

CIS 4930/6930-002

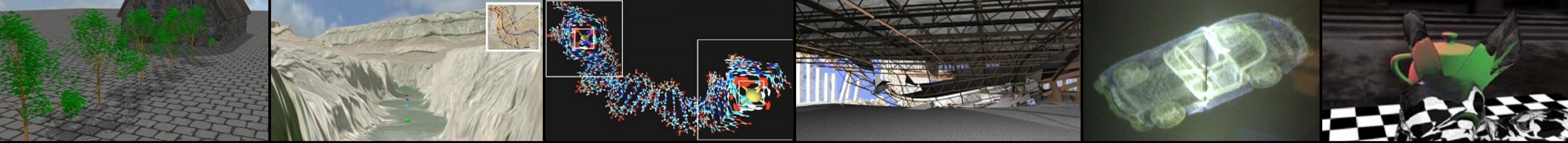
DATA VISUALIZATION



PERCEPTION AND COLOR

Paul Rosen
Assistant Professor
University of South Florida

slides credits Chris Johnson (U of Utah), Hanspeter Pfister (Harvard), Bang Wong (Broad Institute), Miriah Meyer (U of Utah)



PROJECT 2 REFLECTION



REMINDERS

2/5/2018 - Project 2 Peer Reviews

2/7/2018 – Project 3 due



TODAY

eye construction

perceptual vulnerabilities

popout

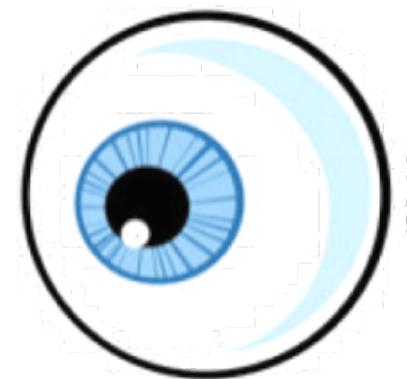
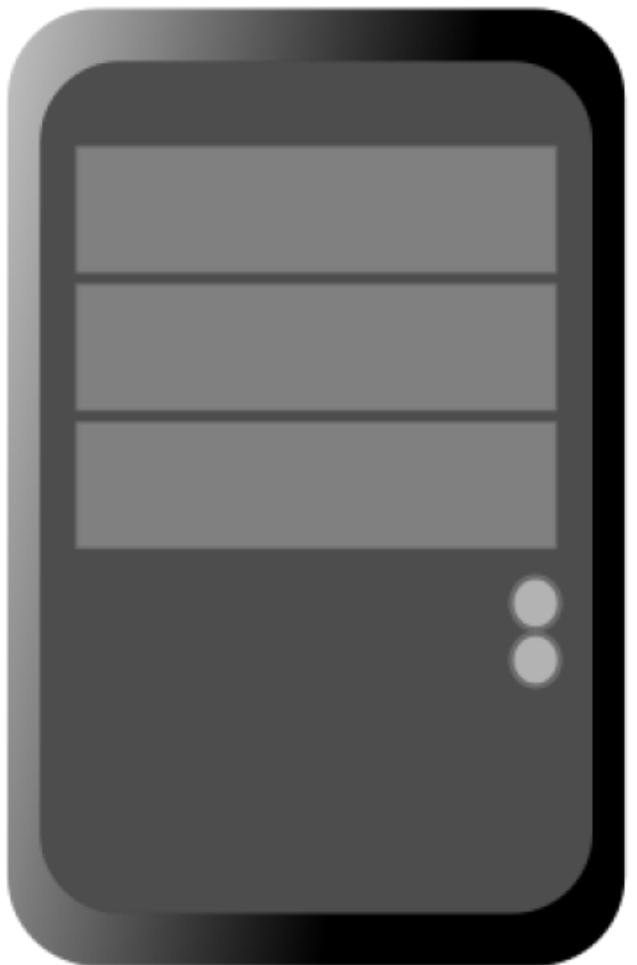
gestalt principles

NEXT TIME

color

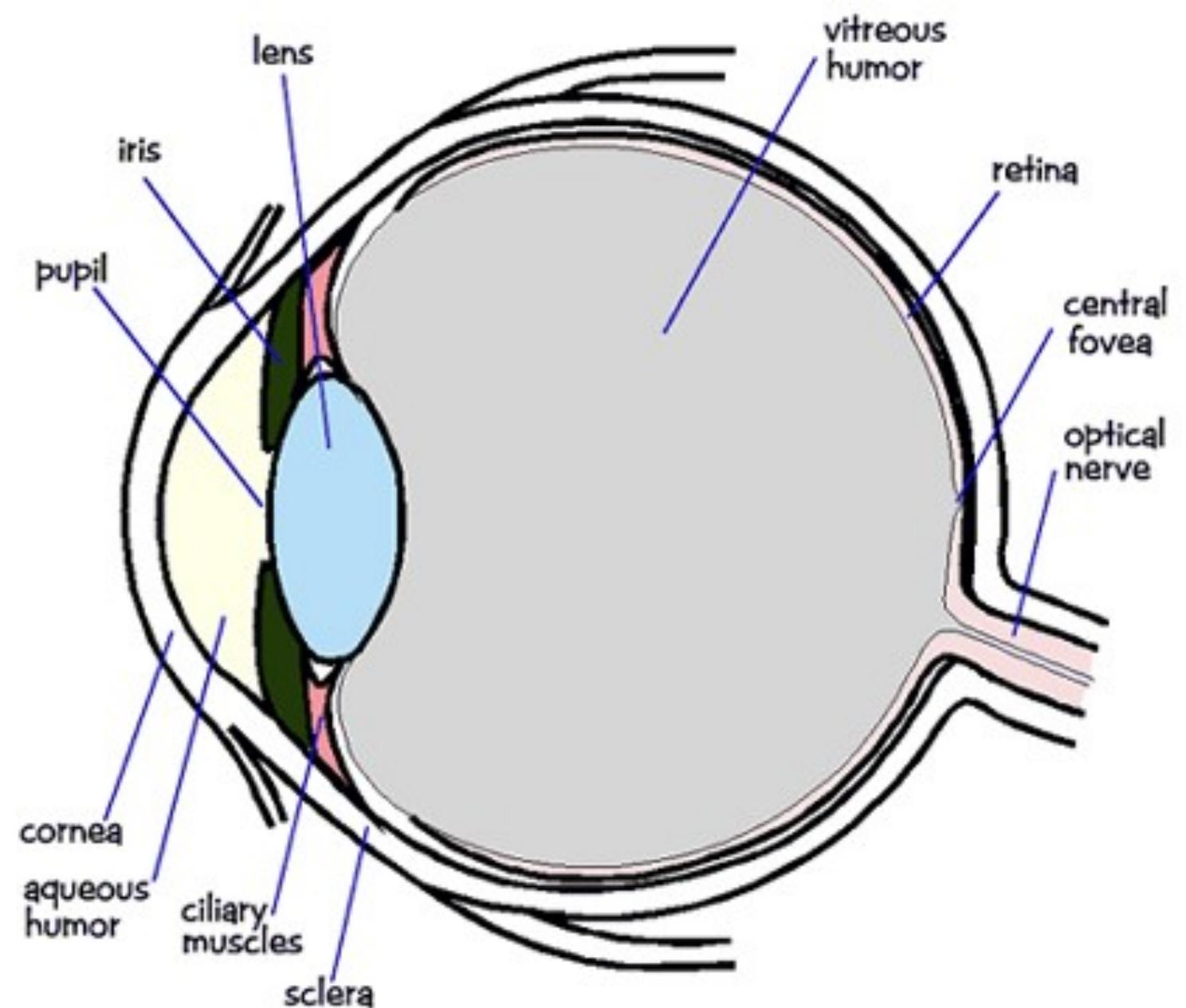


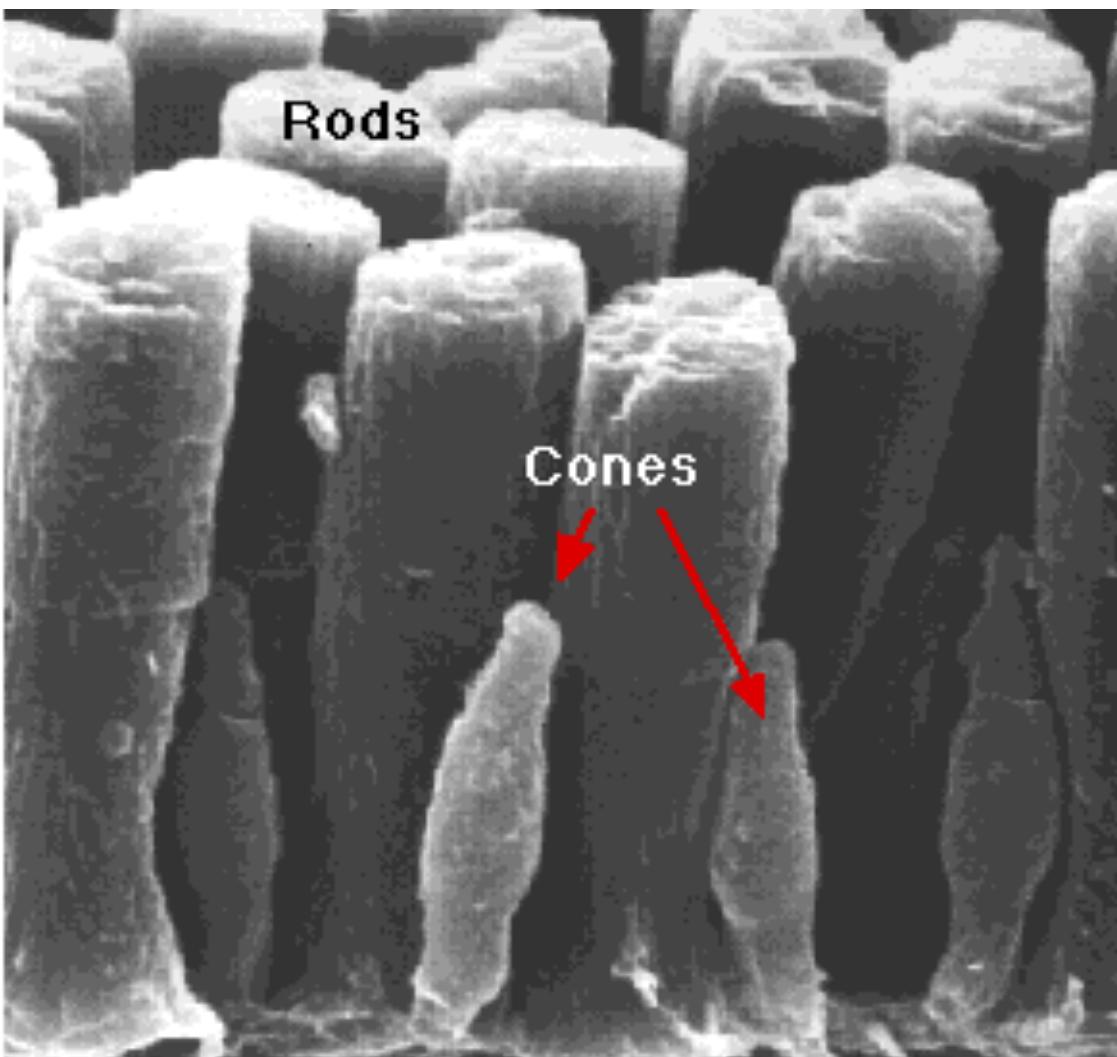
data



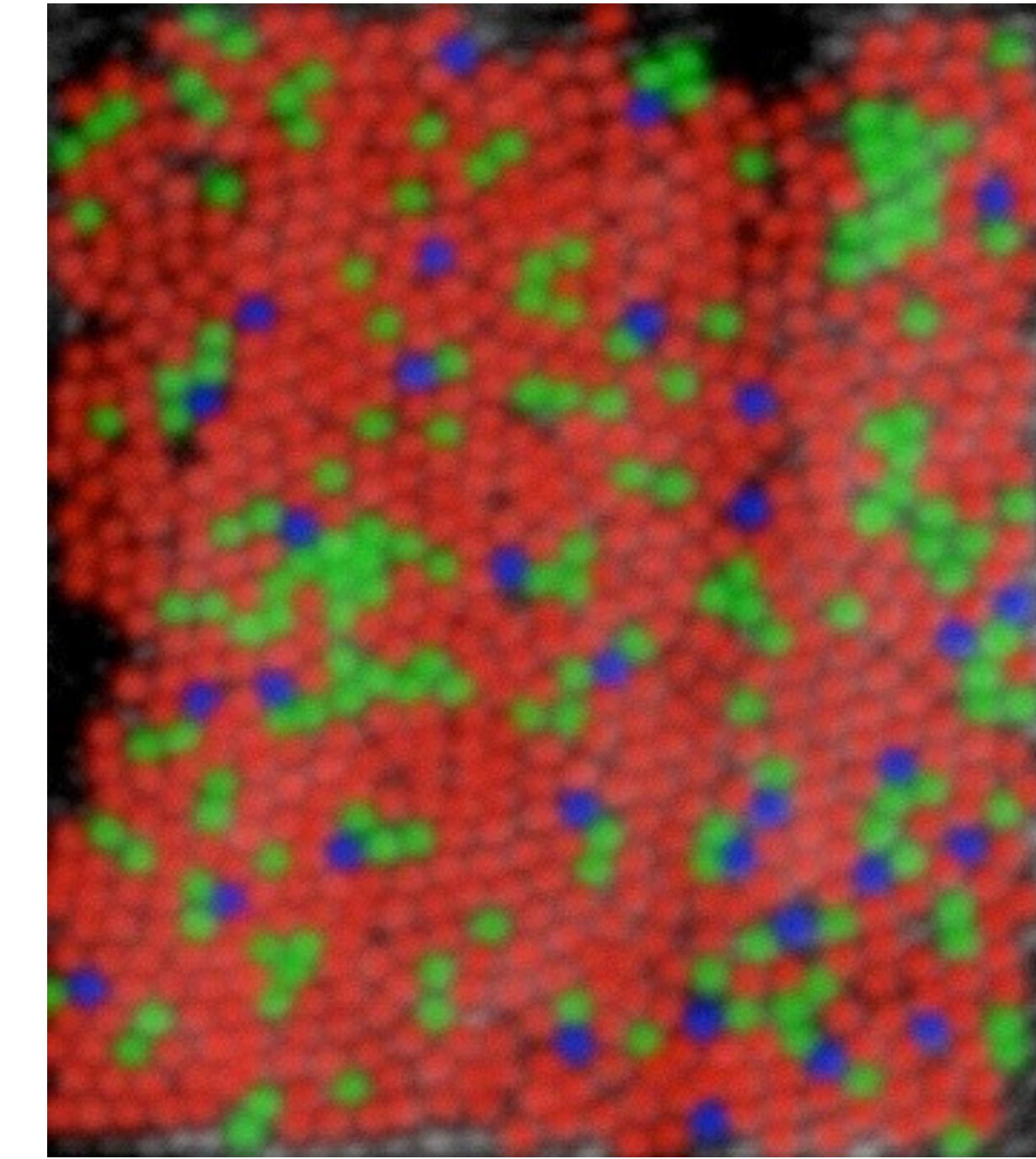
knowledge







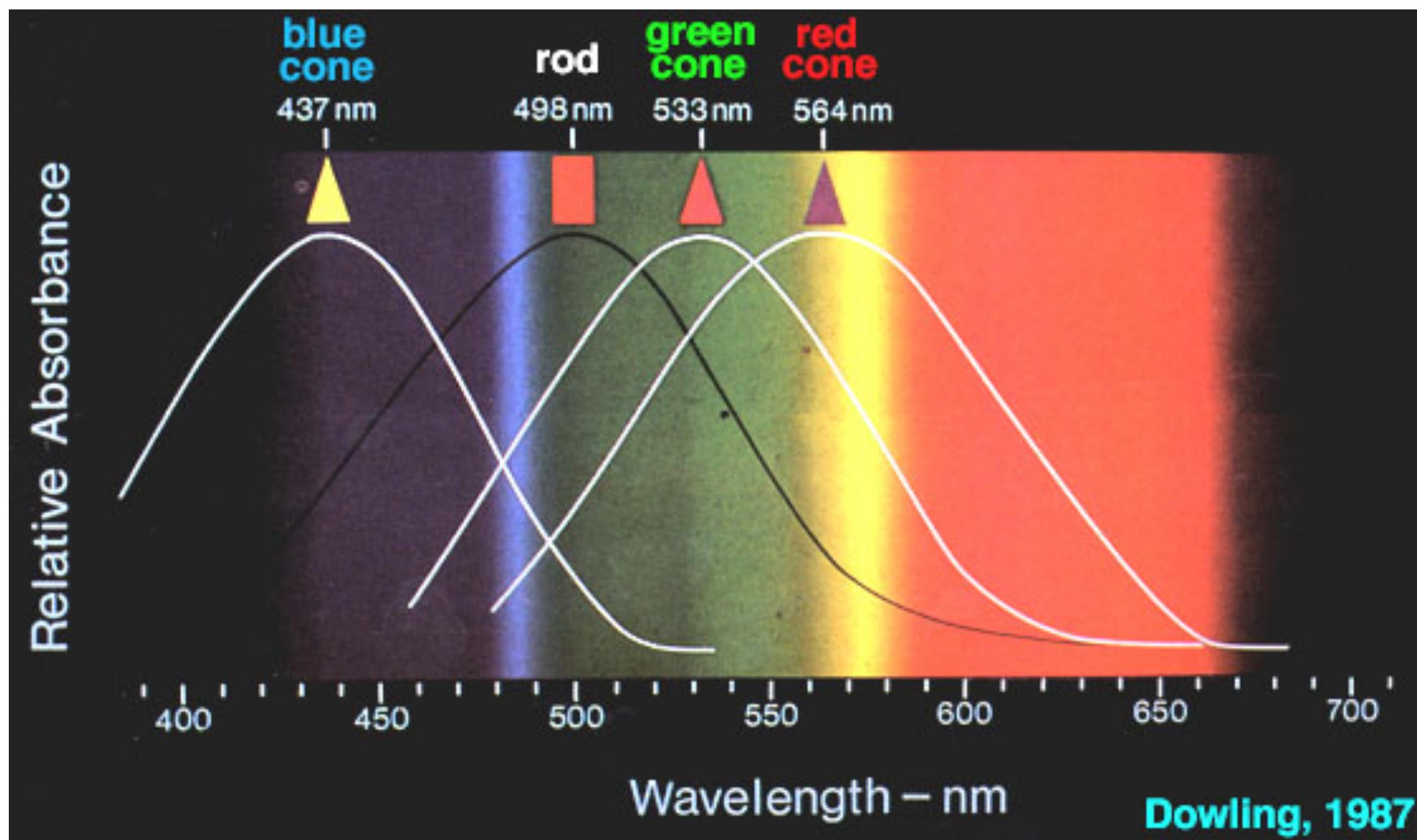
120 million rods

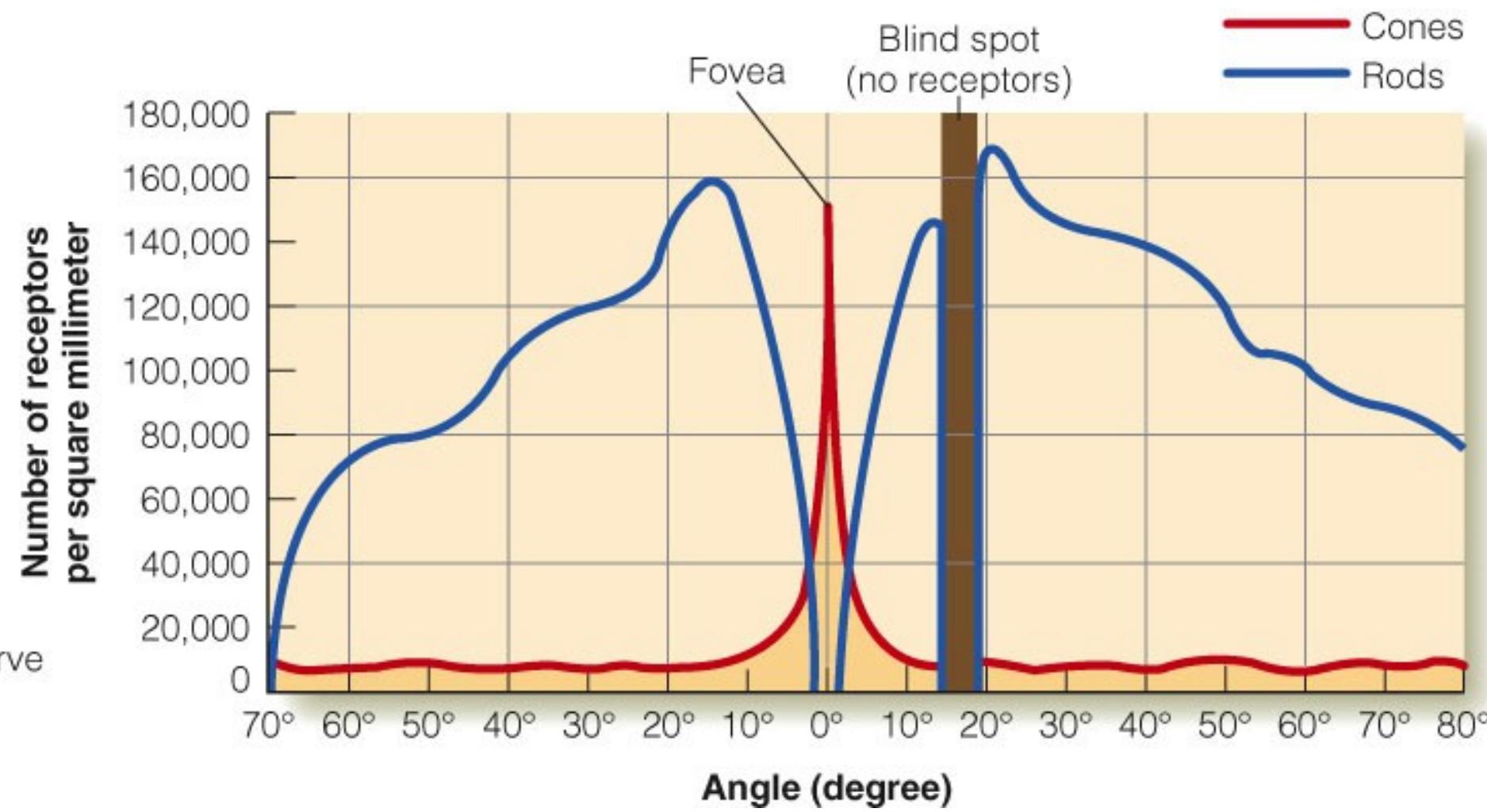
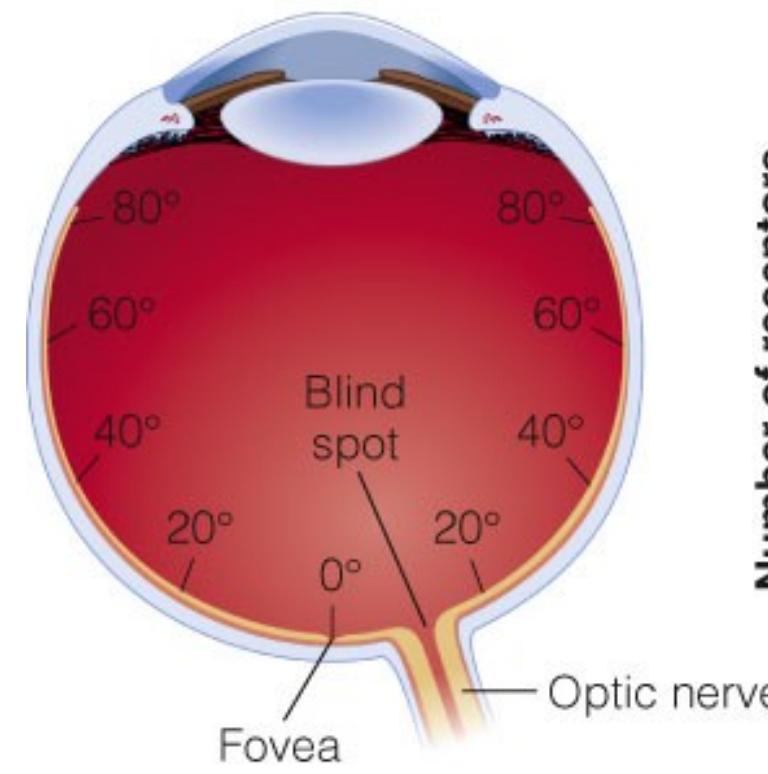


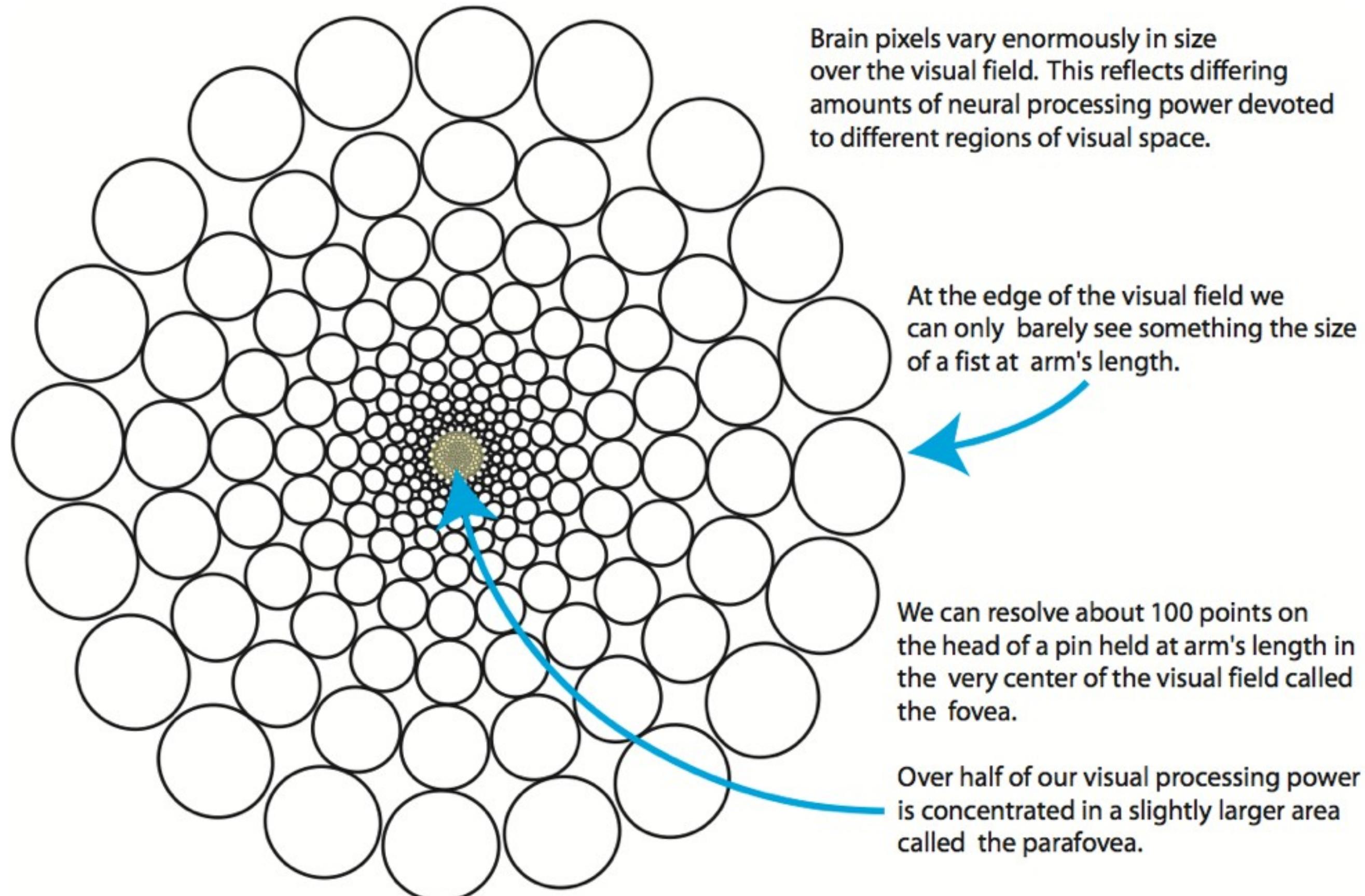
5-6 million cones



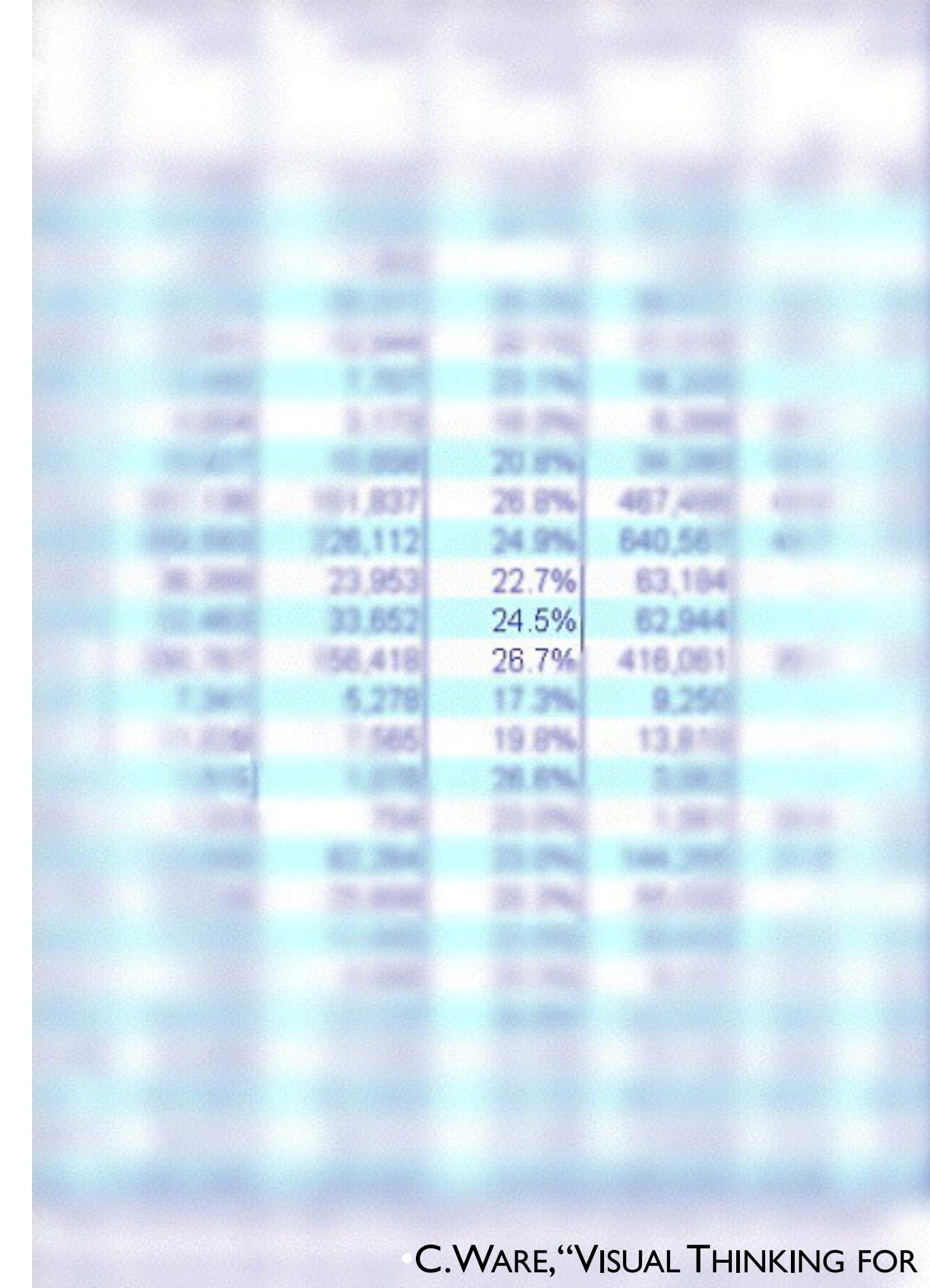
CONE RESPONSE







Foveation is relatively easy to see. The key to recognizing the phenomenon is to stare at a single word **on** the printed page. Then, without moving your gaze, note the blurriness of the surrounding text.

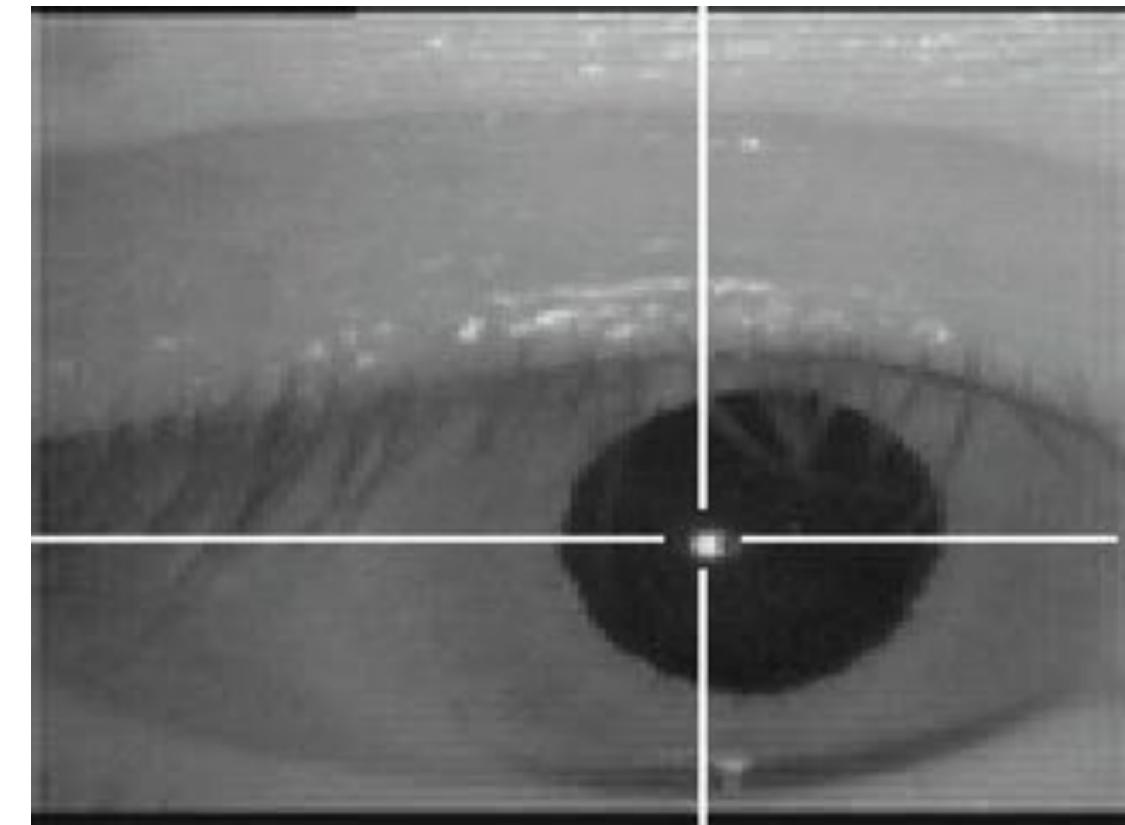


SACCADIC EYE MOVEMENTS

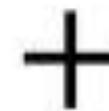
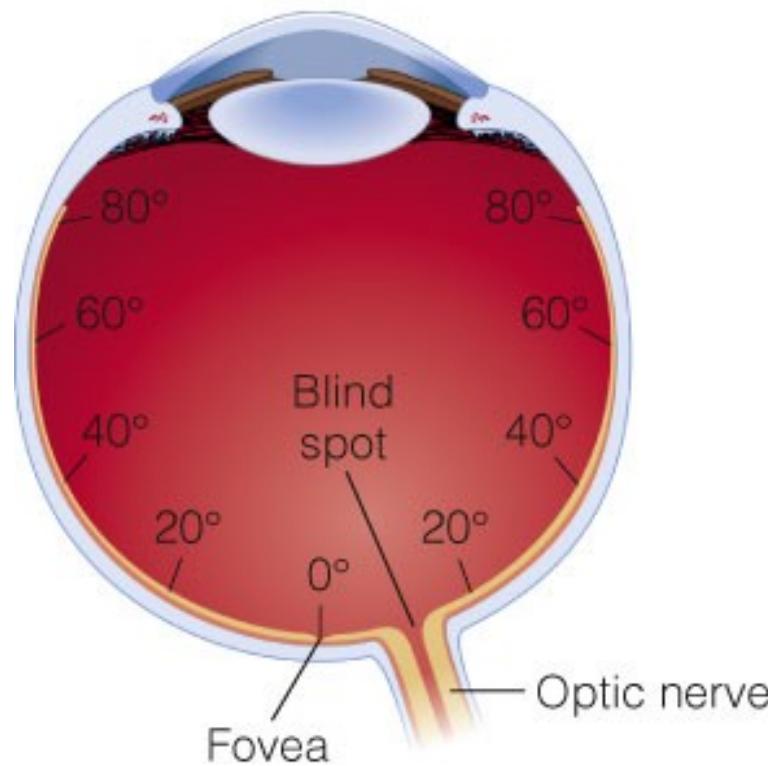
rapid involuntary eye movements

moving: 20-100 ms

fixations: 200-600 ms



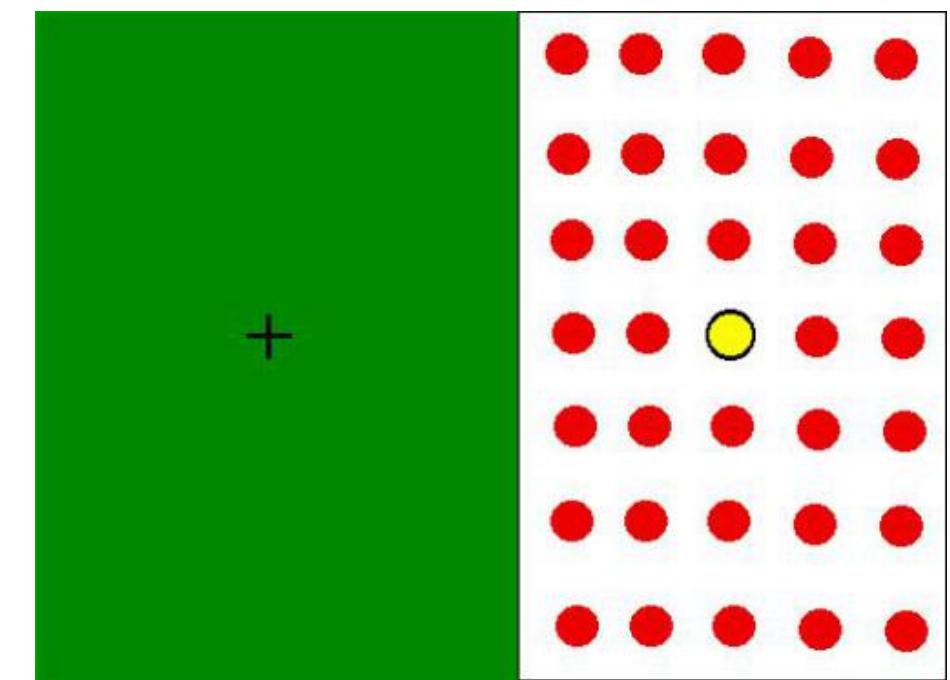
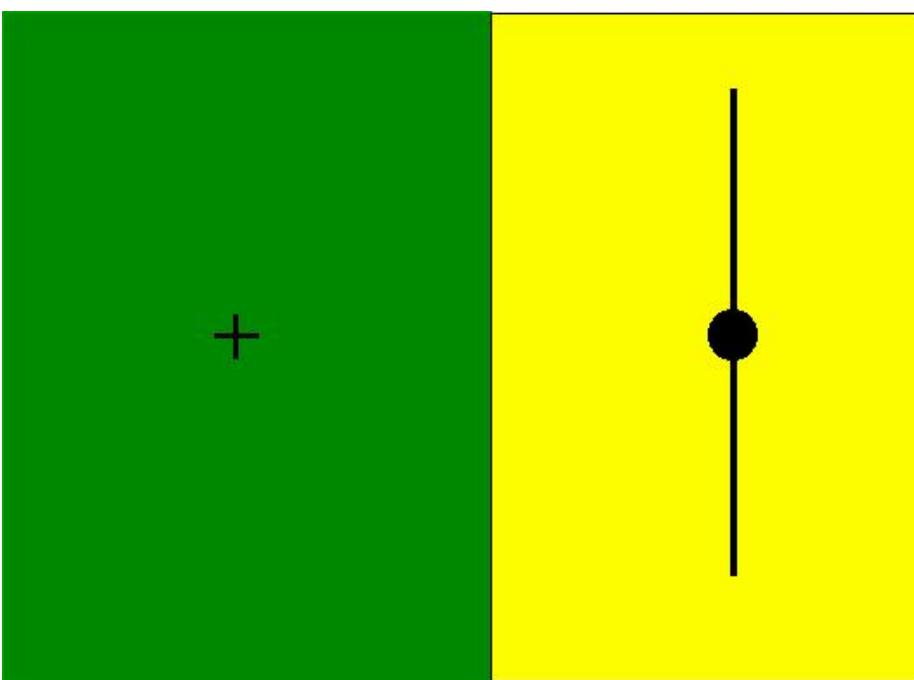
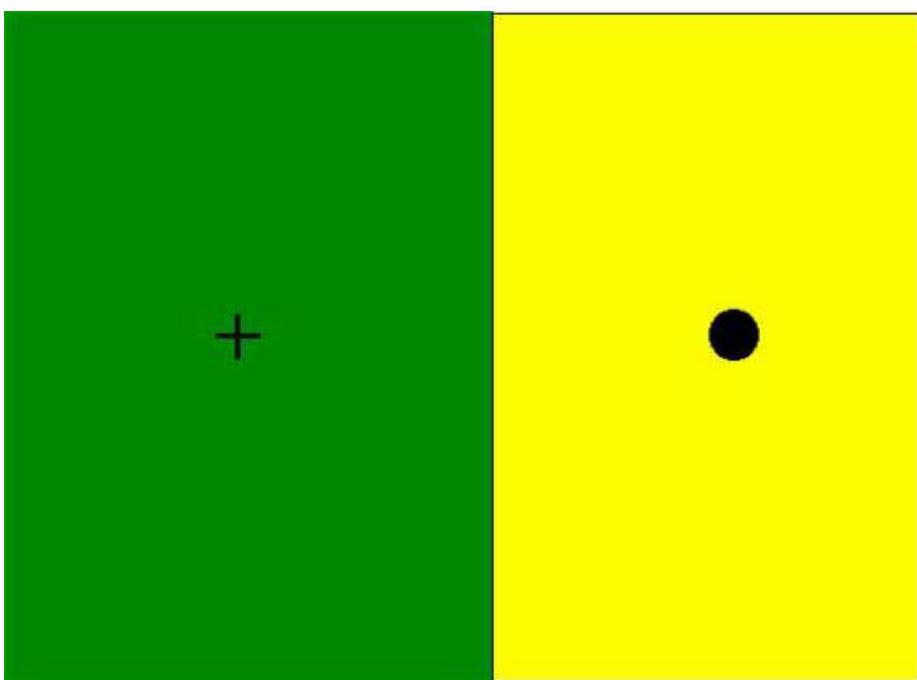
BLIND SPOT



Close **left** eye
Stair at +
Move forward and backward until ● disappears



BLIND SPOT



TAKEAWAY

Our vision at any given moment is relatively limited. Our brain “fills in the missing pieces” using a variety of evolved tools.

