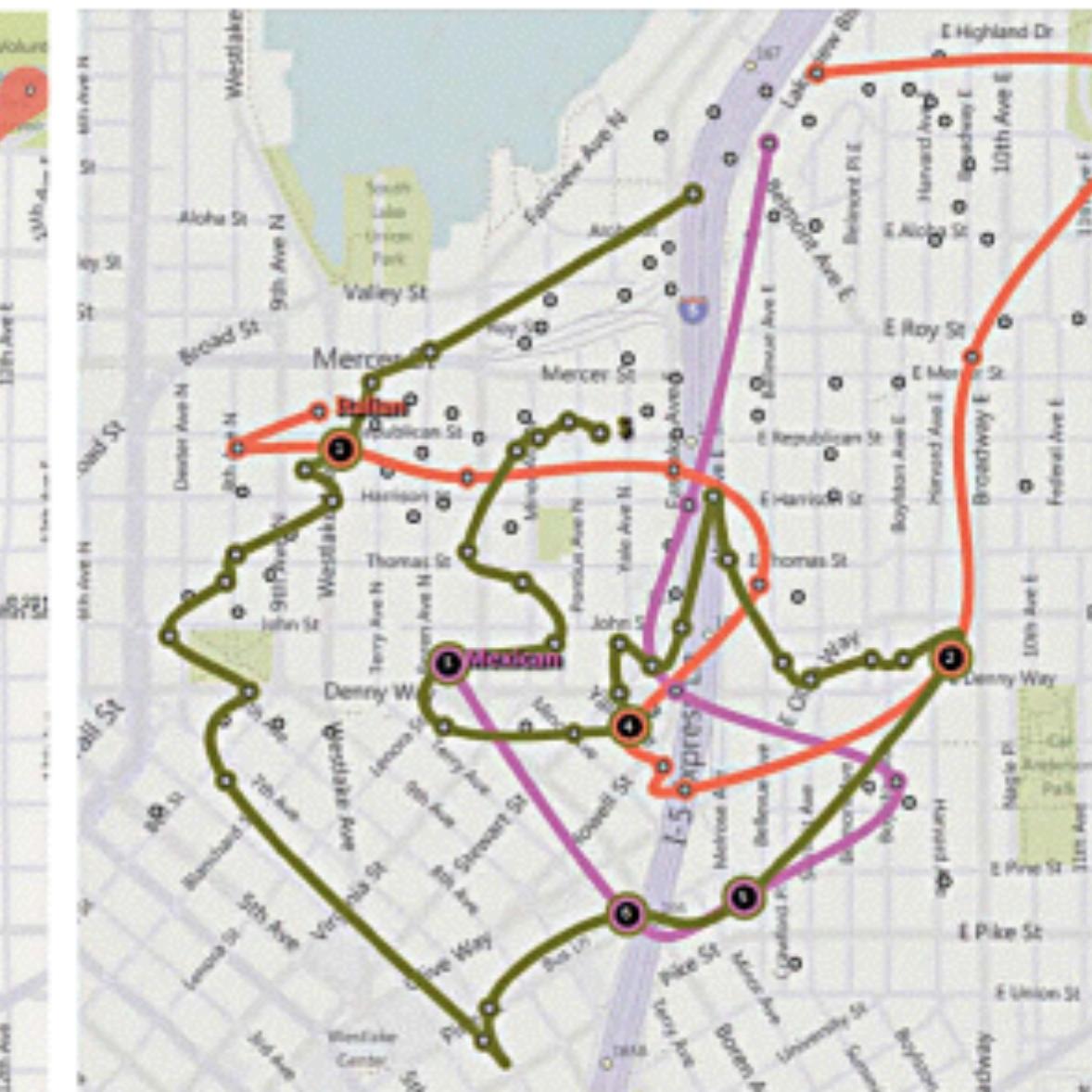


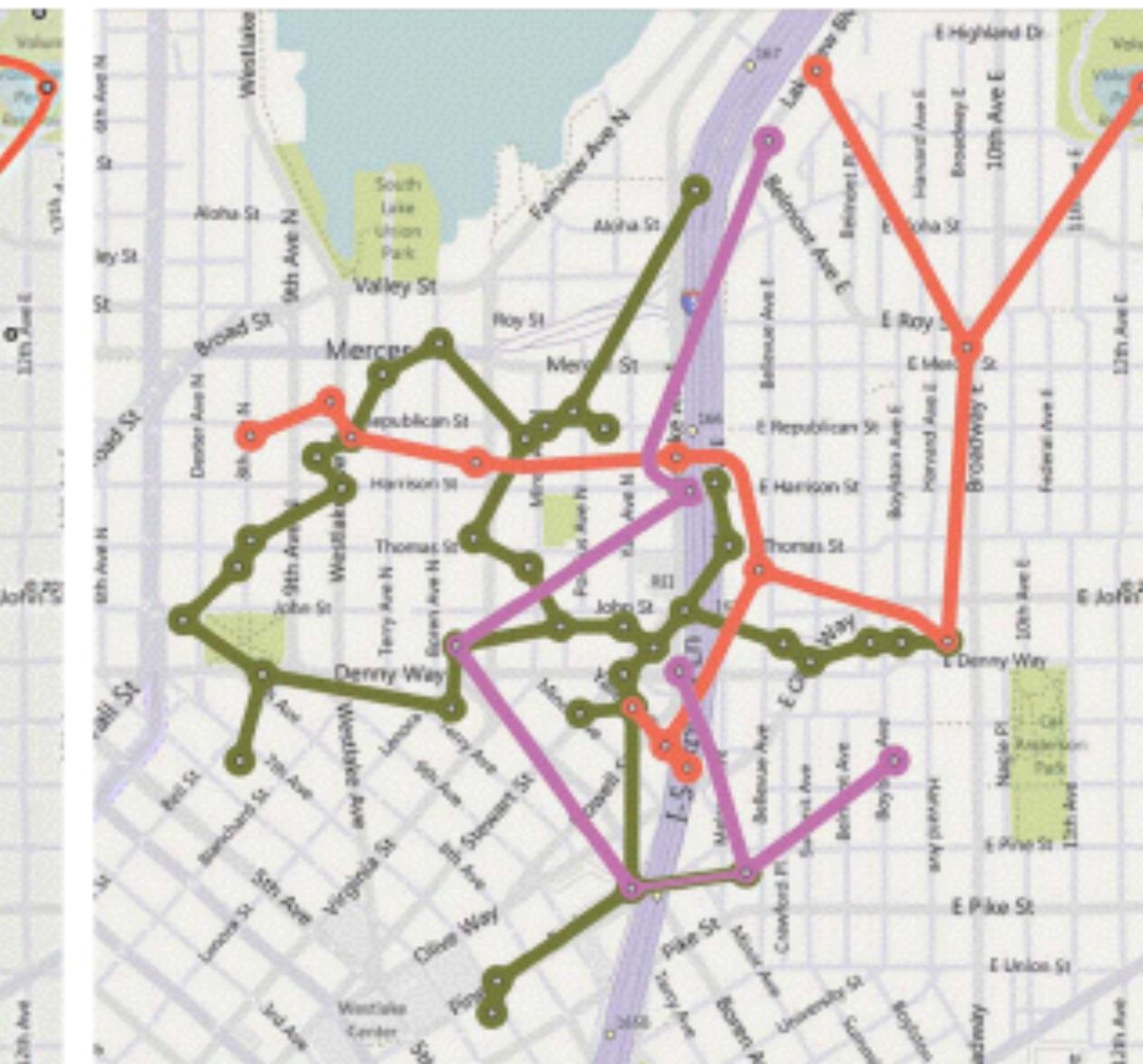
Image by [Dinkla et al., 2011]
Technique by [Collins et al., 2009]

