Human Perception

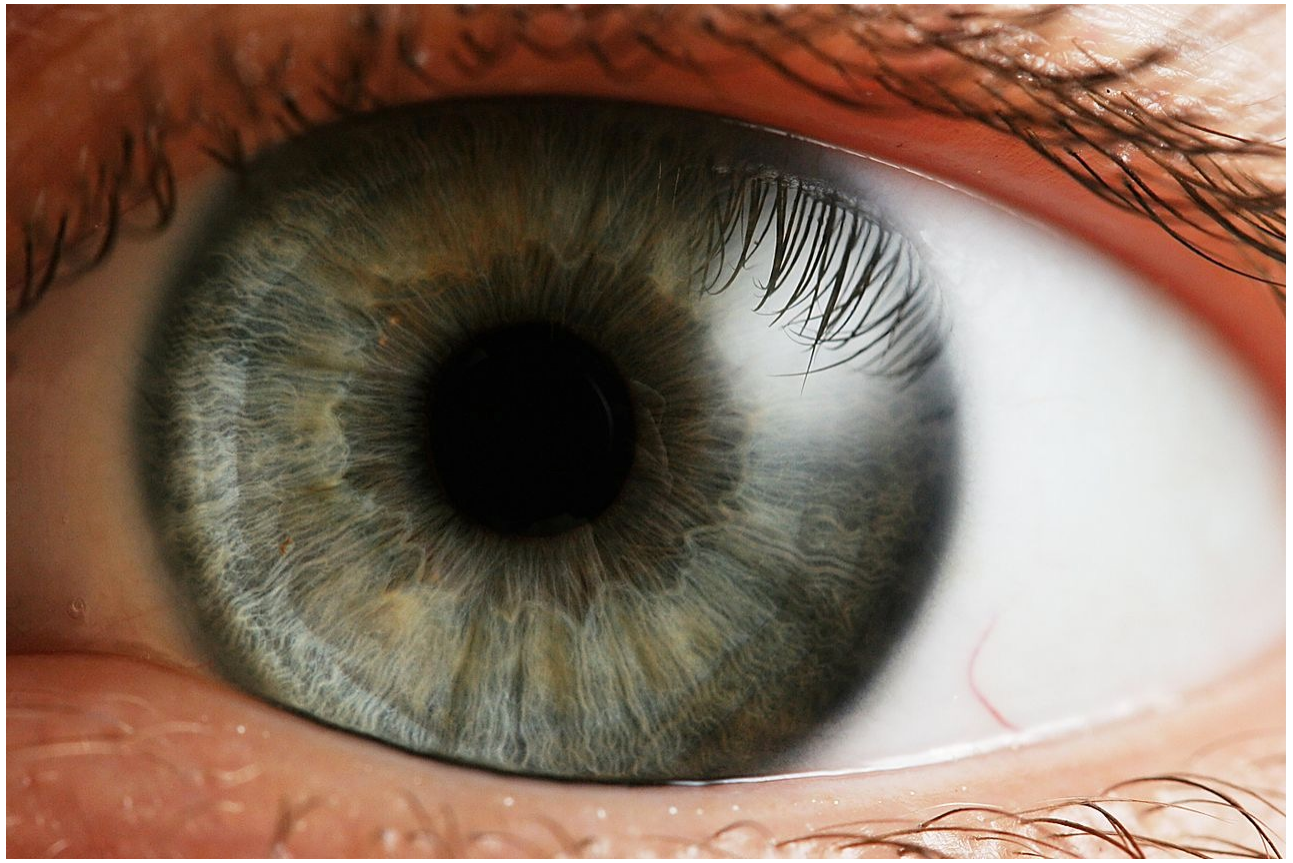
Information Processing

Perception

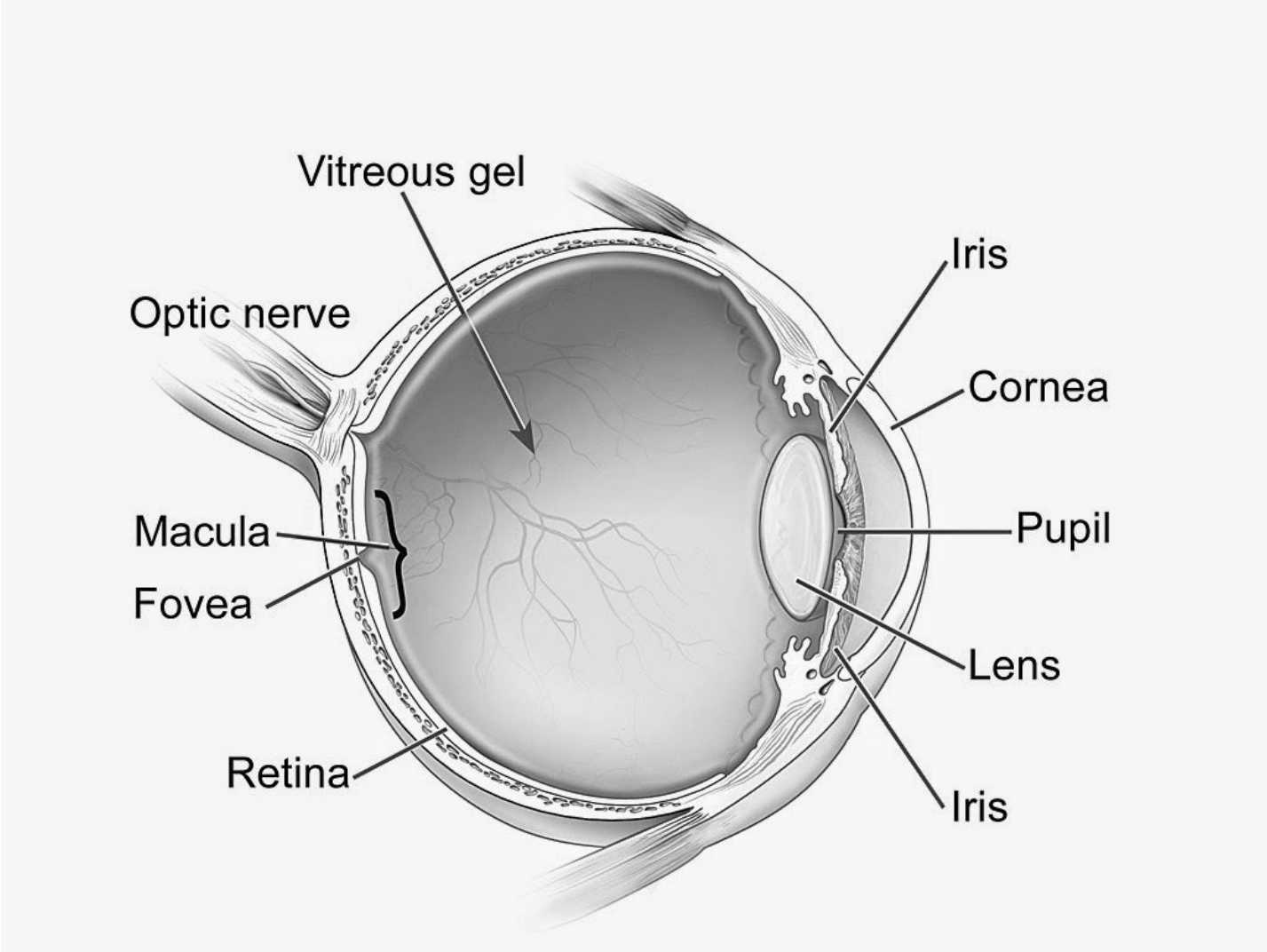
- We study perception to better control the presentation of data.
- Many definitions of perception
  - Process of recognizing (being aware of)
  - Organizing (gathering and storing)
  - Interpreting (binding to knowledge)
- Perception deals with human senses
- Perception is the process by which we interpret the world
- Our mental representation is not isomorphic to the real world

Human Visual System

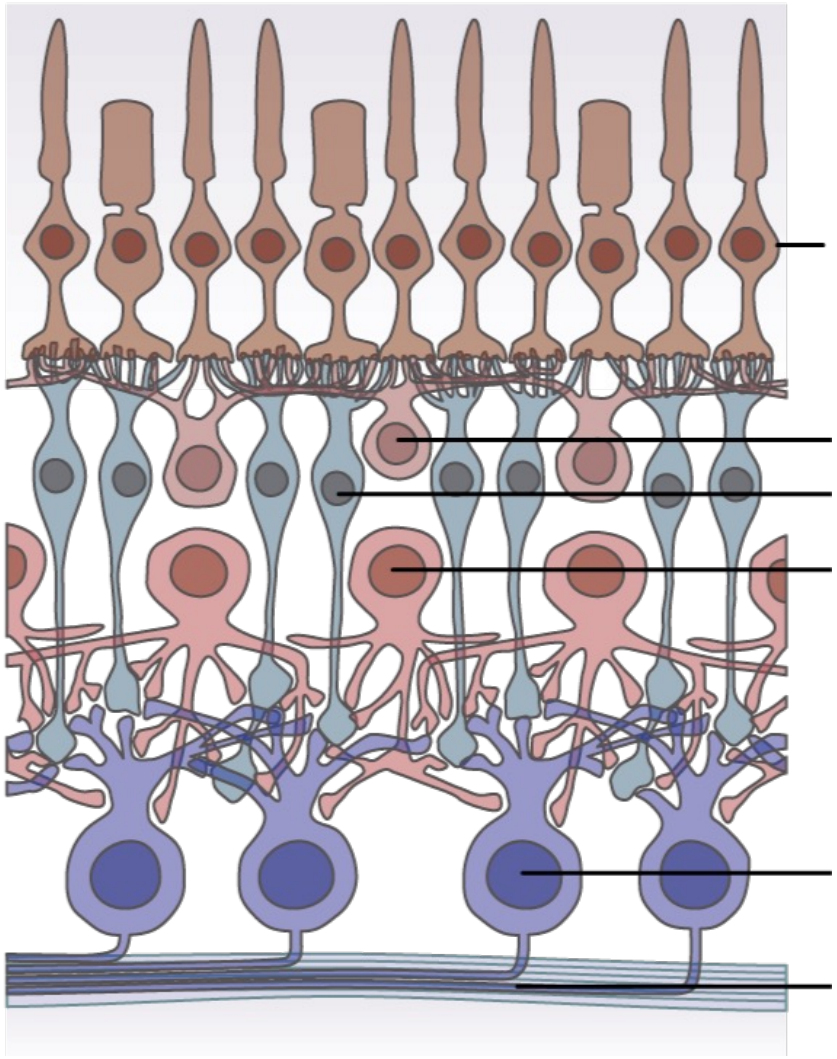
- Very fast processing of large amounts of data
- Perception of
  - Color, contrast, texture
  - Position and movement
  - Lines, shapes, objects
  - Relations among objects
  - Groups of objects



Eye


Vitreous gel
Optic nerve
Iris
Cornea
Macula
Fovea
Pupil
Lens
Retina
Iris

Photoreception



Photoreceptors convert light into signals

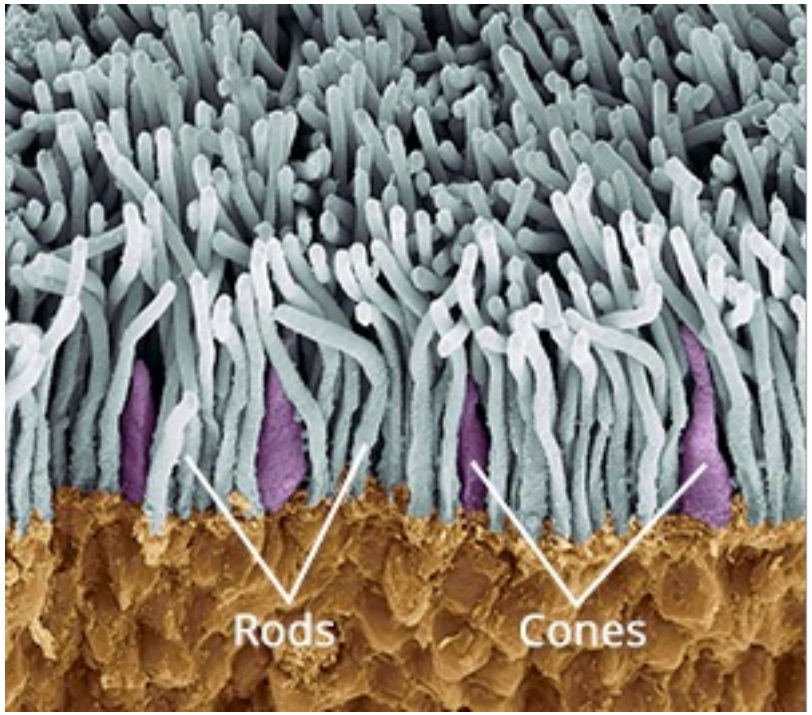
Various mid-layer cells process signals

Ganglion cells aggregate signals

The optic nerve sends color and shape information to the brain

Photoreceptors

Turn light into signals to create a mental sensation of the real world



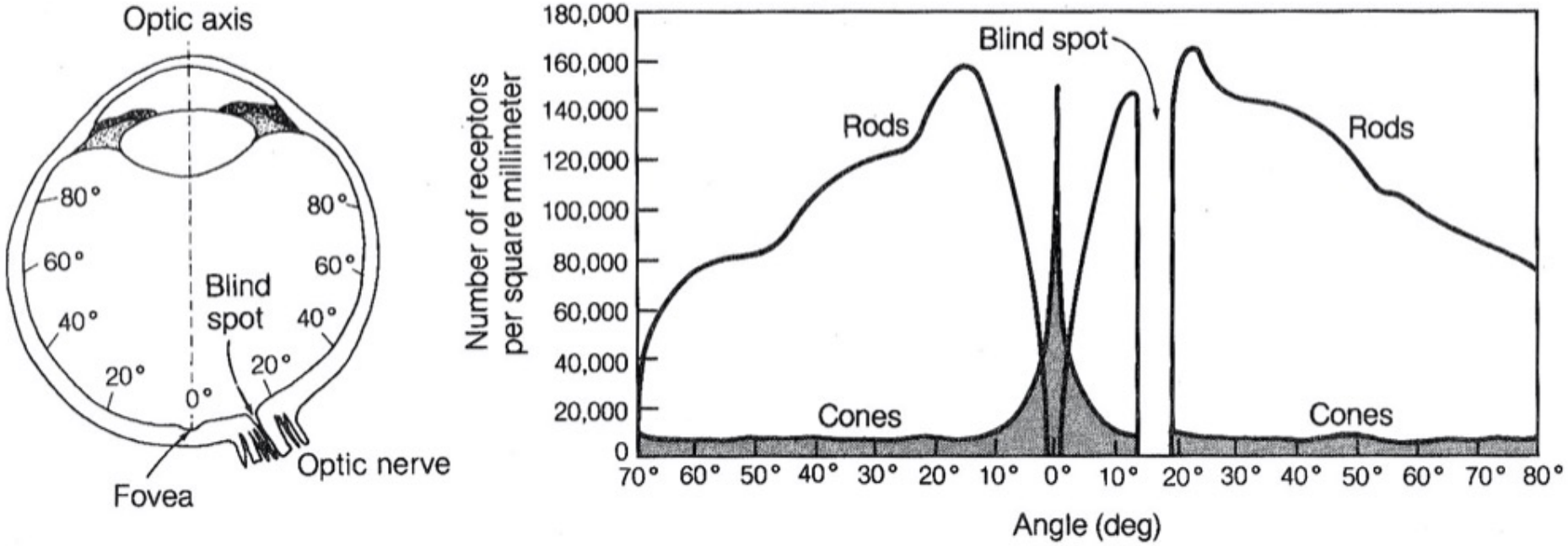
Rods (~90 million cells)