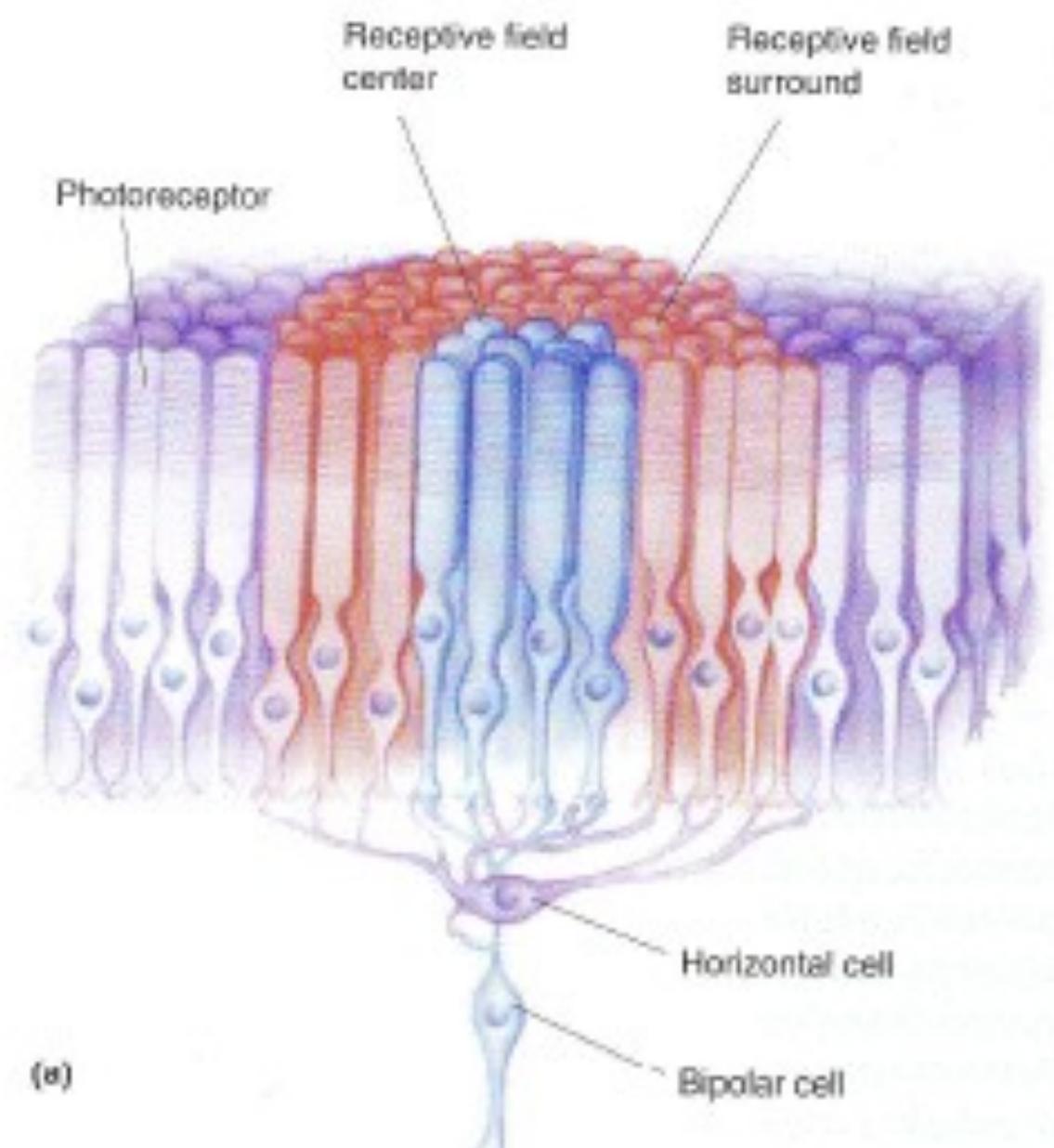
Be careful placing too much data on the screen. Crisp and clear will result in the best interpretation.



EDGE DETECTION

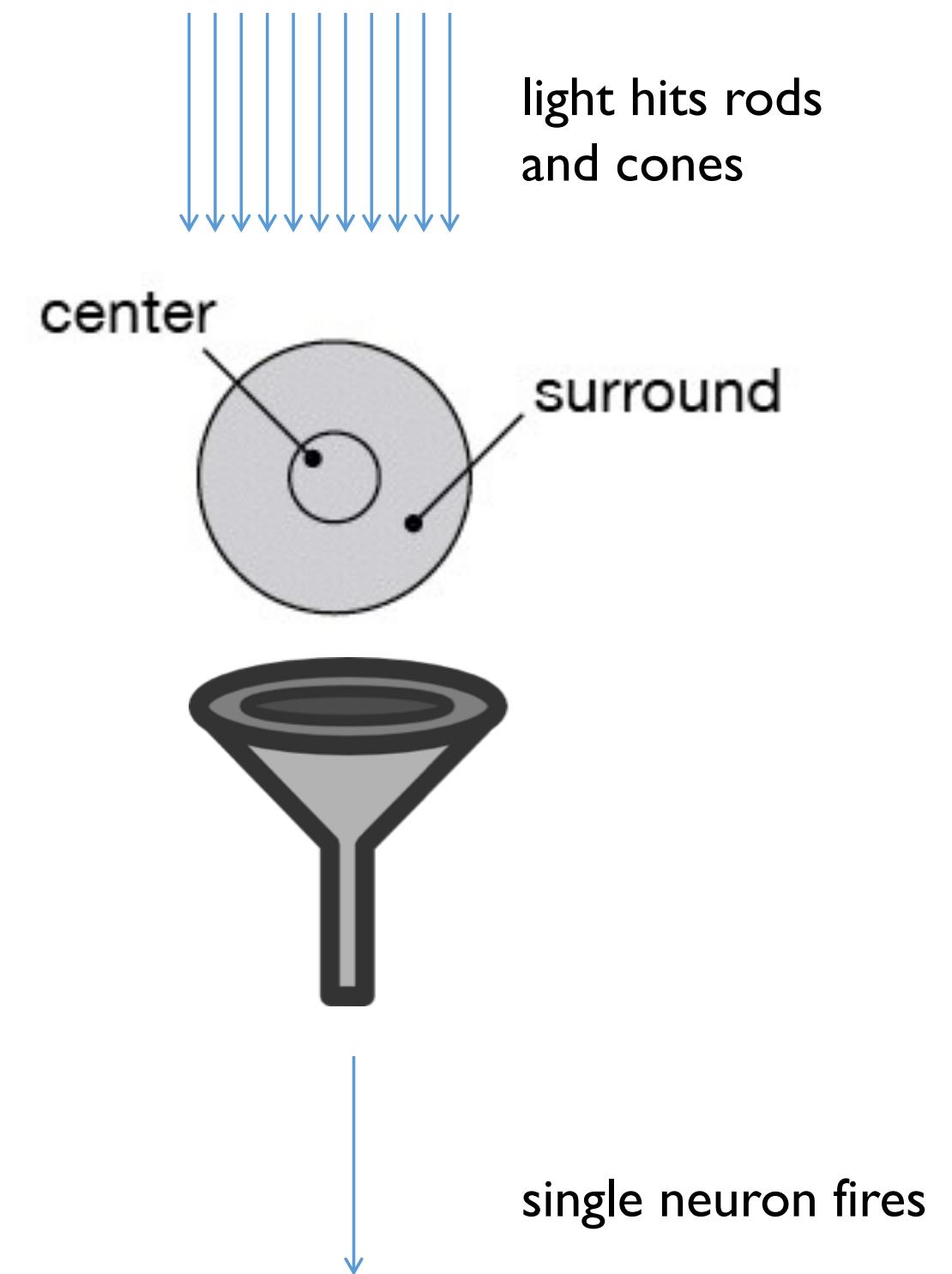


RECEPTIVE FIELD



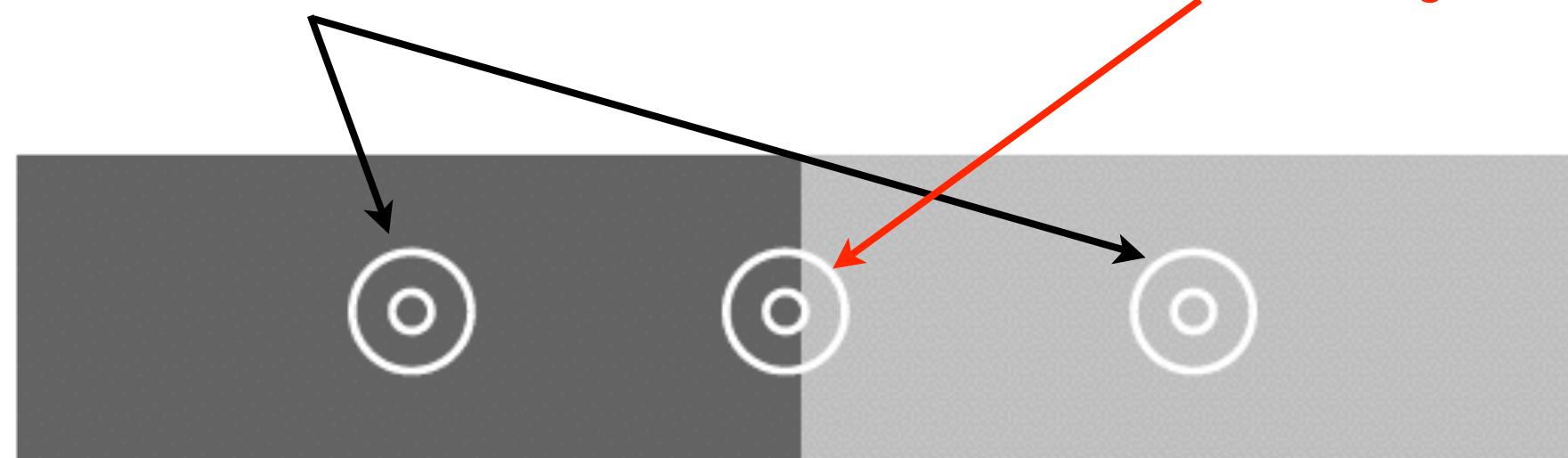
100M rods and cones

1M ganglion cells



low activity
center and surrounds cancel

**activity increased
or decreased at edges**

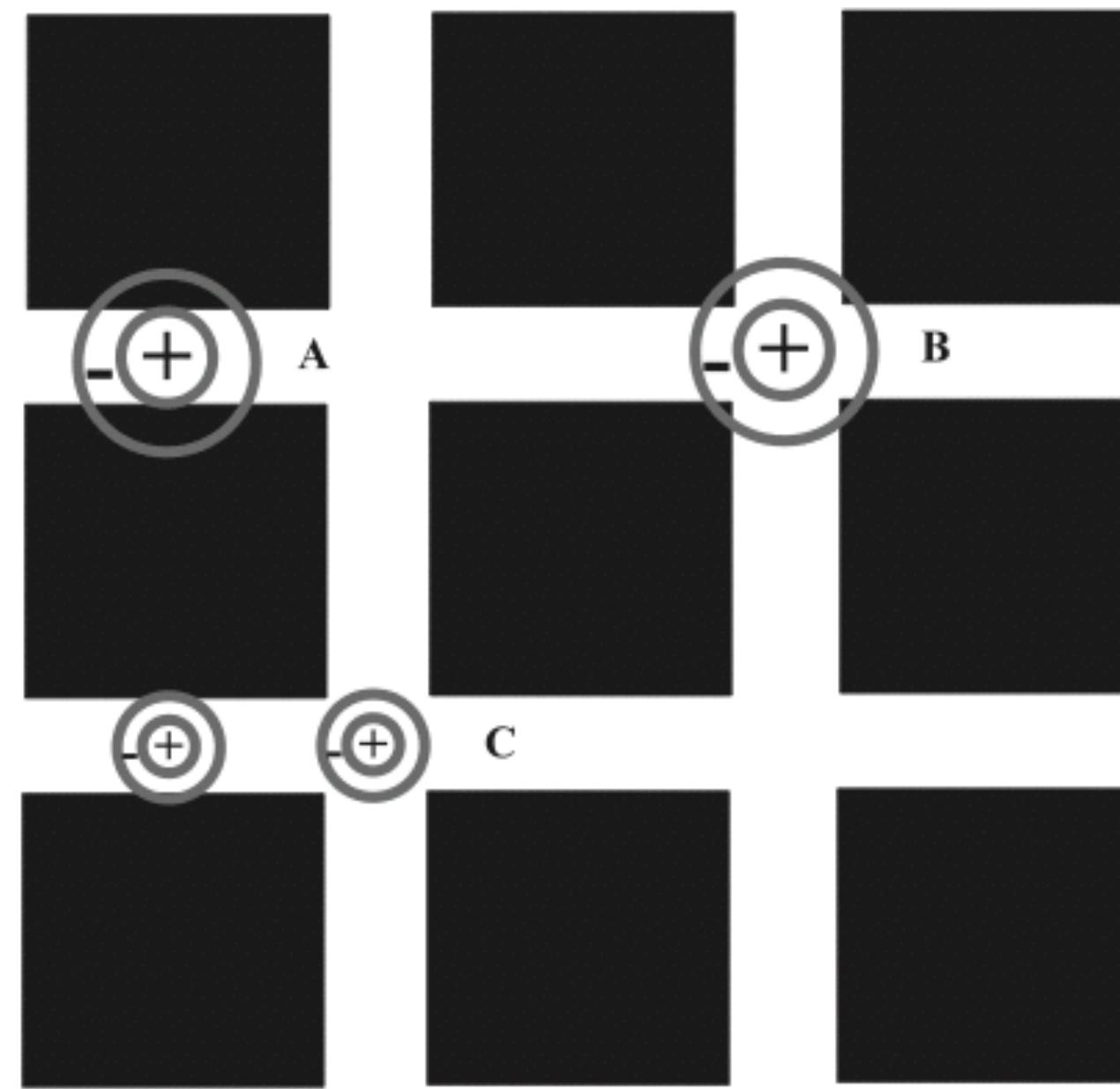


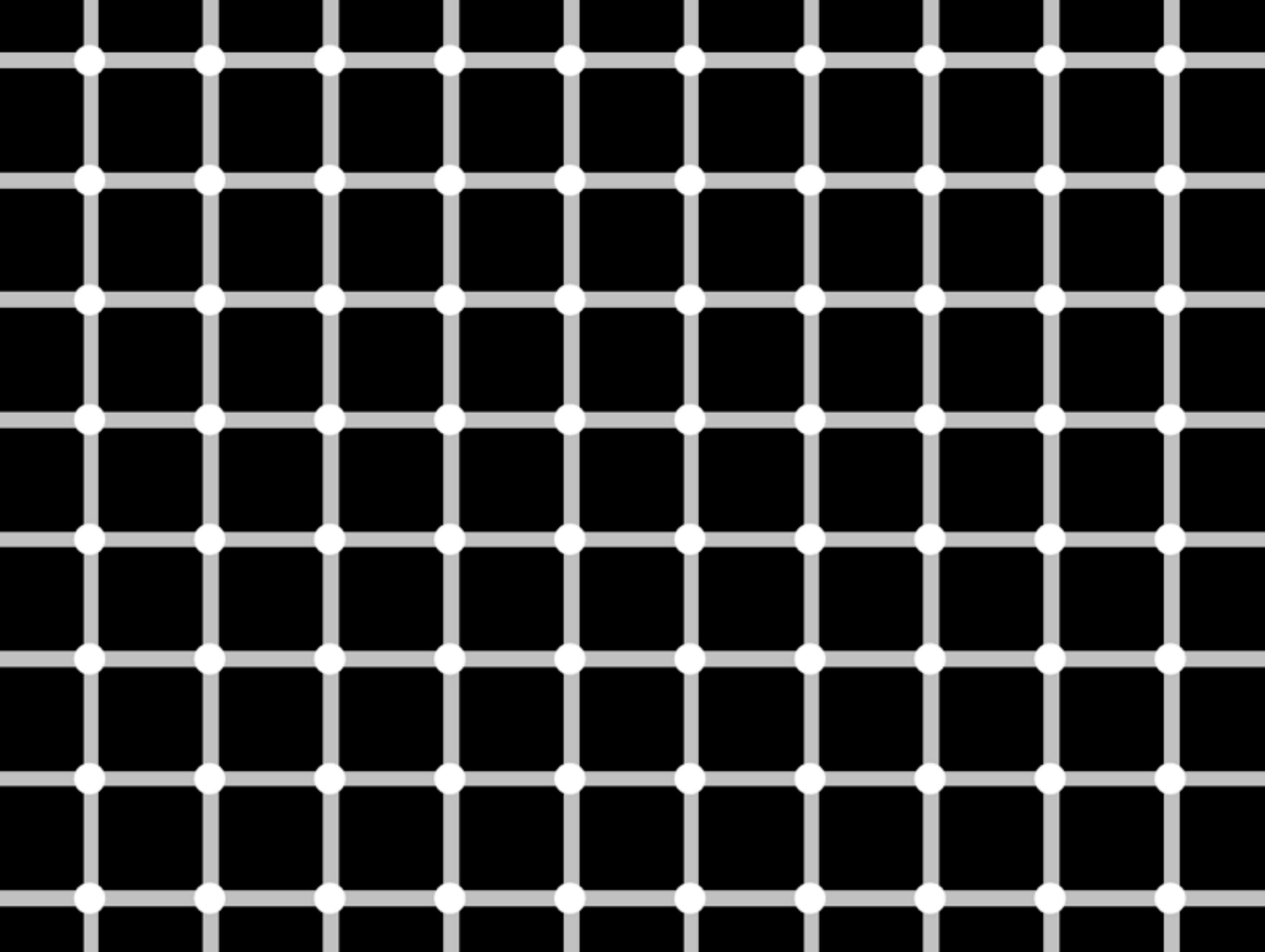
luminance L

$$\frac{dL}{dx}$$



HERMANN GRID EFFECT

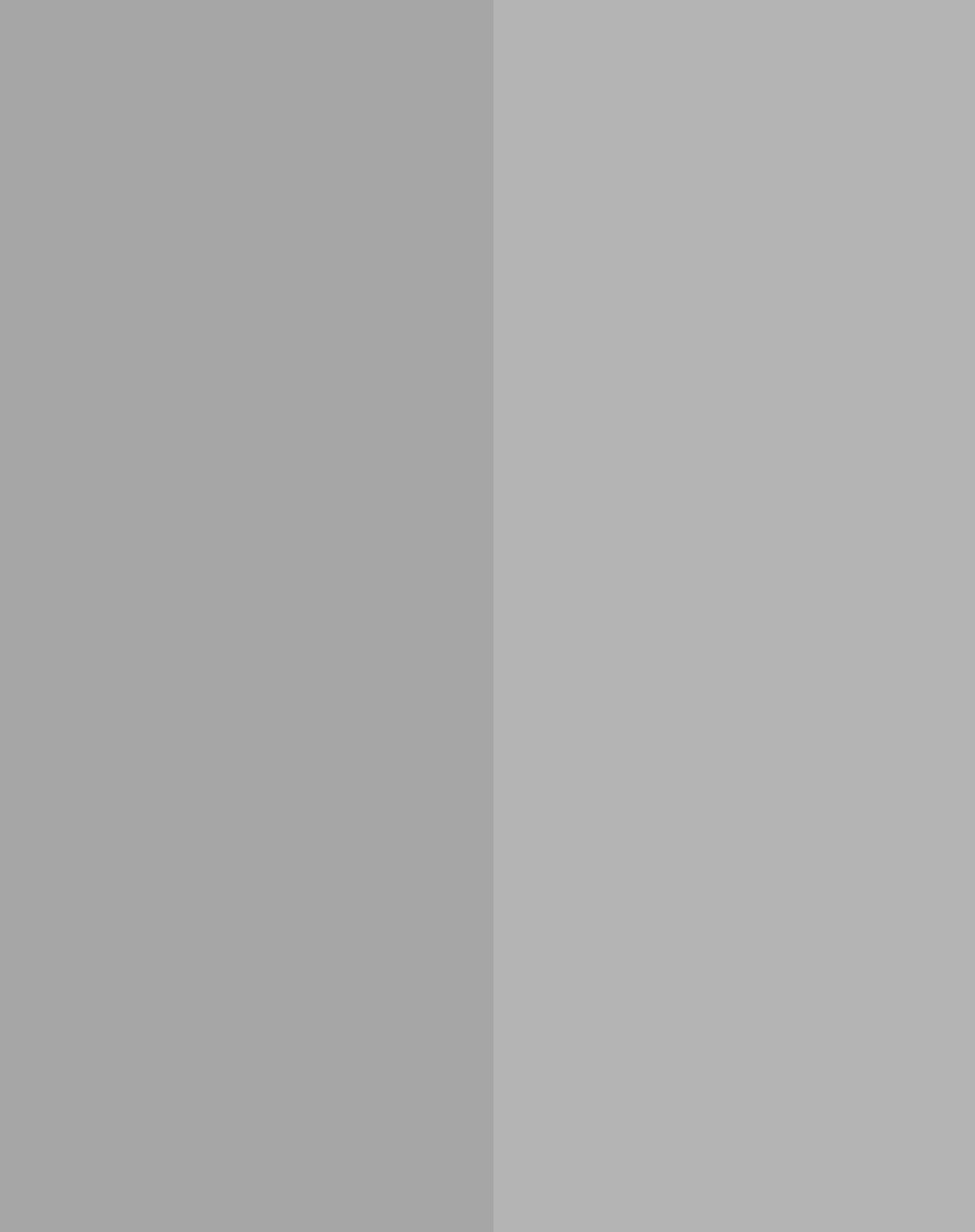




CONSEQUENCES OF EDGE EXTRACTION



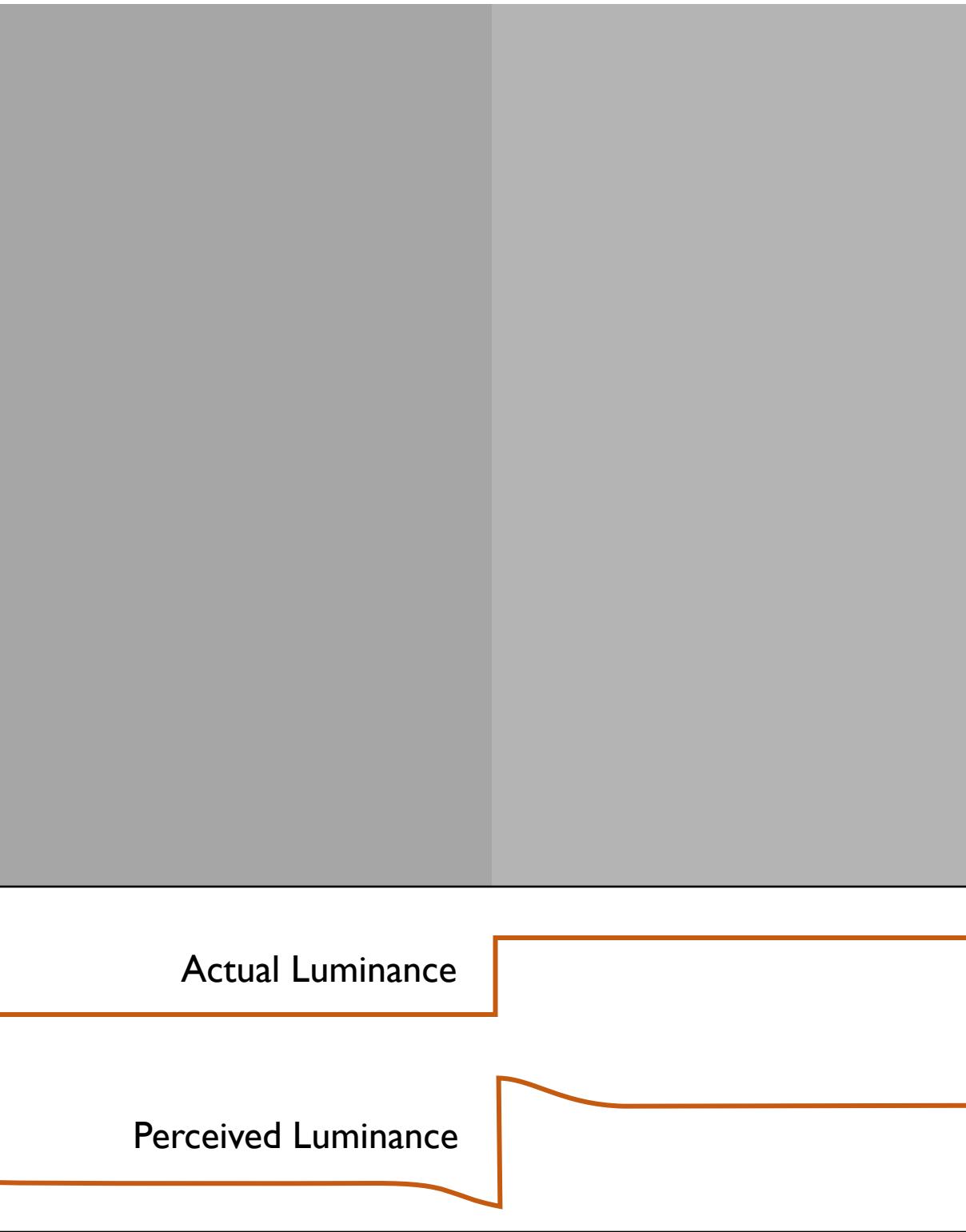
CORNSWEET ILLUSION



CORNSWEET ILLUSION



CORNSWEET ILLUSION



CORNSWEET ILLUSION



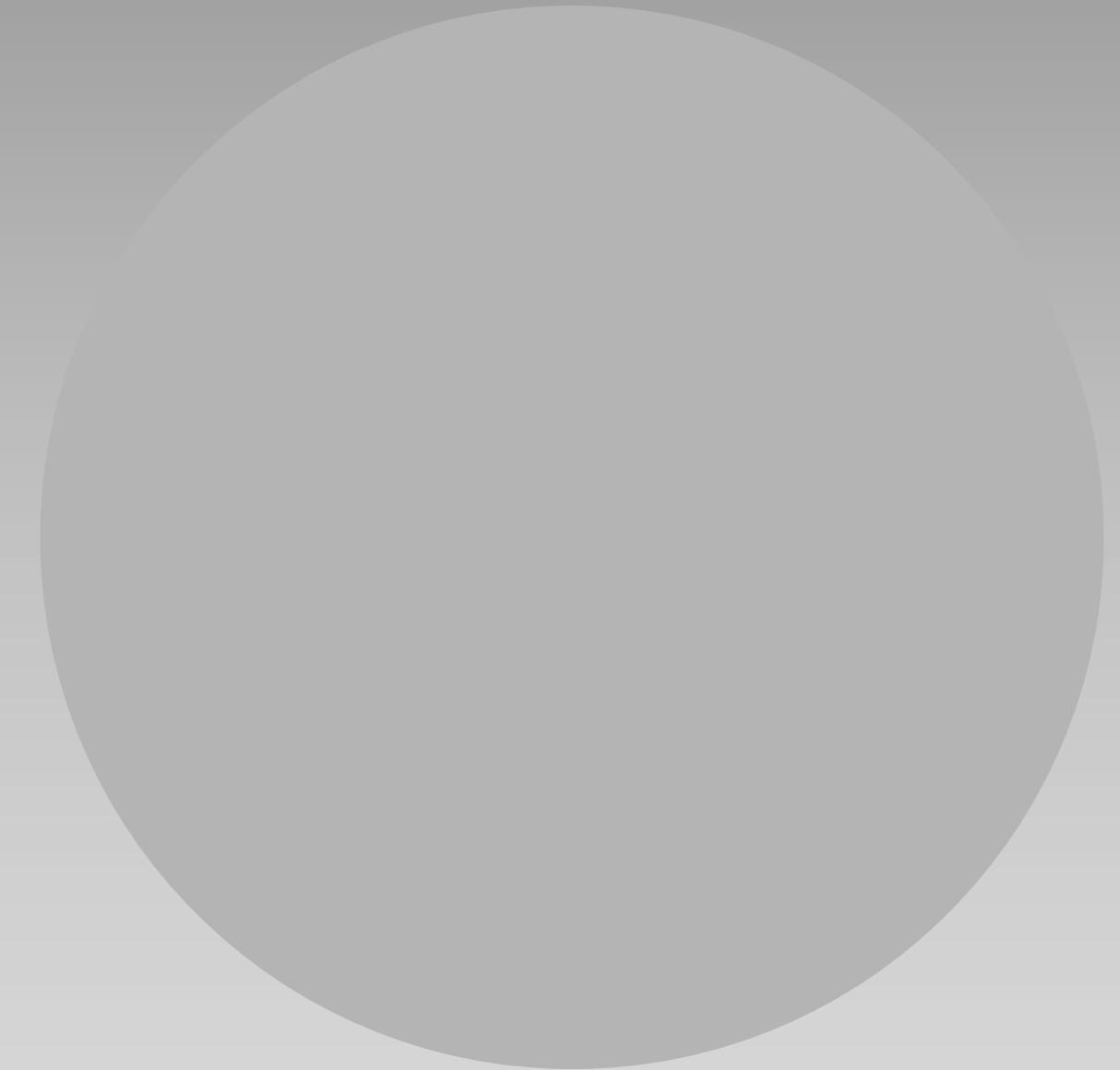
D. PURVES AND R. B. LOTTO



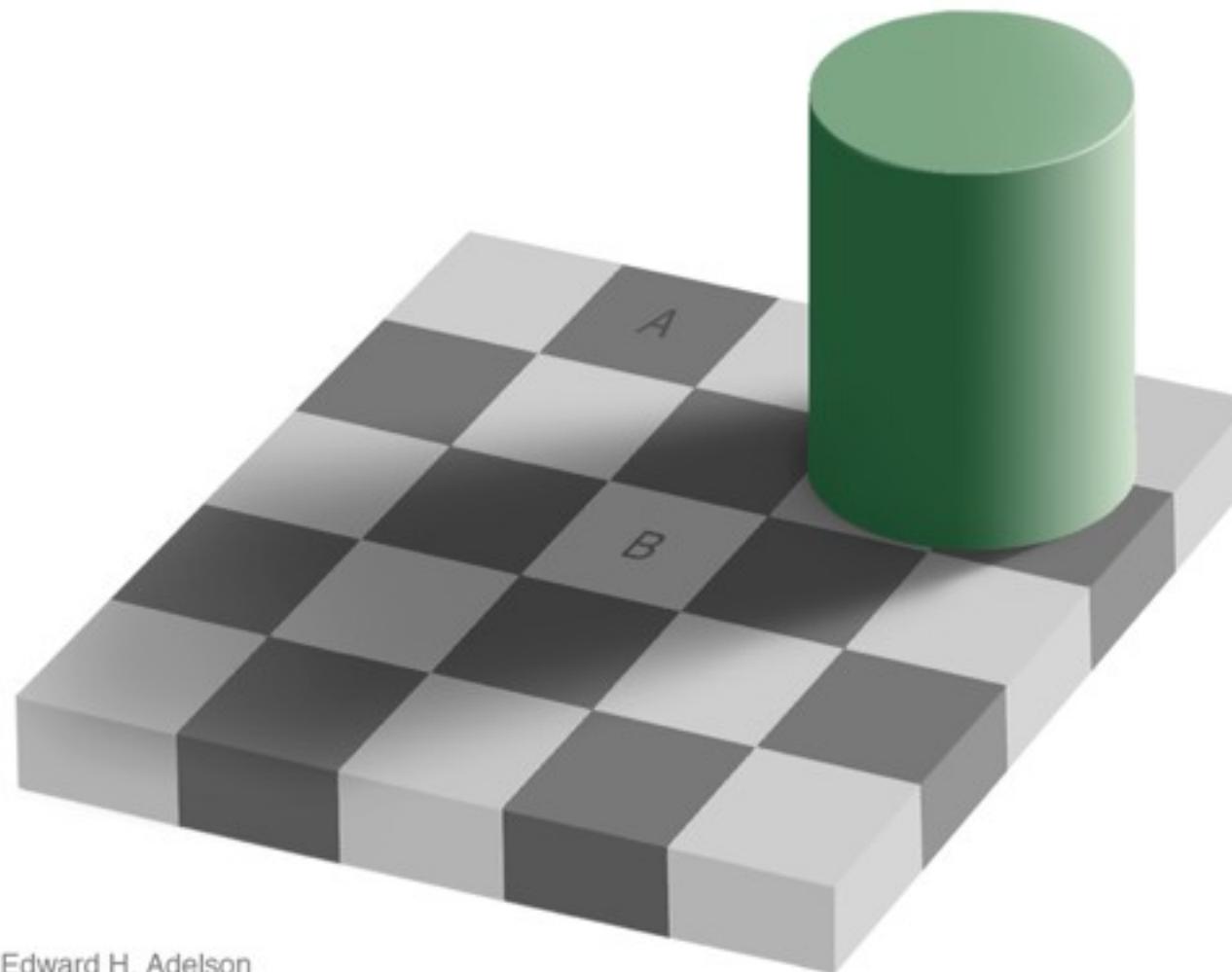
MACH BANDING



SIMULTANEOUS CONTRAST



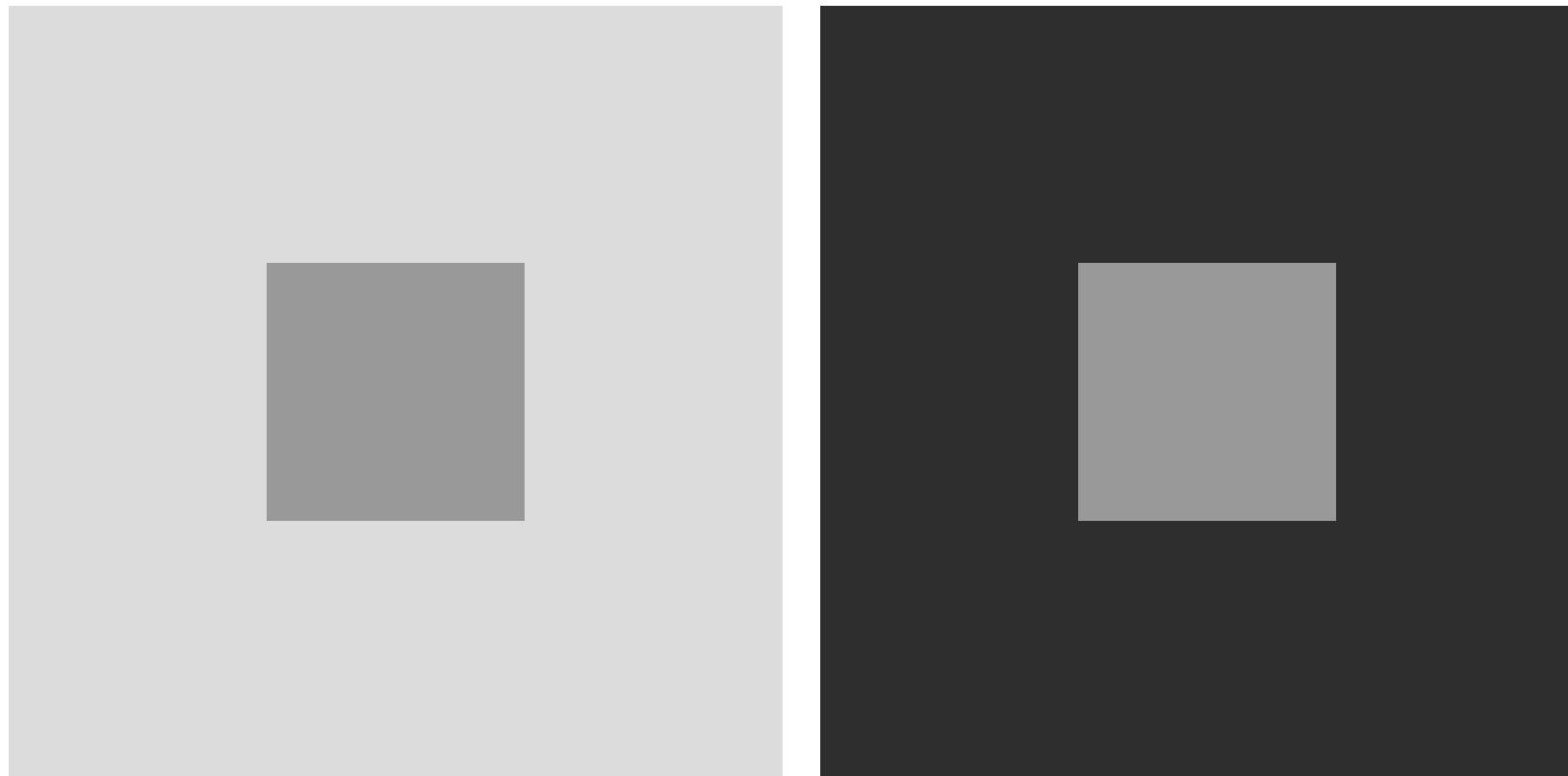
SIMULTANEOUS CONTRAST



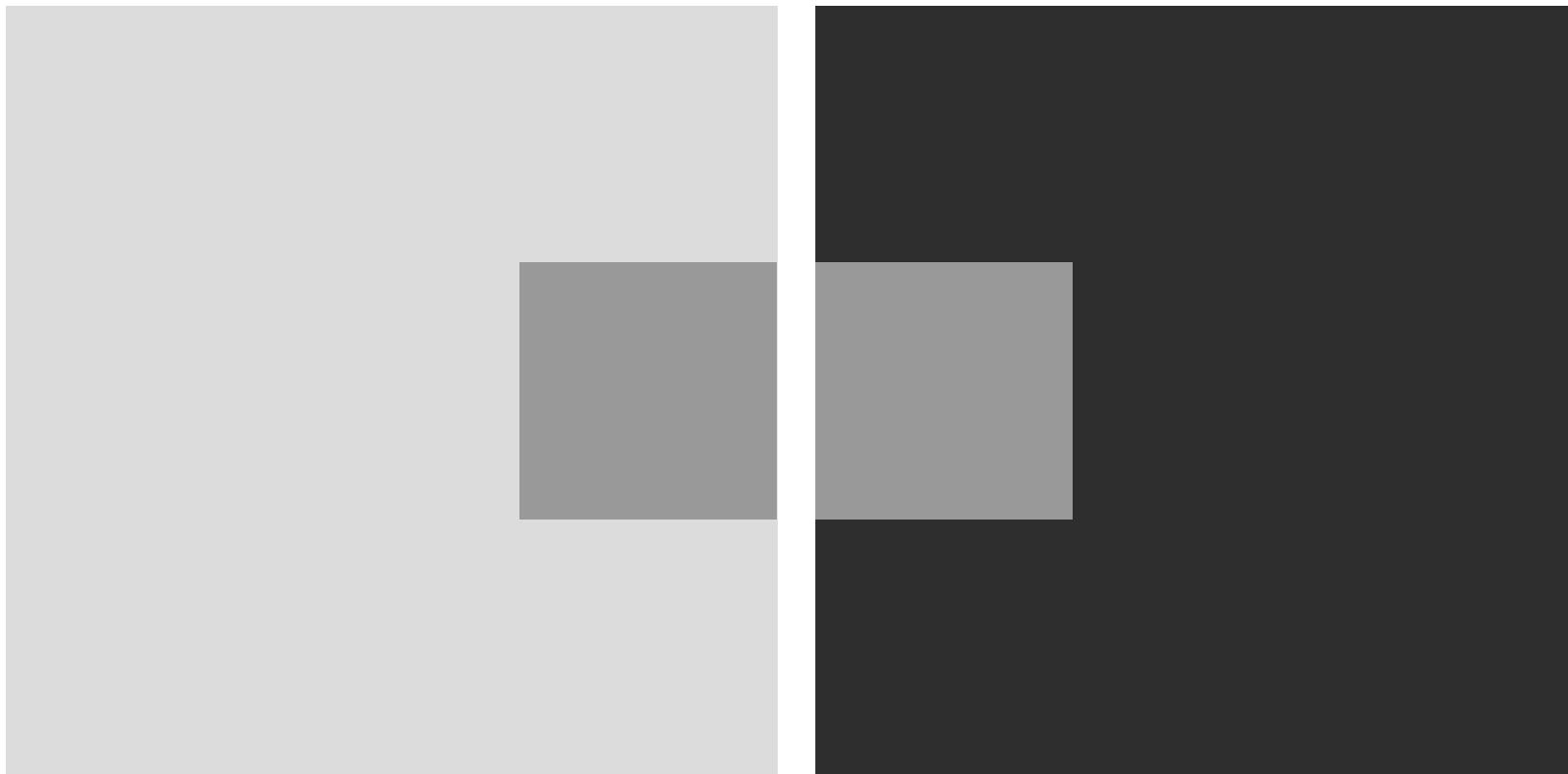
Edward H. Adelson



SIMULTANEOUS CONTRAST



SIMULTANEOUS CONTRAST



SIMULTANEOUS CONTRAST



TAKEAWAY

Our visual system is attracted to edges and is sensitive to differences, not absolute values.

Maximize the contrast with the background if the outlines of shapes are important.



WEBER'S LAW

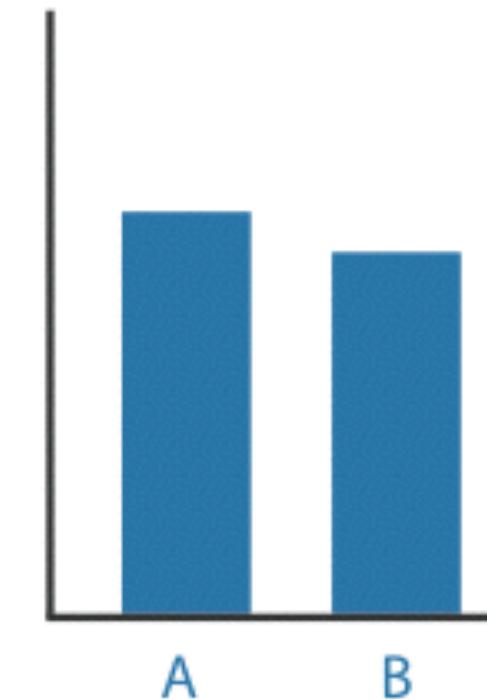
we judge based on relative, not absolute,
differences



Unframed
Unaligned



Framed
Unaligned



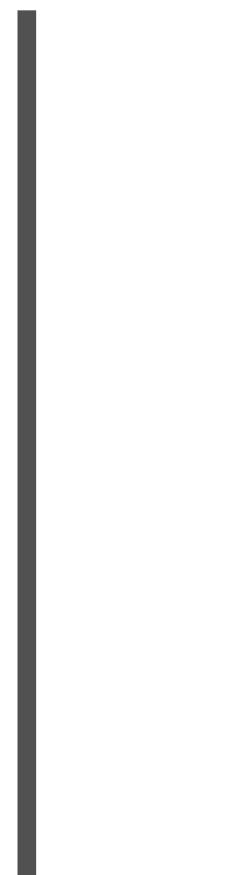
Unframed
Aligned



AXIS OF ALIGNMENT



AXIS OF ALIGNMENT



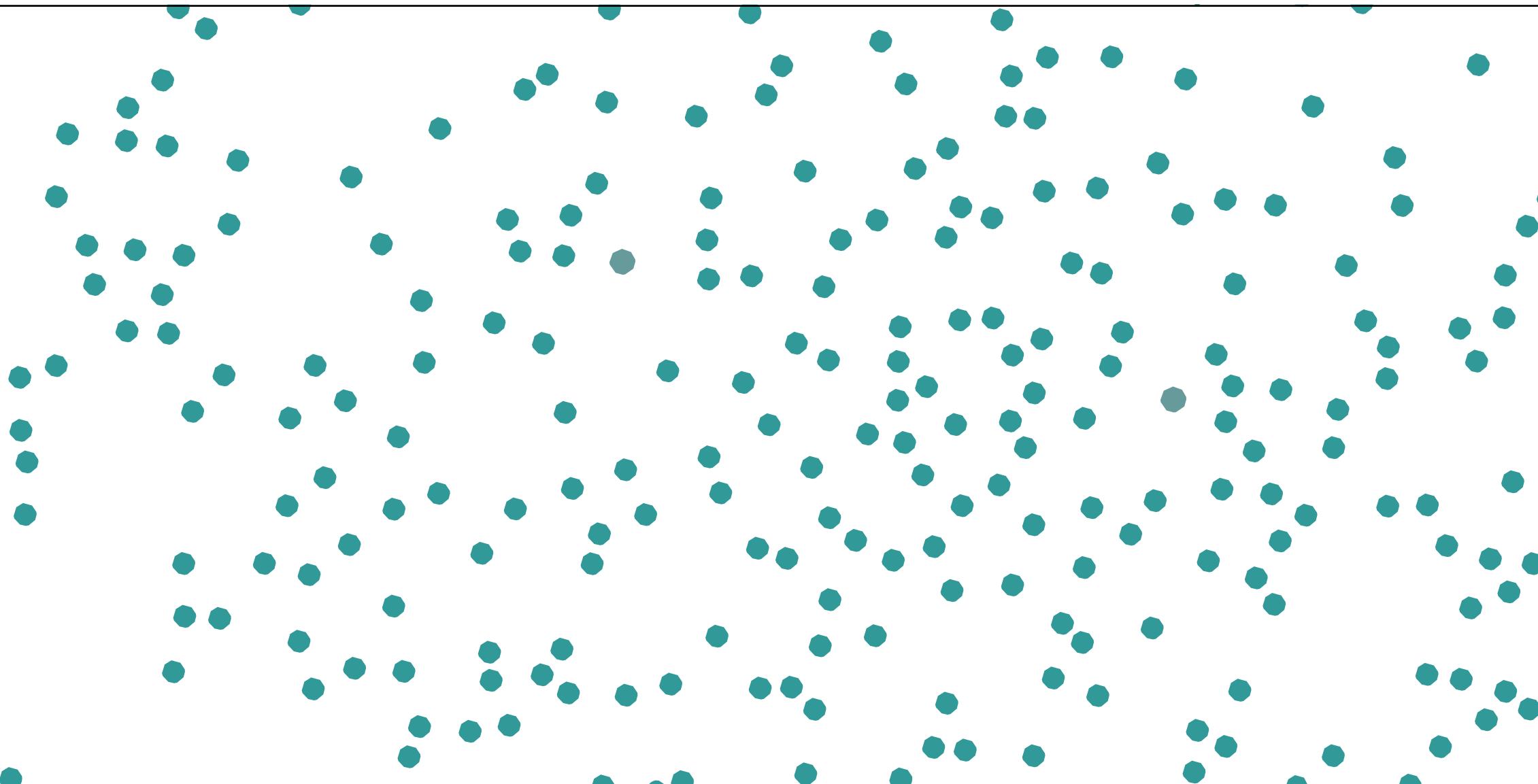
TAKEAWAY

We have a strong propensity to assume our judgments are absolute, when in fact they are generally relative to the local context.