Line Sets



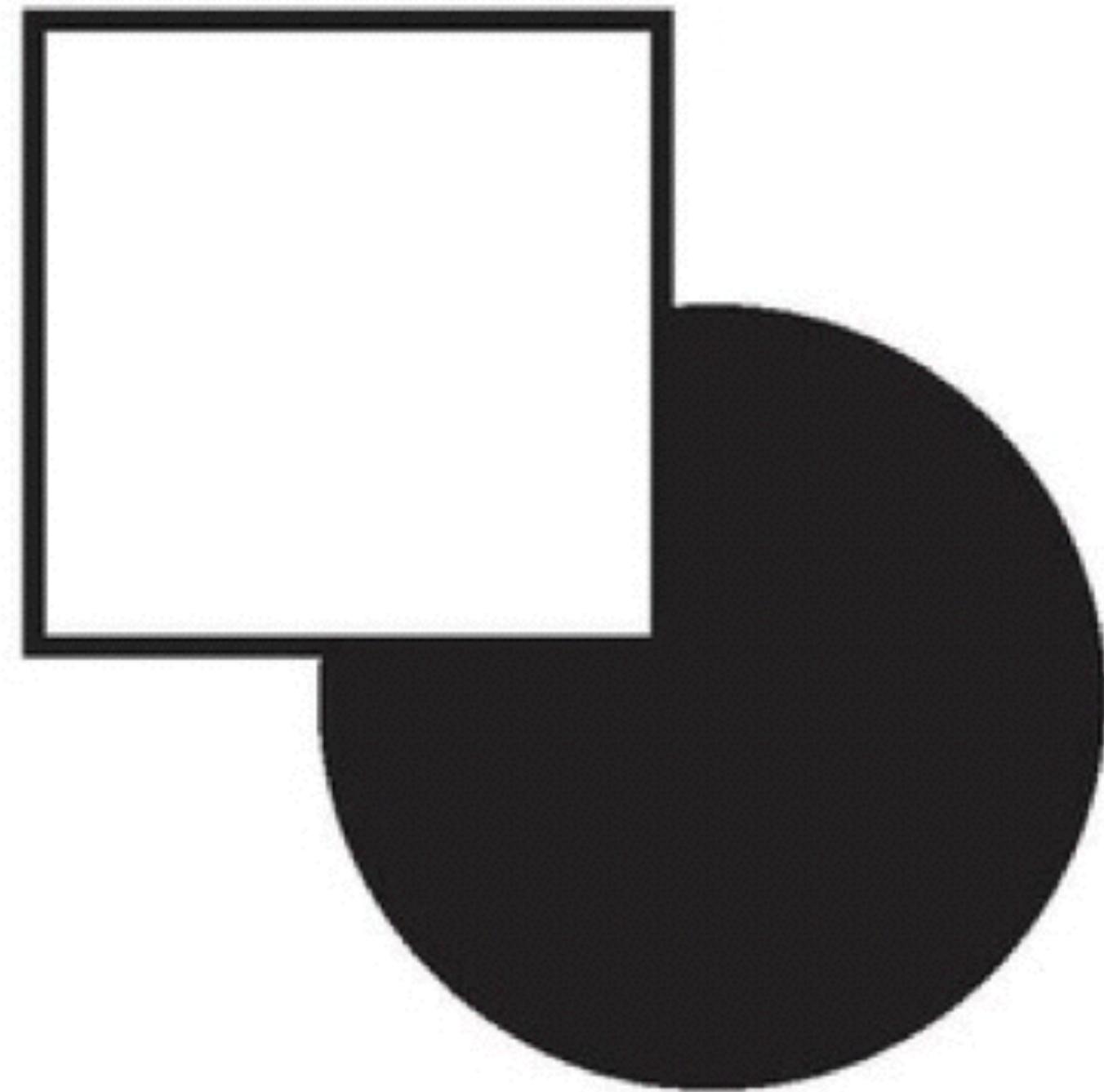
[Alper et al., 2011]