- Distributed evenly around retina,
- but not present in the fovea
- Recognizing gray-values
- Response to a stimulus ≈ 300ms
- Very light sensitive
- Suited for night vision

Cones (~5 million cells)

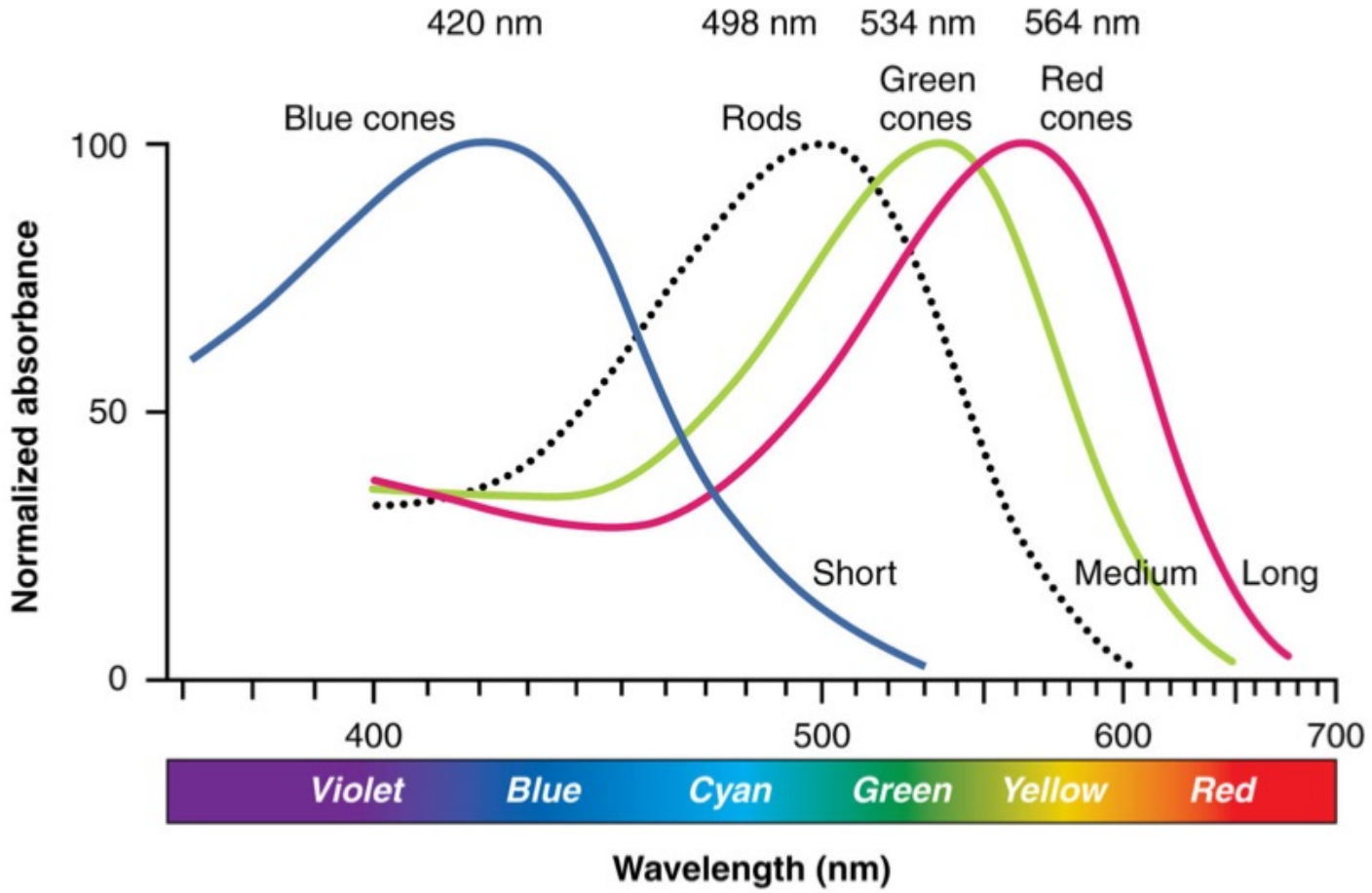
- Highly concentrated around fovea
- Recognizing colors
- Response to a stimulus ≈ 80ms
- 3 kinds which are sensitive to different bands of the visual spectrum (red, green and blue)
- Not effective in dark settings