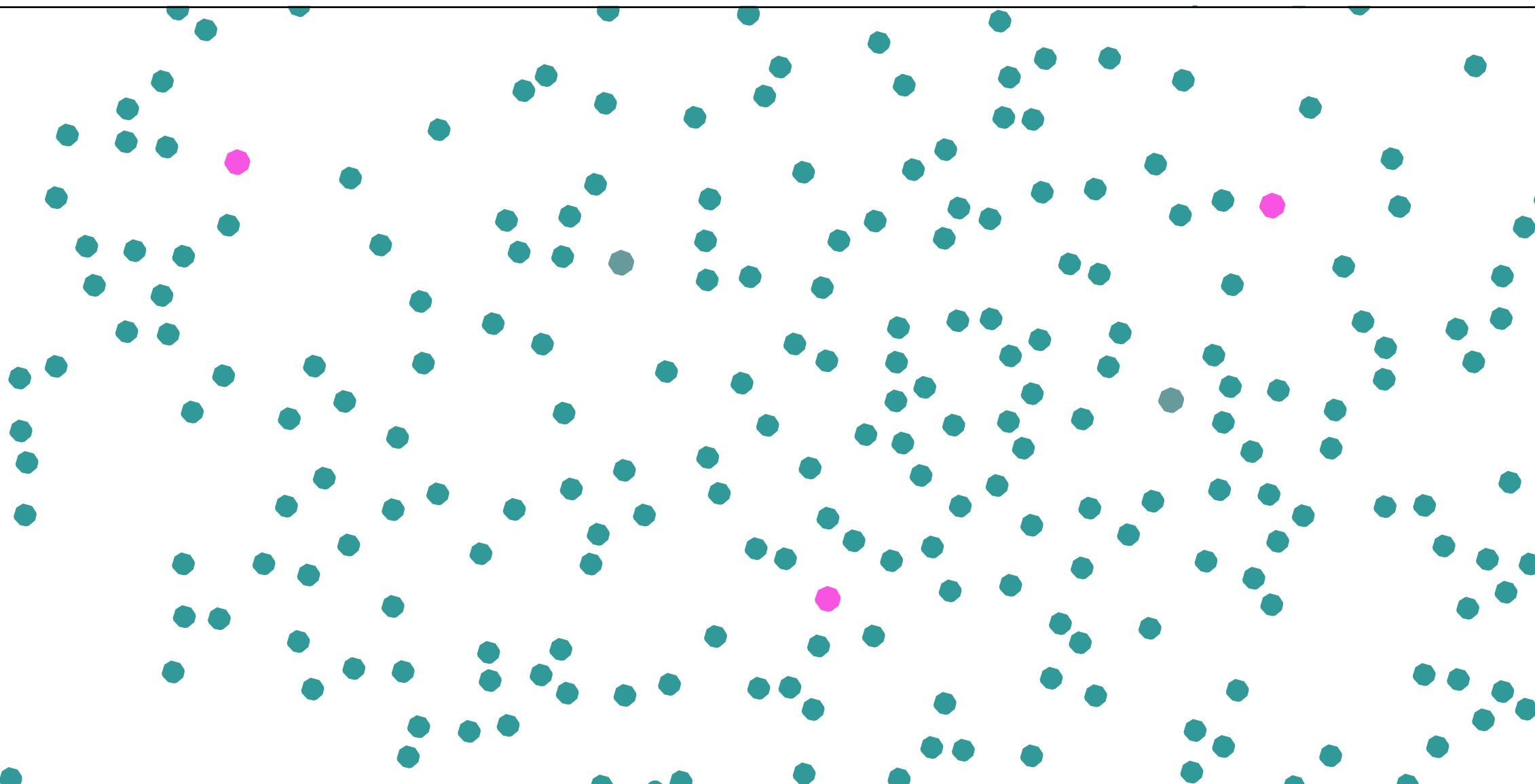
Do your best to not place data in difficult contexts. Choose position and orientation of objects carefully.



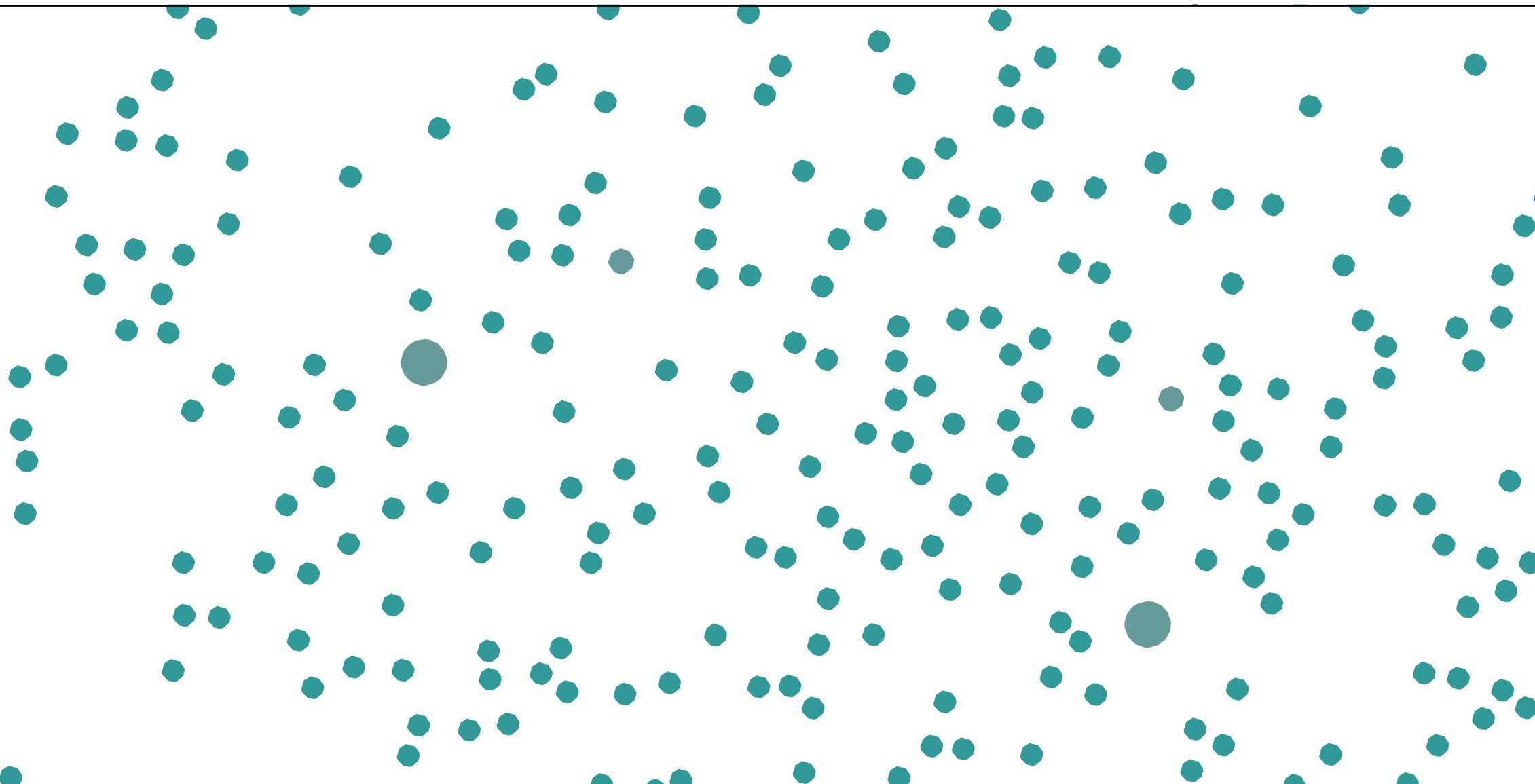
POPOUT



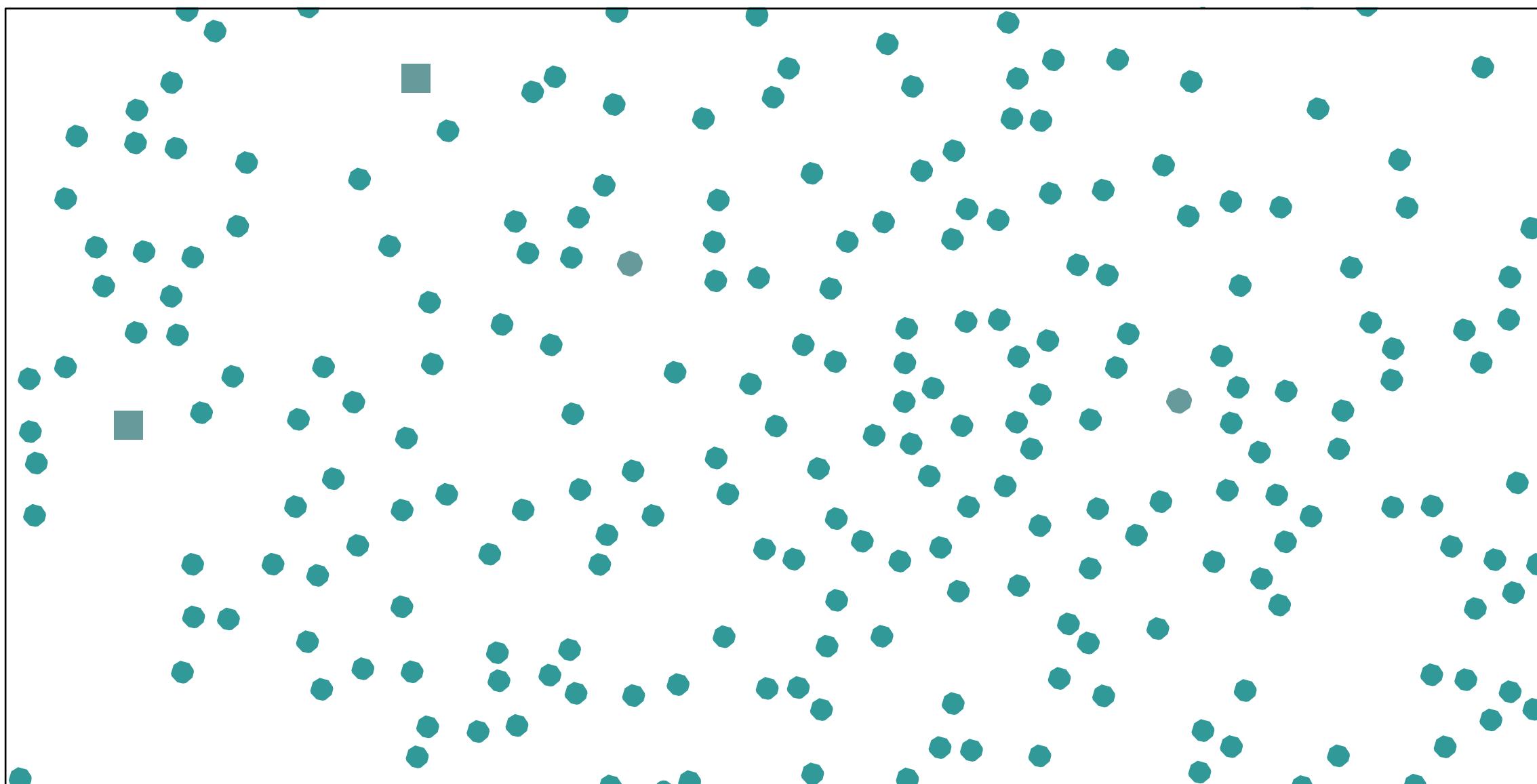
POPOUT



POPOUT



POPOUT



PRE-ATTENTIVE PROCESSING

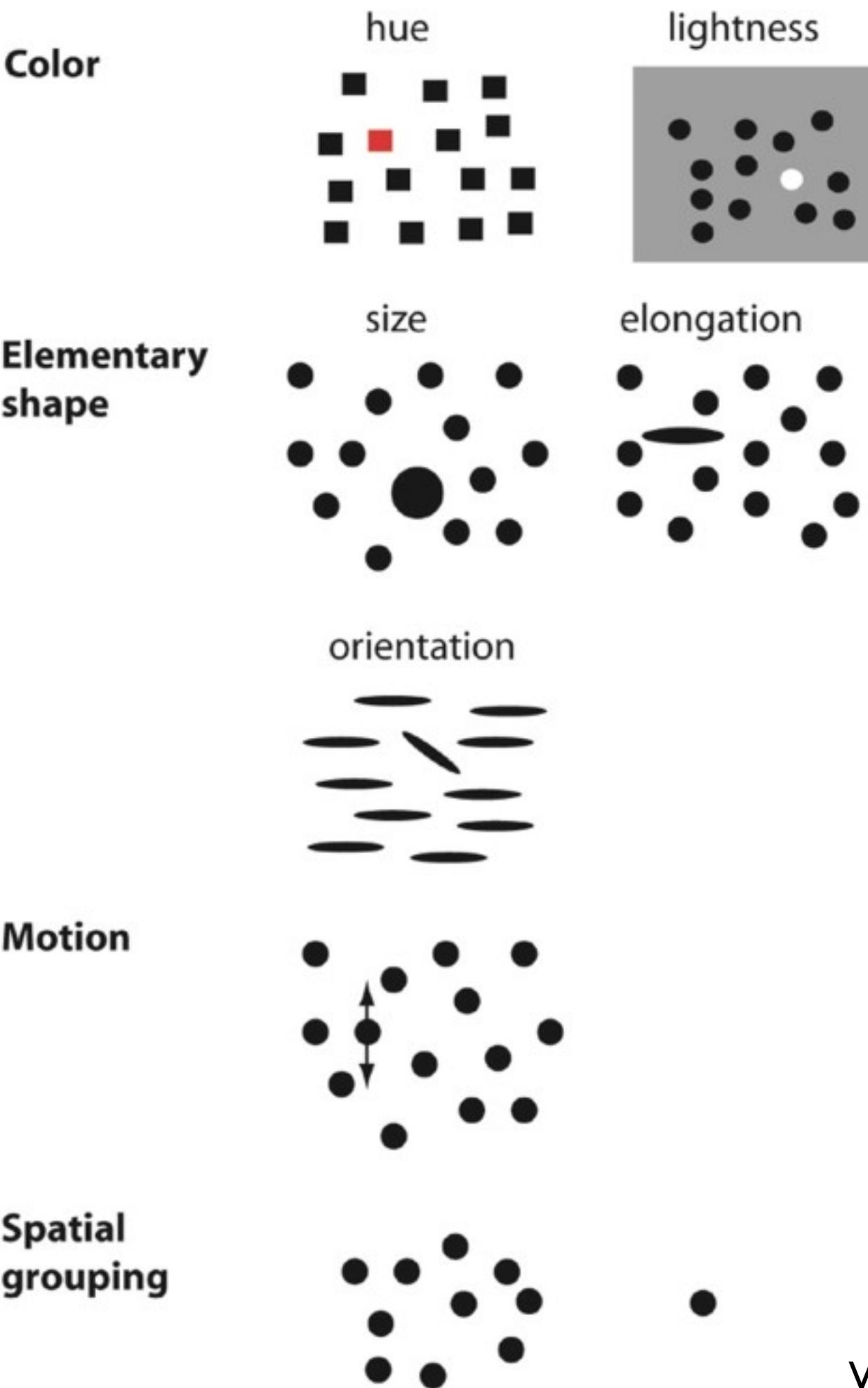
requires attention, despite name

very fast: <200 ms

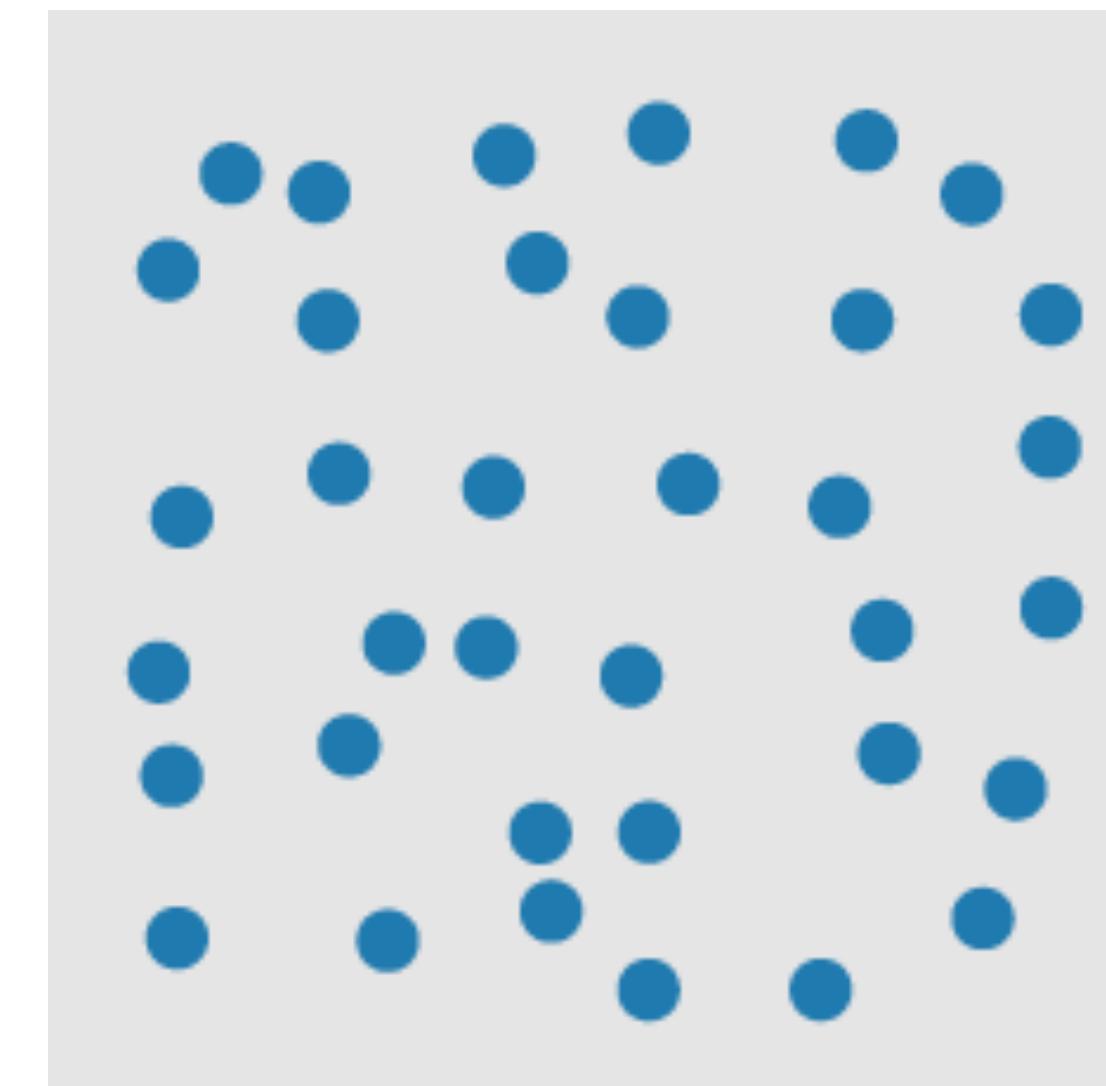
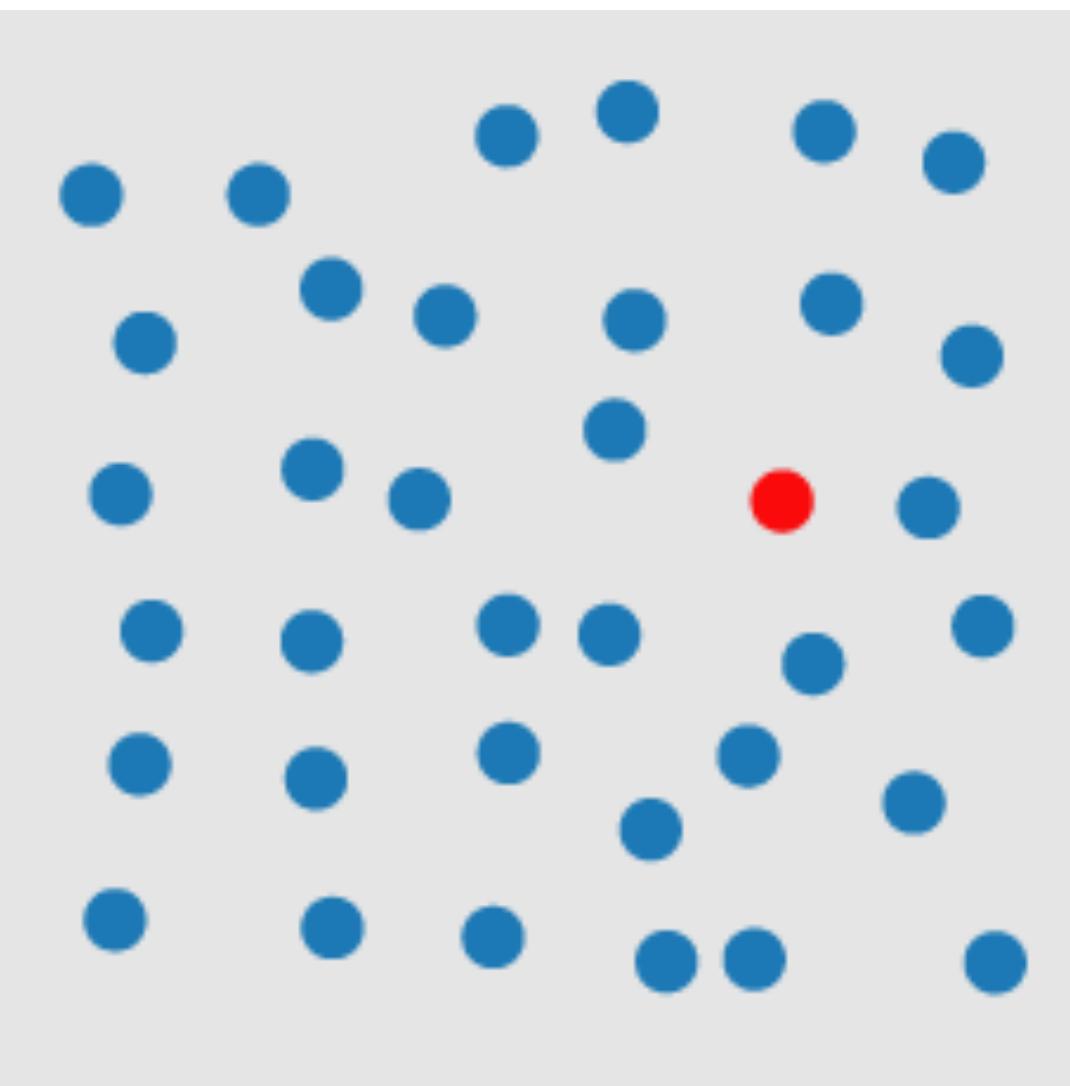
what matters most is contrast between
features



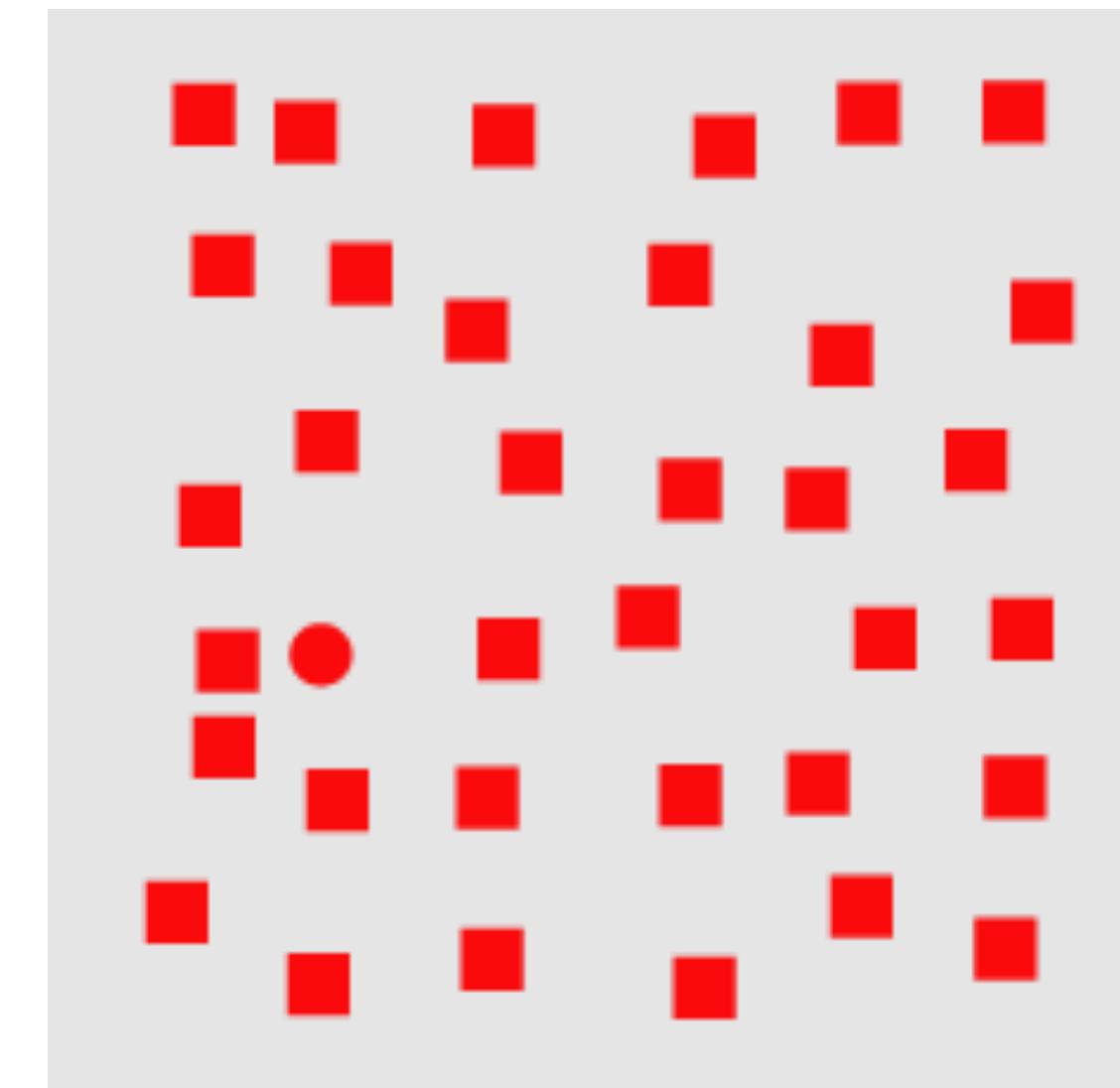
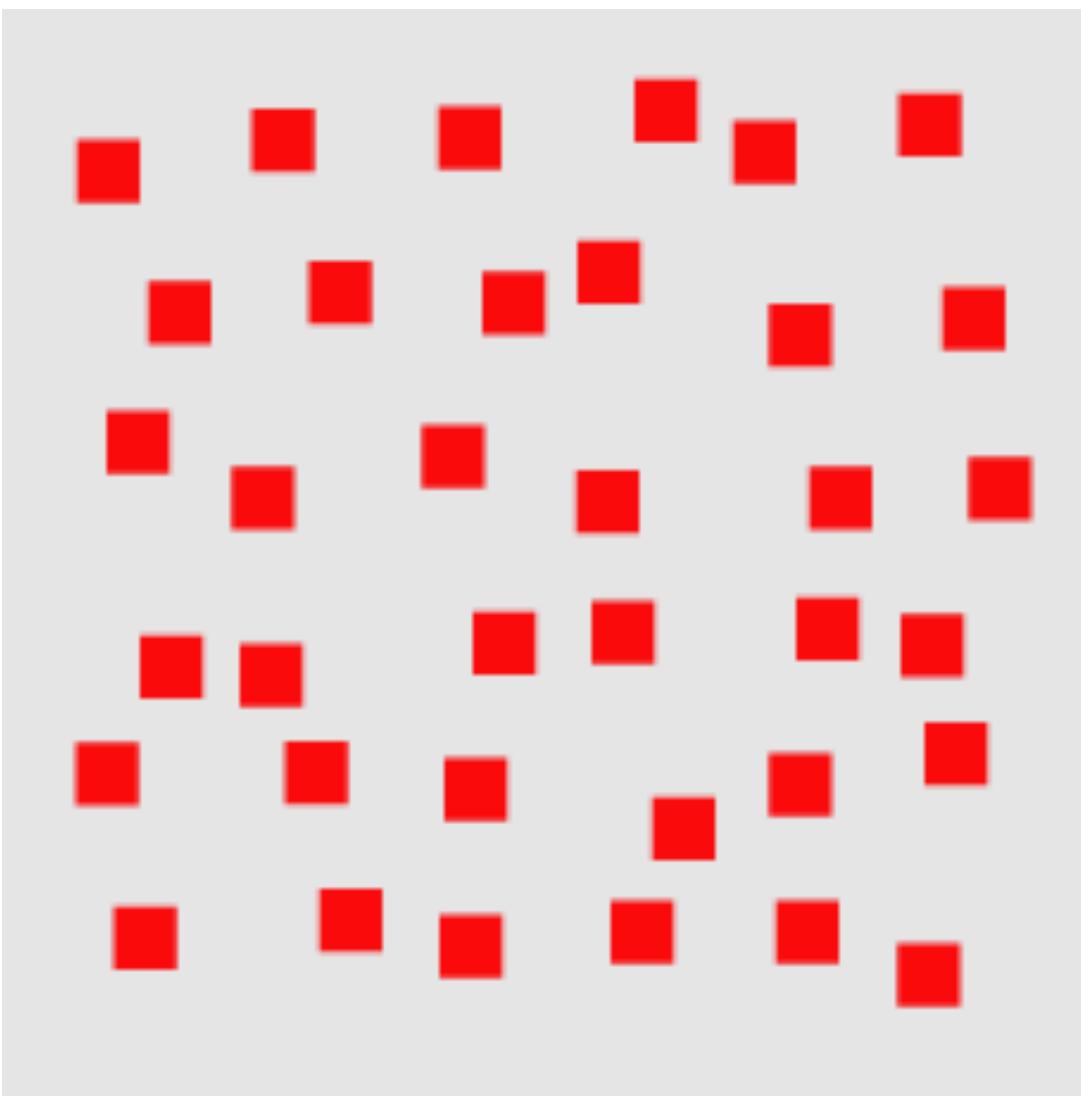
BASIC POPOUT CHANNELS



PICK THE OUTLIER

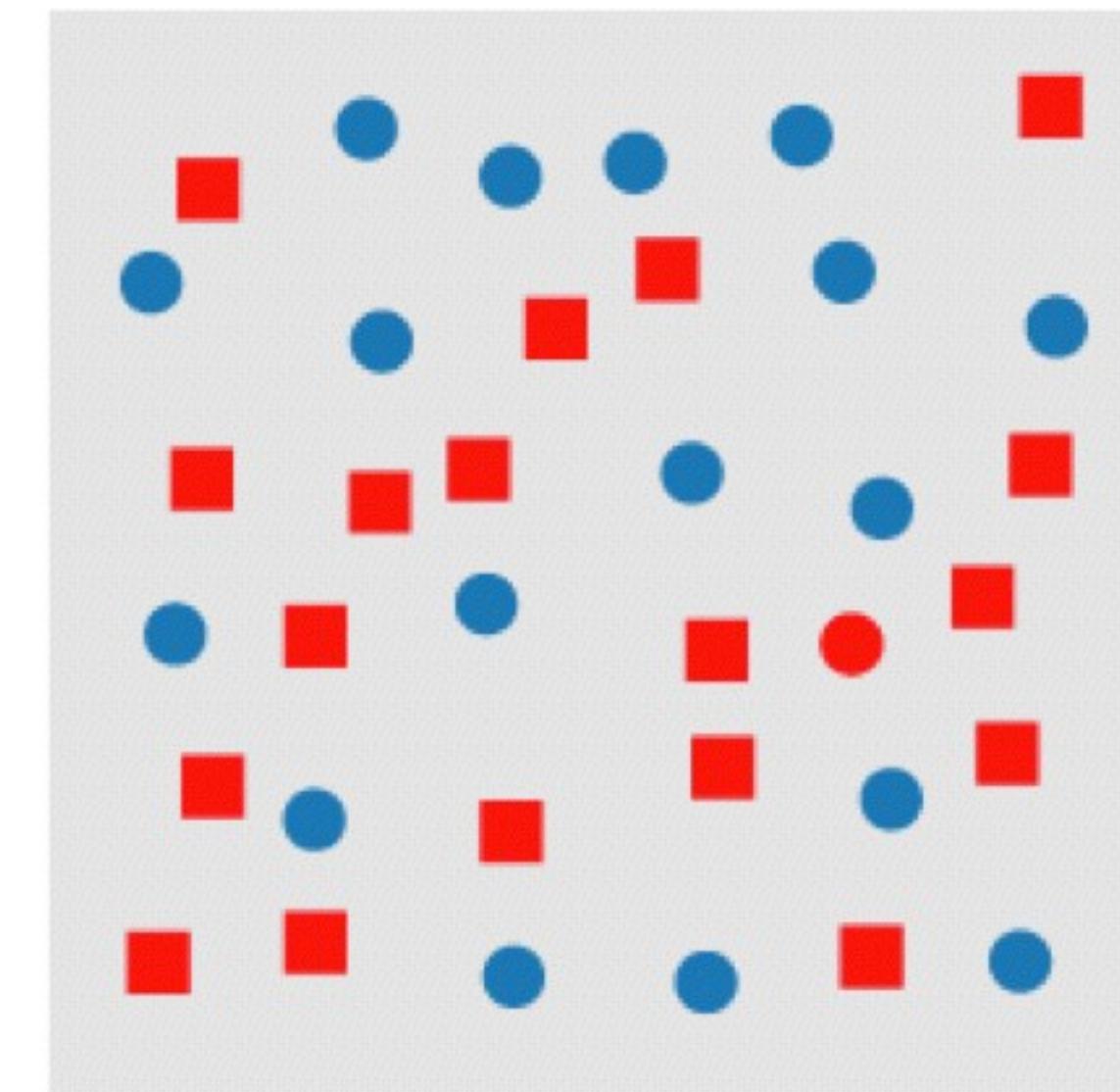
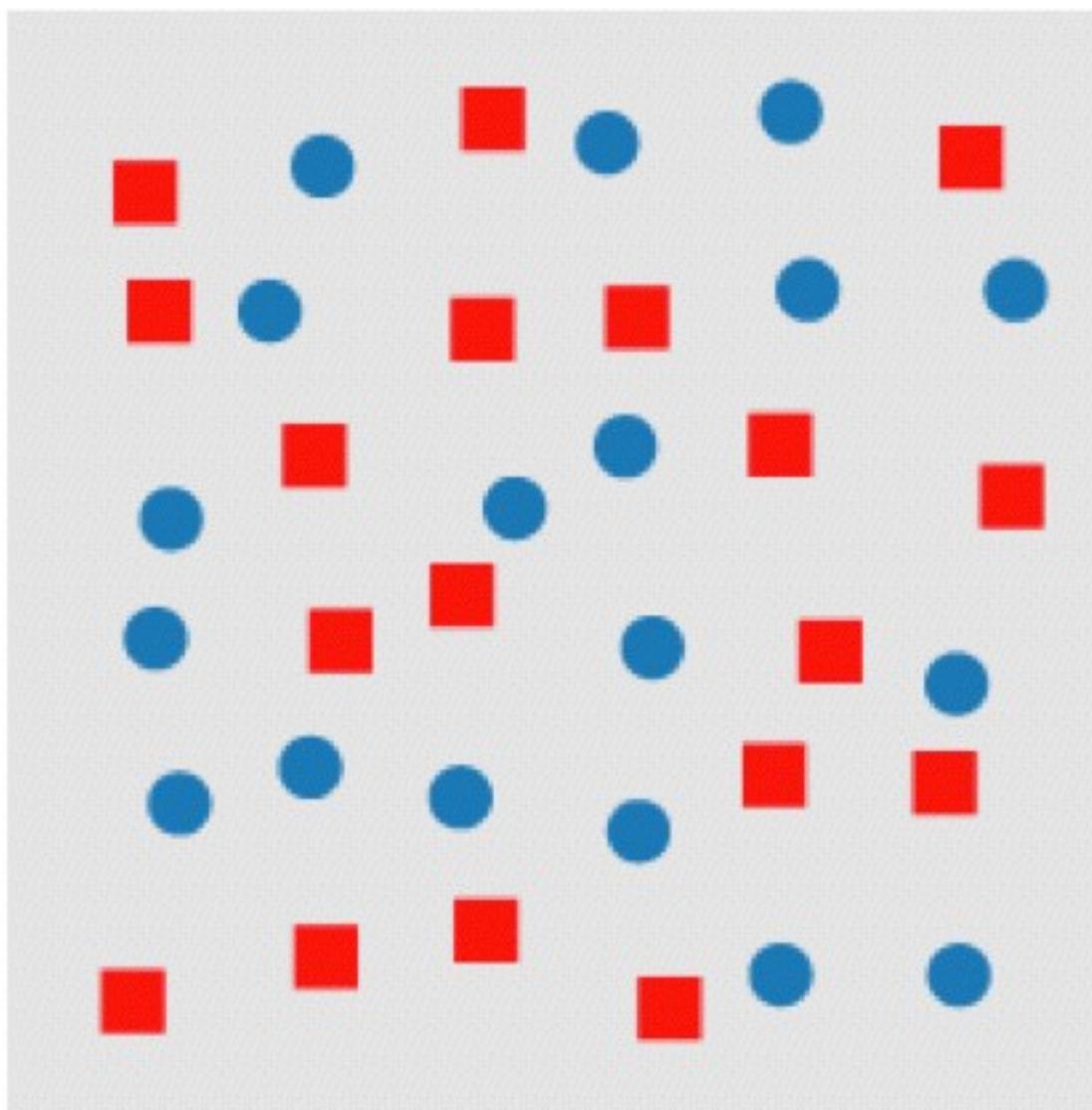


PICK THE OUTLIER



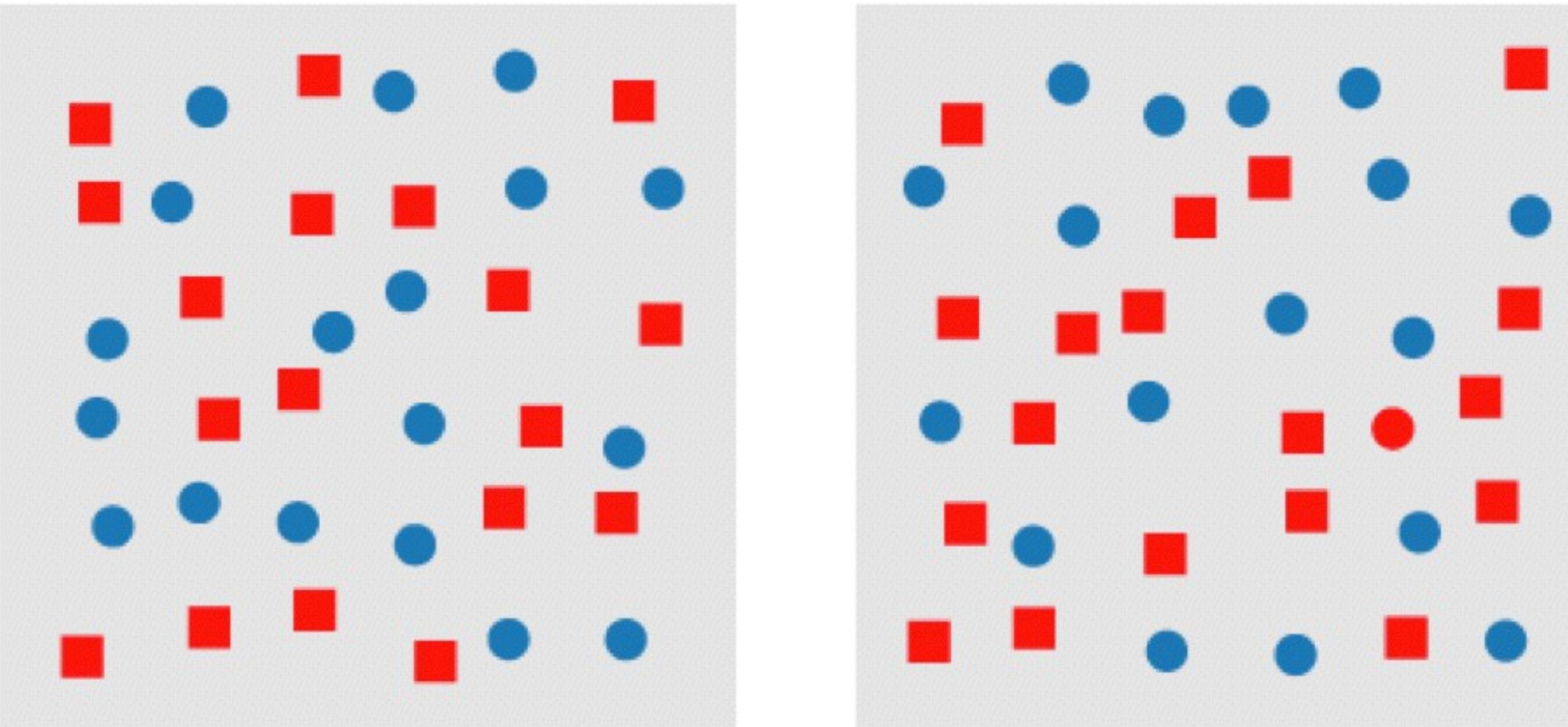
HEALY 2007

PICK THE OUTLIER



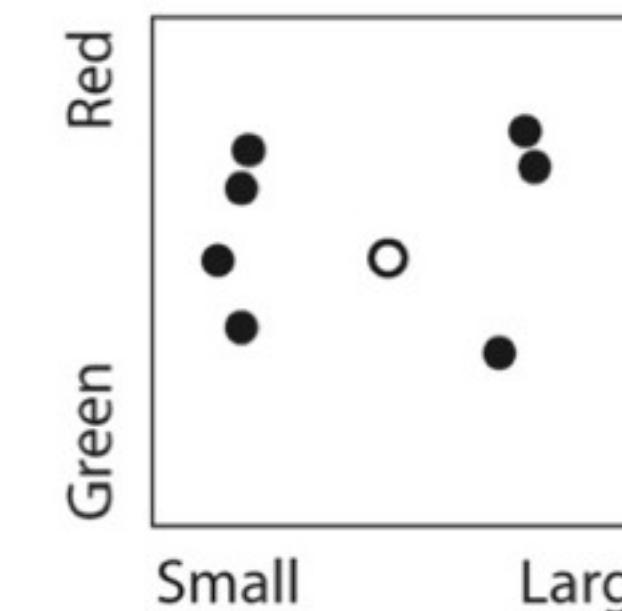
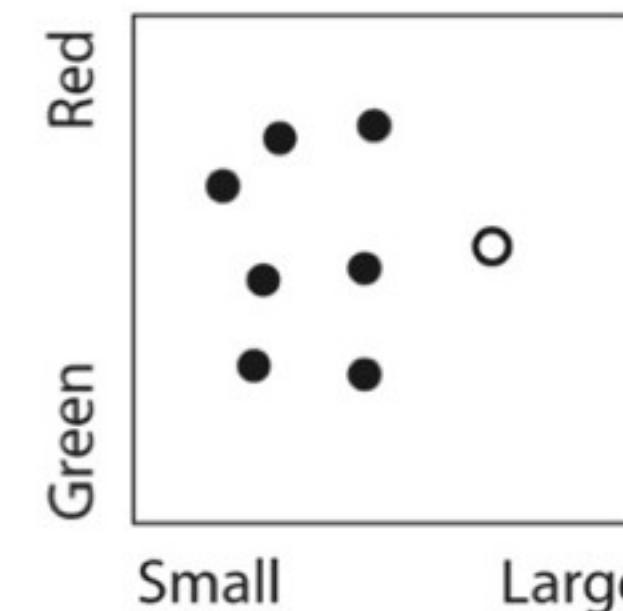
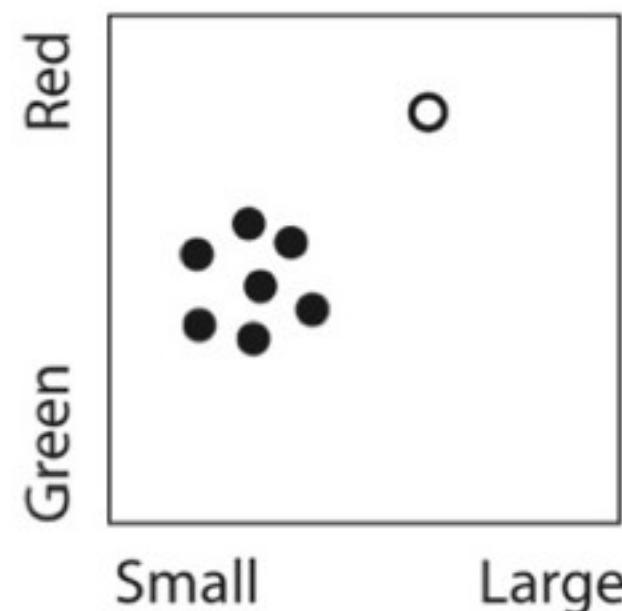
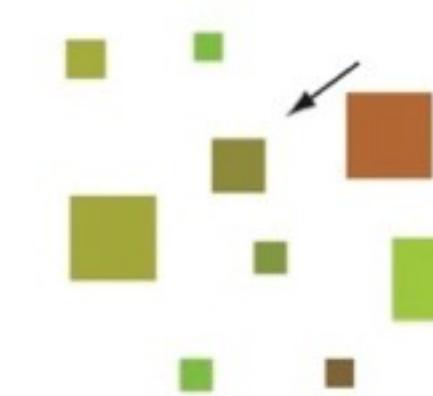
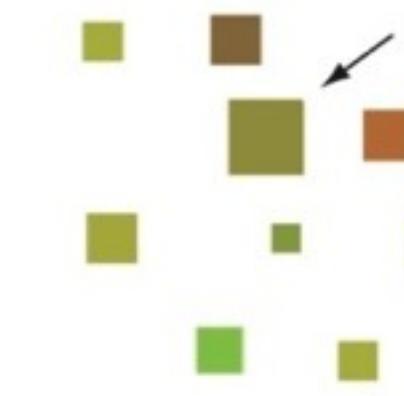
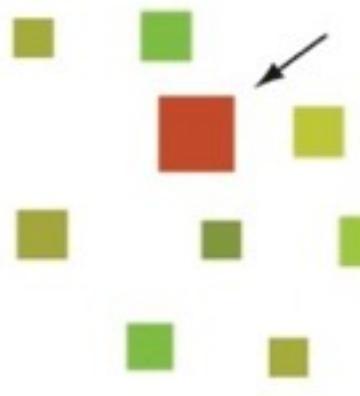
CONJUNCTION

