

Applied Data Visualization Perception

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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, ...

What is There vs.
What do we See



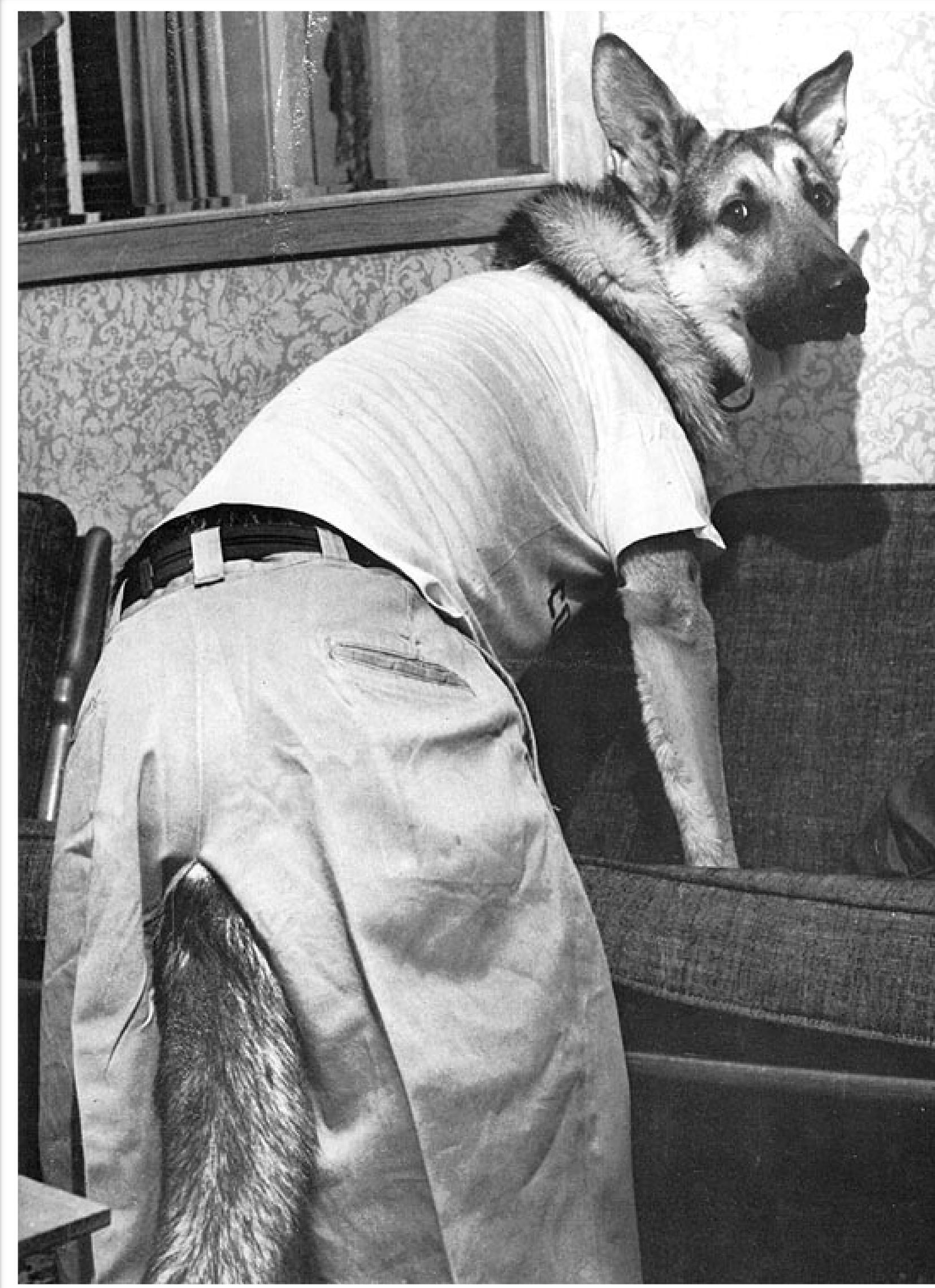
Emergence Images. Perceptual Hysteresis.

Our perception is based on priors

We have a model of the world

We try to fit what we see into this model.

We get confused if something we see doesn't fit our 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/Ffph1wzTvy



The tendency for perception to impose a meaningful interpretation on a nebulous stimulus.

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

Human Visual System

5-6 mio cones

color vision (COnes for COLOR)

dense in the center

require more light (hence it's grey at night)

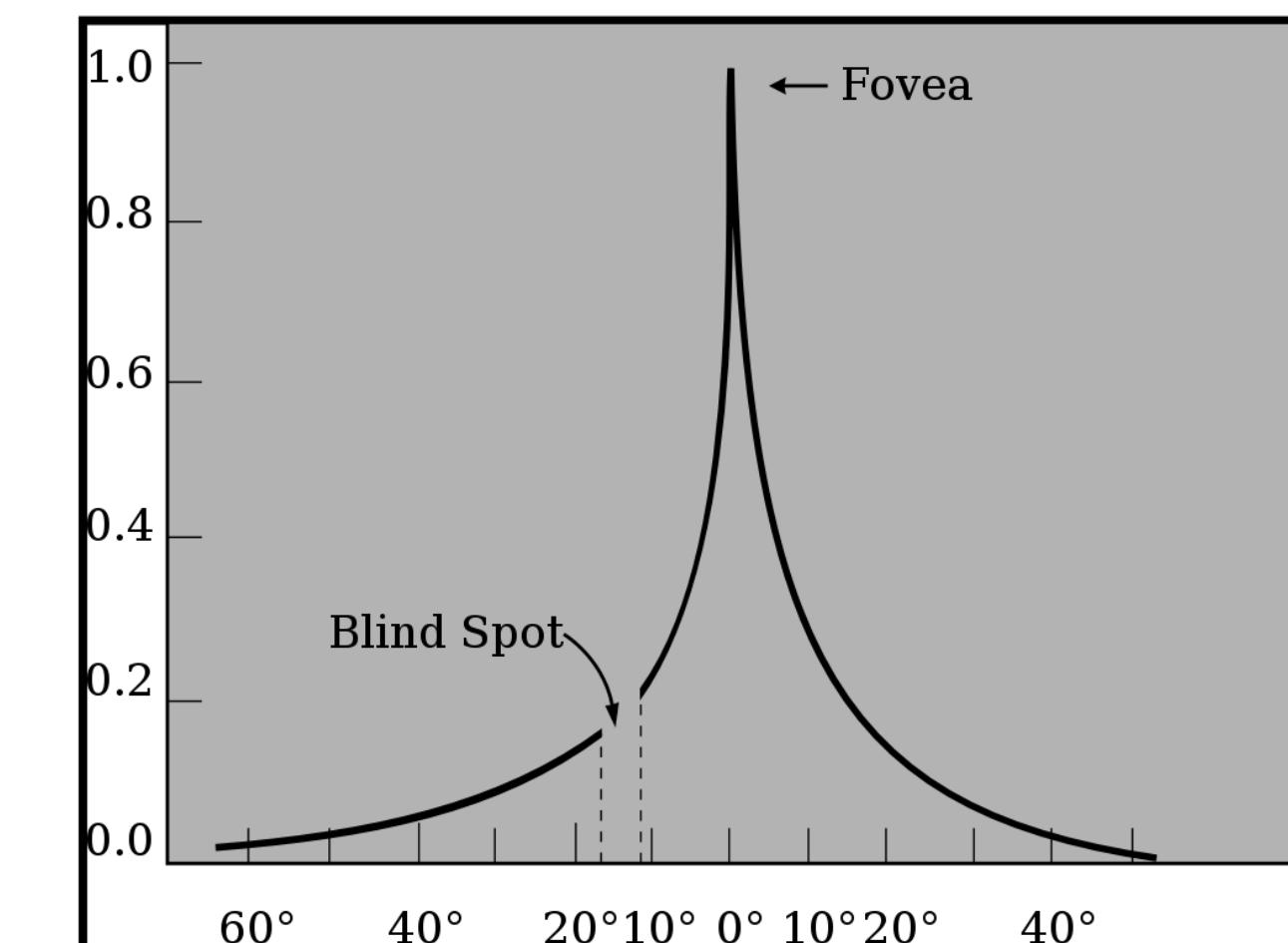
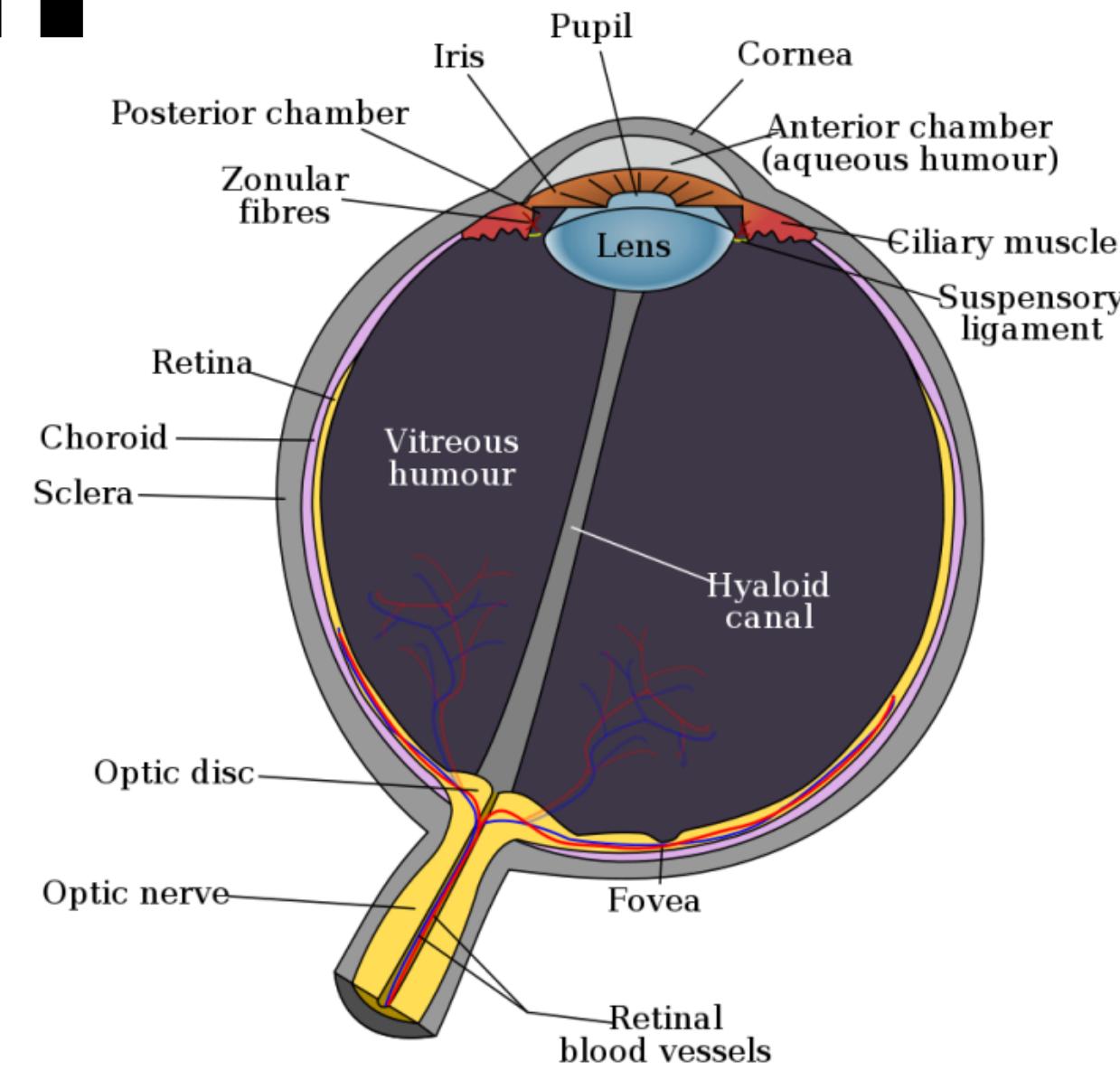
Fovea: 27 times the density

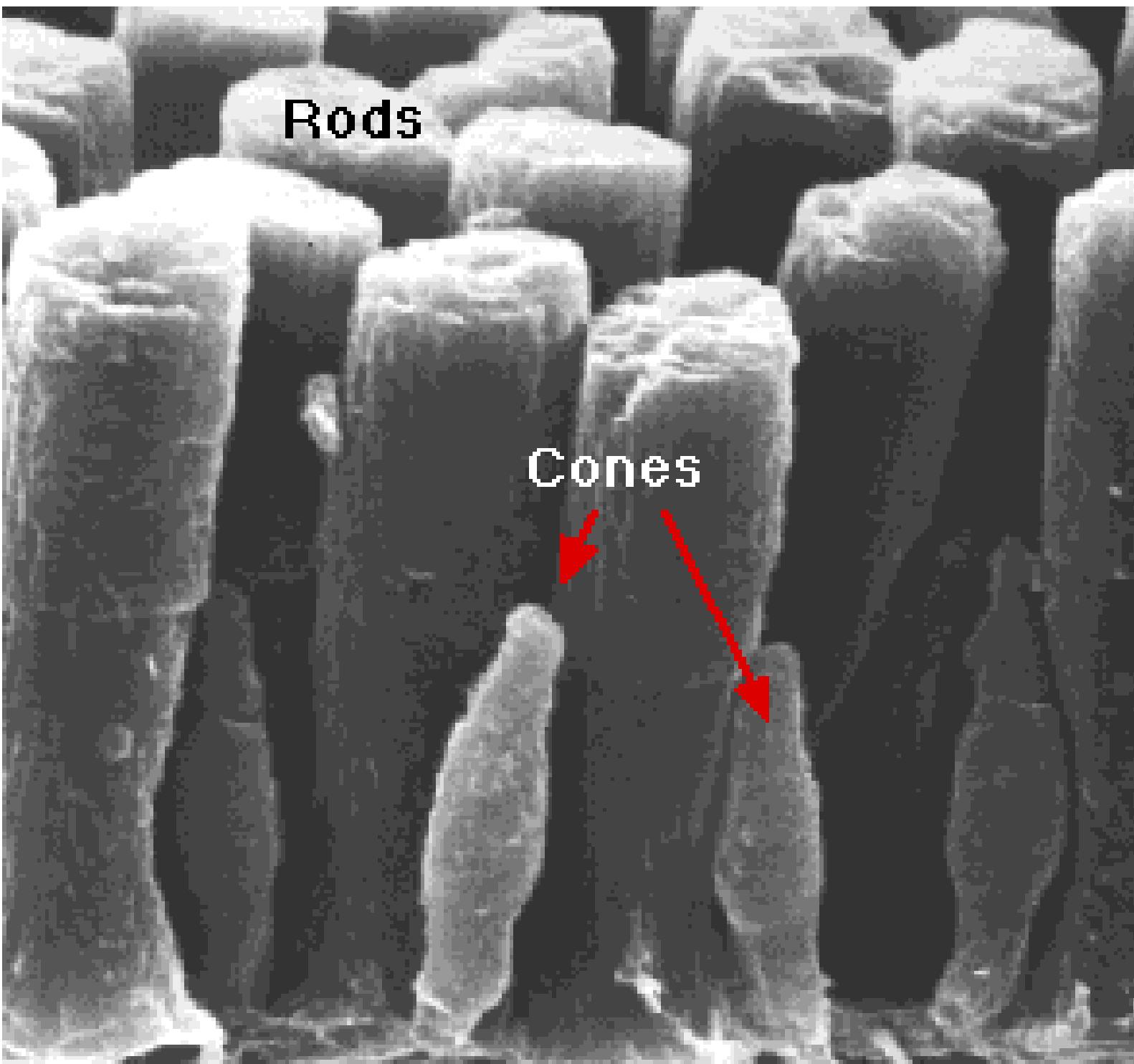
responsible for sharp central vision

only cone cells

~120 mio rods

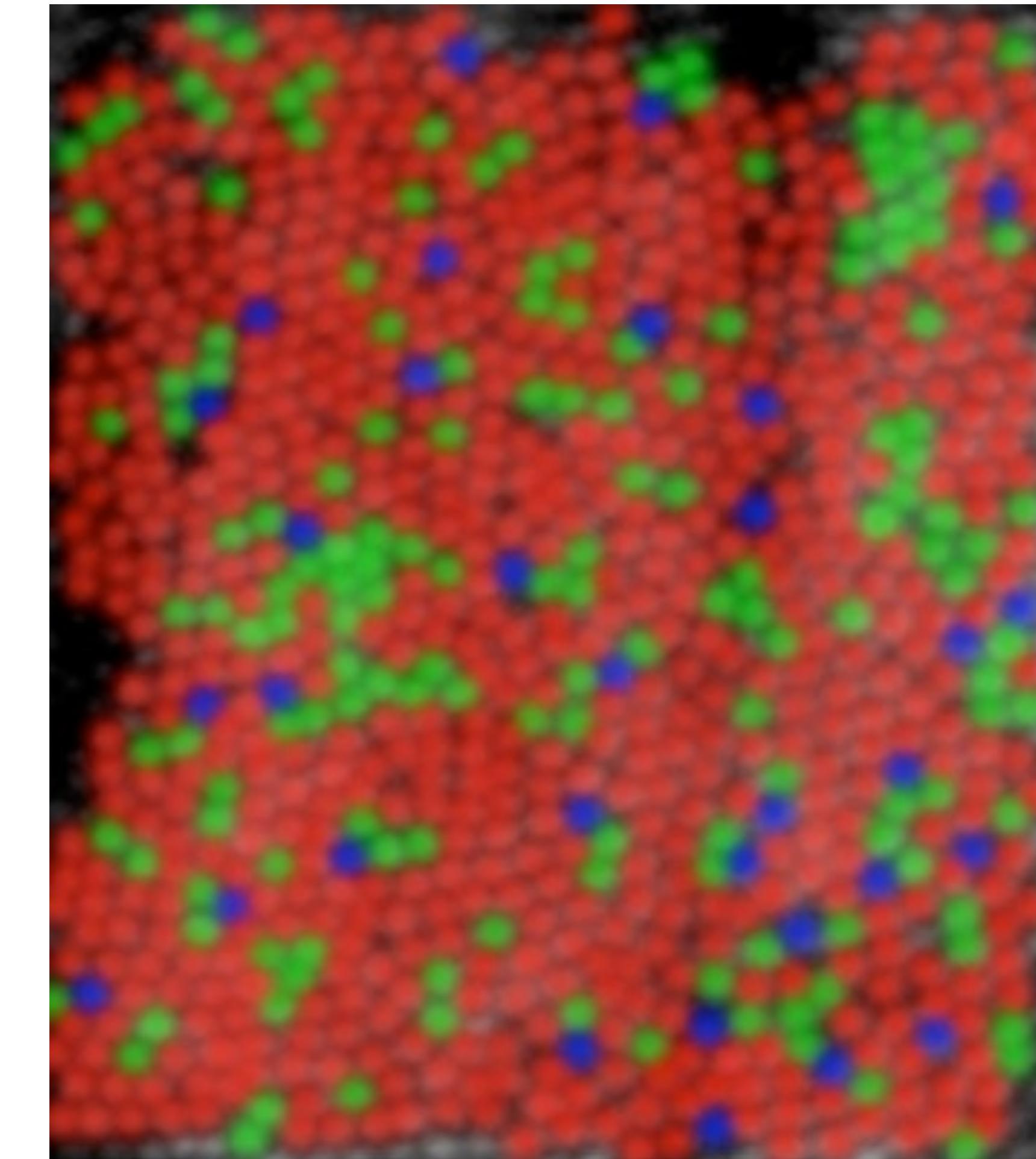
black/white





~120 million rods

~5-6 million cones

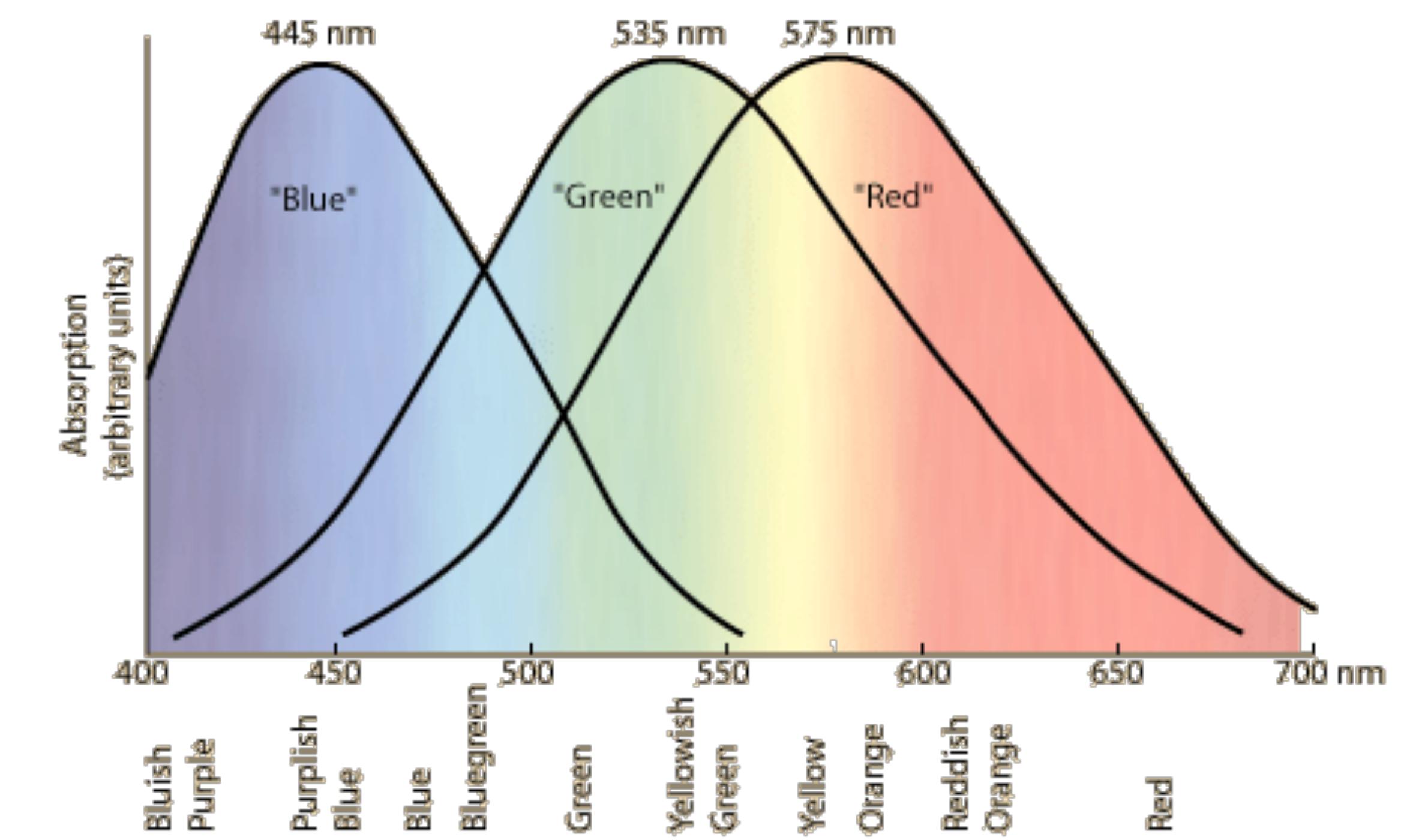
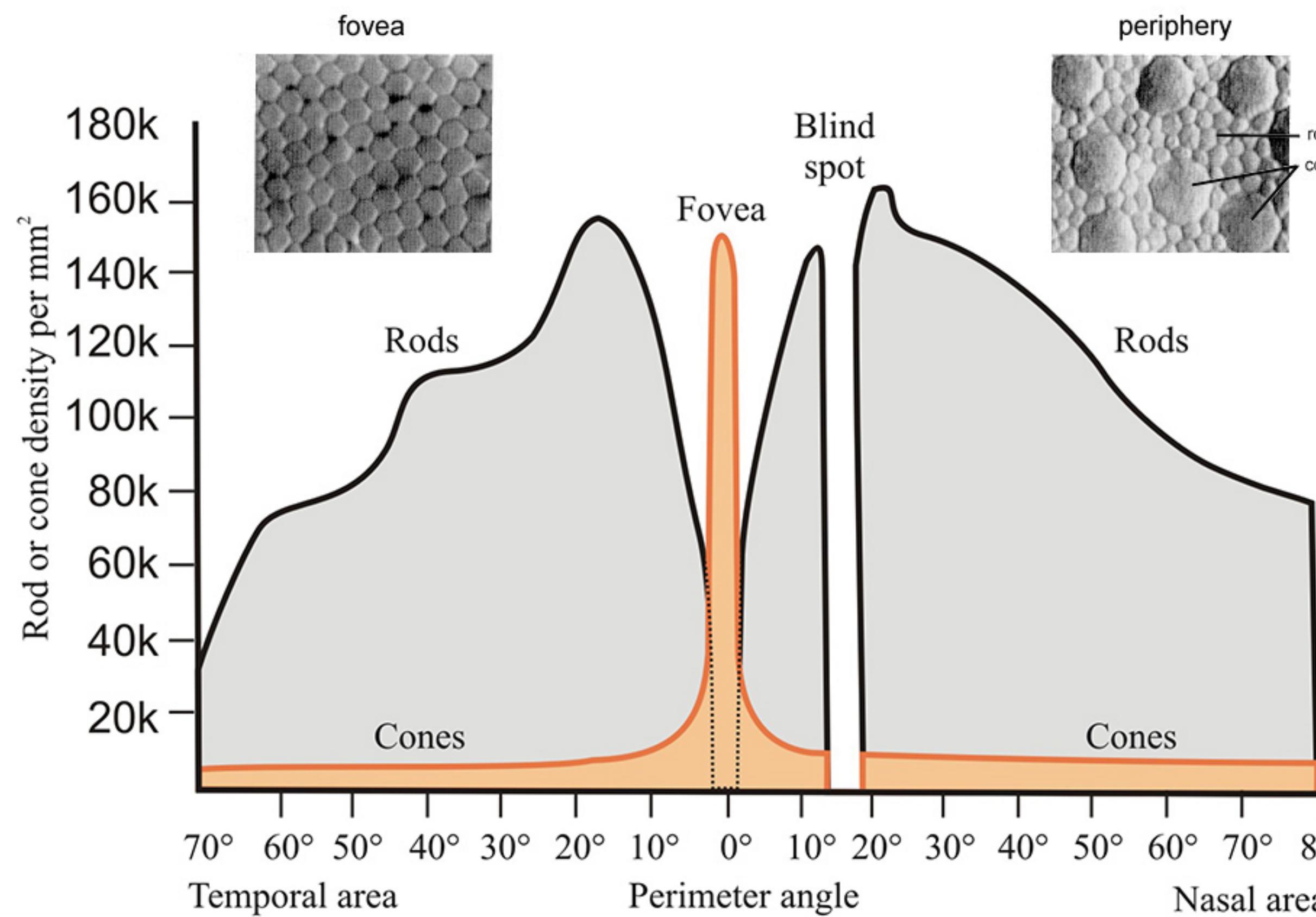


R 63% - G 31% - B 2-6%

Wandell, "Foundations of Vision" (left)

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

Cone Response



Human Visual System

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

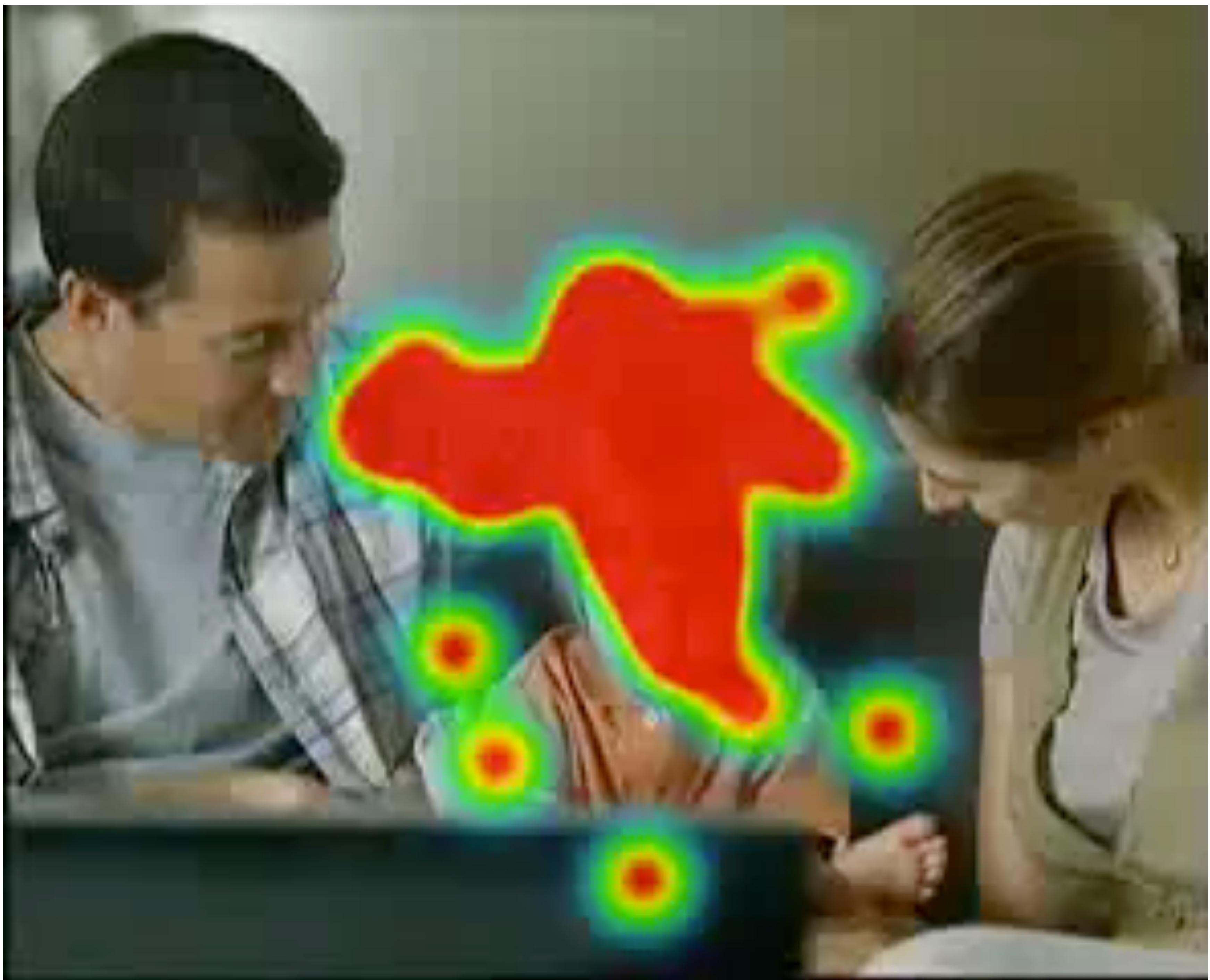
fixations: maintaining gaze on single location (200-600 ms)

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

Vision not similar to a camera

More similar to a dynamic and ongoing construction project





Human Visual System

No general purpose vision

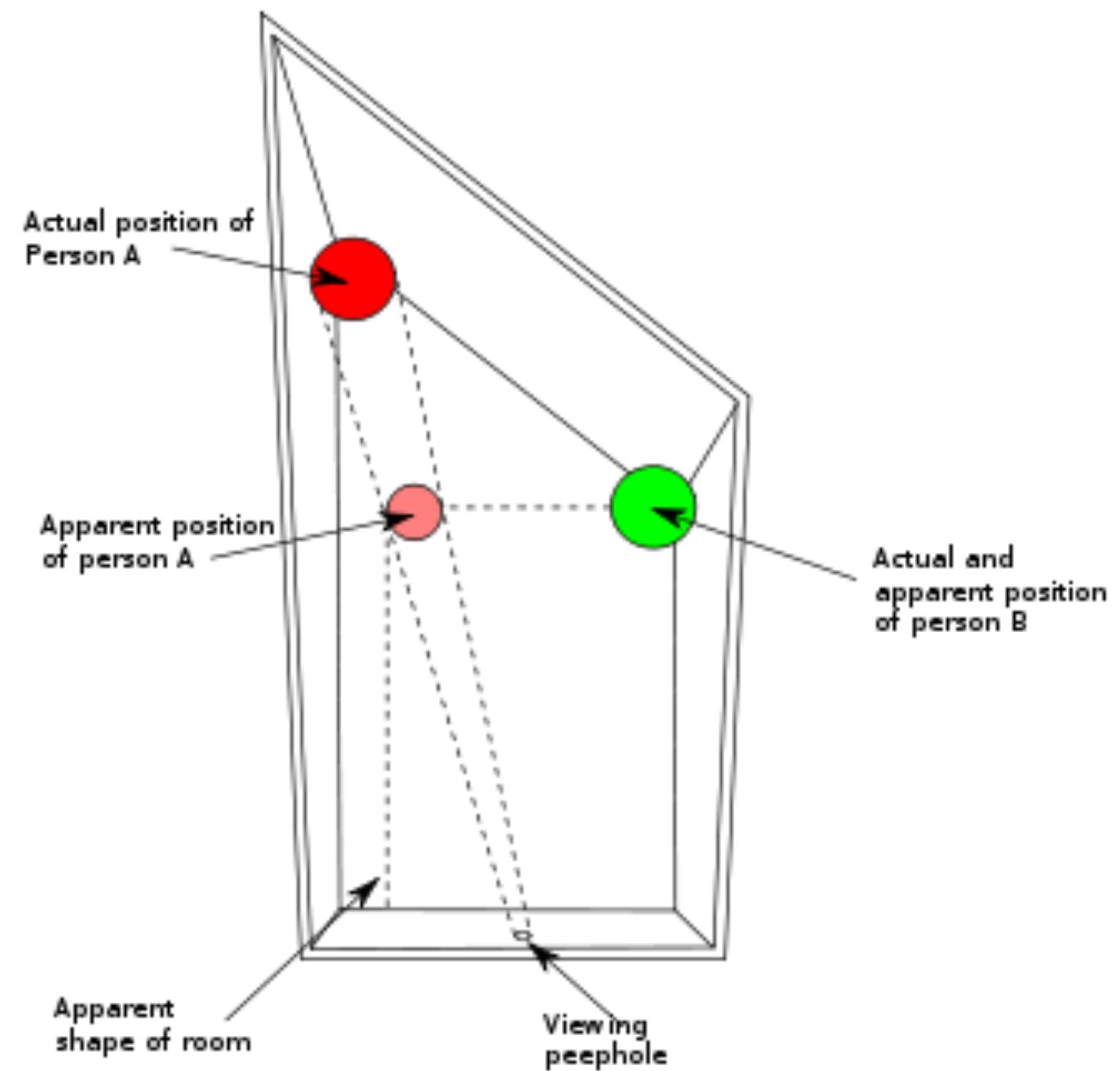
What we see depends on our goals and expectations

Relative judgments: strong

Absolute judgments: weak



Ames Room





Color

Color Basics

Visible part of the electromagnetic spectrum

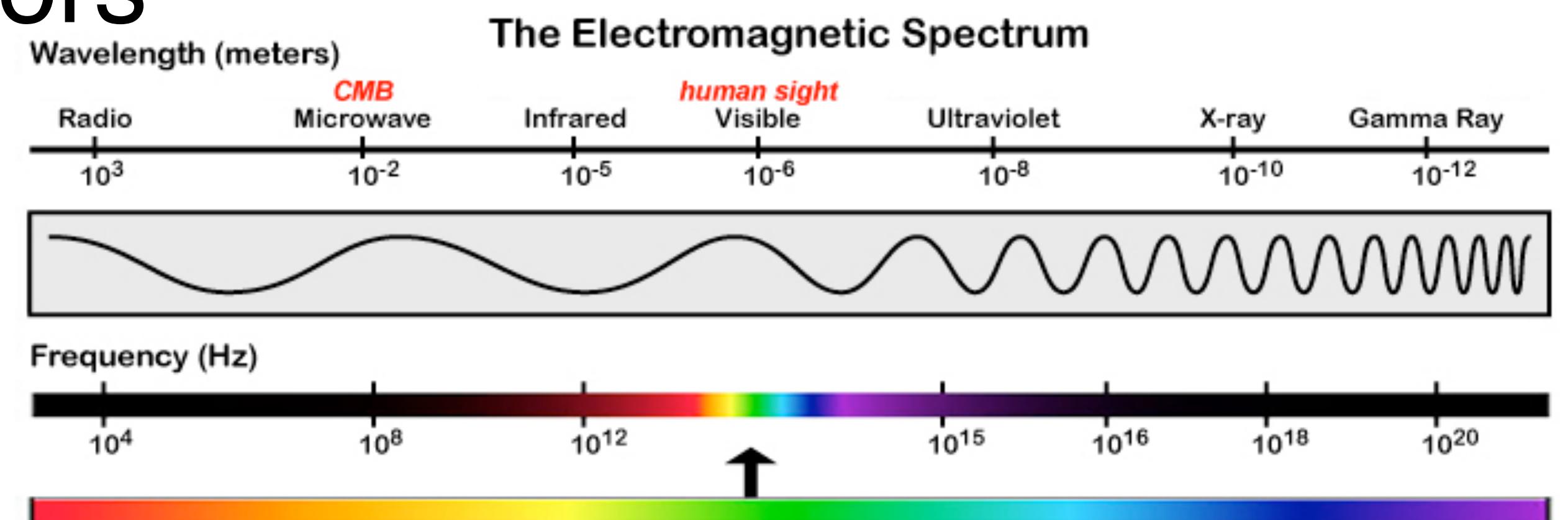
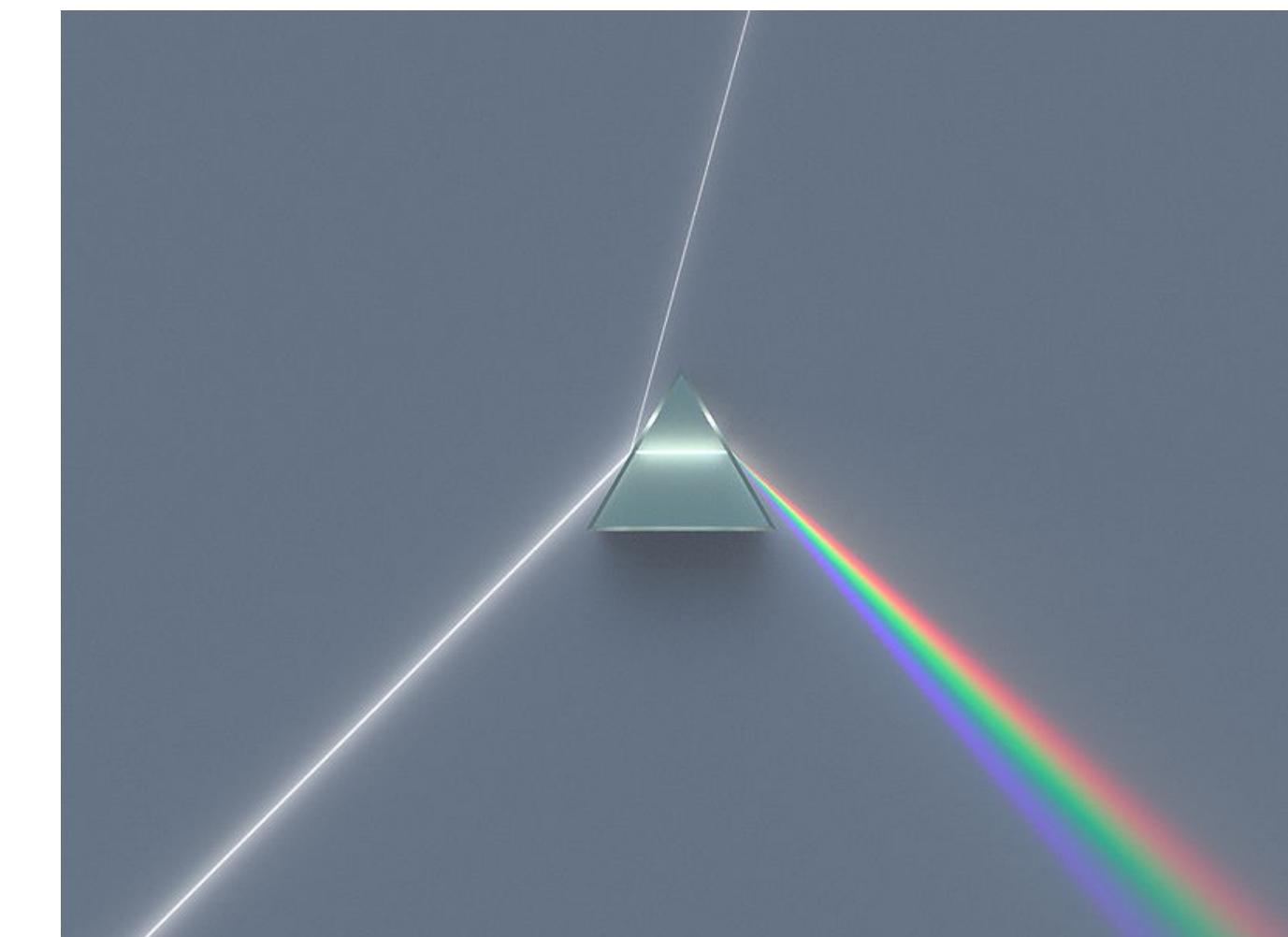
390-750 nm

Spectral colors

evoked by a single wavelength (monochromatic colors, rainbow colors), e.g., red, orange, yellow, green, blue, and violet