Distribution of Rods and Cones



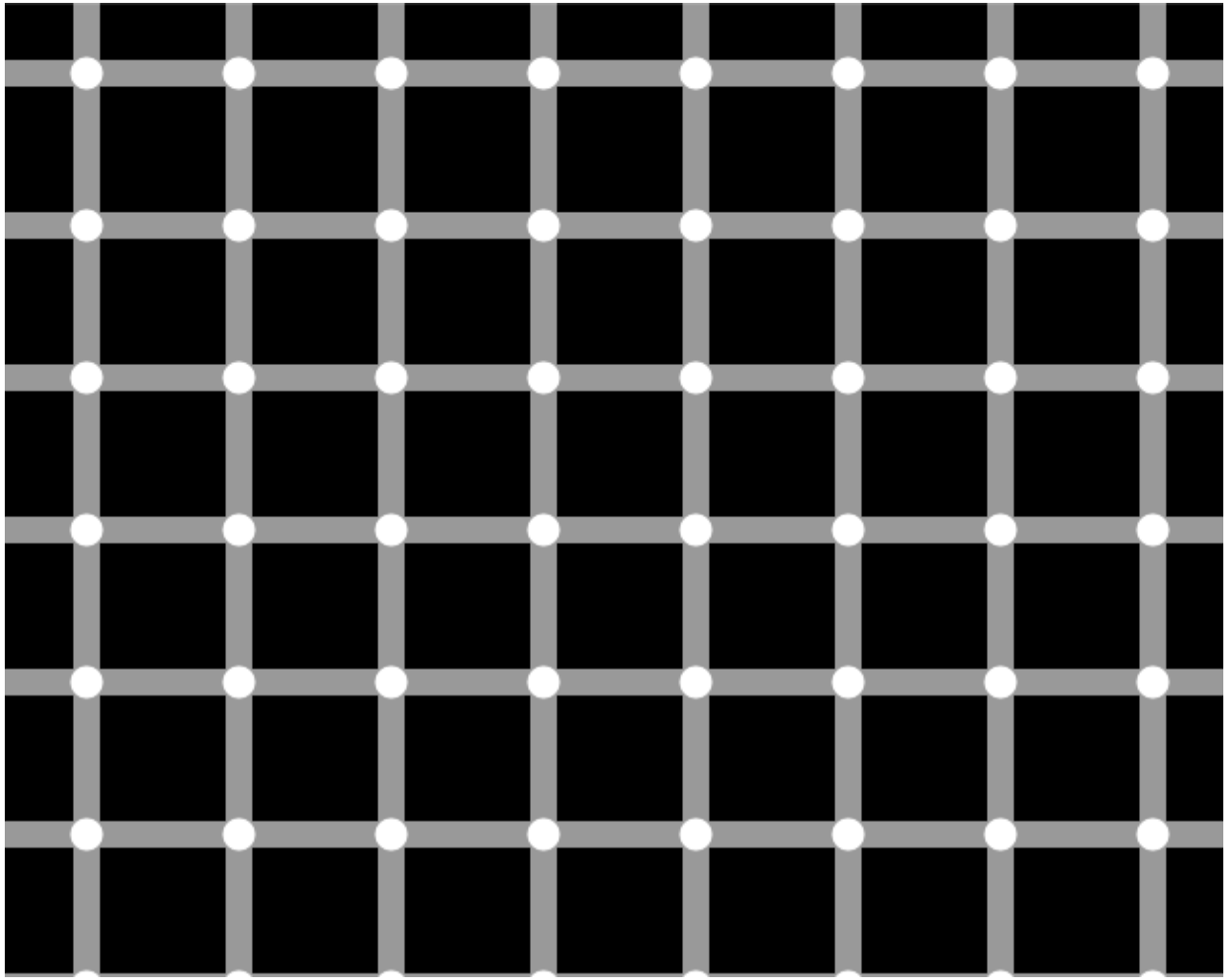
Trichromatic Color Vision

- Three cone types: short, medium, long for blues, greens and reds

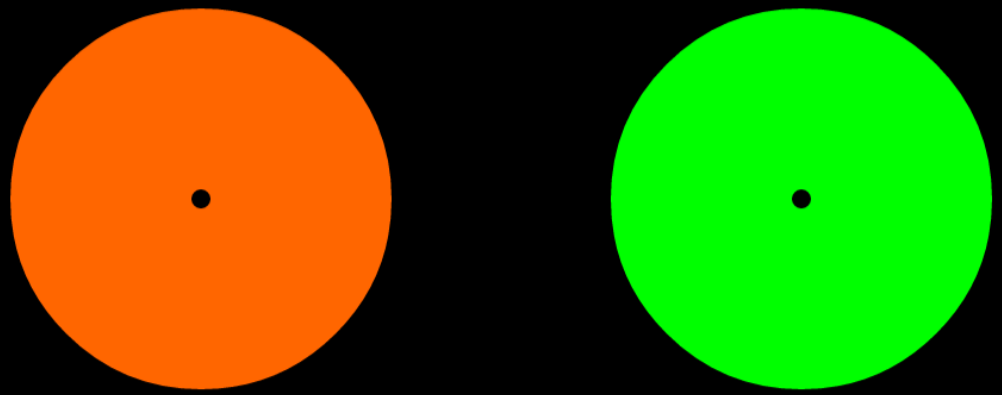


Foveatic vs Peripheral Vision

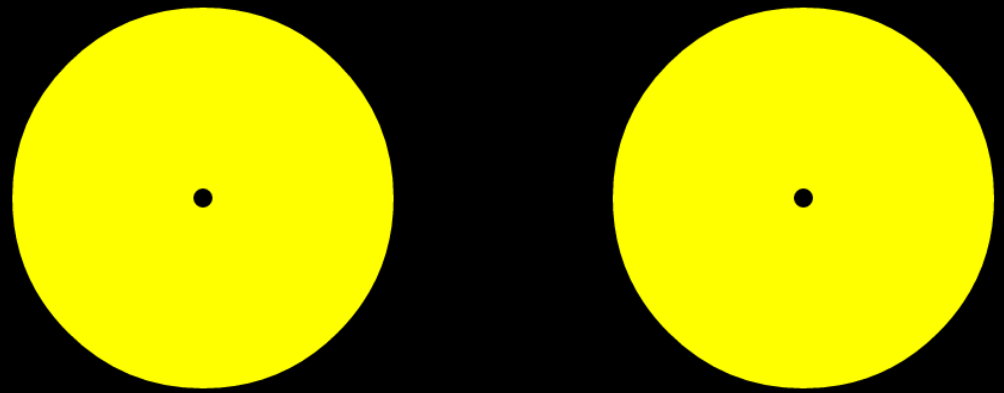
Scintillating Grid



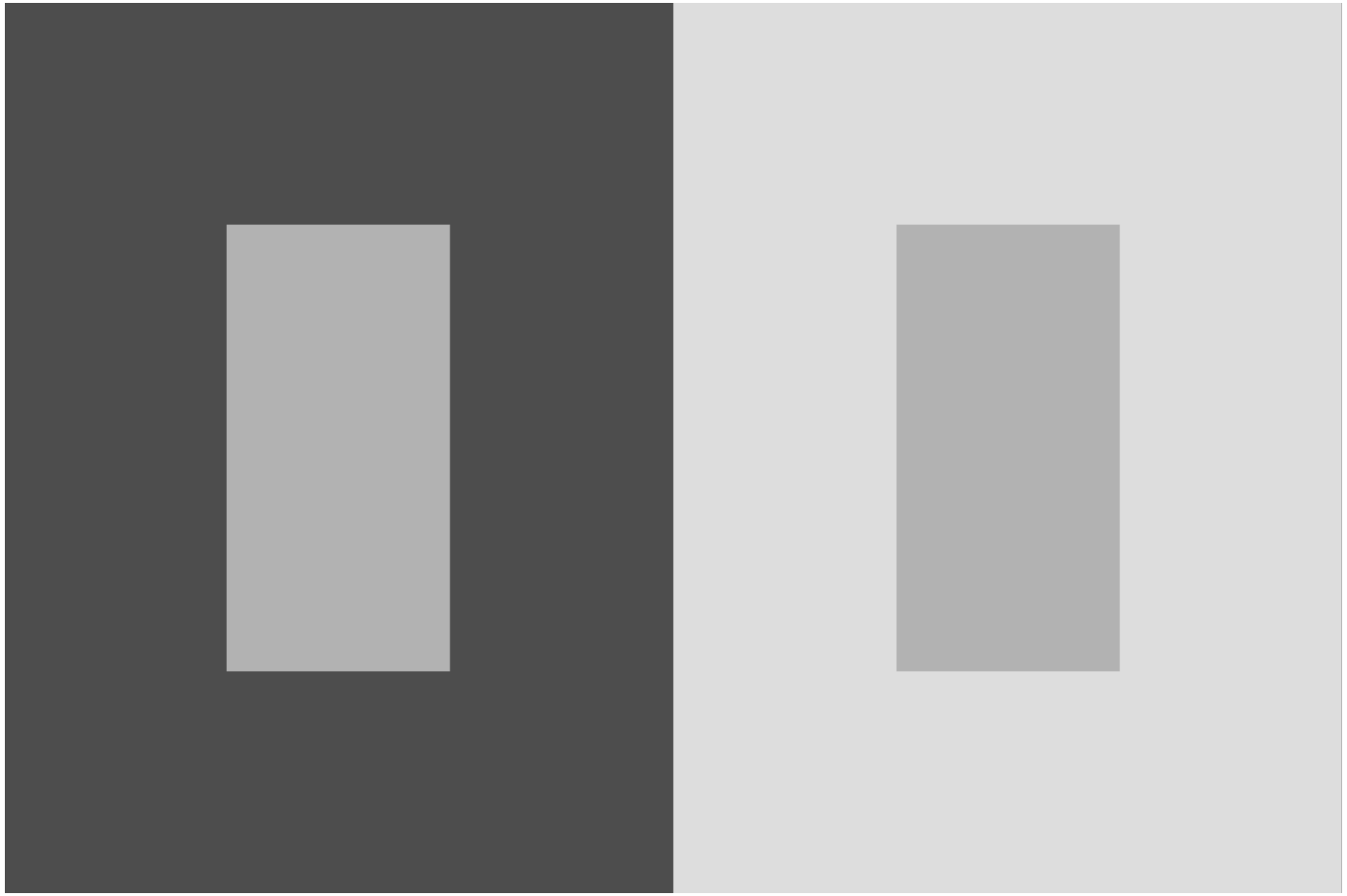
Successive Contrast



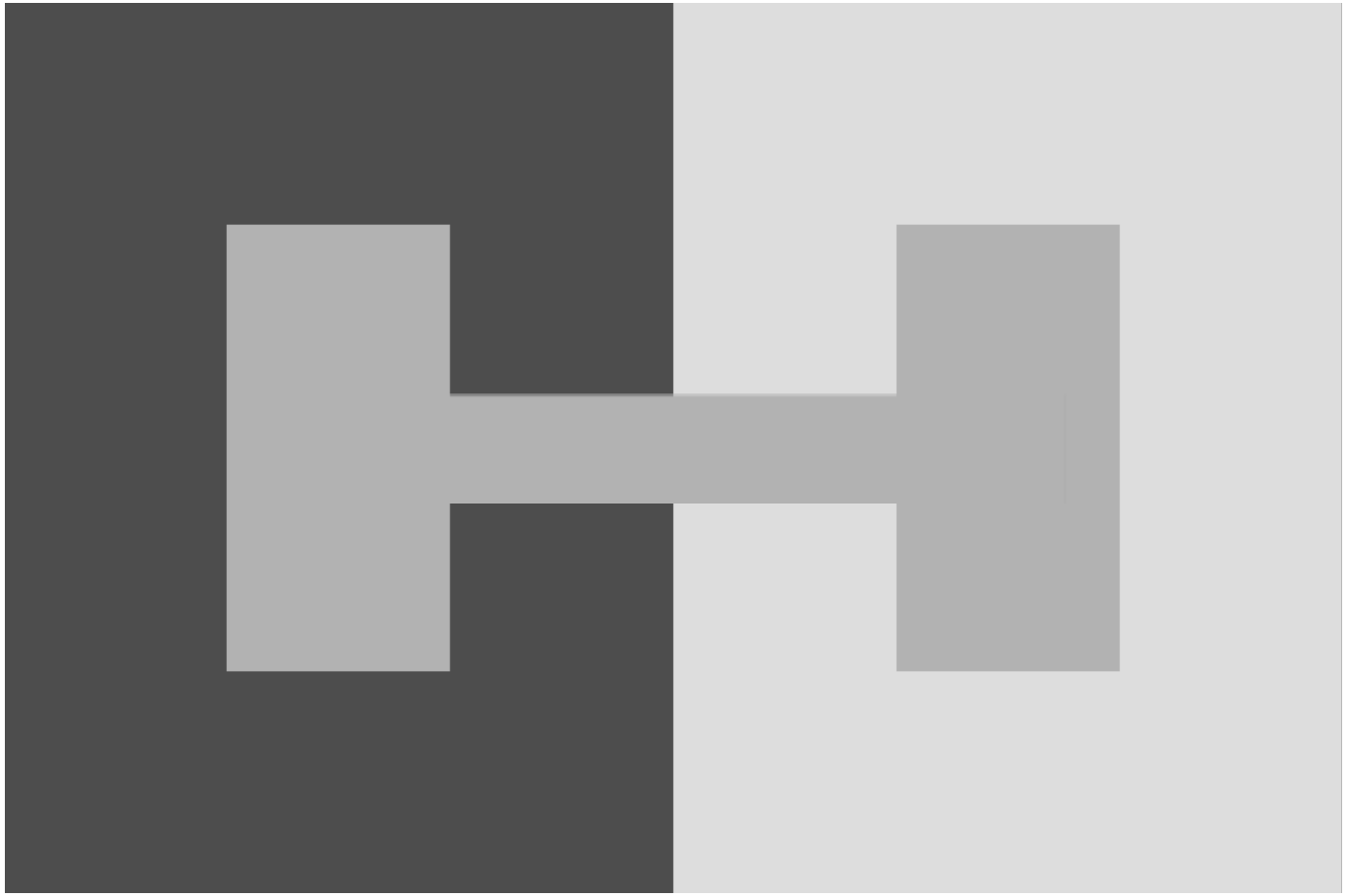
Successive Contrast



Simultaneous Contrast

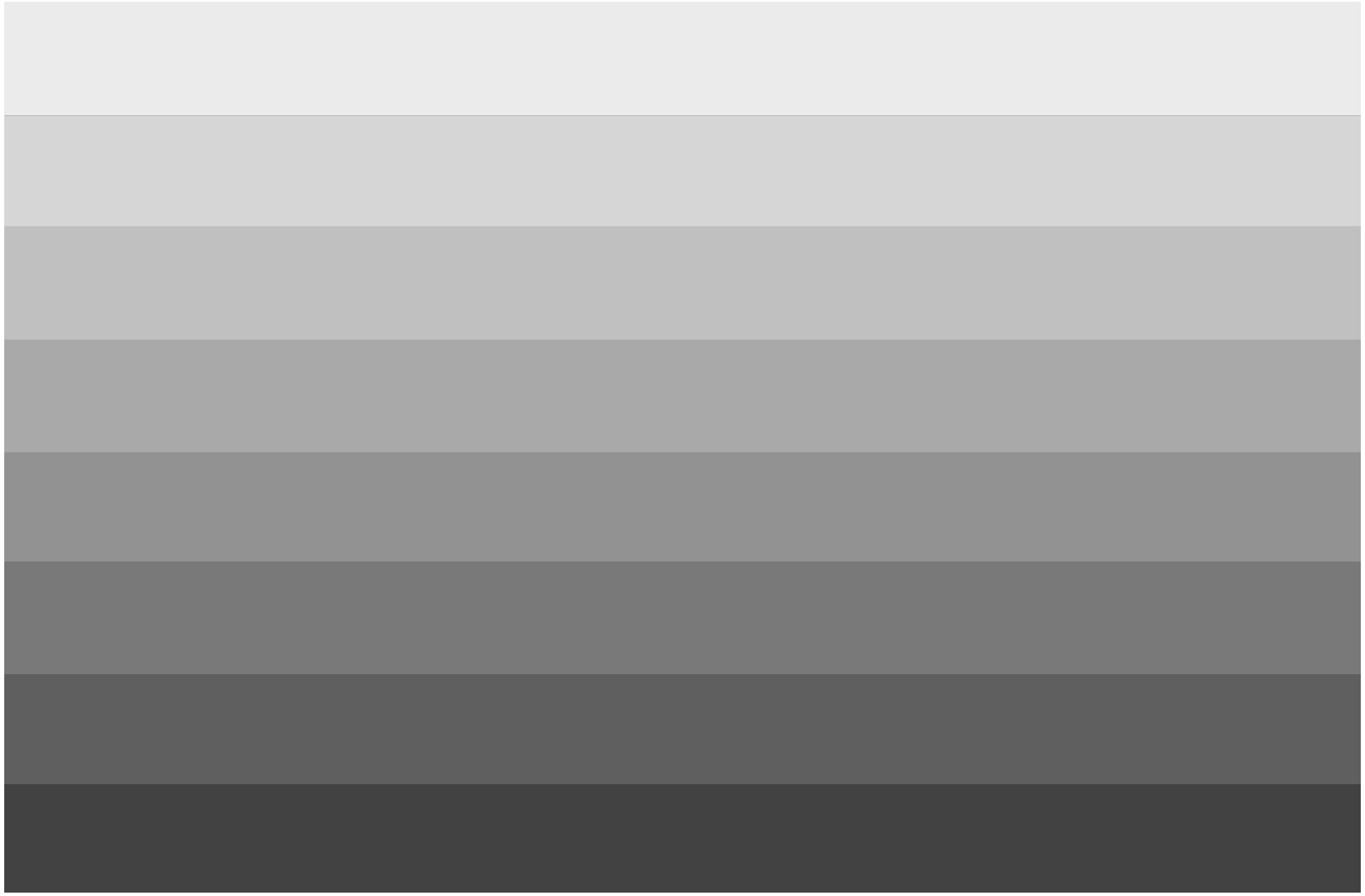


Simultaneous Contrast



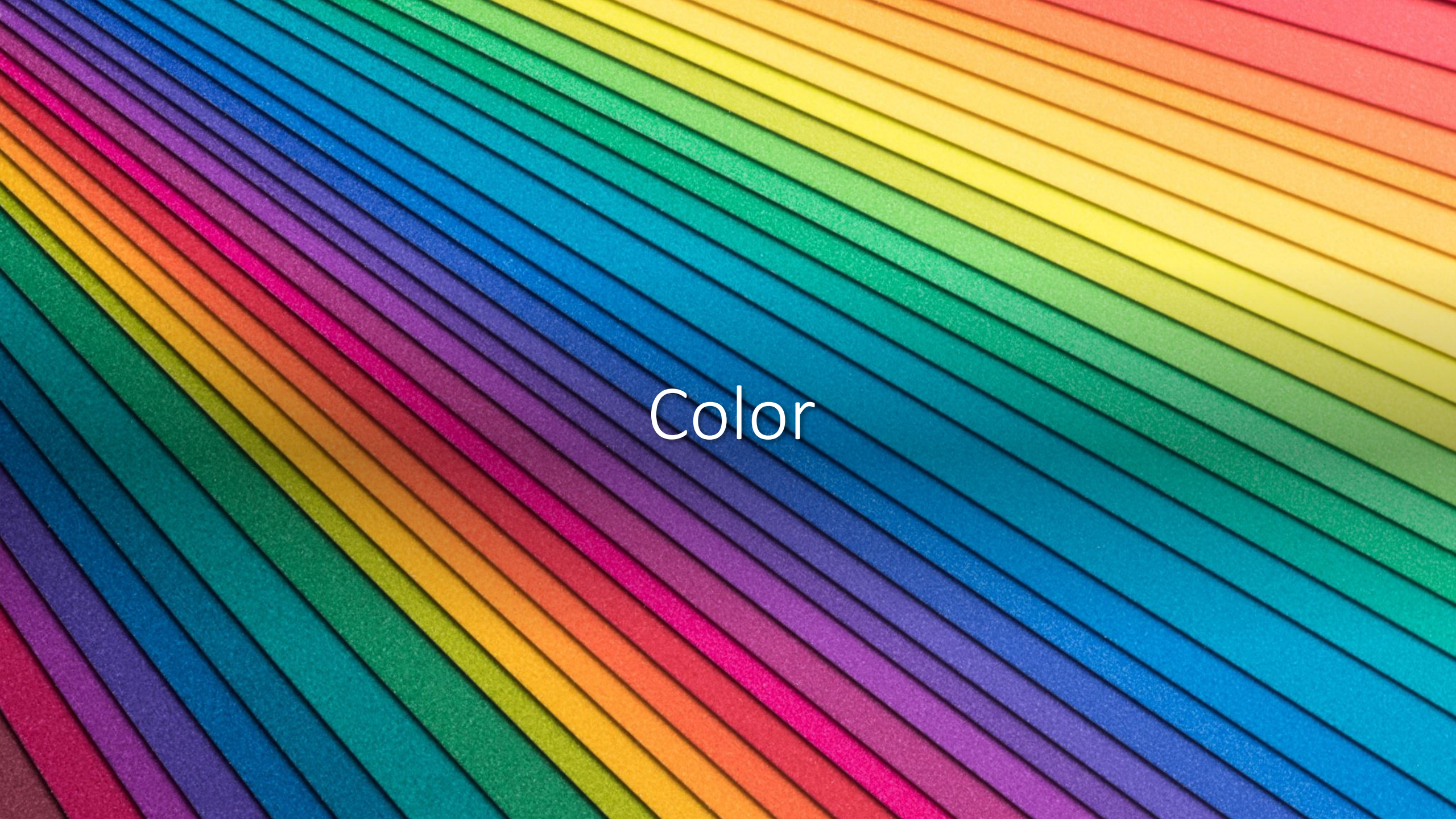
Mach bands

Mach bands

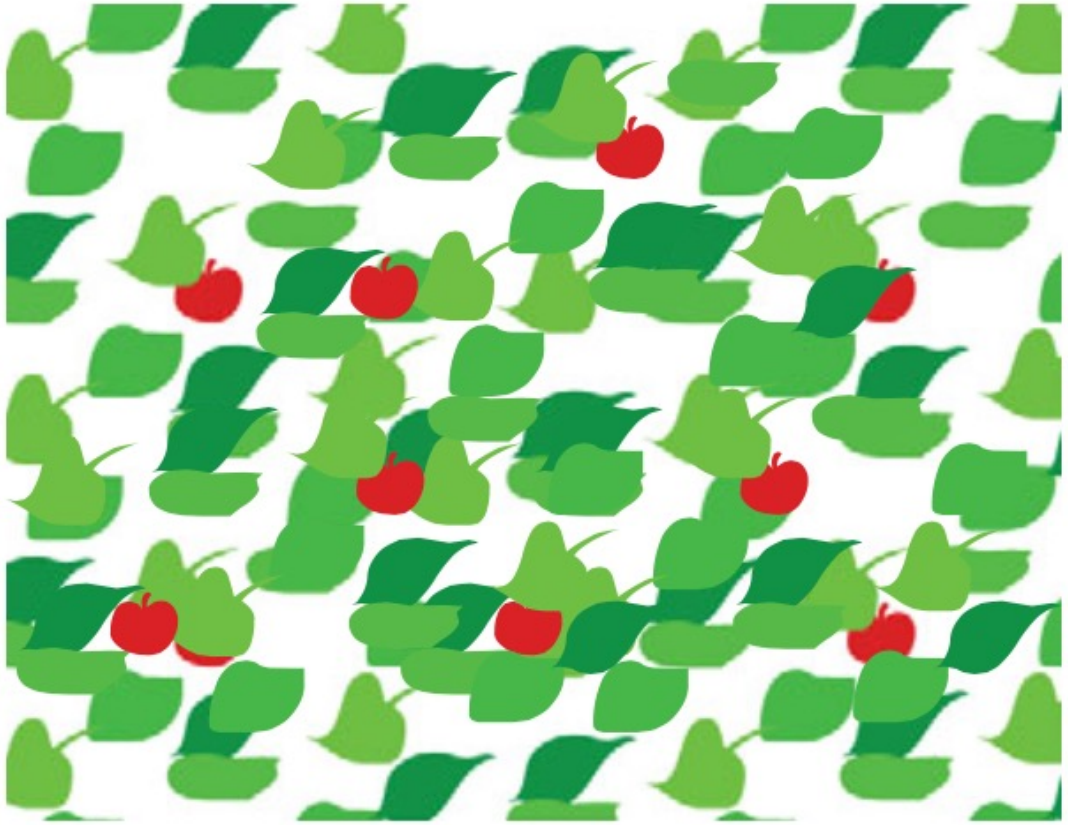


Implications of Relative Perception

- We see differences, not absolutes
- Human eye is not an accurate photometer
- Design with the relativity of visual perception in mind