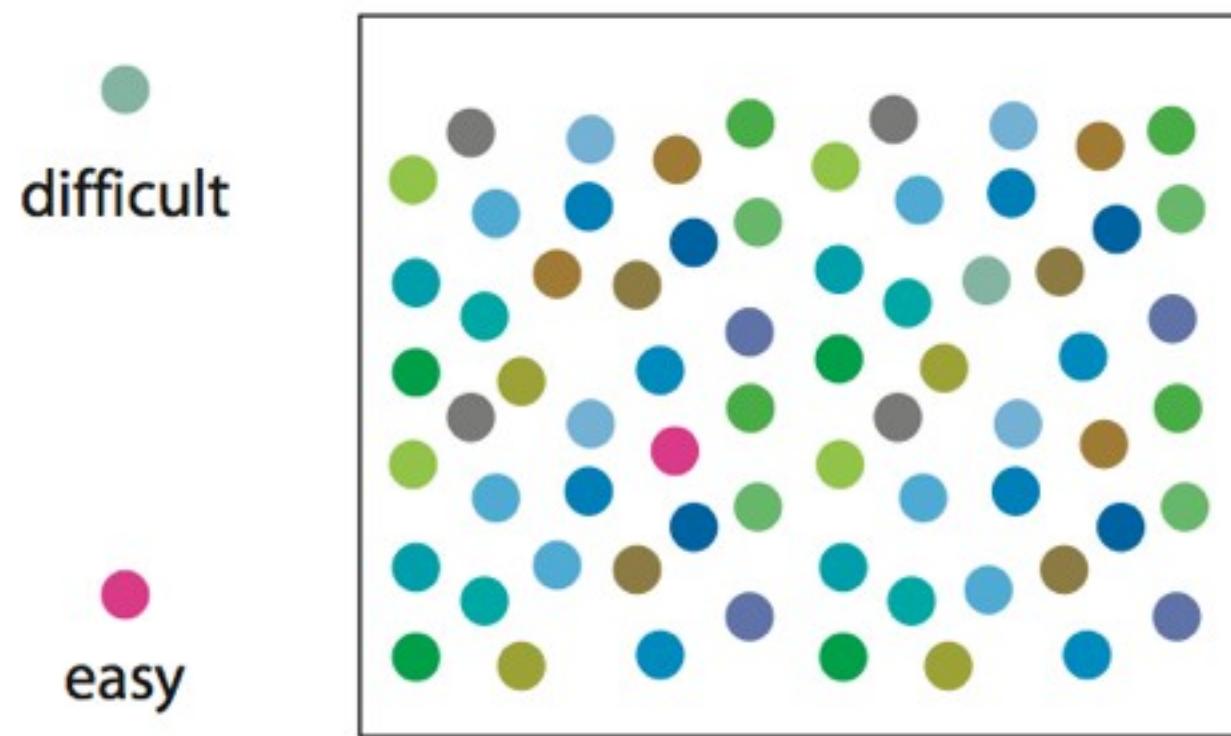
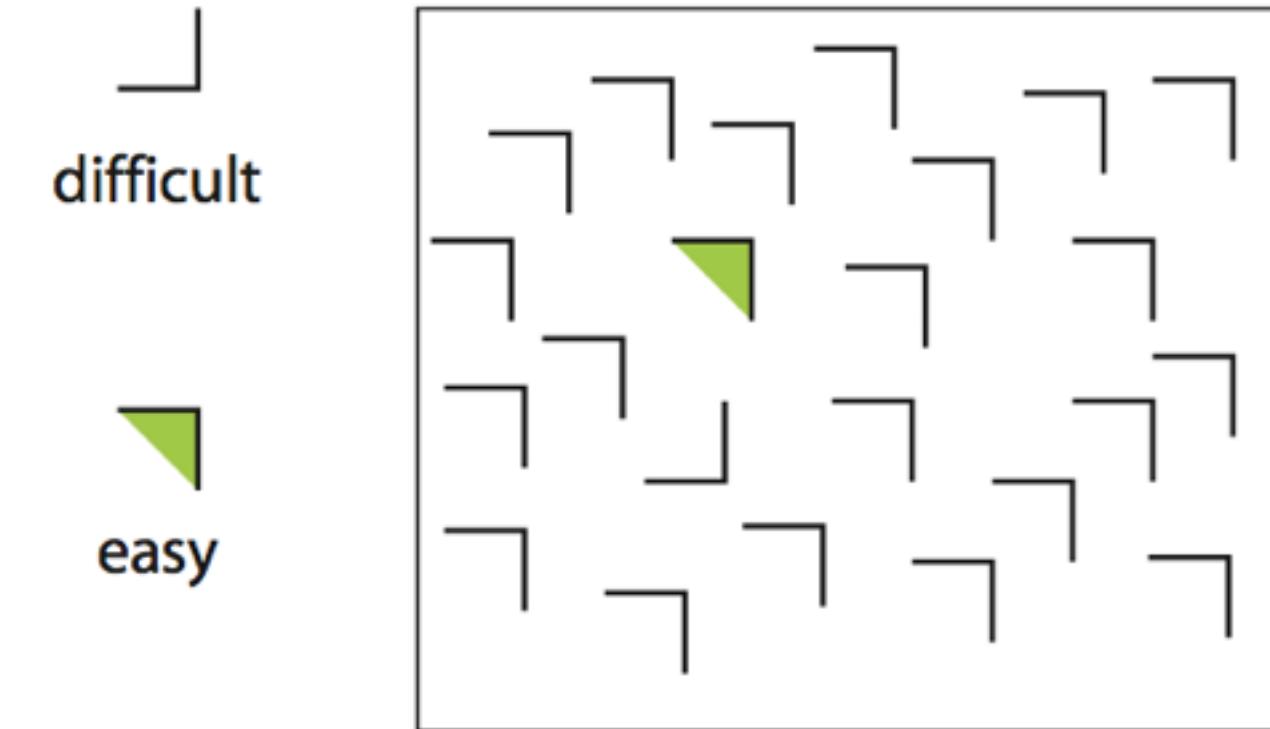
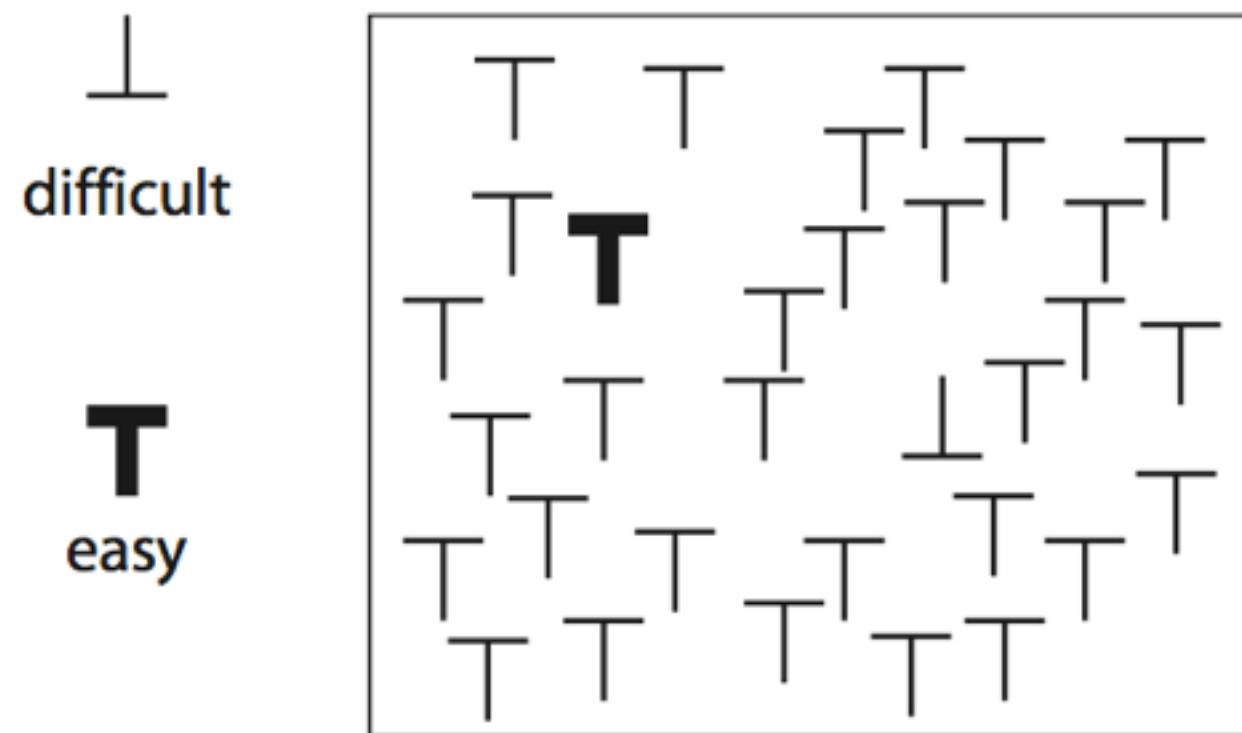
or, why to use a single channel at a time



CONJUNCTION

or, why to use a single channel at a time





TAKEAWAY

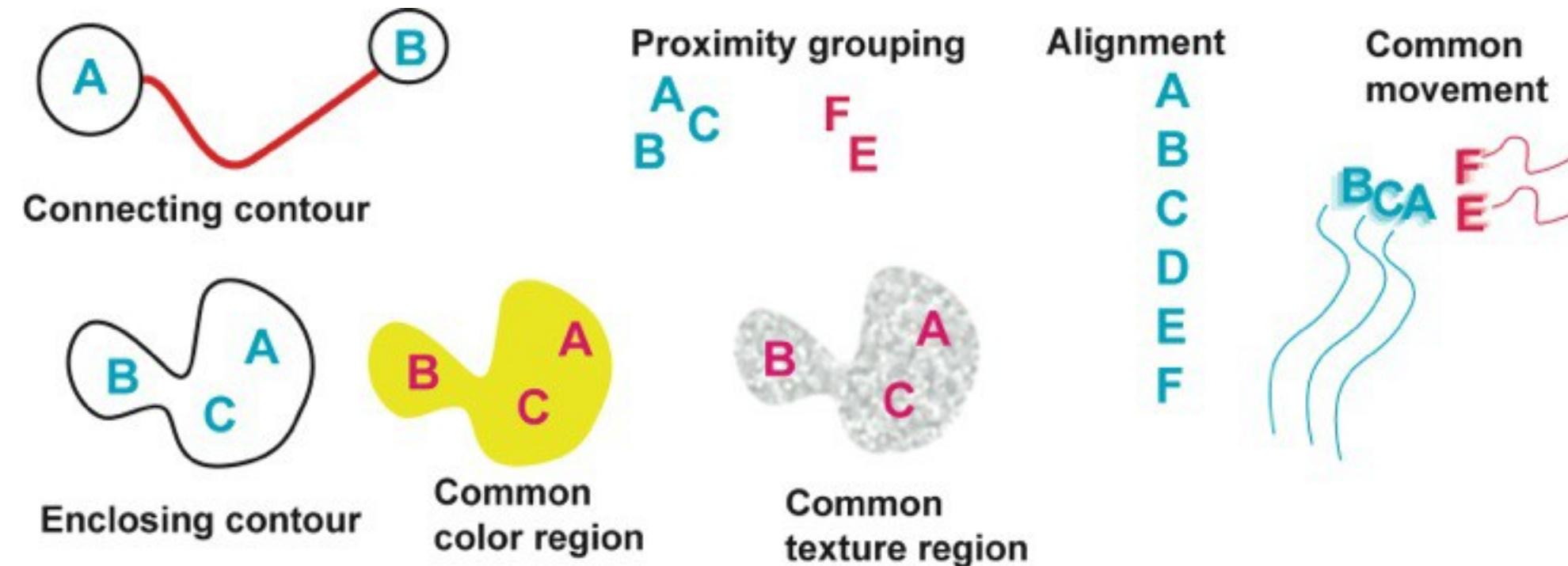
We can easily see objects that are different in color and shape, or that are in motion.

Use color and shape sparingly to make the important information pop out.

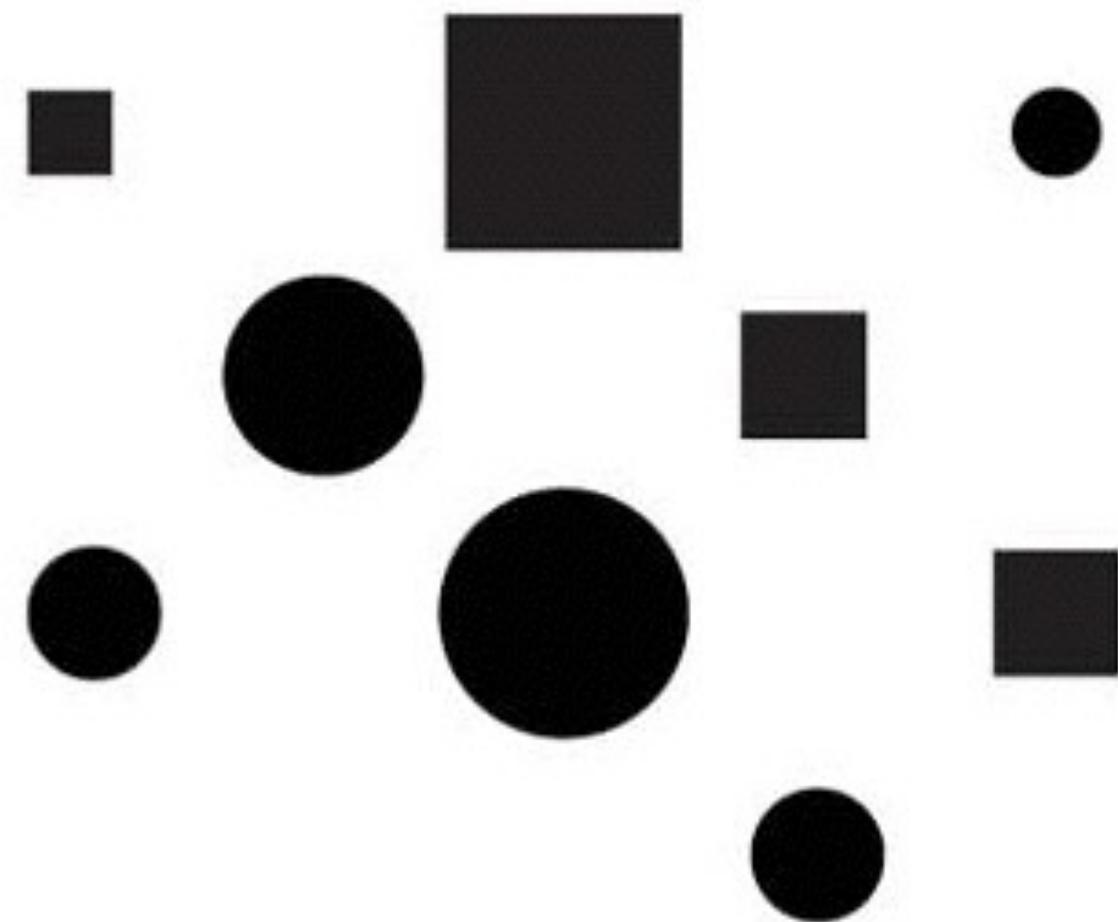


GESTALT PRINCIPLES

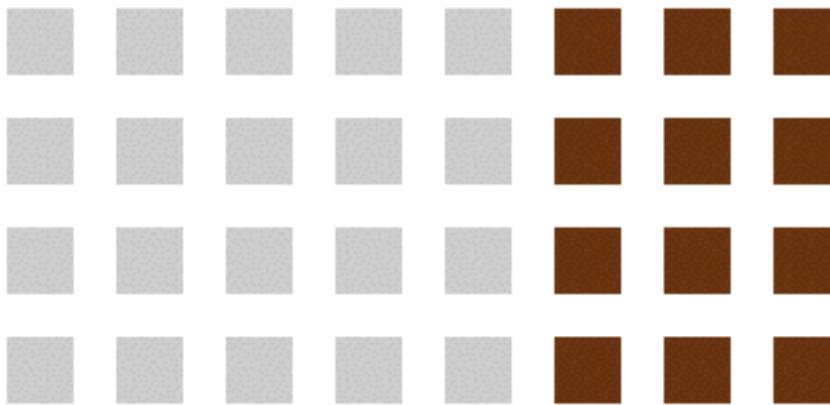
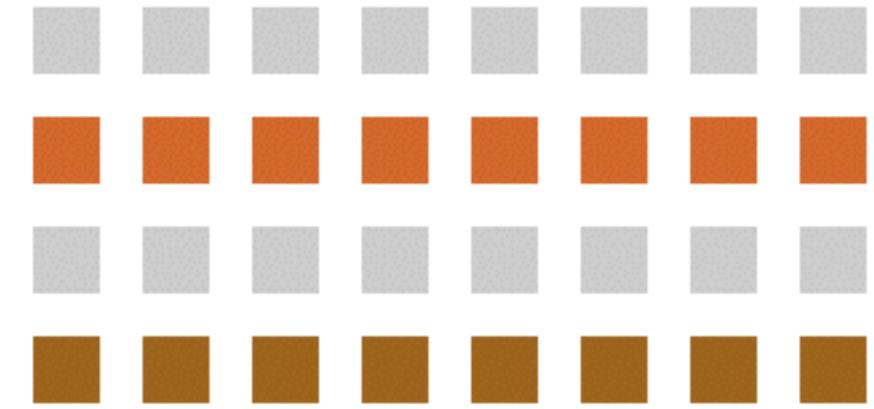
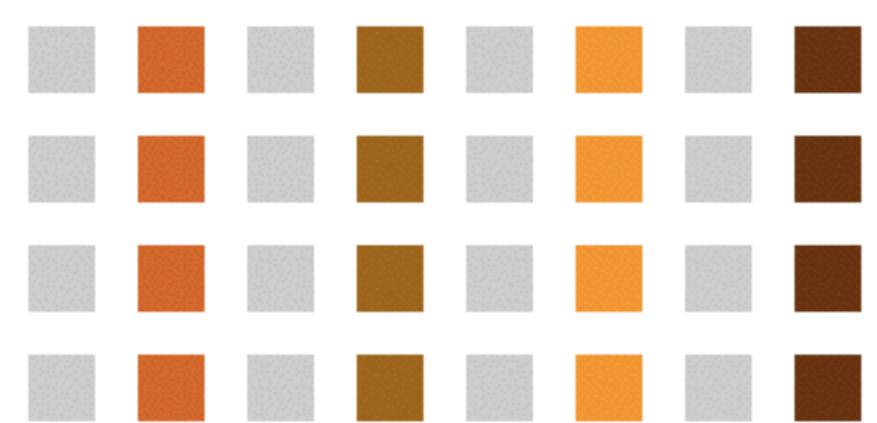
German: “Gestalt” = form
patterns transcend the visual stimuli that produced them



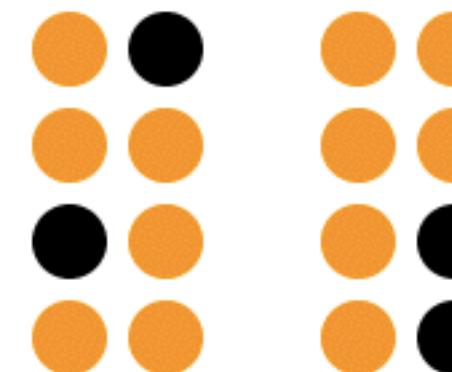
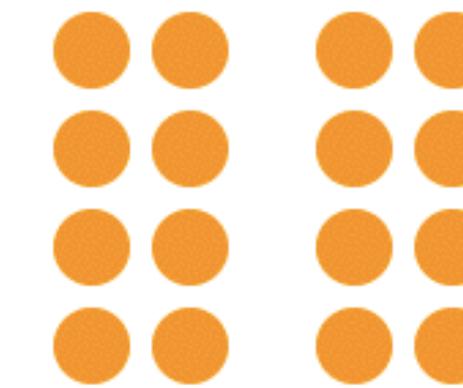
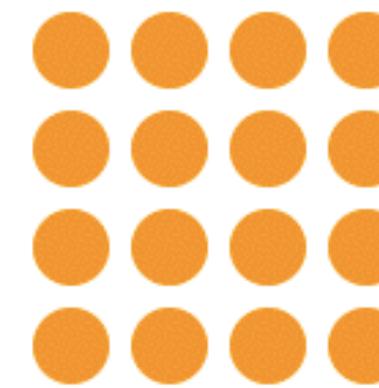
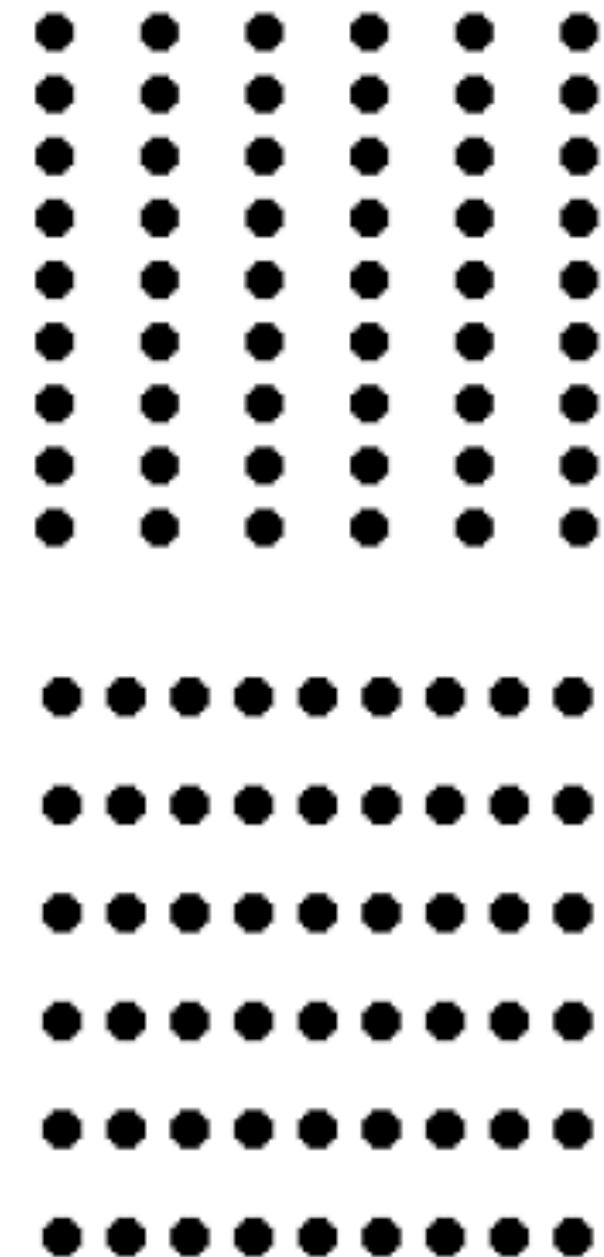
SIMILARITY



SIMILARITY



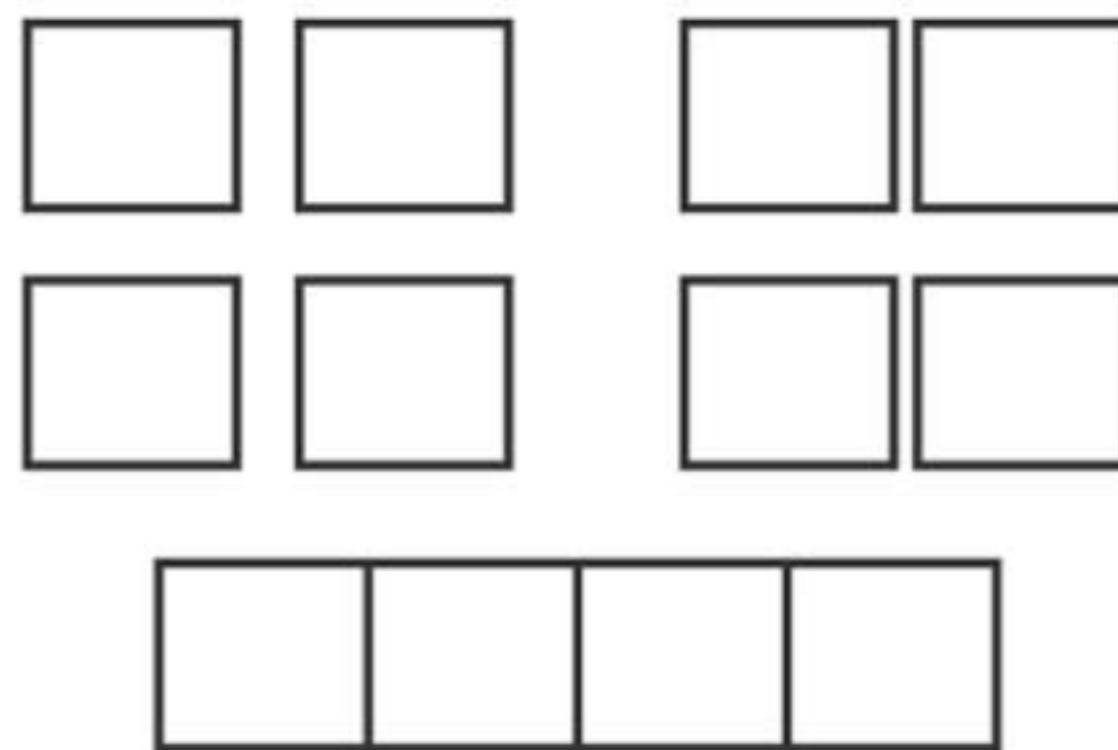
PROXIMITY



ANDY RUTLEDGE, "GESTALT PRINCIPLES OF PERCEPTION"



PROXIMITY

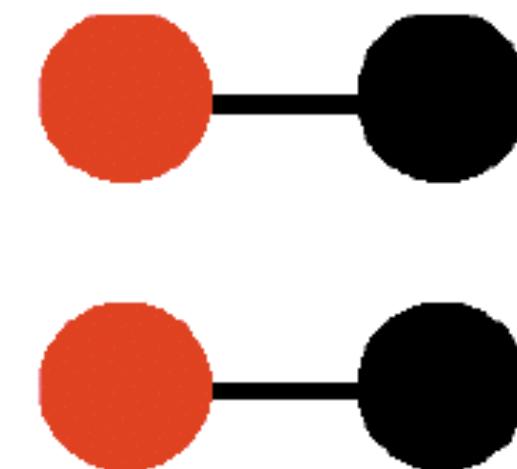


CONNECTEDNESS

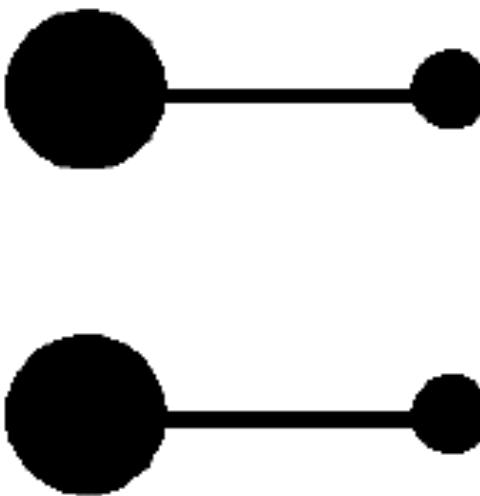
a



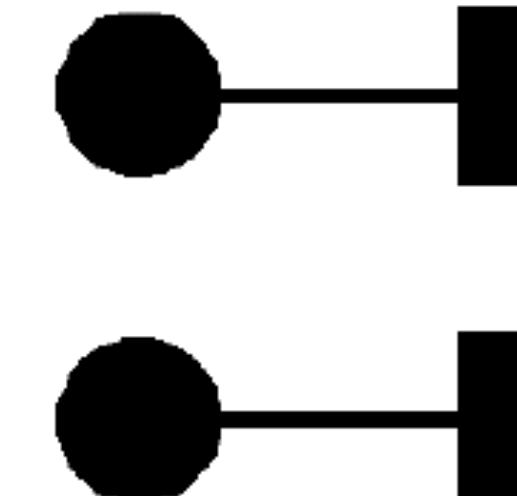
b



c



d



GROUPING

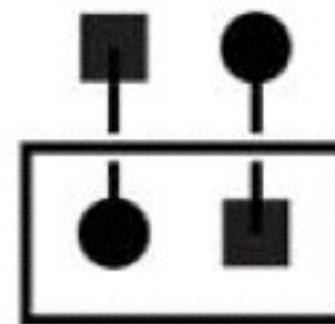
Similarity



Connection

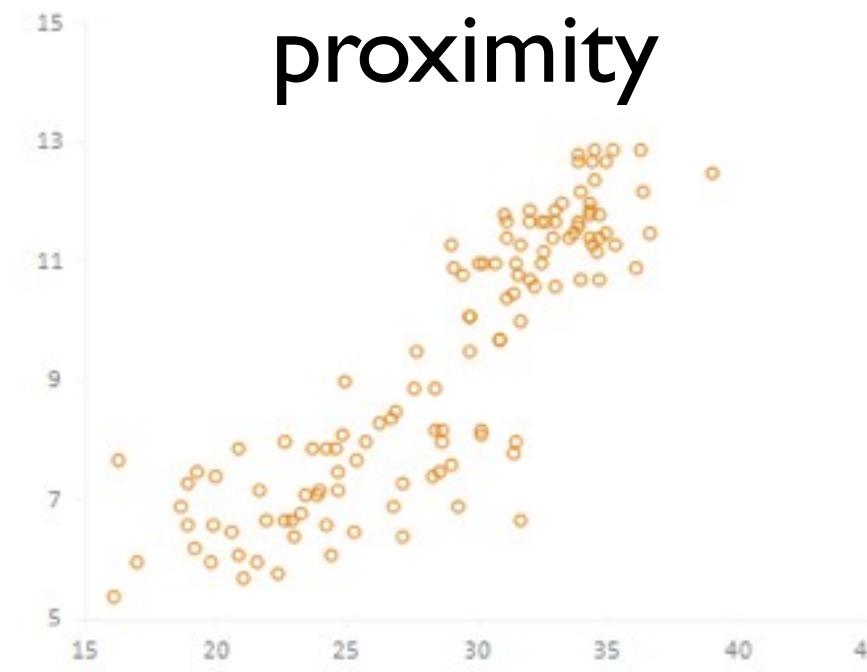


Enclosure

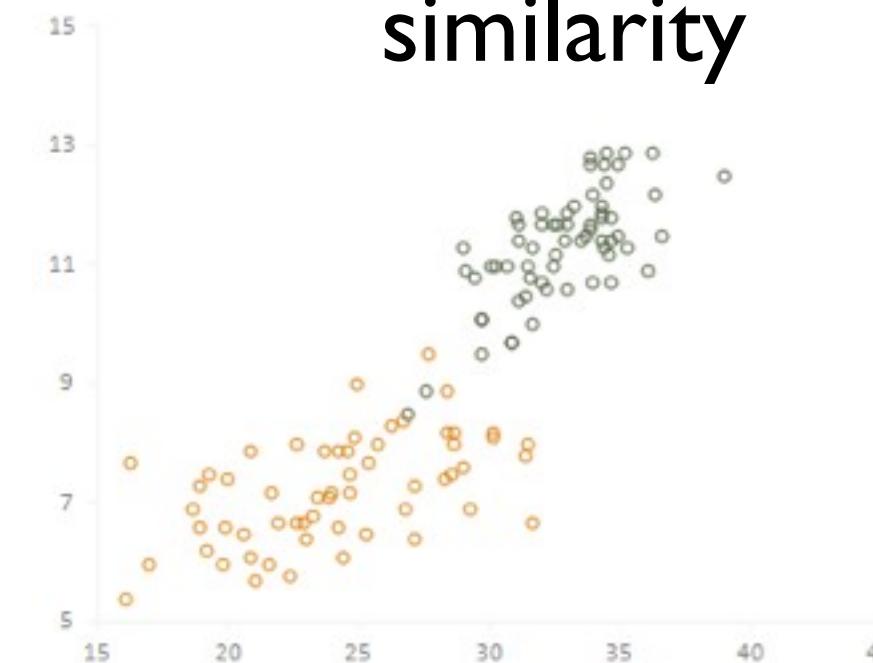


GROUPING

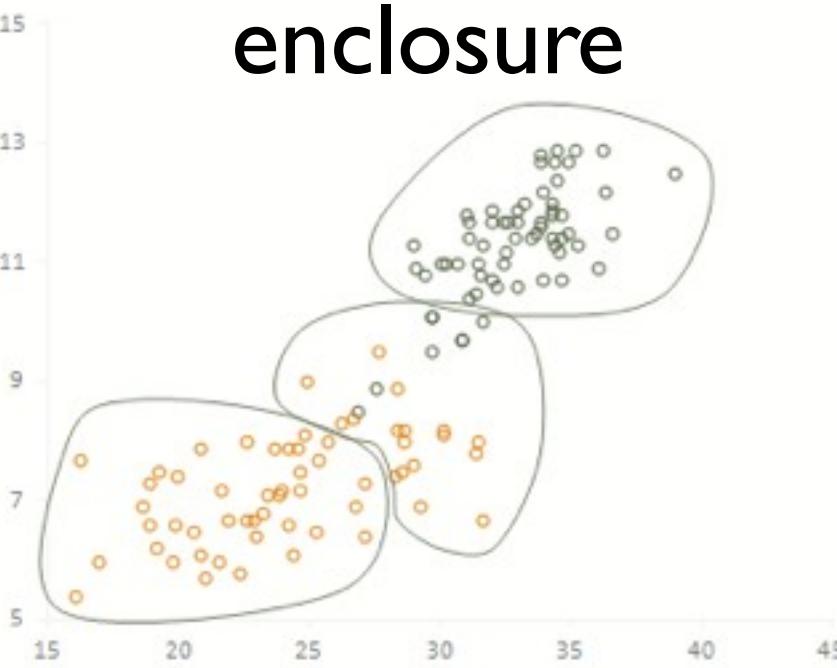
proximity



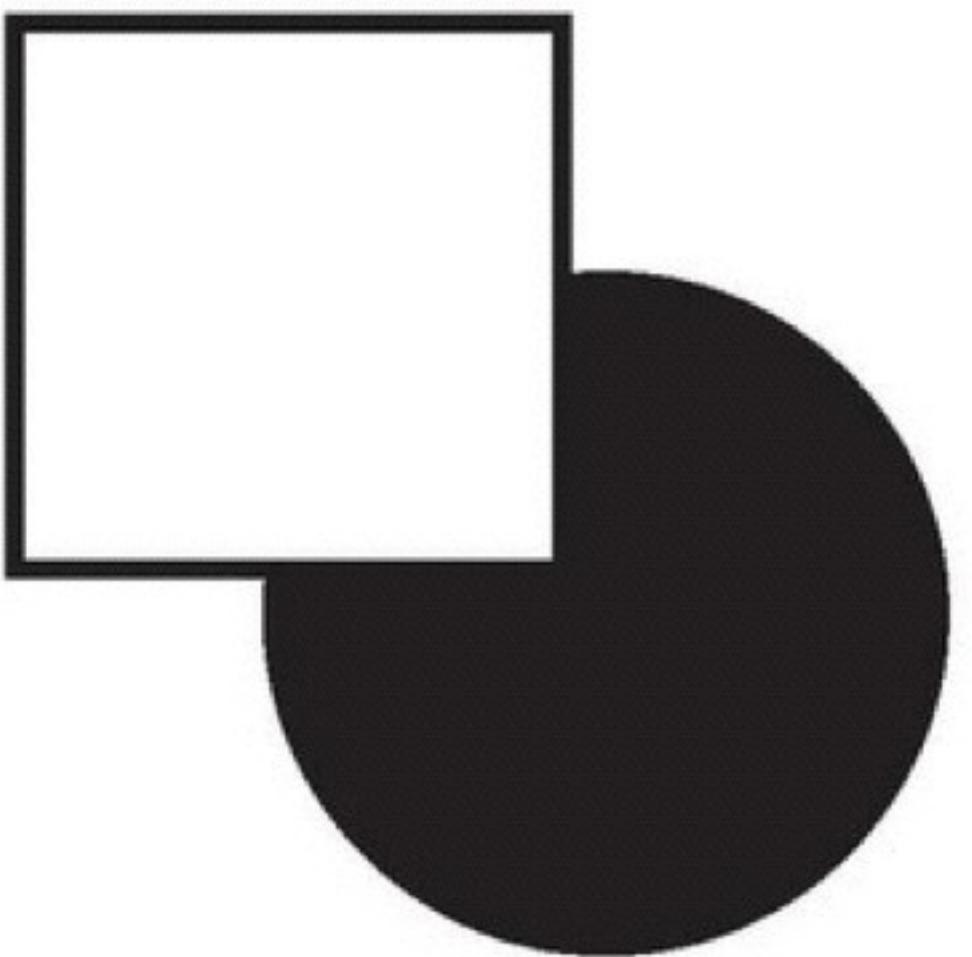
similarity



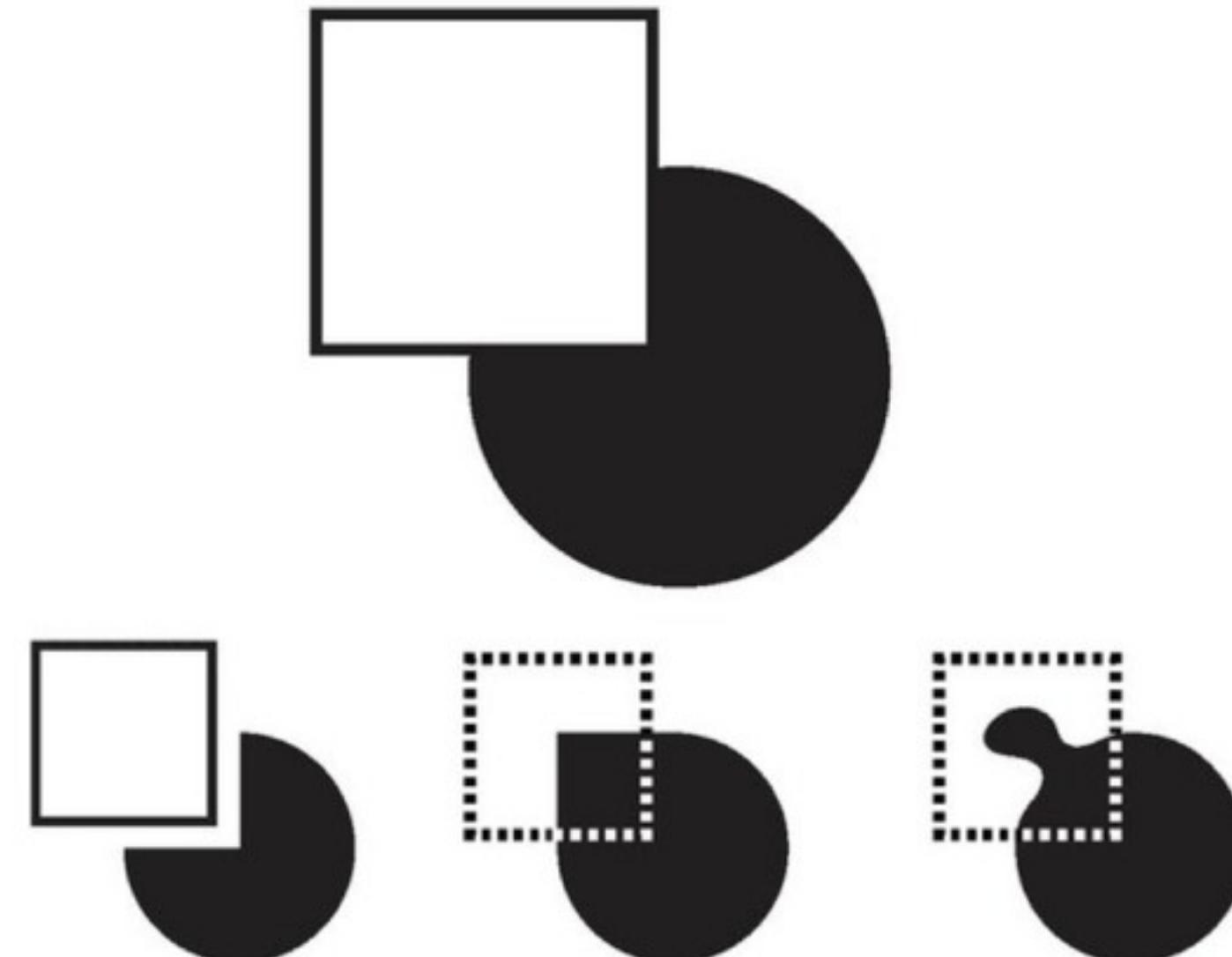
enclosure



CONTINUITY



CONTINUITY



CLOSURE

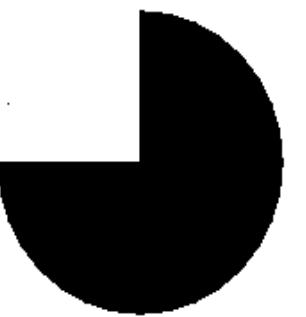
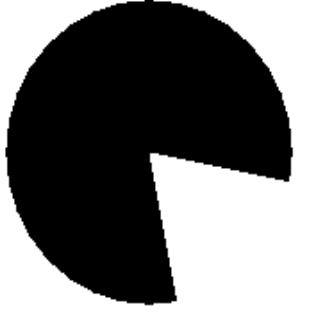
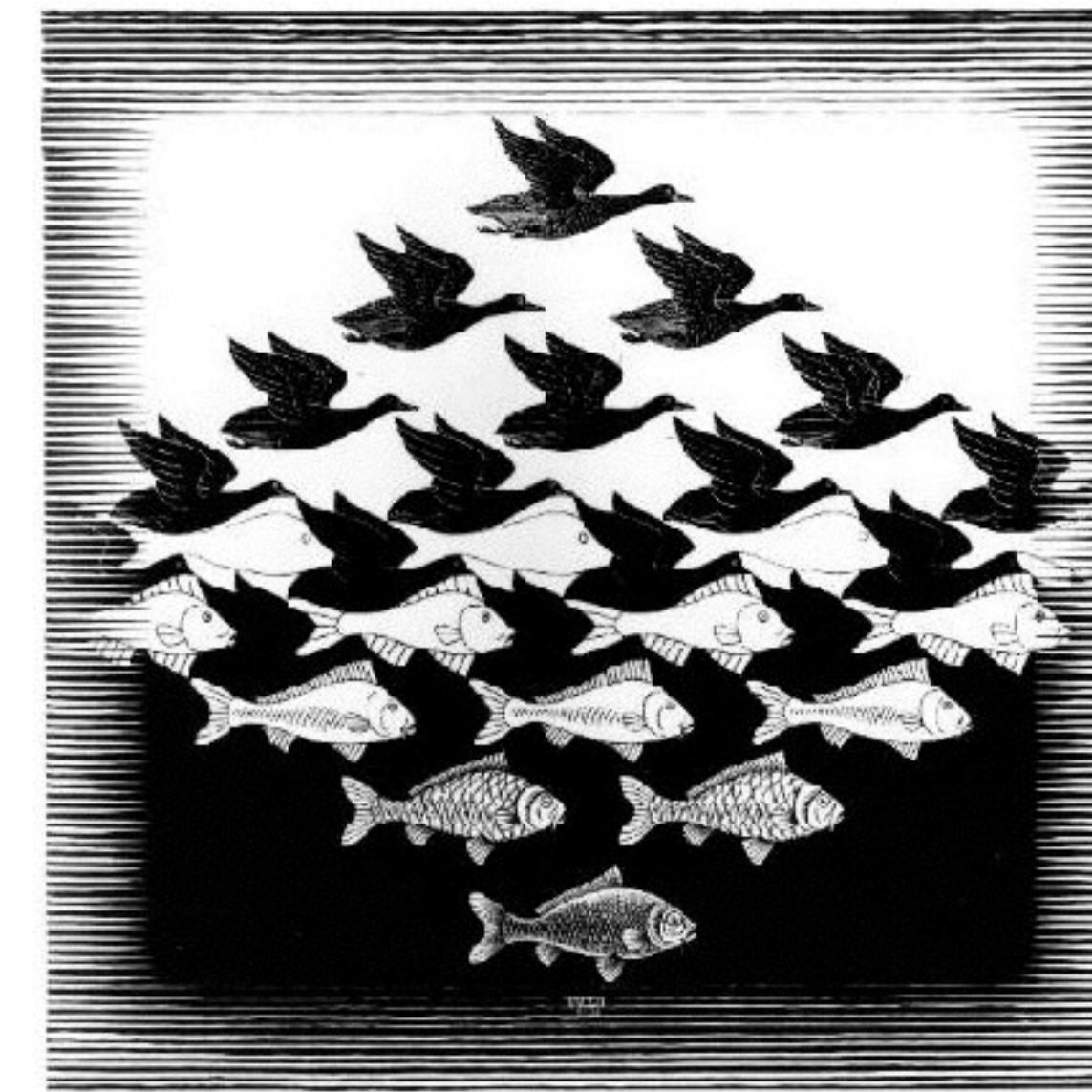


FIGURE / GROUND



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



COMMON FATE



GESTALT PRINCIPLES

similarity: things that look like each other (size, color, shape) are related

proximity: things that are visually close to each other are related

connection: things that are visually connected are related

continuity: we complete hidden objects into simple, familiar shapes

closure: we see incomplete shapes as complete

figure / ground: elements are perceived as either figures or background

common fate: elements with the same moving direction are perceived as a unit



TAKEAWAYS

Gestalt principles give us a conceptual understanding of the way our mind converts shapes into structured thought.