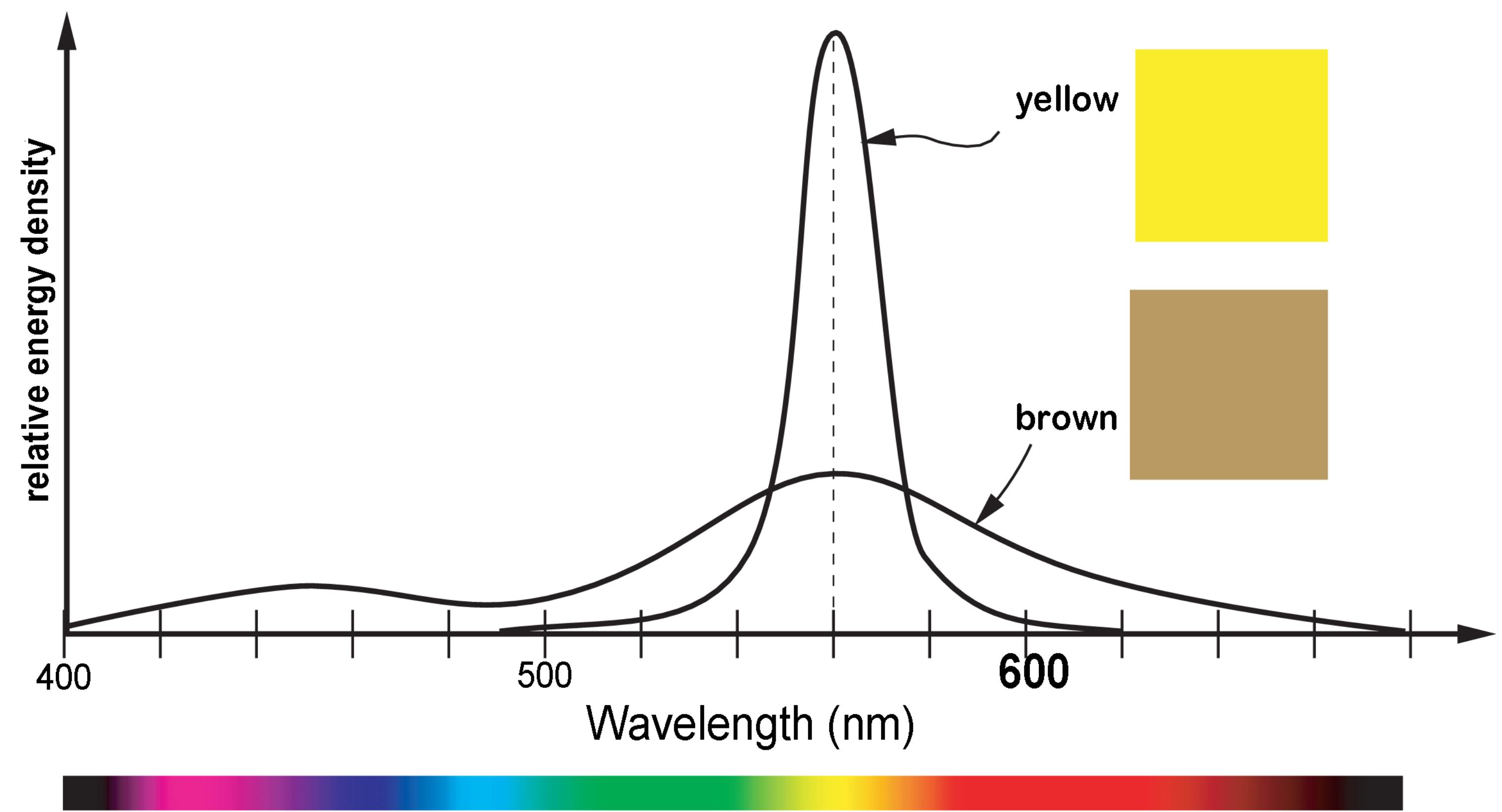
Other colors: unsaturated colors

Mix of multiple wavelengths
e.g. purple, magenta, gray scale
(achromatic colors) including white

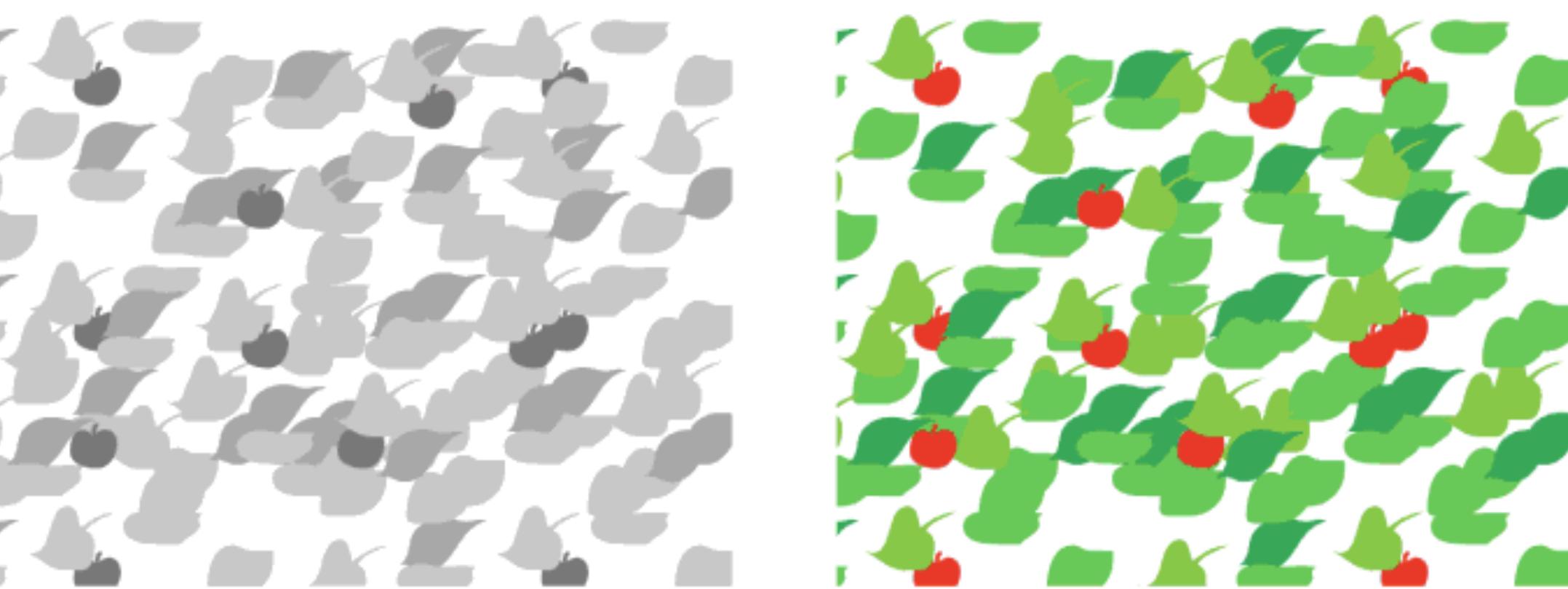


color != wavelength

but rather, a combination of
wavelengths and energy



Color



Color vision is irrelevant to much of normal vision!

does not help to perceive layout of objects

how they are moving

what shape they are

Color breaks camouflage

Tells about material properties (judging quality of food)

Dimensions of Color

Hue

Saturation

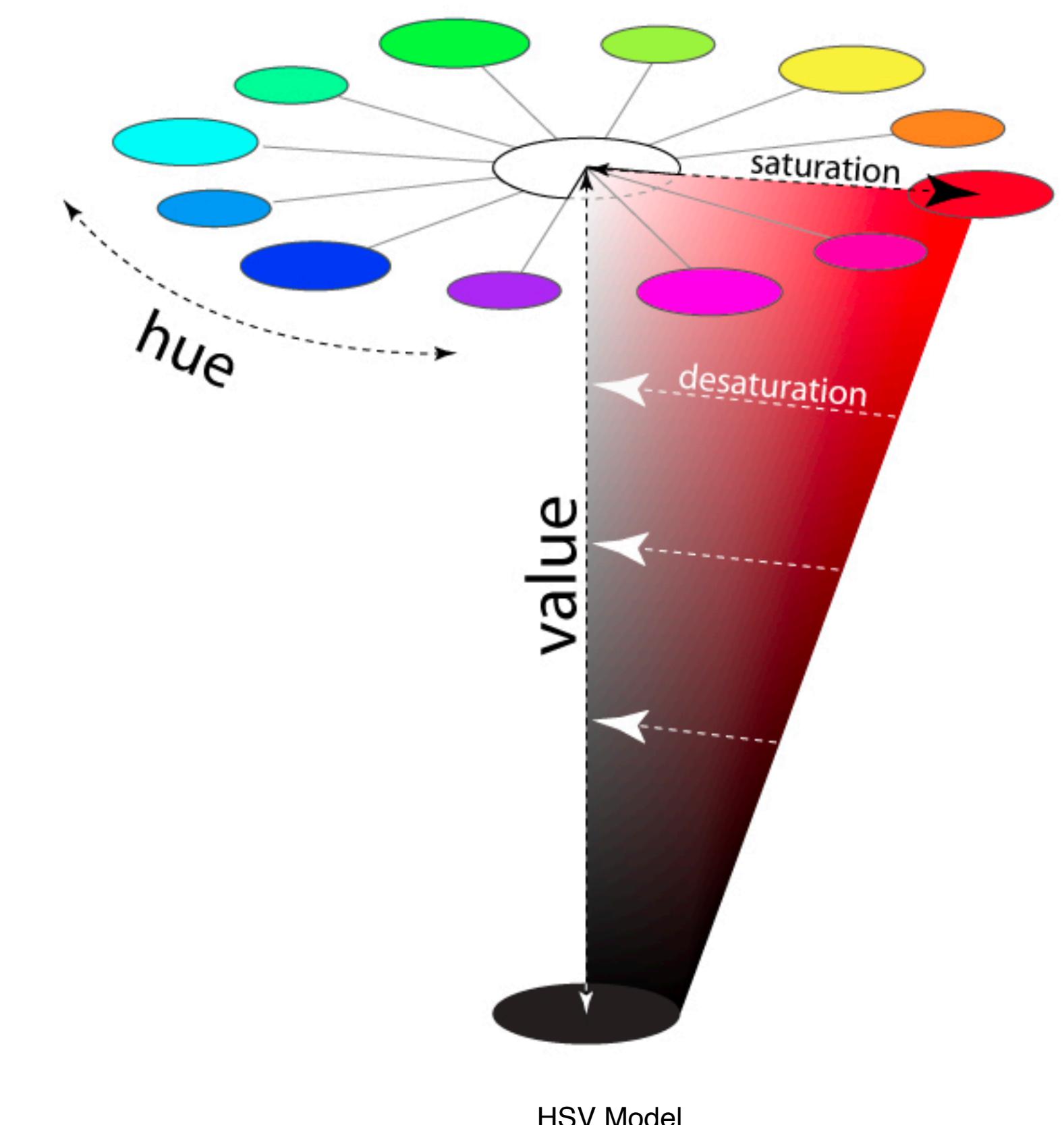
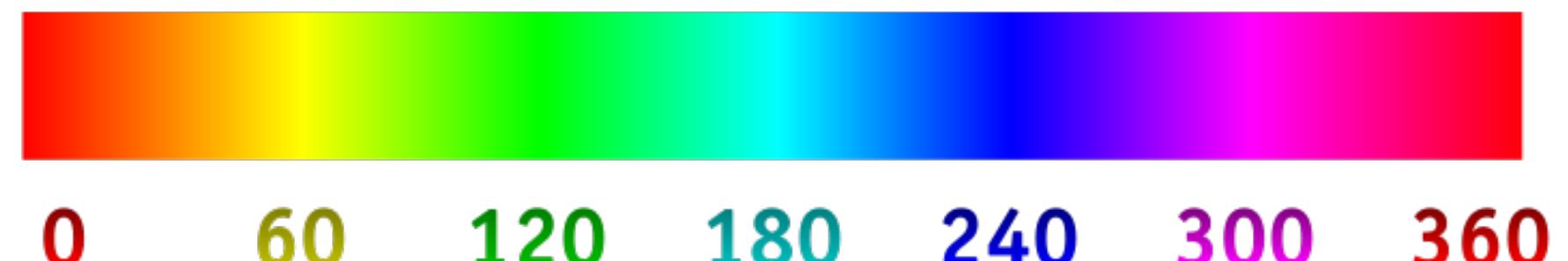
The purity of a color

When thinking of pigments: no white/black is added

When thinking of light: what's the ratio of dominant wavelength to others

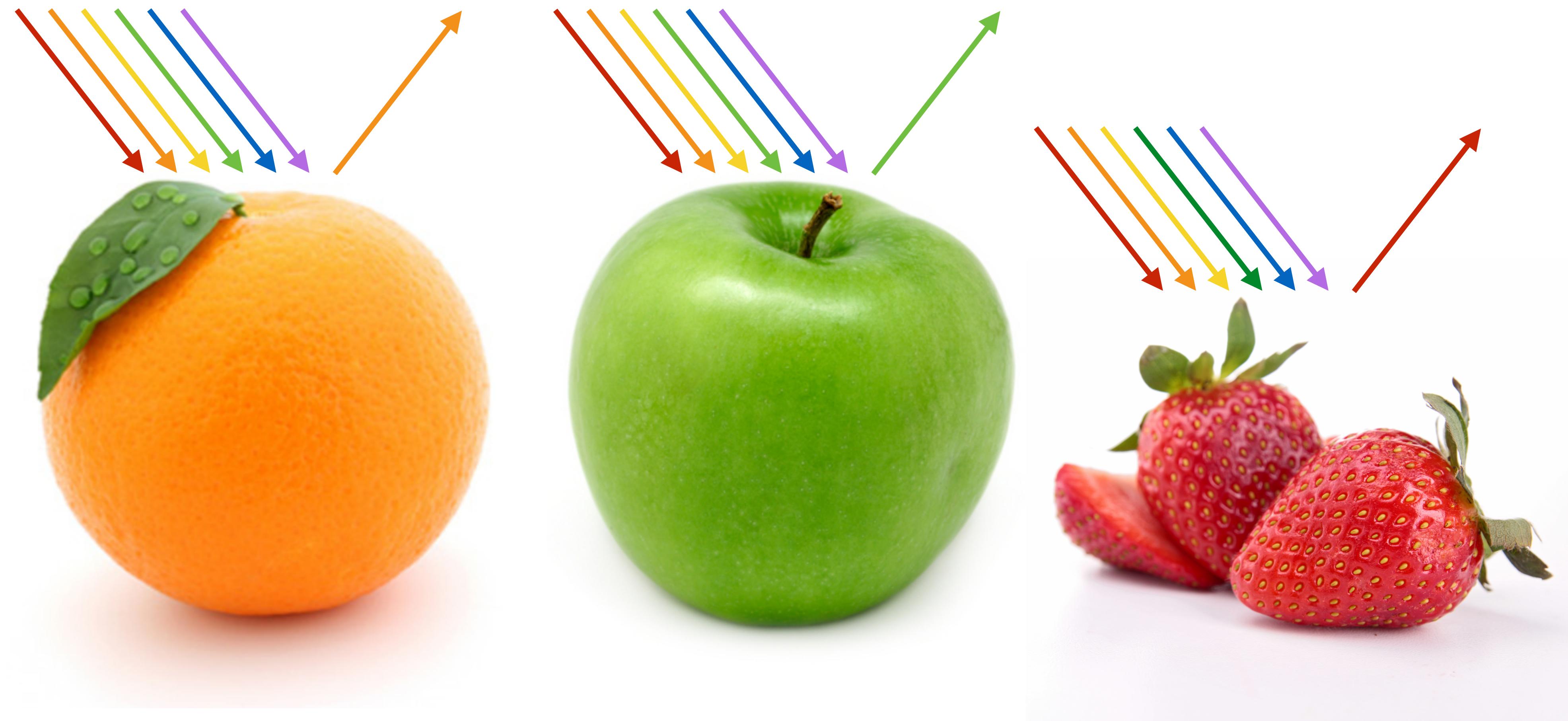
Value (Luminance, Brightness)

lightness or darkness of a color, i.e., the overall intensity of light



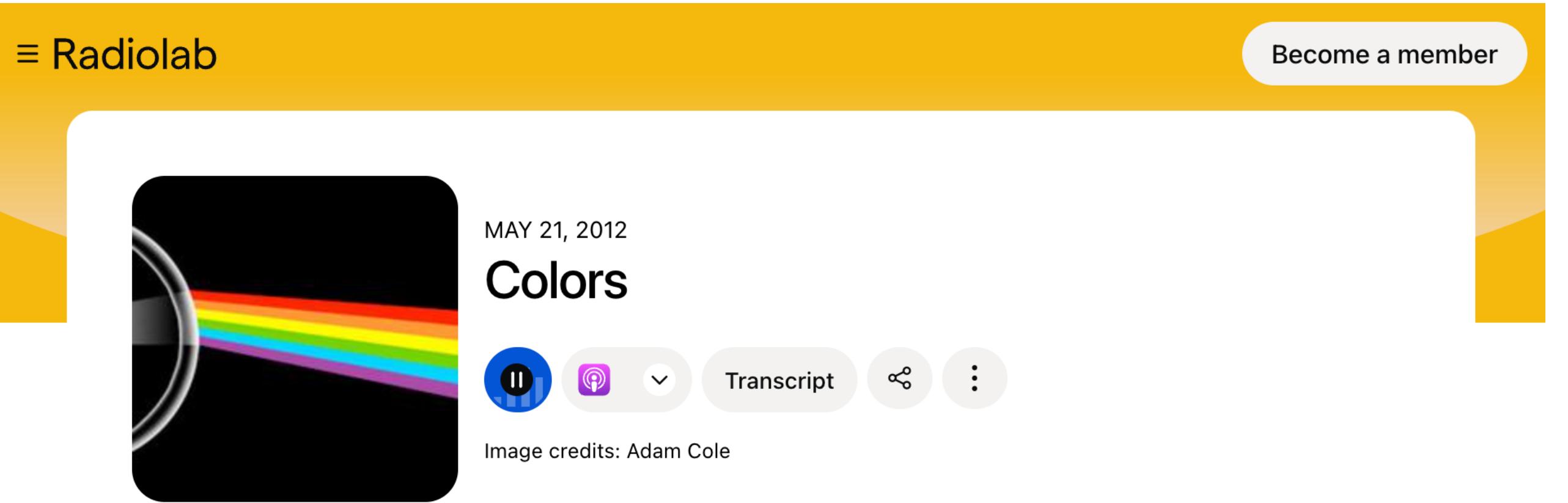
The role of objects

real light is more than a single wavelength:



≡ Radiolab

Become a member



MAY 21, 2012

Colors

Transcript

Image credits: Adam Cole

Our world is saturated in color, from soft hues to violent stains. How does something so intangible pack such a visceral punch? This hour, in the name of science *and* poetry, Jad and Robert tear the rainbow to pieces.

≡ Radiolab

Become a member



MAR 15, 2018

Rippin' the Rainbow an Even Newer One

Listen

Image credits: Roy Caldwell

One of our most popular episodes of all time was our [Colors episode](#), where we introduced you to a sea creature that could see a rainbow far beyond what humans can experience.

Peacock mantis shrimps are as extraordinary as they are strange and boast what may well be the most complicated visual system in the world. They each have 16 photoreceptors compared to our measly three.

But recently researchers in Australia put the mantis shrimps' eyes to the test only to discover that, sure, they

<https://www.radiolab.org/episodes/211119-colors>

<https://radiolab.org/episodes/rippin-the-rainbow-an-even-newer-one>

What are the primary colors?

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

What's a “primary color” depends on the medium.

Paint mixing

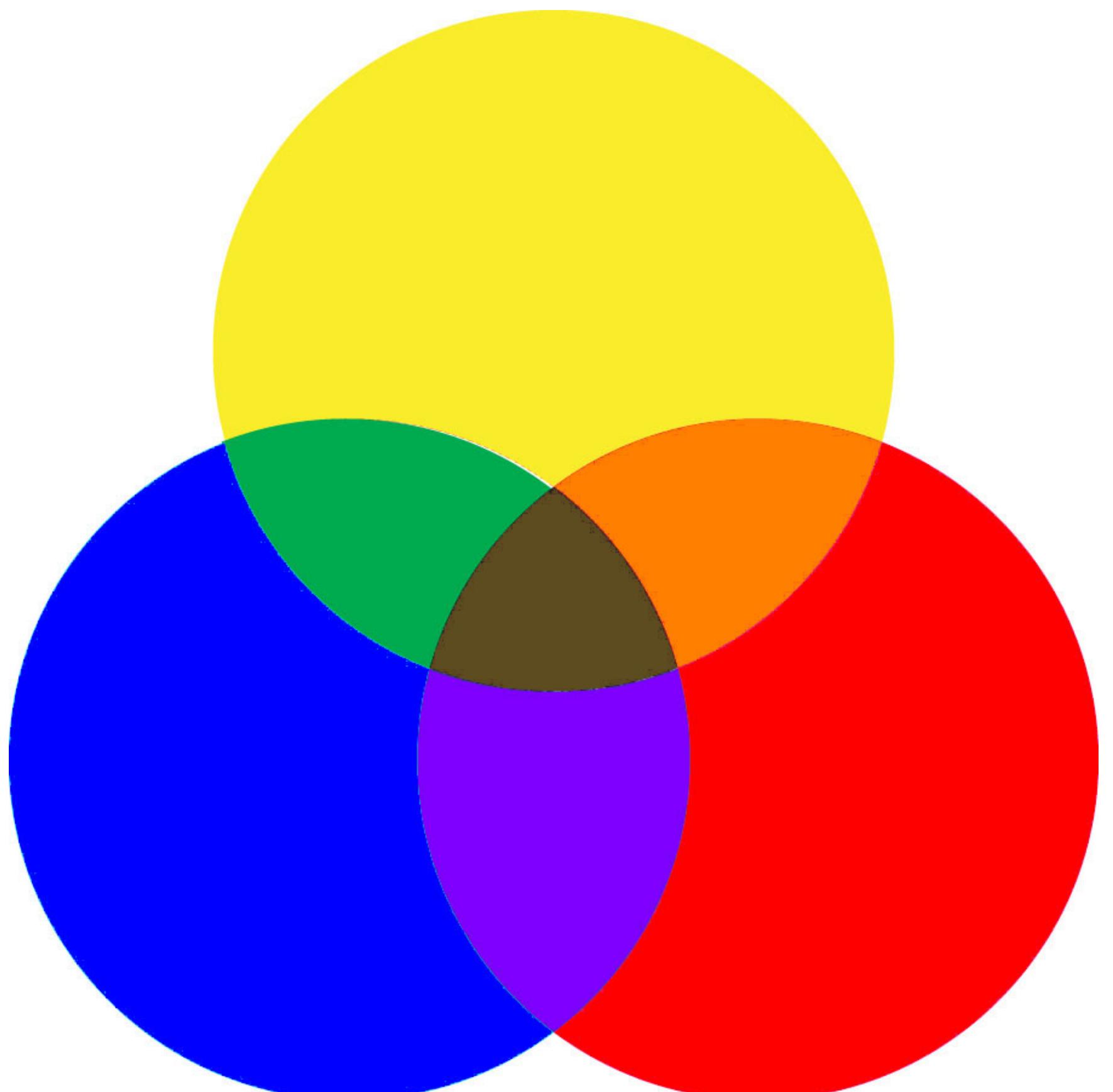
physical mixing of opaque paints

primary: Red, Yellow, Blue

secondary (mixed): Green, Orange,
Purple

subtractive

Historical primary colors



Ink mixing (Inkjet Printers)

subtractive mix of transparent
inks

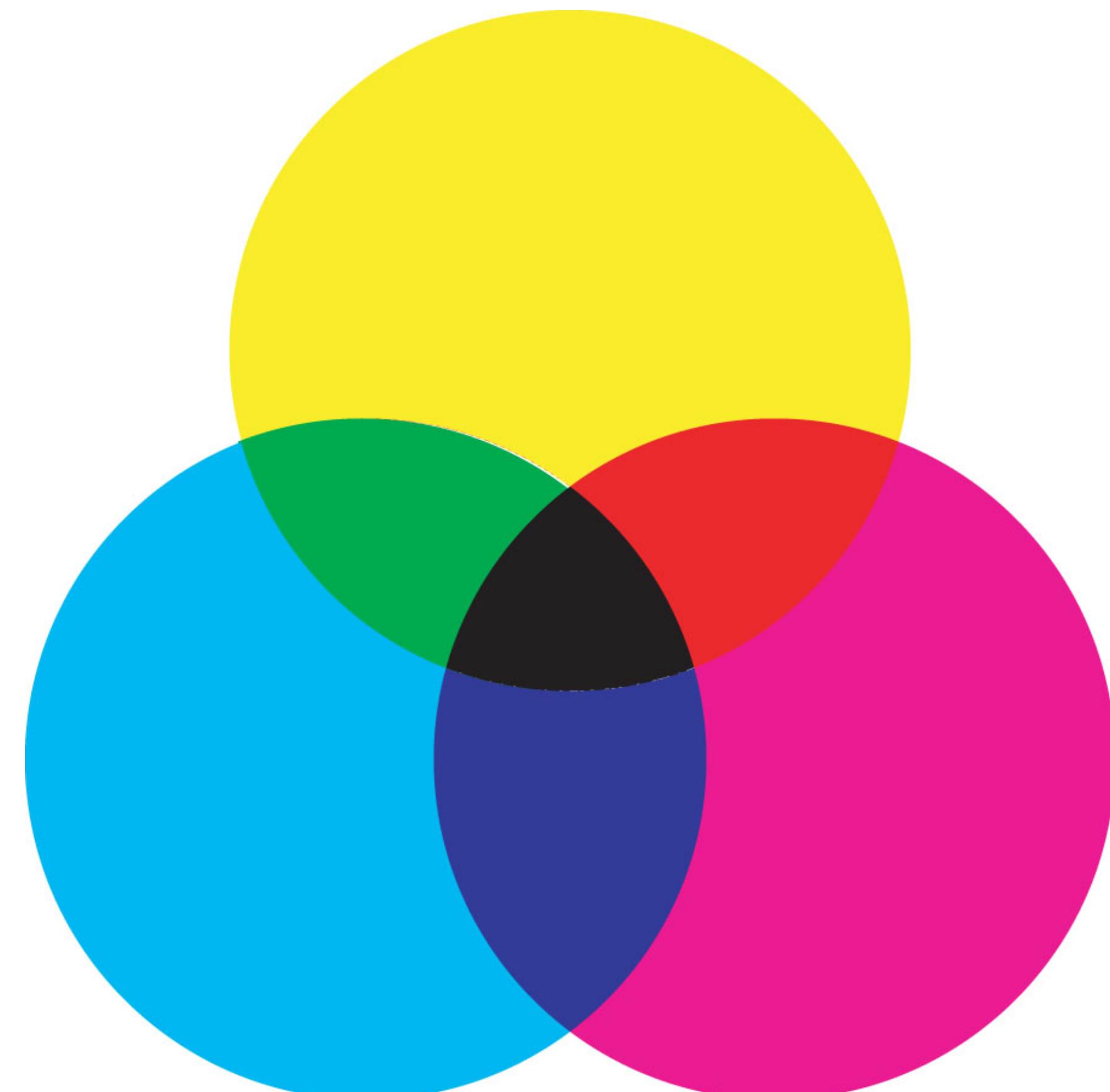
primary: Cyan, Magenta, Yellow

secondary: RGB

approx. black = C+M+Y

true black = C+M+Y+K

subtractive



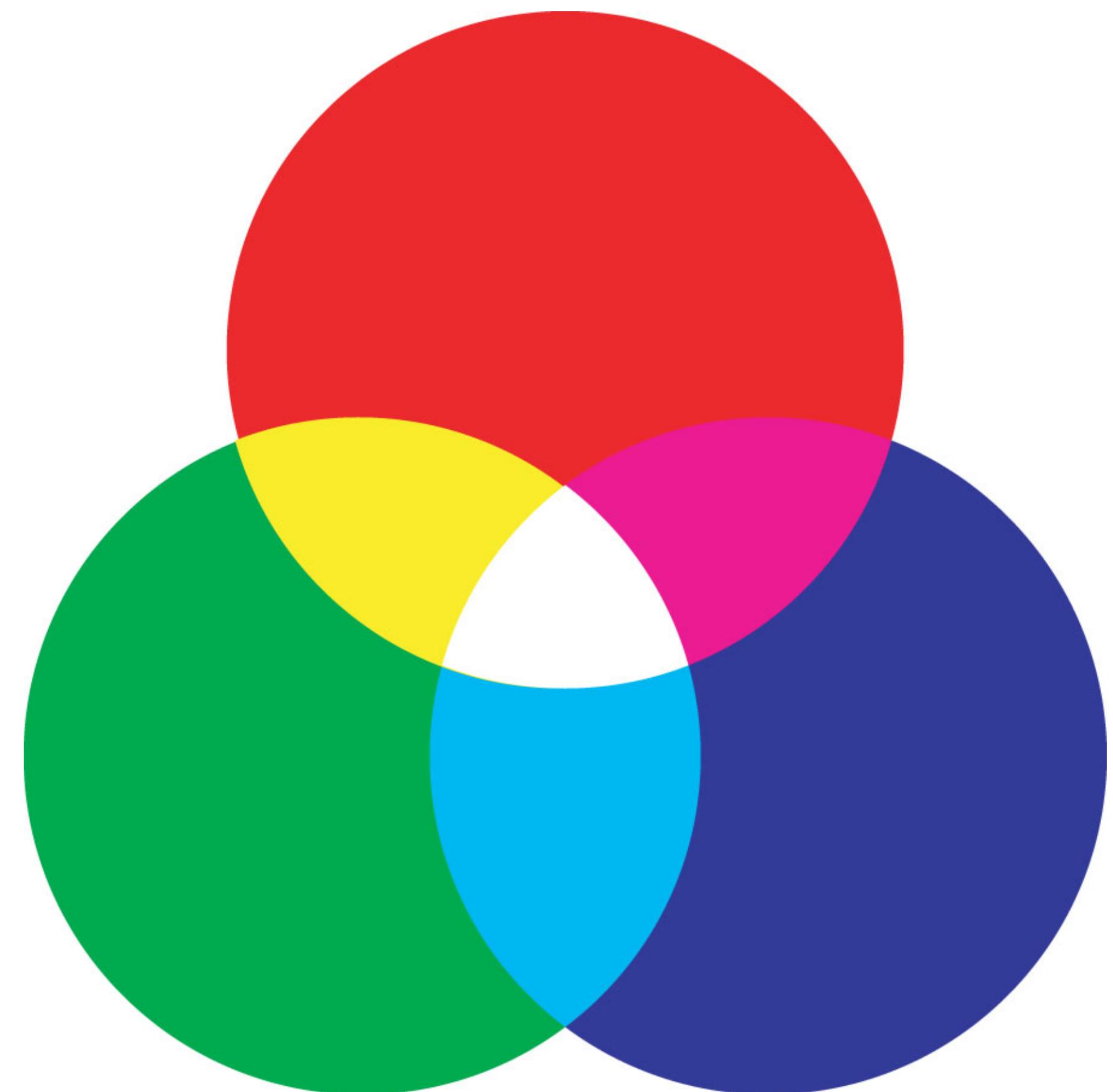
Light mixing (Computer Screens)

additive mix of colored lights

primary: Red, Green, Blue

secondary: Cyan, Magenta, Yellow

additive

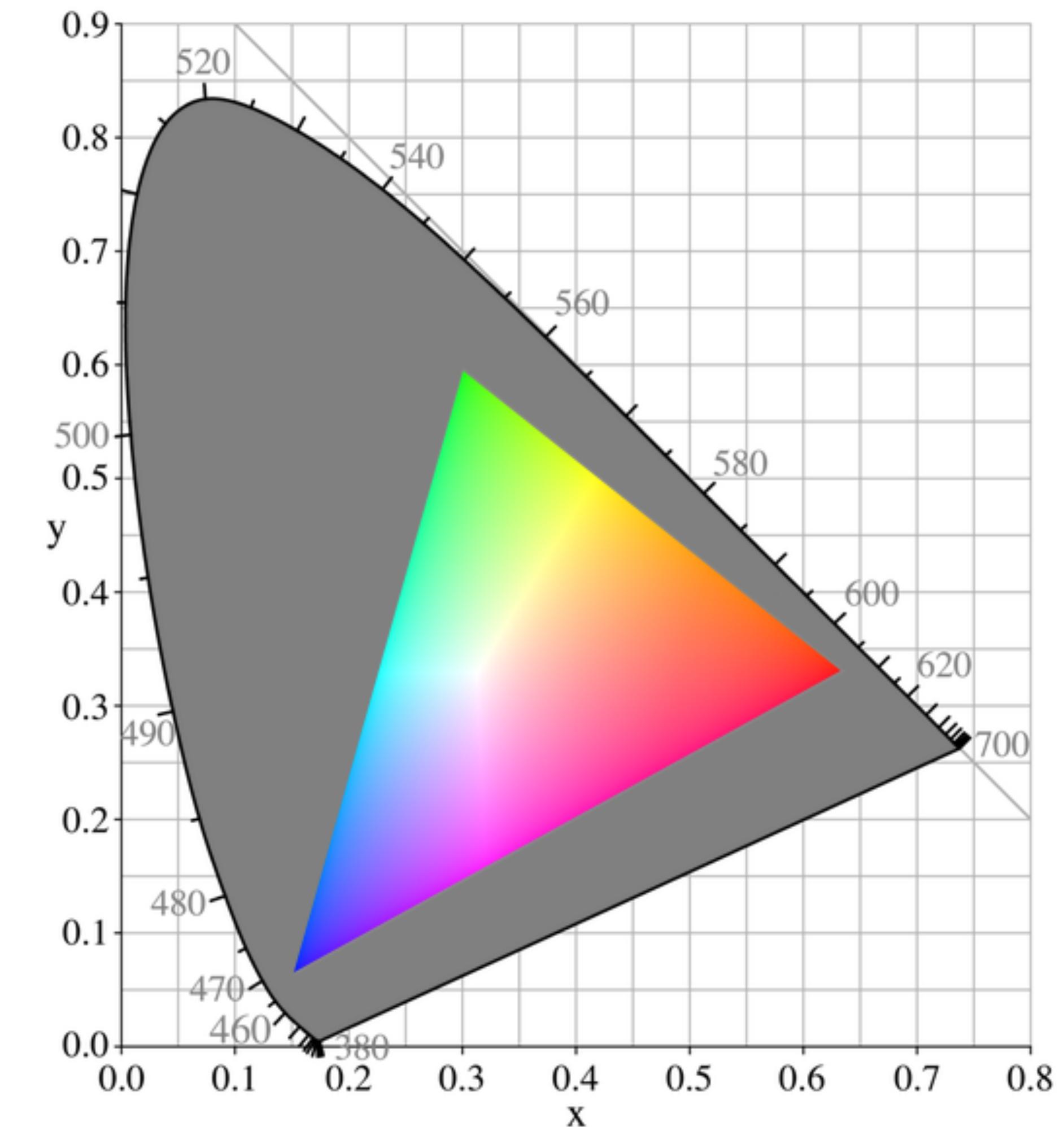
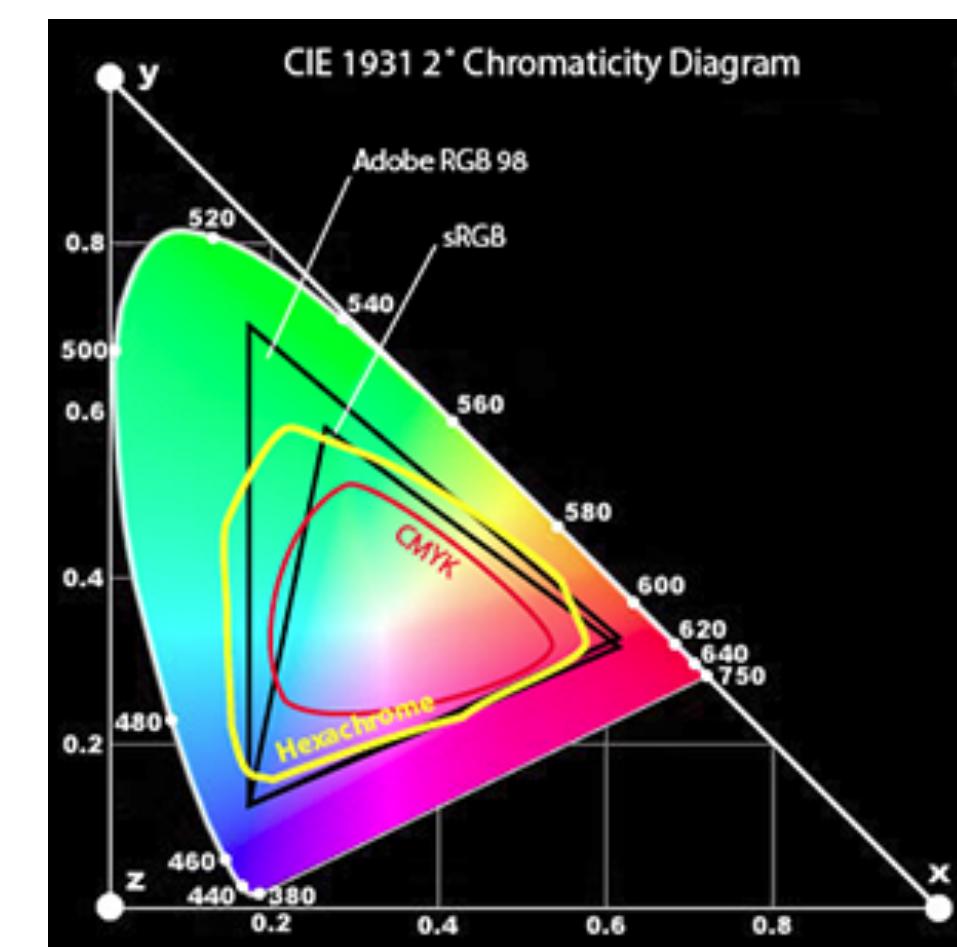


Gamut

Set of all colors that can be produced by a device

Area between the primary colors used can be shown

Primaries are arbitrary



All colors visible to the average human eye are contained inside the diagram

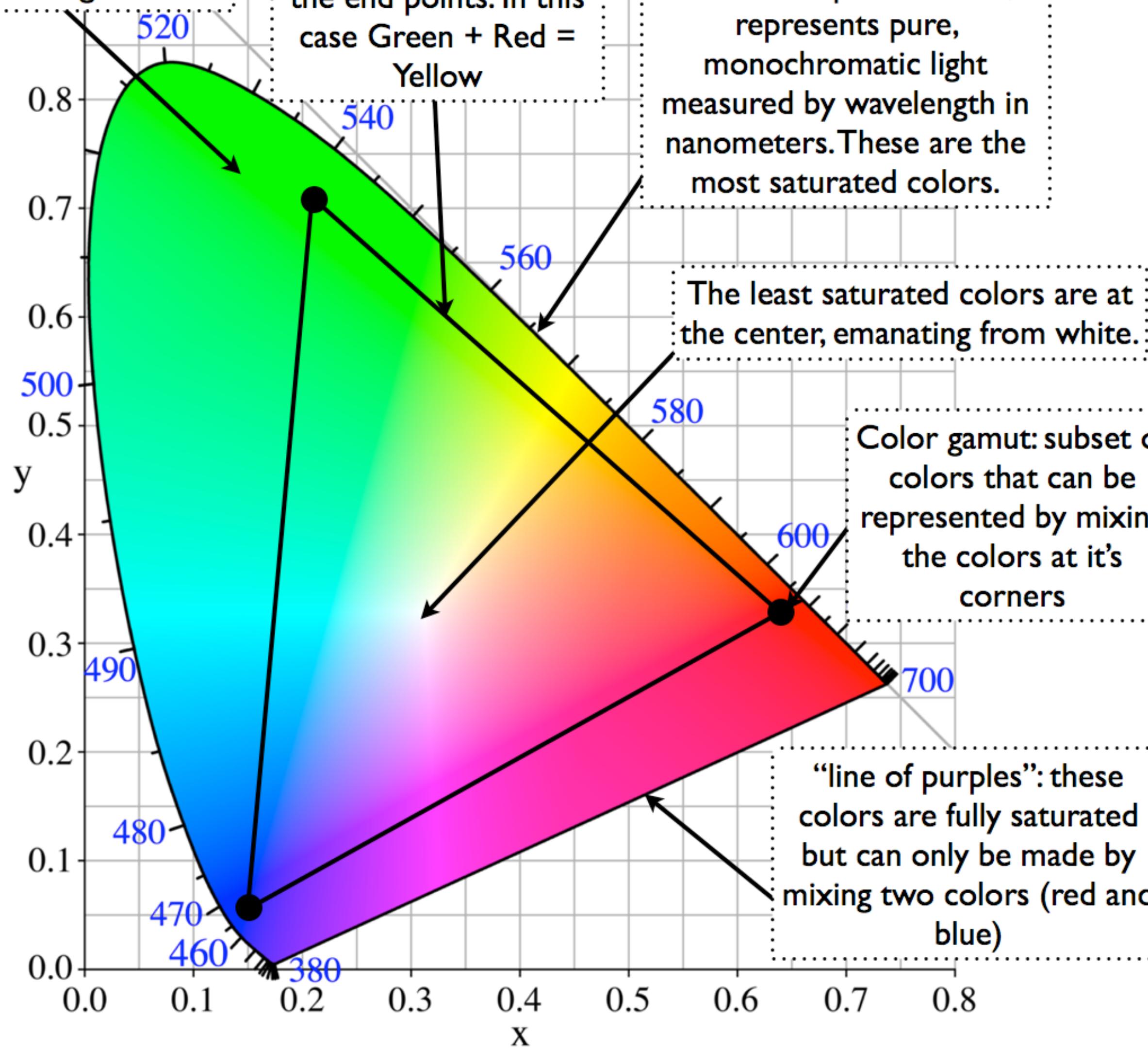
The colors along any line between two points can be made by mixing the colors at the end points. In this case Green + Red =

The edge of the diagram, called the spectral locus, represents pure, monochromatic light measured by wavelength in nanometers. These are the most saturated colors.

The least saturated colors are at the center, emanating from white.