Color

Color



“the property possessed by an object of producing different sensations on the eye as a result of the way it reflects or emits light” [OED]

Conceptualizing Color

Physical light beams reflected from surfaces

Perceptual impressions on the retina's photoreceptors

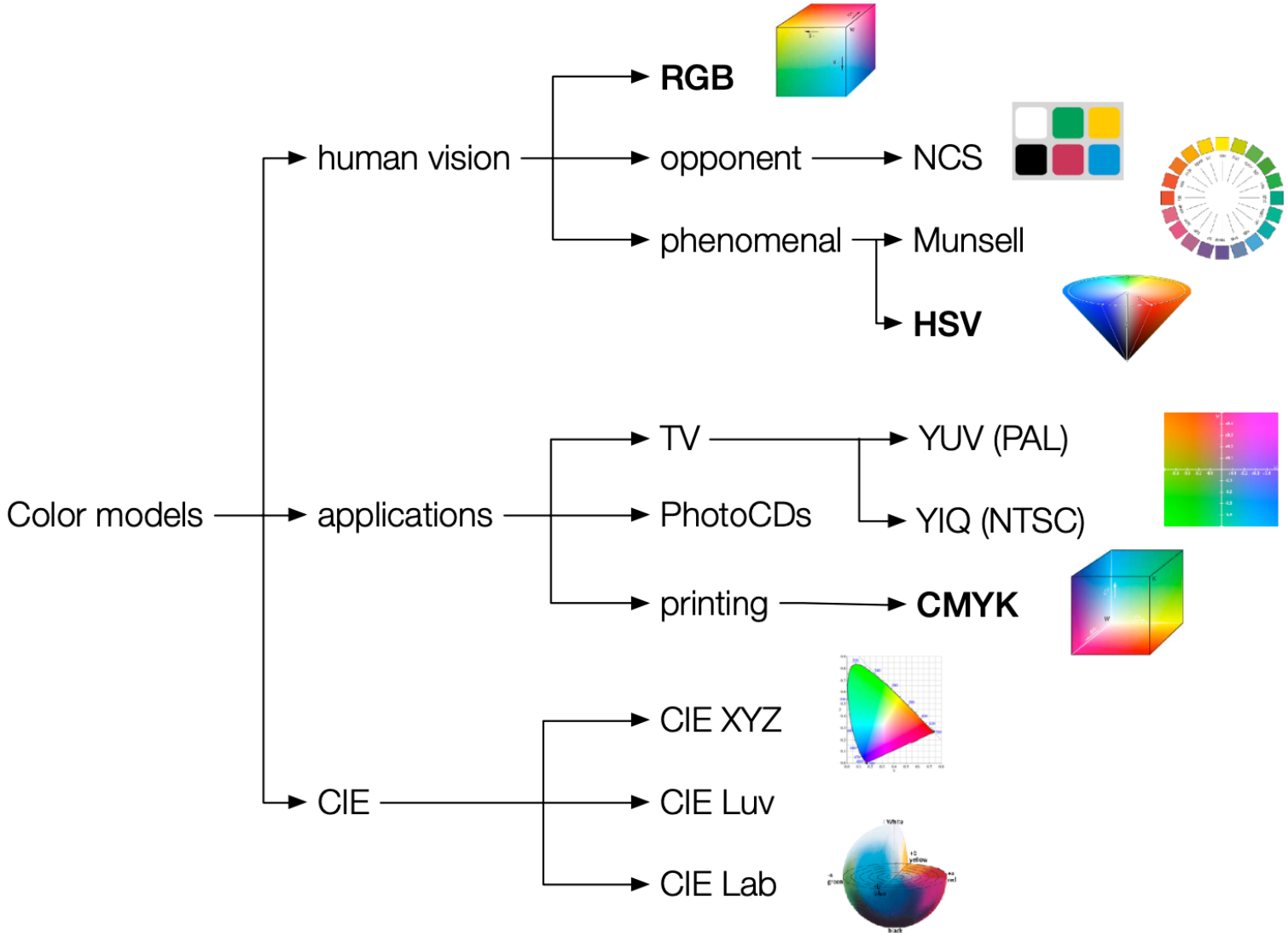
Mental models for hues, combinations and contrasts

Emotional associations with certain colors

Cultural conventions of color use for specific situations

Technical methods to re-create a specific visual impression

Color Models

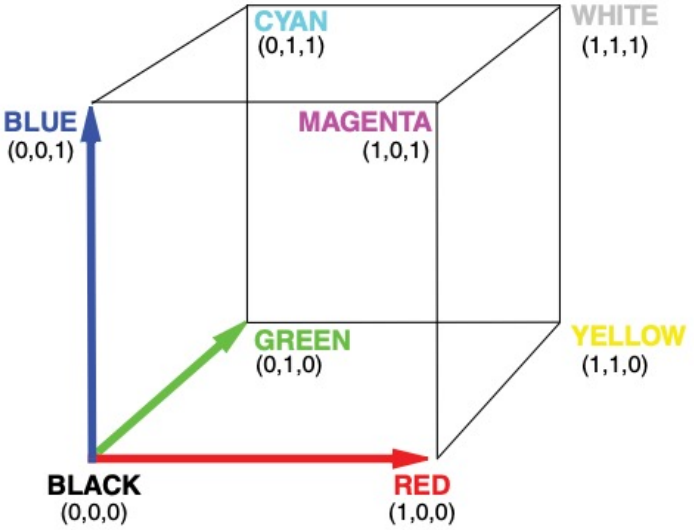


RGB

Additive color system based on excitation of cones in retina and used by computer displays

Problems

– Device dependent
– High correlation between components
– Not intuitive
– Not perceptually uniform

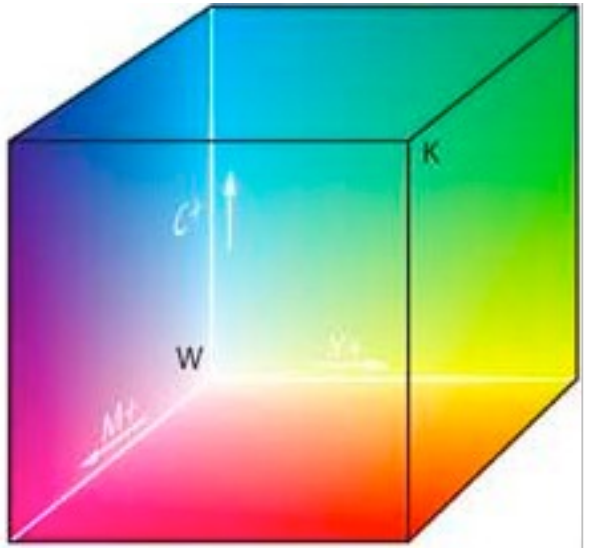


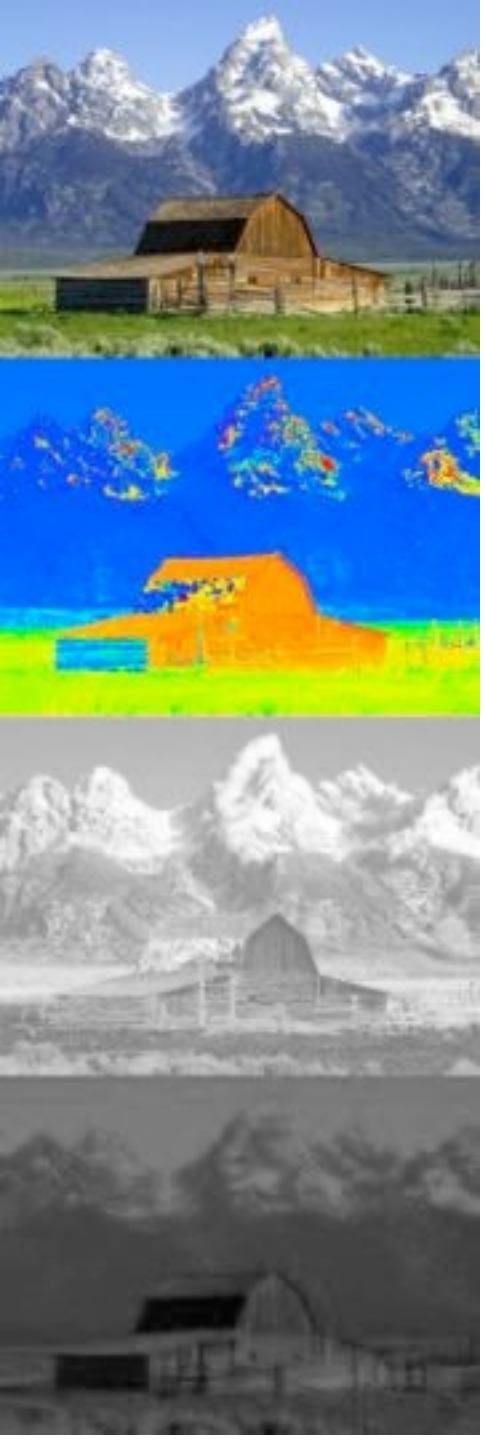
Color definitions in HTML/CSS

– Hex triplets: #ff0000 #00ff00 #0000ff
– Integers: rgb(255, 0, 0) rgb(0,255,0) rgb(0,0,255)

CMY(K)

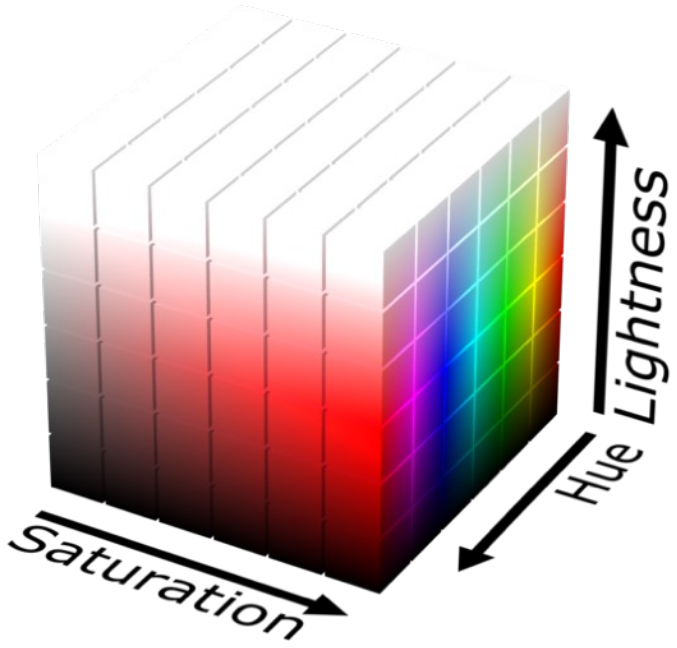
- Subtractive color system used for printing
- Components
  - Cyan = 1 - Red
  - Magenta = 1 – Green
  - Yellow = 1 - Blue
- Problems comparable to RGB





HSL

- Based on an intuitive understanding of color, neither additive nor subtractive
- Components
  - Hue: tone of color in degrees [0-360]
  - Saturation: color purity [0-100]
  - Lightness: level of brightness [0-100]
- Problems
  – Hue discontinuity around 360°



Design with Color

- Main uses of color in visualizations
  - group (color as noun)
  - measure (color as quantity)
  - represent reality (color as imitation)
  - enliven or decorate (color as beauty)
  - highlight specific items (color as emphasis

Emphasize (pop out)

459290780597720987759726556651100498366452710746214465420707901473810974389701097143907097349266847858715819048630901889074257470723547456661420187740728498753 10

Emphasize (pop out)

459290780597720987759720
655665110049836645271077
462144654207079014738109
974389701097143907097340
926684785871581904863090
018890742574707235474560
661420187740728498753100

Group

	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
red	25.37	13.70	0.05	26.27	14.13	0.04	18.41	10.16	0.05	17.43	9.30	0.00
green	22.14	51.24	0.35	20.68	49.17	0.44	21.11	46.00	0.20	16.36	37.95	0.12
blue	13.17	3.71	74.89	15.38	5.20	86.83	11.55	3.37	65.53	9.96	3.44	56.14
gray	63.46	73.30	78.05	64.66	71.99	90.08	52.96	62.49	67.99	45.54	53.65	58.14
black	0.66	0.70	0.77	0.63	0.66	1.09	0.47	0.58	0.70	0.44	0.54	0.71

	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
red	25.37	13.70	0.05	26.27	14.13	0.04	18.41	10.16	0.05	17.43	9.30	0.00
green	22.14	51.24	0.35	20.68	49.17	0.44	21.11	46.00	0.20	16.36	37.95	0.12
blue	13.17	3.71	74.89	15.38	5.20	86.83	11.55	3.37	65.53	9.96	3.44	56.14
gray	63.46	73.30	78.05	64.66	71.99	90.08	52.96	62.49	67.99	45.54	53.65	58.14
black	0.66	0.70	0.77	0.63	0.66	1.09	0.47	0.58	0.70	0.44	0.54	0.71