Kelp Diagrams

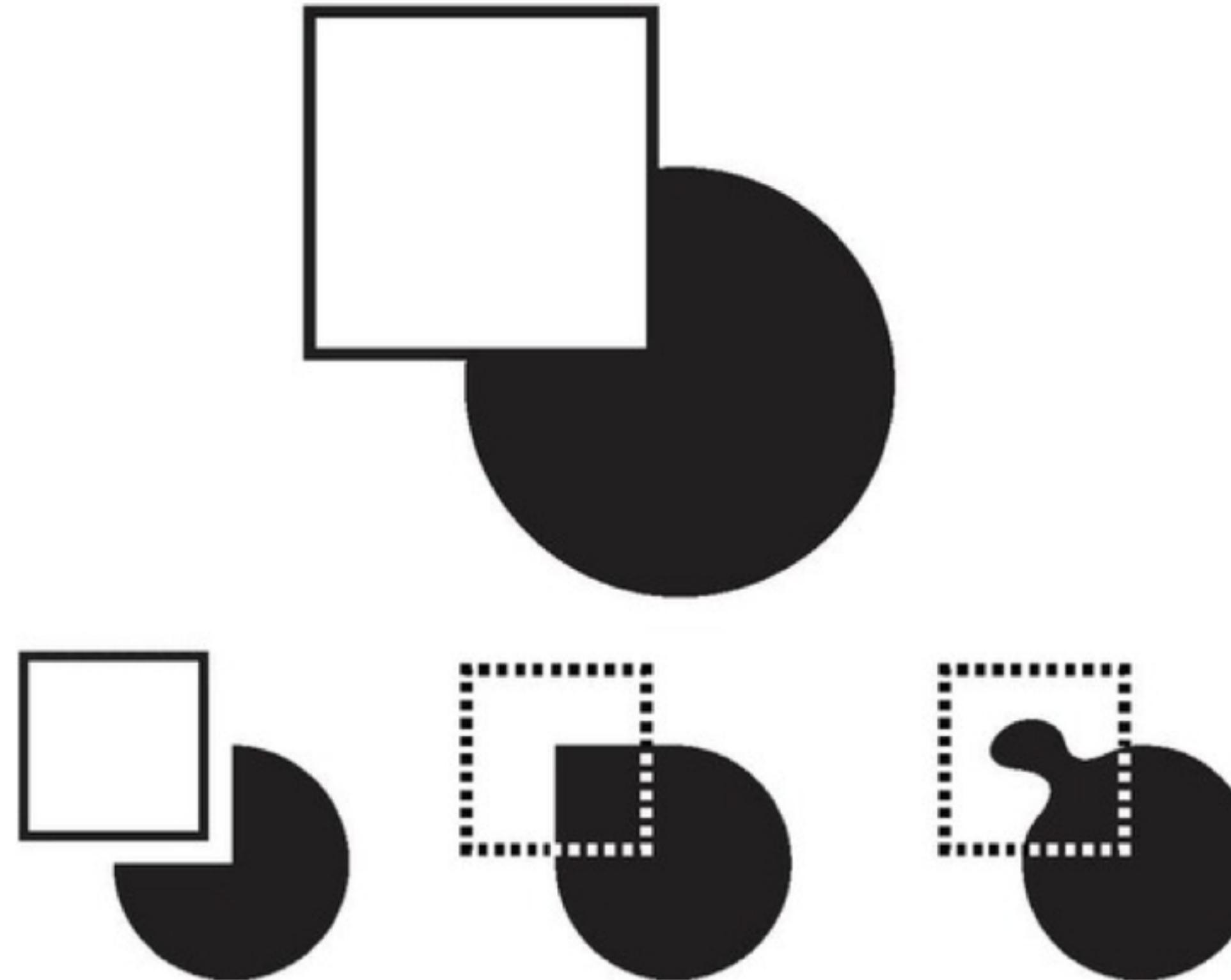


[Dinkla et al., 2012]

Continuity

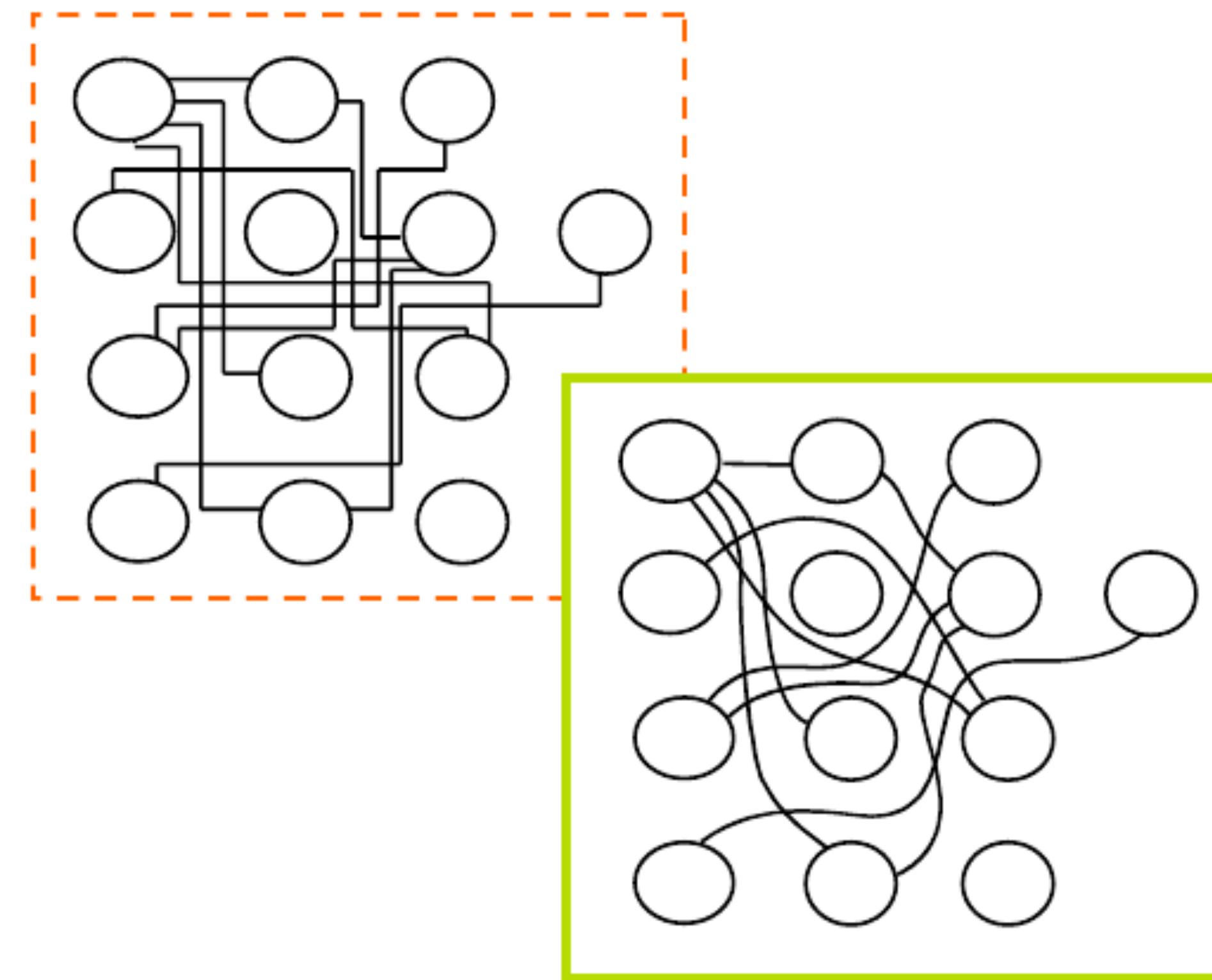
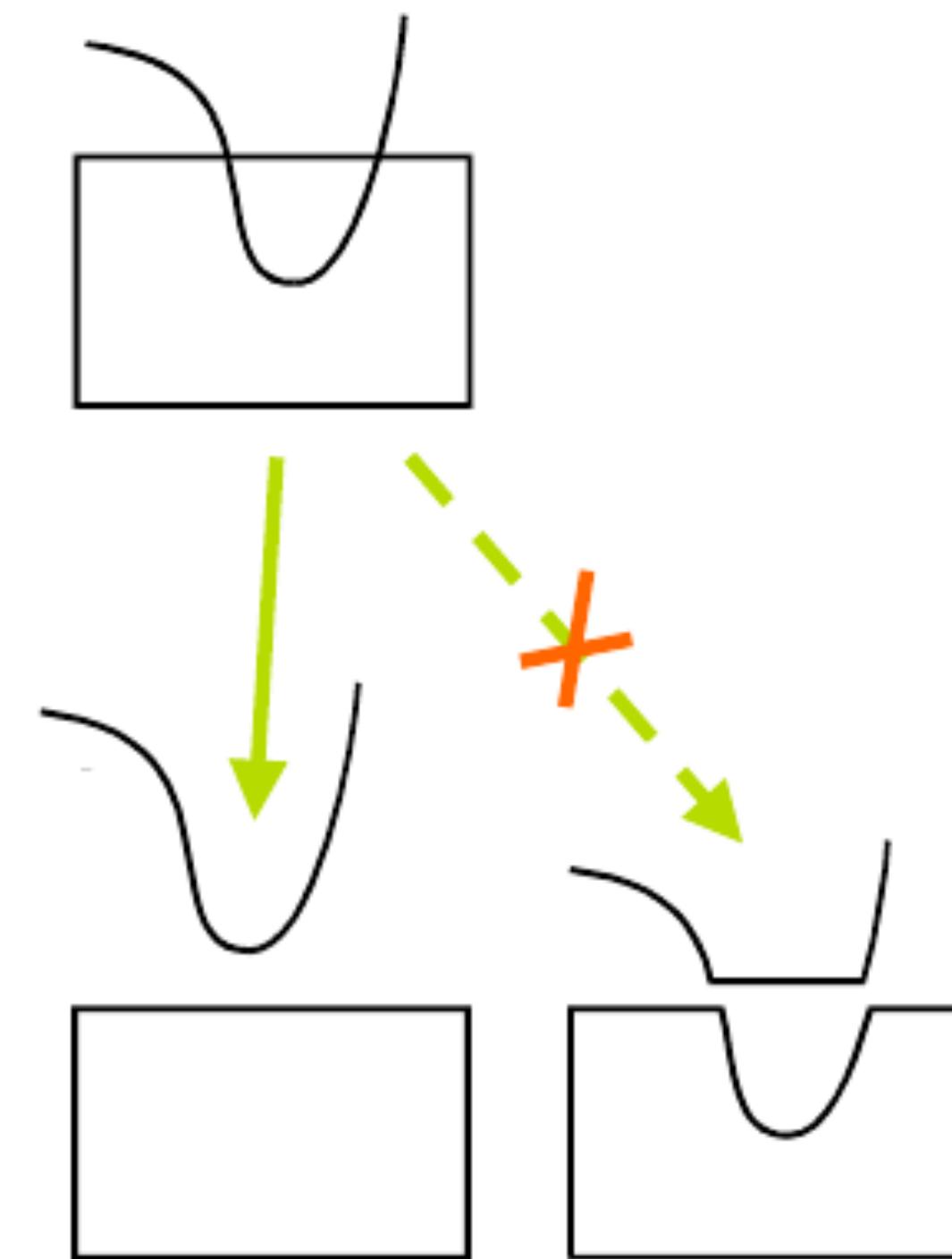