Color gamut: subset of colors that can be represented by mixing the colors at its corners

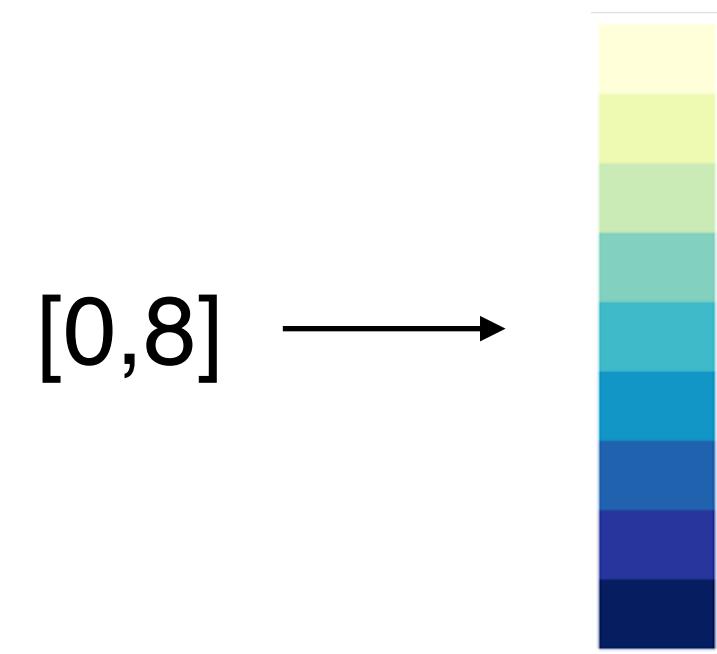
"line of purples": these colors are fully saturated but can only be made by mixing two colors (red and blue)



x, y are derived values that specify chromaticity in the CIE XYZ model

Anatomy of a CIE Chromaticity Diagram

What is a colormap?



specifies a mapping between
color and values

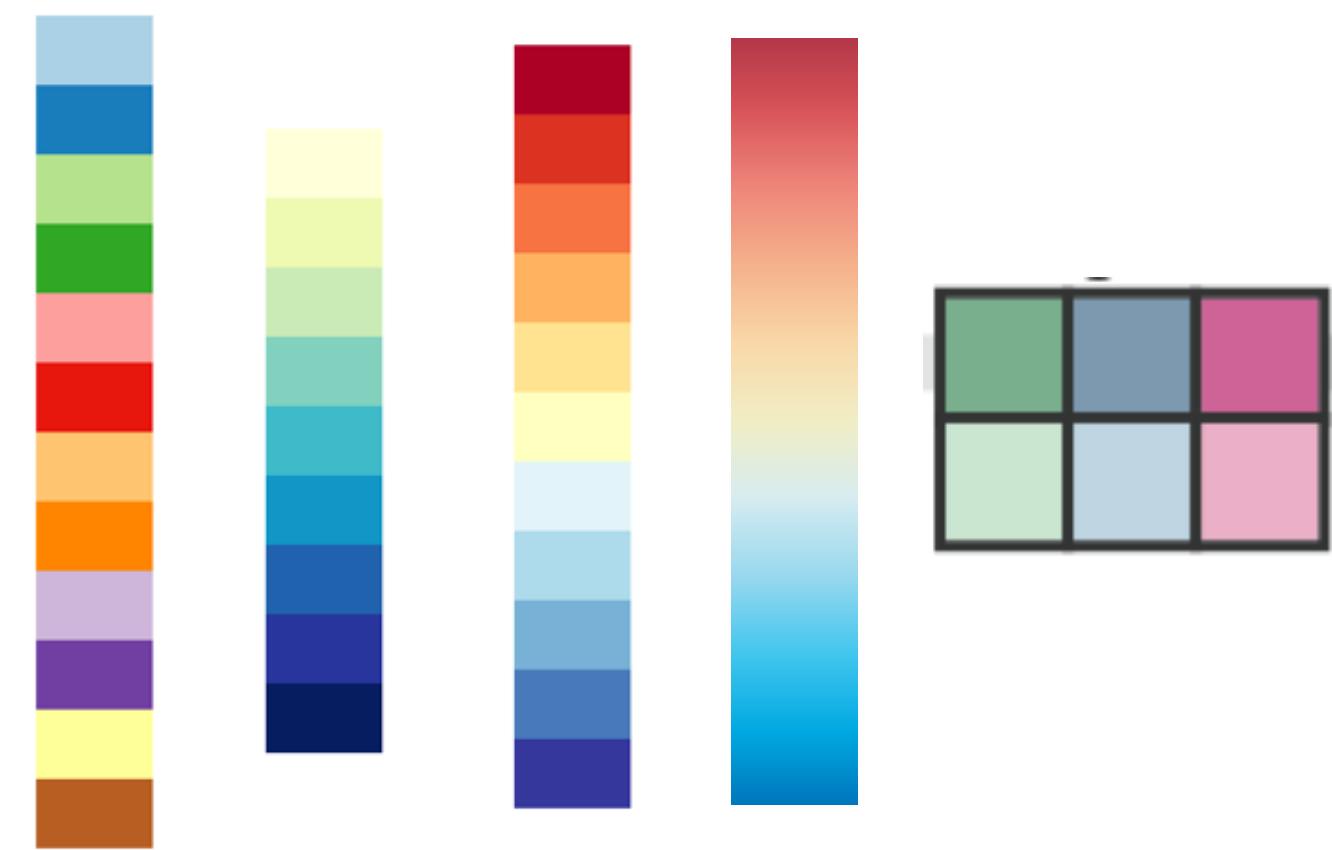
categorical vs ordered

sequential vs diverging

segmented vs continuous

univariate vs bivariate

Match colormap to attribute
characteristics!



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)

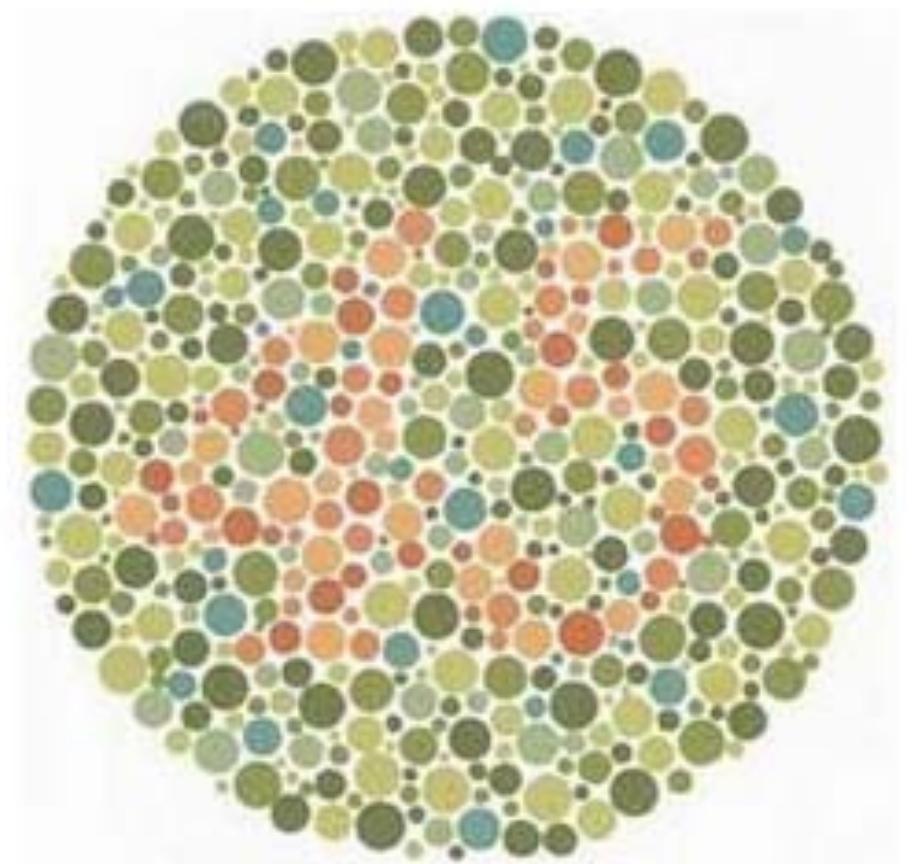
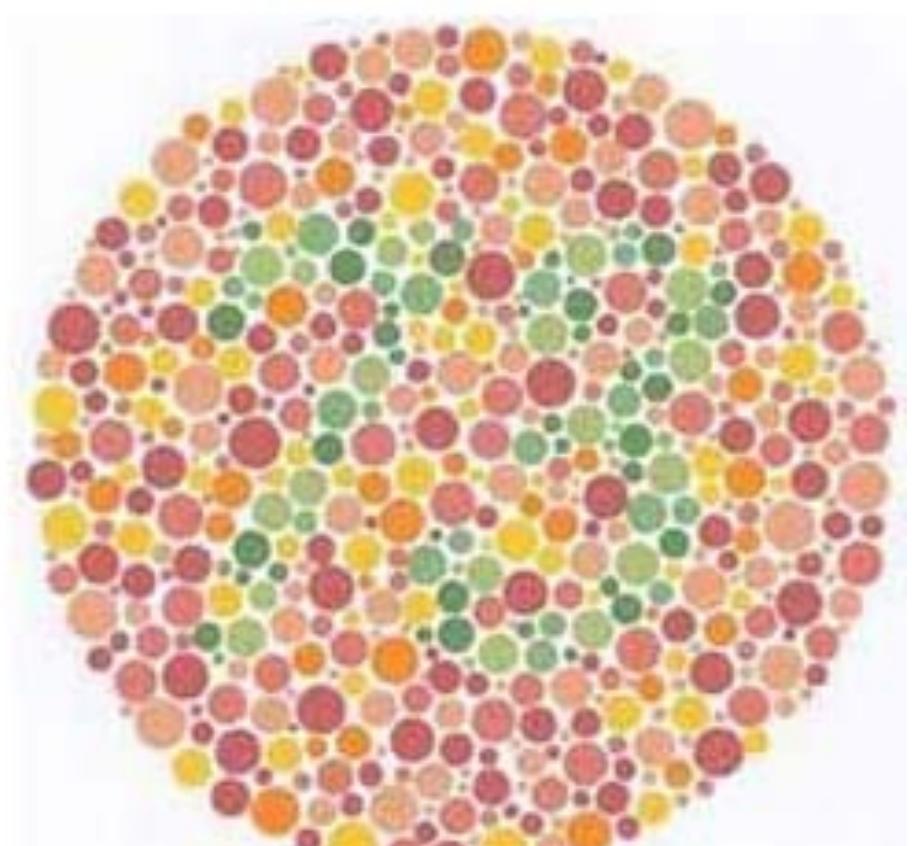
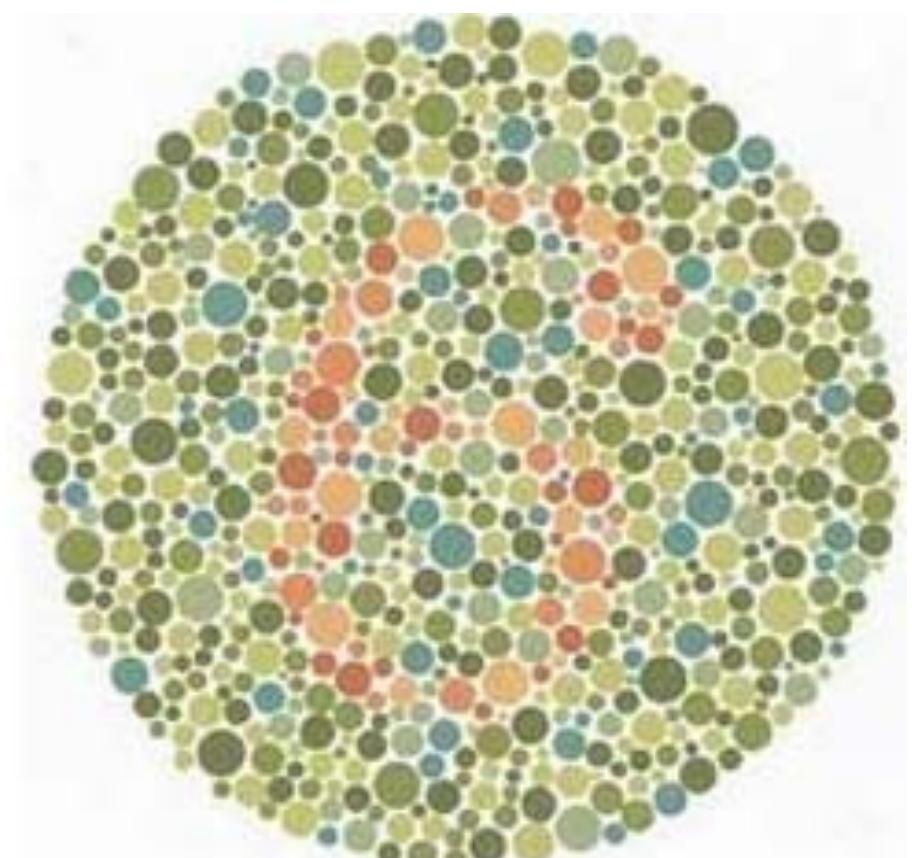
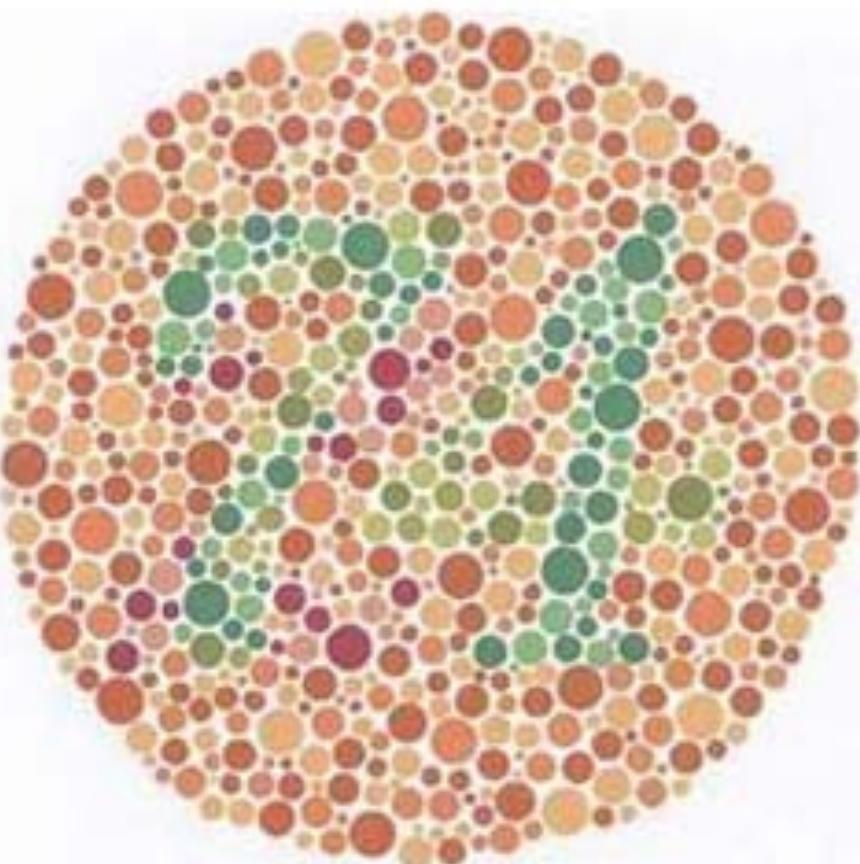
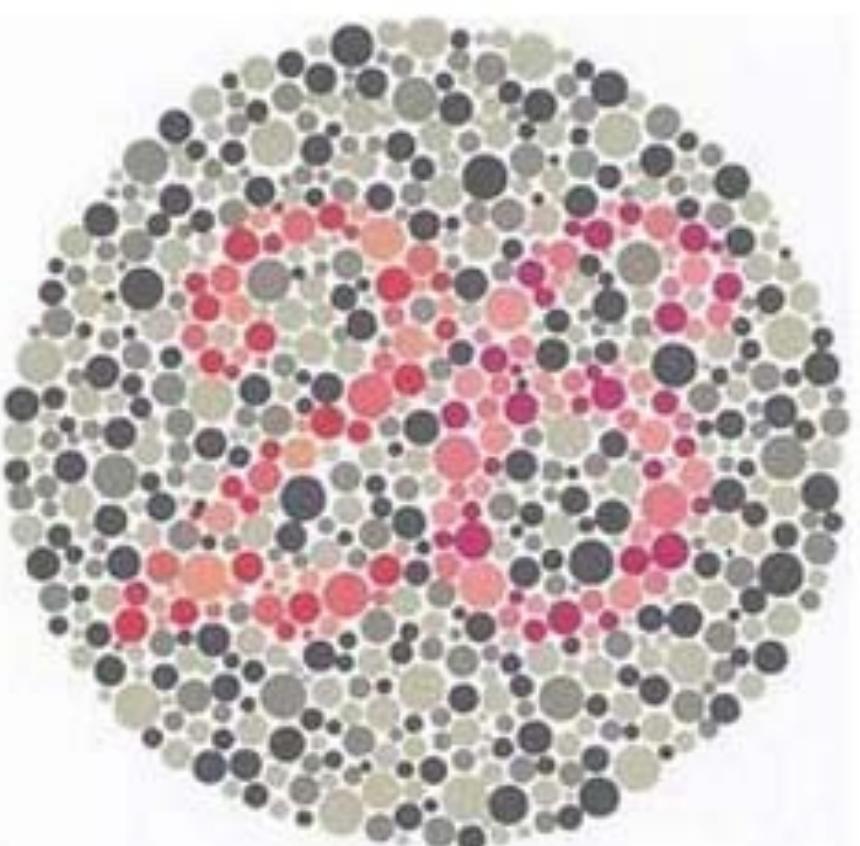
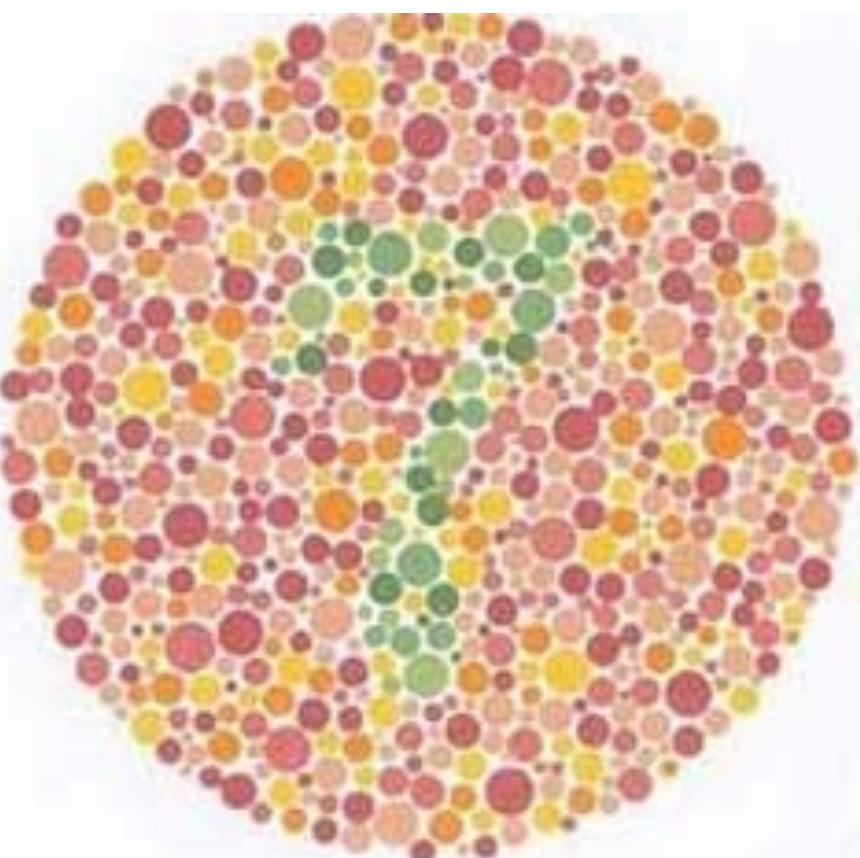
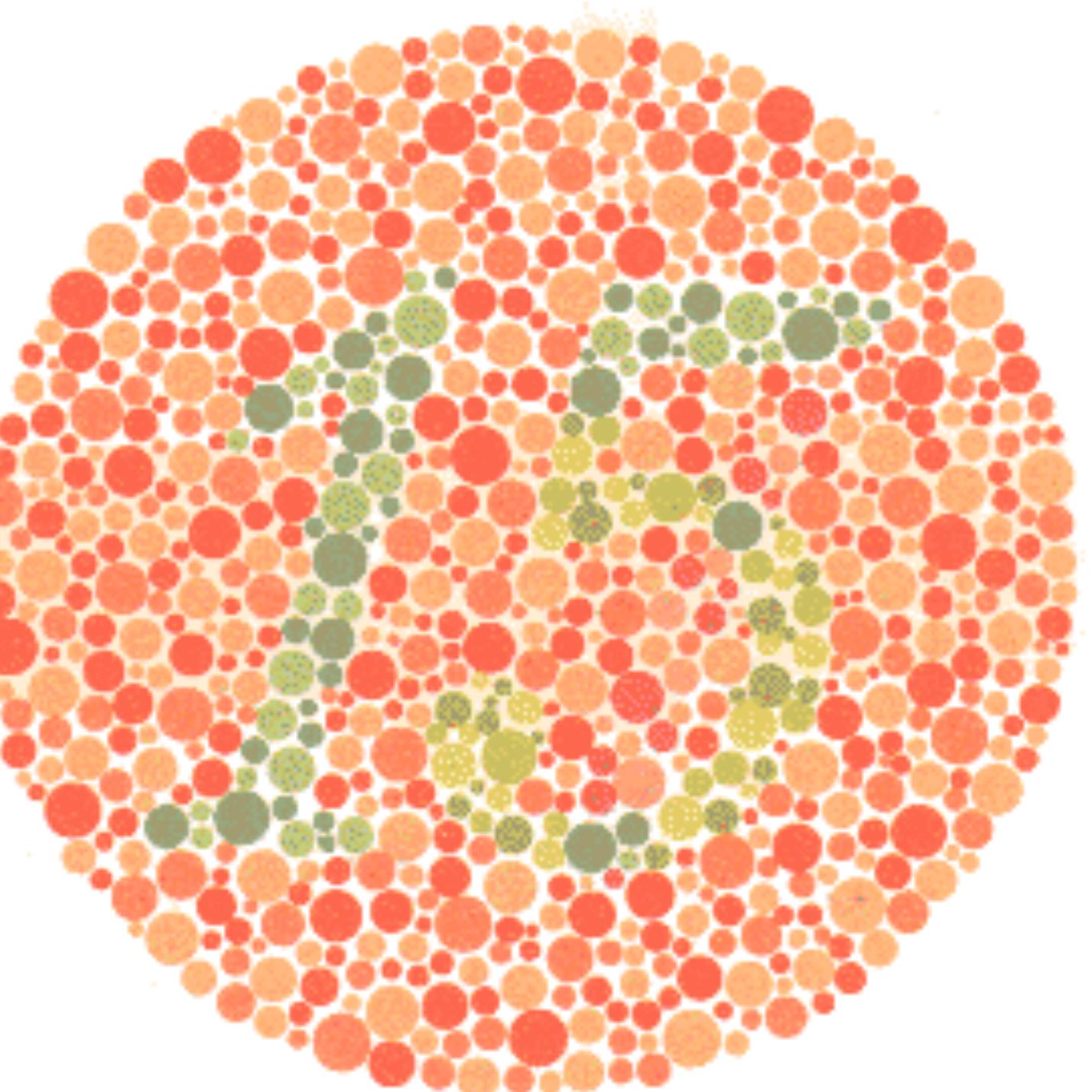
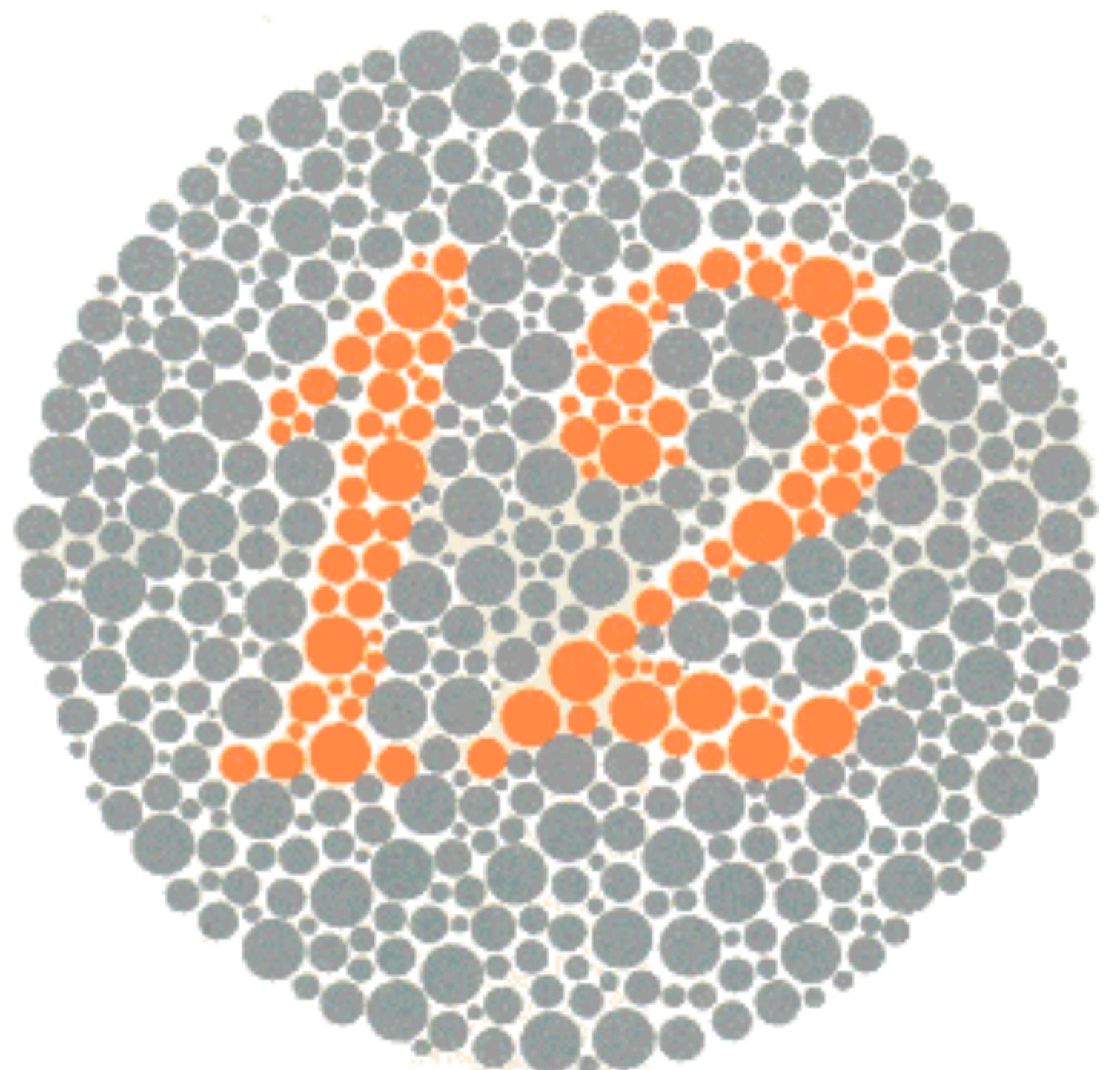


Normal Color Perception

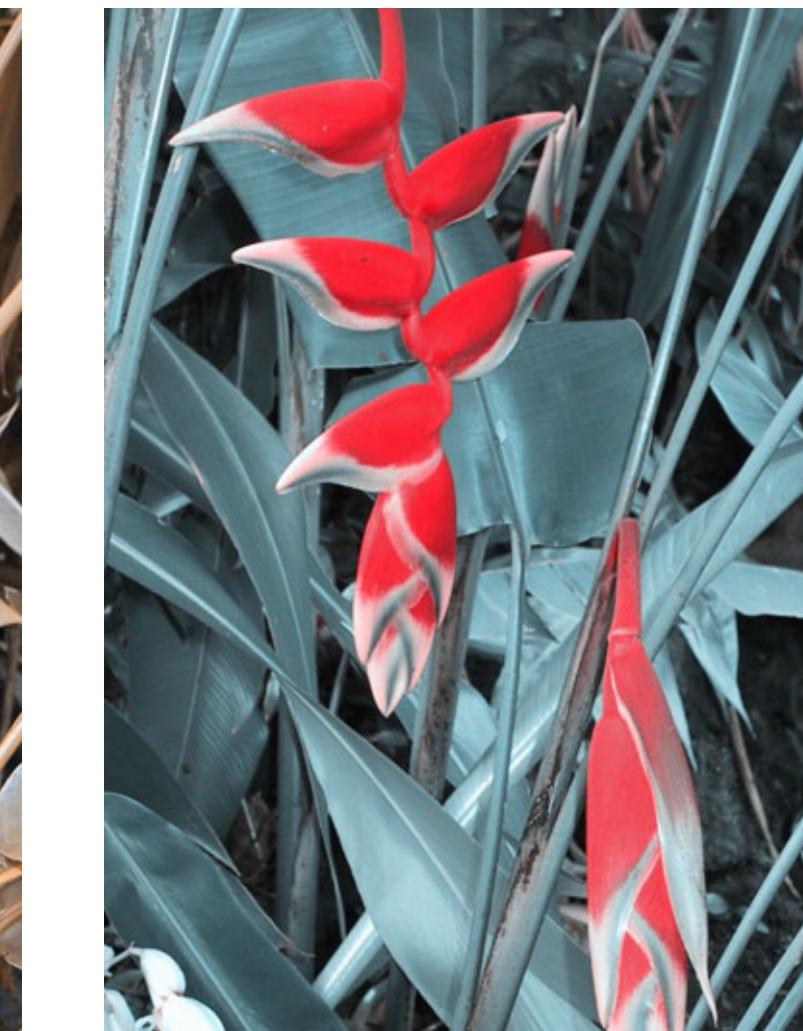
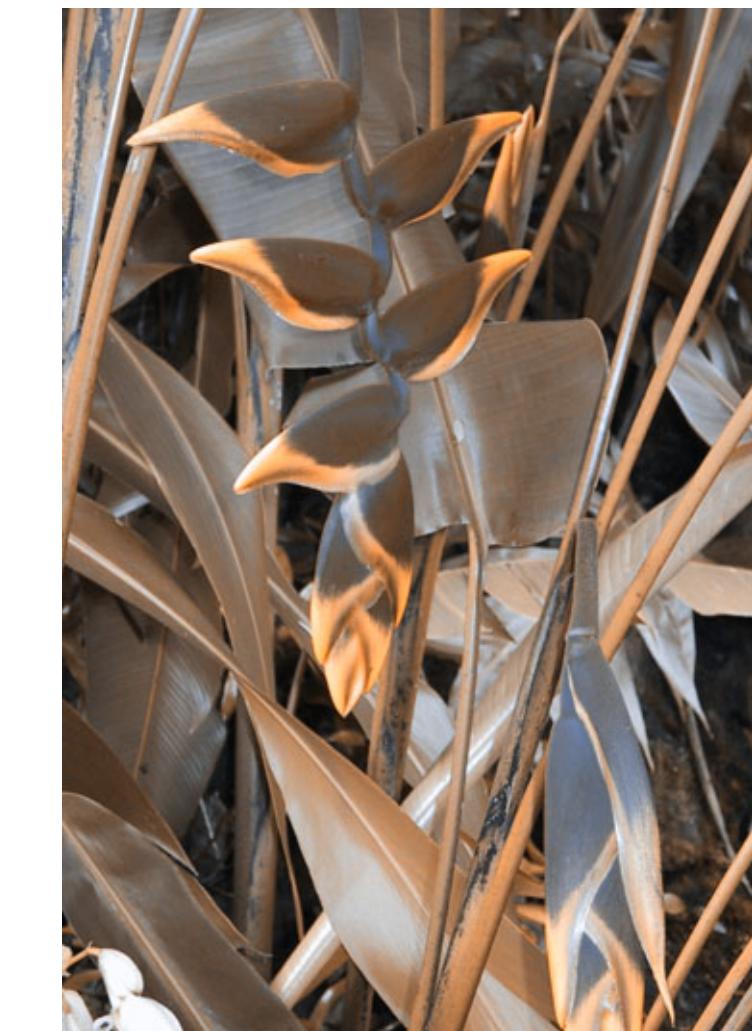
Deuteranopia (no green receptors)

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

All Spending Types of Spending Changes Department Totals

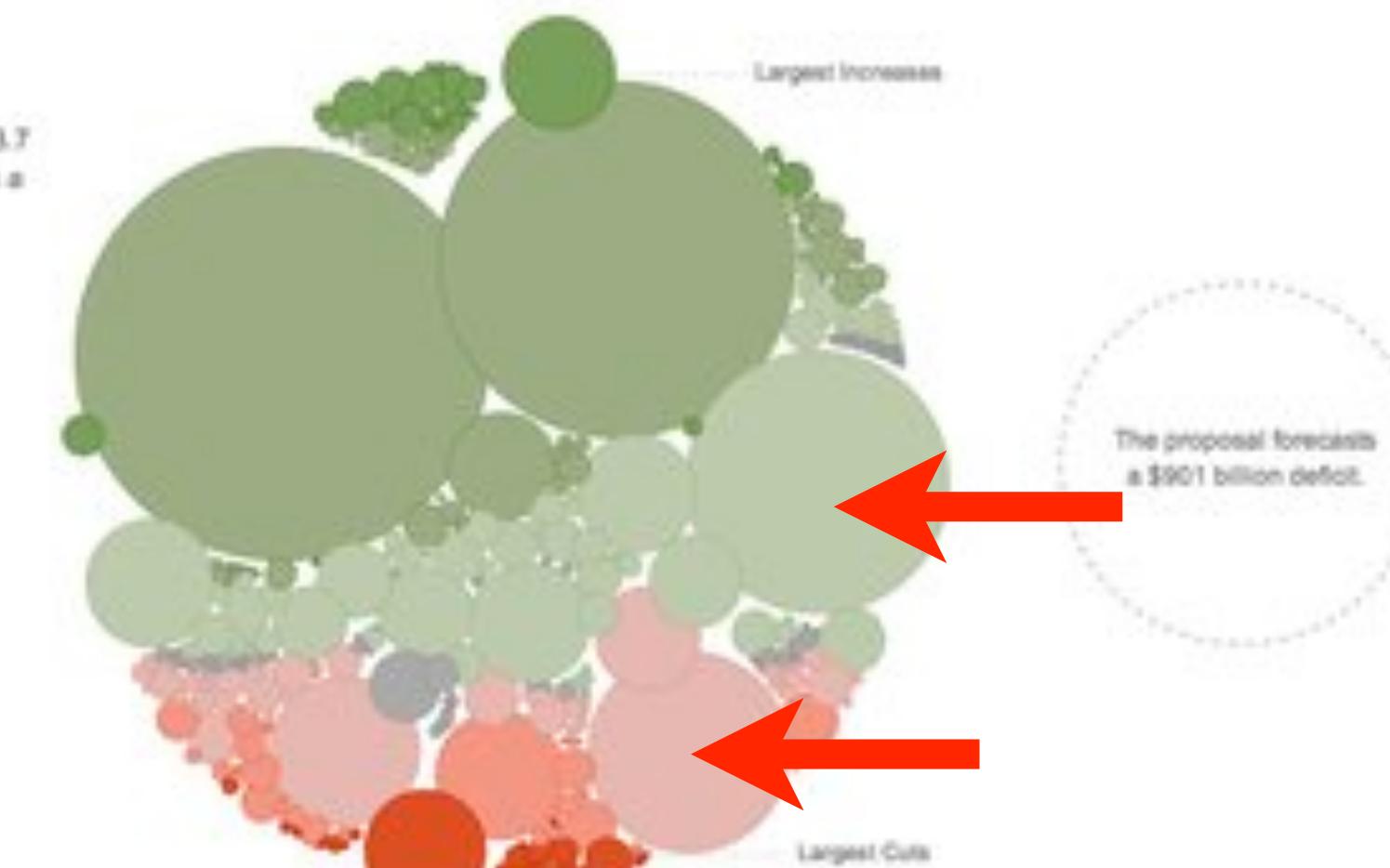
How \$3.7 Trillion Is Spent

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

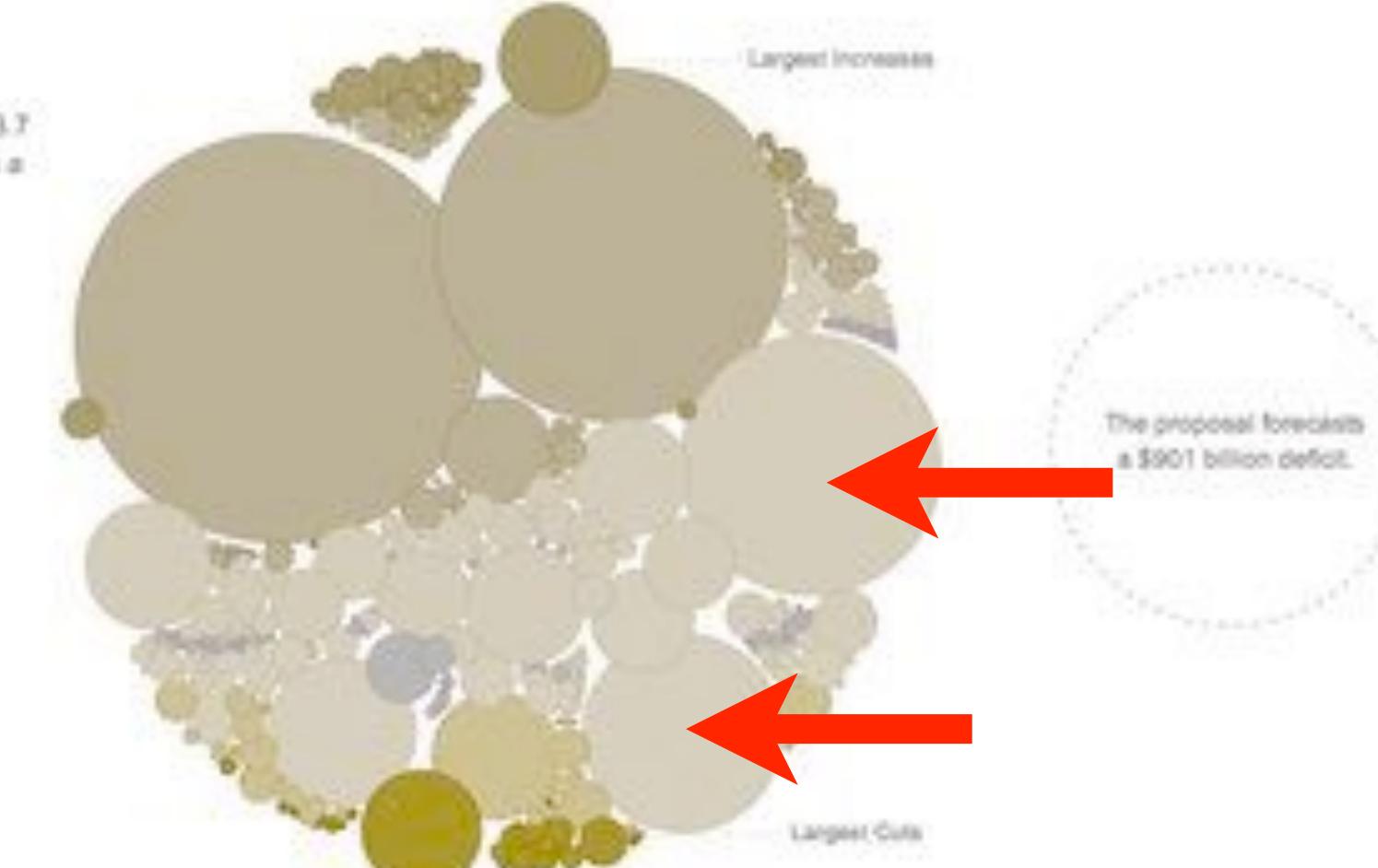
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Simulate Color Vision Deficiencies



The screenshot shows the homepage of the Coblis - Color Blindness Simulator. At the top left is the logo 'Colblindor' with a stylized eye icon. The top right has navigation links 'Home' and 'CVD Essential'. Below the header is a large black rectangular area. Underneath it, the title 'Coblis — Color Blindness Simulator' is displayed in a dark font. A descriptive paragraph follows, stating: 'If you are not suffering from a color vision deficiency it is very hard to imagine how it looks like to be colorblind. The Color BLIndness Simulator can close this gap for you. Just play around with it and get a feeling of how it is to have a color vision handicap.' Another paragraph explains: 'As all the calculations are made on your local machine, no images are uploaded to the server. Therefore you can use images as big as you like, there are no restrictions. Be aware, there are some issues for the "Lens feature" on Edge and Internet Explorer. All others should support everything just fine.' A third paragraph encourages users to try the simulator: 'So go ahead, choose an image through the upload functionality or just drag and drop your image in the center of our Color BLIndness Simulator. It is also possible to zoom and move your images around using your mouse – try it out, I hope you like it.' At the bottom of the page is a form for file upload and a list of color vision deficiency types with radio buttons. It also includes options for lens selection and a 'Reset View' button. A preview image of colorful crayons is shown at the bottom.

Drag and drop or paste your file in the area below or: No file chosen

Trichromatic view: Anomalous Trichromacy: Normal Red-Weak/Protanomaly Green-Weak/Deutanomaly Blue-Weak/Tritanomaly **Dichromatic view:** Red-Blind/Protanopia Green-Blind/Deutanopia Blue-Blind/Tritanopia **Monochromatic view:** Monochromacy/Achromatopsia Blue Cone Monochromacy

Use lens to compare with normal view: No Lens Normal Lens Inverse Lens

[Reset View](#)



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

Chrome Dev Tools: Rendering

Screenshot of the ColorBrewer 2.0 website (colorbrewer2.org/#type=qualitative&scheme=Set1&n=3) displayed in the Chrome Dev Tools Rendering panel.