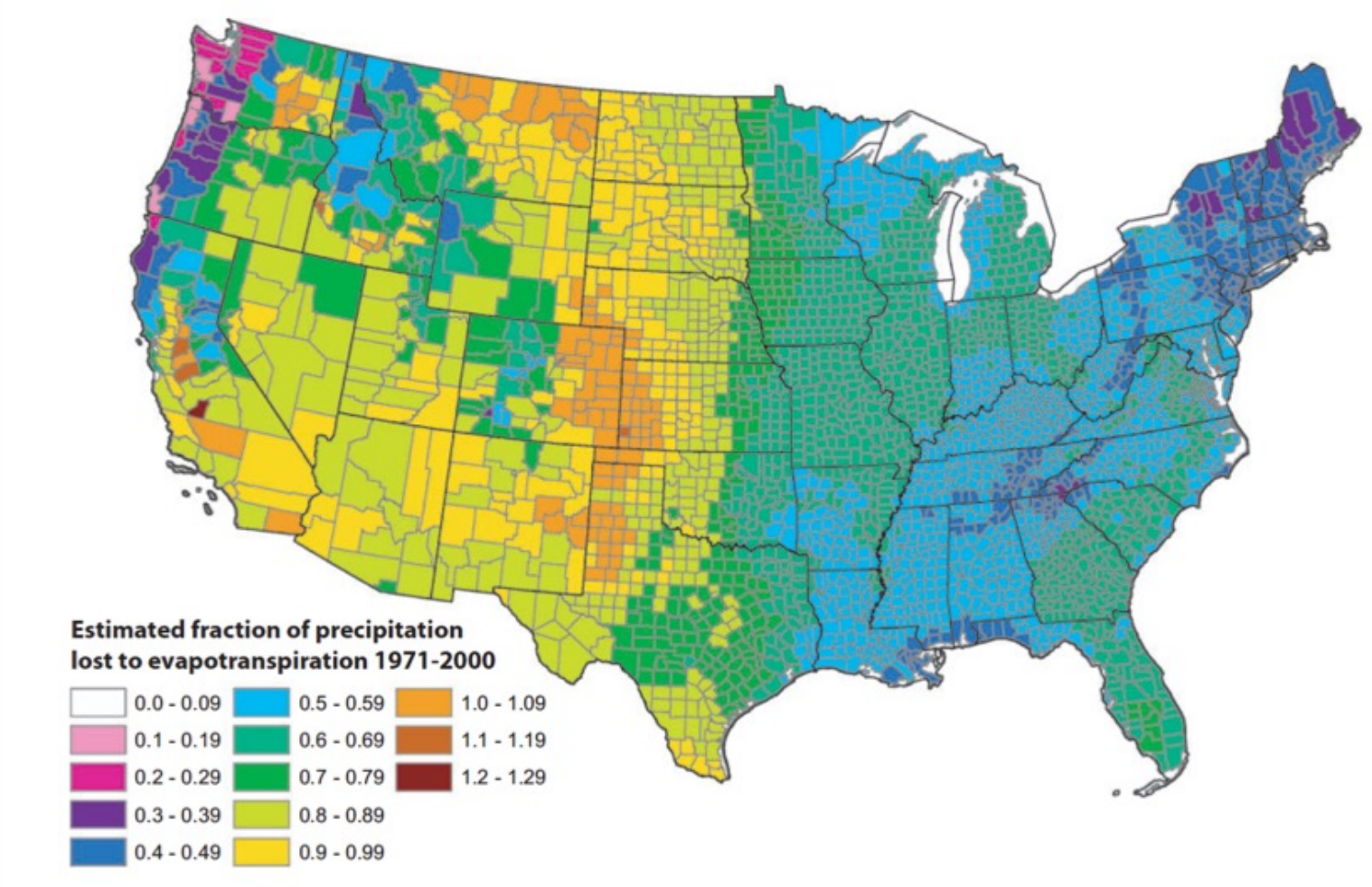
Quantify and order

Color scales map quantitative data to gradual color variation

- The infamous, but often used rainbow scale is perceptually non-linear:

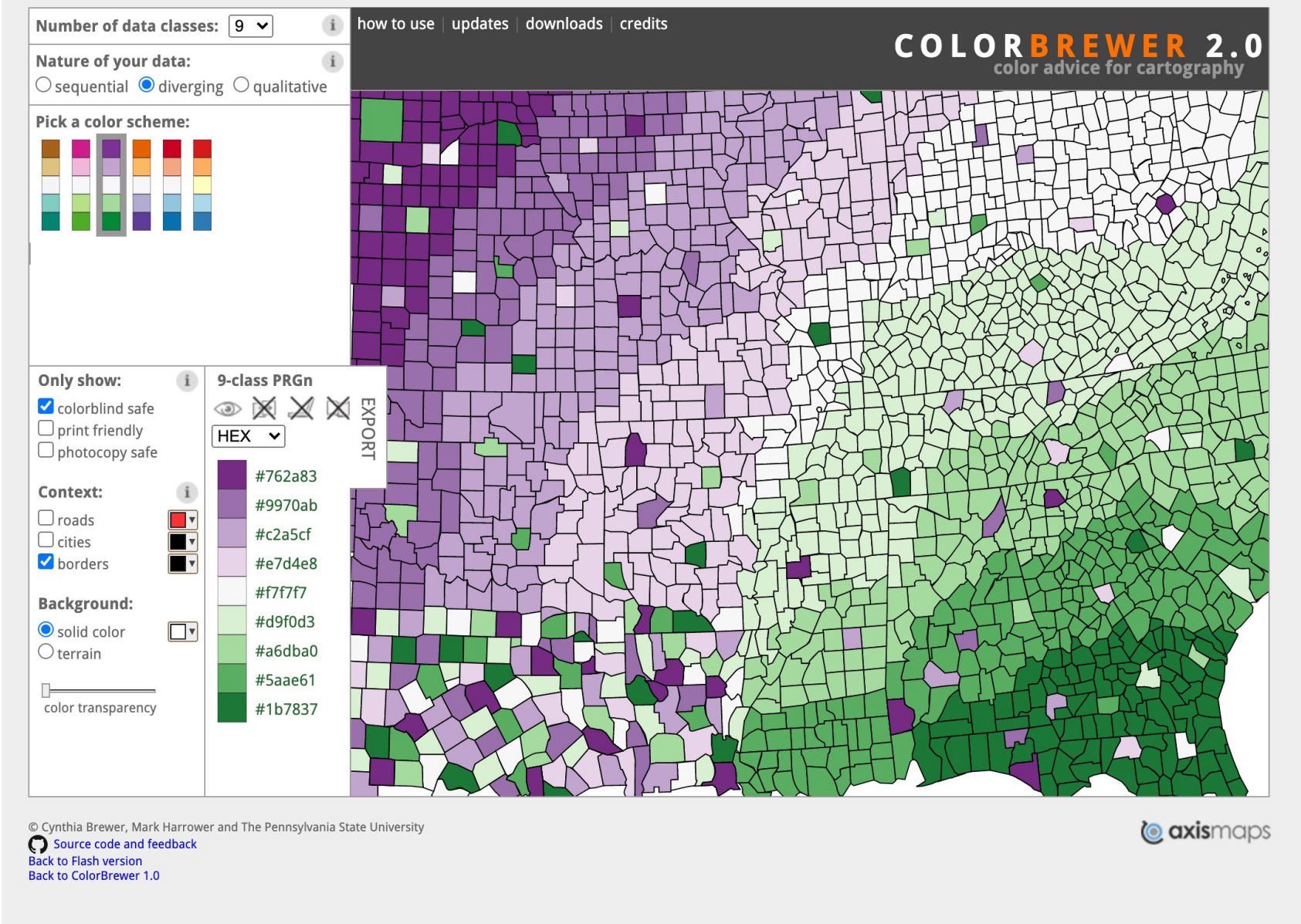
- A combination of hue and variation avoids non-linearity in brightness:

Rainbow Color Map (bad example)



https://eagereyes.org/basics/rainbow-color-map

https://colorbrewer2.org/



Color Blindness

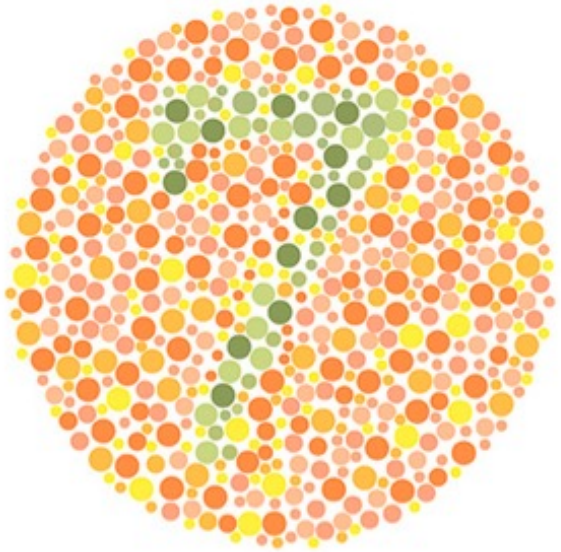
- 10% of males, 1% of females (probably due to X- chromosomal recessive inheritance)
- Most common: red-green weakness / blindness
- Reason: lack of medium or long wavelength receptors, or altered spectral sensitivity (most common: green shift)

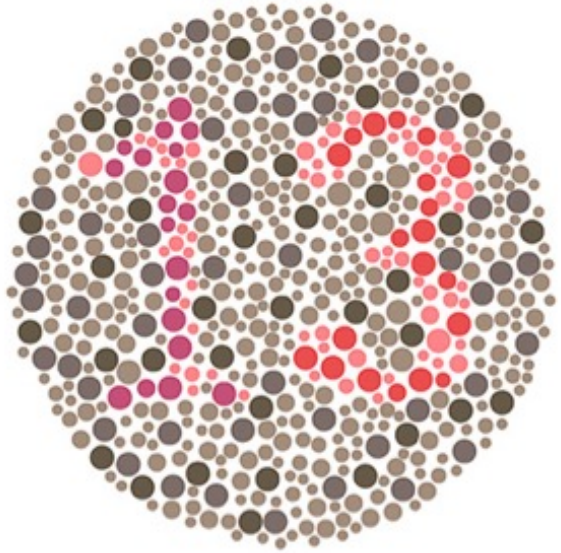
Normal Color Perception

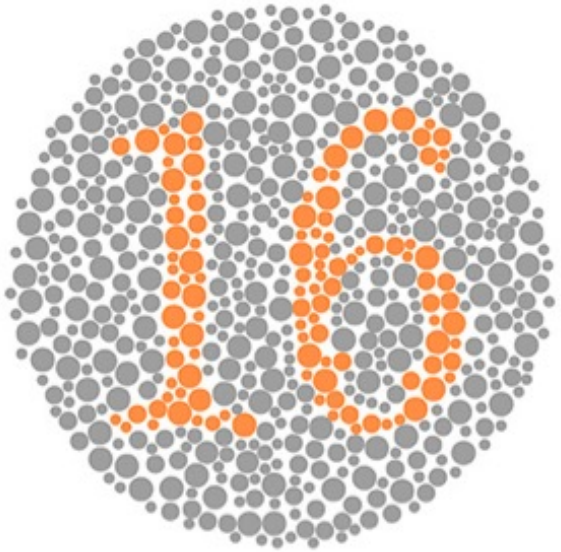
Deuteranopia (no green receptors)

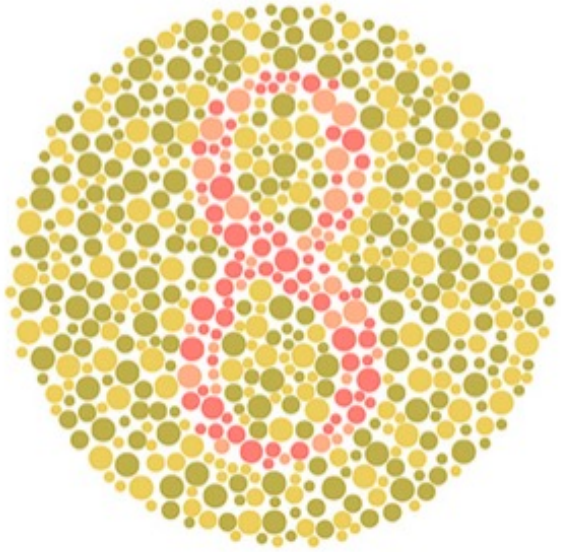
Protanopia (no red receptors)