Continuity

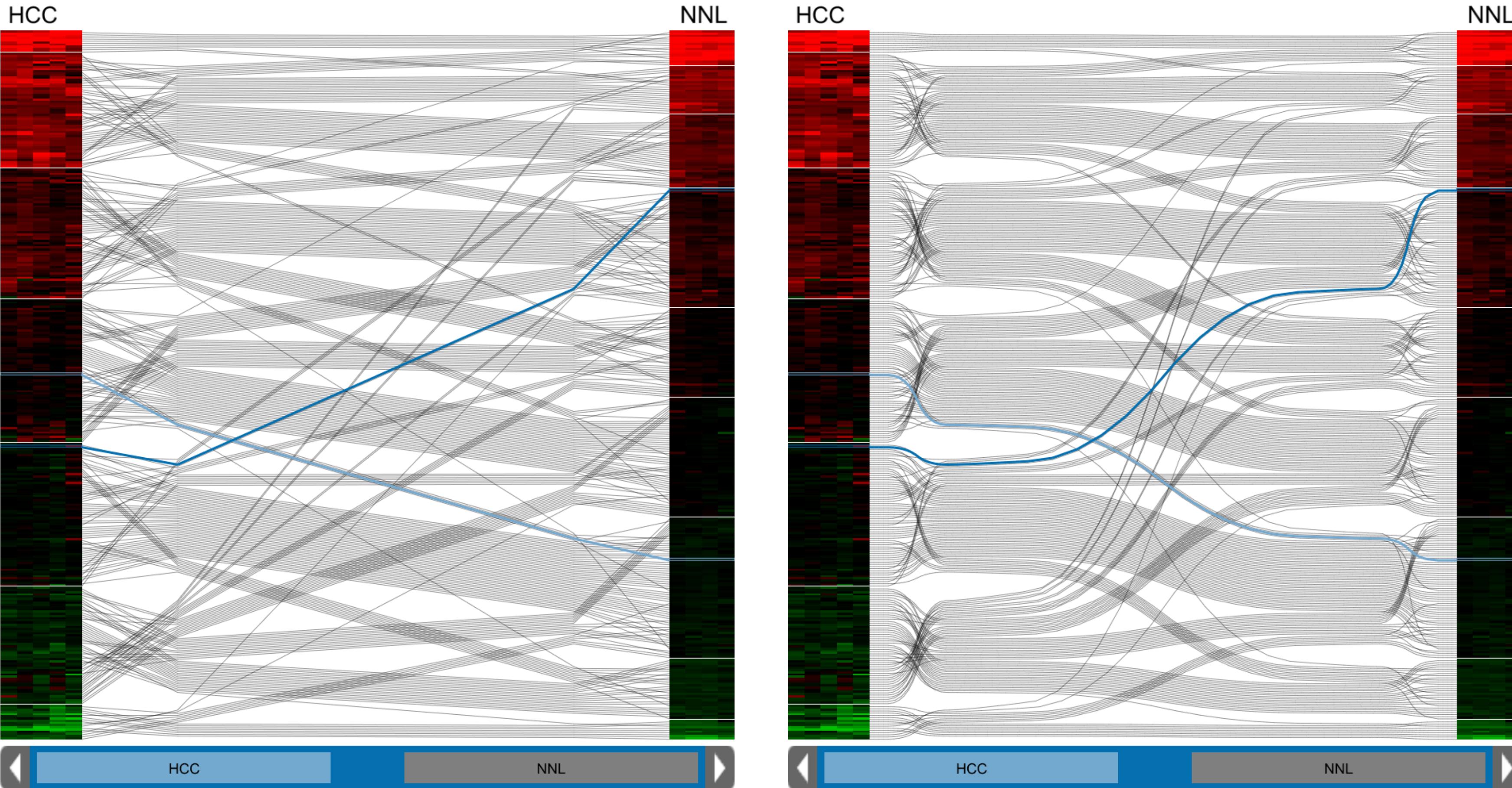


Continuity

Things: smooth & continuous



Continuity



Closure



Closure

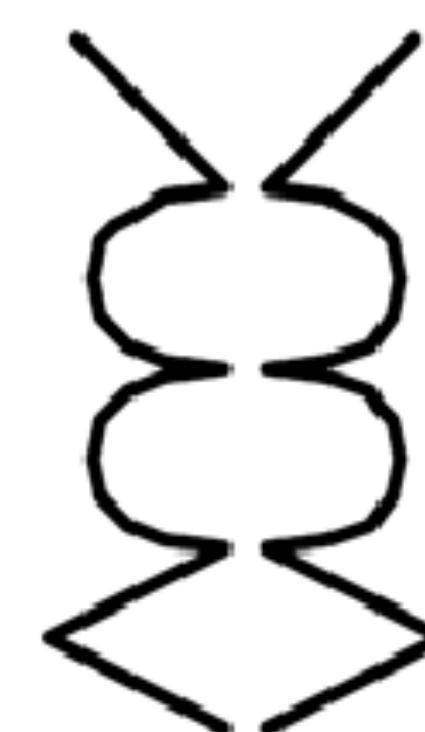


Symmetry

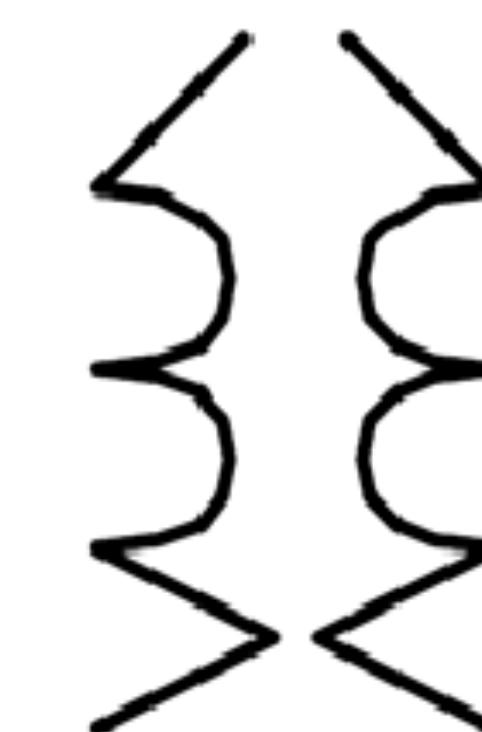
Things: symmetric



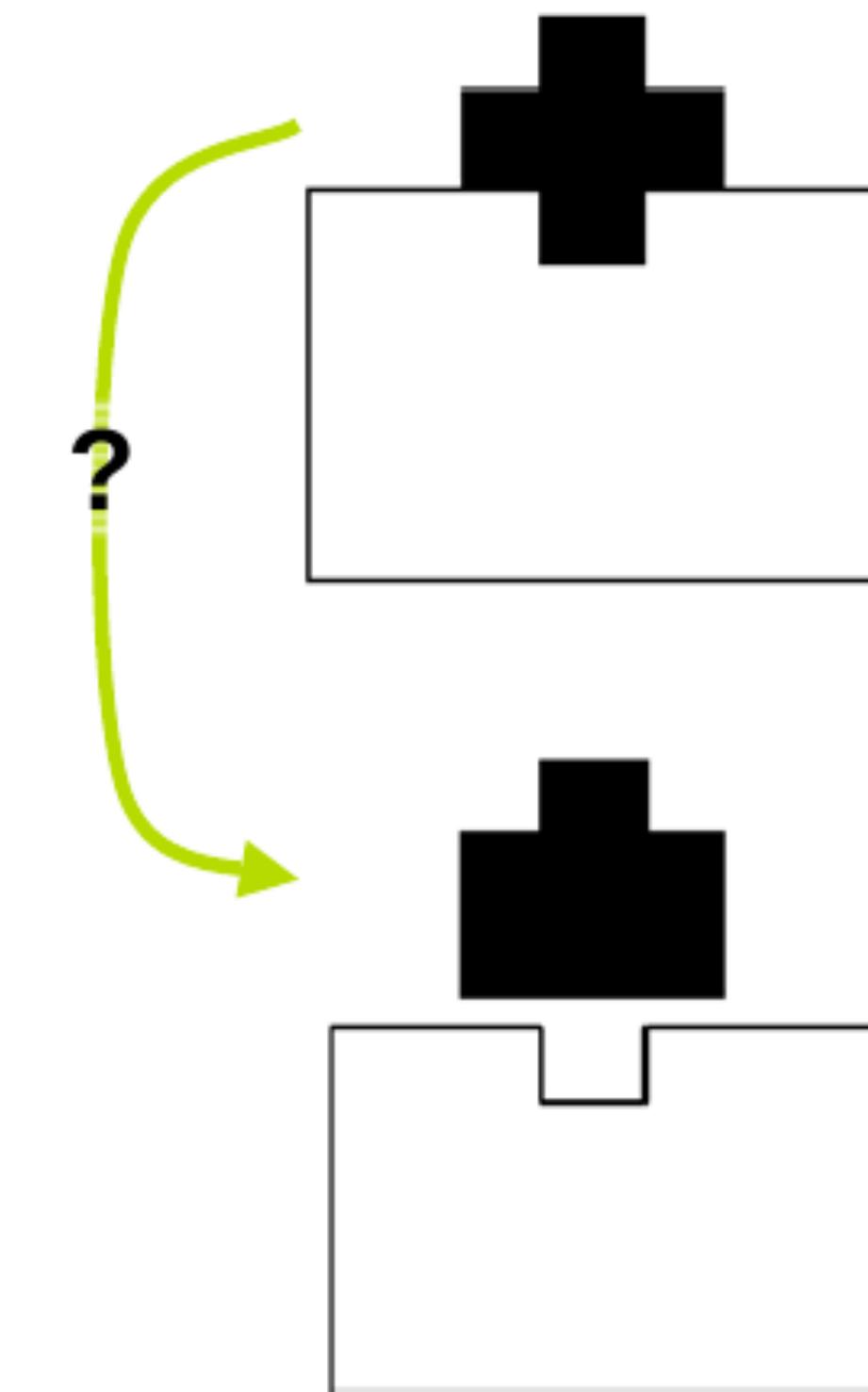
figure?



figure!



figure!