The main interface shows a map of the United States divided into states, each colored according to a qualitative color scheme. The scheme used is "Set1" with 3 data classes, resulting in three colors: red (#e41a1c), blue (#377eb8), and green (#4daf4a). The map is overlaid with state borders and county outlines.

The left sidebar contains settings for the color scheme:

- Number of data classes: 3
- Nature of your data:
 - sequential
 - diverging
 - qualitative
- Pick a color scheme:
A grid of 12 color palette swatches.
- Only show:
 - colorblind safe
 - print friendly
 - photocopy safe
- Context:
 - roads
 - cities
 - borders
- Background:
 - solid color
 - terrain
- color transparency

The right sidebar shows emulation settings for various CSS media features:

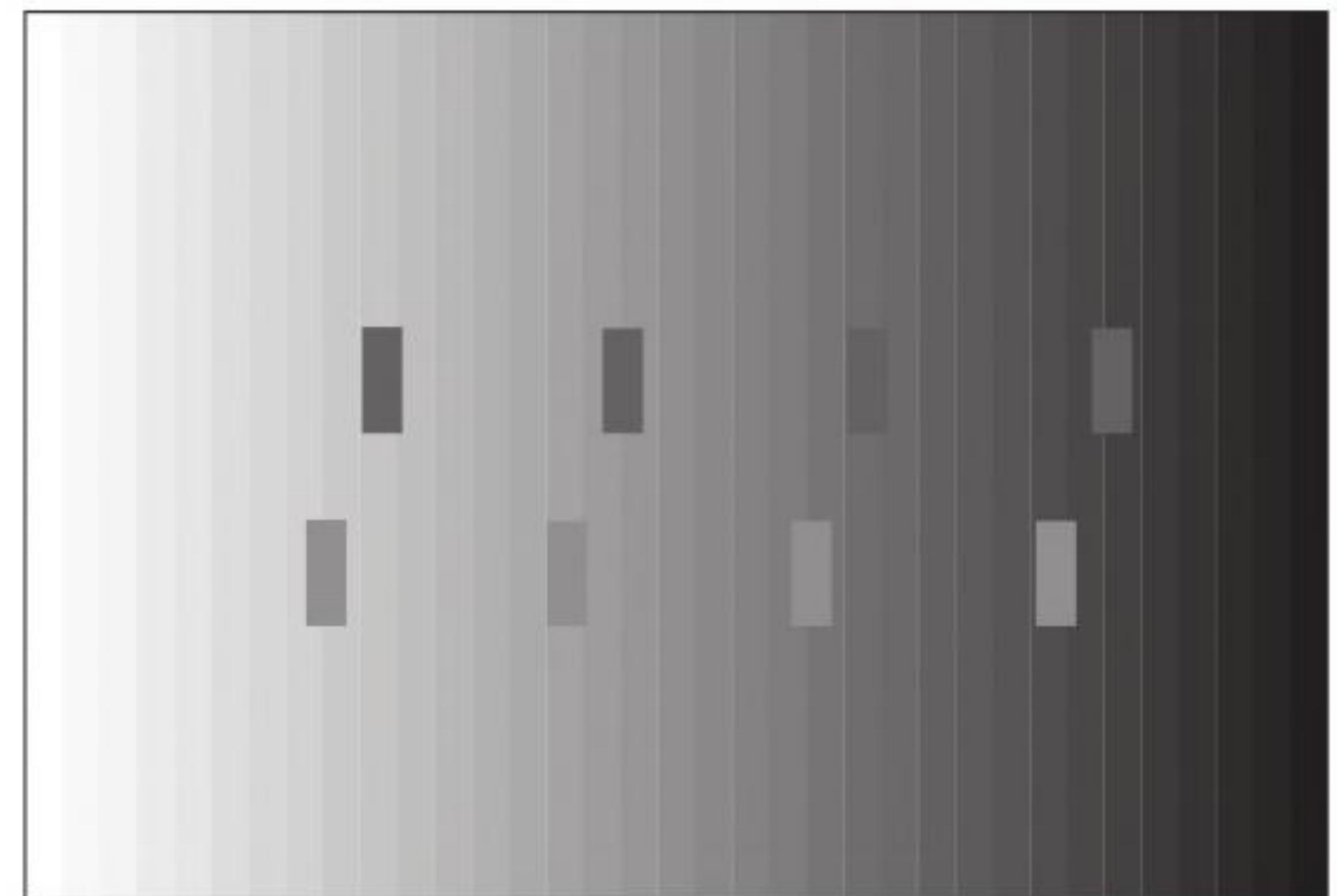
- Emulate CSS media feature prefers-color-scheme
Forces CSS prefers-color-scheme media feature
 - No emulation
- Emulate CSS media type
Forces media type for testing print and screen styles
 - No emulation
- Emulate CSS media feature forced-colors
Forces CSS forced-colors media feature
 - No emulation
- Emulate CSS media feature prefers-contrast
Forces CSS prefers-contrast media feature
 - No emulation
- Emulate CSS media feature prefers-reduced-motion
Forces CSS prefers-reduced-motion media feature
 - No emulation
- Emulate CSS media feature prefers-reduced-data
Forces CSS prefers-reduced-data media feature
 - No emulation
- Emulate CSS media feature color-gamut
Forces CSS color-gamut media feature
 - No emulation
- Emulate vision deficiencies
Forces vision deficiency emulation
 - No emulation
 - Protanopia

At the bottom left, there are links to source code and feedback, and options to back to the Flash version or ColorBrewer 1.0.

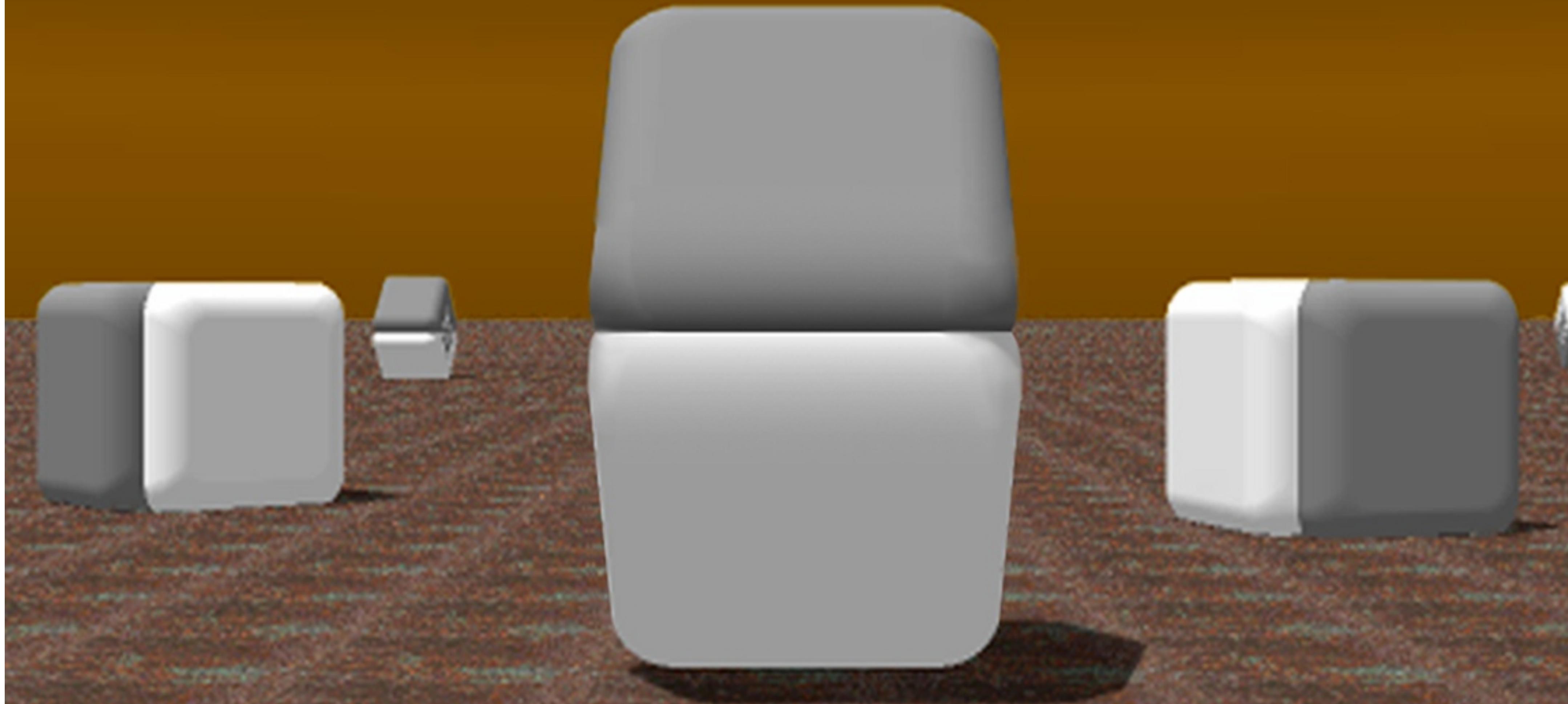
**Color / Brightness is
Relative!**

Simultaneous Brightness Contrast

The perceived brightness
of an object is relative to
its background



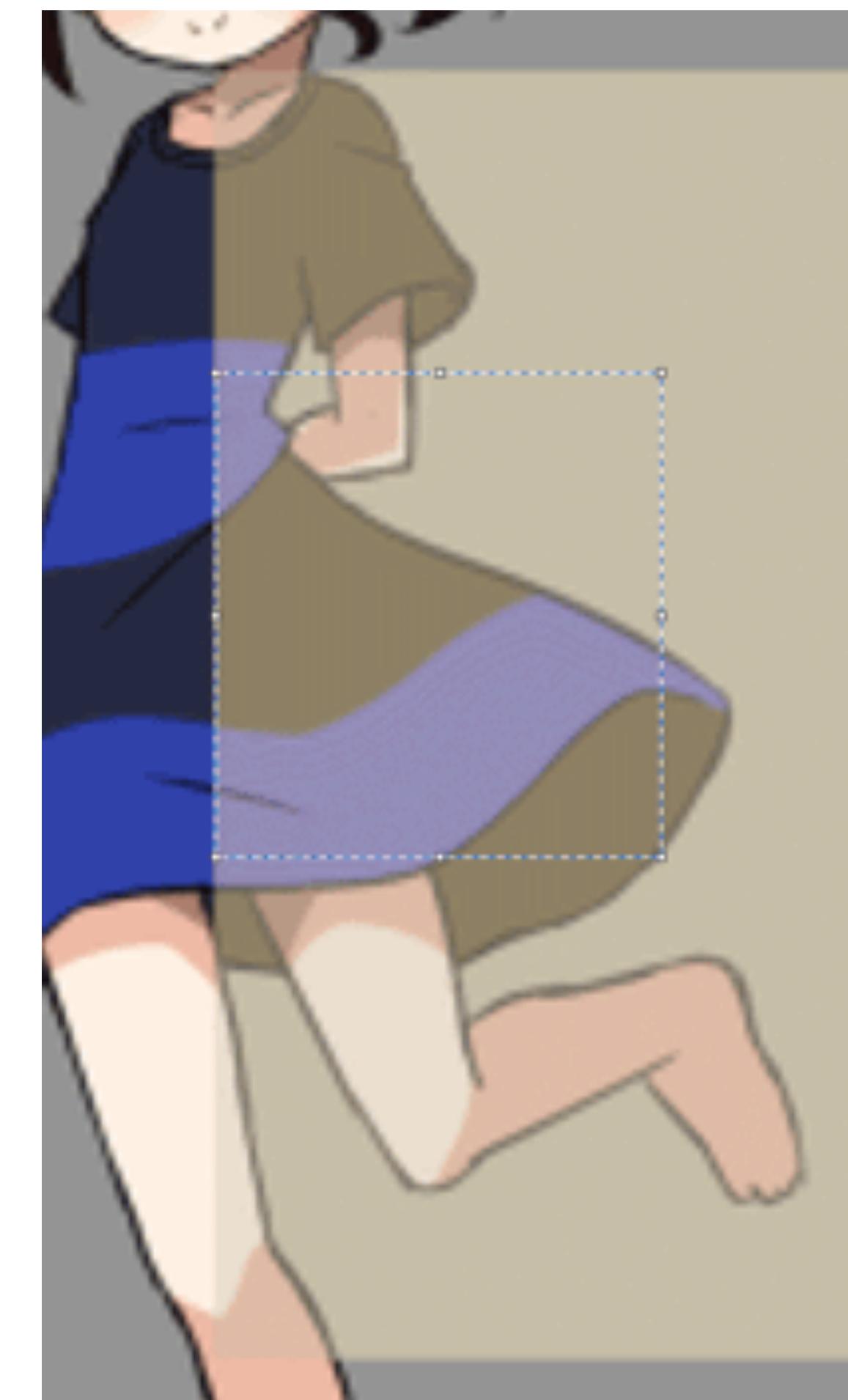
Cornsweet Illusion



Cornsweet Illusion



The Dress Meme

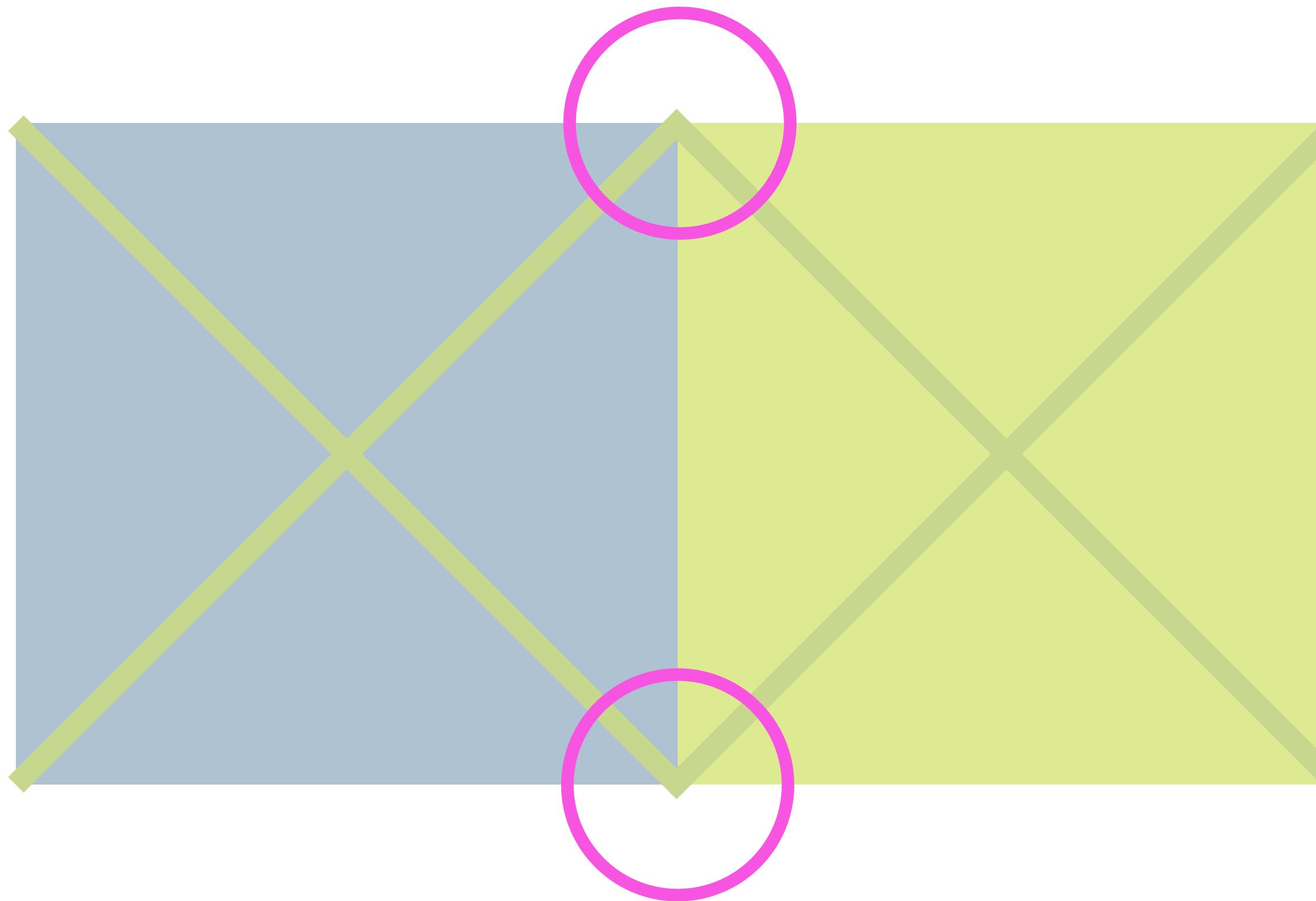


black and blue or white and gold?

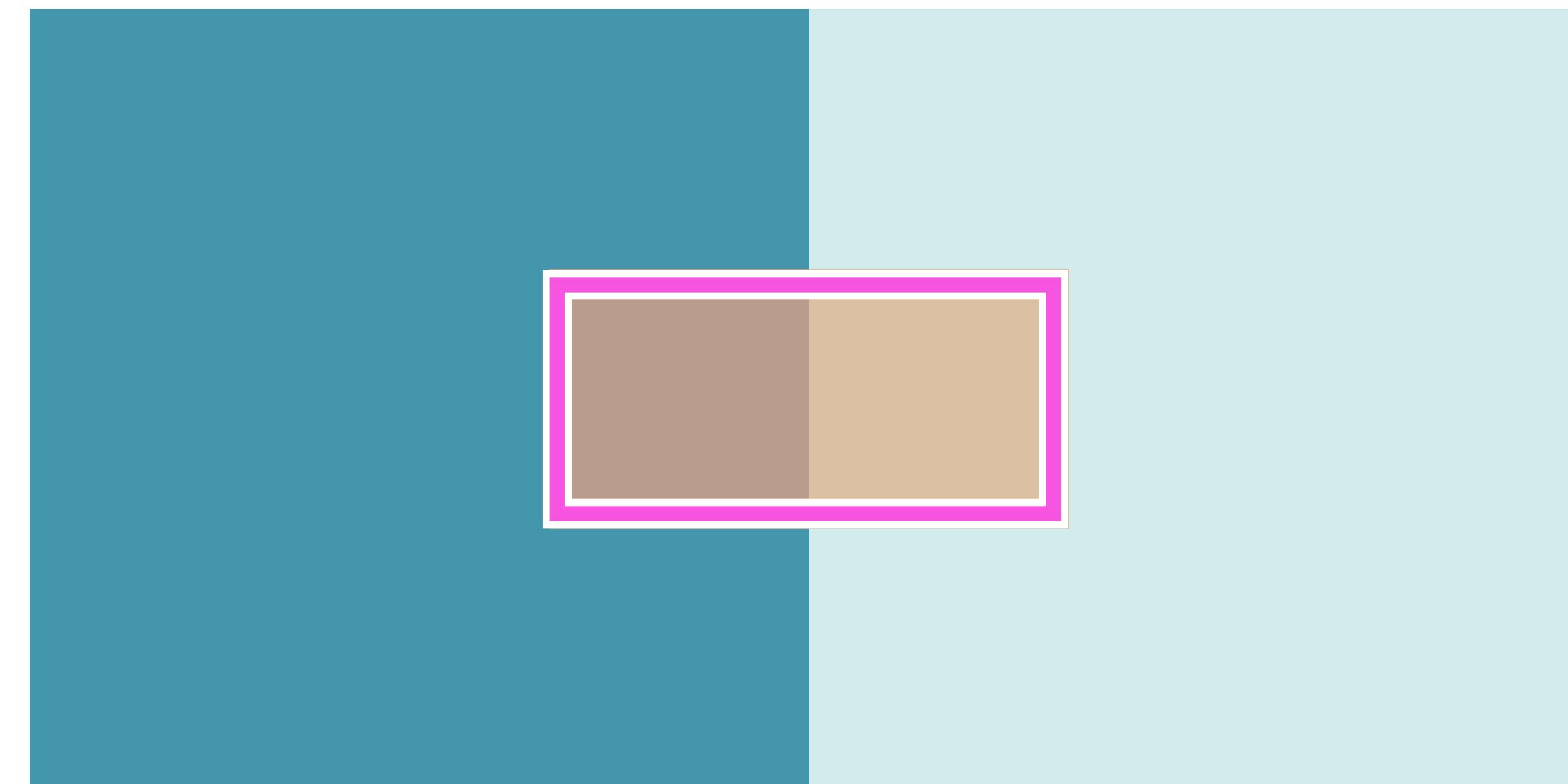
<https://imgur.com/hxJjUQB>

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

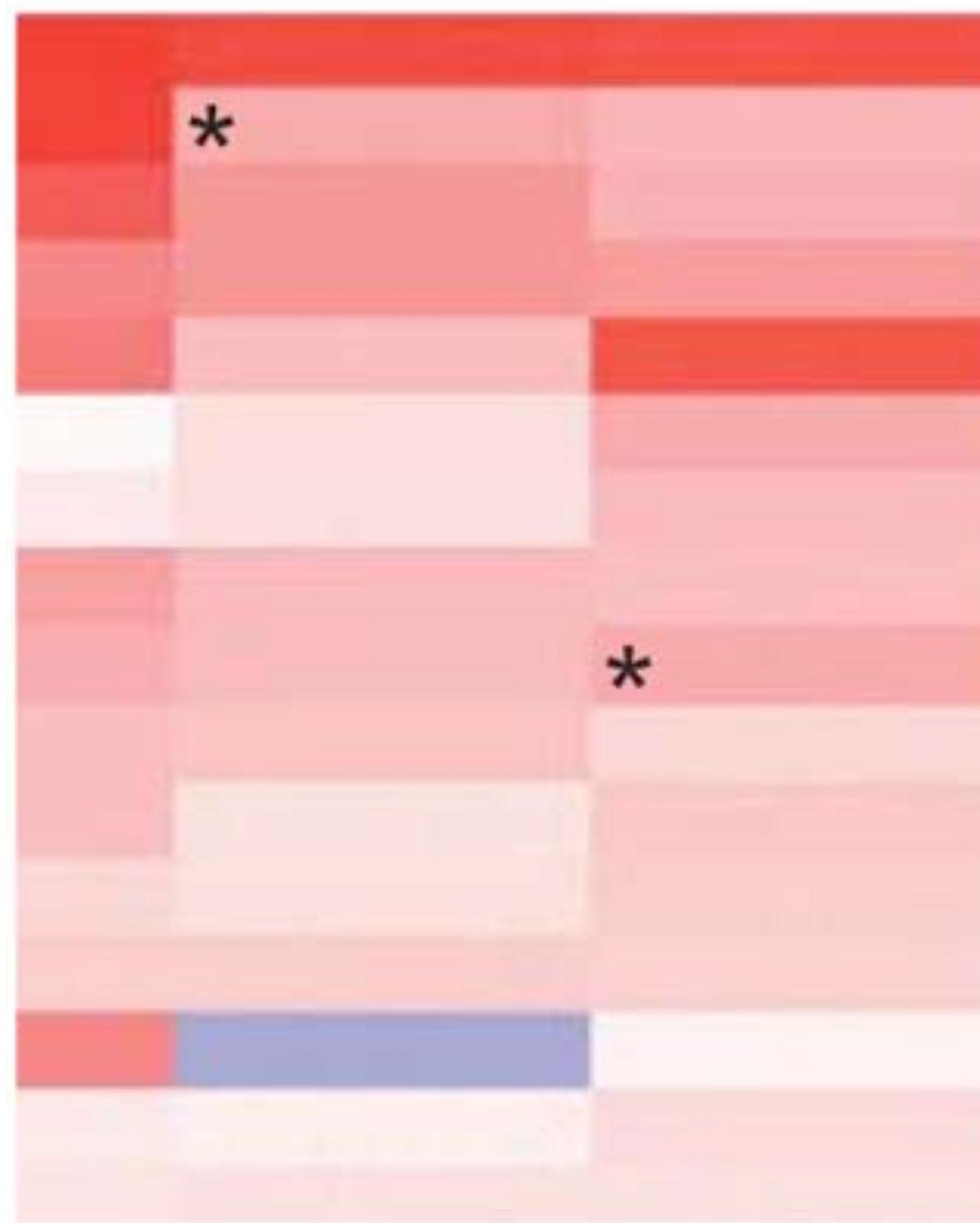
INTERACTION OF COLOR



INTERACTION OF COLOR



INTERACTION OF COLOR

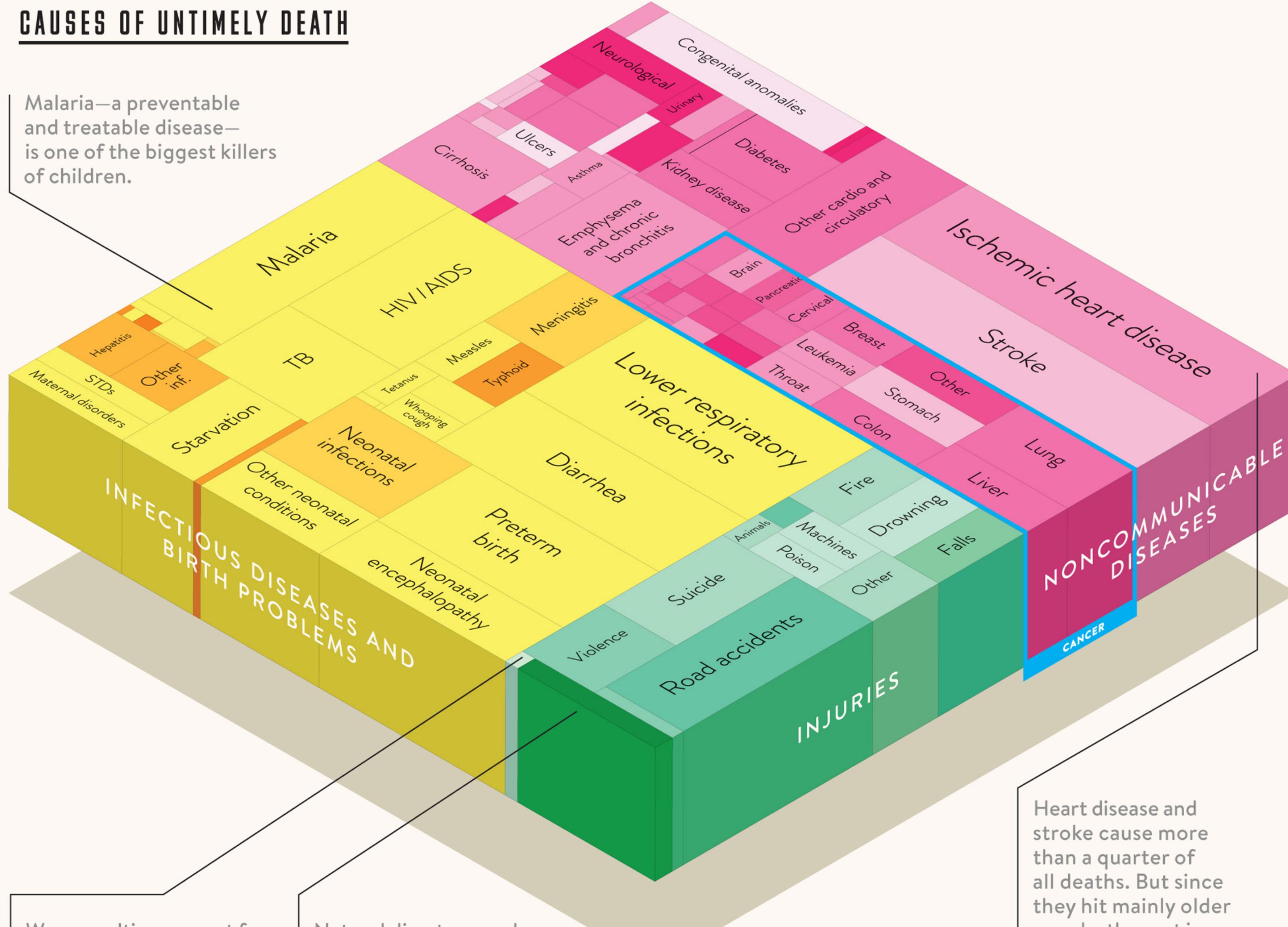


[Wong 2010]

Design Critique

CAUSES OF UNTIMELY DEATH

Malaria—a preventable and treatable disease—is one of the biggest killers of children.



War casualties account for just 0.05 percent of total life-years lost annually.

Natural disasters are by far the fastest-growing contributor to the death toll.

Heart disease and stroke cause more than a quarter of all deaths. But since they hit mainly older people, the cost in years of life lost is relatively small.

ANNUAL % CHANGE (2005 TO 2010)

INFECTIOUS DISEASES/BIRTH PROBLEMS

INJURIES

NONCOMMUNICABLE DISEASES

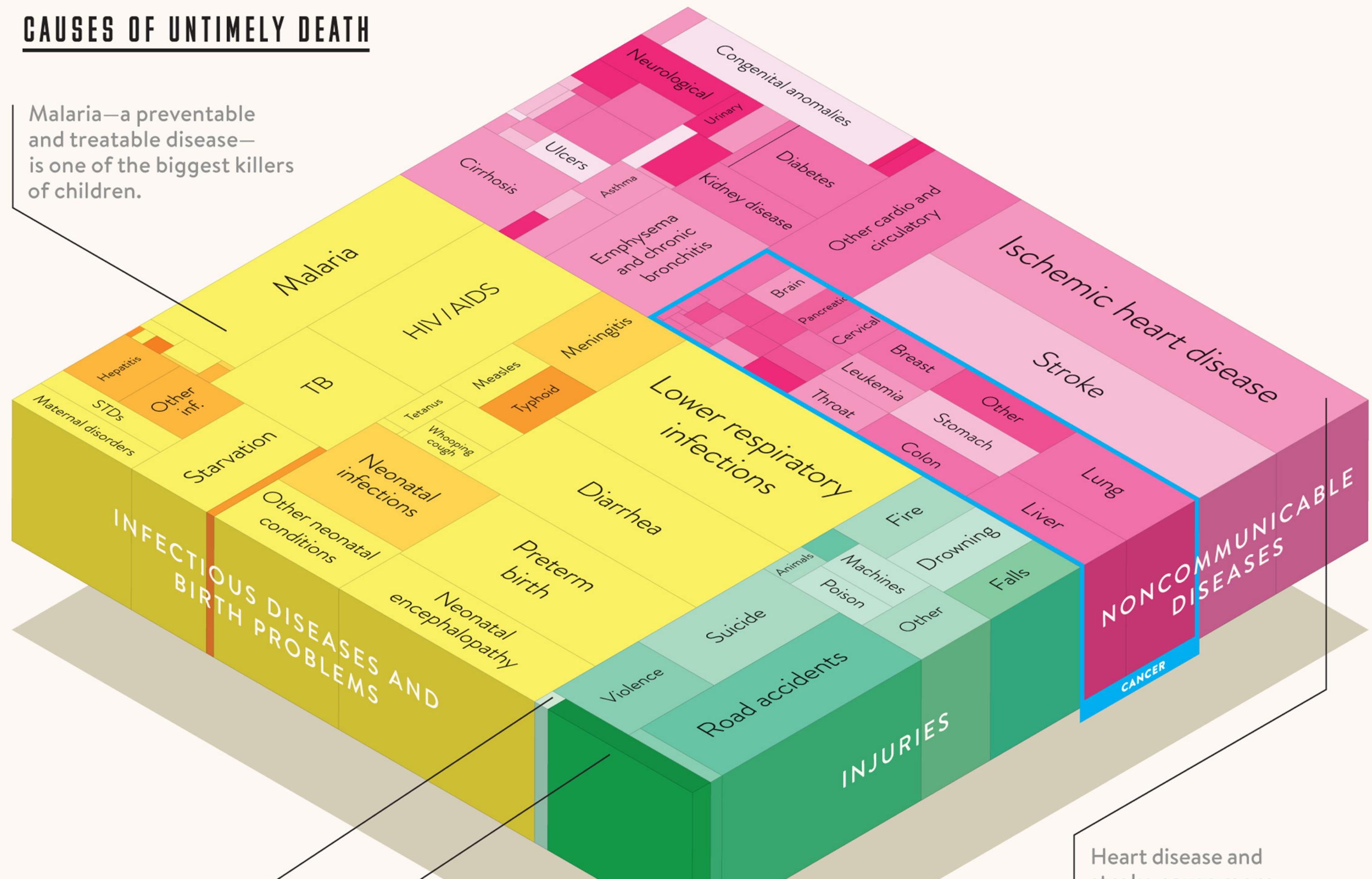
-3% -2% -1% 0% 1% 2% 3%

Graph of the Year?

"I love this graph because it shows that while the number of people dying from communicable diseases is still far too high, those numbers continue to come down. [...] But there remains much to do to cut down the deaths in that yellow block even more dramatically. We have the solutions. But we need to keep up the support where they're being deployed [...]"

-Bill Gates

CAUSES OF UNTIMELY DEATH

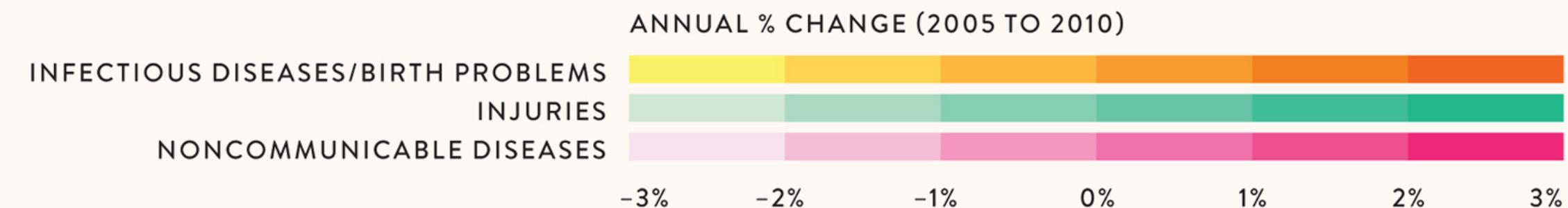


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War casualties account for just 0.05 percent of total life-years lost annually.

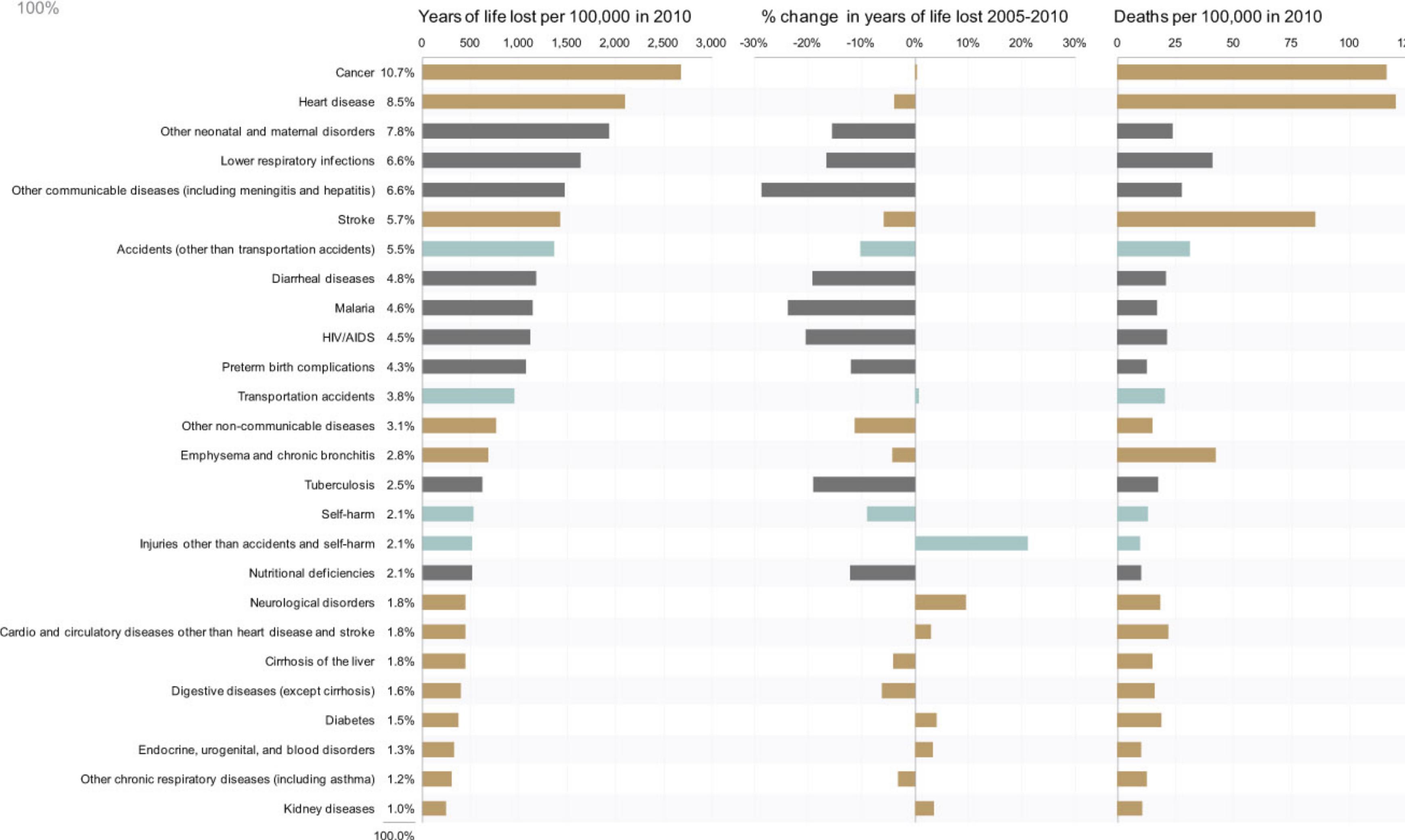
Natural disasters are by far the fastest-growing contributor to the death toll.

Heart disease and stroke cause more than a quarter of all deaths. But since they hit mainly older people, the cost in years of life lost is relatively small.



Global Causes of Lost Life

44% ■ Communicable, maternal, neonatal, and nutritional disorders
 43% ■ Non-communicable diseases
 13% ■ Injuries



Some causes of death contribute disproportionately to years of life lost because of their effect on the young. For example, malaria, while not huge in the number of deaths, is much more significant in the number of years that are lost.

Two interesting changes reside in "Injuries other than accidents and self-harm." War, which accounted for only 0.05% of years of life lost, decreased since 2005 by 31.5% in years of life lost per 100,000 people. Natural disasters, which accounted for 0.65% of years of life lost, increased by 217% in years of life lost per 100,000.

Communicable, maternal, neonatal, and nutritional disorders (the gray bars) are often easier to prevent through healthcare than other causes of death. This reveals itself in the graph above by the fact that all of these disorders have decreased during this five year period.

The five forms of cancer that cause the most deaths are trachea/bronchus/lung (2.9%), stomach (1.4%), liver (1.4%), colon/rectum (1.4%), and breast (0.8%). All cardiovascular and circulatory diseases combined account for 30% of deaths.

Comparing the number of deaths alone, as shown in the right-most graph below, doesn't tell the entire story. Some causes of death have a greater effect on the young, which can be seen when comparing years of life lost in the leftmost graph.