Using the Gestalt principles wisely will lead improve performance in interpretation of visualizations. Poor use may cause users to see things that aren't there...



CIS 4930/6930-002

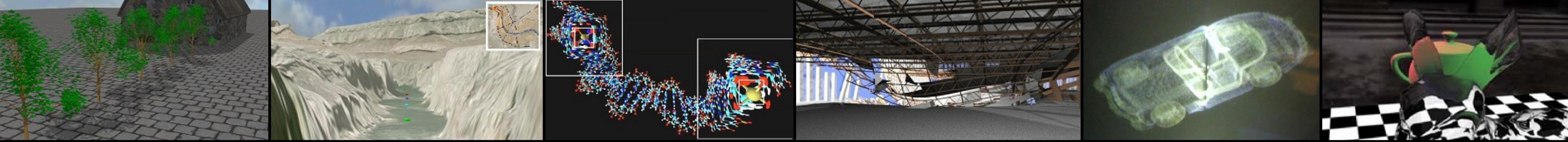
DATA VISUALIZATION



COLOR

Paul Rosen
Assistant Professor
University of South Florida

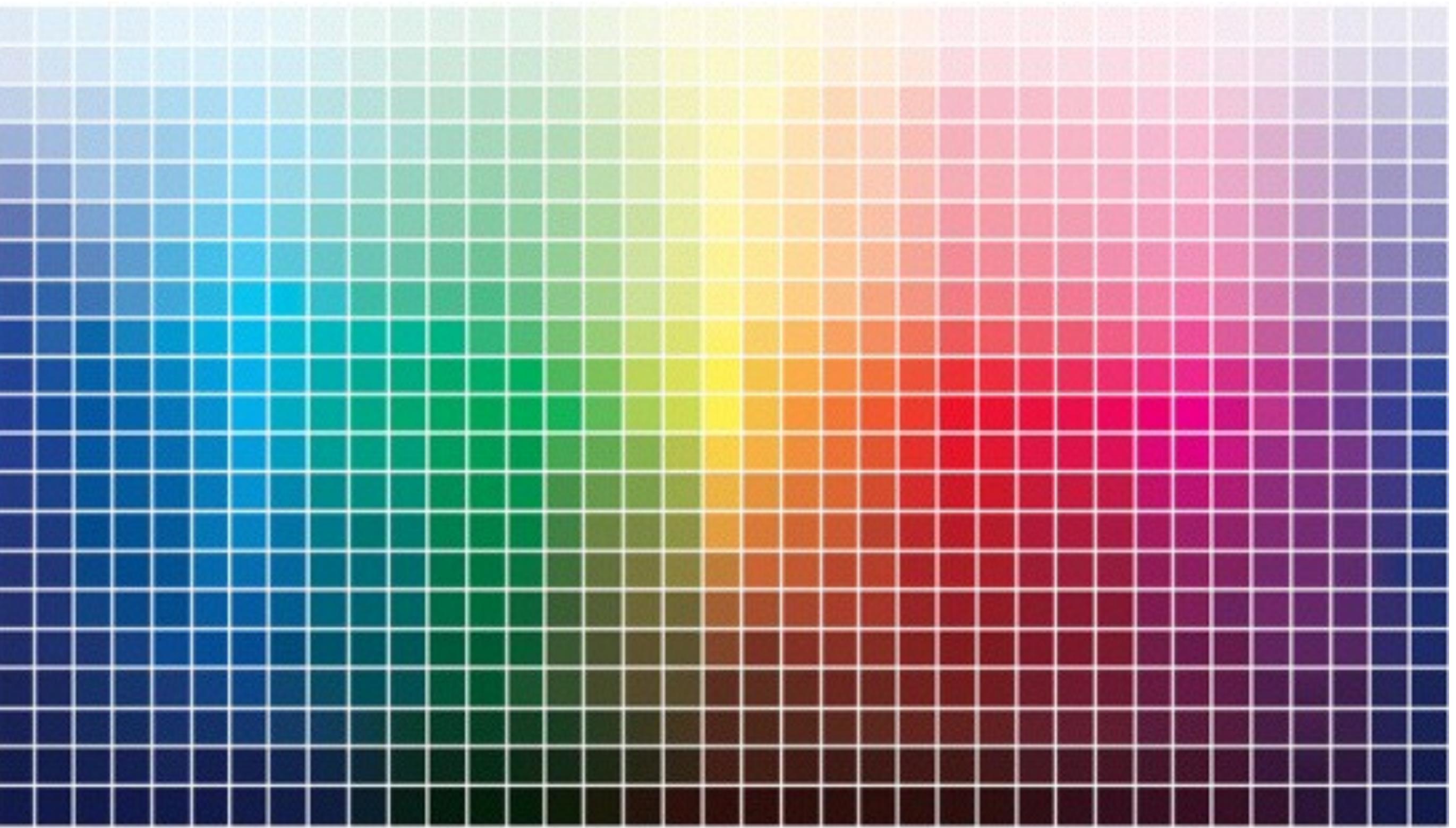
slides credits Chris Johnson (U of Utah), Hanspeter Pfister (Harvard), Bang Wong (Broad Institute), Miriah Meyer (U of Utah)



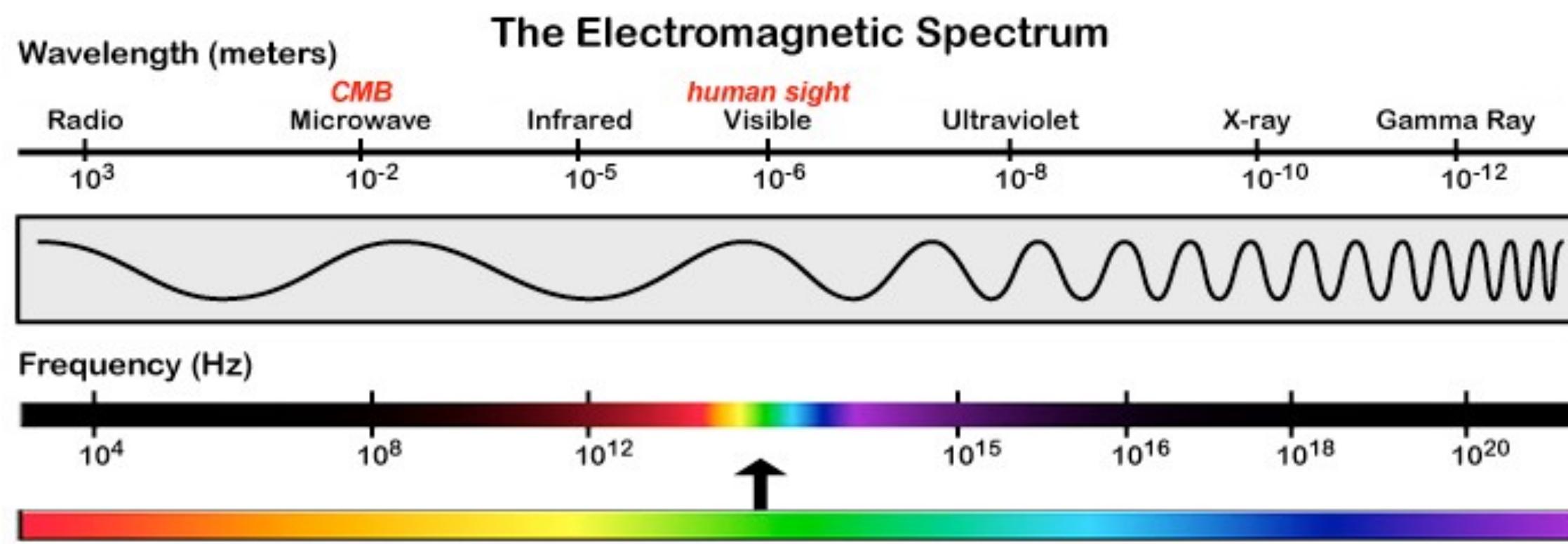
REMINDERS

2/7/2018 – Project 3 due

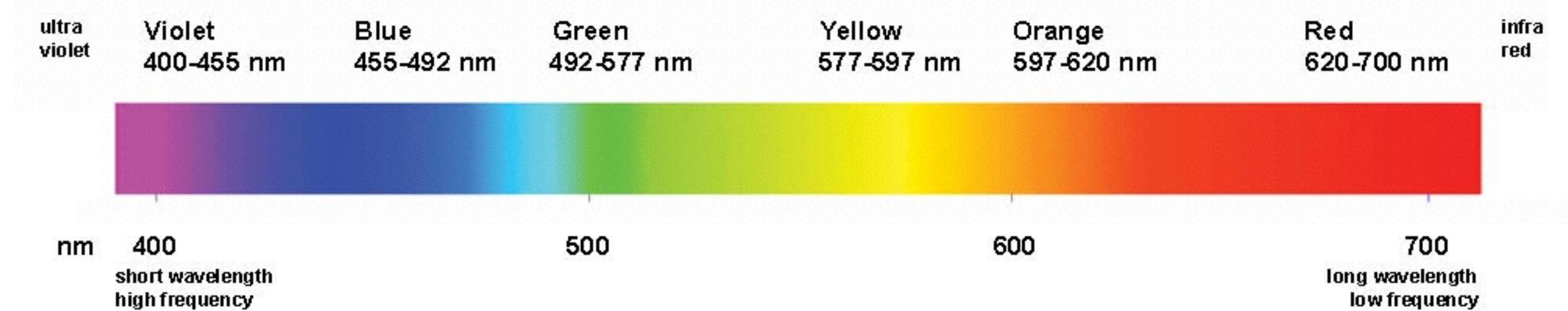




LIGHT

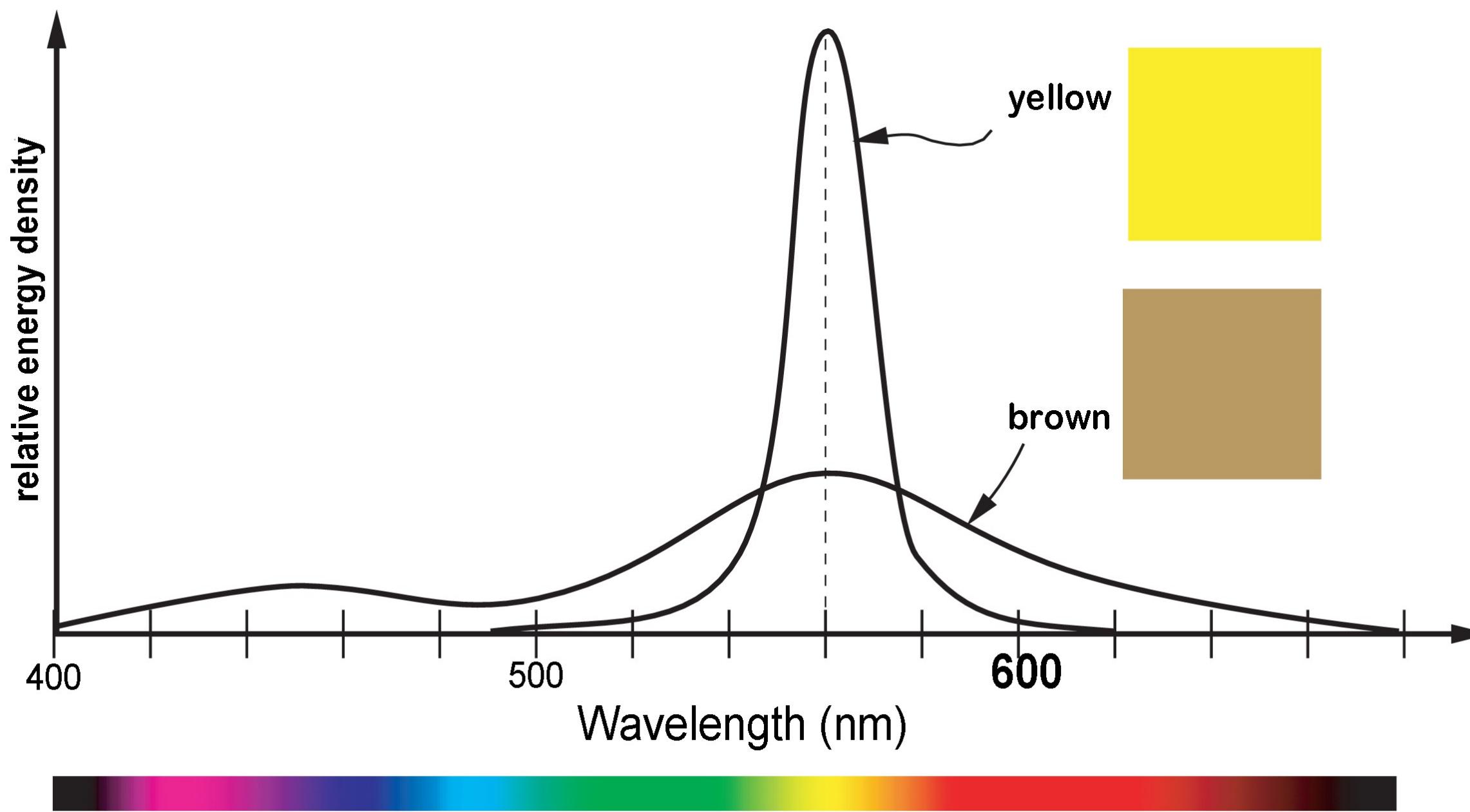


(HUMAN) VISIBLE LIGHT

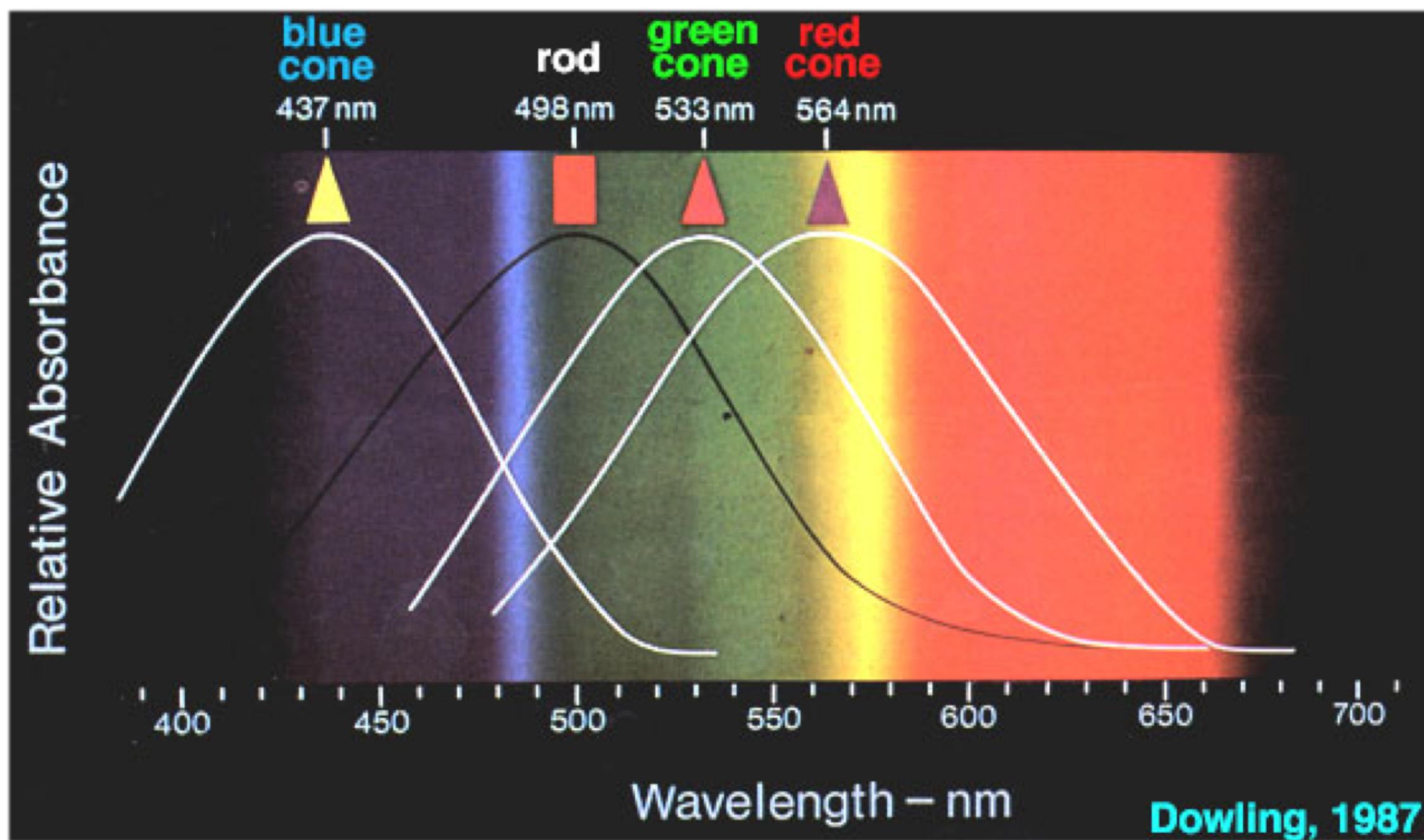


COLOR != WAVELENGTH

but rather, a combination of wavelengths and energy



CONE RESPONSE





RADIOLAB

Listen Read Watch



Return Home

Rippin' the Rainbow a New One

« Back to Episode



00:30 / 19:37



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(jared/flickr/CC-BY-2.0)

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

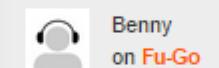
Jonah Lehrer restores some of the lost magic by way of

Goethe--who turned a simple observation into a deep thought: even though color starts in the

[PODCAST](#) [SUPPORT](#)

Latest Comments

What a fascinating story! I found it interesting as some aspects of it reminded me of the conflict in Gaza ...



Benny
on Fu-Go

The Most

[Viewed](#) | [Listened](#) | [Commented](#)

- ▶ Remembering Oliver Sacks
- ▶ American Football
- ▶ The Rhino Hunter
- ▶ Elements
- ▶ Shrink
- ▶ Colors
- ▶ Photos: Before and After Carlisle
- ▶ Looking Back With Dr. Sacks
- ▶ Antibodies Part 1: CRISPR
- ▶ The Poetry of "Elements"

Sign Up



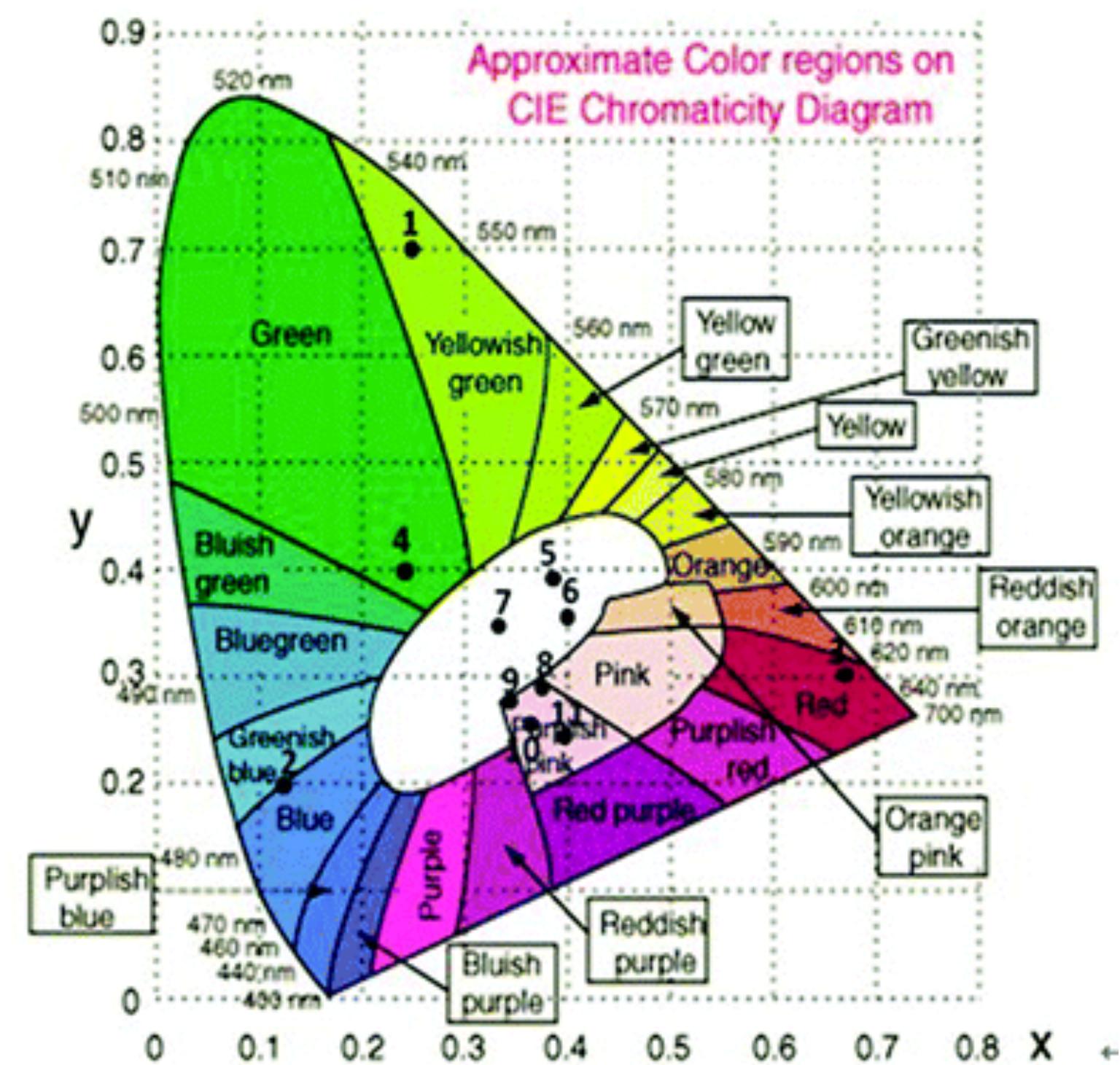
Send me Radiolab Updates

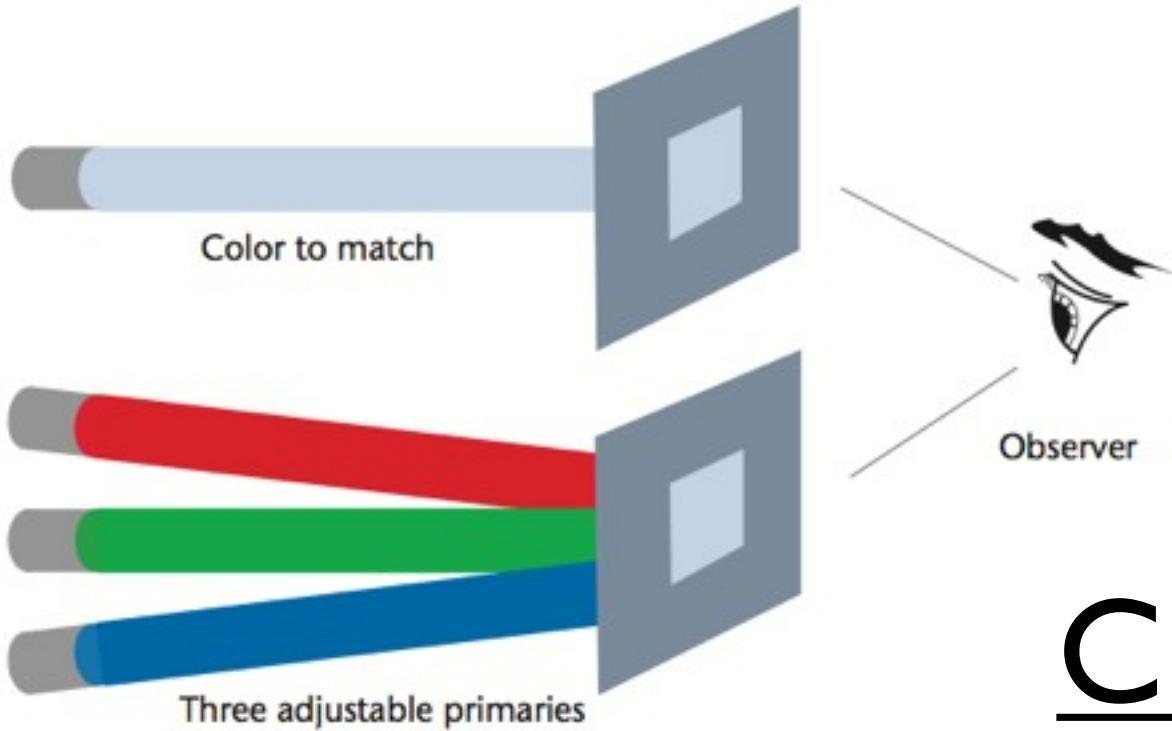


COLOR ABSTRACTION,
REPRESENTATION



SPACE OF HUMAN COLOR





CIE COLOR SPACE

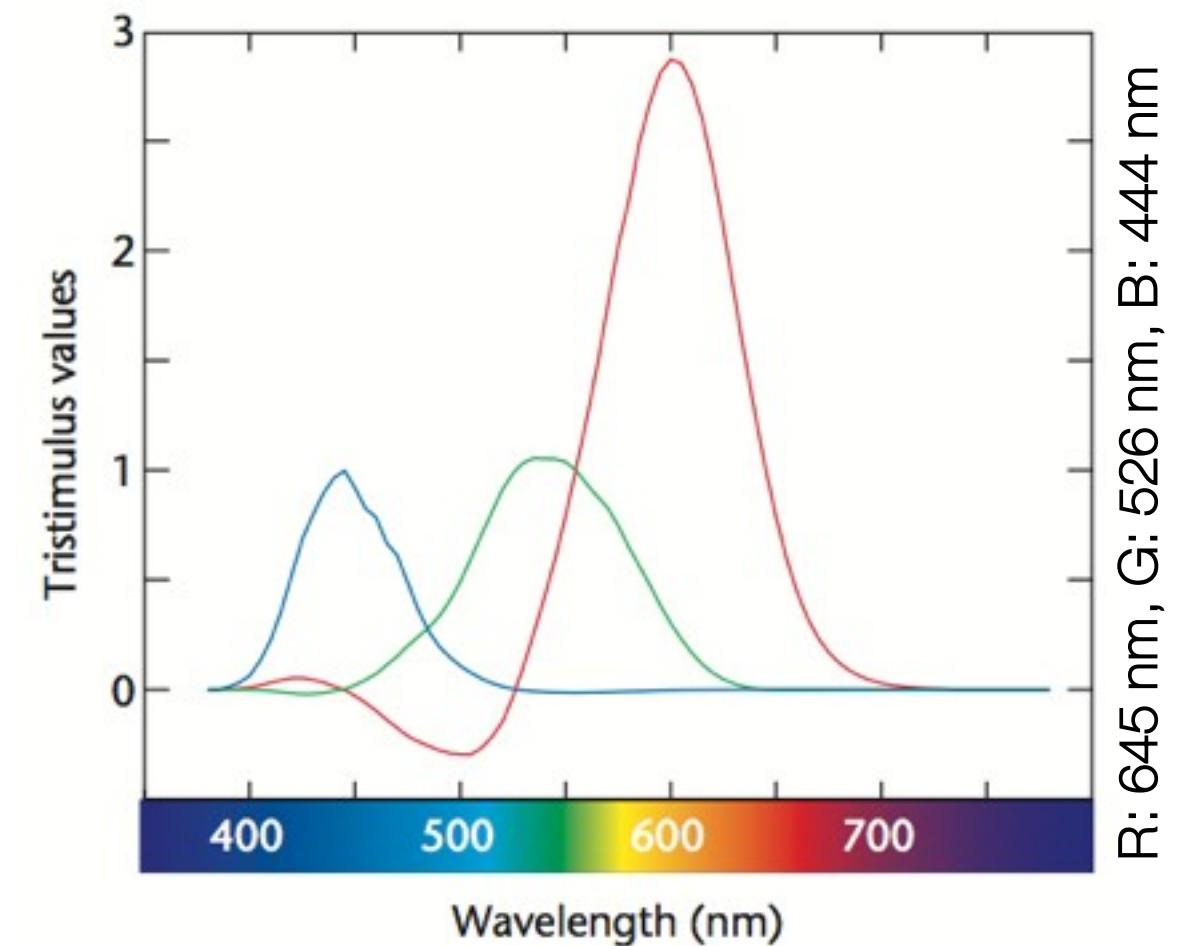
CIE (International Commission on Illumination) standardized a set of color-matching functions that form the basis for most color measurement instruments

experiments done in the 1920's and 1930's
humans can mimic any pure (visible) light by addition and subtraction of three primary lights



CIE COLOR SPACE

with RGB, addition and subtraction were required to get all visible wavelengths in nature, light adds (but does not subtract)
any three primaries (additive) can produce only a subset of all visible colors

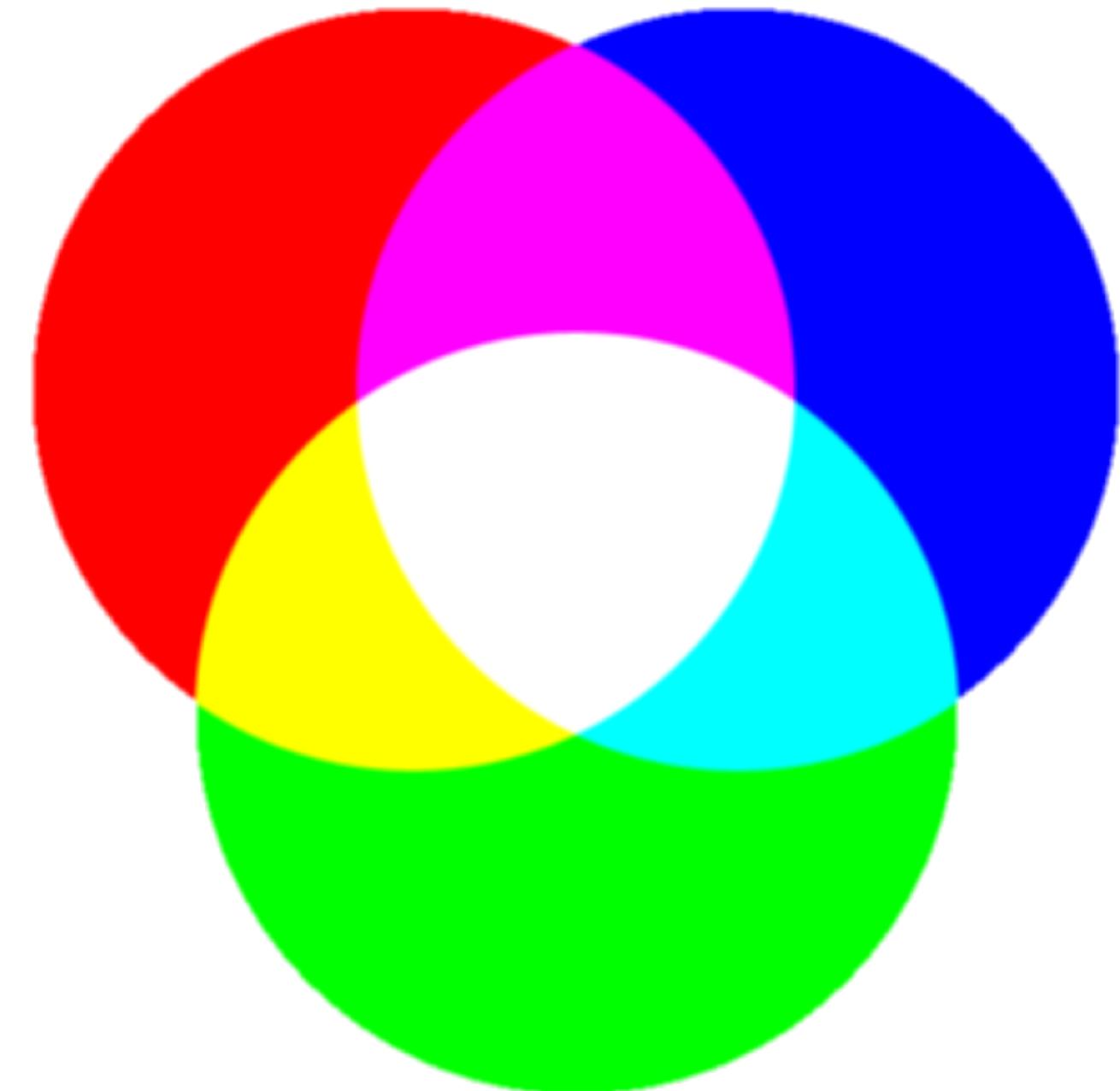


ADDITIVE COLOR

(like we see in light)

primary: RGB

secondary: CMY

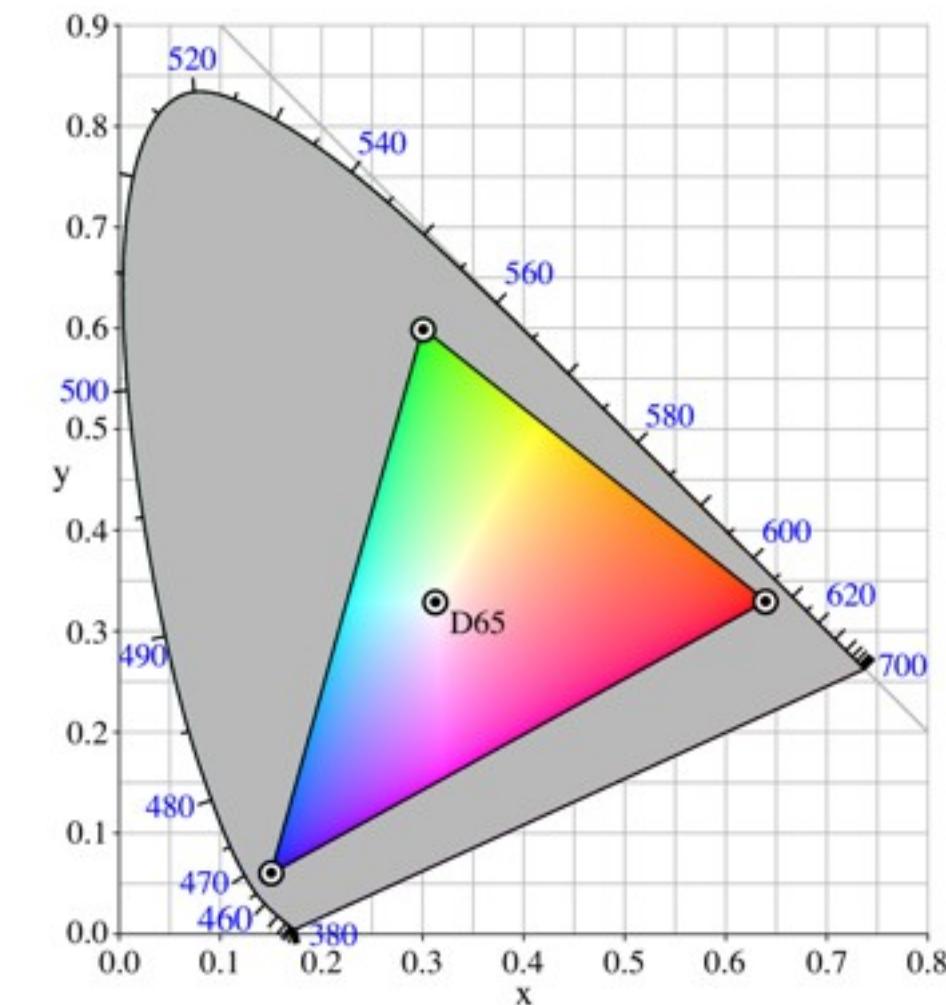


RGB COLOR SPACE

very common color space

not perceptually uniform

actual color is device-dependent

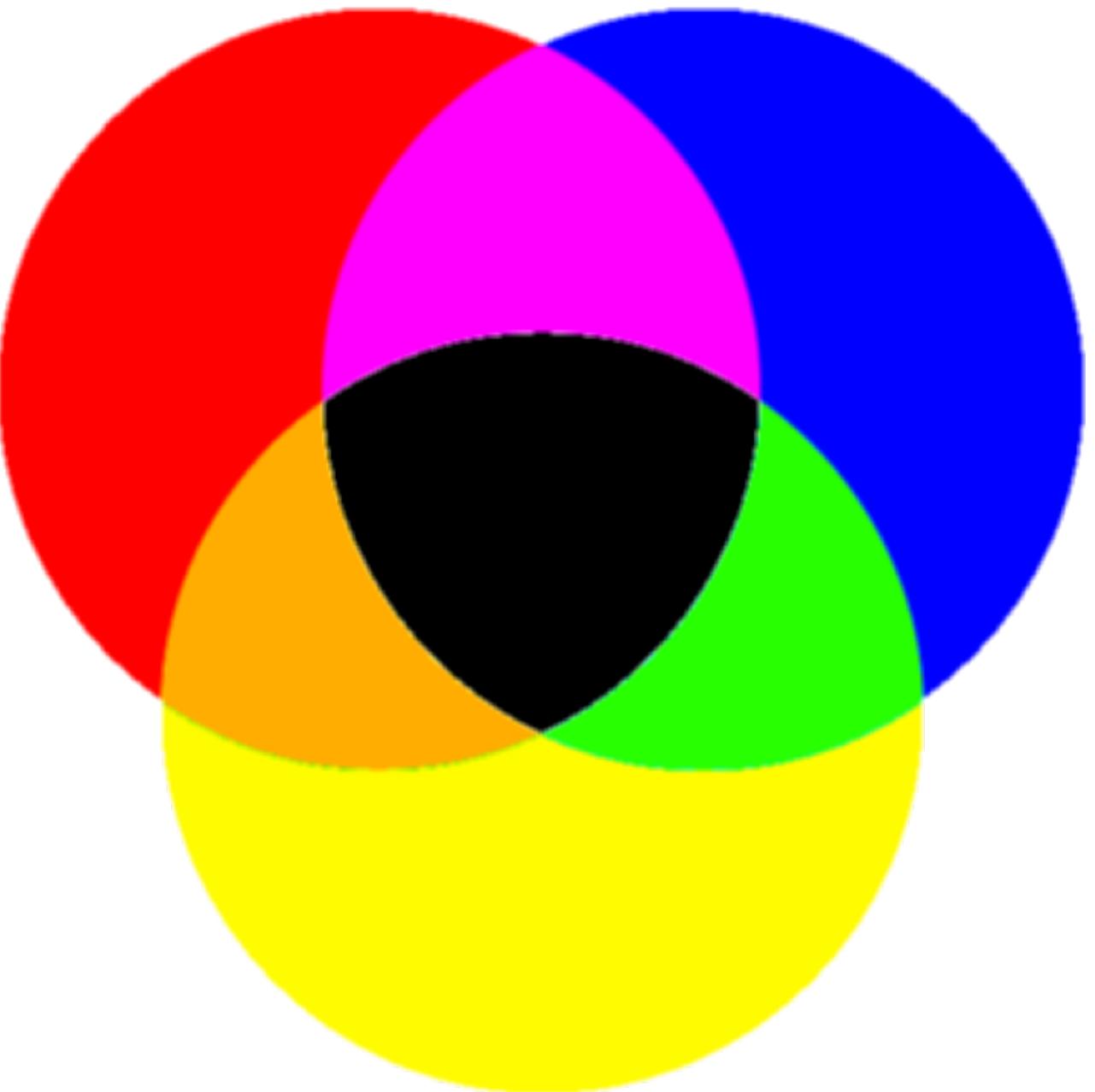


SUBTRACTIVE COLOR

(used in painting)

primary: RYB

secondary: OGV



SUBTRACTIVE COLOR

(used in print ink)