Population Pyramid

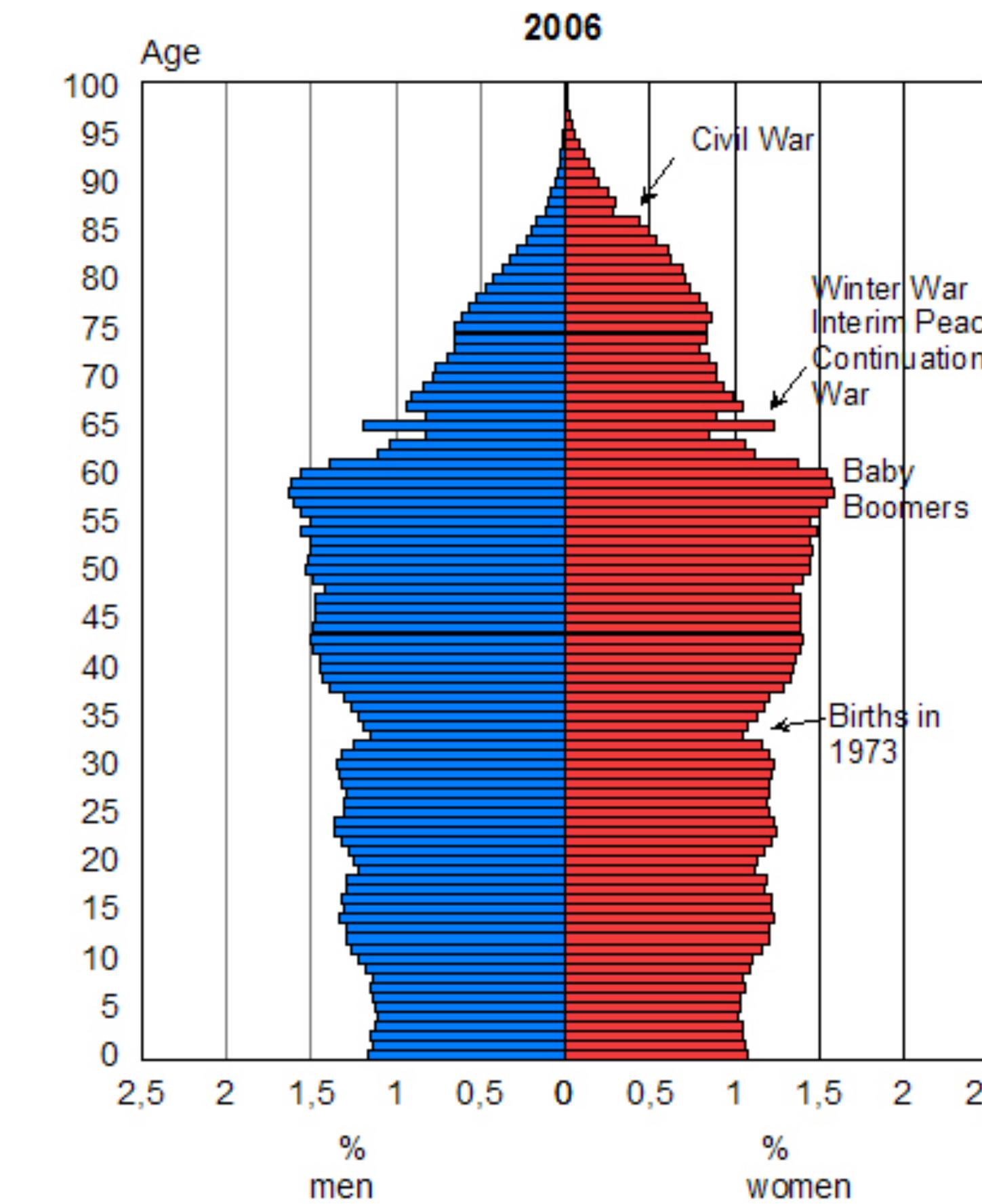