Redesign by
Perceptual Edge

Popout

Popout

Properties detected by the low-level visual system

very rapid – 200-250 milliseconds

very accurate

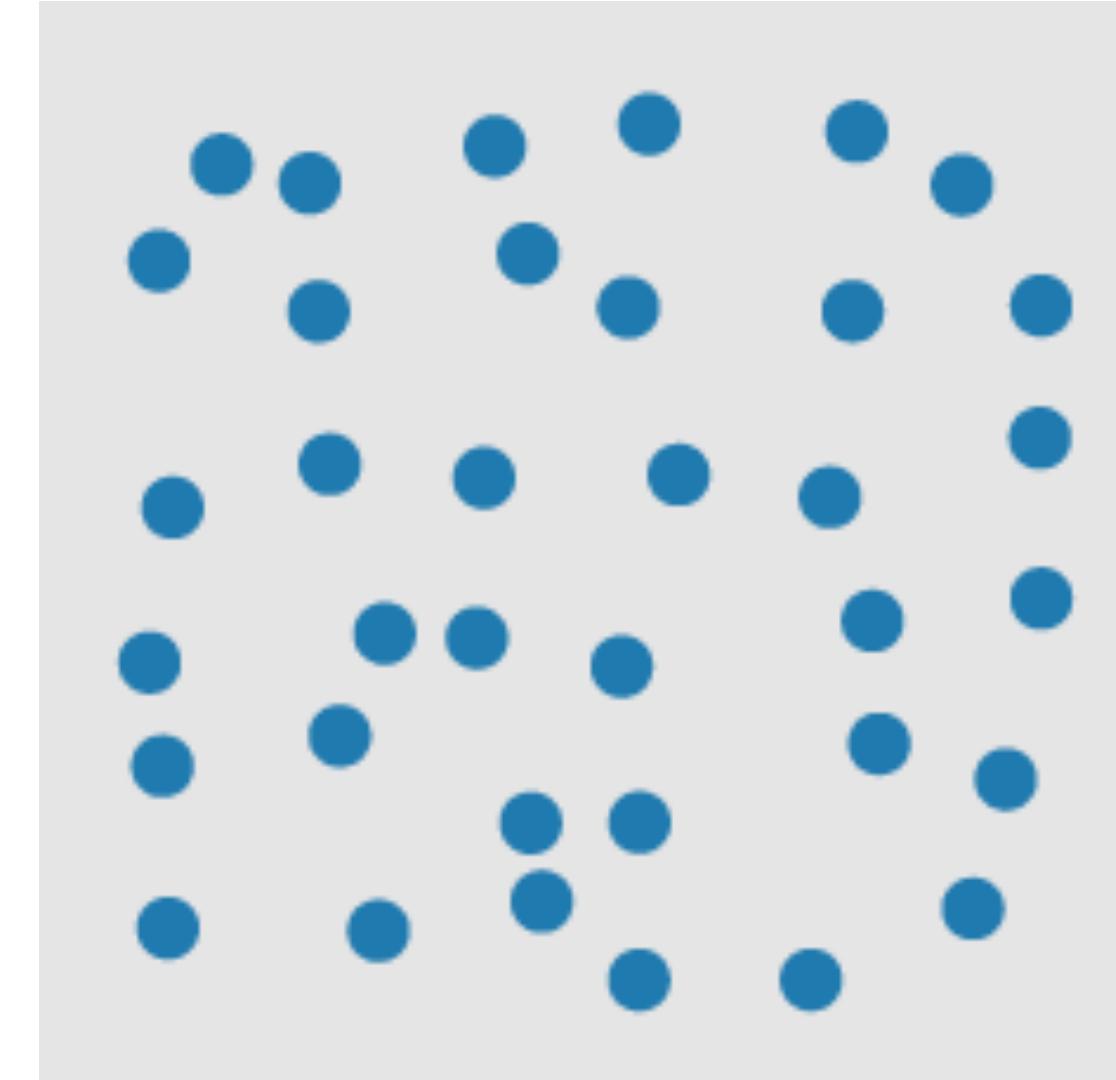
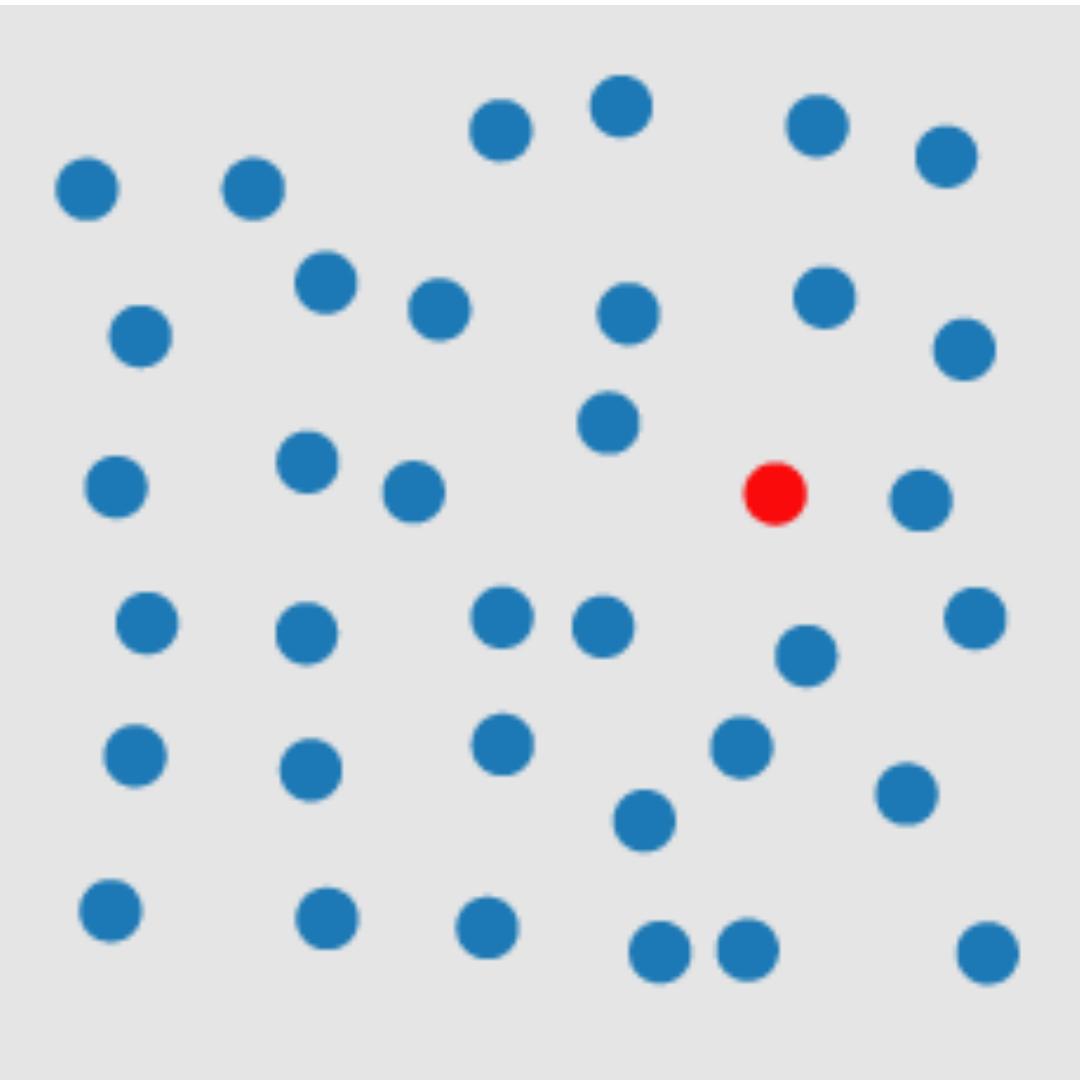
processed in parallel

happens before focused attention -> „pre“attentive
attention is very important for cognition

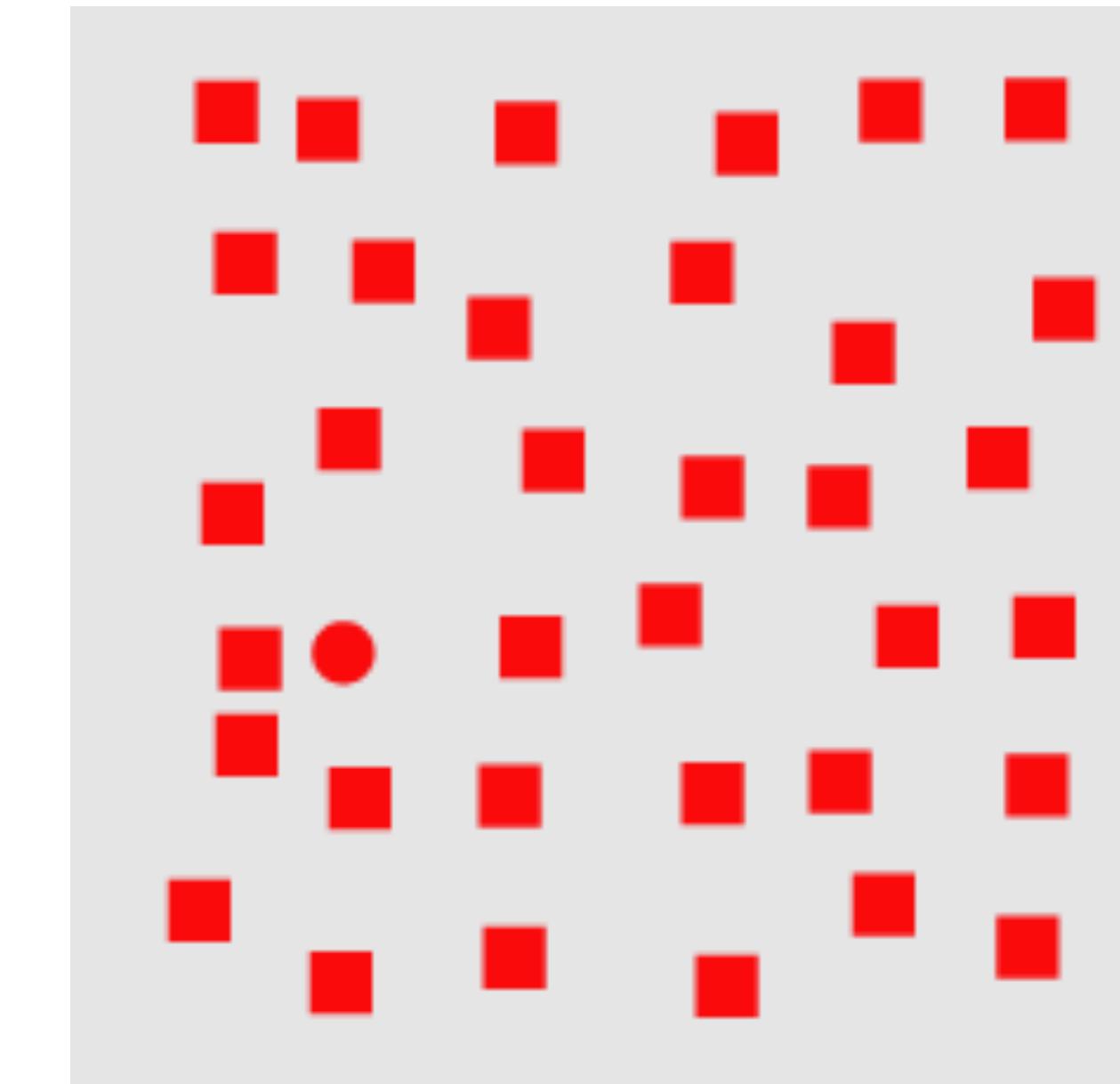
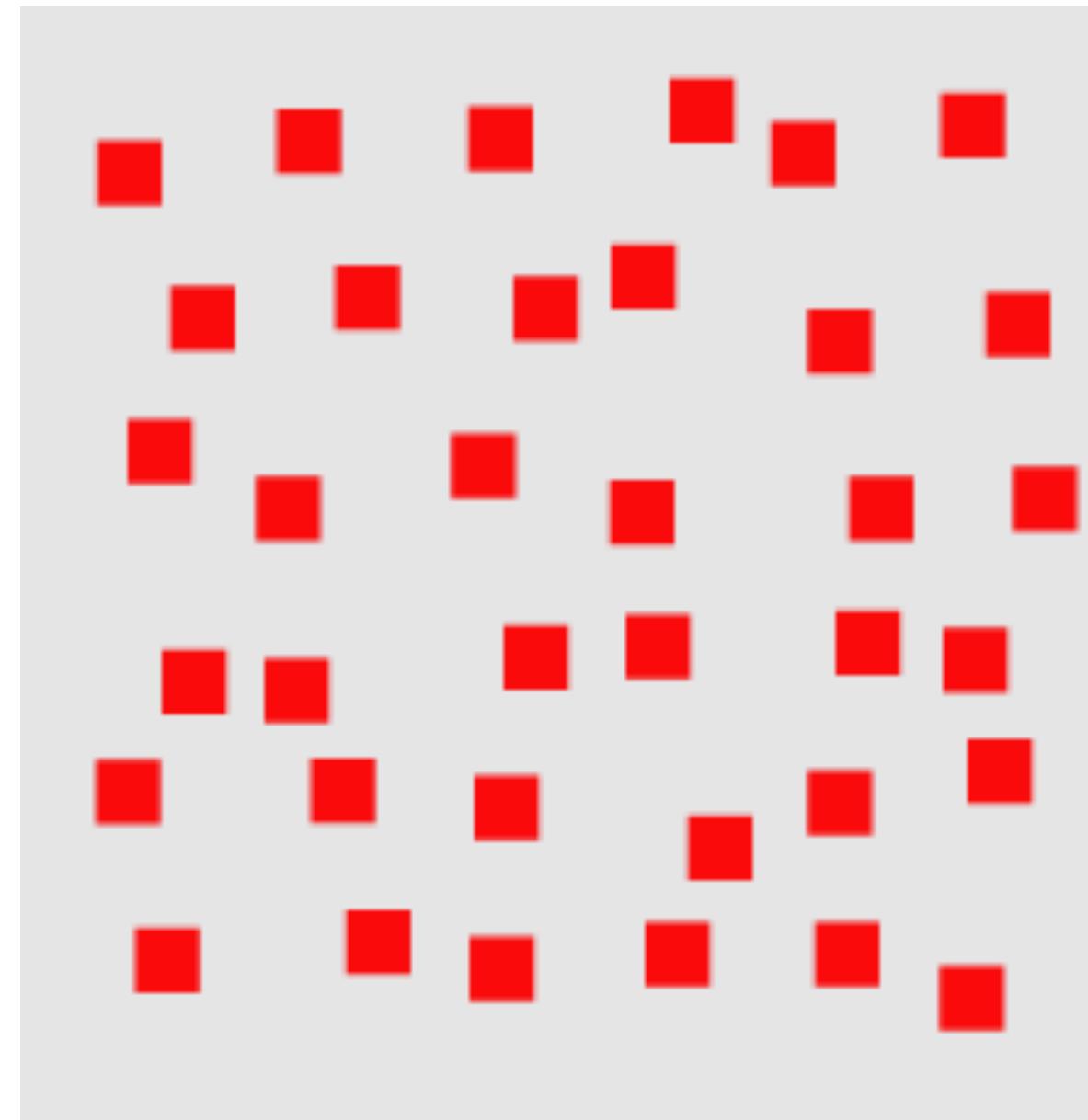
Independent of the number of distractors!

Opposite: sequential search (processed serially)

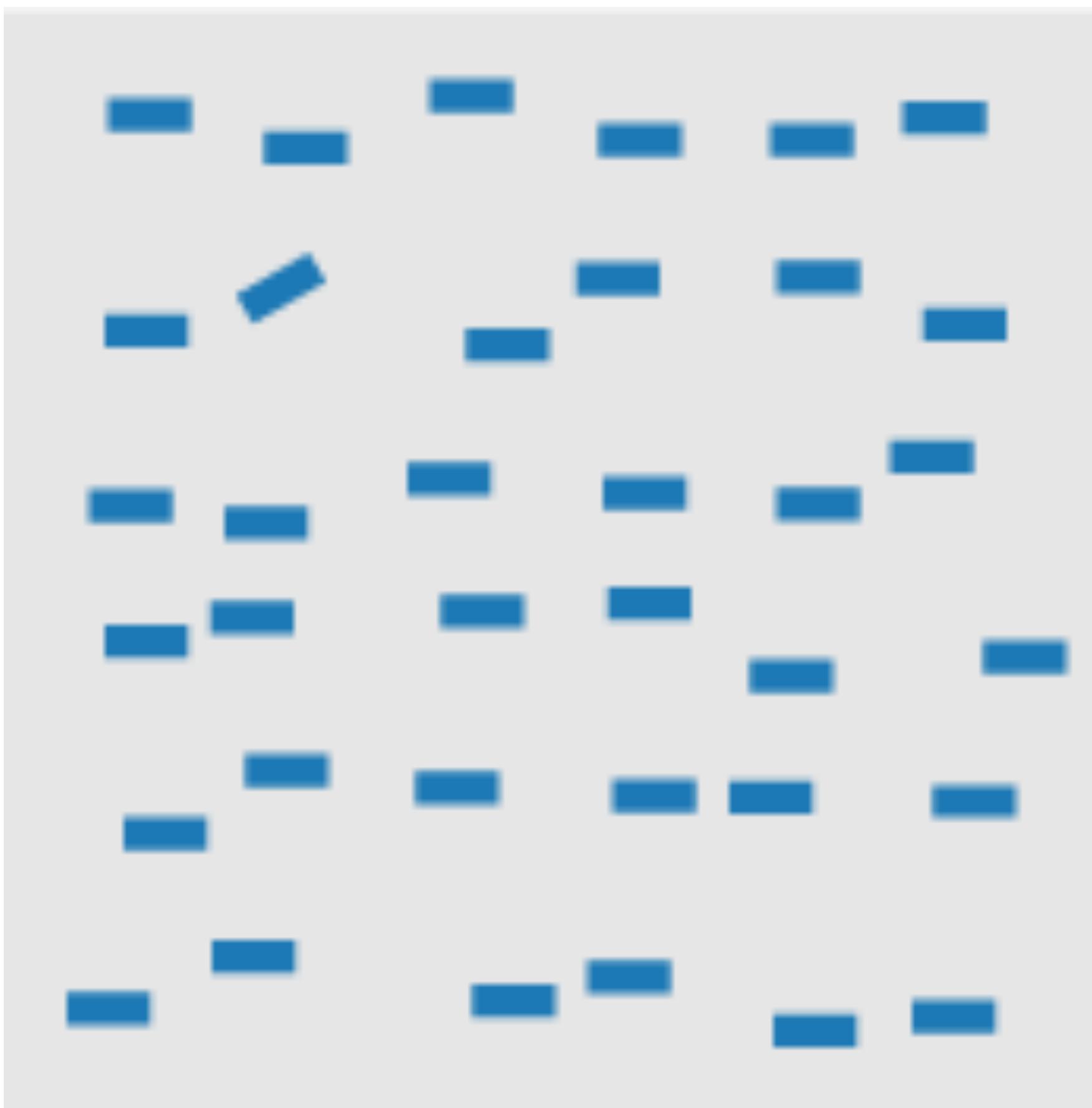
Difference in Hue



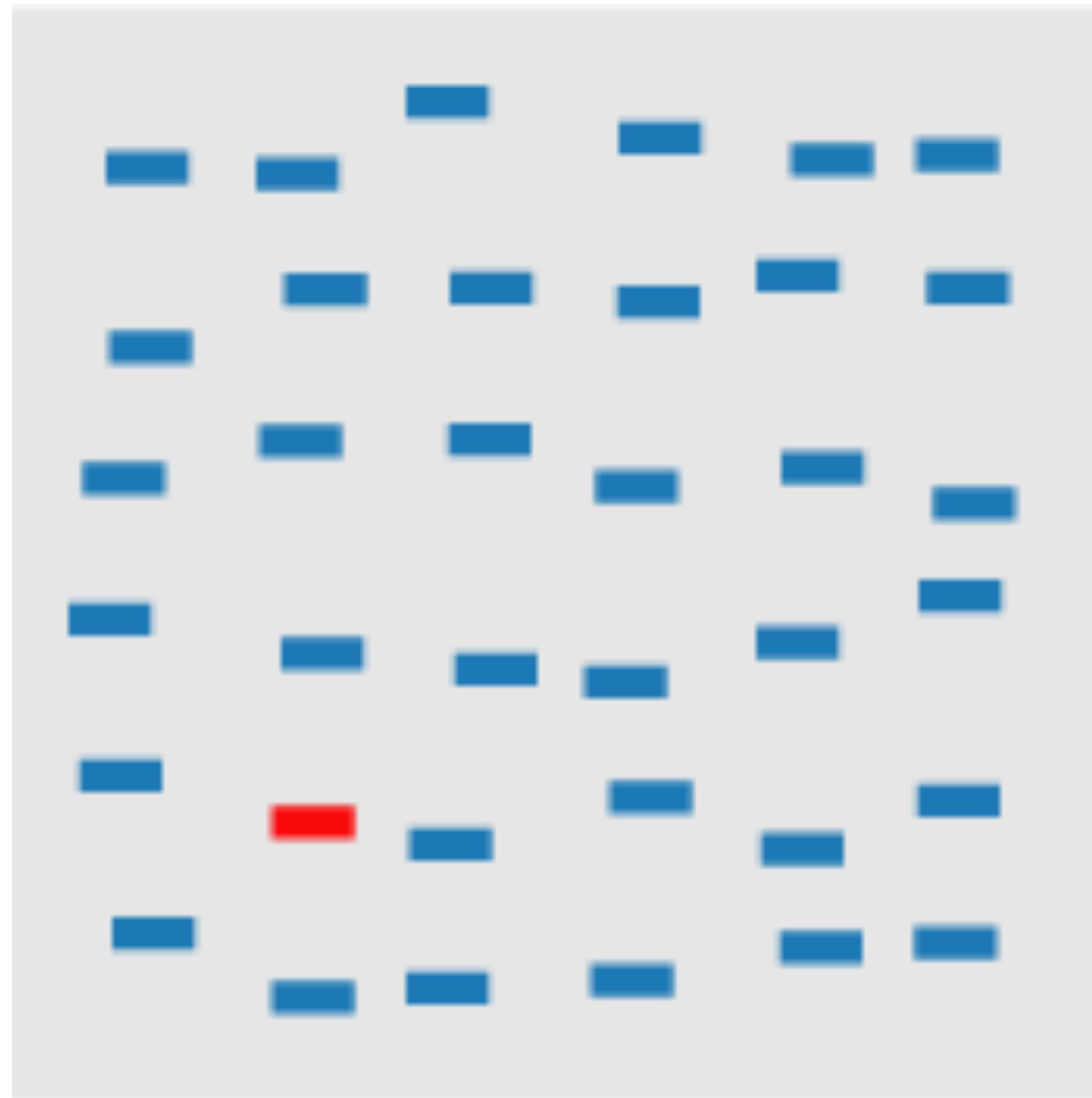
Difference in Curvature / Form



Clap when you spot the
odd one!



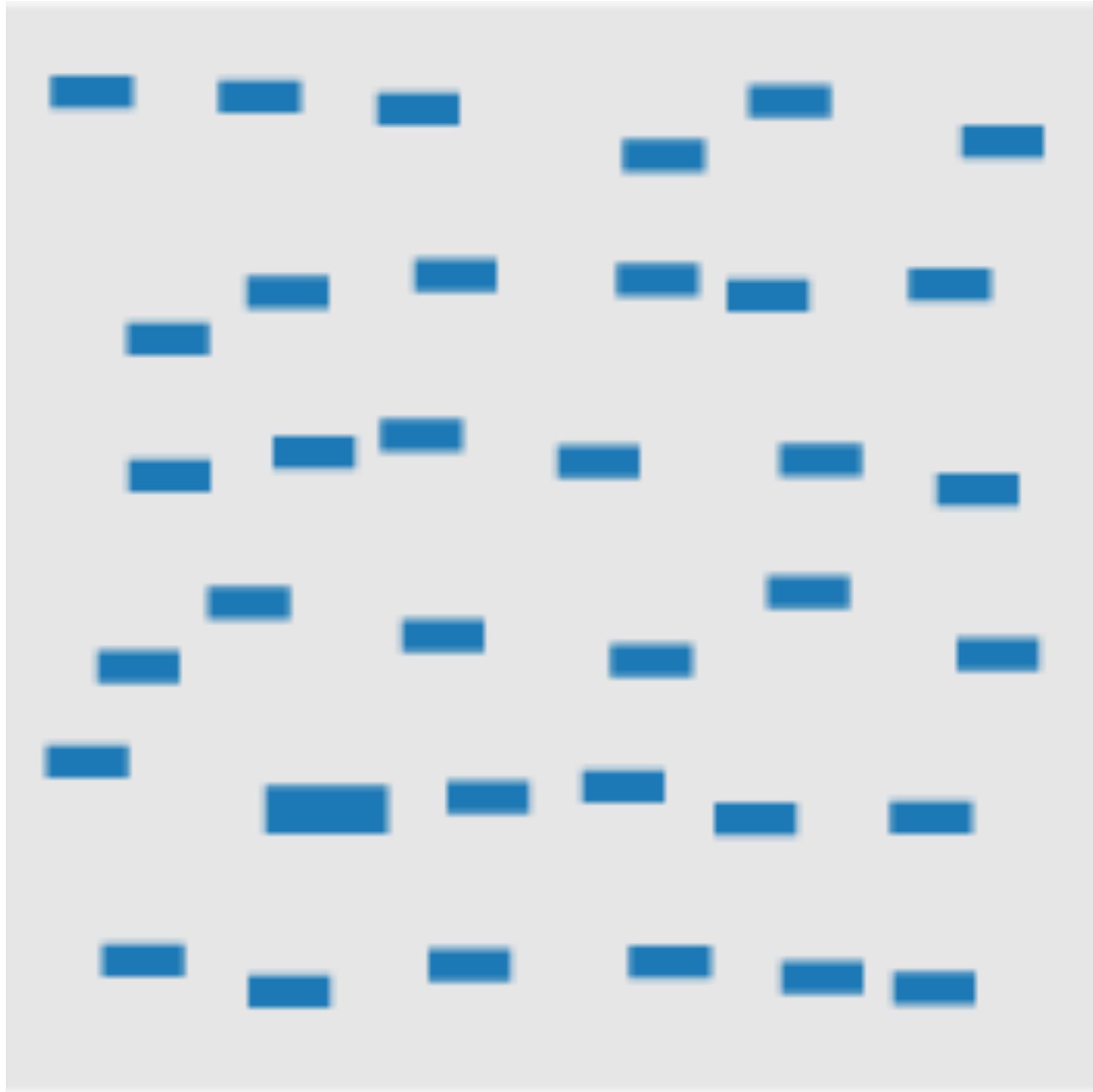
orientation



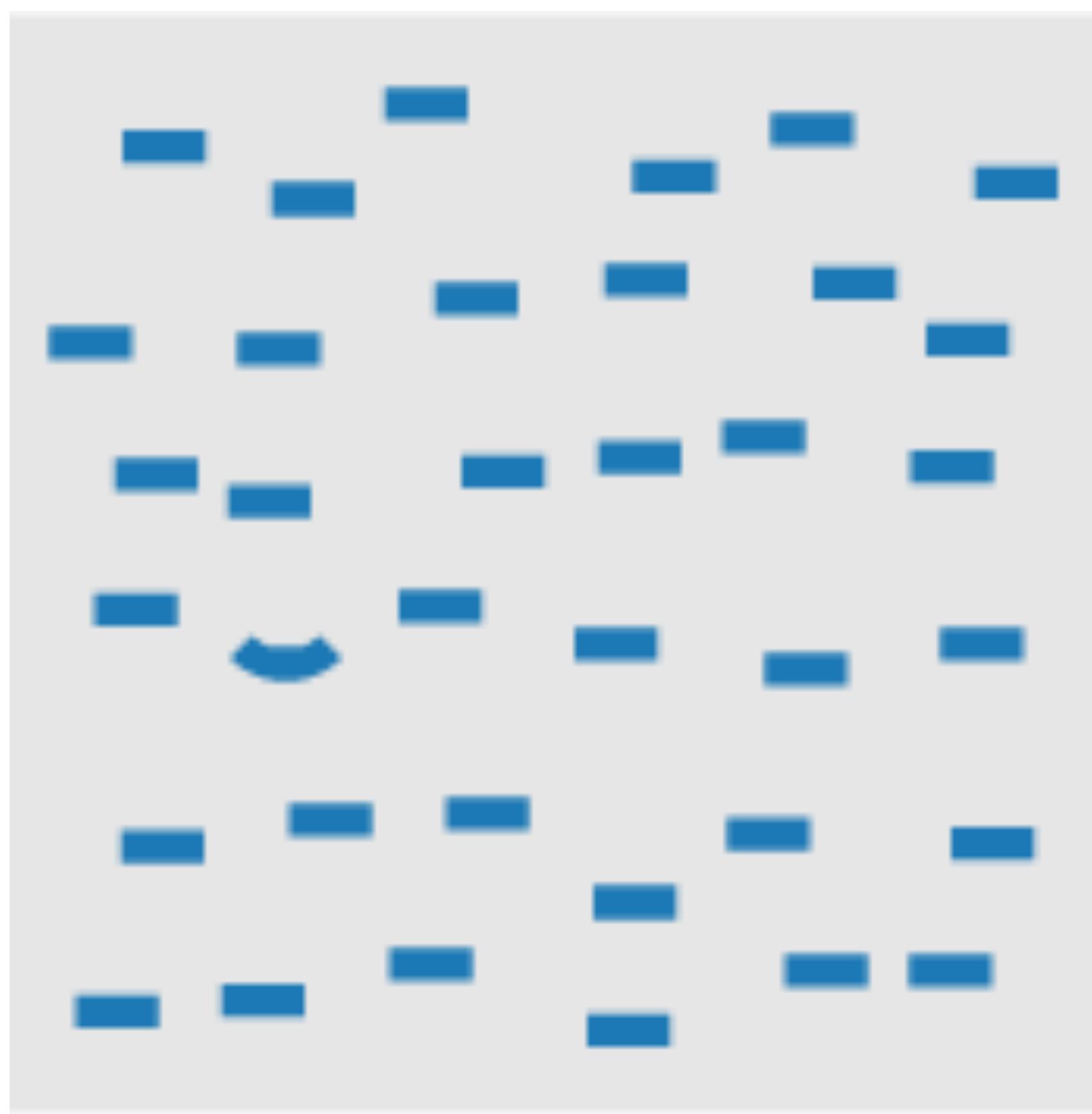
hue



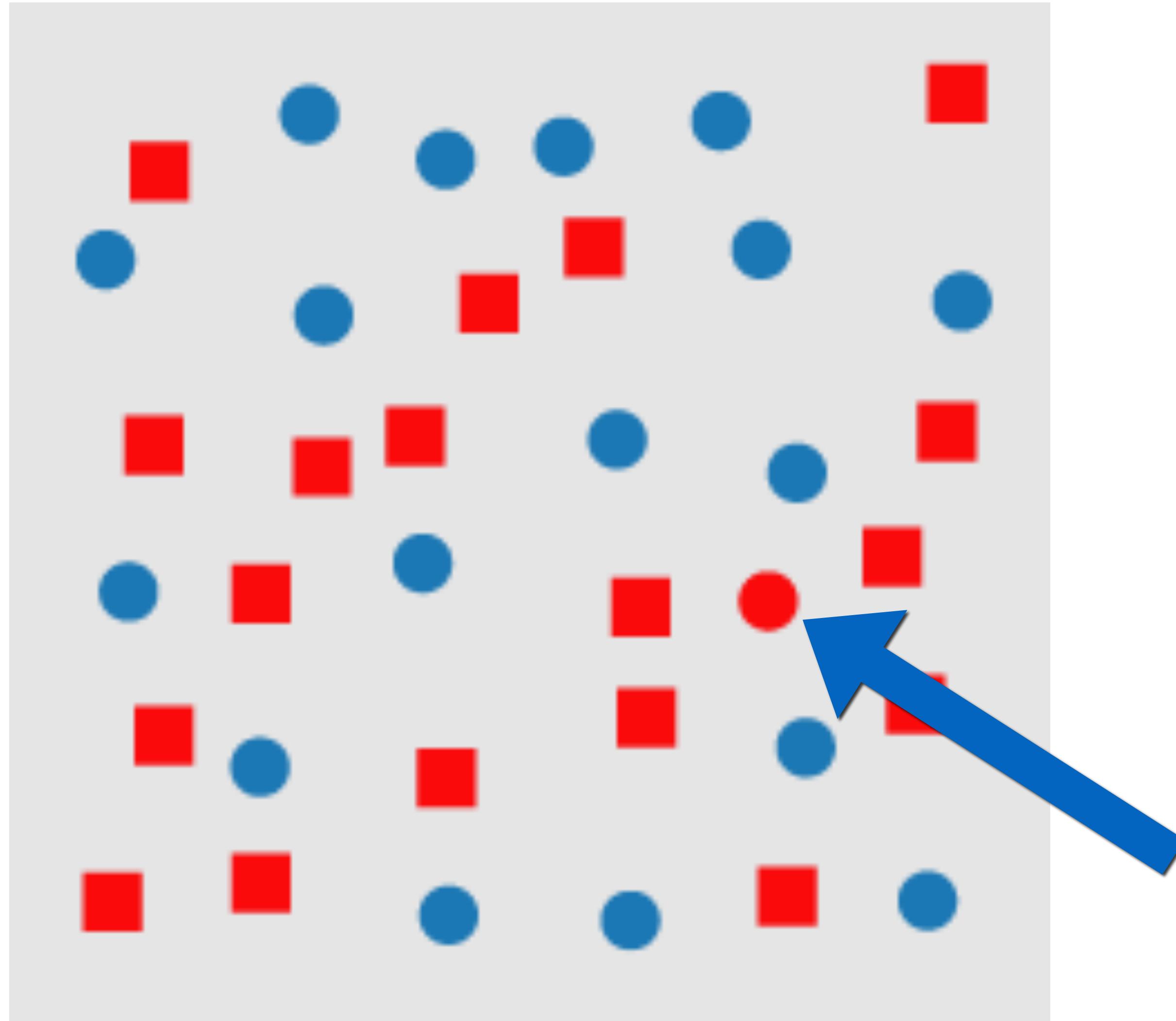
closure



size

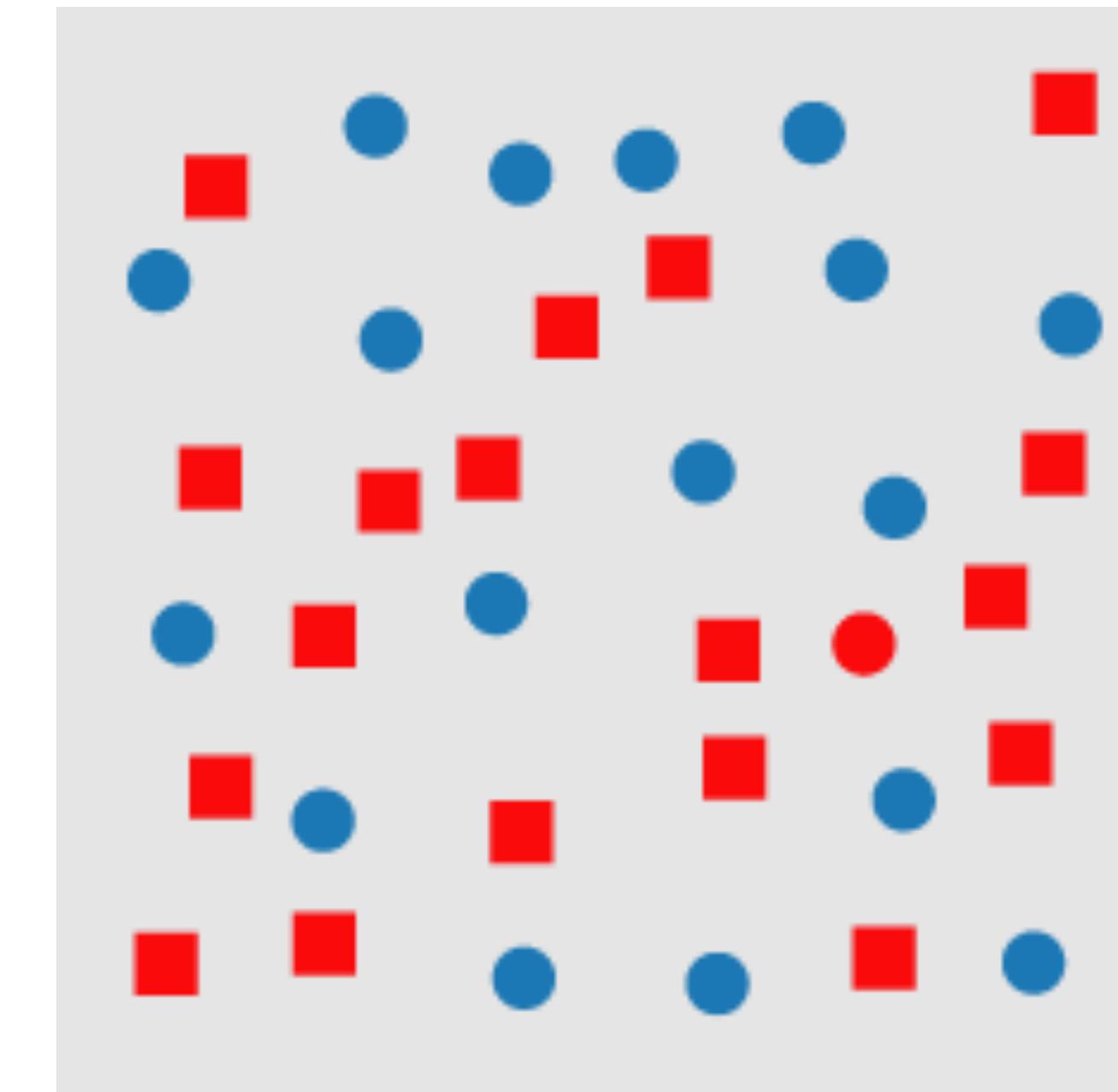
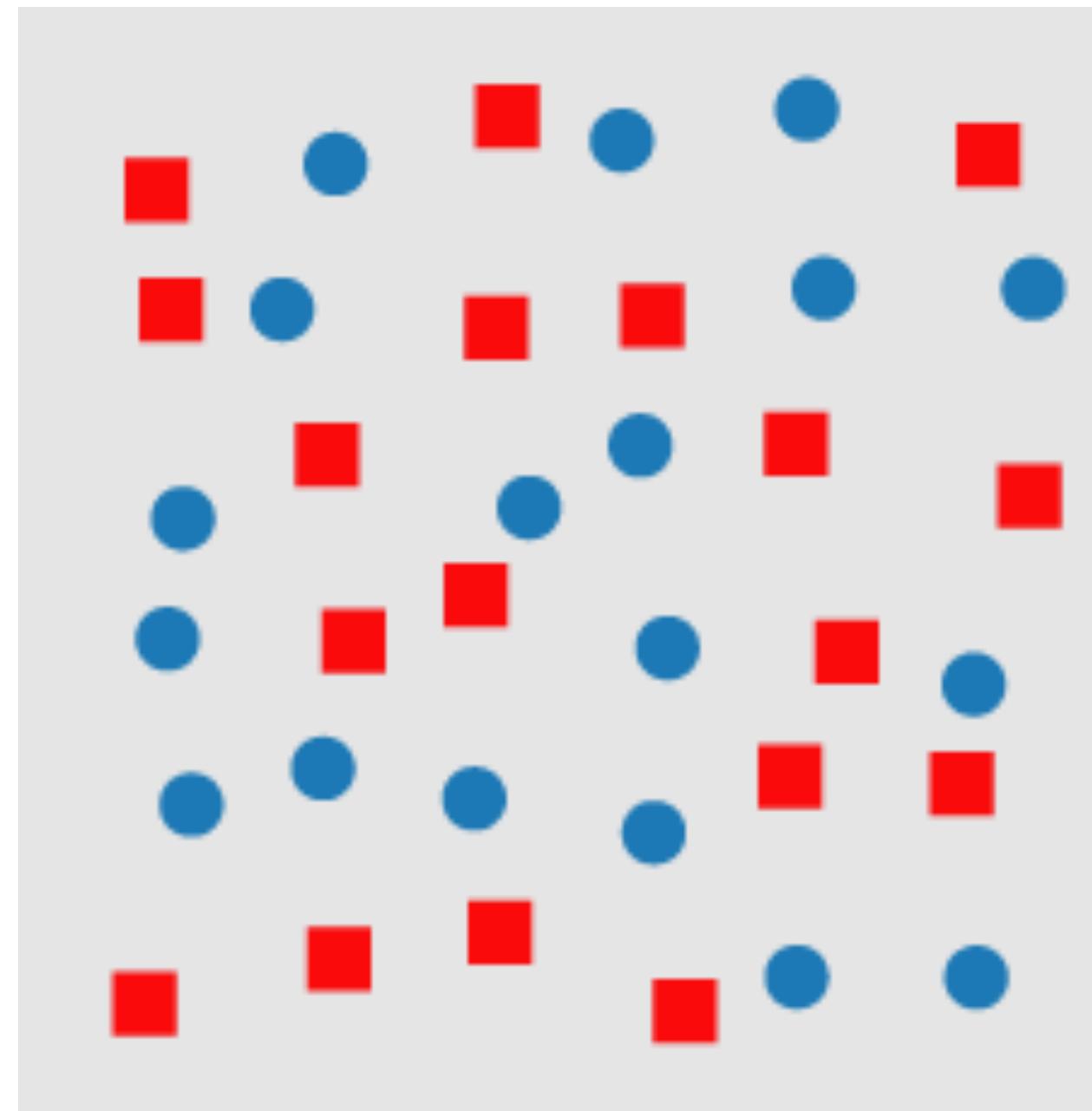


curvature



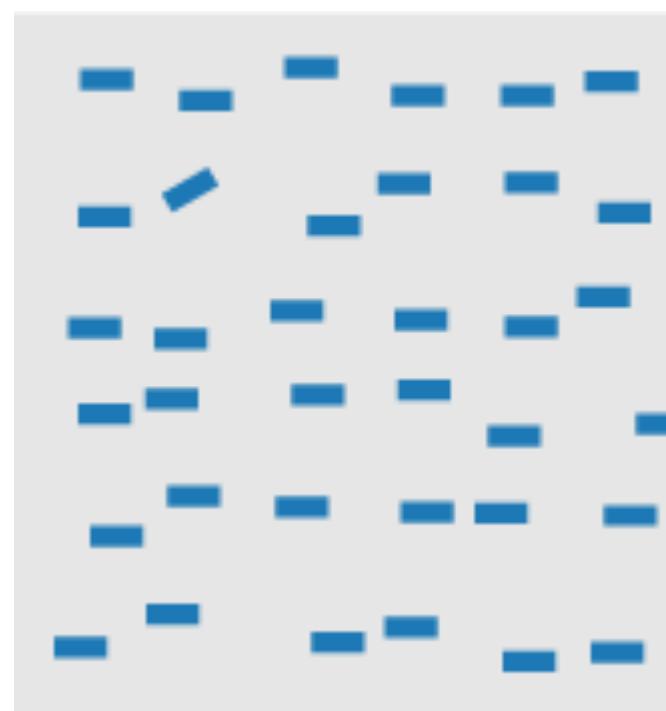
?