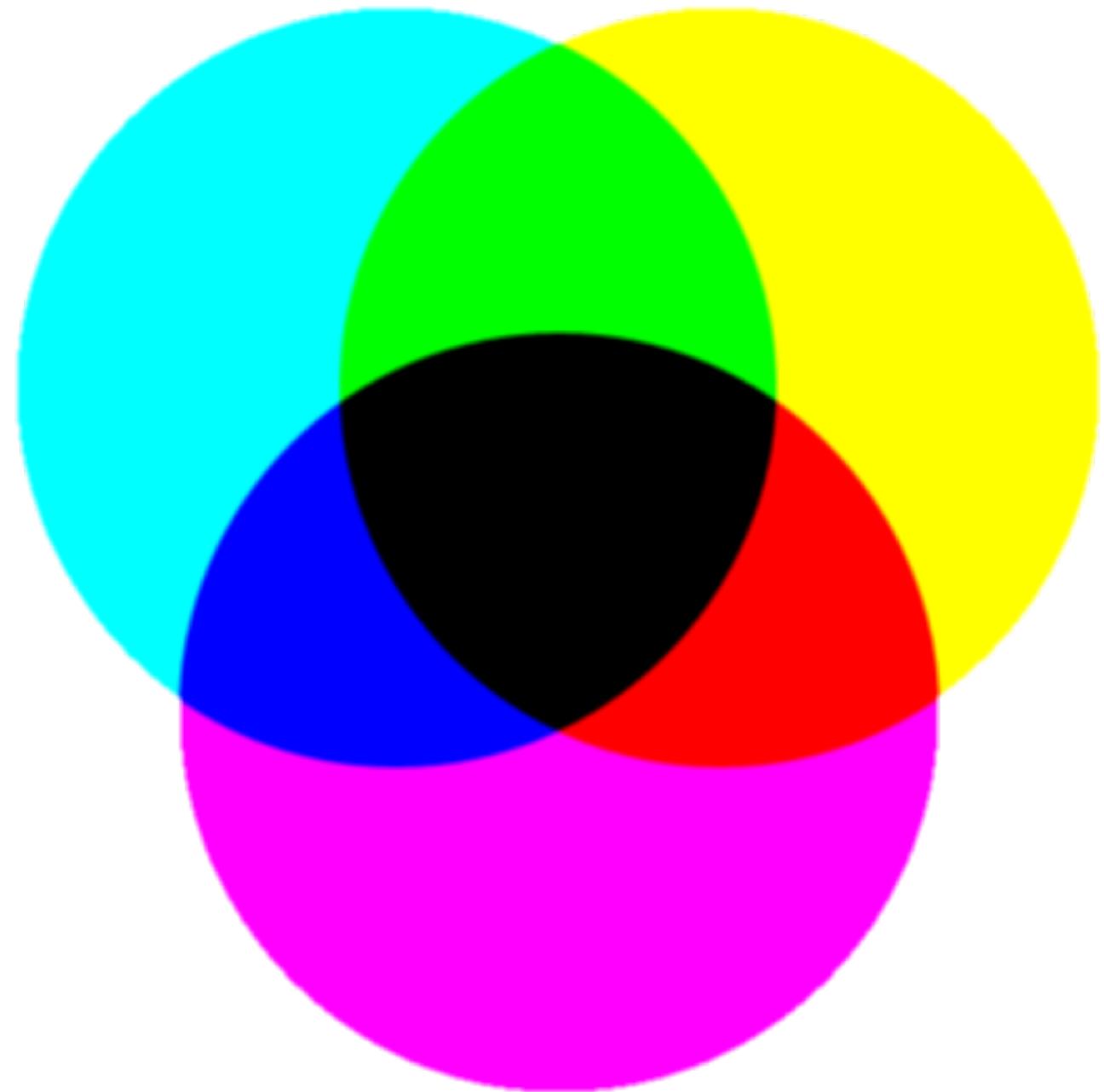
primary: CMY

secondary: RGB

approx black = C+M+Y

true black = C+M+Y+K

actual color is device-dependent



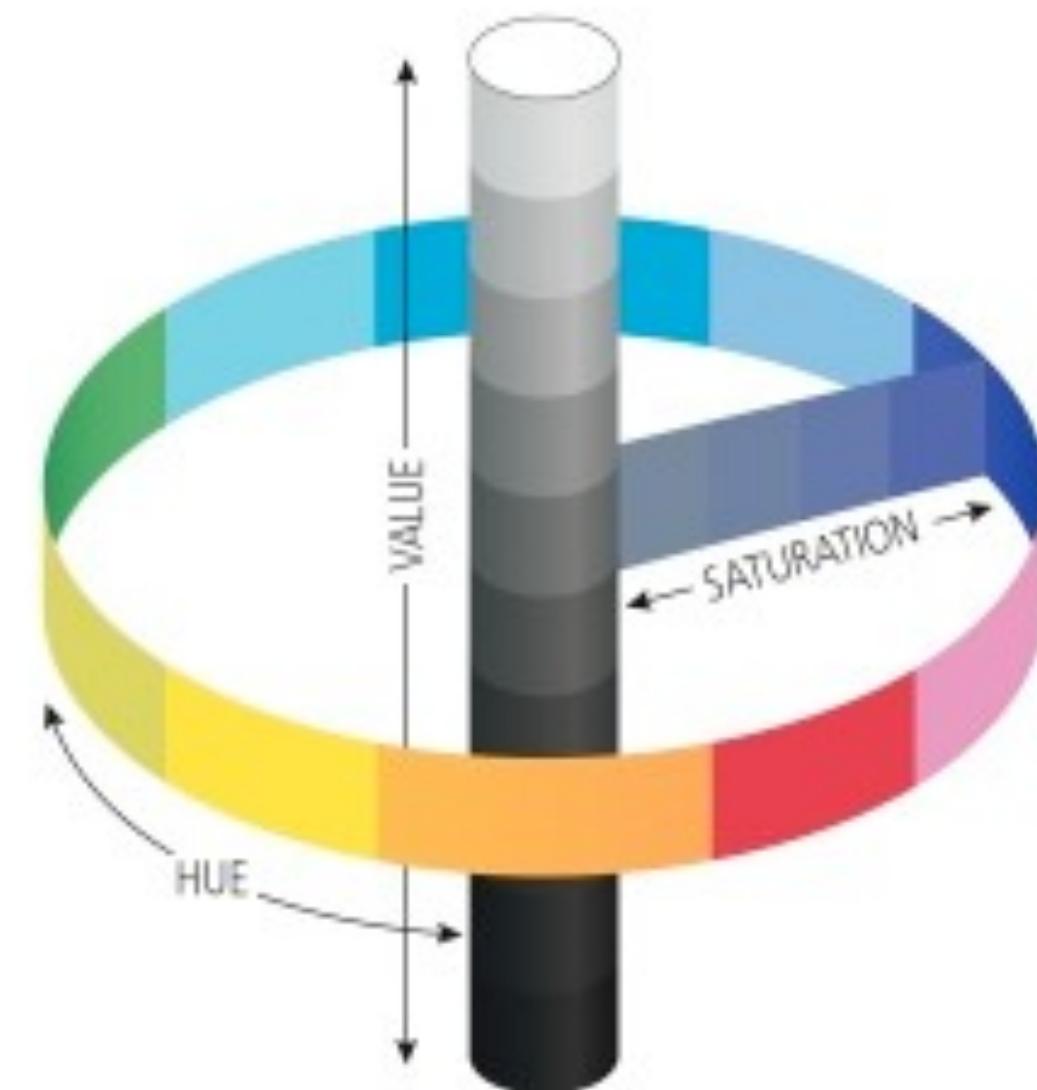
HSV [B, L, I] (ADDITIVE)

Hue, Saturation, [Value, Brightness,
Lightness, Intensity]

polar coordinate representations
of RGB space

conical or cylindrical shaped space

more intuitive than RGB for color
tuning



HSV [B, L, I] (ADDITIVE)

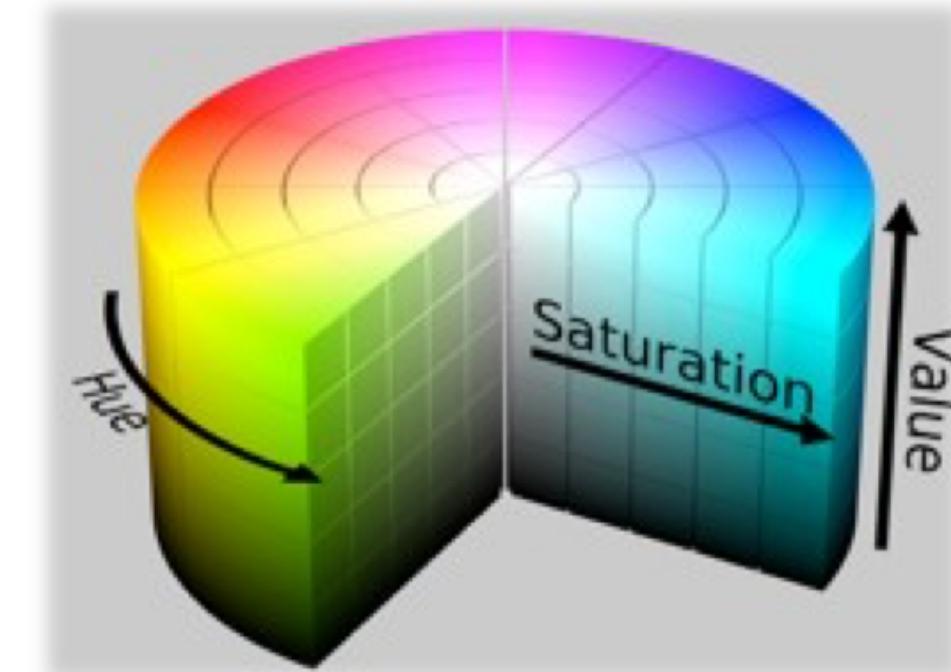
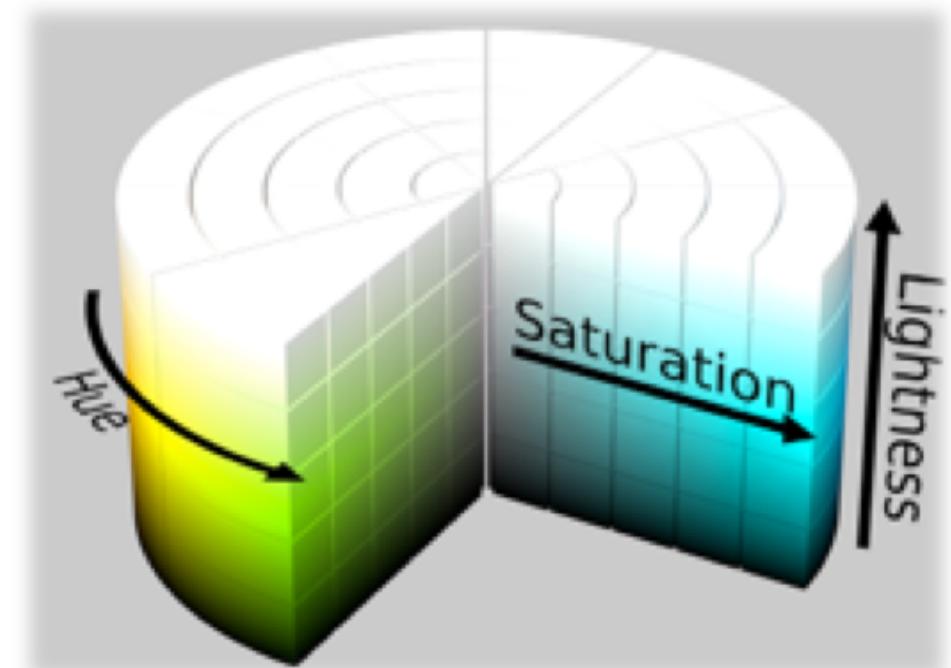
hue: what people think of as color

saturation: amount of white mixed in

luminance: amount of black mixed in

lightness vs value (or brightness)

intensity, in computer vision applications



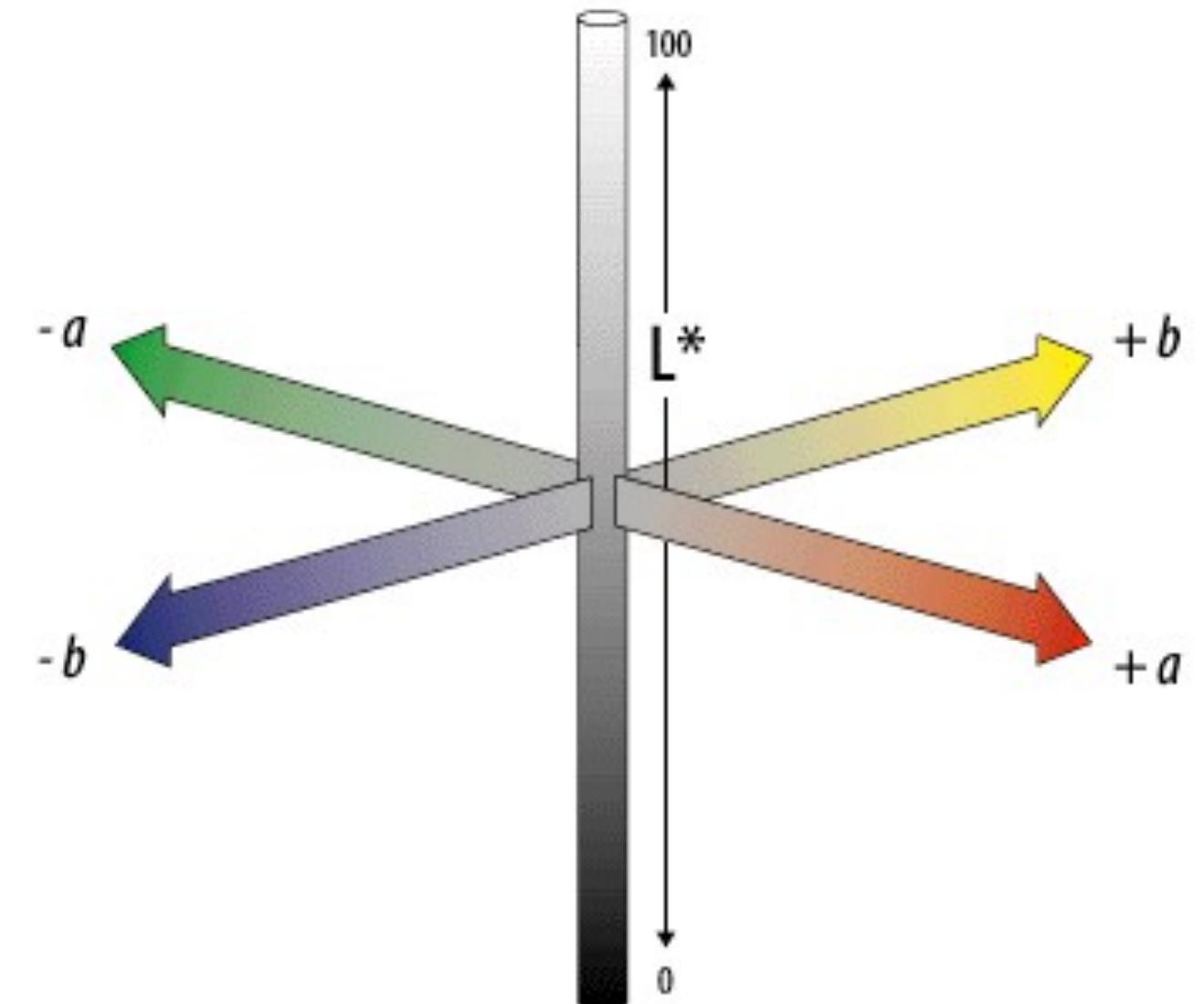
CIE LAB/LUV

mathematically defined &
perceptually based to include all
perceivable colors

a: red to green

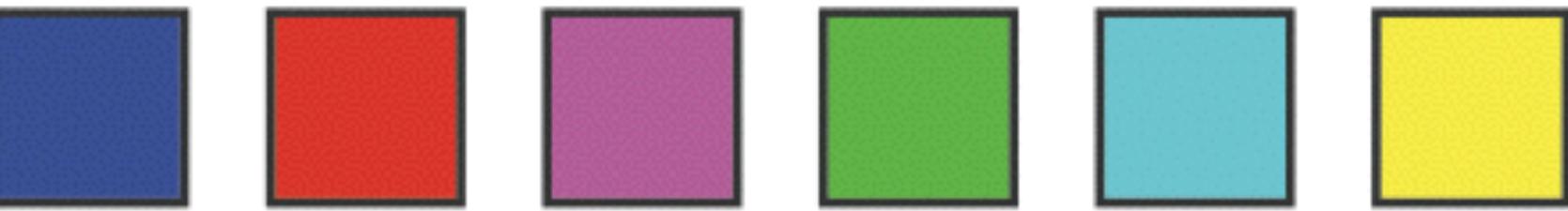
b: yellow to blue

L*: lightness (black to white)

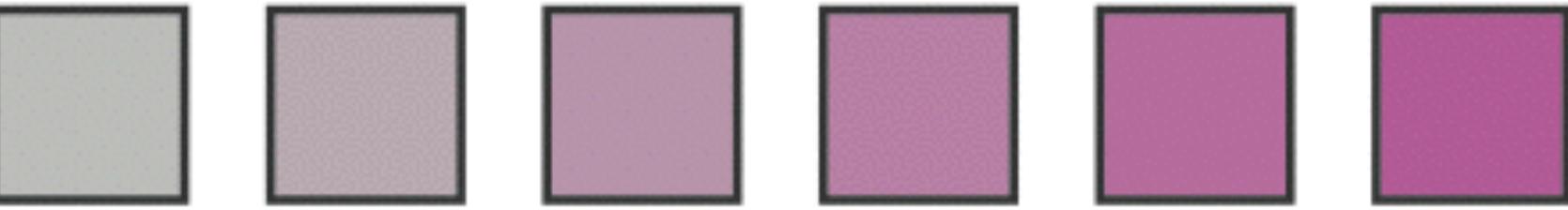


IN THIS CLASS...

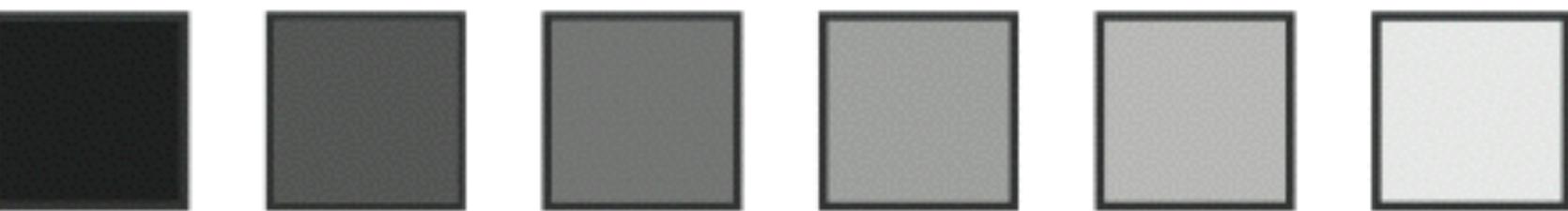
hue



saturation



luminance



COLOR DEFICIENCIES & LIMITATIONS



COLOR BLINDNESS

deficiency in color vision

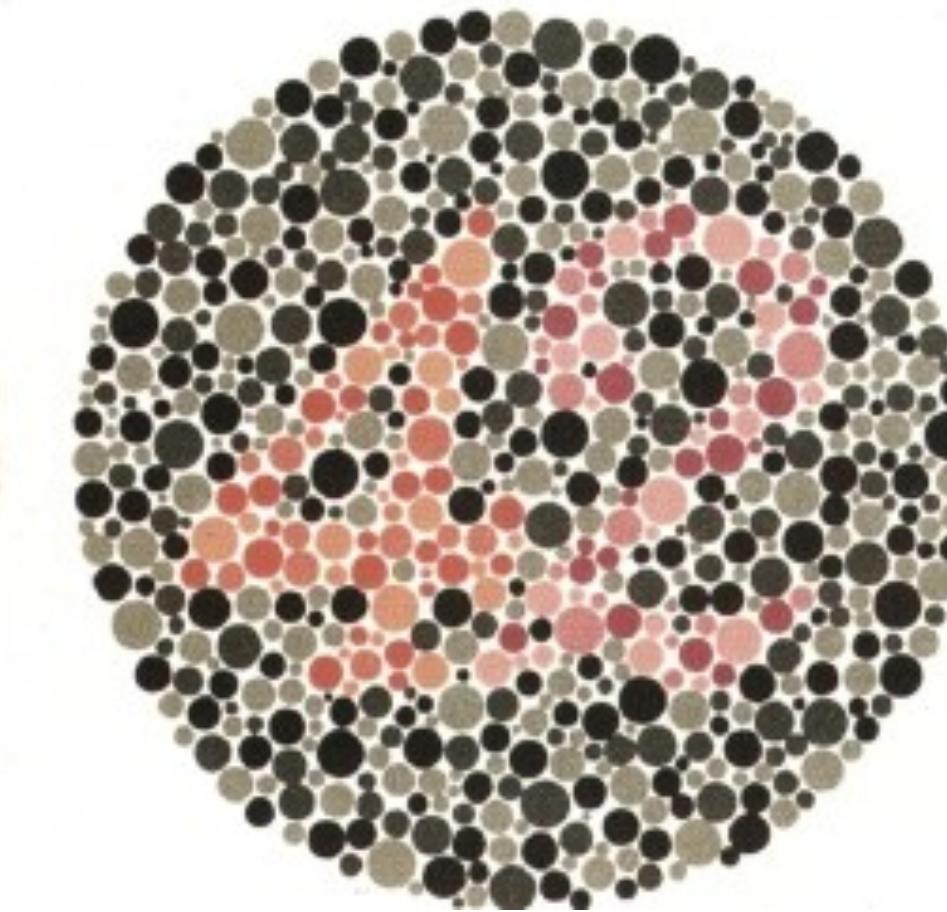
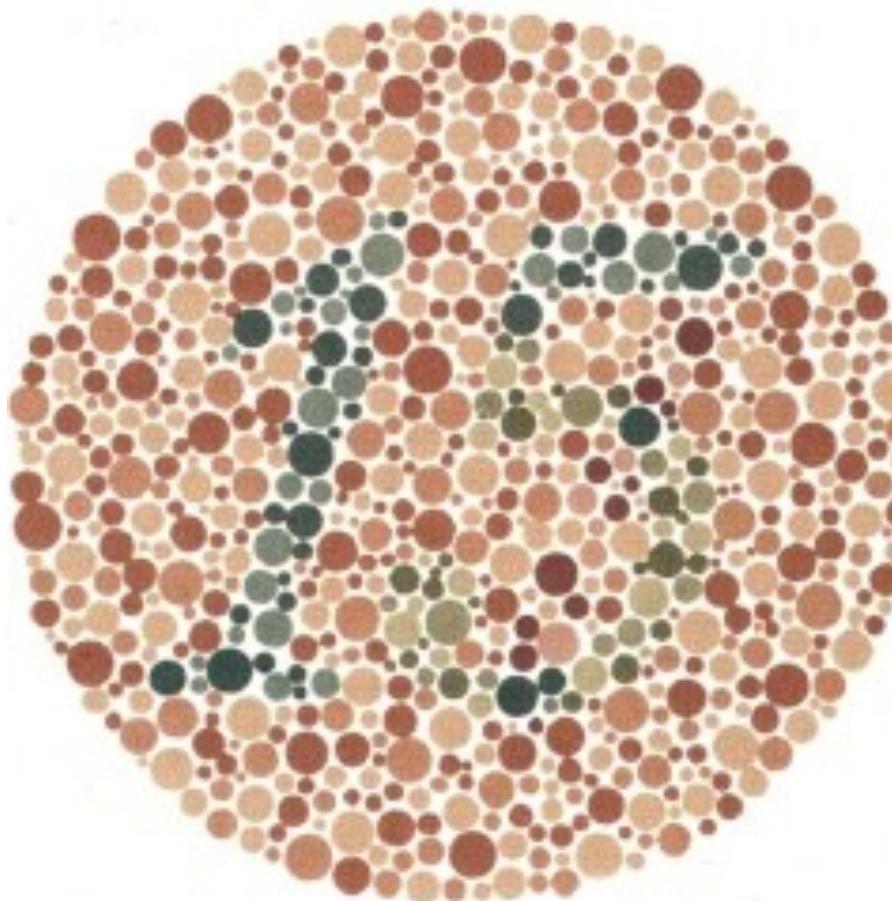
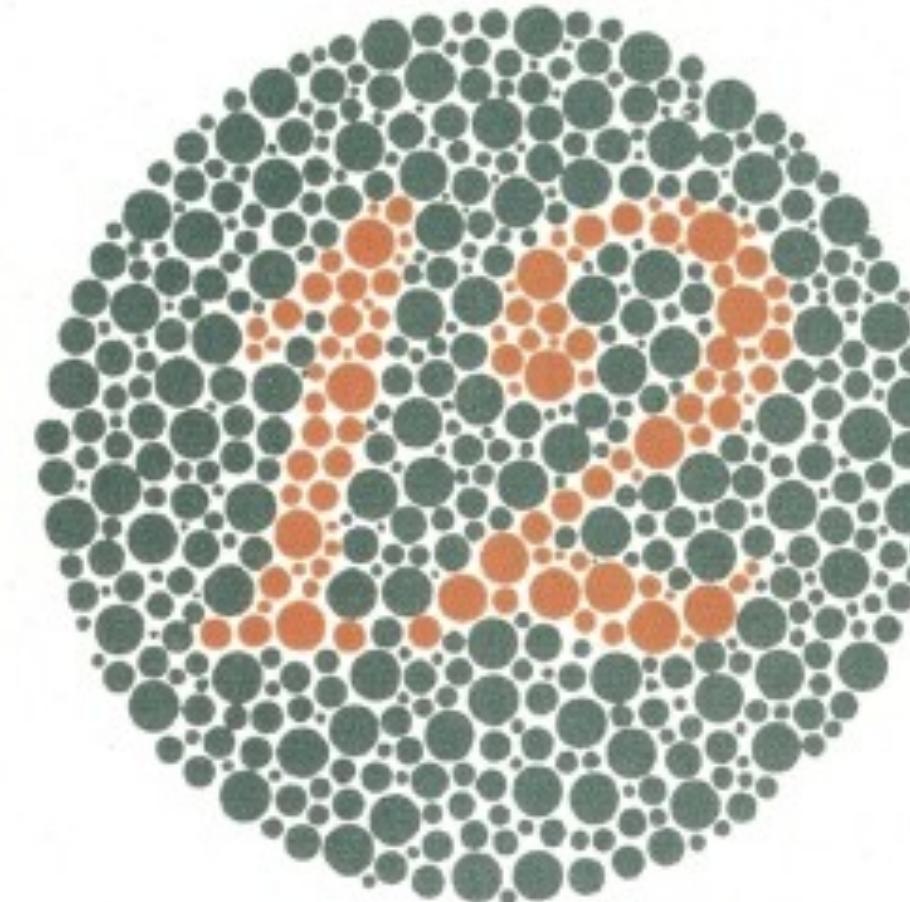
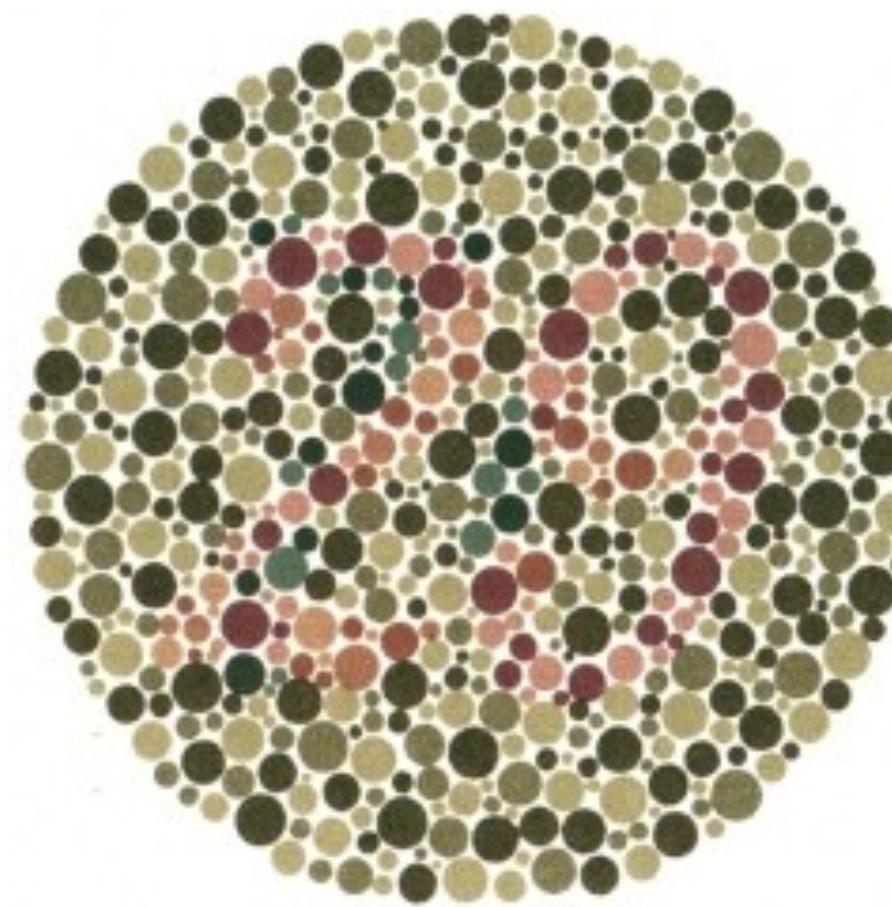
typically caused by faulty cone development

found more in men than women

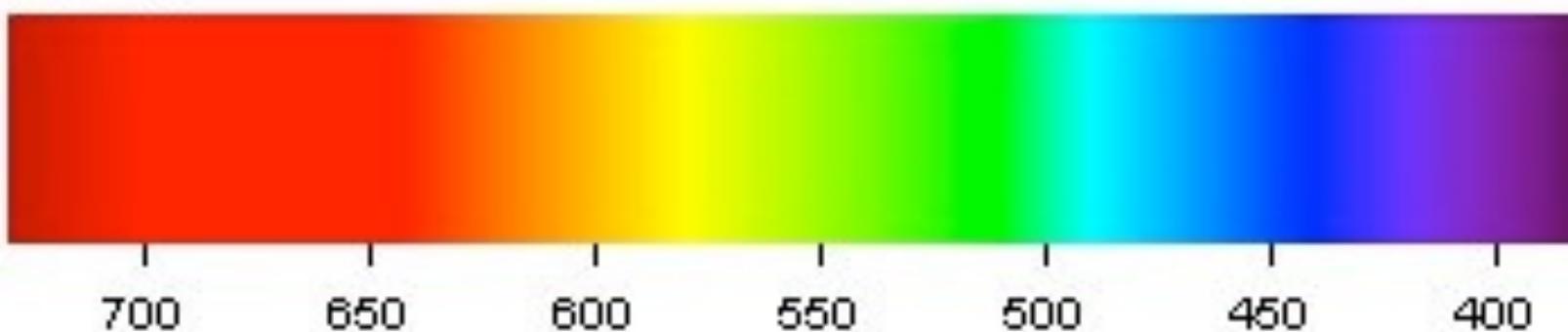
photopigment genes carried in x-
chromosome

5-8% of men and 0.5% of women

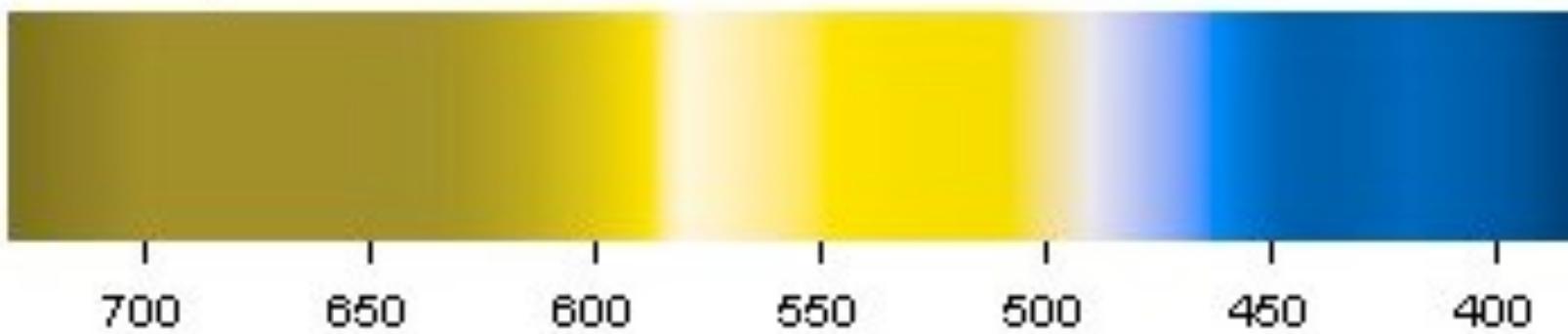




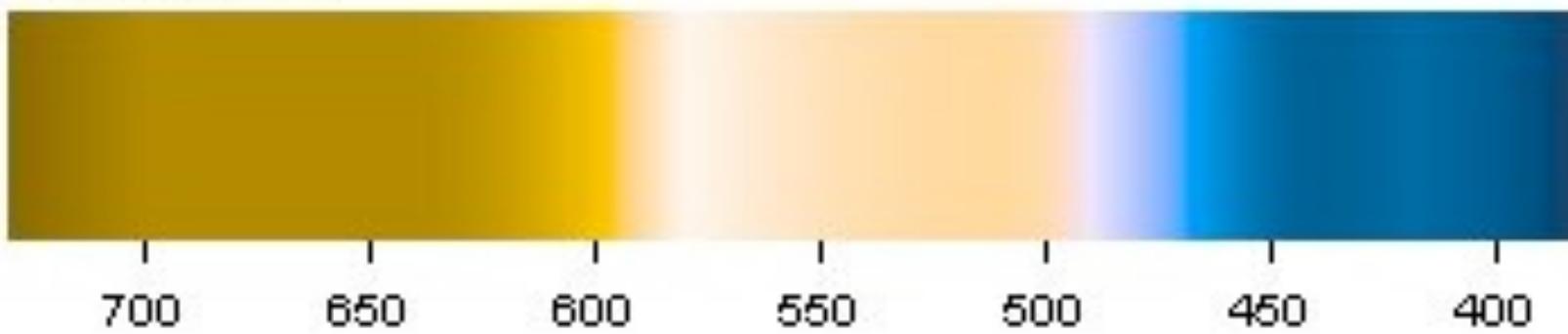
Normal



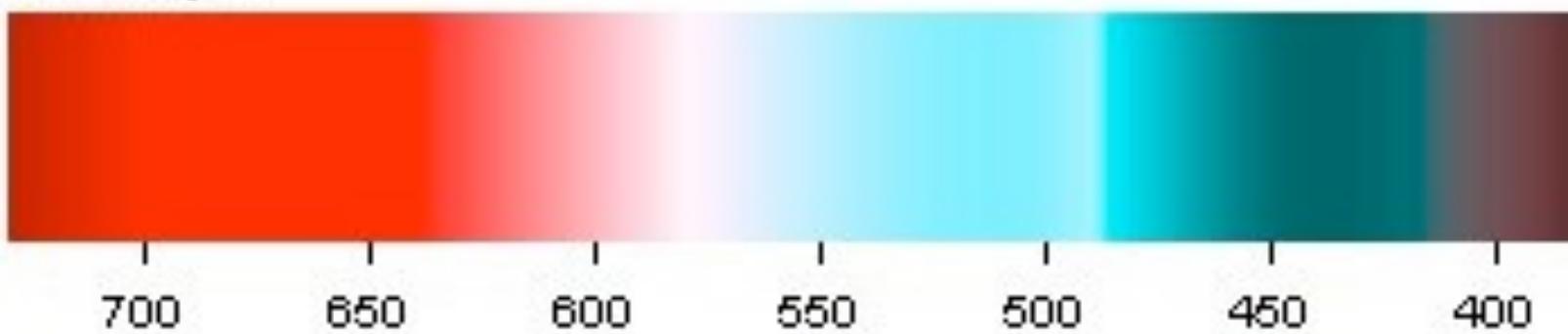
Protanopia

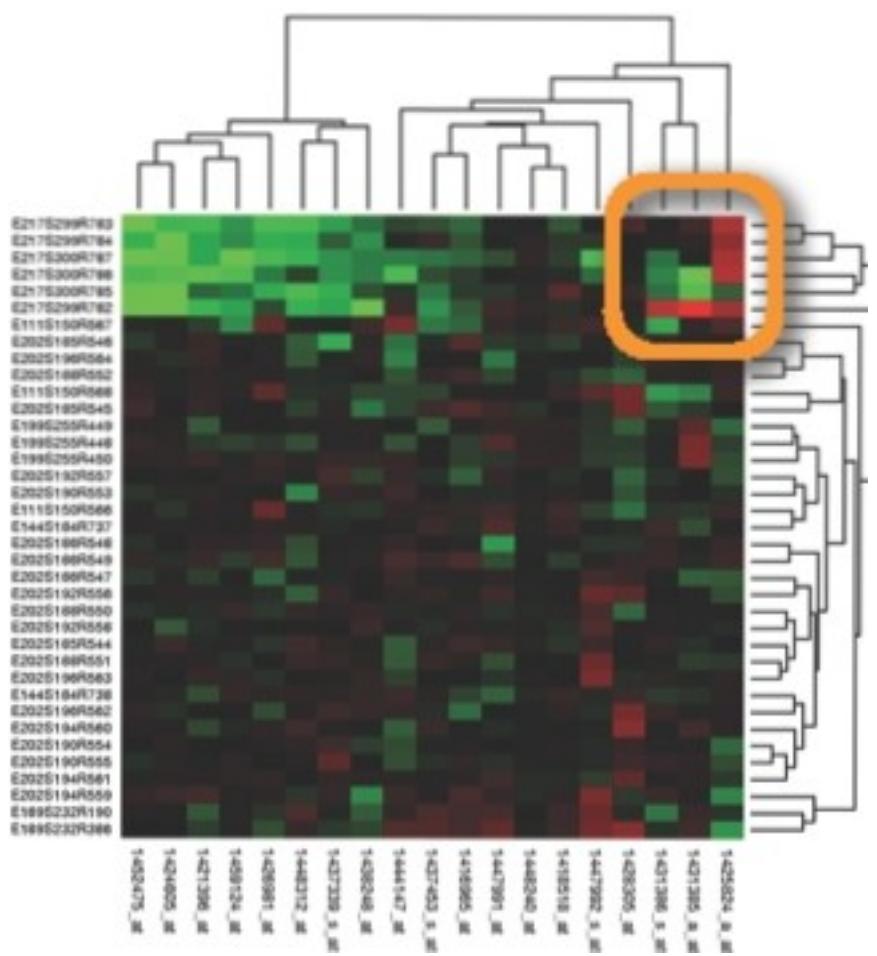


Deuteranopia



Tritanopia

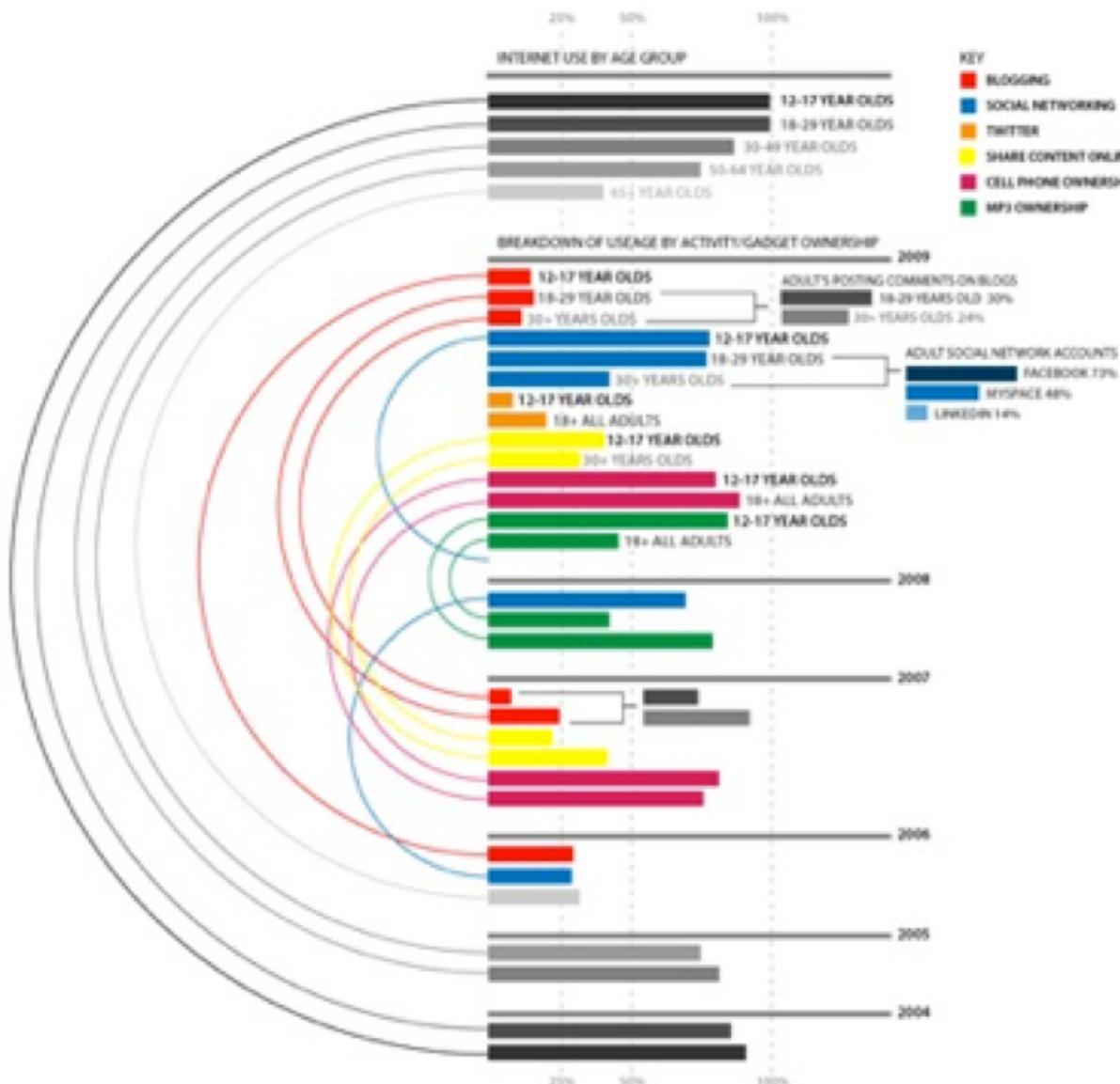




How different age groups are using the internet

With the growth of social media networks such as Facebook and Twitter, traditional blogging has been usurped by micro-blogging quick and short 140 character updates instead of lengthy, in-depth (and sometimes still-equally-pointless) articles.

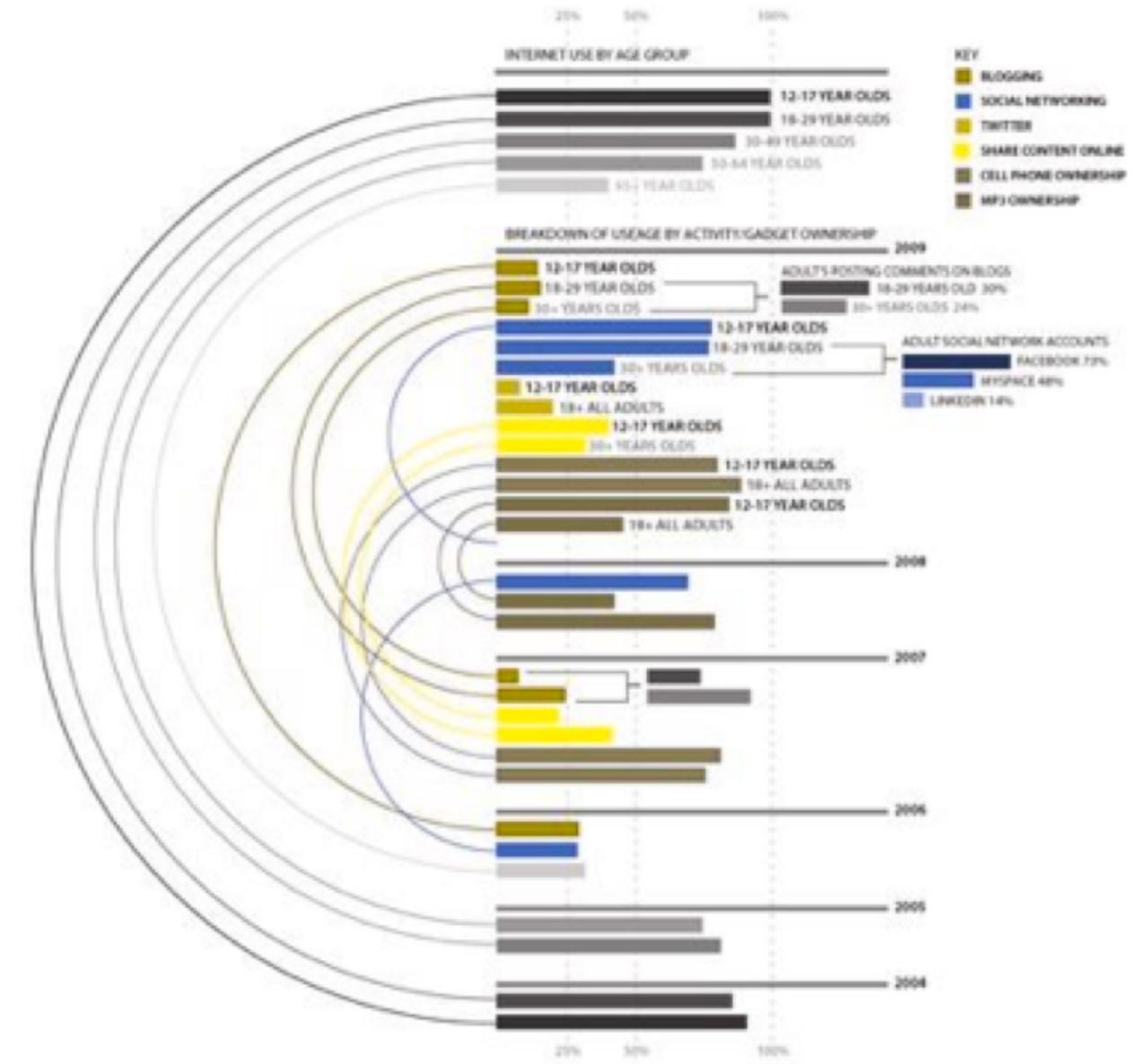
However, while teens and young adults seem to be shunning blogging, it is still strong among the over 30s...