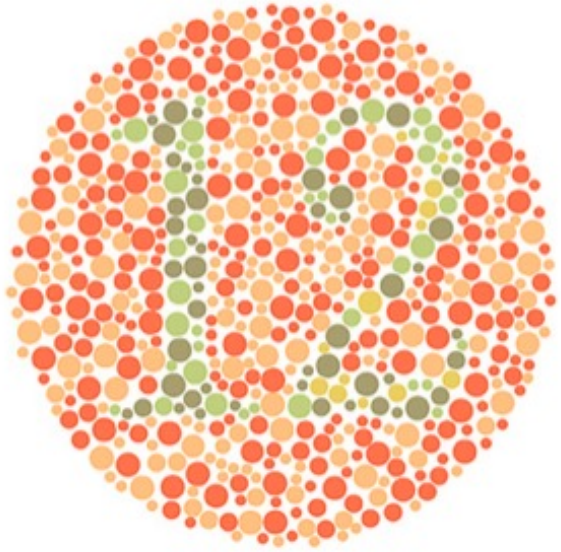
Common Color Blindness Tests

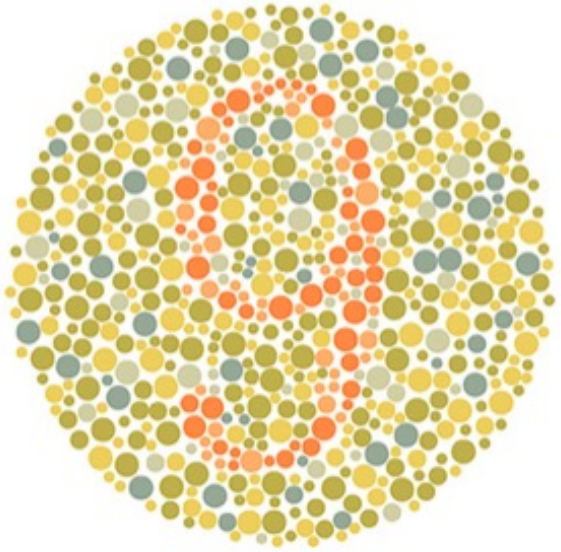












https://www.color-blindness.com/

Color Blindness

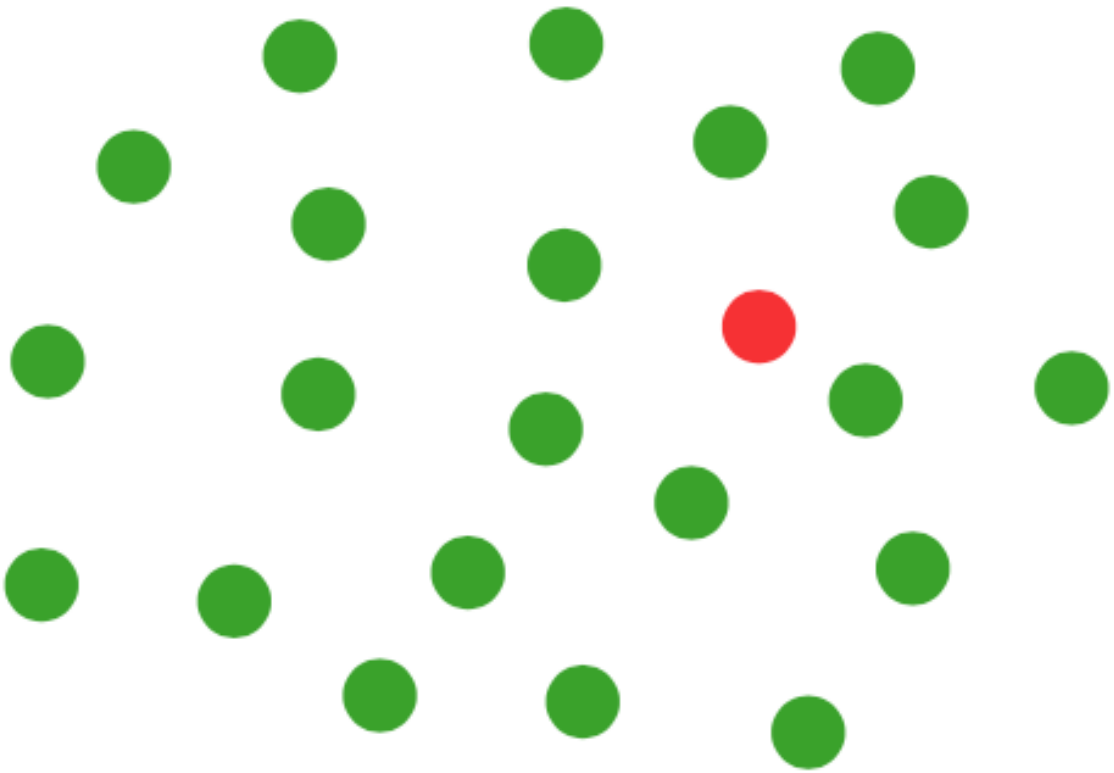
https://www.color-blindness.com/coblis-color-blindness-simulator/

Guidelines for Color in Information Visualization

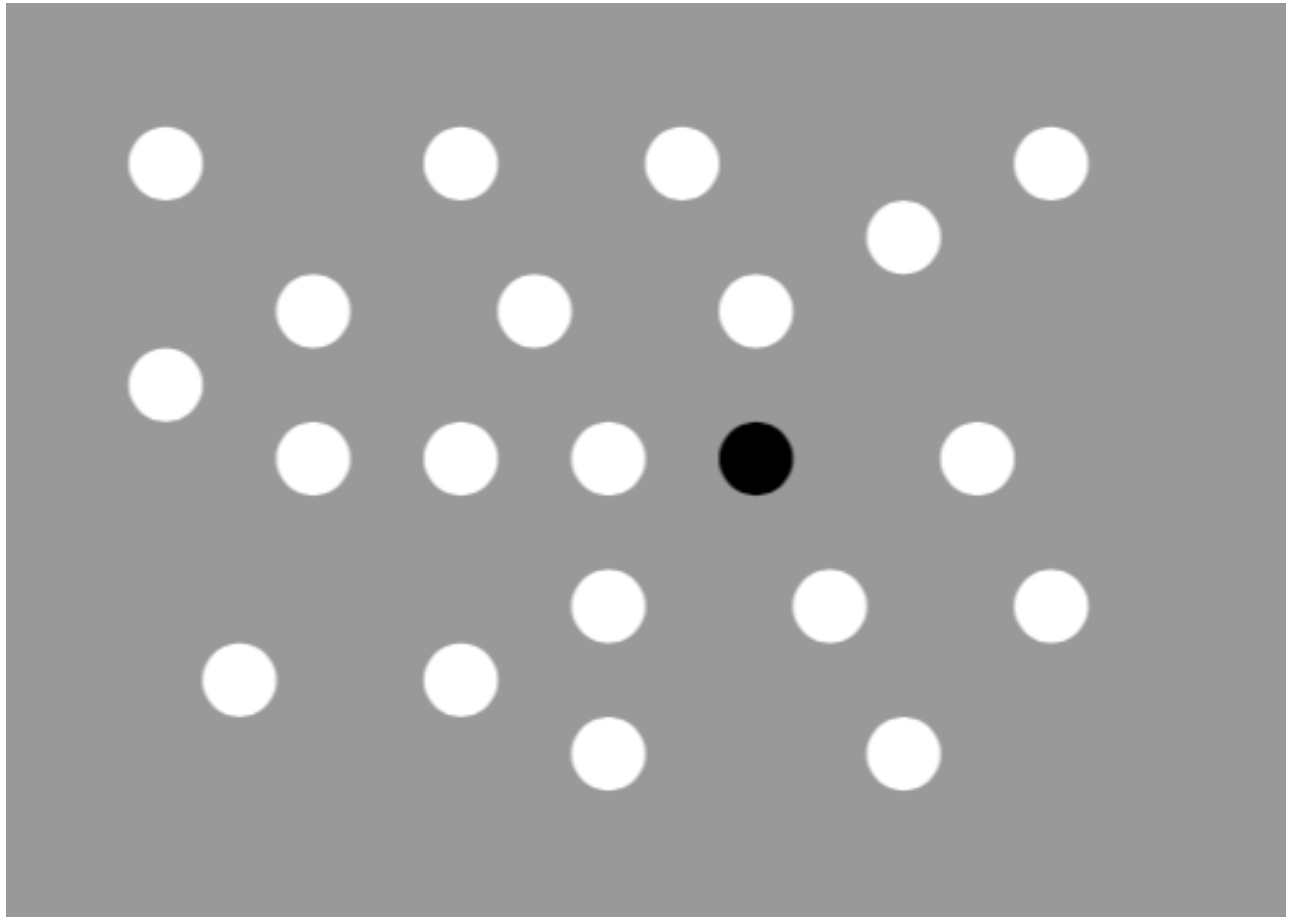
- When representing categories use no more than 7±2 colors
- When representing quantities ensure perceptually linear encoding
- Be careful with highly saturated colors and high contrasts
- Consider culture and conventions of color for a given context
- Limit the use of color to one purpose and use it consistently
- Check your visualization for colorblindness perception