Not Valid for Combinations

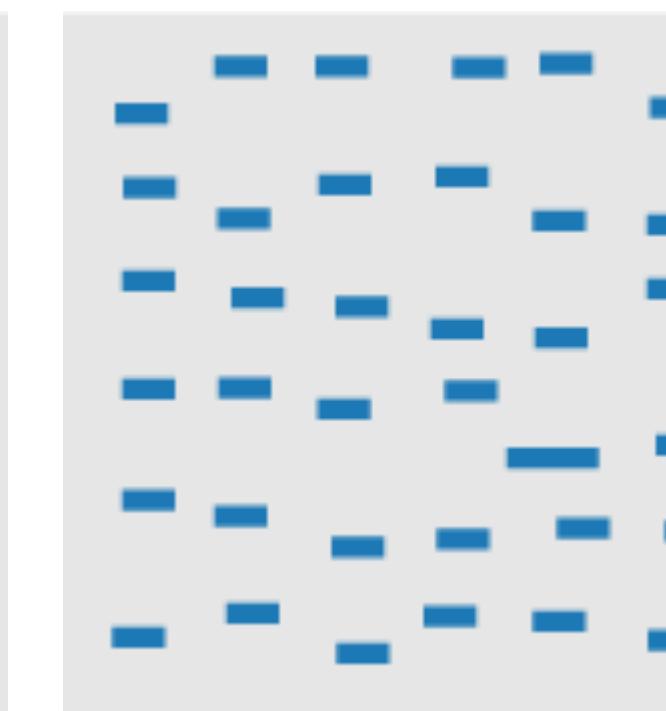


Conjunction Targets – no unique visual property
target: red, circle
distractor objects have both properties

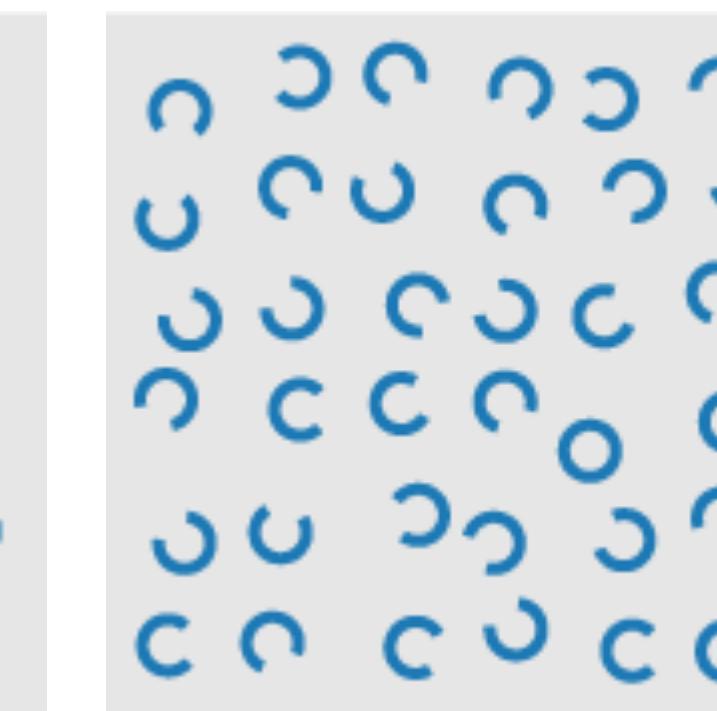
Some Preattentive Properties



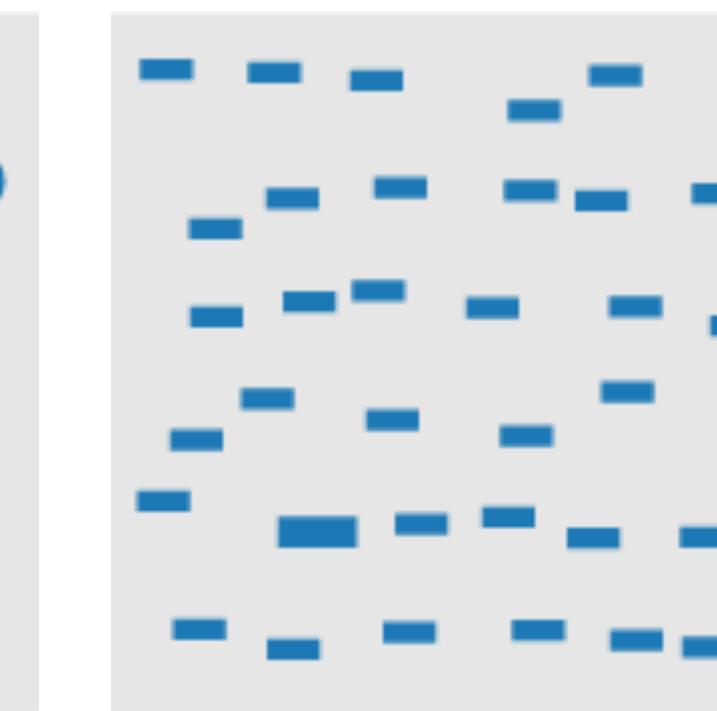
orientation



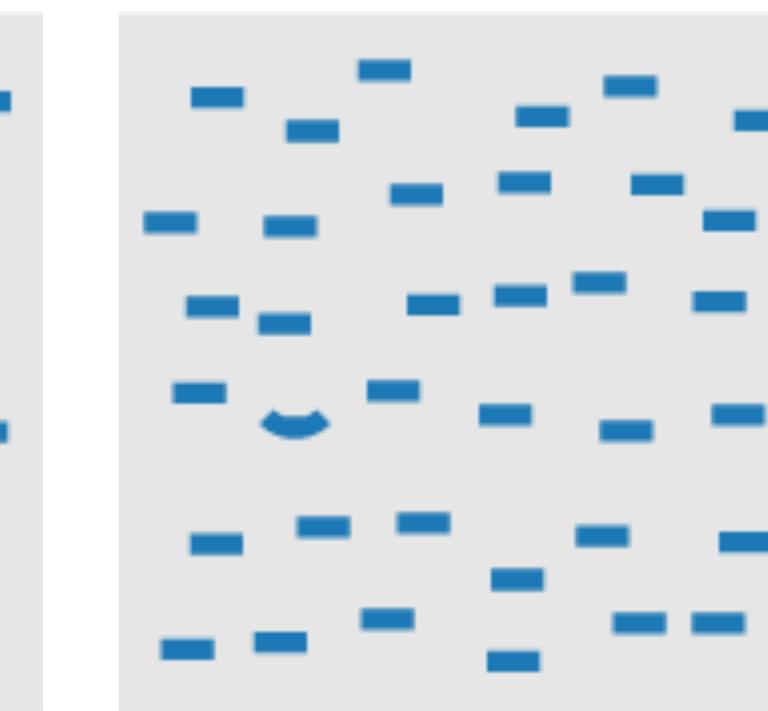
length



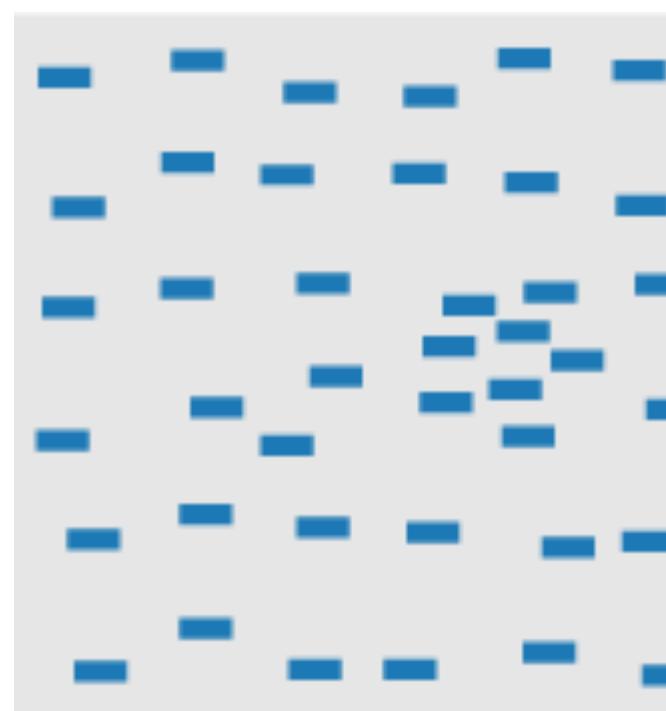
closure



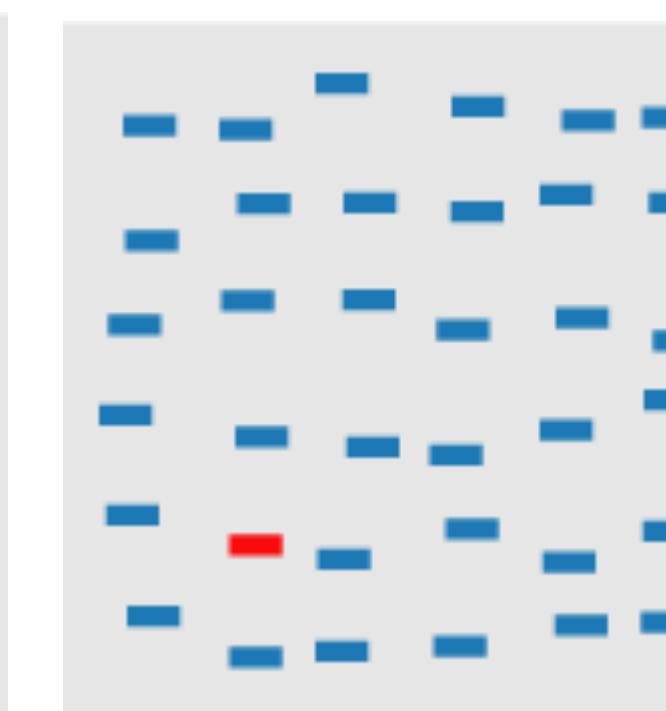
size



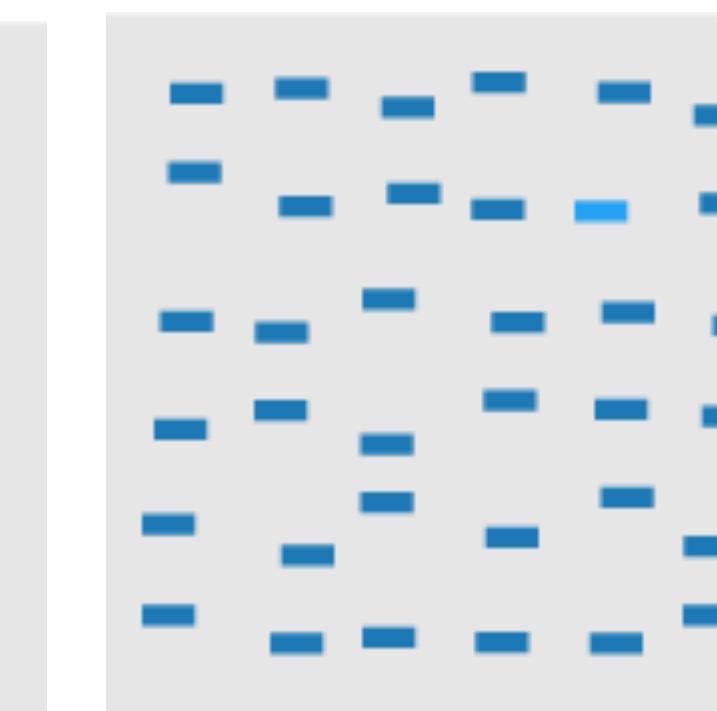
curvature



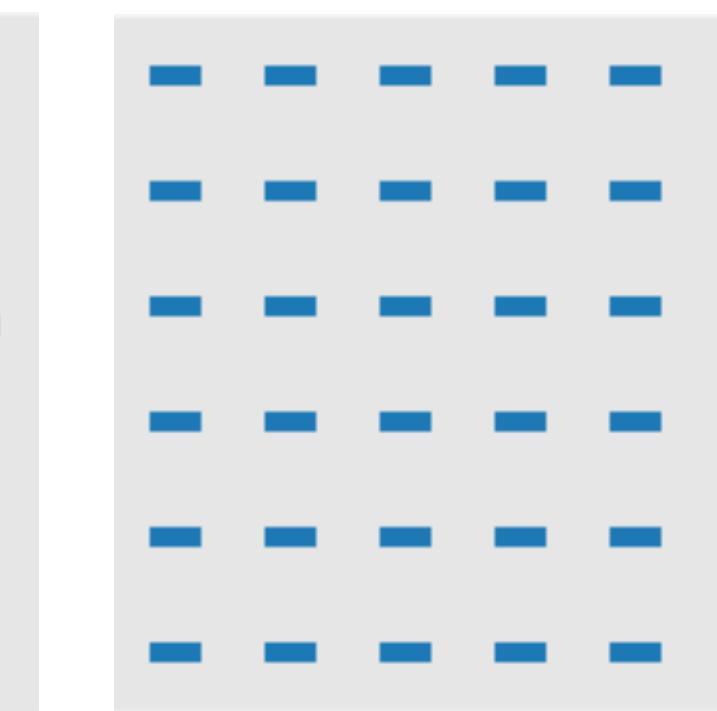
density



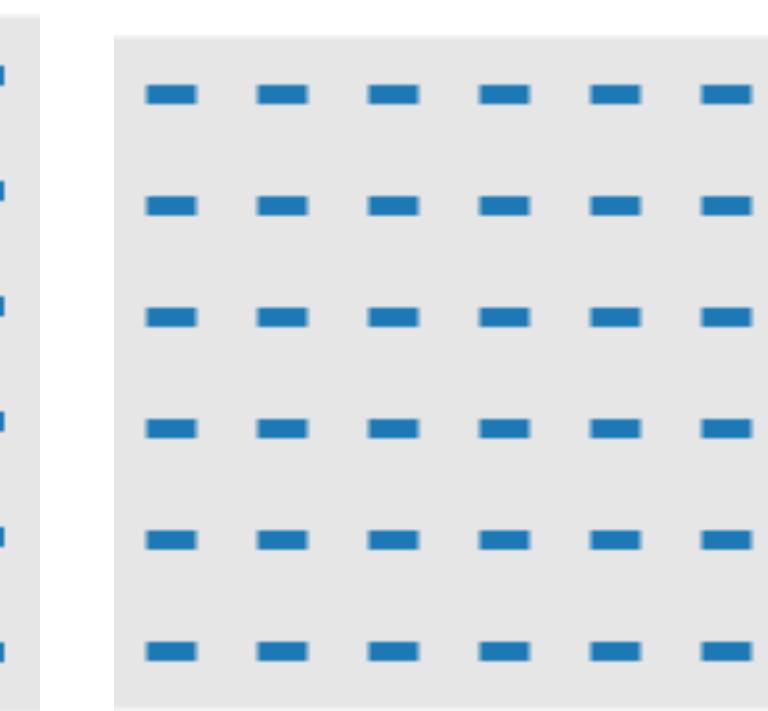
hue



color value / brightness



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

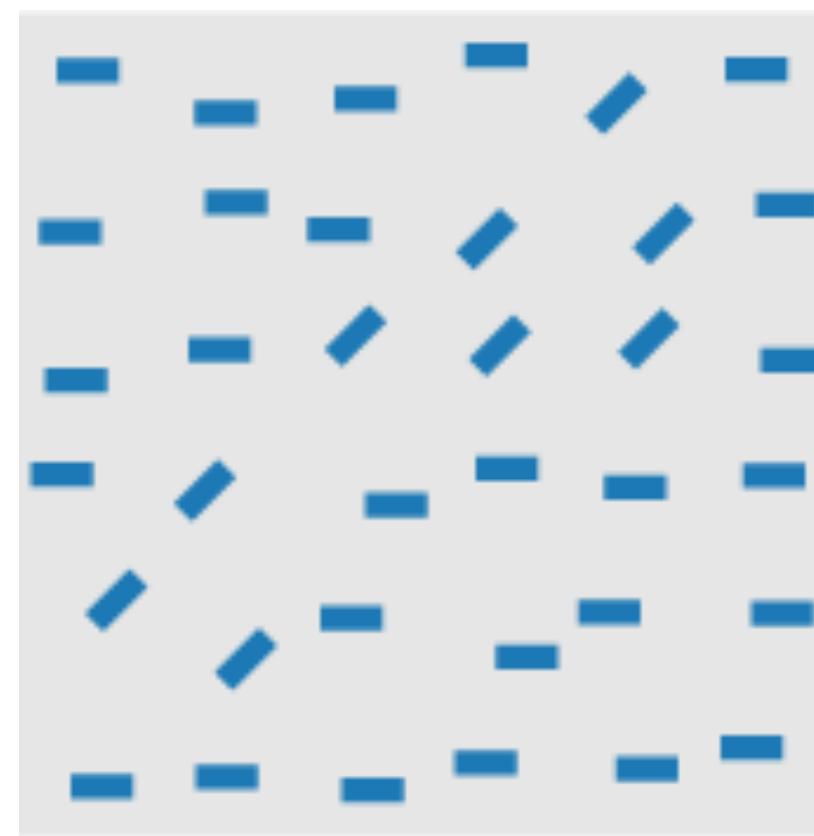
track one or more elements with a unique visual feature as they move in time and space

counting and estimation

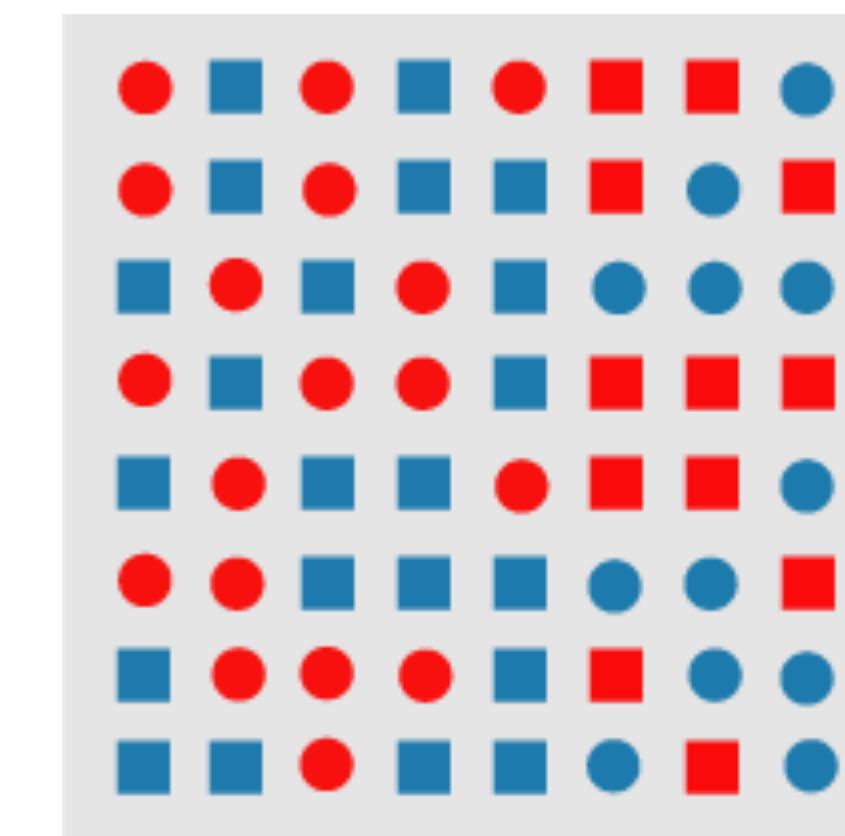
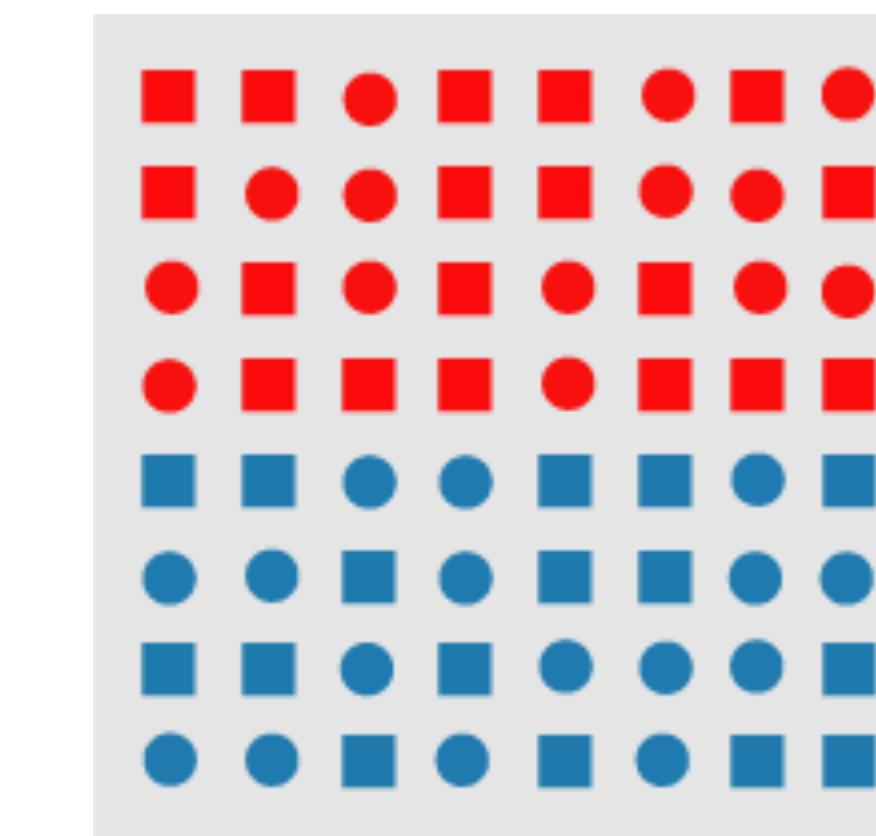
users count or estimate the number of elements with a unique visual feature.

Tasks

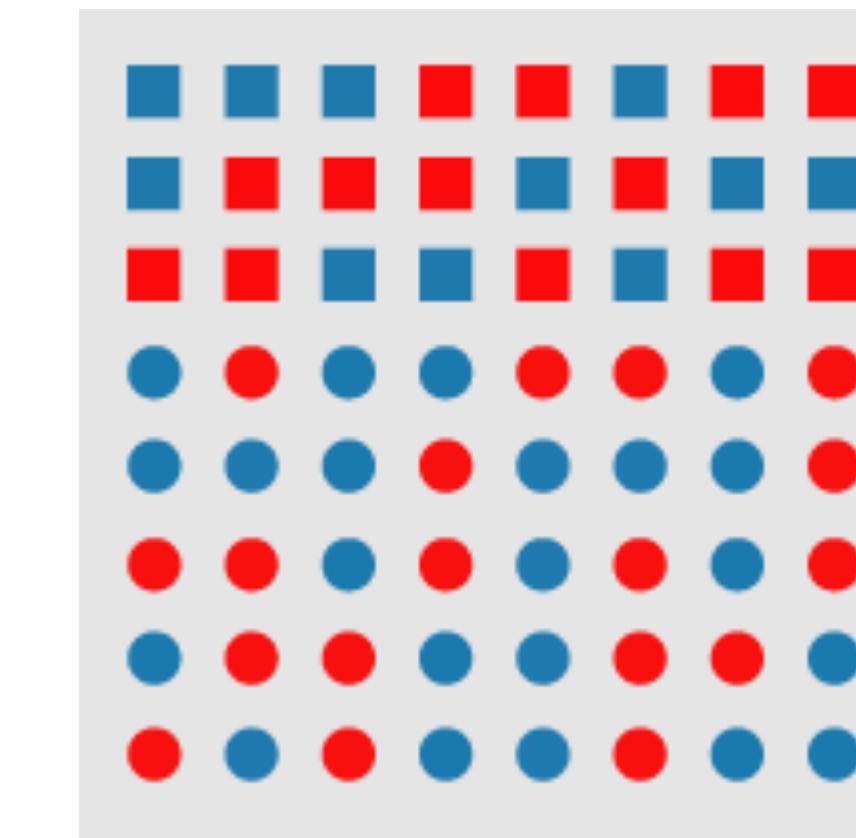
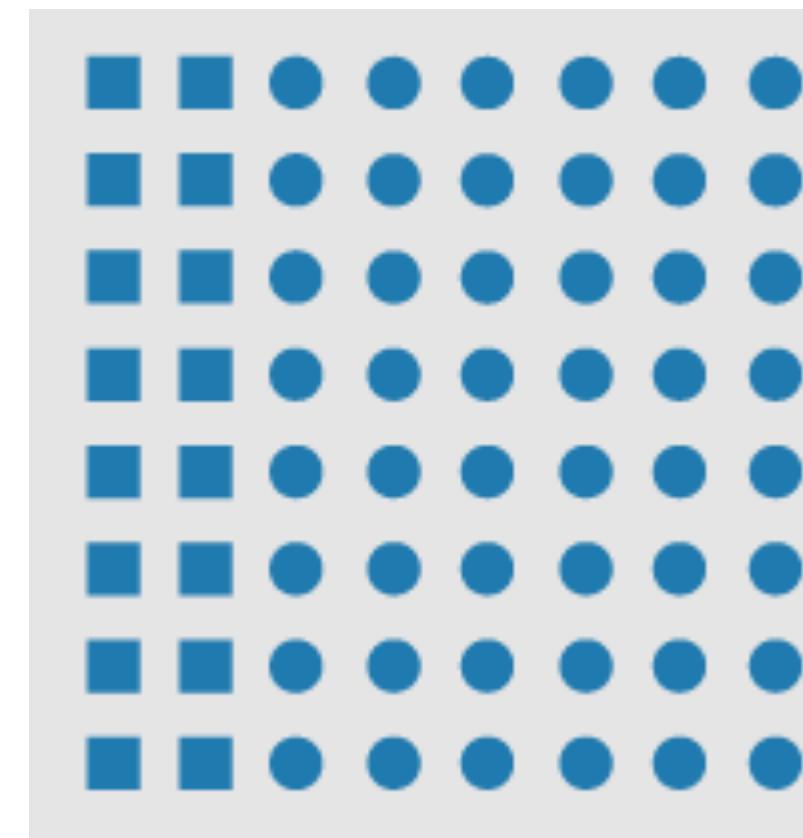
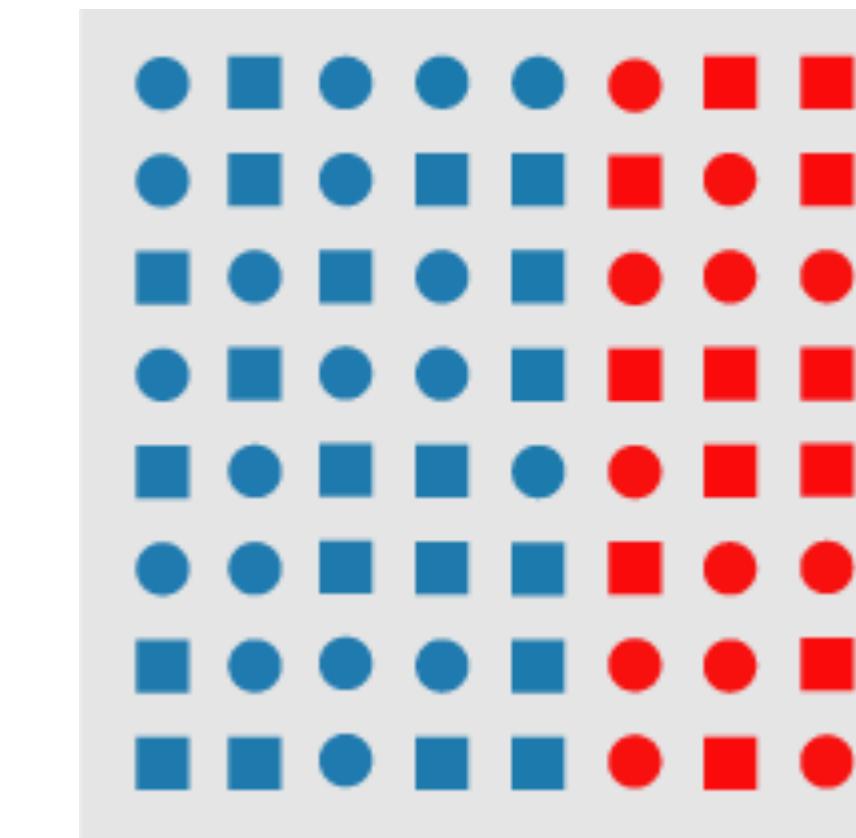
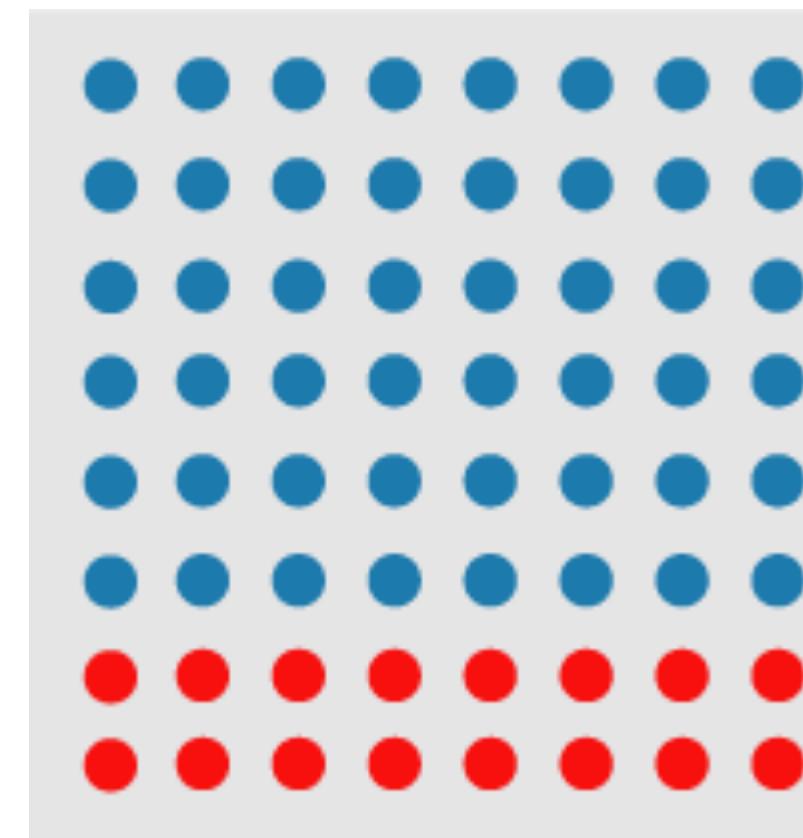
Number Estimation



Boundary Detection



Hierarchy of Preattentive Features



Popout in Vis

Can be used to draw attention to areas of interest

Can be used to express similarity/group memberships

Visual features must be carefully designed

Conjunctions must be avoided

Examples are „Cues“ (Focus and Context technique)

Change Blindness

Change Blindness

Details of an image cannot be remembered across separate scenes

except in areas with focused attention

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

Not failure of vision system

failure due to inappropriate attentional guidance



Ron Rensink 2002



Ron Rensink 2002

Change Blindness

Various theories about causes

Overwriting: Information that was not abstracted is lost

First Impression: Only initial view is abstracted

Nothing is Stored: Only abstract concepts are committed to memory

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

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

Influencing factors

attention

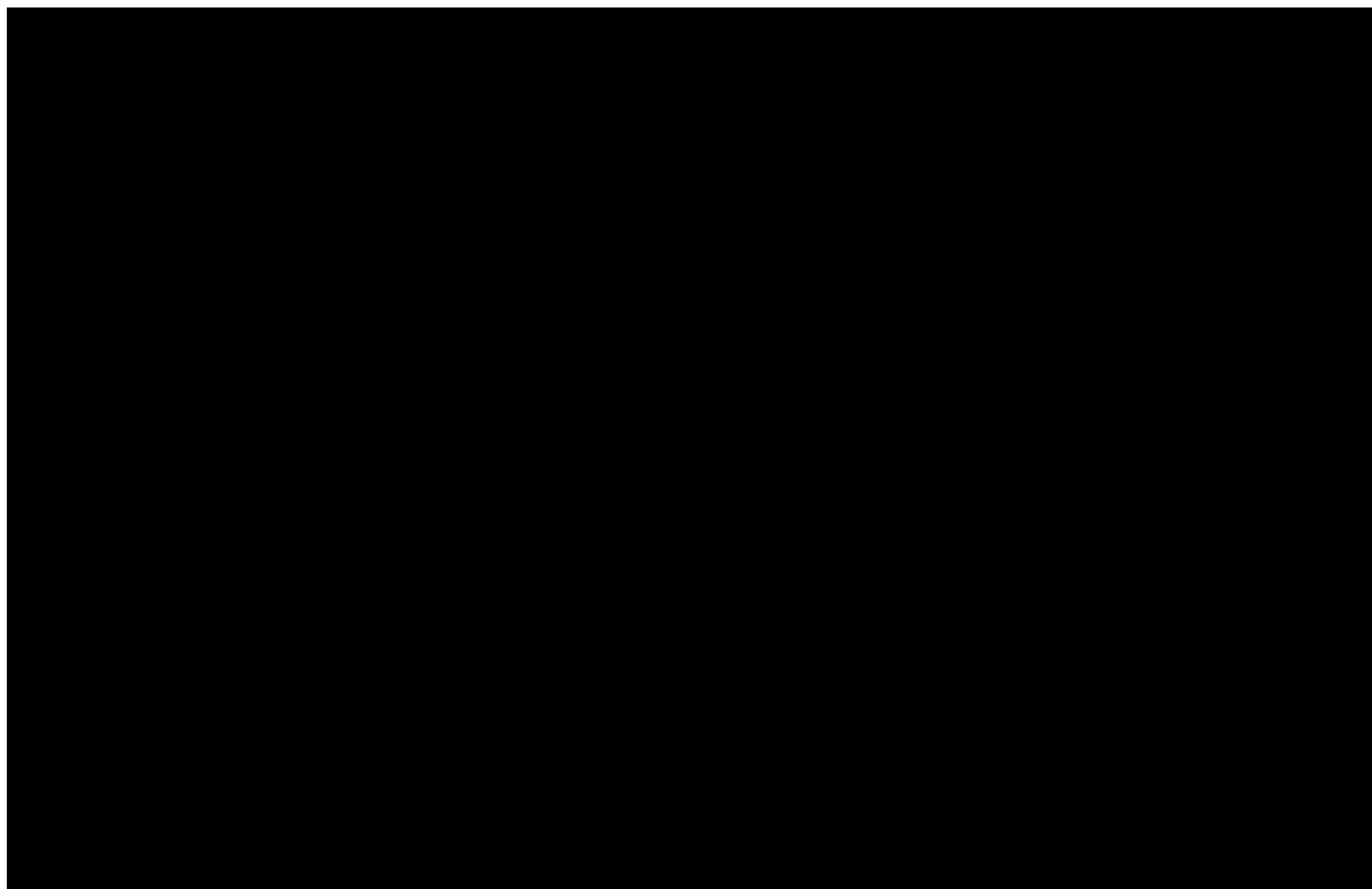
expectation (knowing something will change)

semantic importance of changed object

low level object properties overlooked more easily



Attention Blindness



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

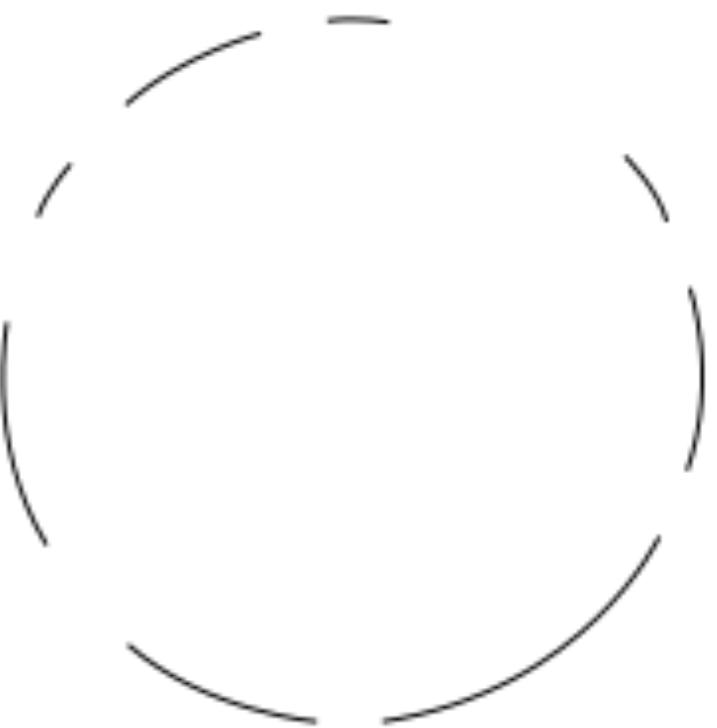
- *Das Ganze ist etwas anderes als die Summe seiner Teile.*
- *The whole is something else than the sum of its parts.*

Kurt Koffka

Koffka disagreed with the

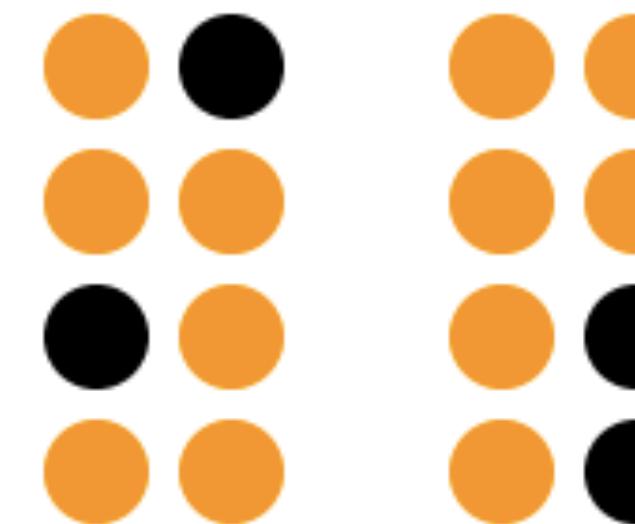
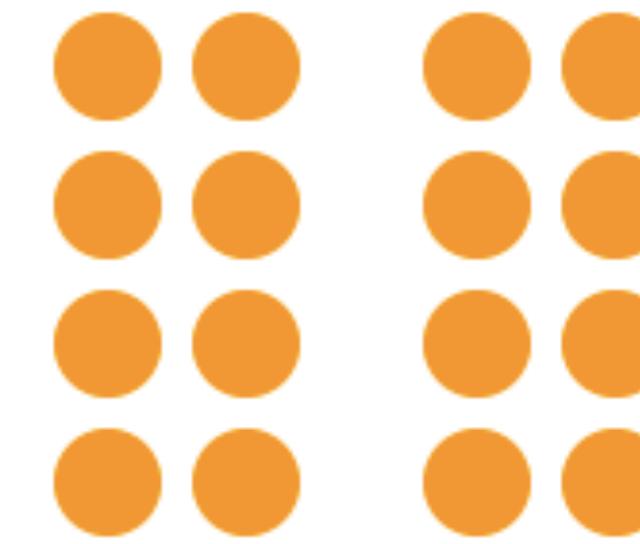
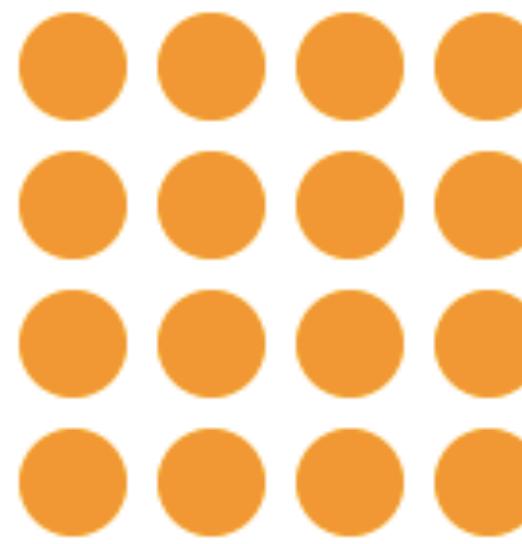
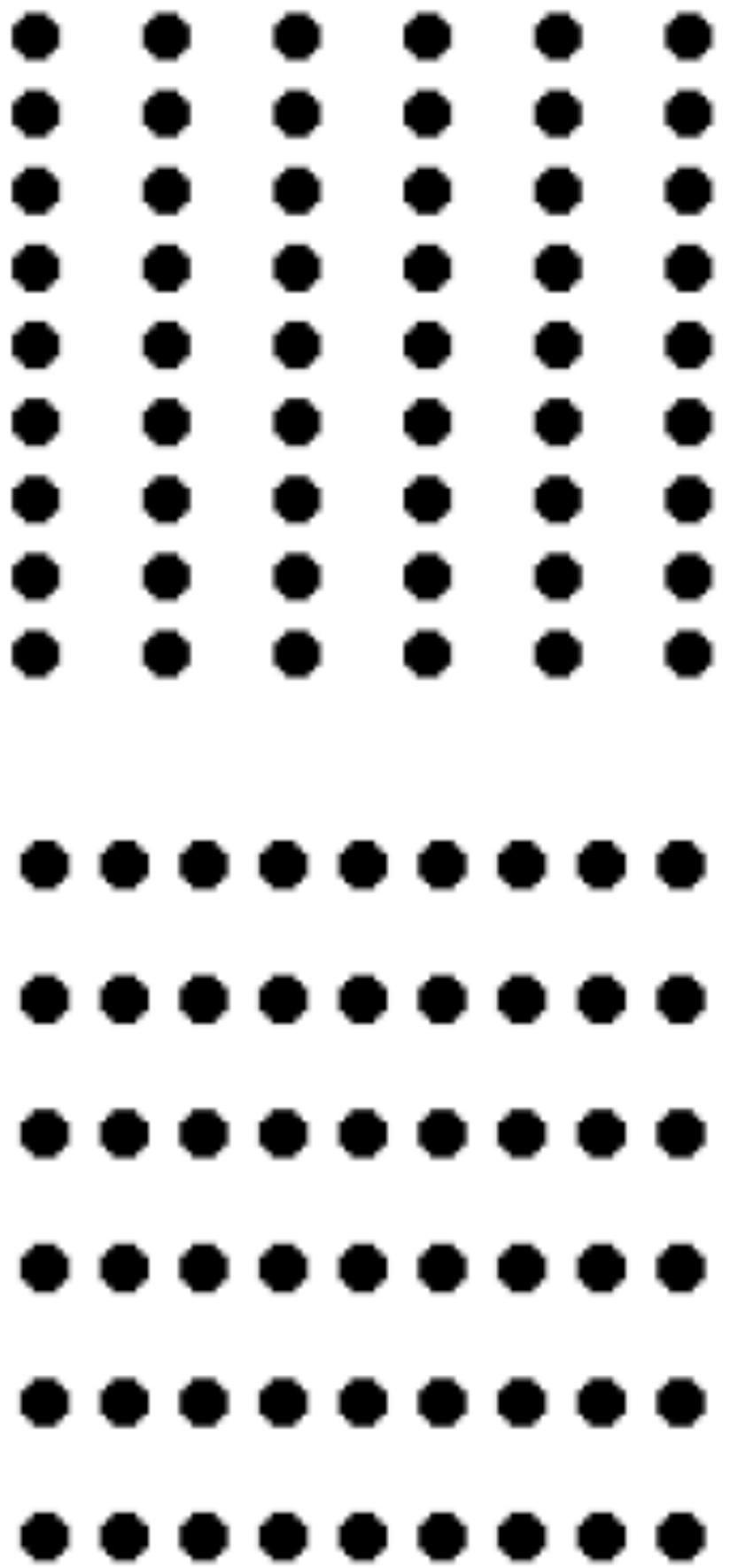
-The whole is greater than the sum of the parts.