How different age groups are using the internet

With the growth of social media networks such as Facebook and Twitter, traditional blogging has been usurped by micro-blogging quick and short 140 character updates instead of lengthy, in-depth (and sometimes still-equally-pointless) articles.

However, while teens and young adults seem to be shunning blogging, it is still strong among the over 30s...



MONOCHROMACY

total color blindness, very rare

1 dimensional color vision

2 or 3 cone pigments are missing

rod monochromacy: non-functioning or
missing cones (achromatopsia)

cone monochromacy: multiple deficient cones

Normal Vision



Achromatopsia



DICHROMACY

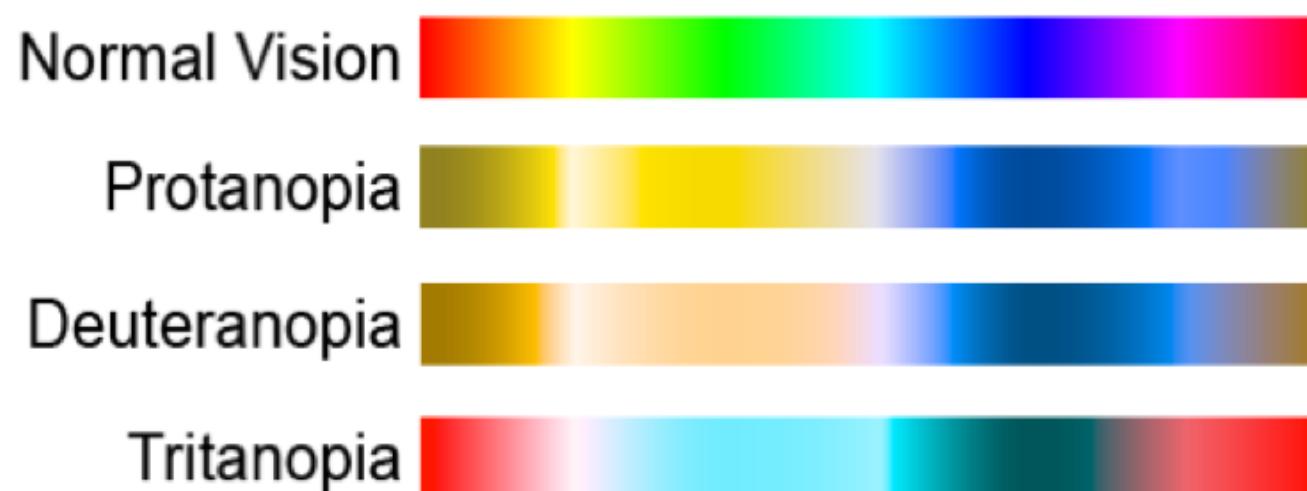
2 dimensional color vision

1 cone pigment is missing

protanopia: absence of red receptors

deuteranopia: absence of green receptors

tritanopia: absence of blue receptors



TYPES: TRICHOMACY

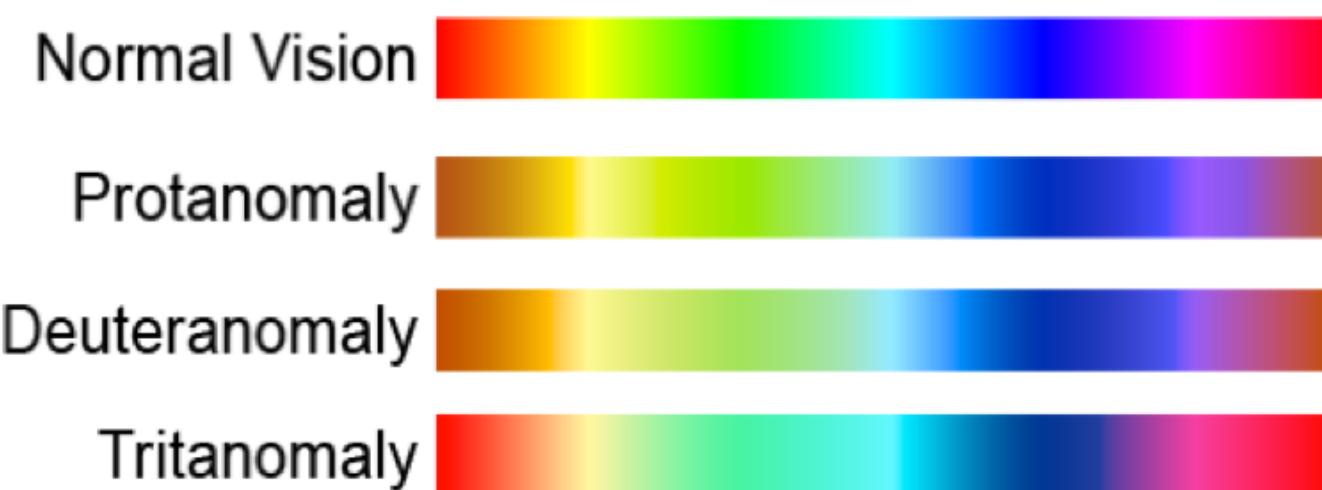
3 dimensional color vision

1 cone is altered in spectral sensitivity—impairment rather than loss

protanomaly: shift in red, poor red-green discrimination

deuteranomaly: shift in green, poor red-green discrimination (most common form of color deficiency)

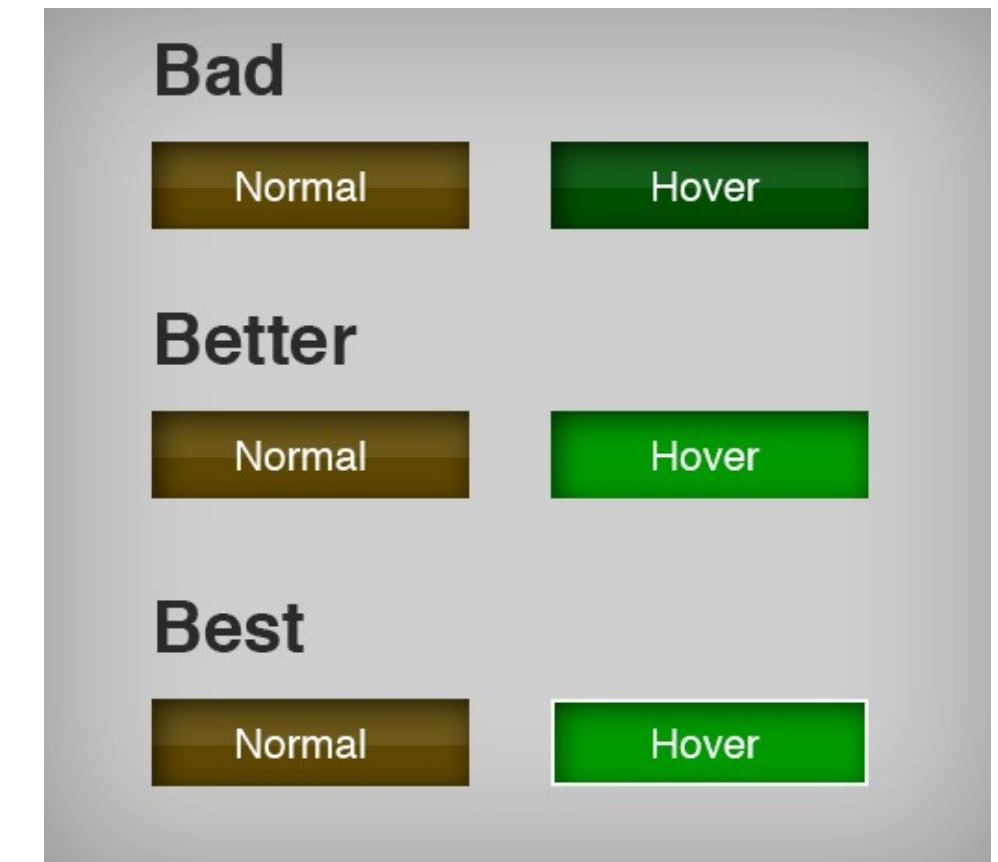
tritanomaly: poor blue-yellow discrimination



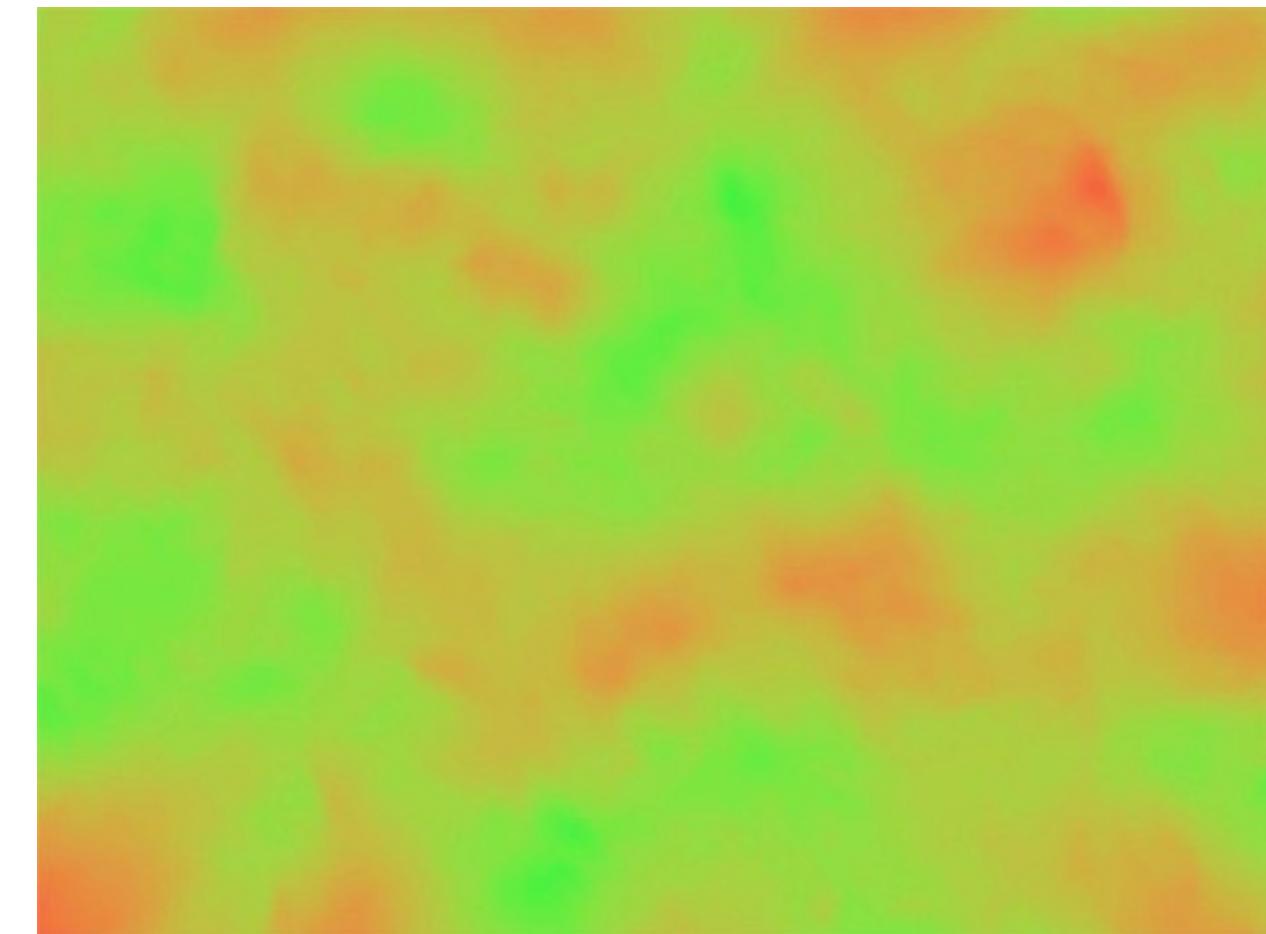
TAKEAWAY

Even if you aren't colorblind, someone you're working with could be.

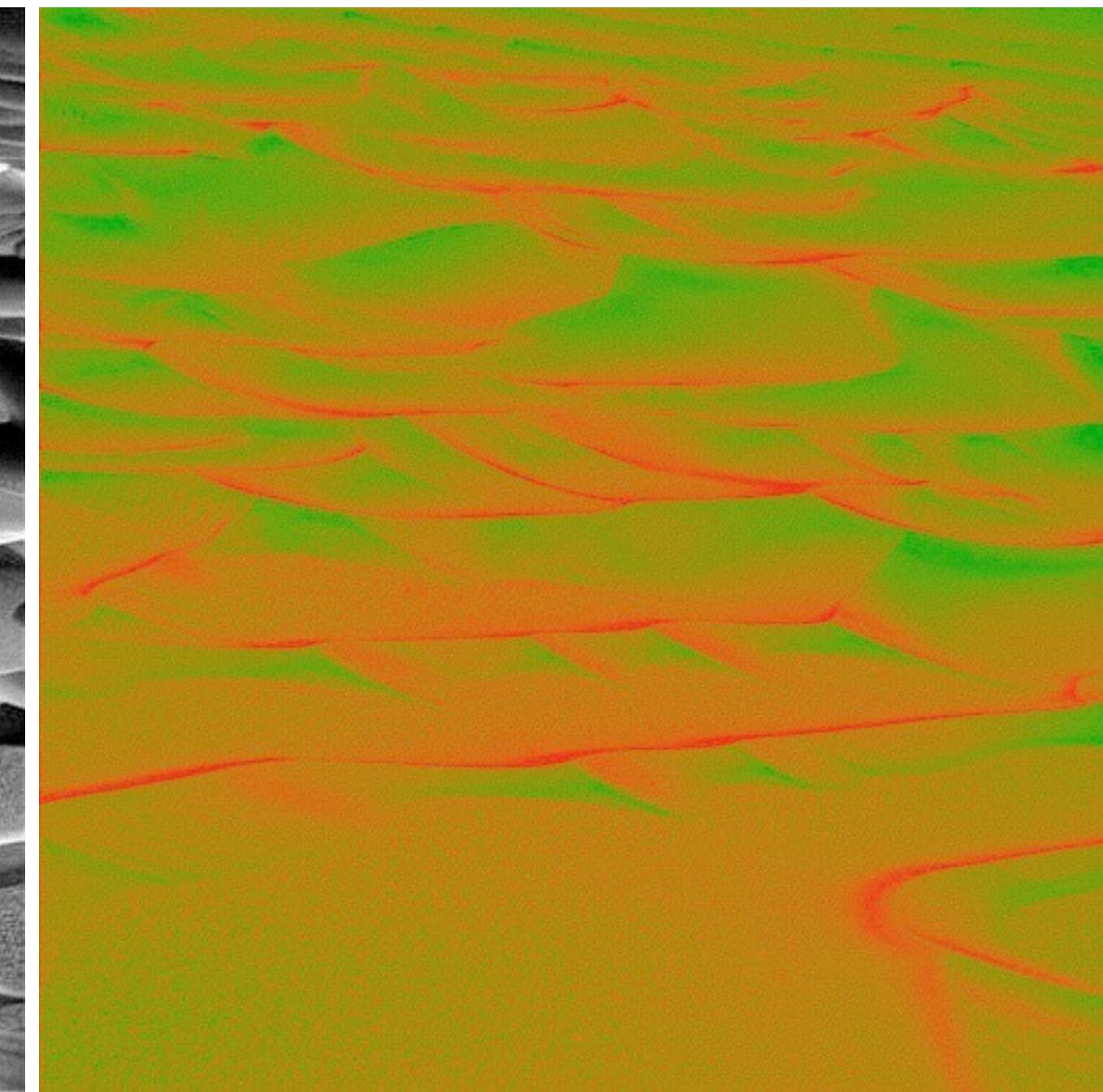
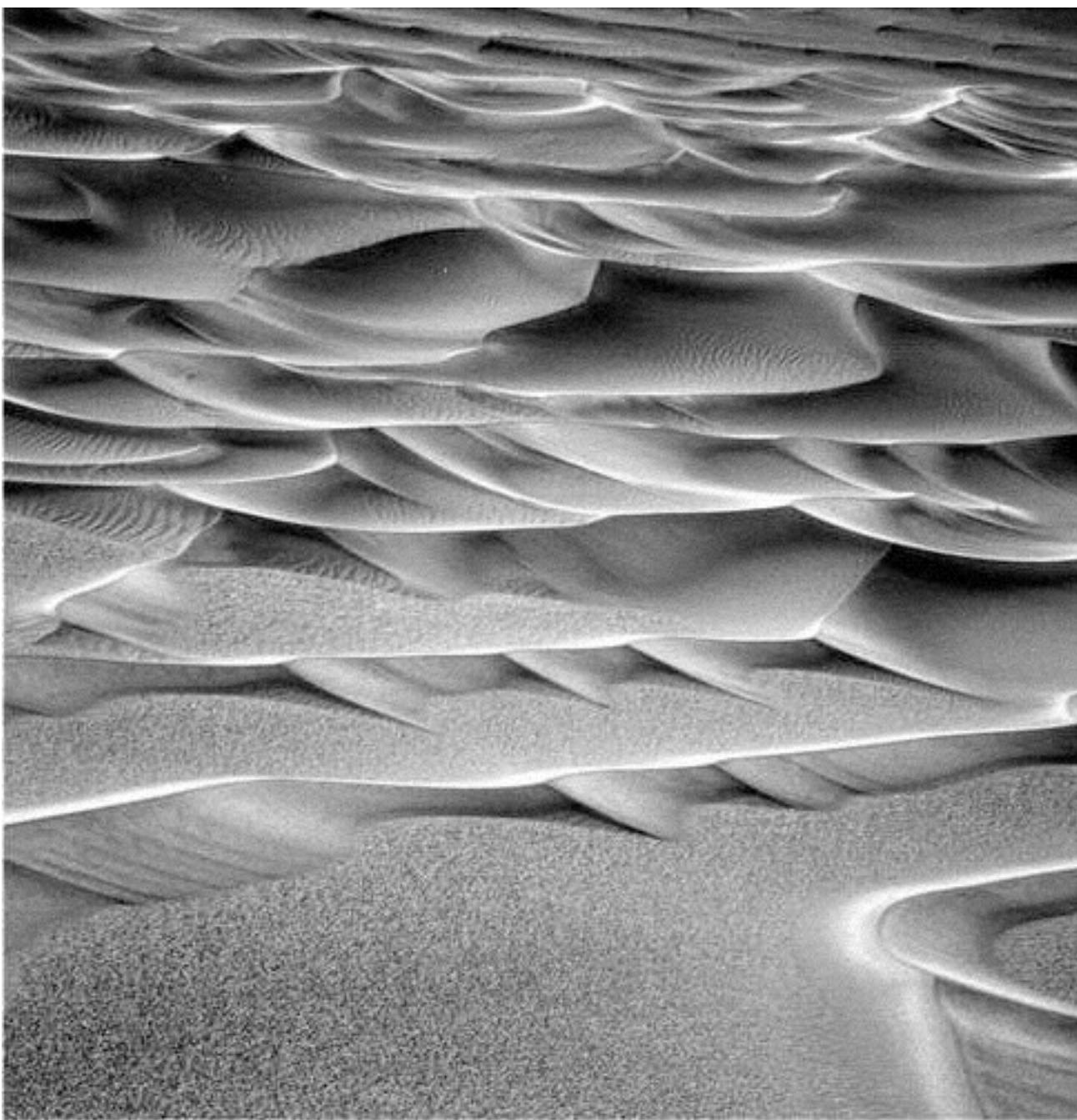
**Be sure to design with colorblindness in mind by:
varying hue, saturation, brightness
using monochrome color schemes
using cues besides/in addition to color
software solution, vischeck
(<http://www.vischeck.com>)**



CONTRAST SENSITIVITY



CONTRAST SENSITIVITY

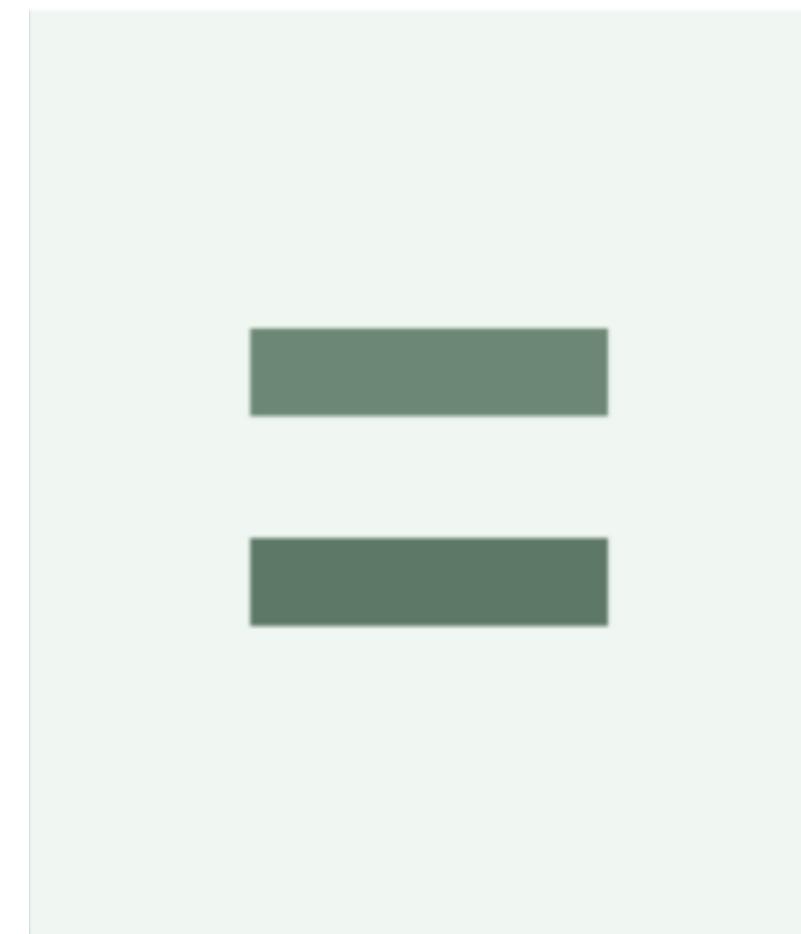
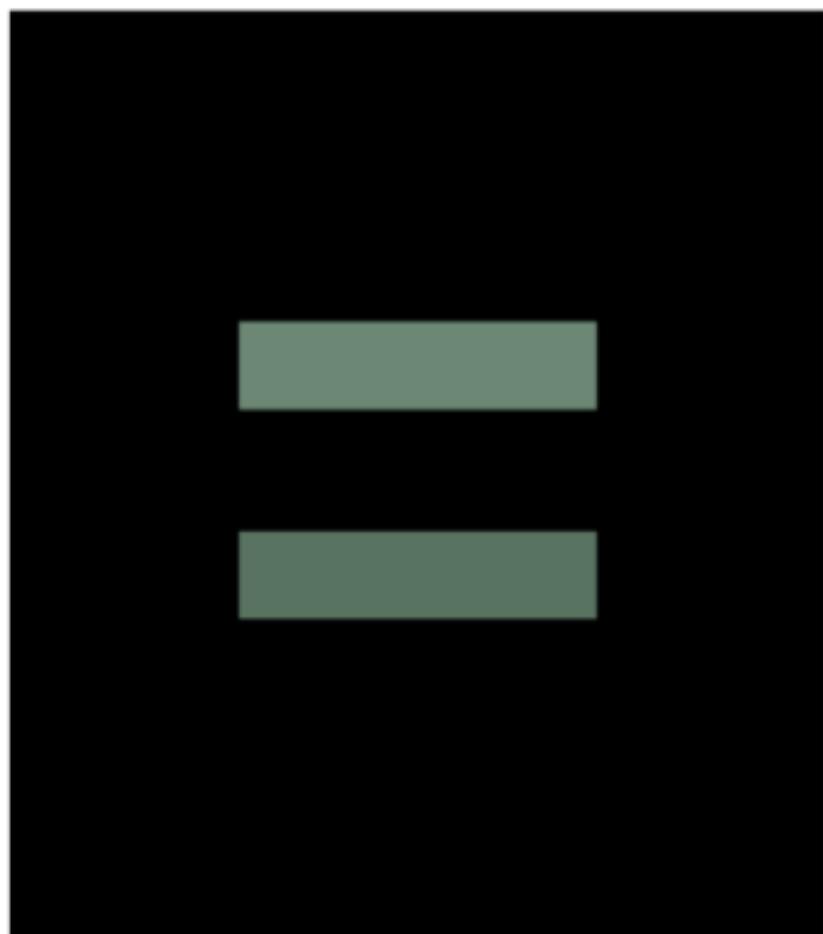


TAKEAWAY

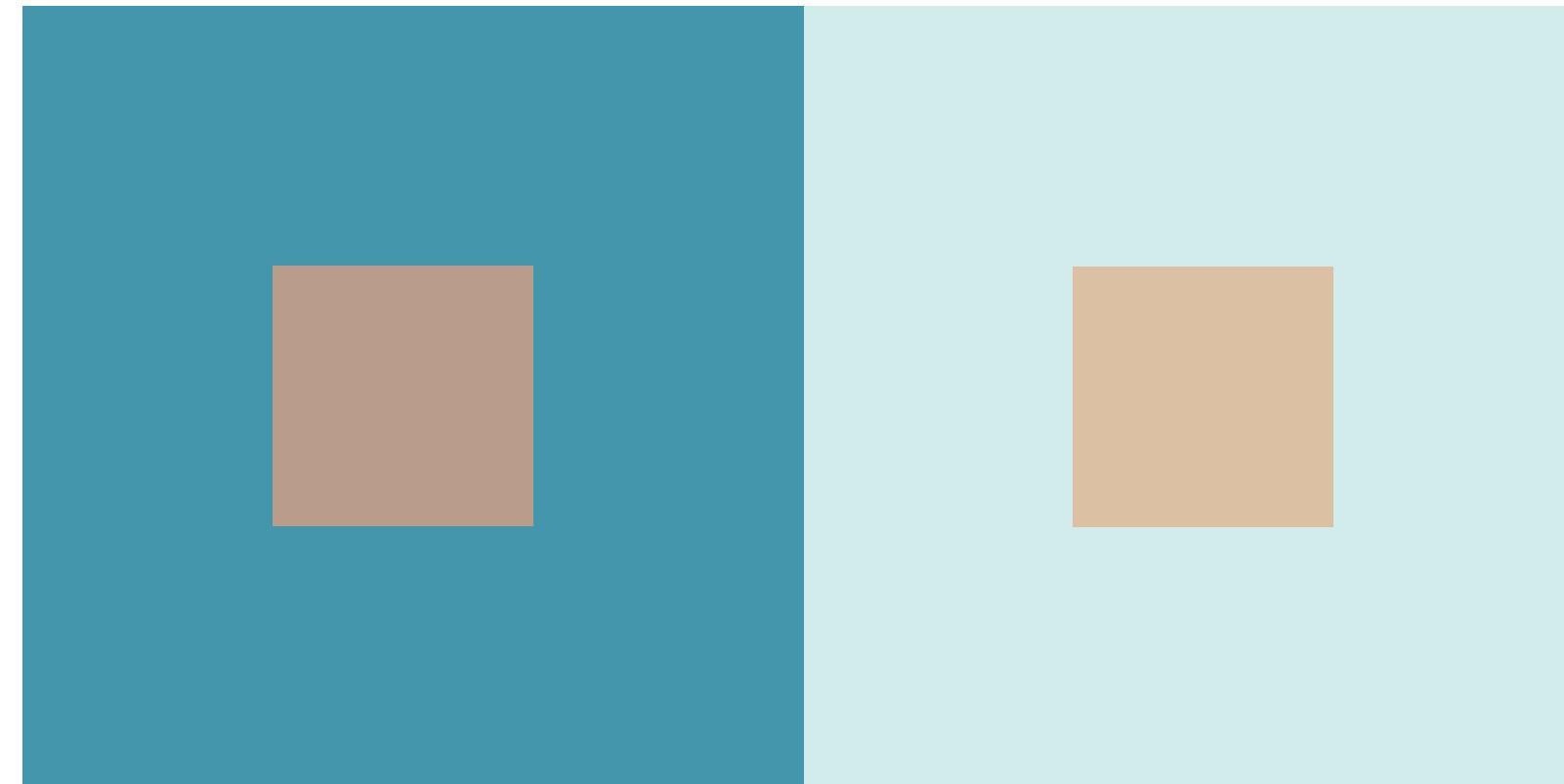
We have higher contrast sensitivity in the luminance than in the chrominance channel. Show preference to luminance for encoding detail.



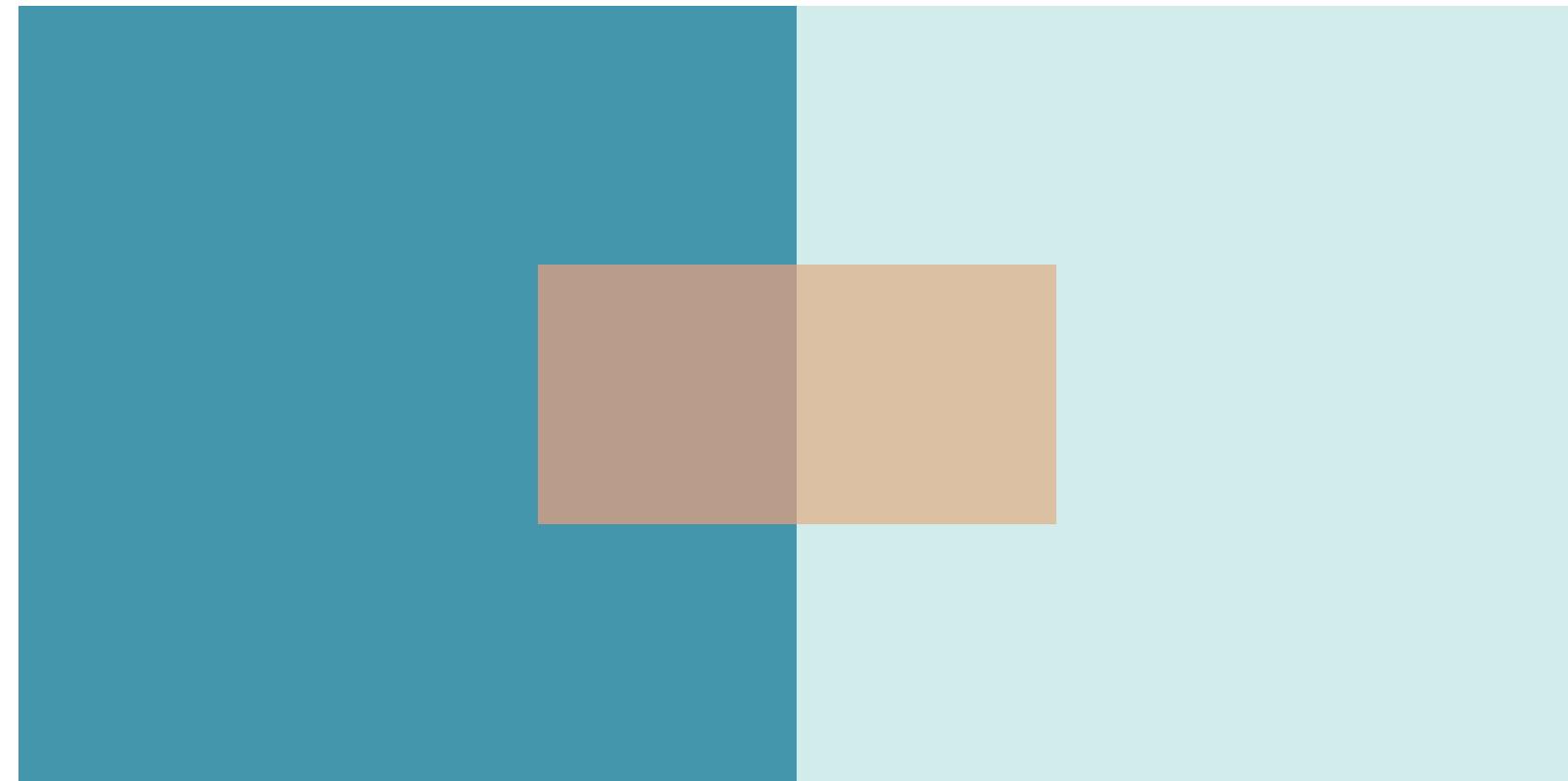
COLOR RELATIVITY



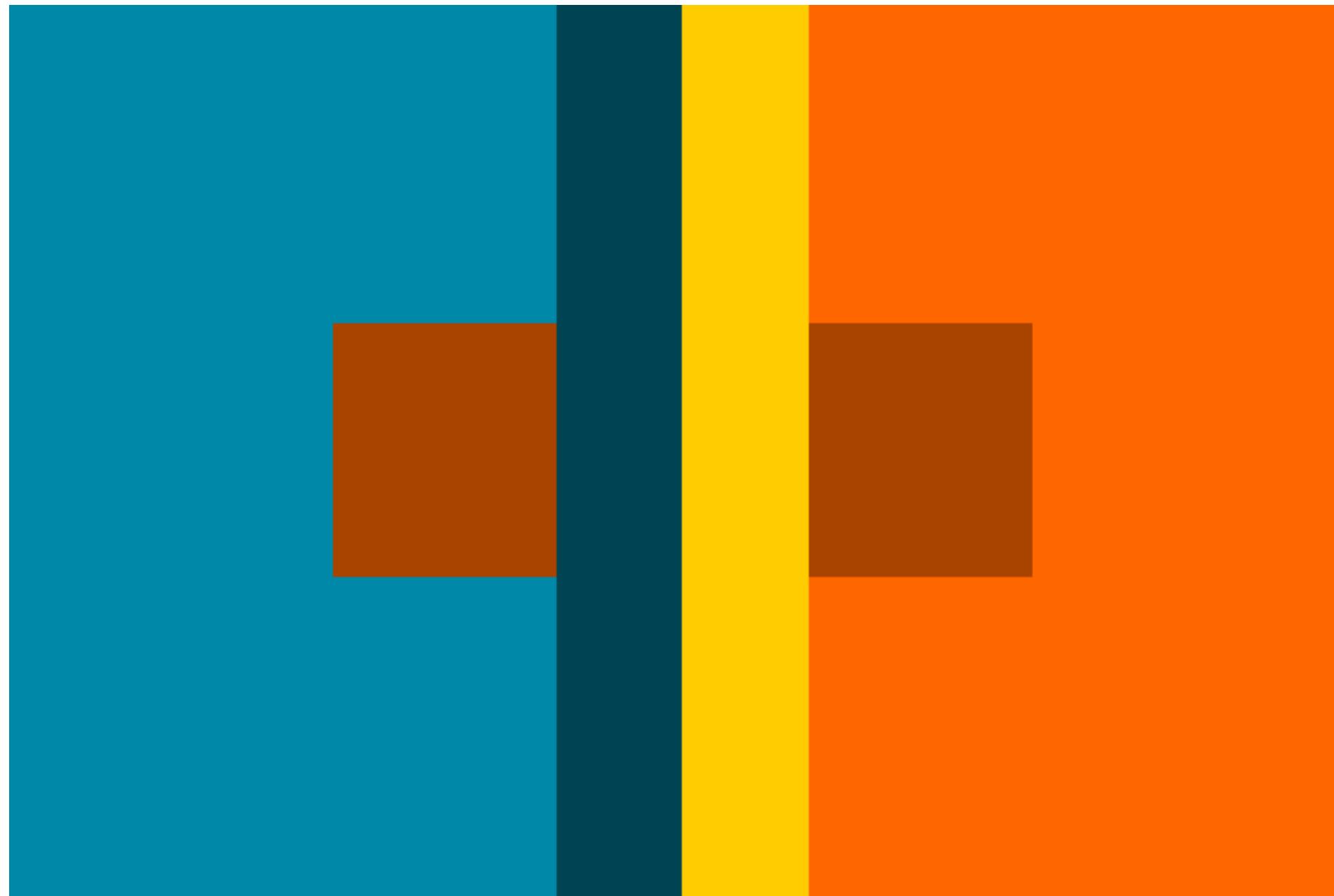
COLOR RELATIVITY



COLOR RELATIVITY



COLOR RELATIVITY



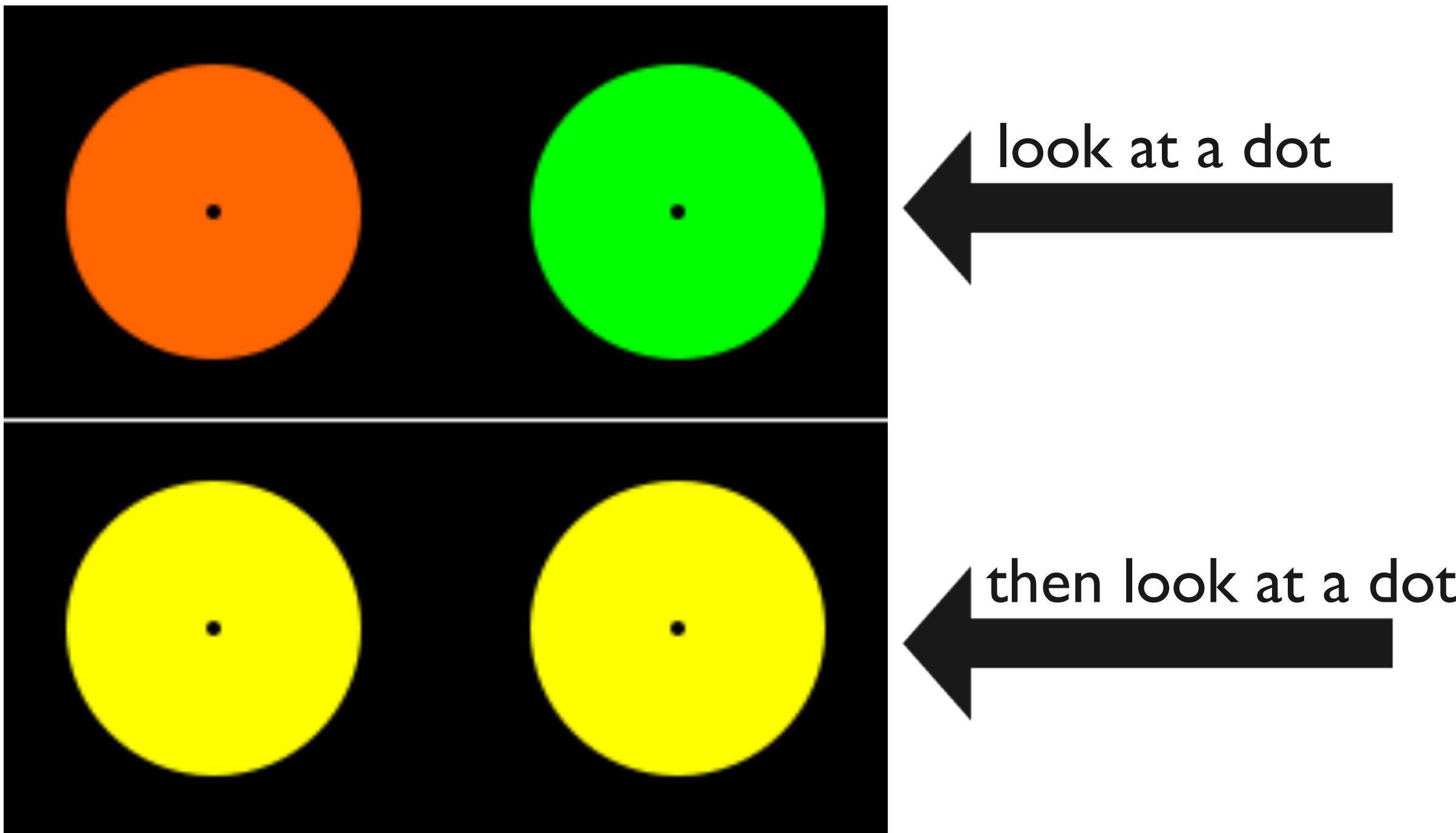
COLOR RELATIVITY



COLOR RELATIVITY



SUCCESSIVE CONTRAST



LUMINANCE CONTRAST

Showing small blue text on a black background is a bad idea.
There is insufficient luminance contrast.

Showing small blue text on a black background is a bad idea.
There is insufficient luminance contrast.

Showing small yellow text on a white background is a bad idea.
There is insufficient luminance contrast.

Showing small yellow text on a white background is a bad idea.
There is insufficient luminance contrast.