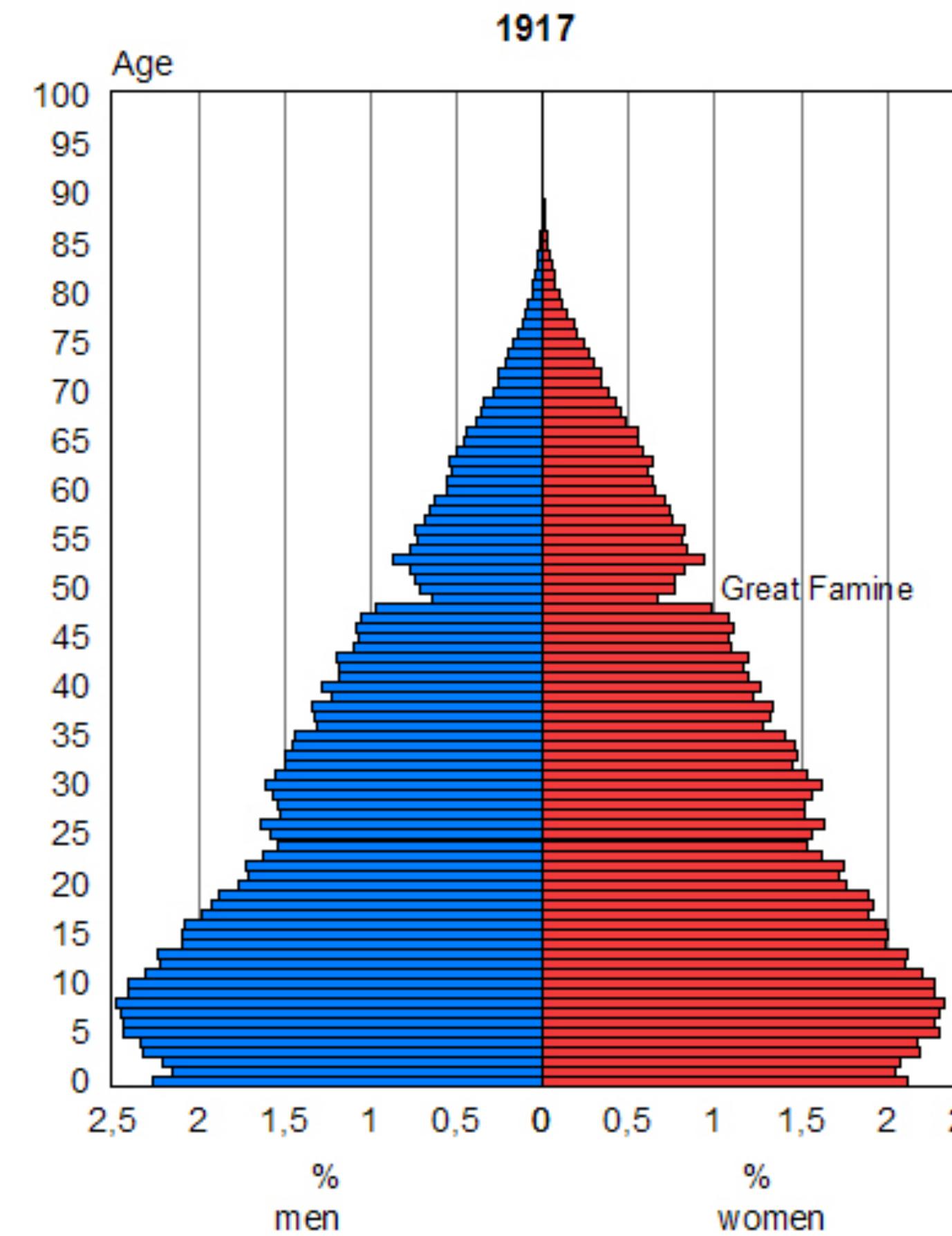
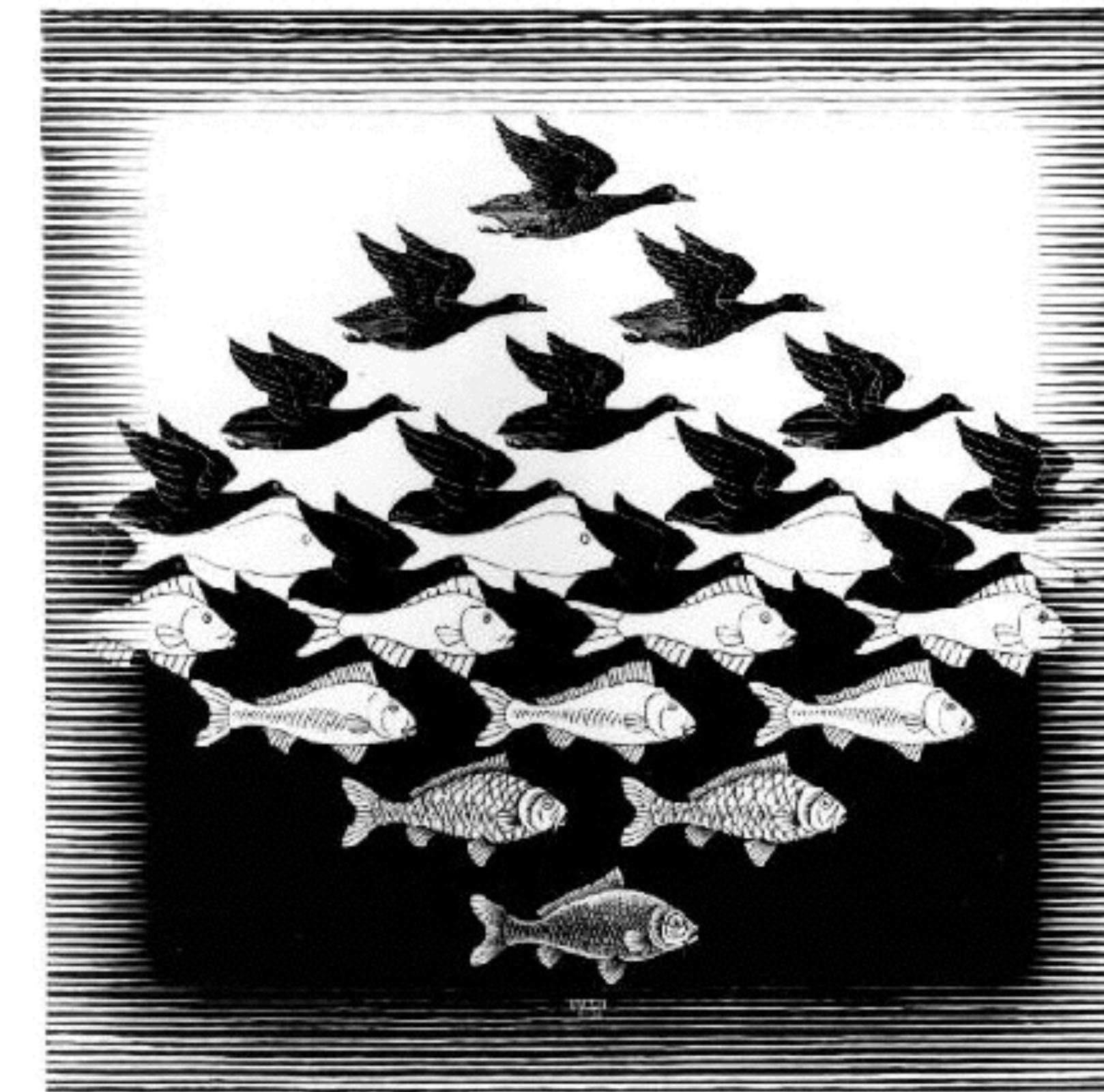