quote which is attributed to Aristoteles



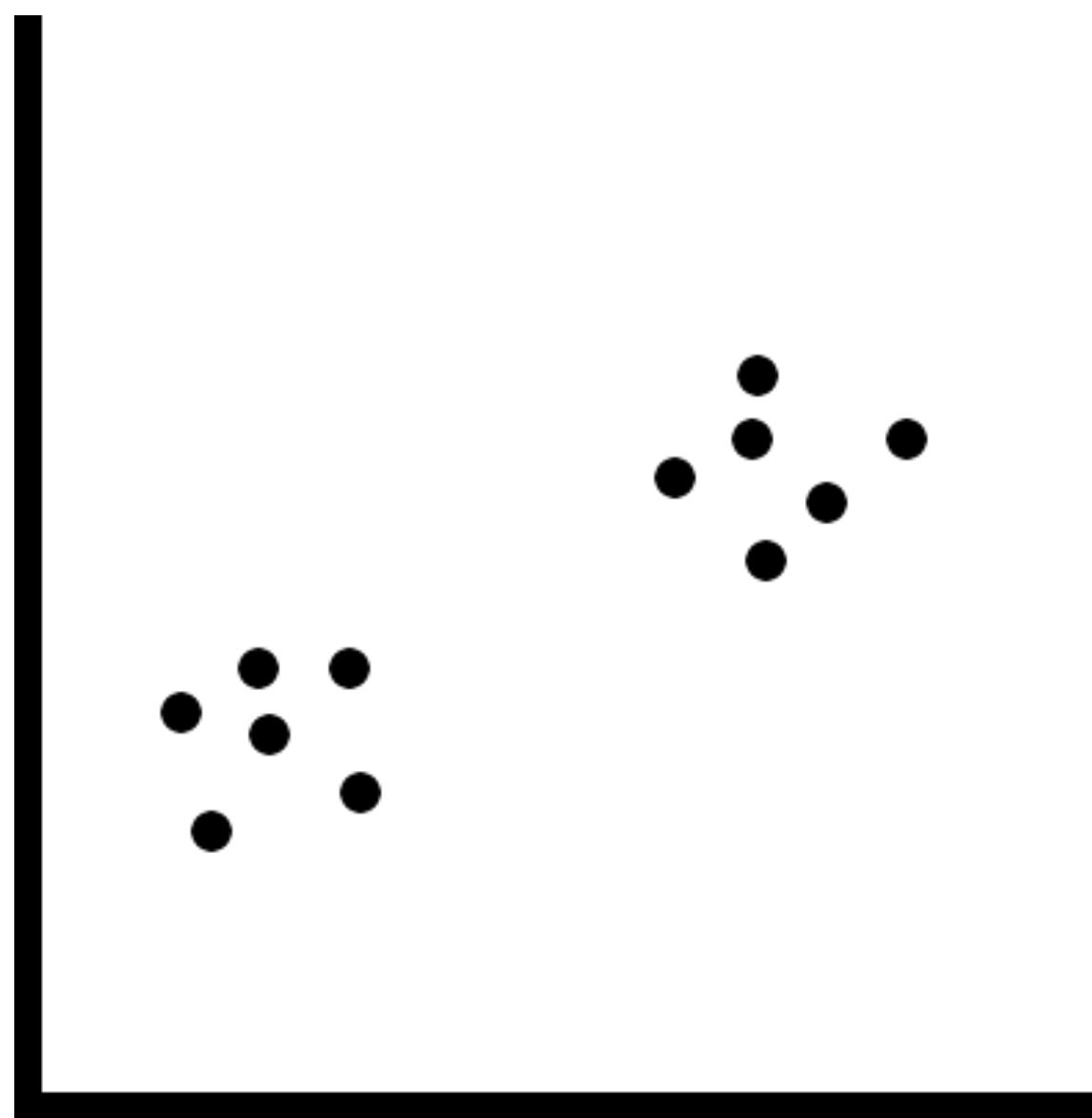
Gestalt Effects for Grouping

Proximity



Proximity

Grouping/linking by placing entities in close proximity



Similarity

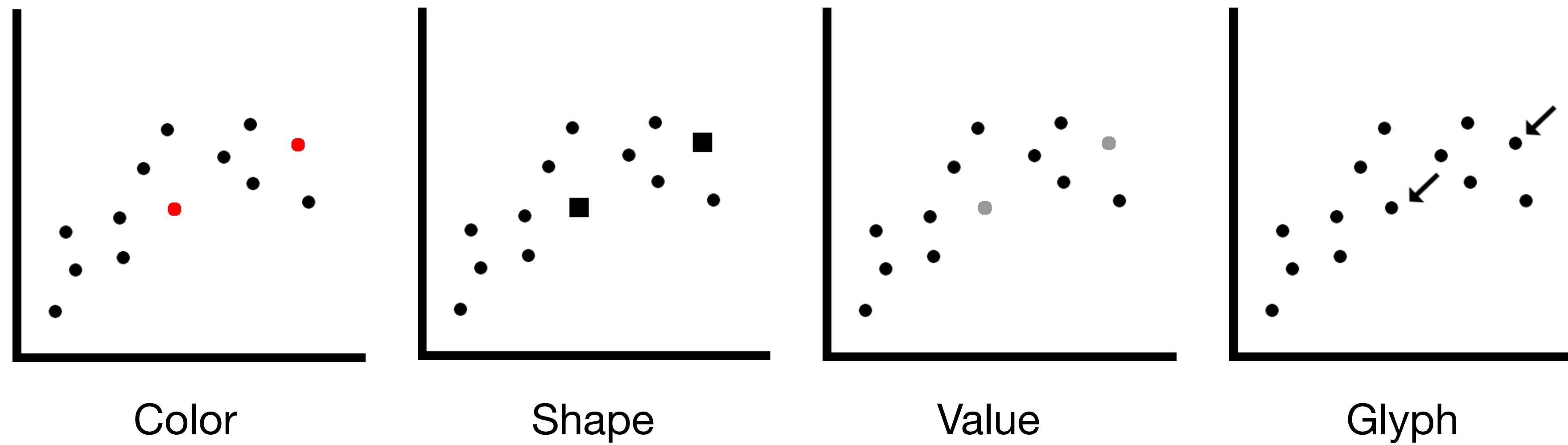


Similarity

Co-modulation of a **channel**

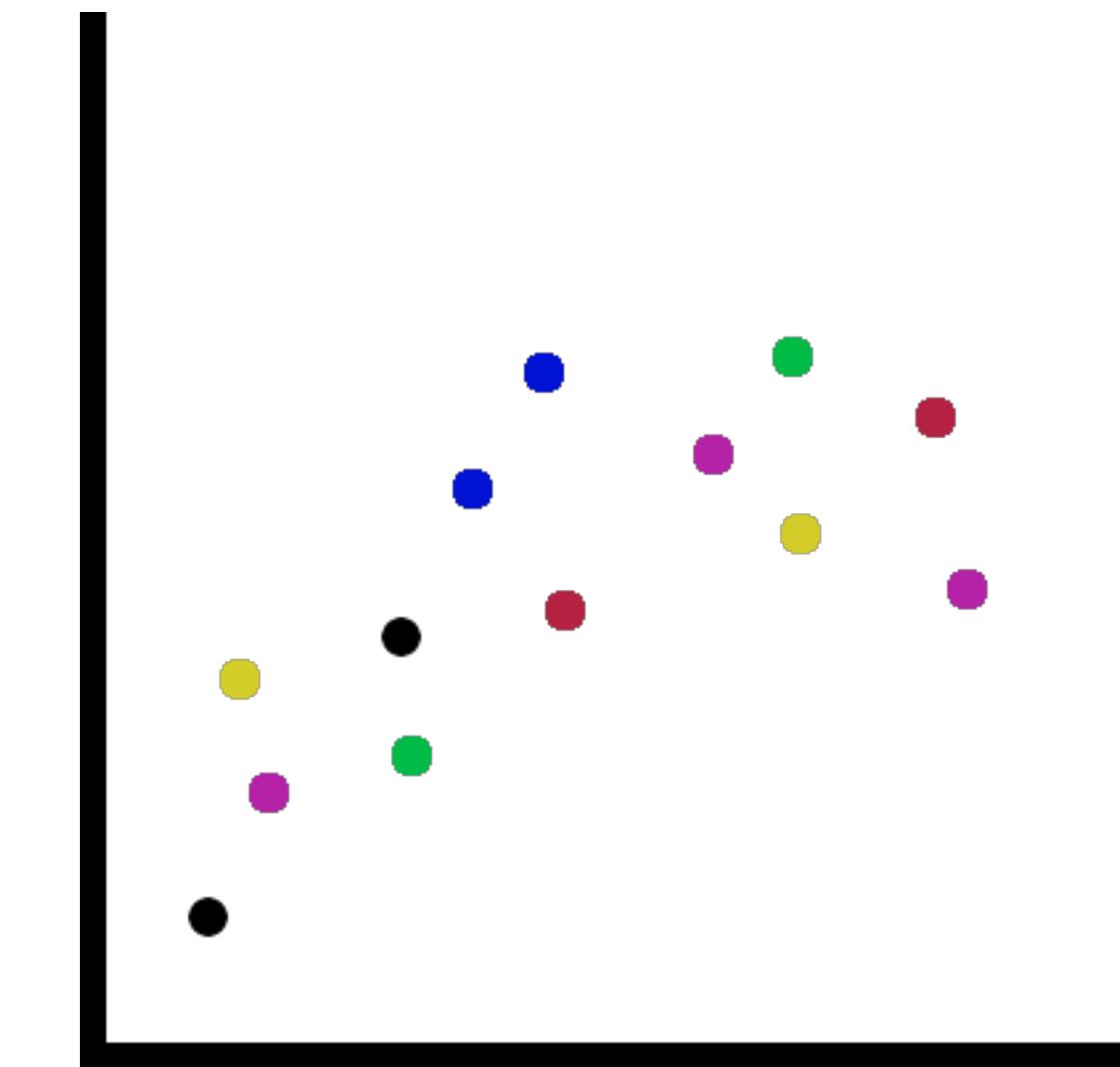
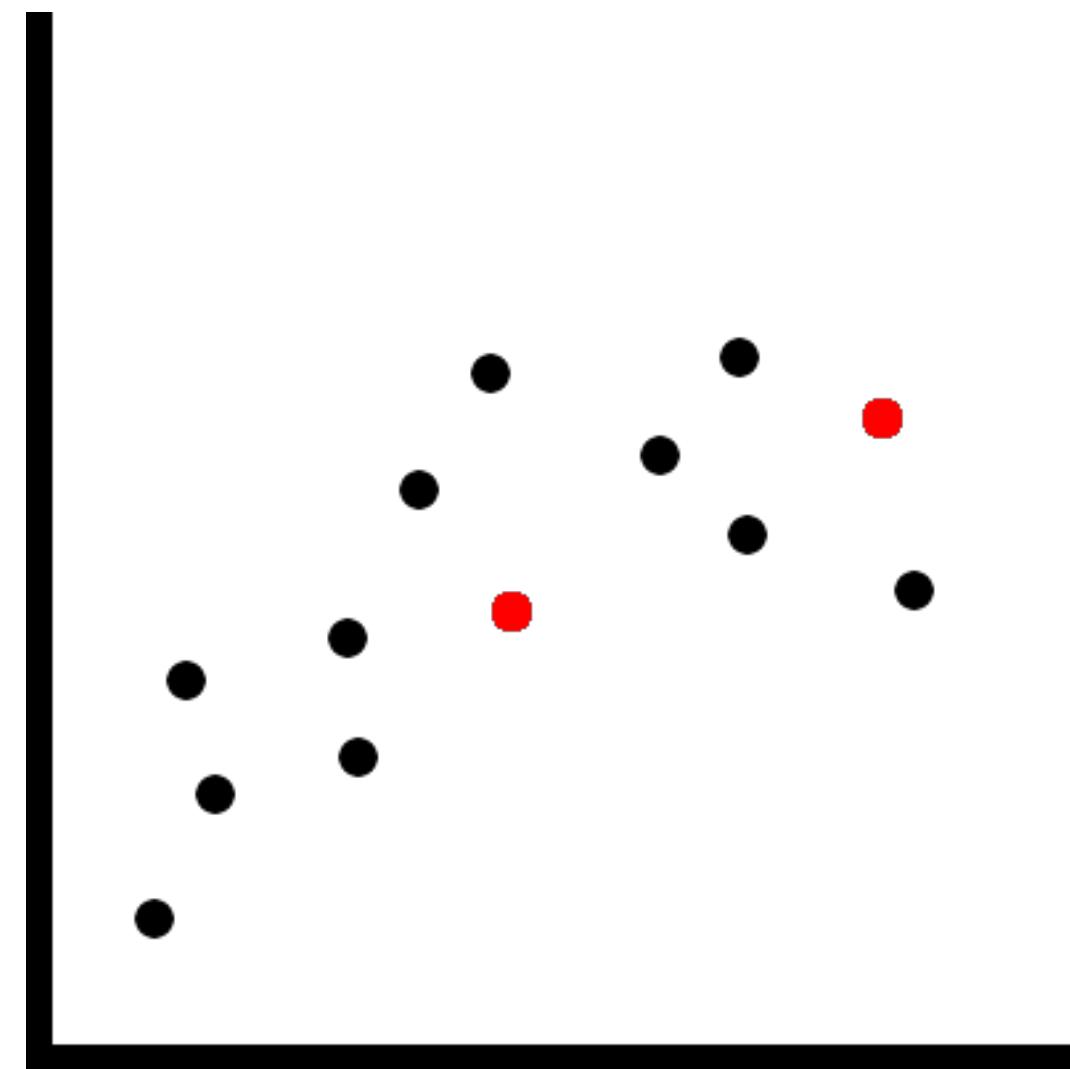
color, shape, size, value, orientation, texture, ...

Adding a glyph, label, frame, background



Color - Perception Issues (1/2)

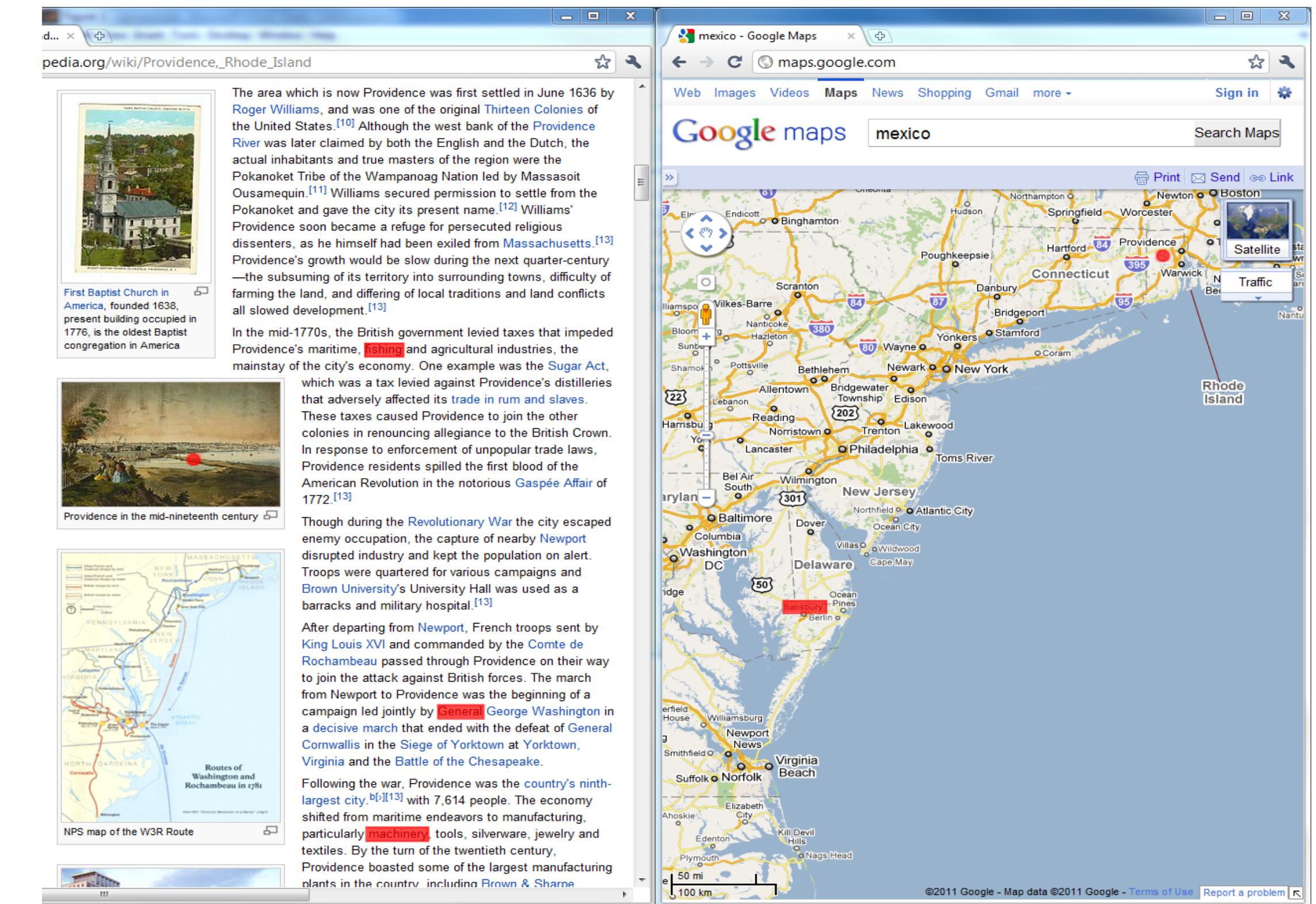
Popout properties: Very good for 1-2 simultaneous, **serial** search for more



Color - Perception Issues (2/2)

Slower in a cluttered environment

Size of colored object relevant.



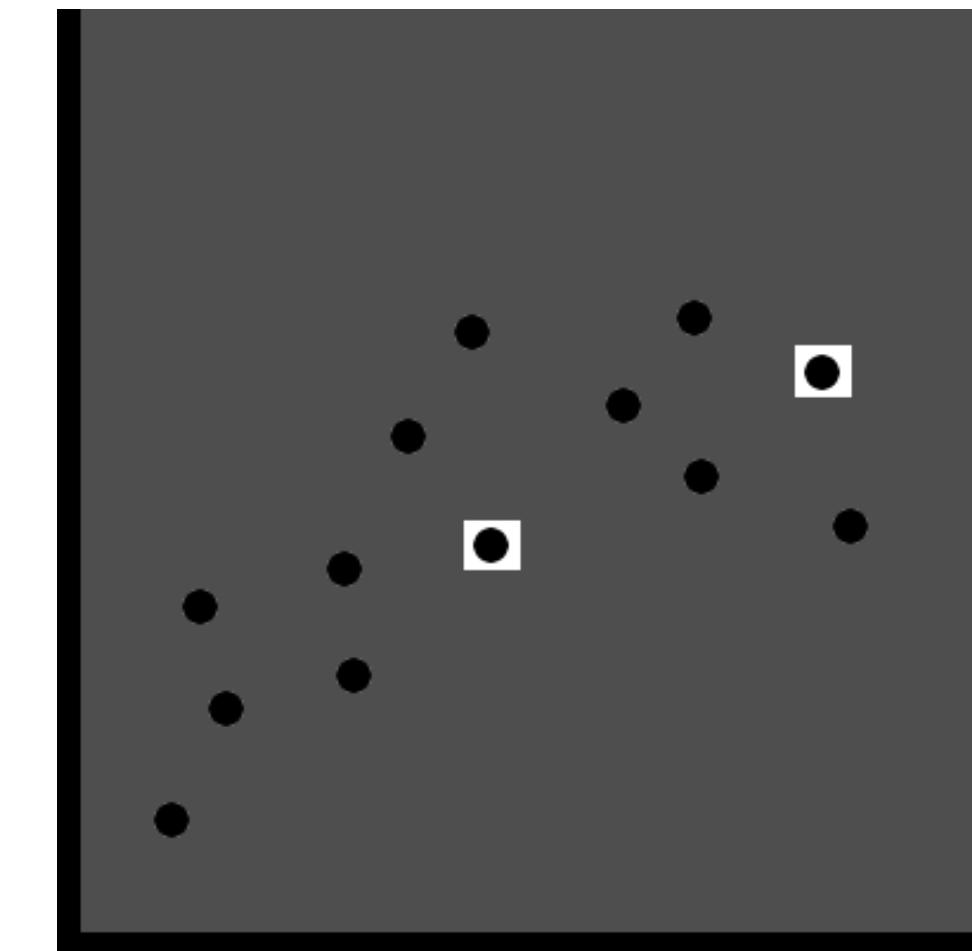
Similarity

Modulate everything else

Blurring, darkening, desaturating, etc.

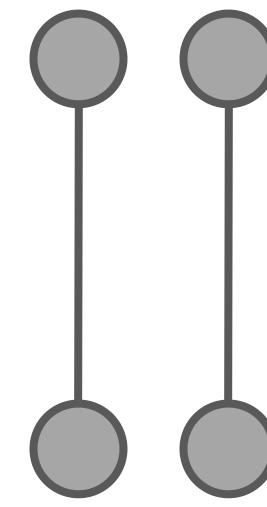


Blur

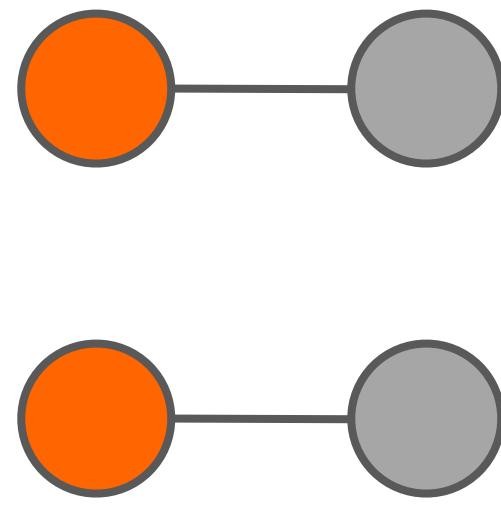


Darkening

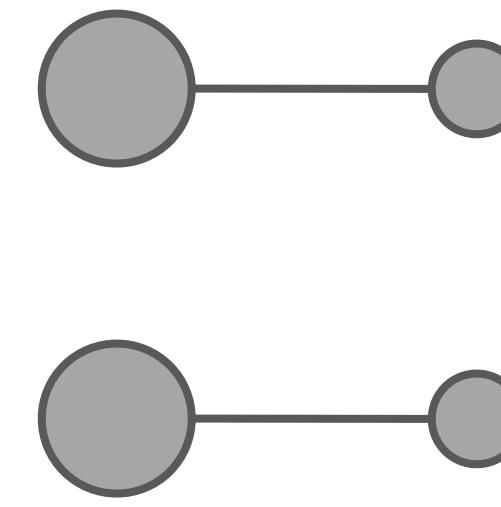
A Little Experiment...



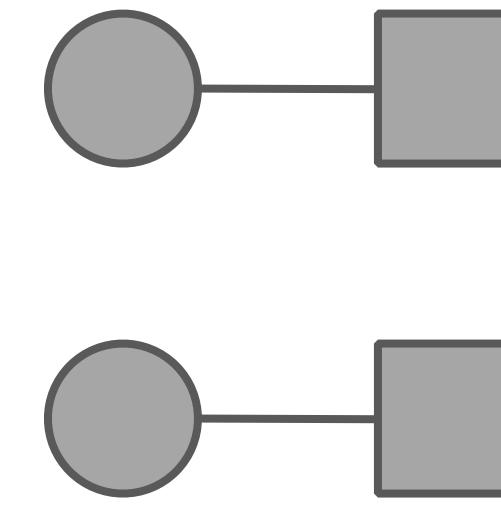
Proximity



Color



Size

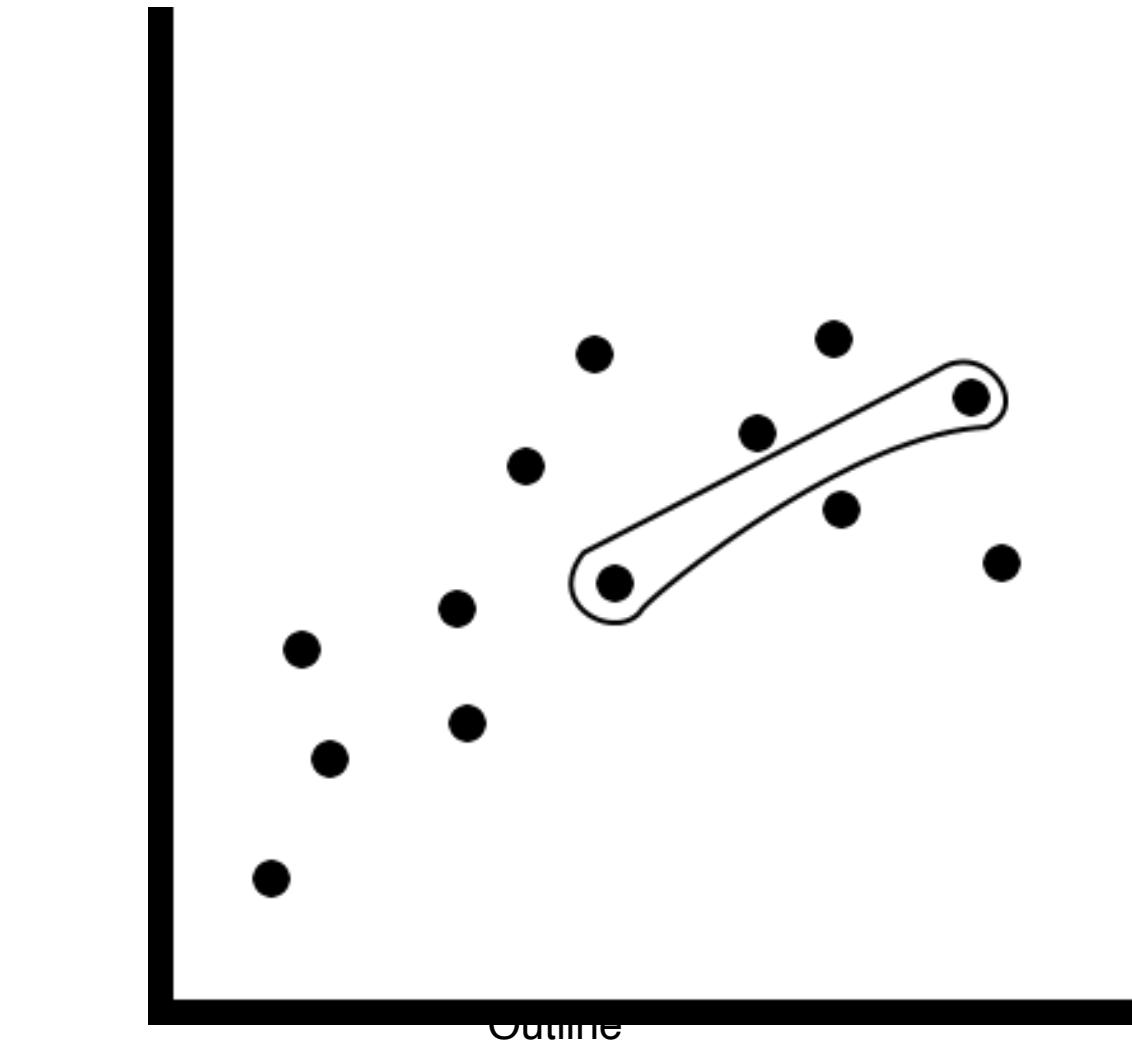
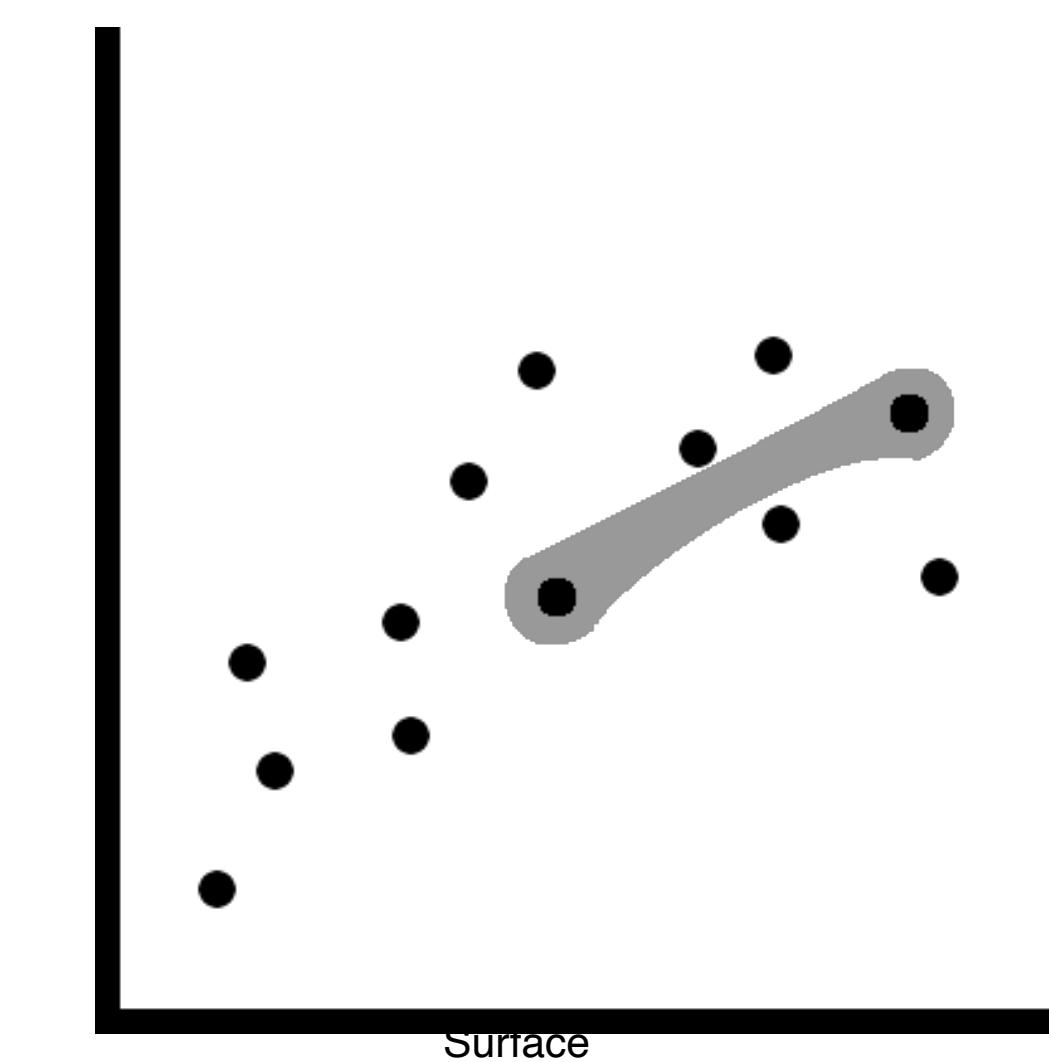
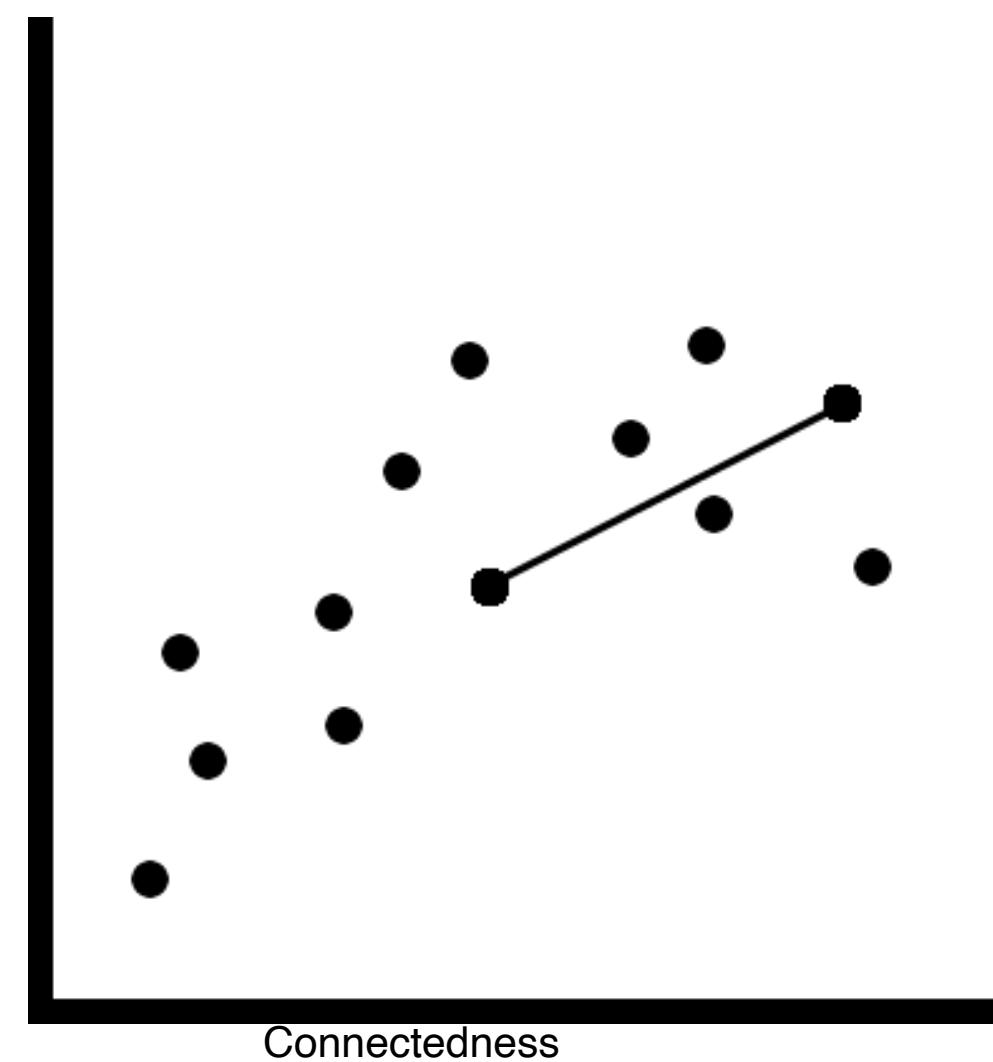