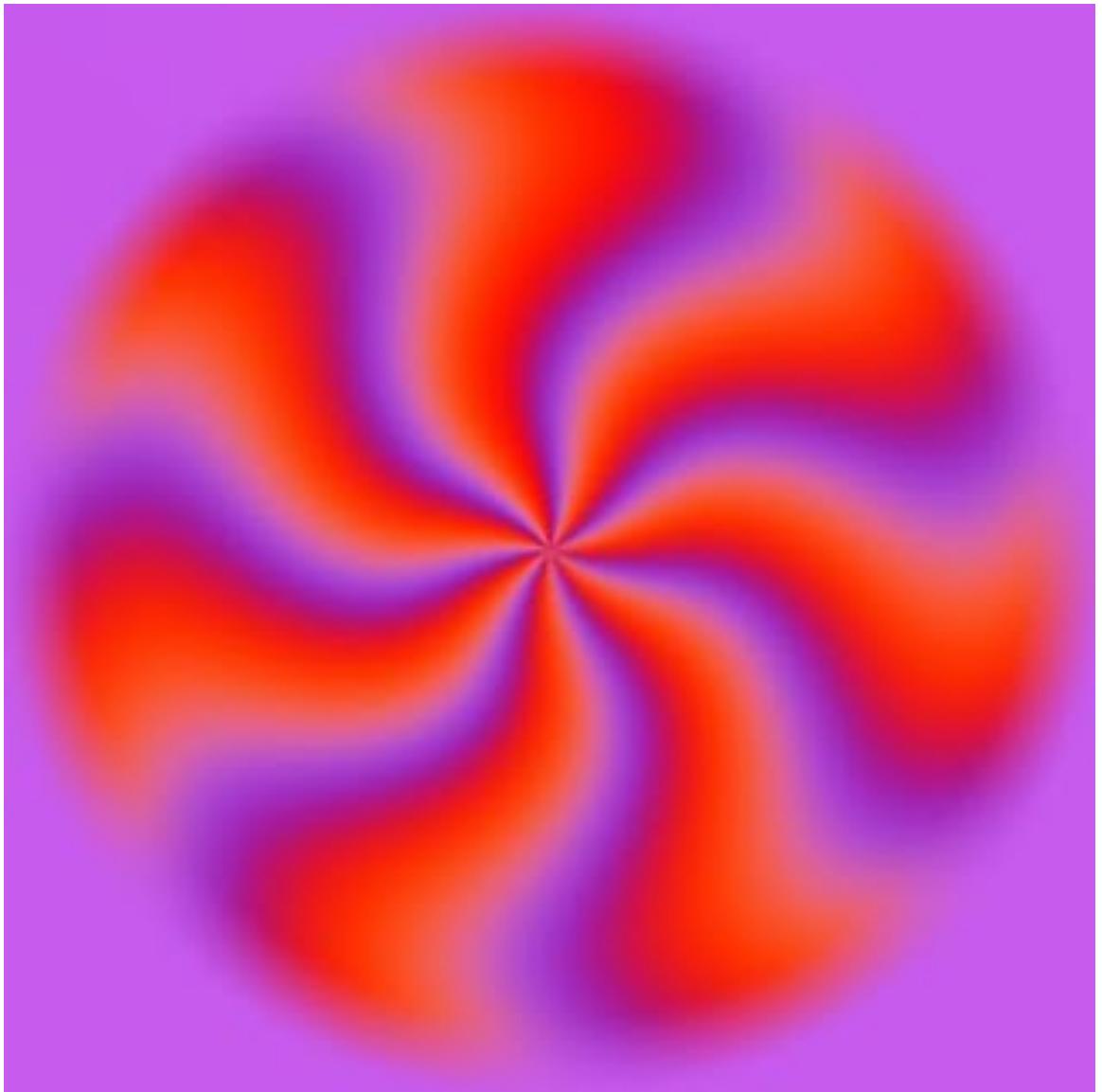


EQUILUMINANT COLORS

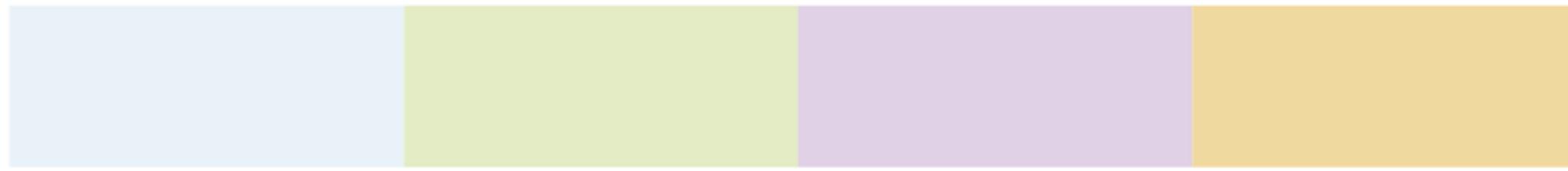
strong contrast: shapes seen by
color sensitive cells

equiluminance: hides positions
from light sensitive cells

flickering/movement caused by this
disconnect



SIZE & COLOR



“the smaller the mark, the less
distinguishable are the colors”

-Jacques Bertin



© The American Statistician, May 1983, Vol. 37, No. 2

WHICH AREA IS
LARGER, RED OR
GREEN?

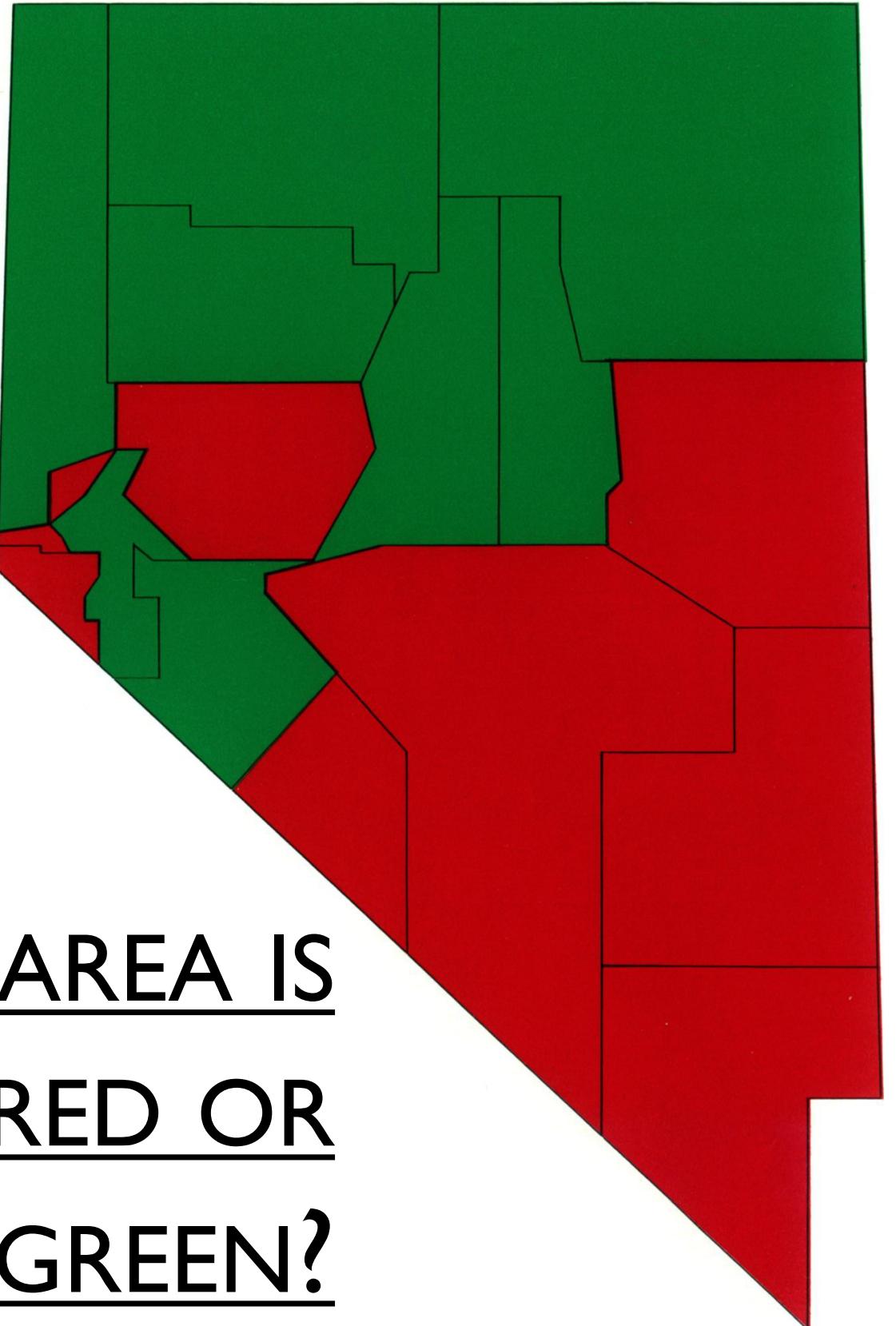


Figure 1. Stimulus From the High-Saturation Group



TAKEAWAY

We have a strong propensity to assume our judgments of color are absolute, when in fact they are extremely relativistic.

Do your best to not place data in difficult contexts. Use color sparingly.



GUIDELINES

color is a relative medium—if encoding ordinal data with color, place marks on solid, neutral background

because of contrast effects, it is difficult to perceive absolute luminance of noncontiguous regions

for text, ideally use 10:1 ratio, 3:1 minimum

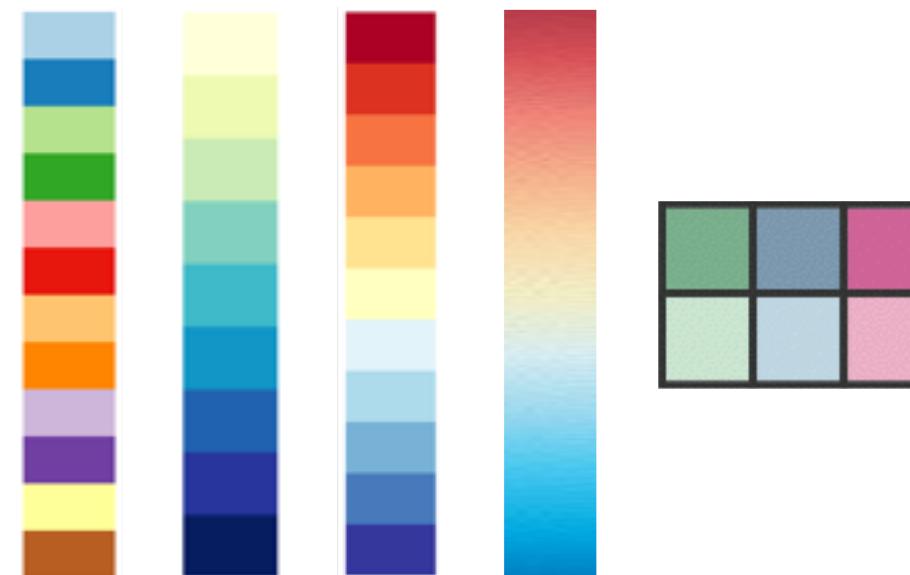


GUIDELINES

in small regions use bright, highly saturated colors
for points and lines use just two saturation levels
use low saturation pastel colors for large regions and
backgrounds



$[0, 8] \rightarrow$



WHAT IS A COLORMAP?

specifies a mapping between color and values
also called a transfer function

categorical vs ordered
sequential vs diverging
segmented vs continuous
univariate vs bivariate

EXPRESSIVENESS: MATCH COLORMAP TO ATTRIBUTE TYPE CHARACTERISTICS!



GUIDELINES

categorical colors are easier to remember if
they are nameable

ordered colormaps should vary along
saturation or luminance

bivariate colormaps are difficult to interpret if
at least one variable is not binary

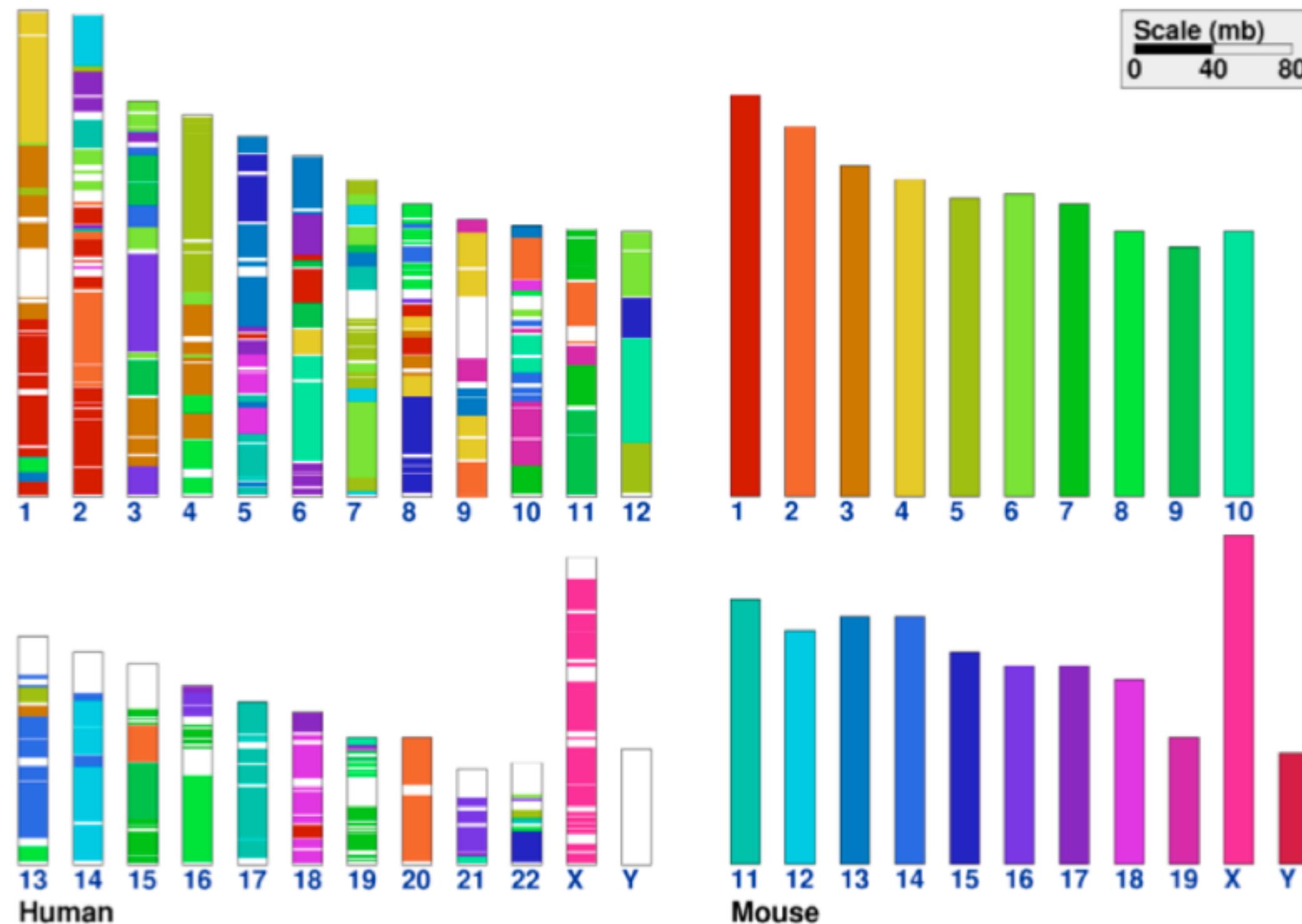


HUES FOR CATEGORIES



DISTINGUISHABILITY

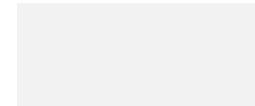
only good at distinguishing 6-12 simultaneous colors



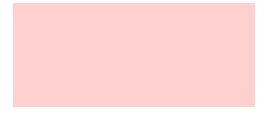
ORDER THESE COLORS...



ORDER THESE COLORS...



ORDER THESE COLORS...



GUIDELINES

luminance and saturation are most effective for ordinal data because they have an inherent ordering

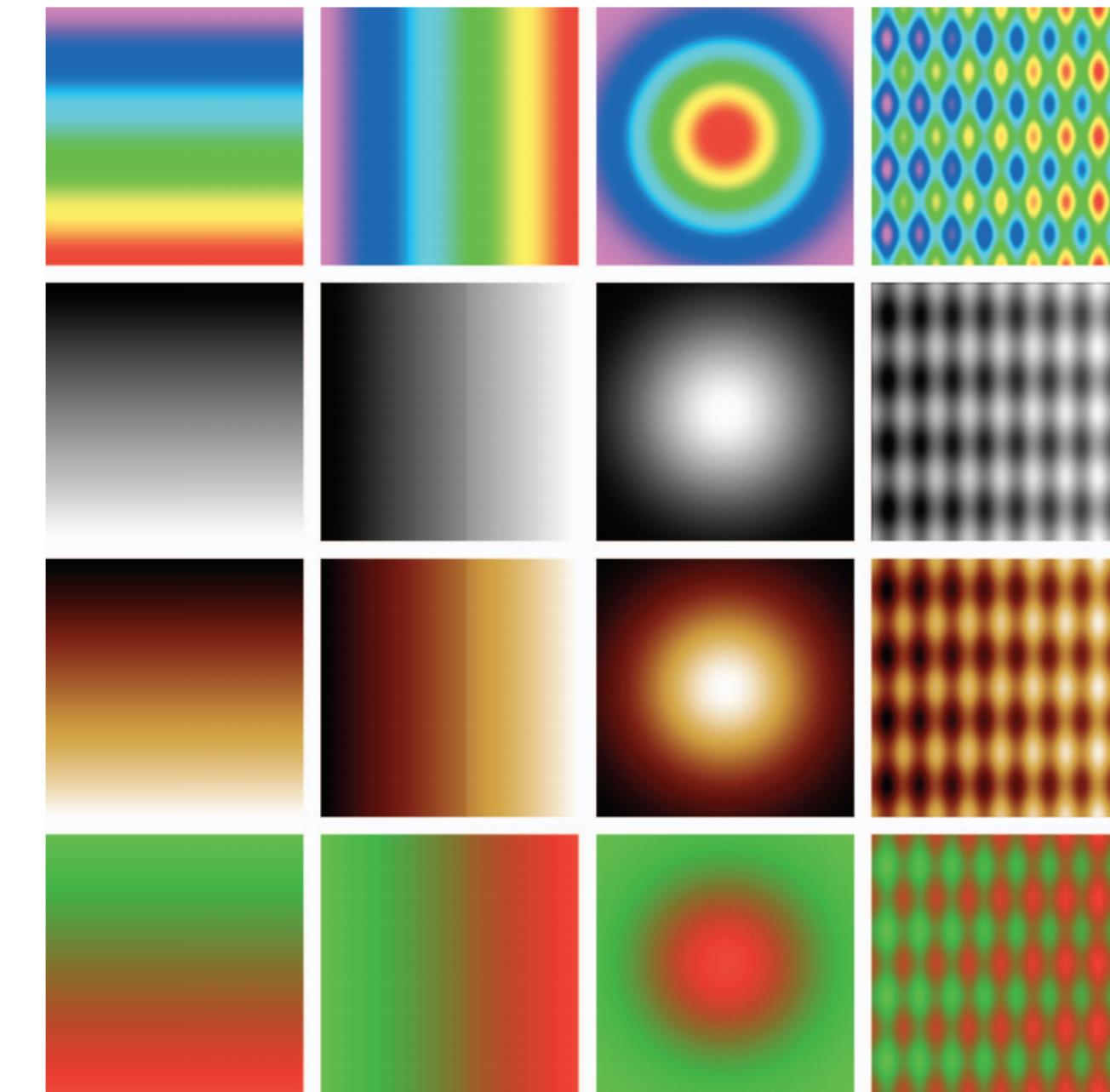
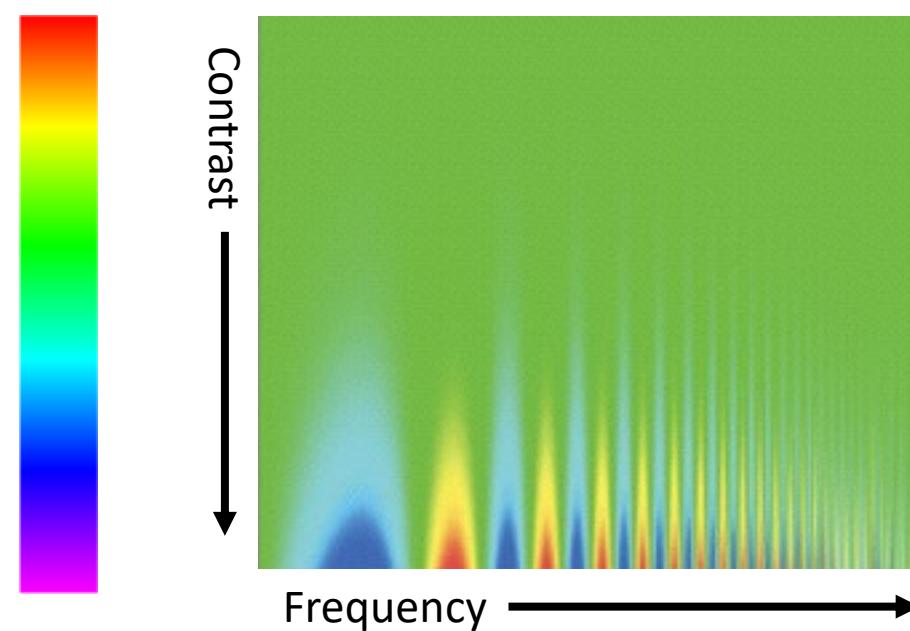
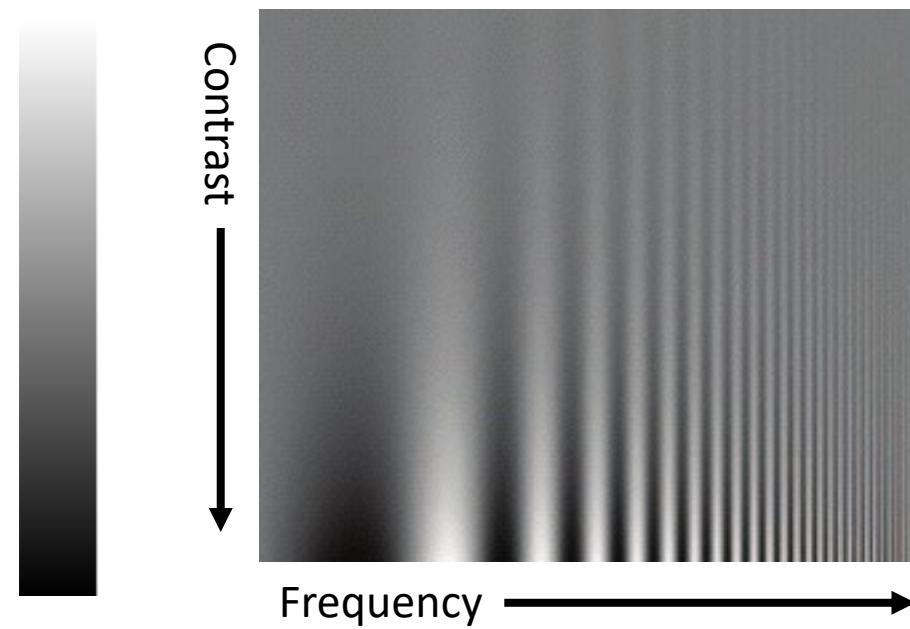
hue is great for categorical data because there is no inherent ordering

but limit number of hues to 6-12 for distinguishability

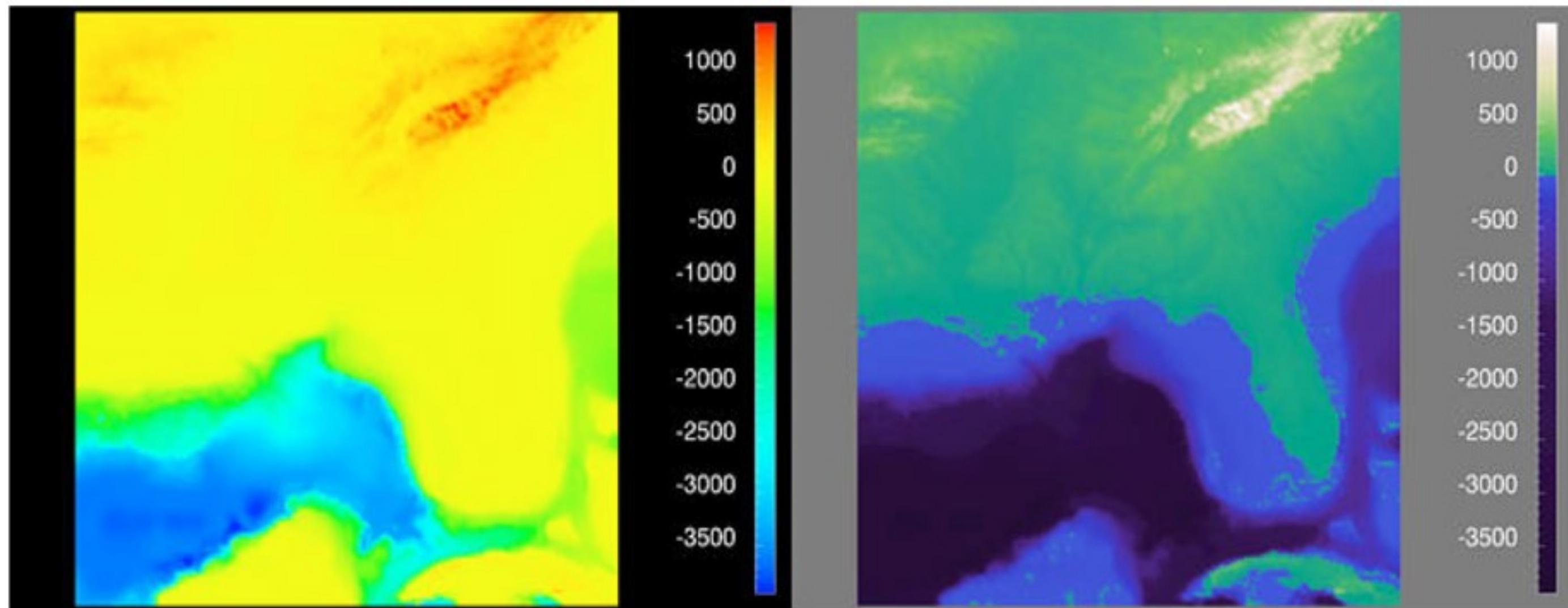
number of hues and distribution on the colormap should be related to which and how many structures in the data to emphasize



RAINBOW COLORMAPS: CHALLENGES



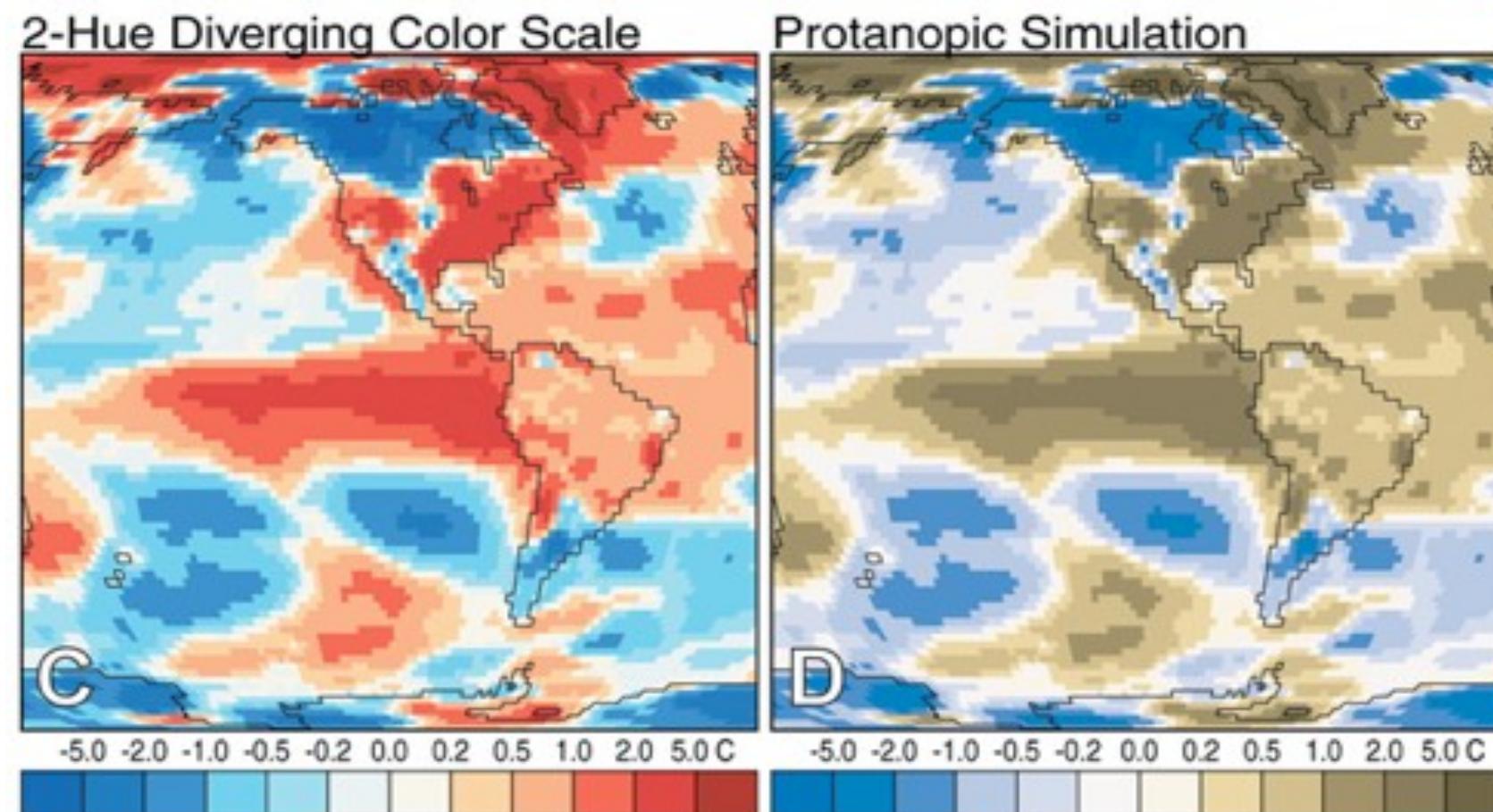
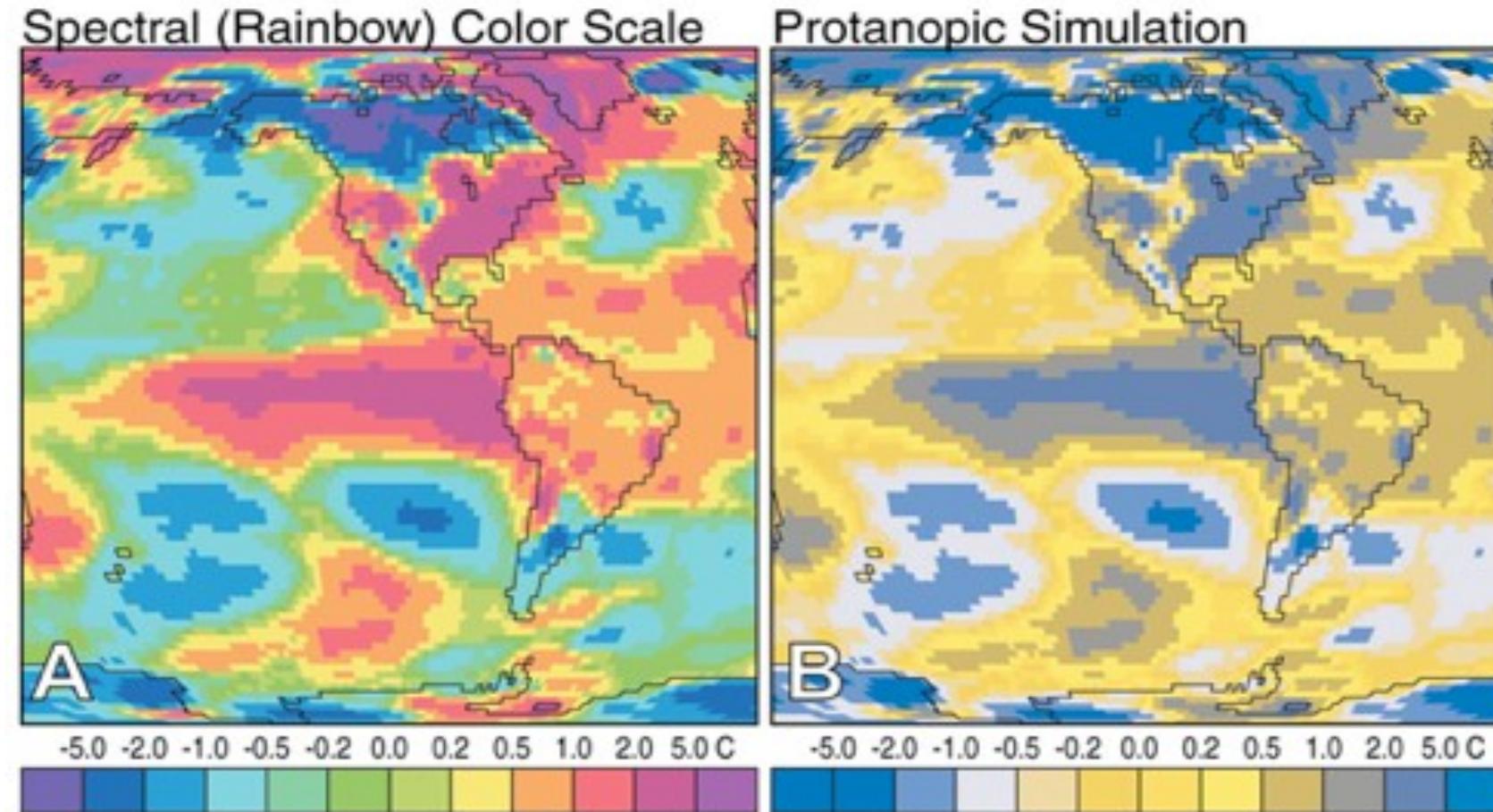
RAINBOW COLORMAPS: CHALLENGES



zero crossing not explicit



RAINBOW COLORMAPS: CHALLENGES



COLOR SECTION GUIDELINES



RAINBOW GUIDELINES

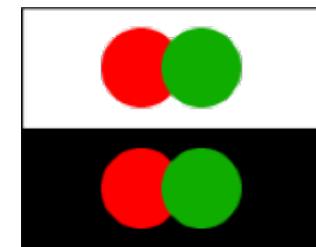
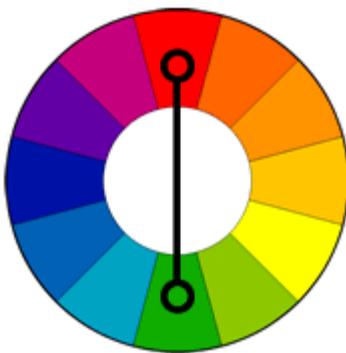
poor



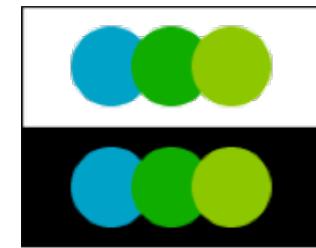
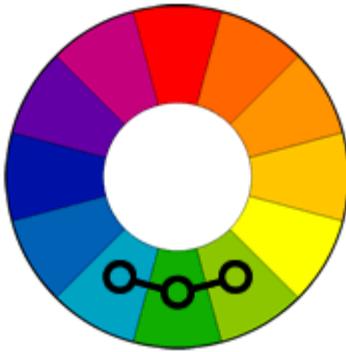
better



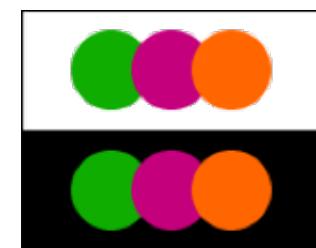
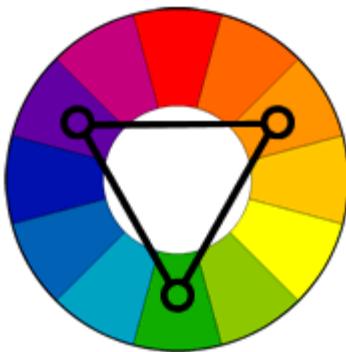
COLOR HARMONIES



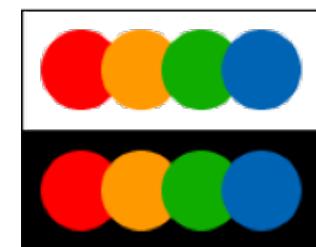
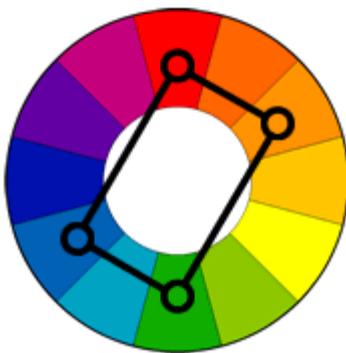
Complementary—high contrast creates a vibrant look



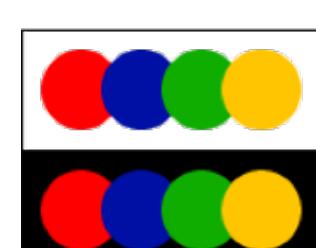
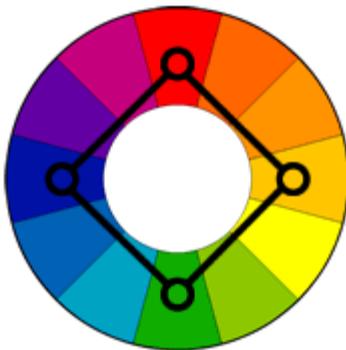
Analogous—often found in nature and are harmonious and pleasing to the eye



Triad—vibrant, even if you use pale or unsaturated versions of your hues



Split-complementary—same strong contrast as the complementary but less tension



Rectangle—rich color scheme offers plenty of possibilities for variation



LOOK TO NATURE



SIMPLICITY

choose one color to be used in
larger amounts

be selective about the base color
use other colors to add interest



AVOIDANCE OF COLOR

use neutrals (work with any scheme)

black, white, grey

use diagrammatic marks (may be better
encoding channels)

size, shape, texture, length, width, orientation, curvature and
intensity



GET IT RIGHT IN BLACK AND WHITE.

Maureen Stone



TOOLS FOR COLOR



ColorBrewer: Color Advice for Maps

colorbrewer2.org

Device(Anonymous) camera http://192.168.2.1/ Google Scholar UT hiking poetry-vis Marriott Library Reader

Number of data classes: 3

Nature of your data: sequential

Pick a color scheme:

Multi-hue: Single hue:

Only show:

- colorblind safe
- print friendly
- photocopy safe

Context:

- roads
- cities
- borders

Background:

- solid color
- terrain

color transparency

how to use | updates | downloads | credits

COLORBREWER 2.0
color advice for cartography

3-class BuGn

EXPORT

HEX

#e5f5f9
#99d8c9
#2ca25f

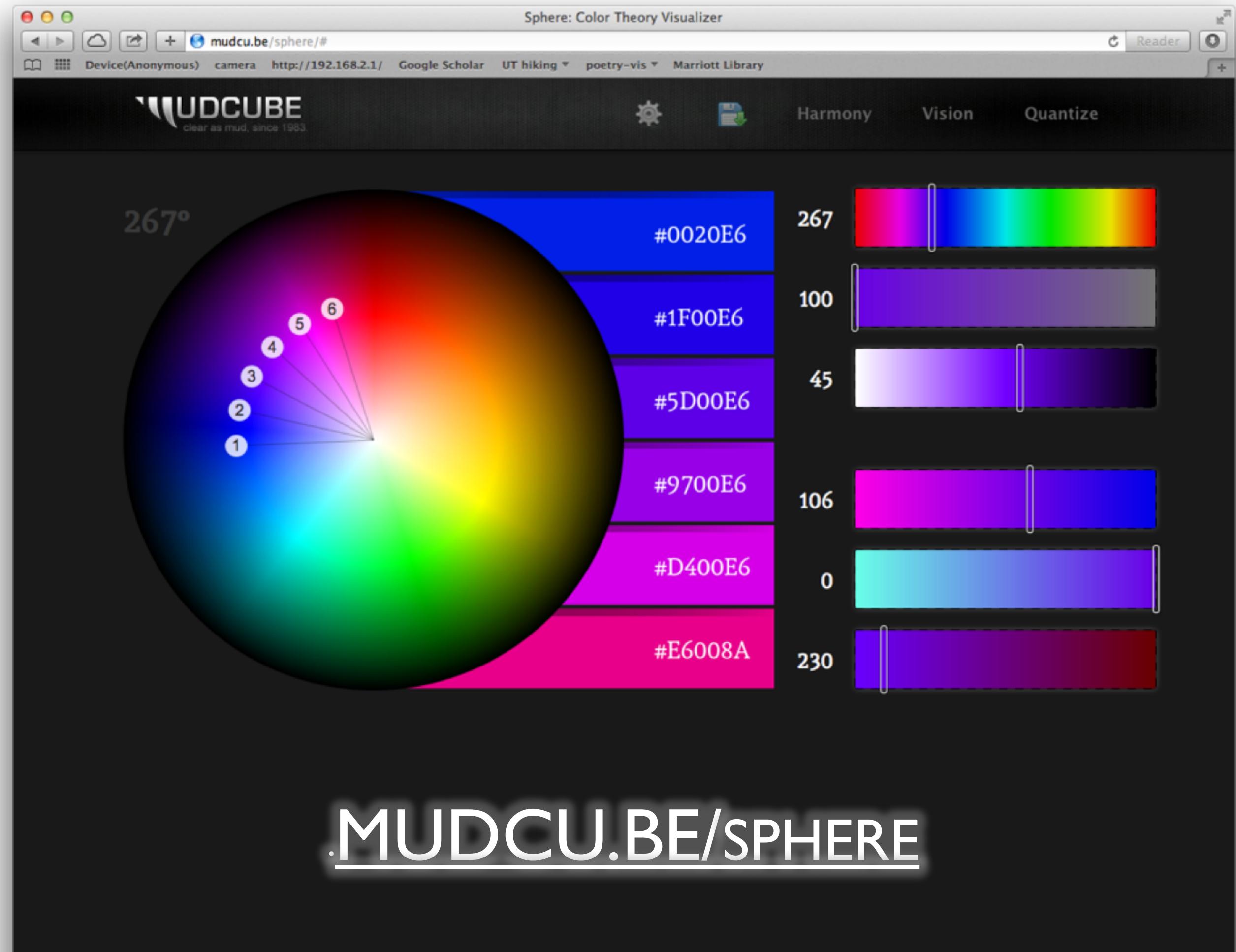
A map of the United States divided into states, each filled with a different shade of green. The colors range from a pale cyan-green in the western states to a deep forest green in the eastern states. The map is overlaid with state boundaries and shows a clear geographic pattern where darker shades are concentrated in the more densely populated and eastern parts of the country.

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Support
[Back to Flash version](#)
[Back to ColorBrewer 1.0](#)

axismaps

COLORBREWER2.ORG





A screenshot of the Adobe Kuler website. At the top, there's a sidebar with a list of mood names: 'Selected a Mood' (with a radio button), 'Colorful', 'Bright', 'Muted', 'Deep', 'Dark', and 'Cultured'. Below this is a large image of a red and yellow flower, likely a zinnia, with several color swatches overlaid on its petals. At the bottom of the image area are two buttons: a green one labeled 'locked' with a lock icon, and a blue one labeled 'Edit' with a pencil icon. The background of the main content area is a gradient from orange to red. In the bottom right corner, the text '.KULER.ADOBE.COM' is displayed in a large, white, sans-serif font.

Create

- From a Color
- From an Image
- Themes
- Community
- Fiber
- Links

Select a Rule

- Analogous
- Monochromatic
- Triad
- Complementary
- Compound
- Shades
- Custom

#34495E

Sign In

Please sign in to save your theme.

RGB: 52, 73, 94
HSL: 144, 46%, 50%
CMYK: 100, 64, 0, 0
LAB: 53, 12, -12
OCT: 000000

RGB: 238, 238, 238
HSL: 0, 0%, 100%
CMYK: 0, 0, 0, 0
LAB: 95, 12, 12
OCT: FFFFFF

RGB: 186, 196, 196
HSL: 186, 34, 58
CMYK: 10, 0, 0, 0
LAB: 53, 12, 12
OCT: E6EAE6

RGB: 166, 166, 166
HSL: 0, 0%, 50%
CMYK: 0, 0, 0, 0
LAB: 48, 12, 12
OCT: D3D3D3

RGB: 136, 136, 136
HSL: 0, 0%, 50%
CMYK: 0, 0, 0, 0
LAB: 43, 12, 12
OCT: C0C0C0

RGB: 106, 106, 106
HSL: 0, 0%, 40%
CMYK: 0, 0, 0, 0
LAB: 38, 12, 12
OCT: A0A0A0

RGB: 76, 76, 76
HSL: 0, 0%, 30%
CMYK: 0, 0, 0, 0
LAB: 33, 12, 12
OCT: 808080

RGB: 46, 46, 46
HSL: 0, 0%, 20%
CMYK: 0, 0, 0, 0
LAB: 28, 12, 12
OCT: 606060

RGB: 16, 16, 16
HSL: 0, 0%, 10%
CMYK: 0, 0, 0, 0
LAB: 23, 12, 12
OCT: 404040

HEX: #34495E

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COLORSCHEMEDESIGNER.COM



Color Converter

colormine.org/color-converter

Device(Anonymous) camera http://192.168.2.1/ Google Scholar UT hiking poetry-vis Marriott Library

Reader

ColorMine.org

Color Converter

Select a color space and enter your values for accurately convert your selection to Rgb, Cmy, Cmyk, Hsl, Xyz, Lab, Lch and Yxy.

Note: ColorMine uses the sRgb color space. [More information on sRgb vs AdobeRgb.](#)

Rgb

We've recently added support for device specific [ICC Profiles](#) for conversions to Cmyk based on your feedback. This is a new feature so please let us know if you have any questions or problems with it using the feedback form below.

R 0

G 0

B 0

Color Space

Rgb

Cmyk Profile

No profile

Convert

.COLORMINE.ORG/COLOR-CONVERTER



Vischeck



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[Vischeck](#)

[Daltonize](#)

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User quotes:

I just stumbled onto your site and I'm pleased with the service that you offer. So far so good on the pages that I have on web. I'm encouraging the folks on my staff to use your site as a check.
-Eve D.

Vischeck [simulates](#) colorblind vision.

Daltonize [corrects](#) images for colorblind viewers.



How do babies see the world? Visit [TinyEyes](#).

Passive monitoring of cognitive health: [Mindstrong Health](#).



Web



Vischeck



Google Search



VISCHECK.COM

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RECOMMENDED READING

Visualization Analysis & Design: Chapter 10 (pp. 218-241)