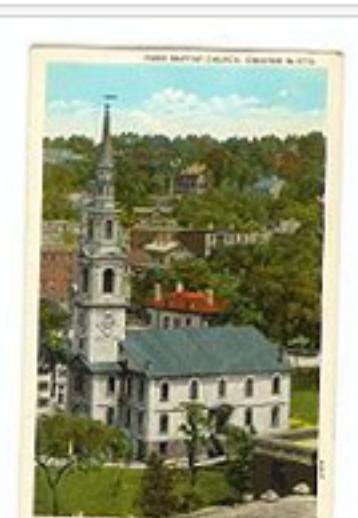
Figure / Ground



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

Applications in Vis

pedia.org/wiki/Providence,_Rhode_Island



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

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.



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



NPS map of the W3R Route

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A Google Map showing the location of Rhode Island relative to New England and the surrounding states. The map includes state boundaries, major cities, and major roads. A red arrow points from the text "Rhode Island" on the map to the text "Rhode Island" in the list of locations below. The map also shows parts of Connecticut, Massachusetts, New Hampshire, Vermont, New York, New Jersey, Delaware, Maryland, and Virginia.

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https://en.wikipedia.org/wiki/Providence,_Rhode_Island

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Following the war, Providence was the country's ninth-largest city^{[17][18]} 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 Reman & Sharpe.

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 WSR Route

<https://www.google.com/maps>

Google maps

mexico

Print Send Link

Satellite

Traffic

Rhode Island

2011 Google - Map data 2011 Google - Terms of Use Report a problem

This is a screenshot of a Google Maps search for "mexico". The map displays the eastern coast of North America, specifically the region from New England down to the southern tip of the state of New Jersey. Major cities like Boston, Providence, Hartford, Springfield, Worcester, and New York City are visible. A red arrow points from the text "Rhode Island" in the left sidebar to the small island of Rhode Island on the map. The map includes standard Google controls for zooming and panning.

[d... < pedia.org/wiki/Providence,_Rhode_Island](http://en.wikipedia.org/wiki/Providence,_Rhode_Island)

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

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[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](#)

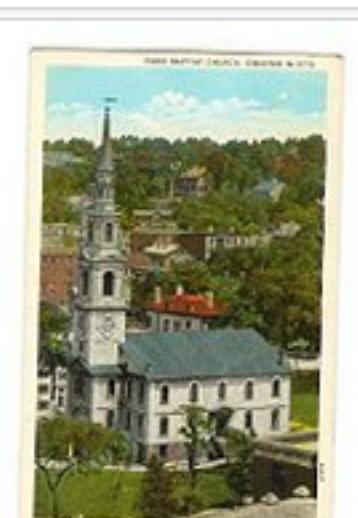
[NPS map of the W3R Route](#)

[Google maps](#) [mexico](#) [Search Maps](#)

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[d... pedia.org/wiki/Providence,_Rhode_Island](http://en.wikipedia.org/wiki/Providence,_Rhode_Island)



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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.^{b[b][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.