Element Detection

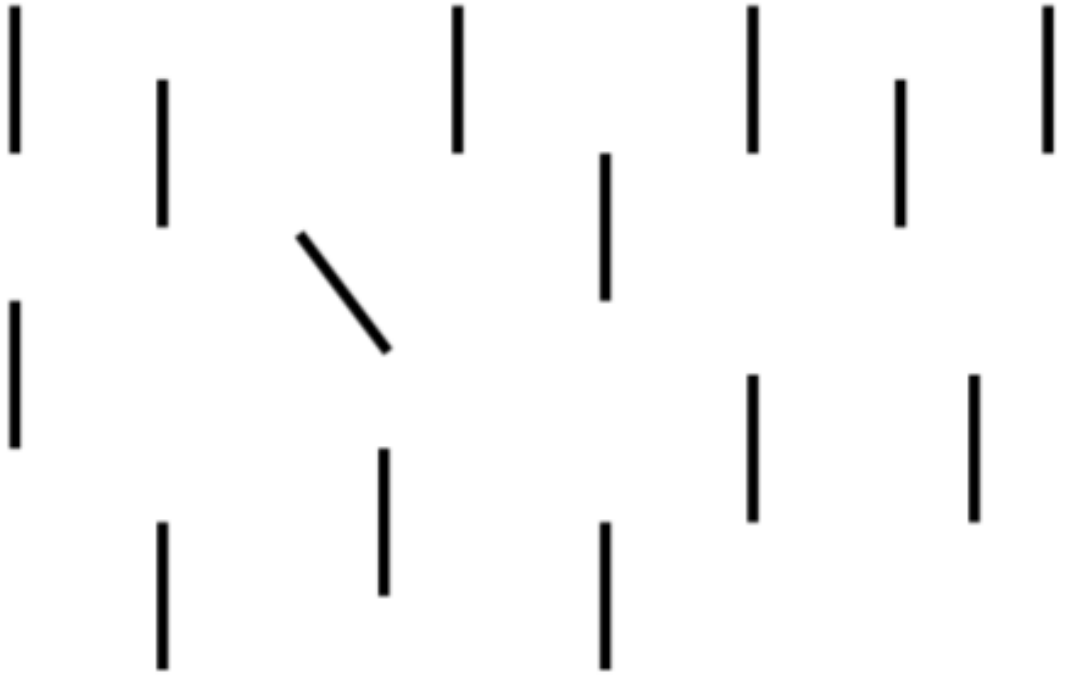
Color



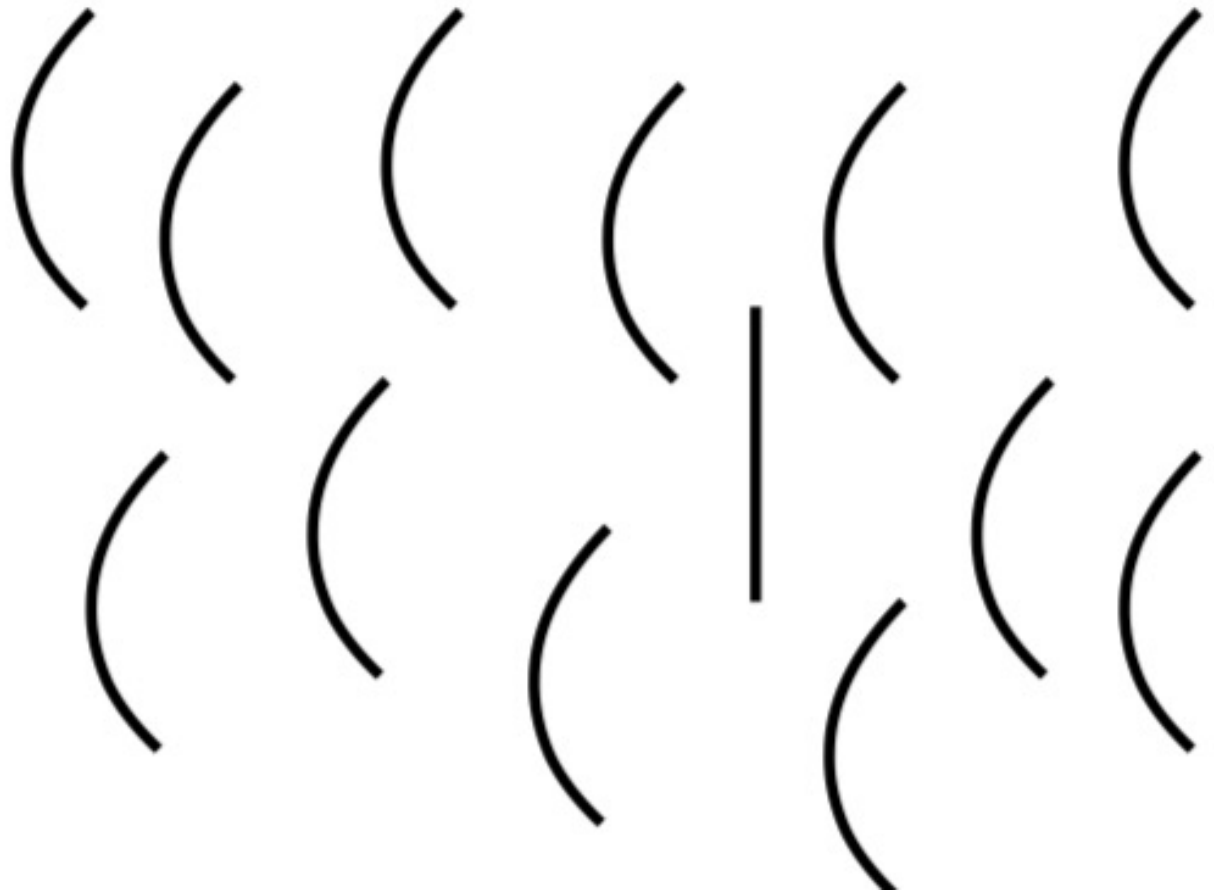
Brightness



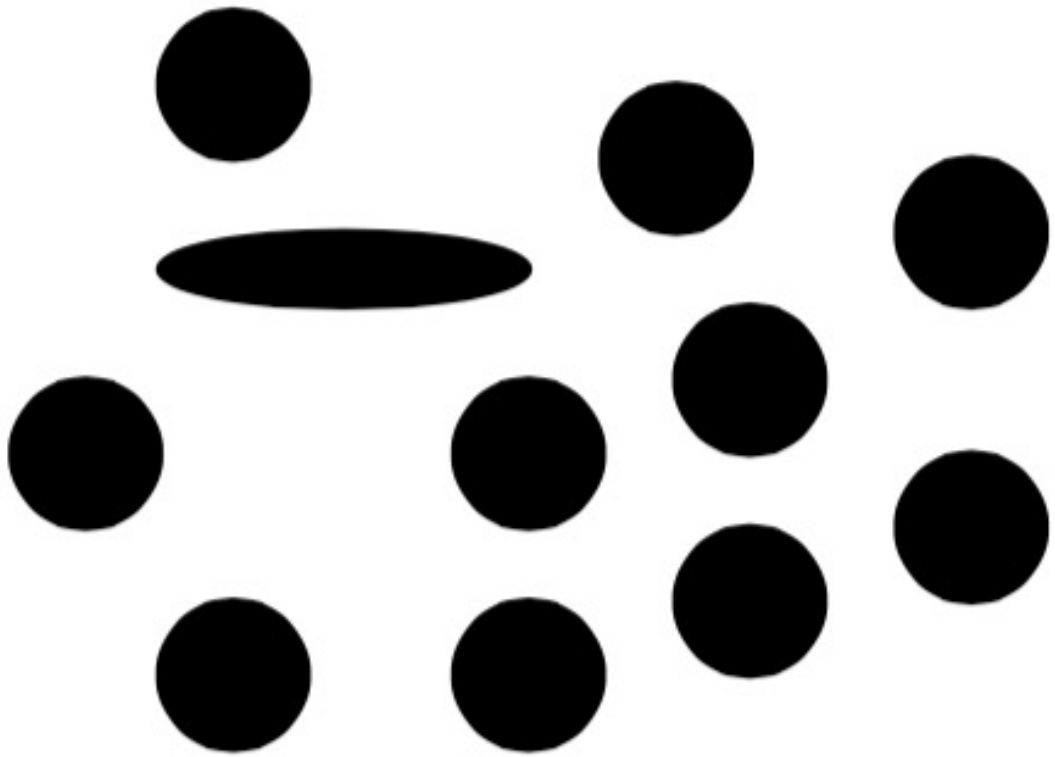
Orientation



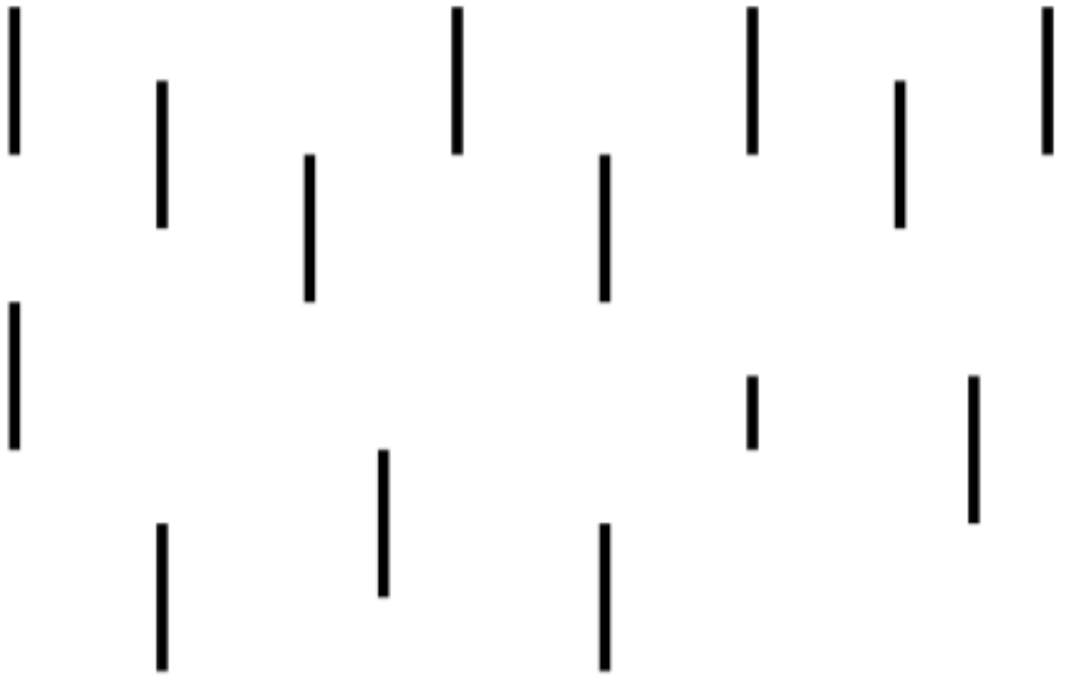
Curvature



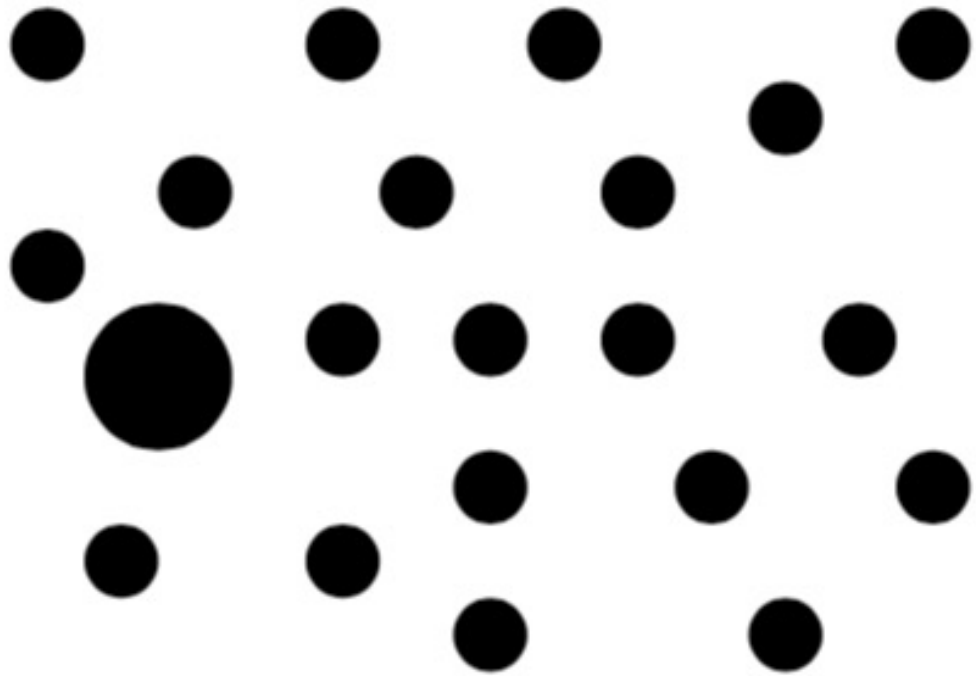
Shape



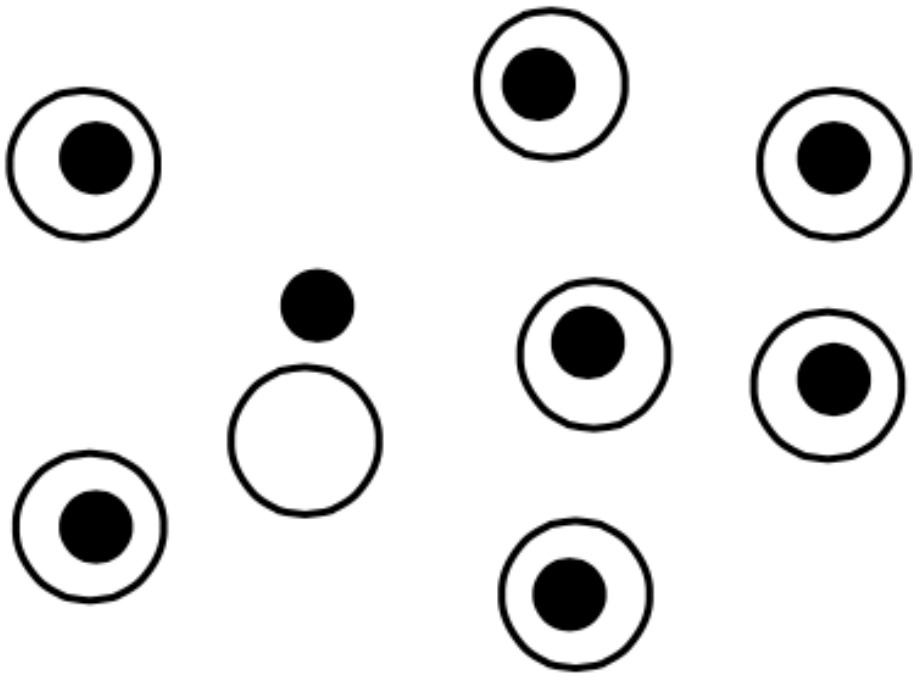
Length



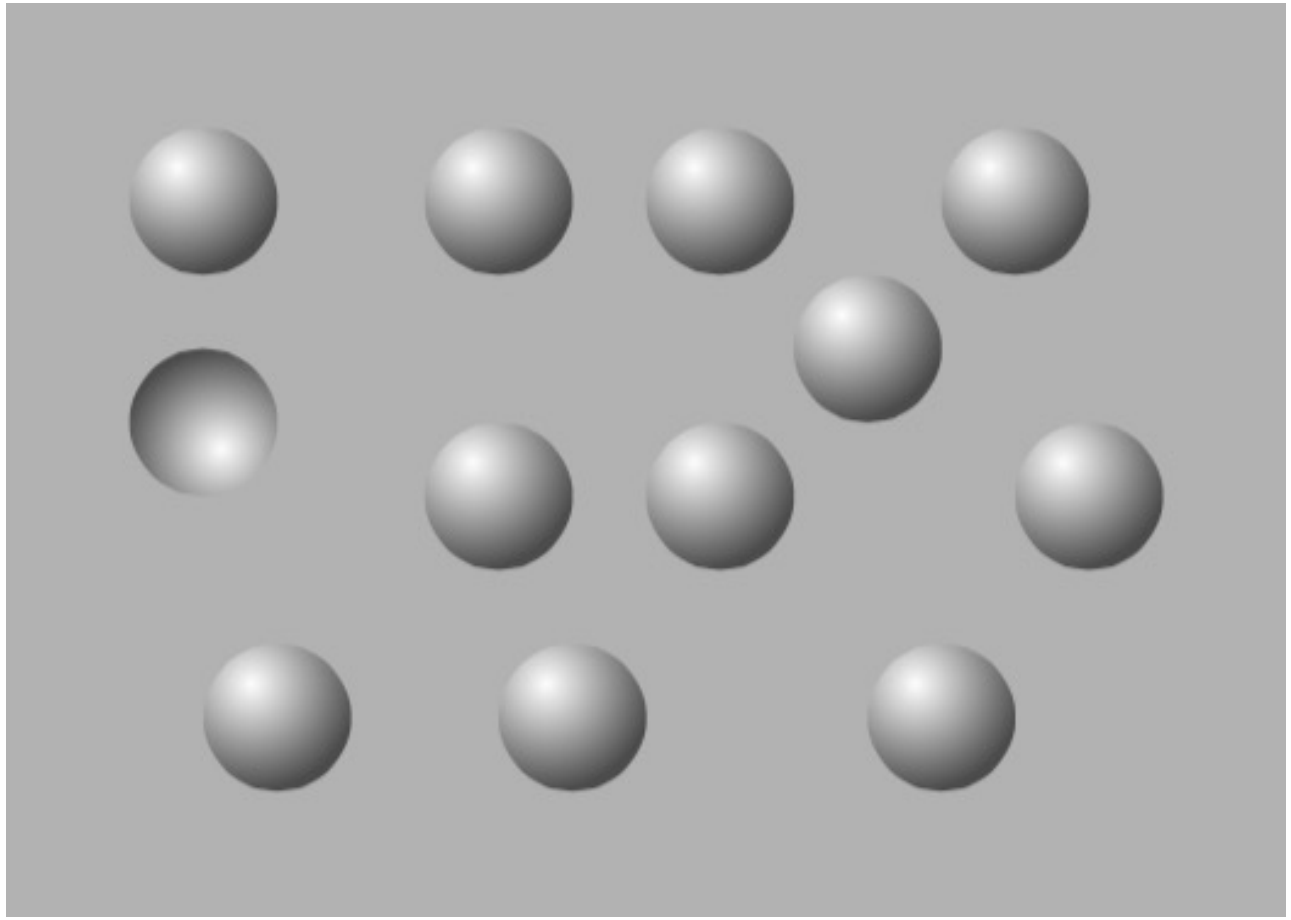
Size



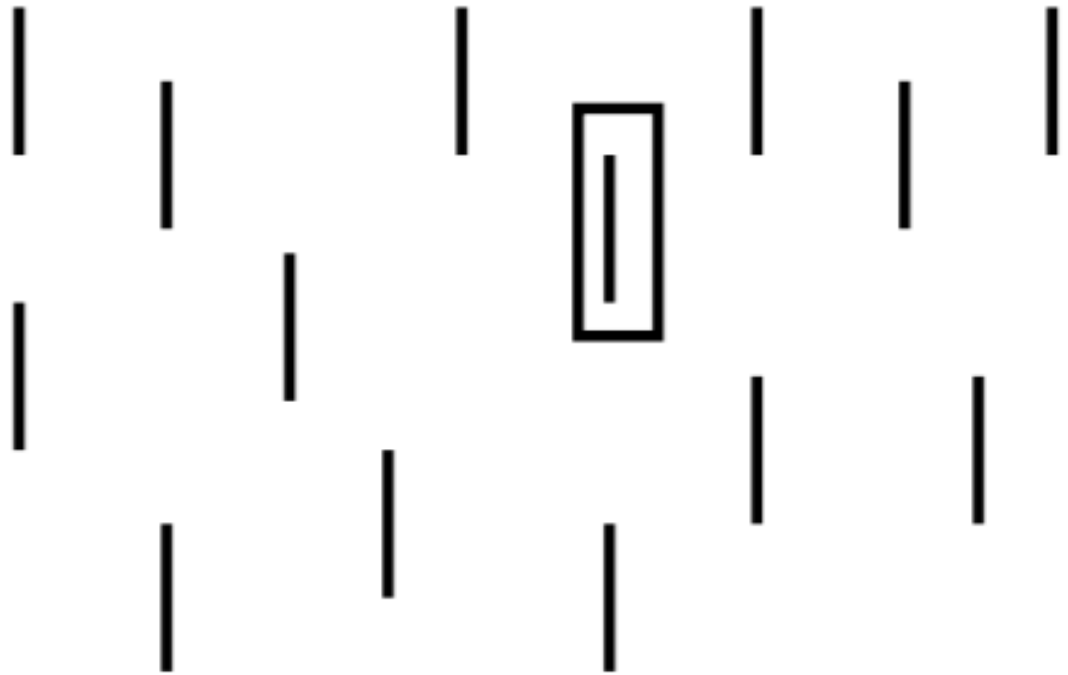
Enclosure



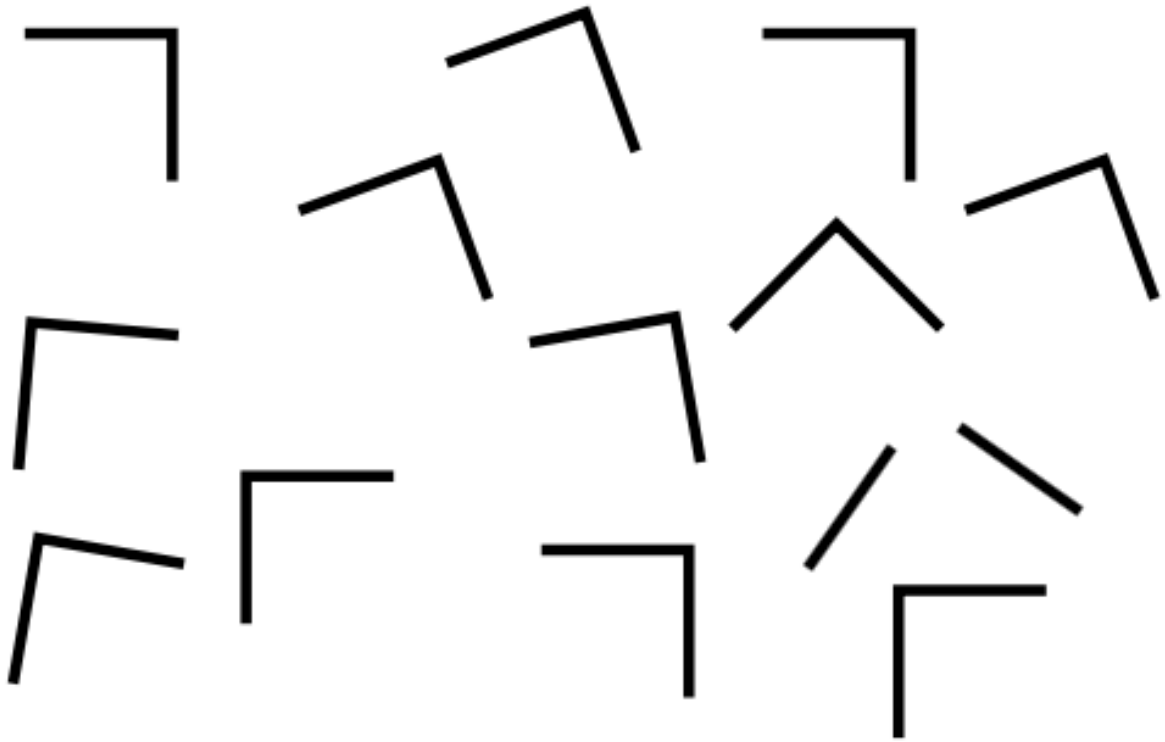
Convexity



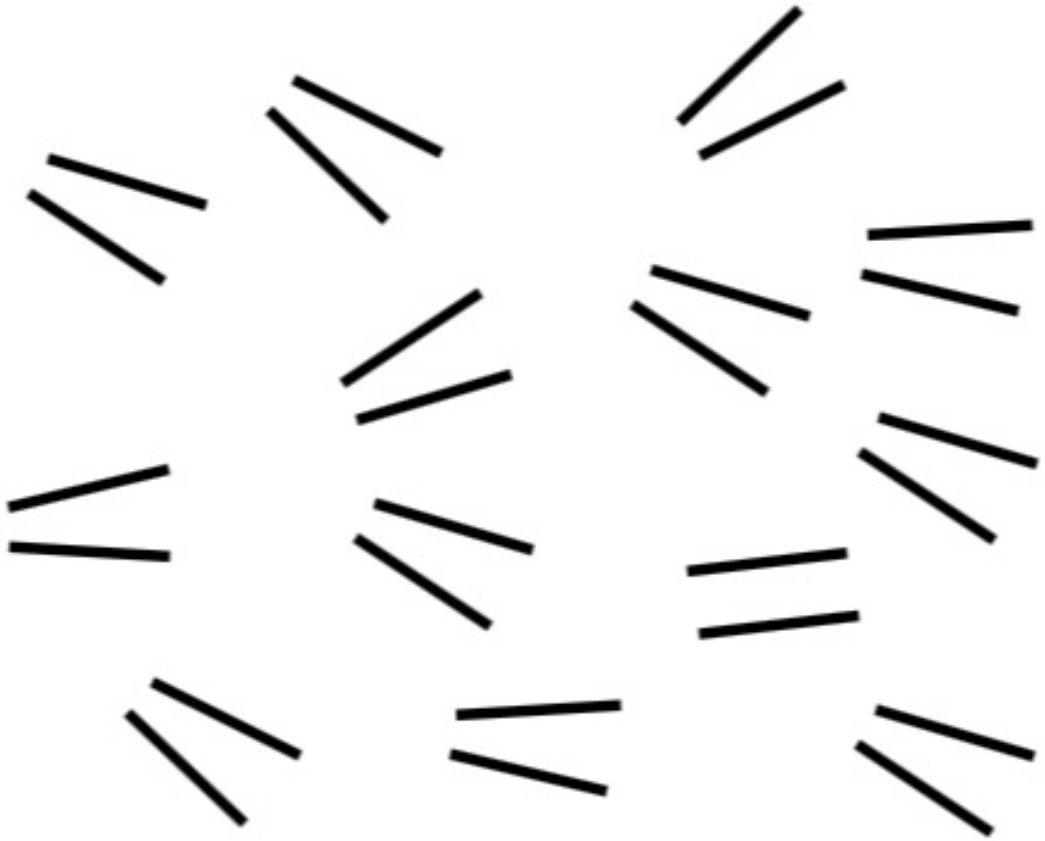
Addition



Junction



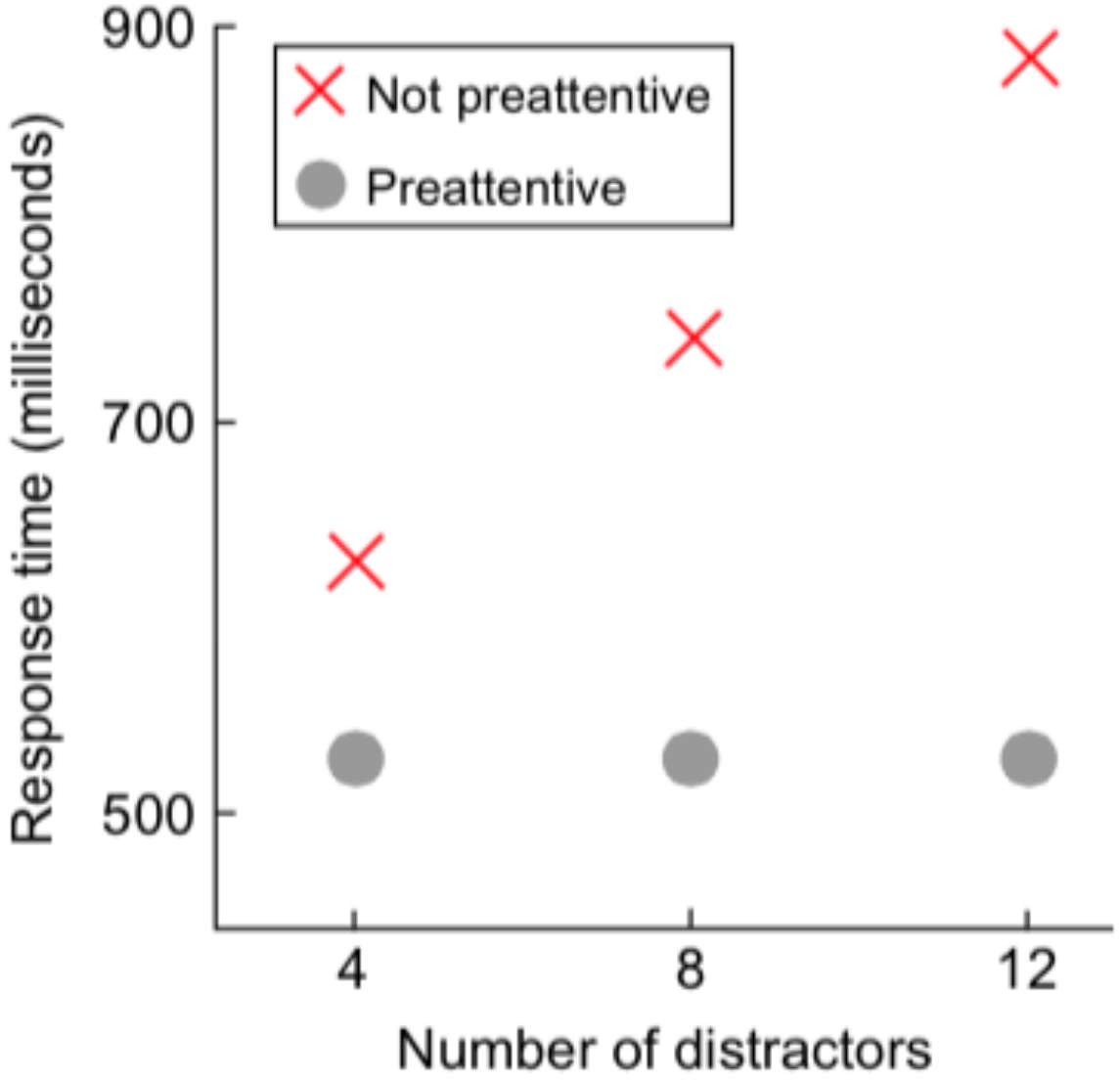
Parallelism



Shape & Color

Preattentive Processing

- Visual system favors both visually salient and newer elements
- Functions across visual field in parallel
- Some perceptual tasks can be greatly accelerated: such as element detection, grouping, and value estimation