Shape

Connectedness and Common Region

Connected items with a line or curve

Surround items with a outline, surface, volume



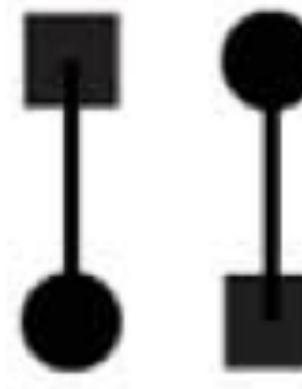
Common Region

Enclosure / Common Region

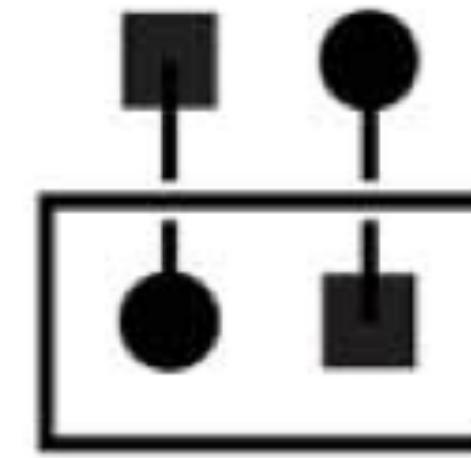
Similarity



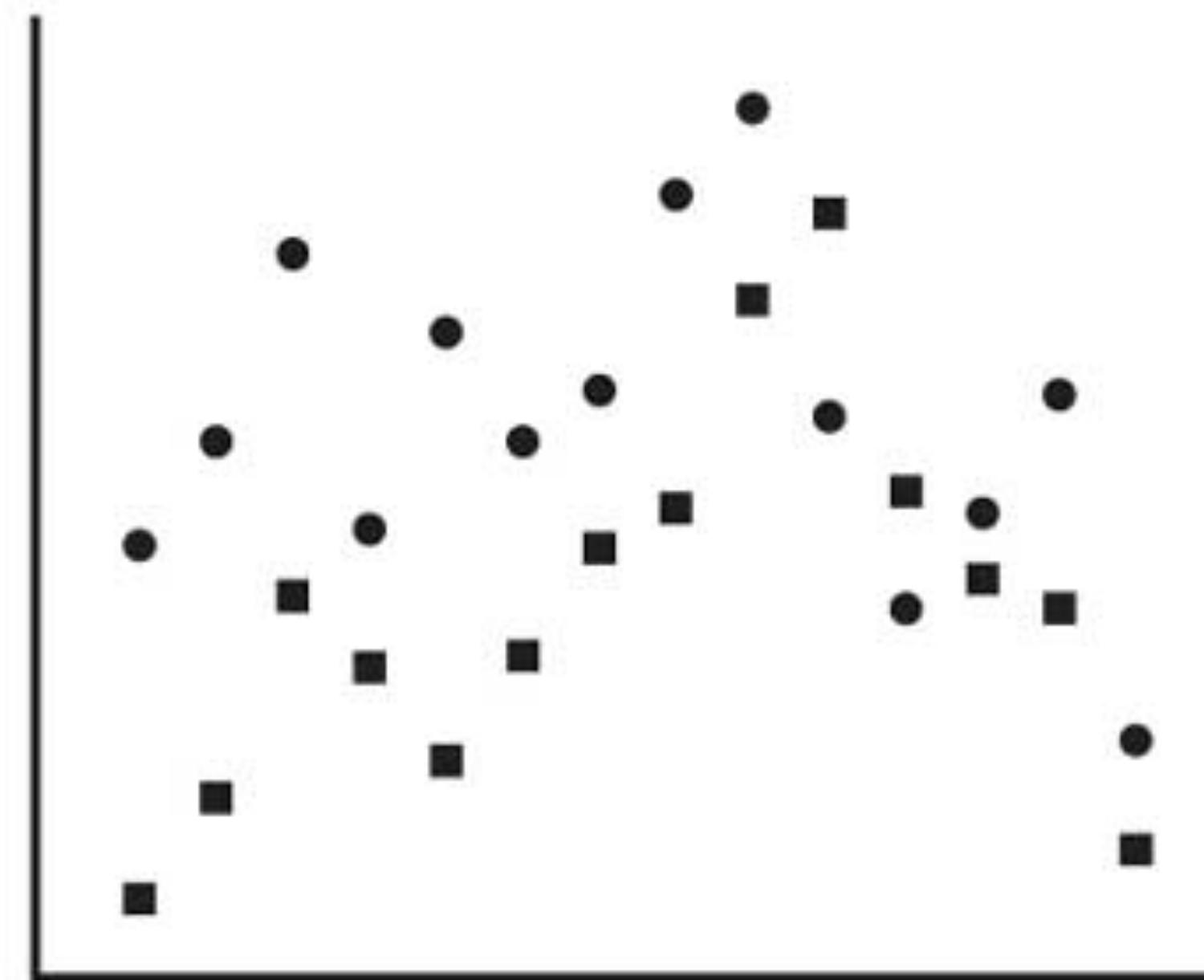
Connection



Enclosure

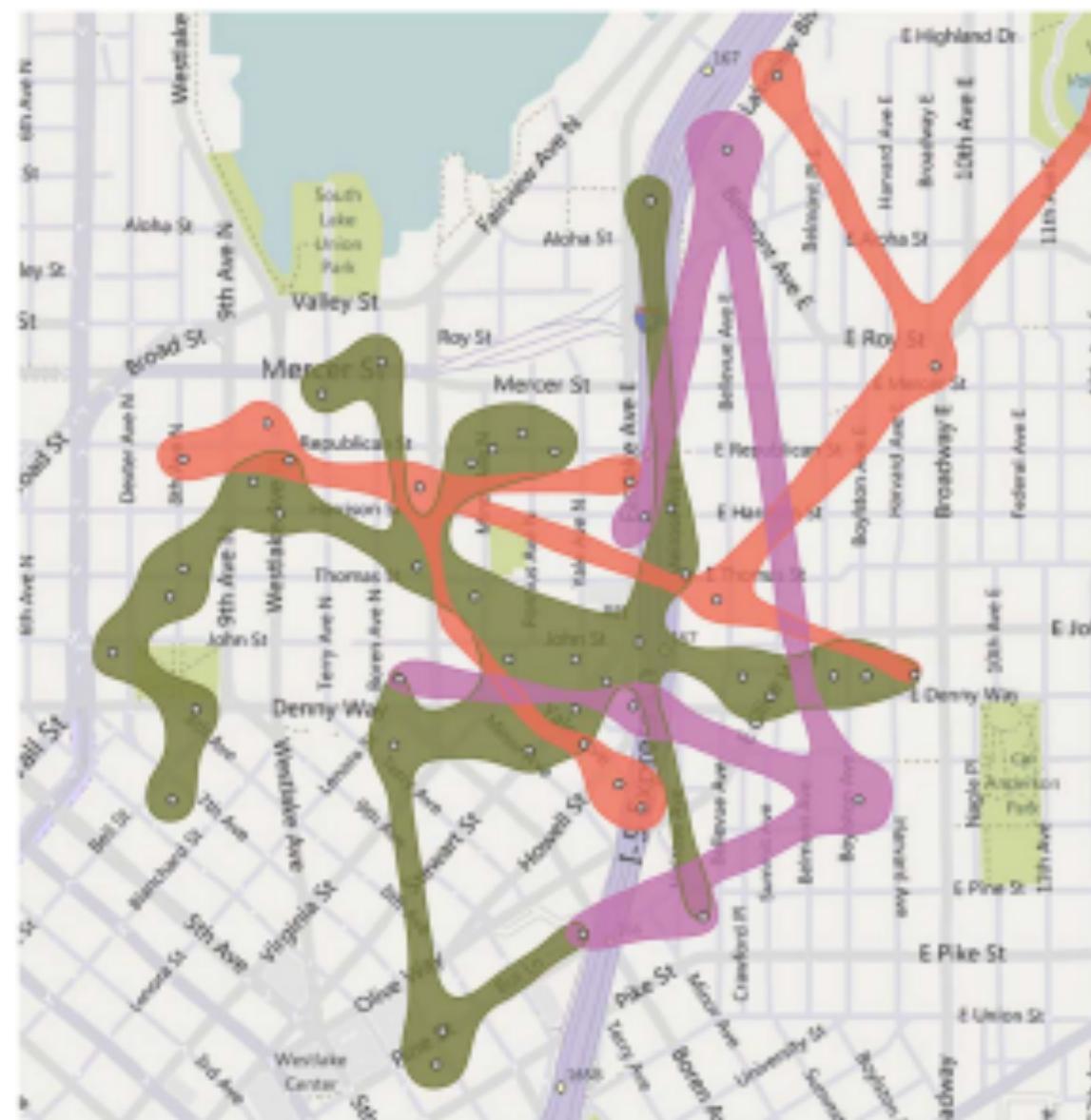


Connectedness / Enclosure

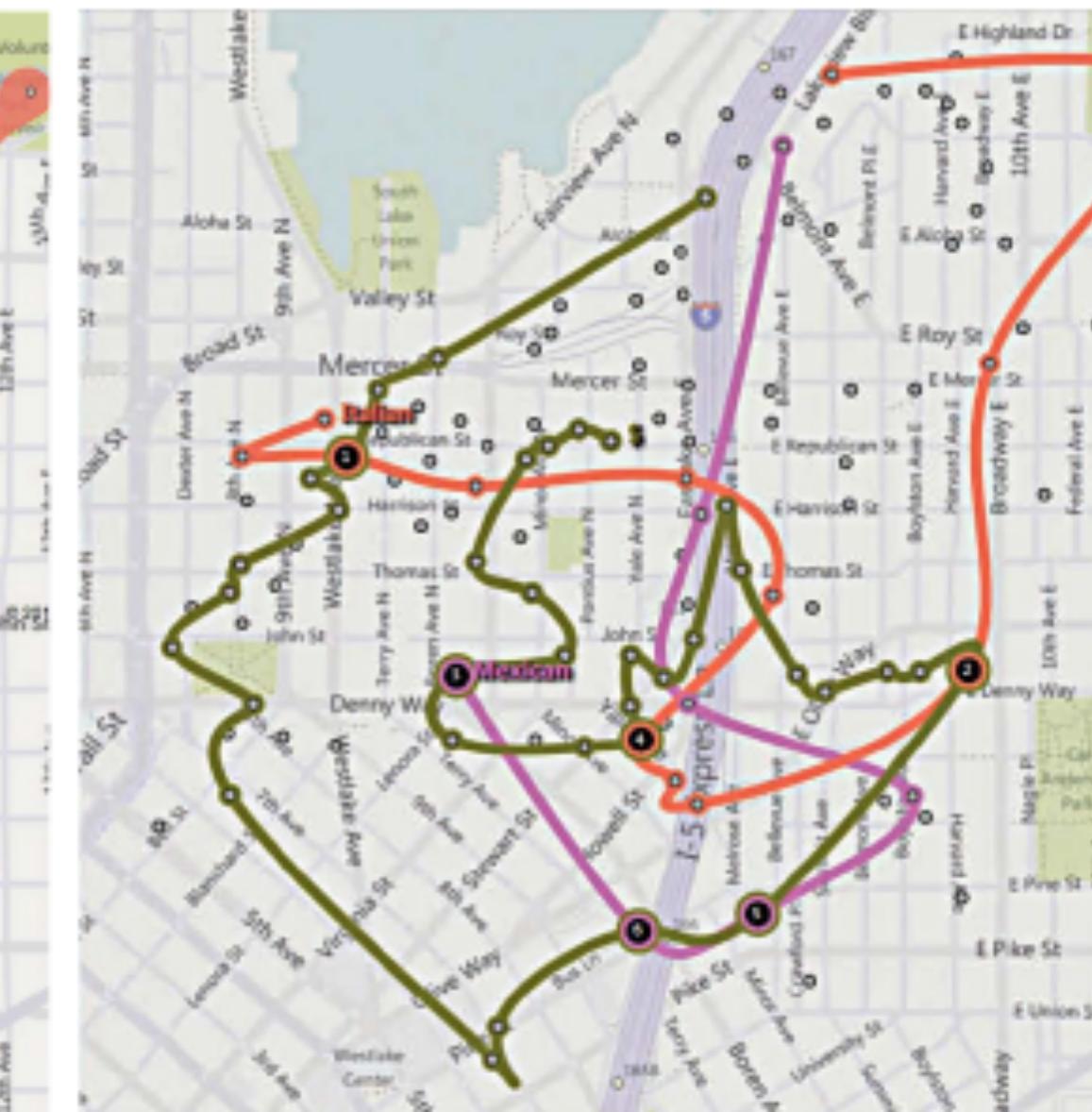


Connectedness Varieties

Bubble Sets



Line Sets



Kelp Diagrams

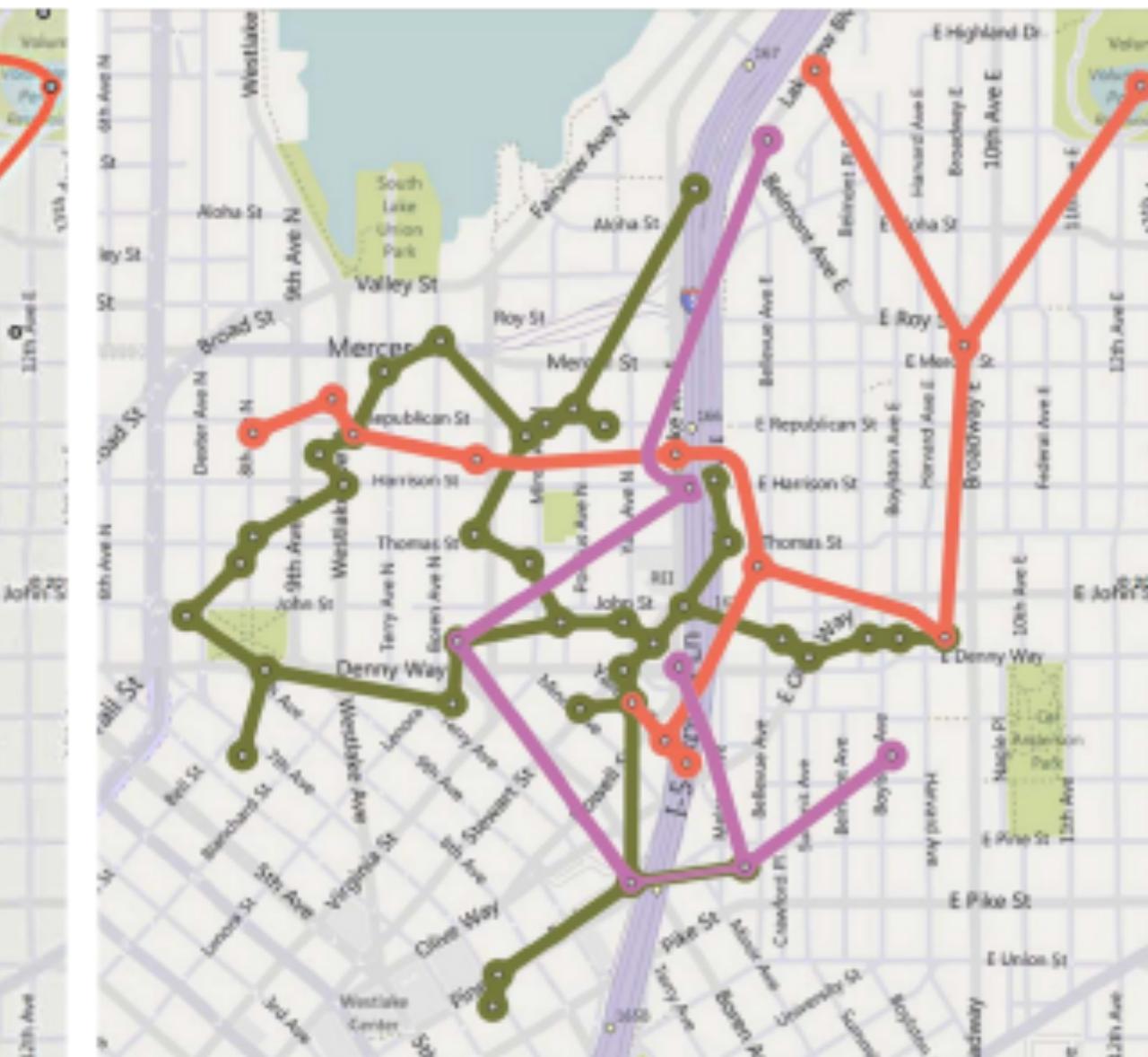


Image by [Dinkla et al., 2011]

Technique by [Collins et al., 2009]

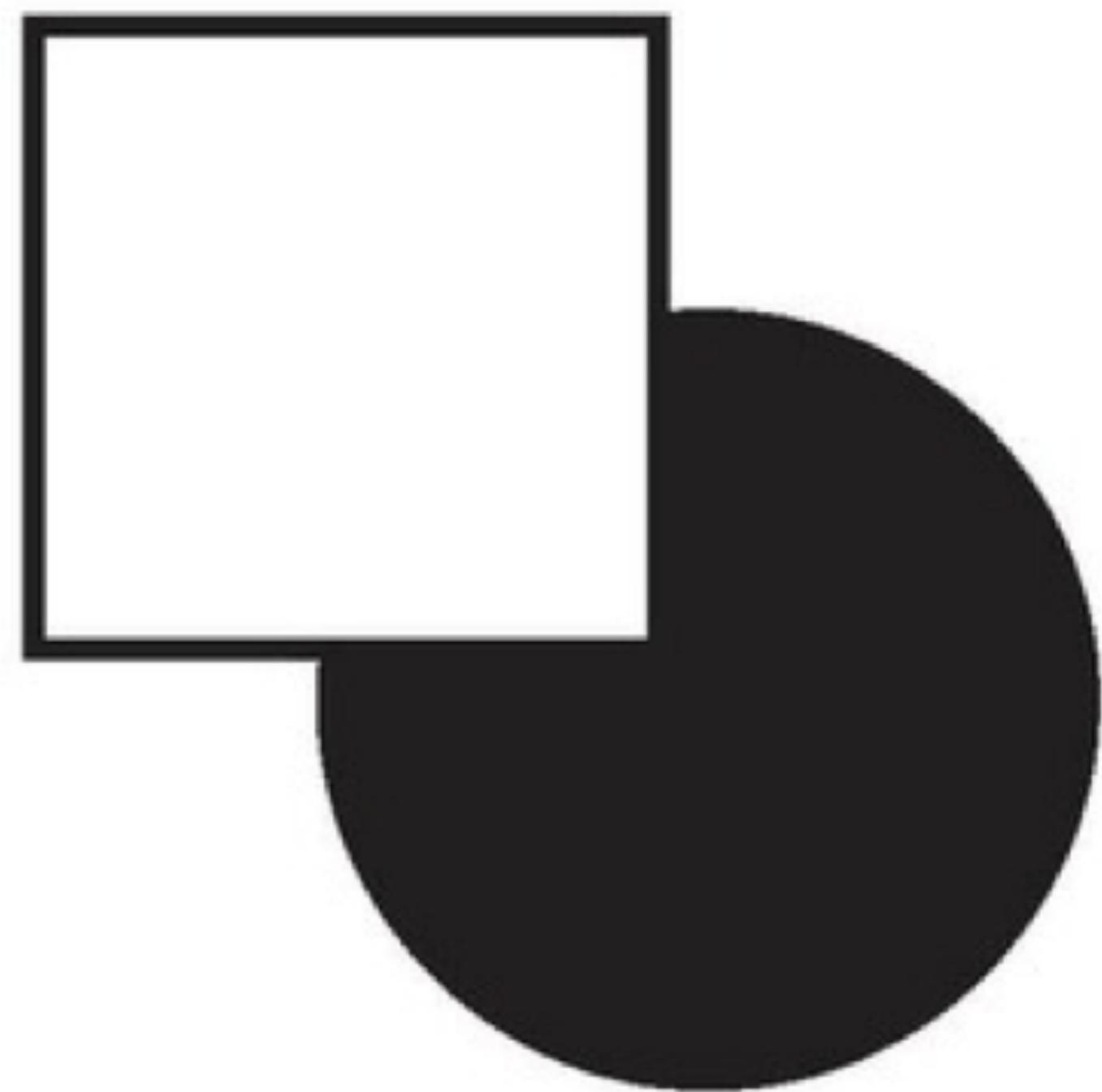
[Alper et al., 2011]

[Dinkla et al., 2012]

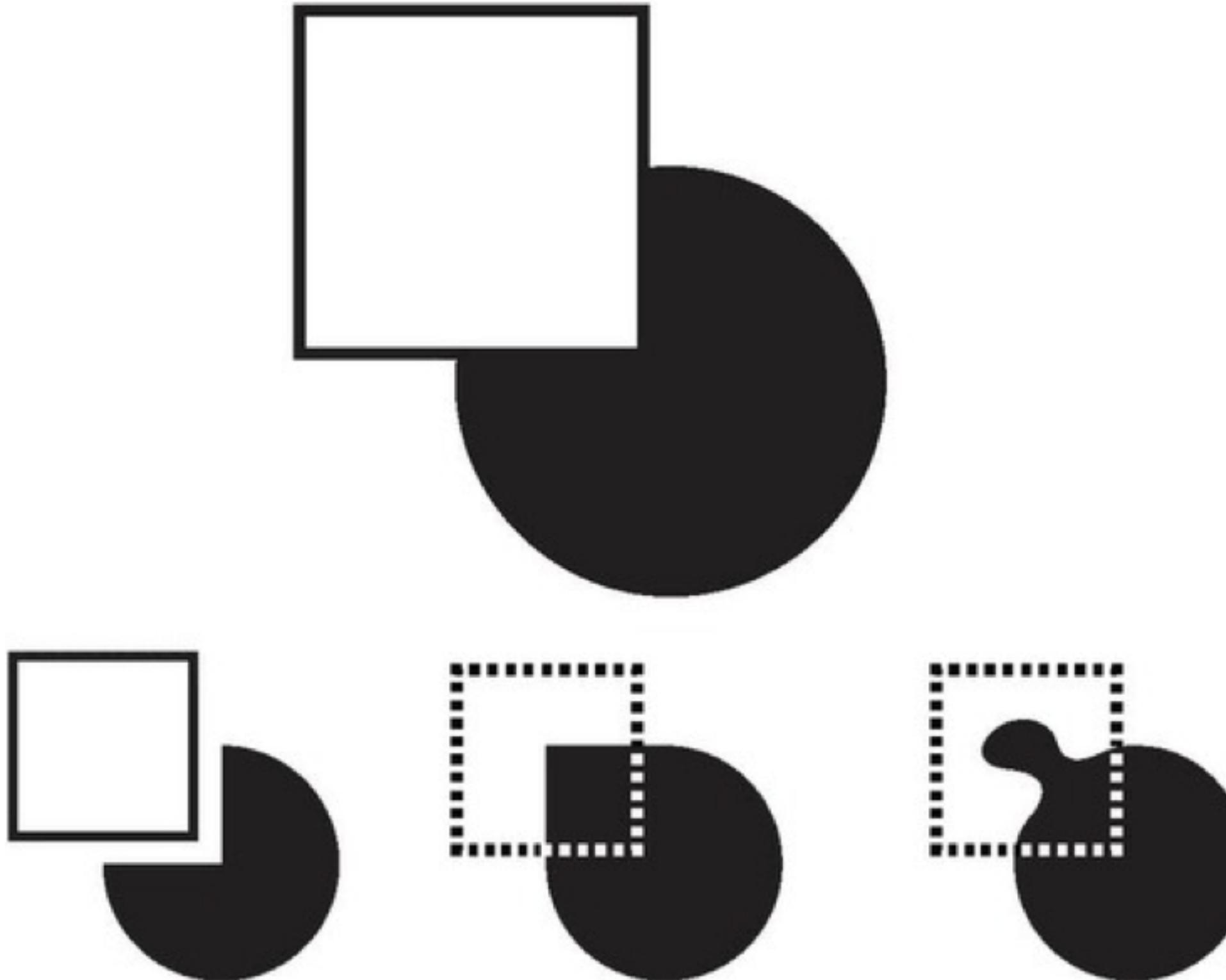
Gestalt Effects for “Emergence”

How Objects Appear to Us

Continuity



Continuity



Closure / Completion



Closure

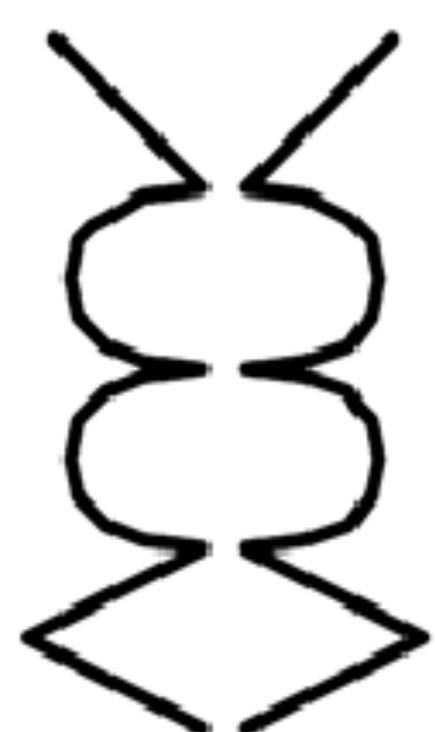


Symmetry

Things: symmetric



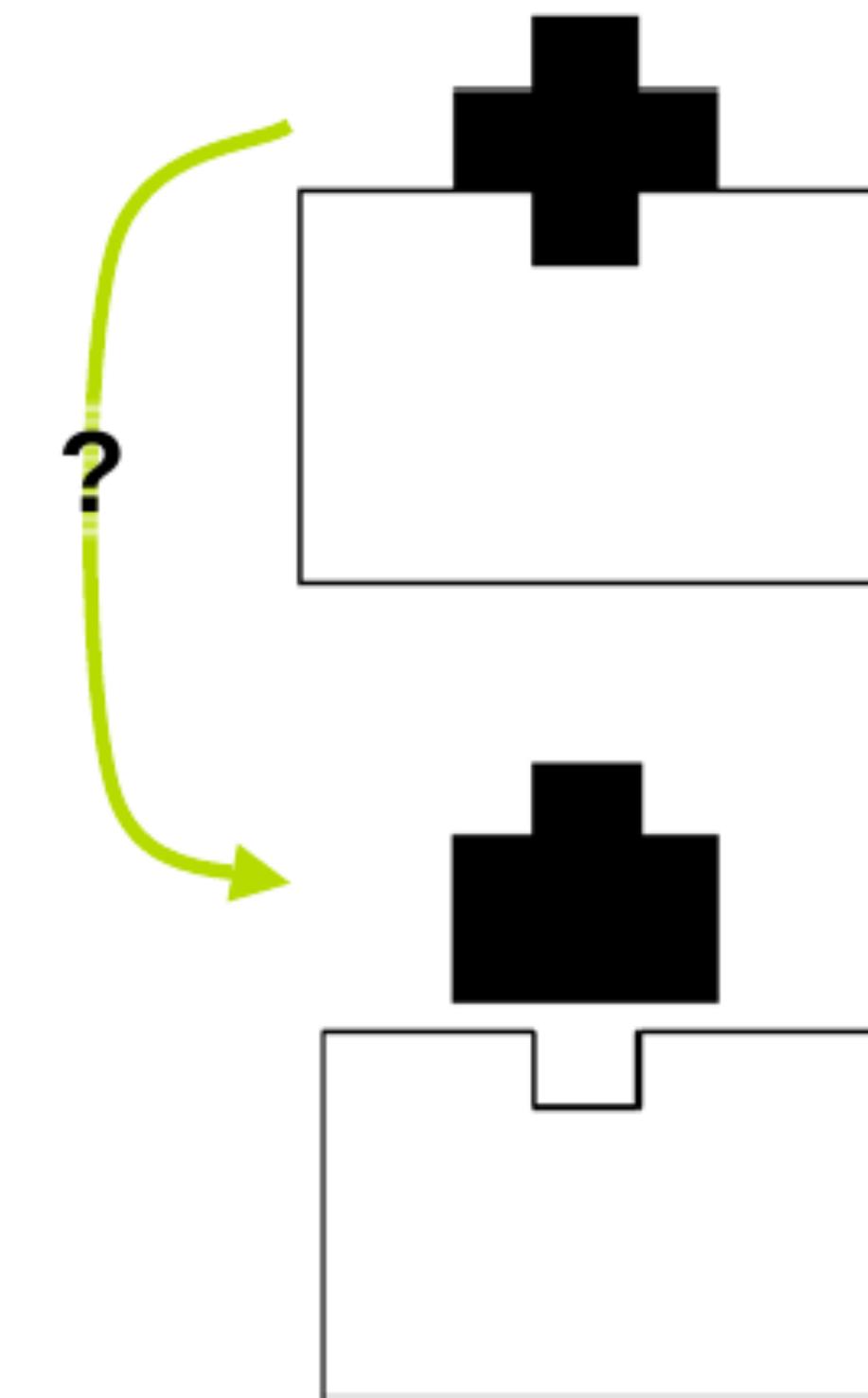
figure?



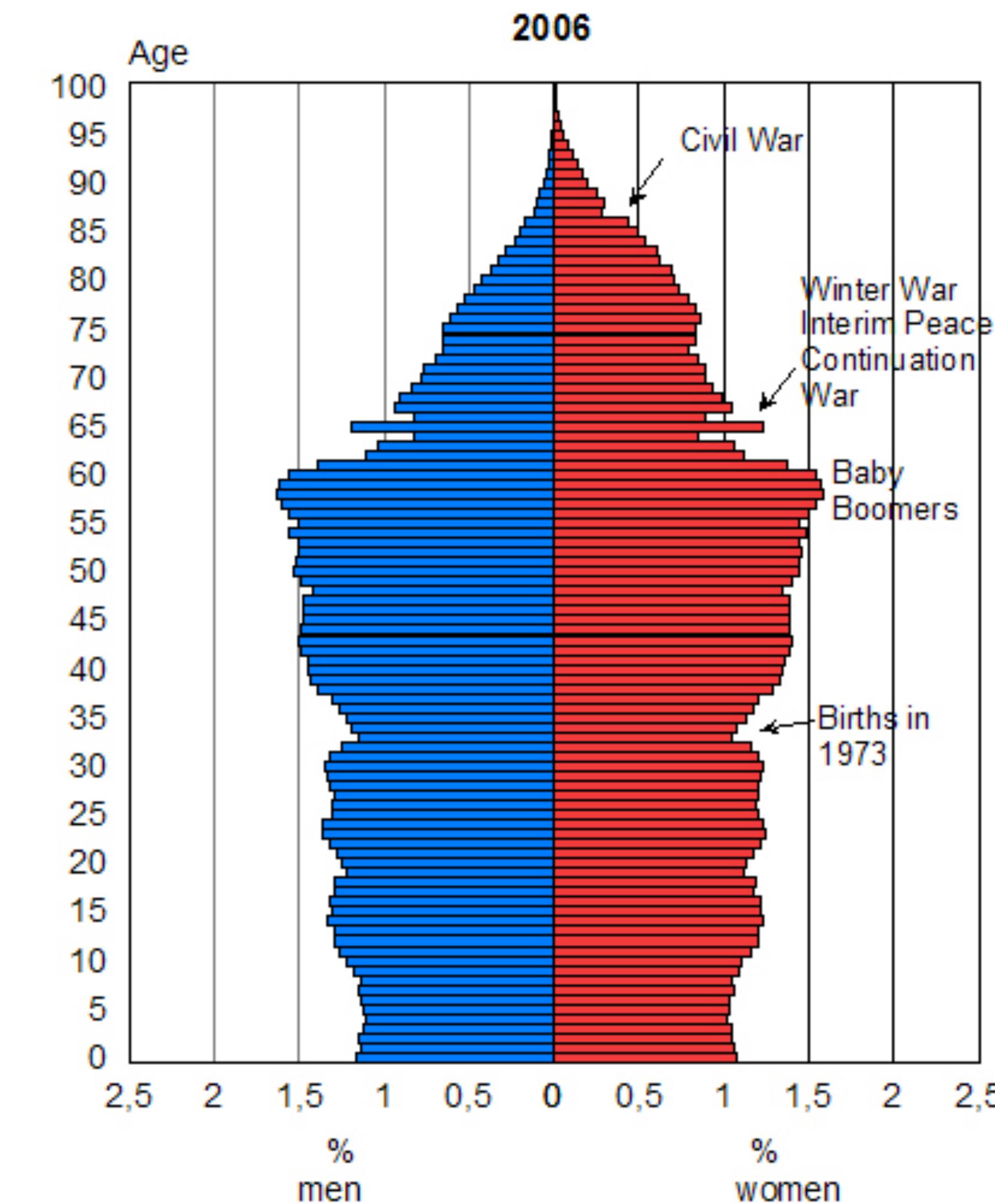
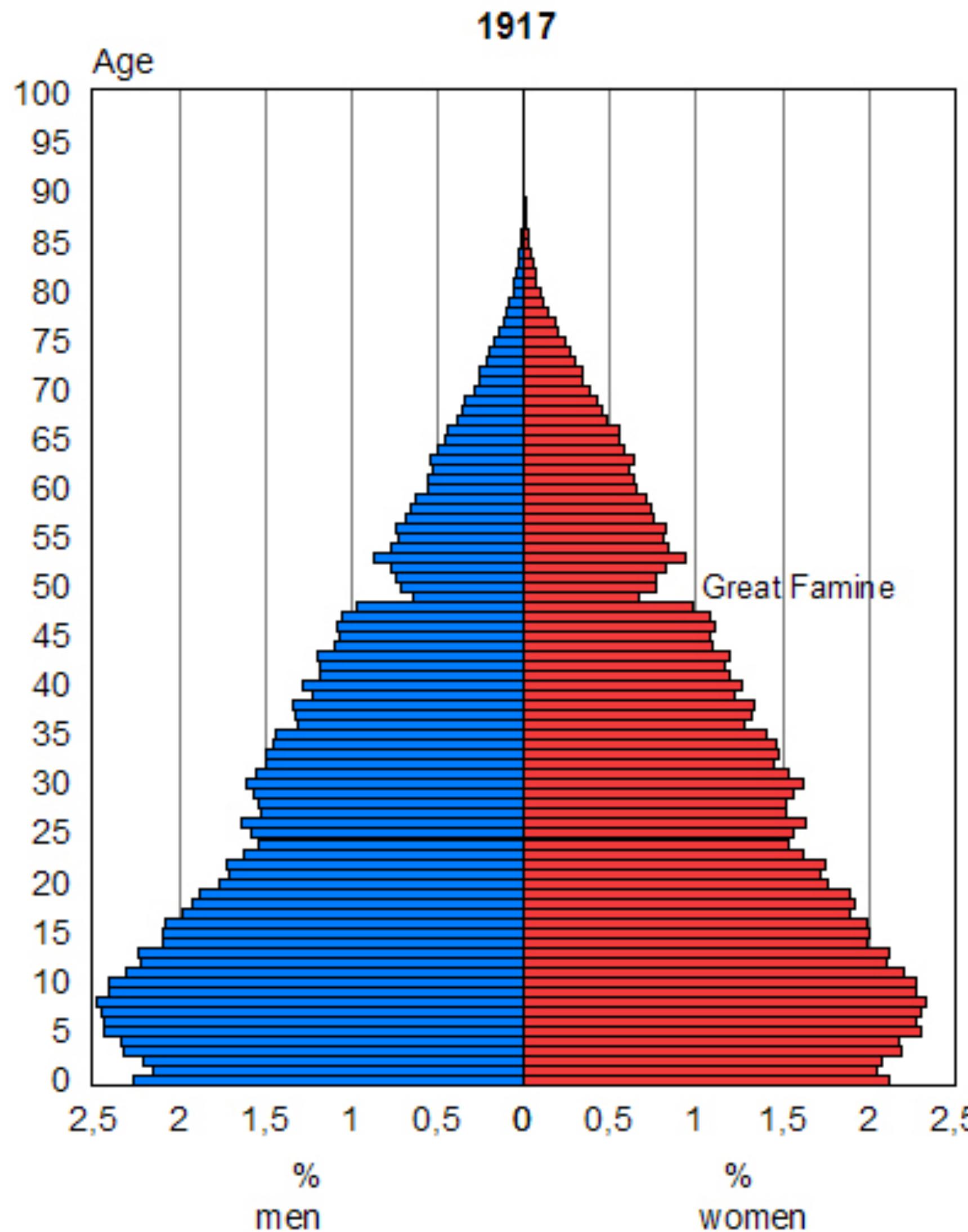
figure!



figure!

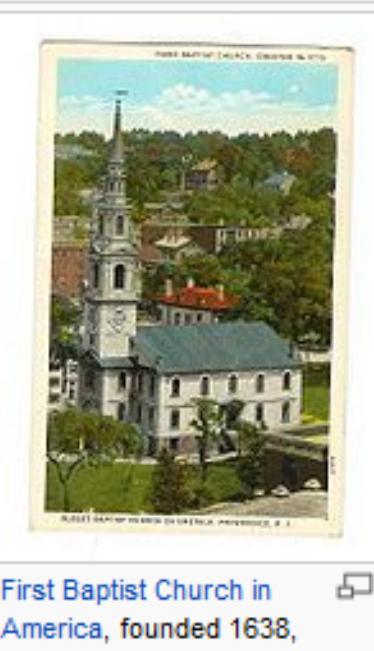


Population Pyramid



Applications in Vis

[d... pedia.org/wiki/Providence,_Rhode_Island](https://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]

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[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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Satellite

Traffic



Map showing the location of Rhode Island, which is highlighted in blue. The map includes state boundaries and major cities like Boston, Providence, and New York. Major roads like I-95, I-90, and I-84 are also visible. A legend in the top right corner shows options for Print, Send, Link, Satellite, and Traffic.

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

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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 WSR Route

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

Google maps

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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 continent. Major cities like Boston, Providence, Hartford, Springfield, Worcester, and New York 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 typical Google features such as a zoom slider, a compass rose, and links for "Print", "Send", and "Link". The "Satellite" and "Traffic" overlays are also visible.

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Traffic

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Providence in the mid-nineteenth century

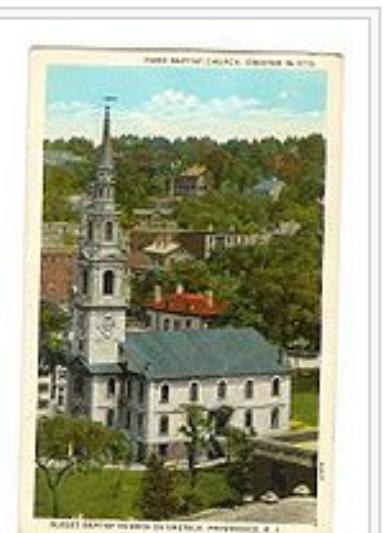
NPS map of the W3R Route

From NPS "American Revolution in a Global Conflict" website

50 mi
100 km

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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.^{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.



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NPS map of the W3R Route

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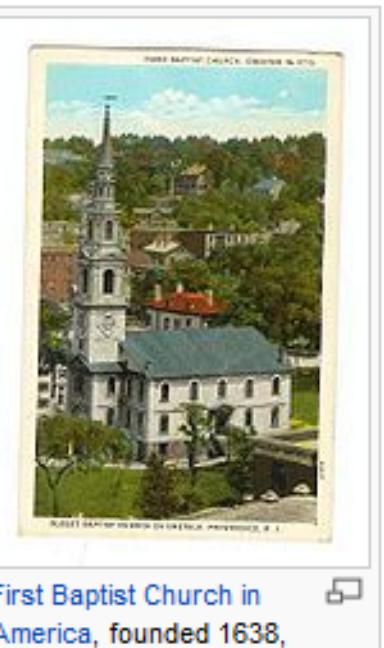
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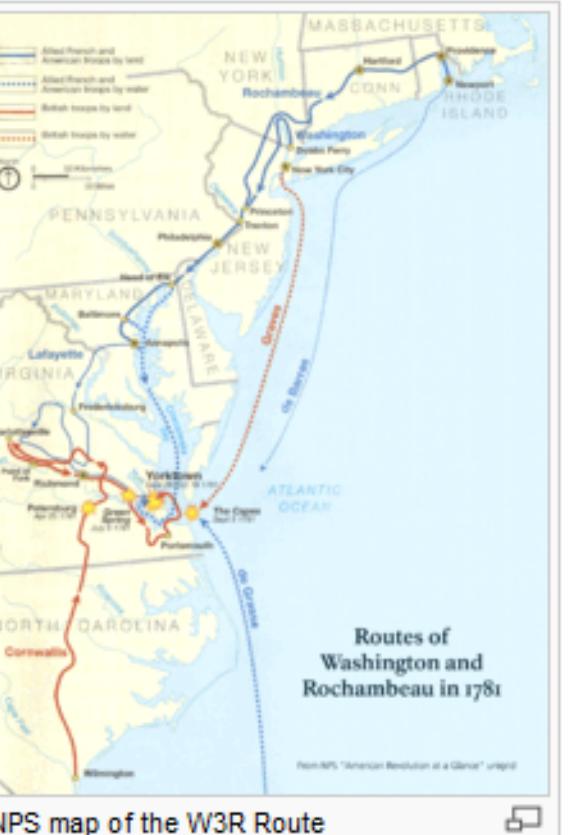
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In the mid-1770s, the British government levied taxes that impeded Providence's maritime, [fishing](#) and agricultural industries, the mainstay of the city's economy. One example was the [Sugar Act](#), which was a tax levied against Providence's 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](#).^{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](#).



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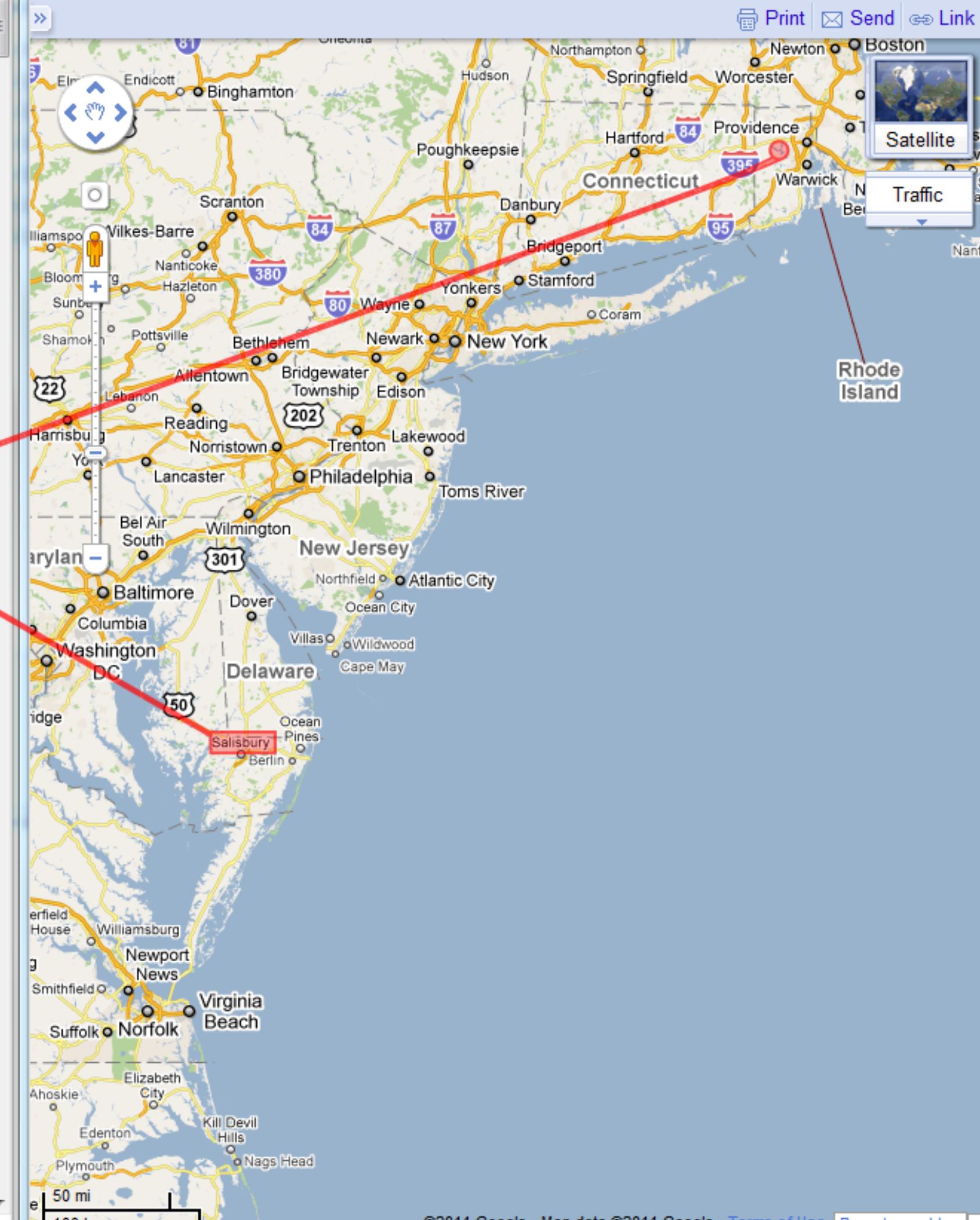
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What is the problem?

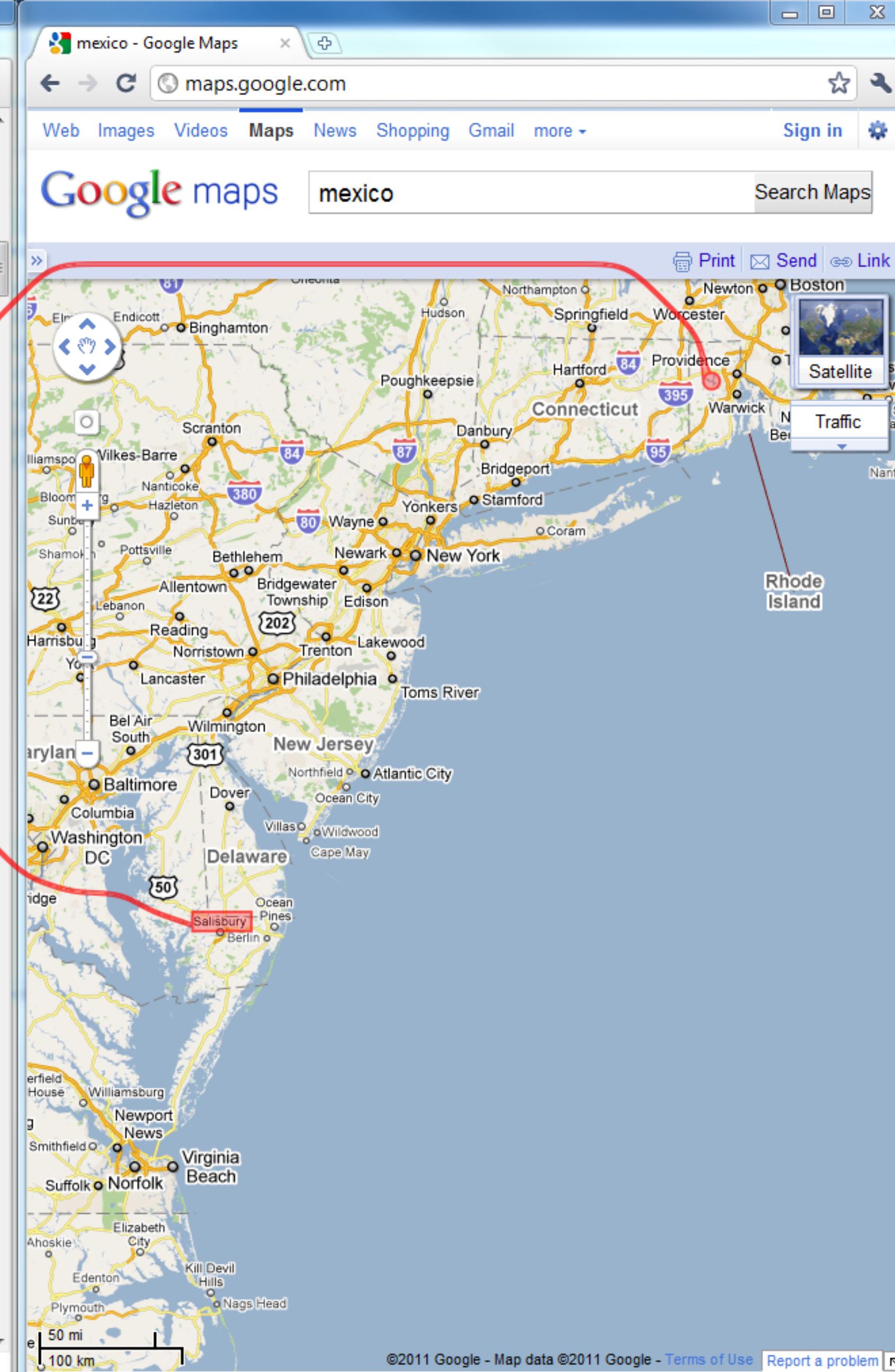
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Context-Preserving Visual Links

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