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



NPS map of the W3R Route

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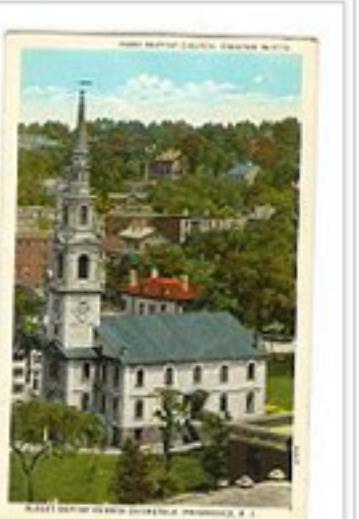
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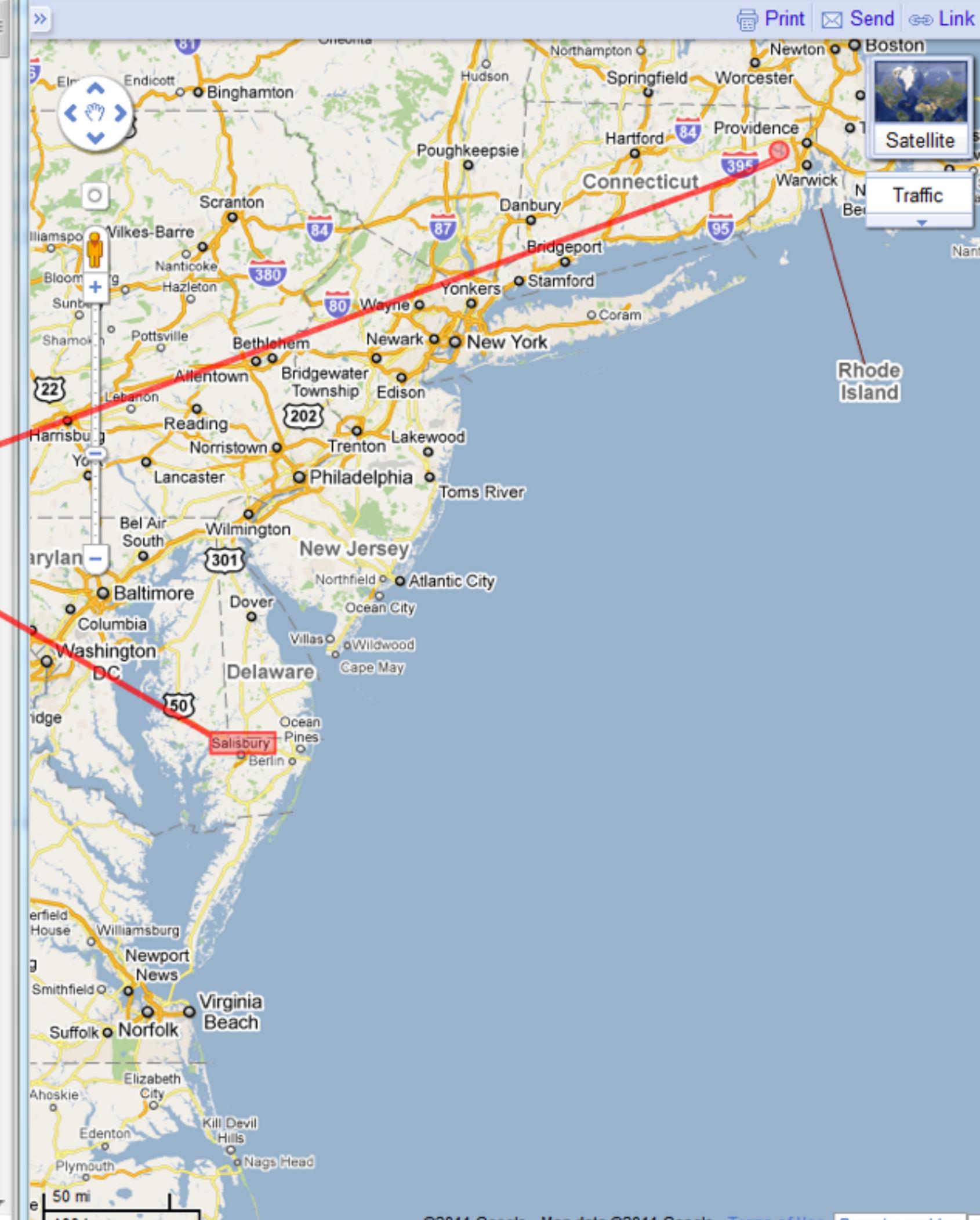
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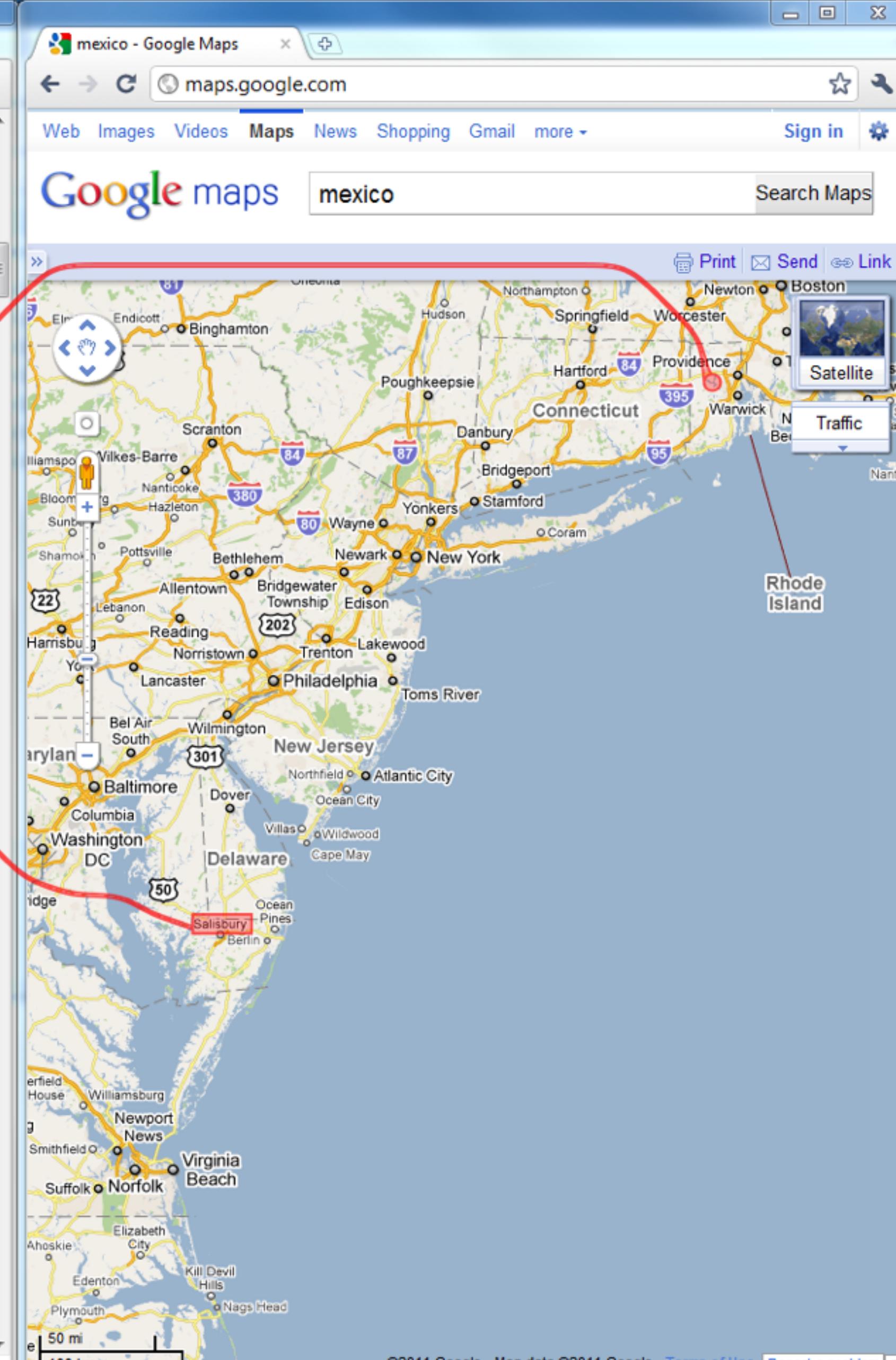
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