- Inhibition of return: Previously scanned locations within a scene have slower response time than those not yet attended



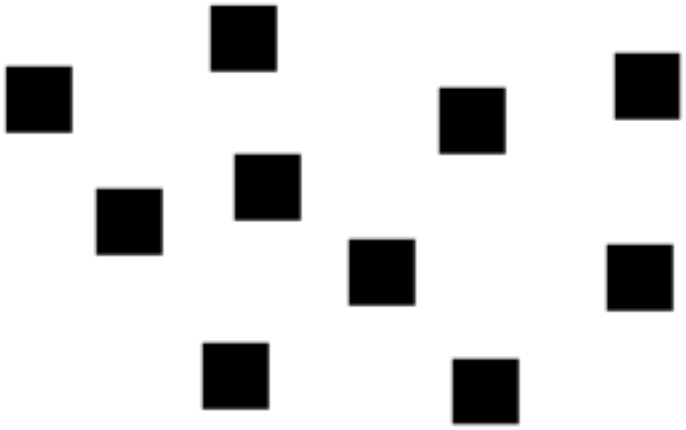
Gestalt Theory

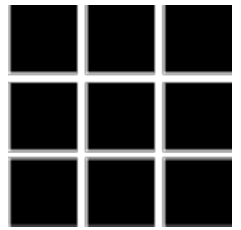
Gestalt Psychology

- Tries to understand the laws of our ability to acquire and maintain meaningful perceptions in an apparently chaotic world
- The central principle of gestalt psychology is that the mind forms a global whole with self-organizing tendencies
- This principle maintains that when the human mind (perceptual system) forms a percept or gestalt, the whole has a reality of its own, independent of the parts
- “The whole is other than the sum of the parts” by Kurt Koffka
- The Founds of Gestalt Psychology: Max Wertheimer, Kurt Koffa, and Wolfgang Kohler, ca 1912

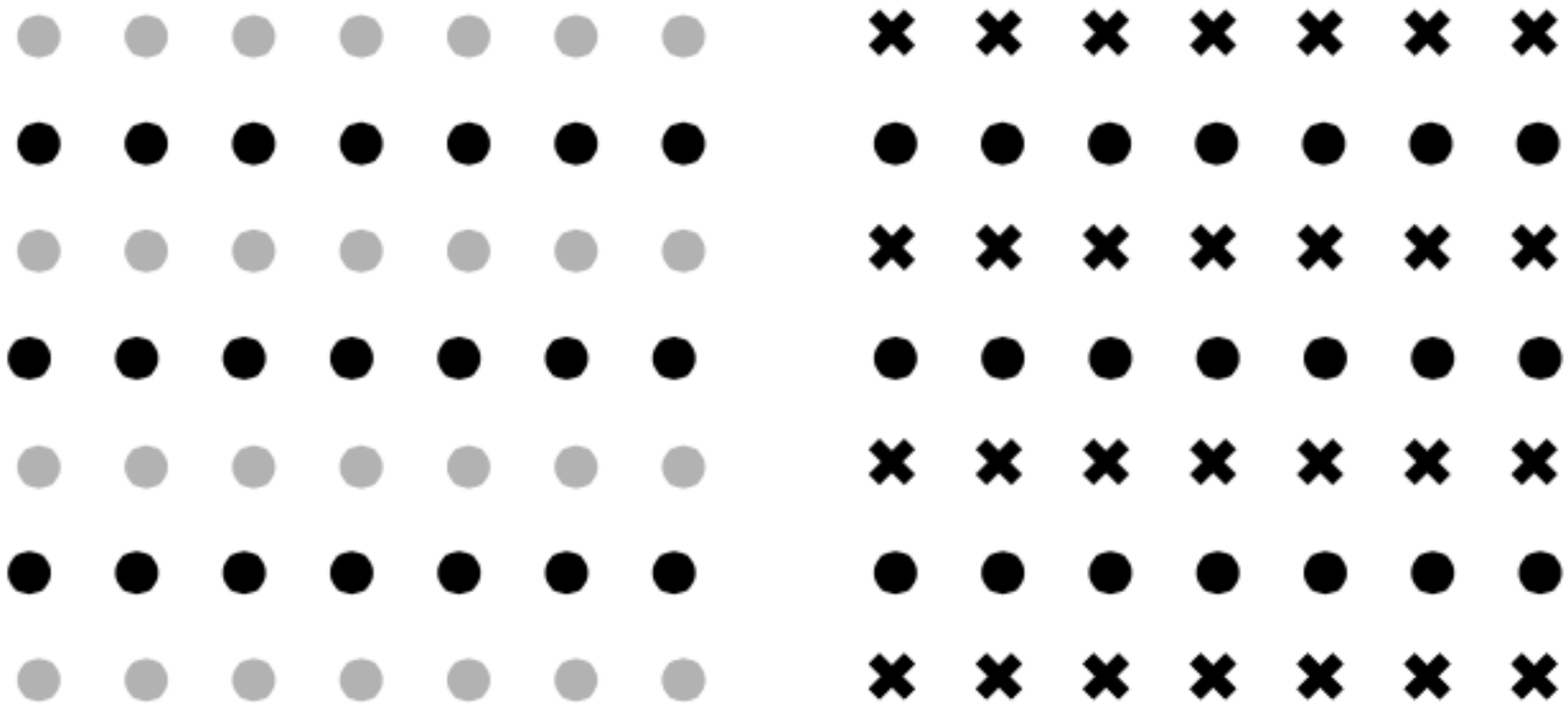
Proximity

Proximity

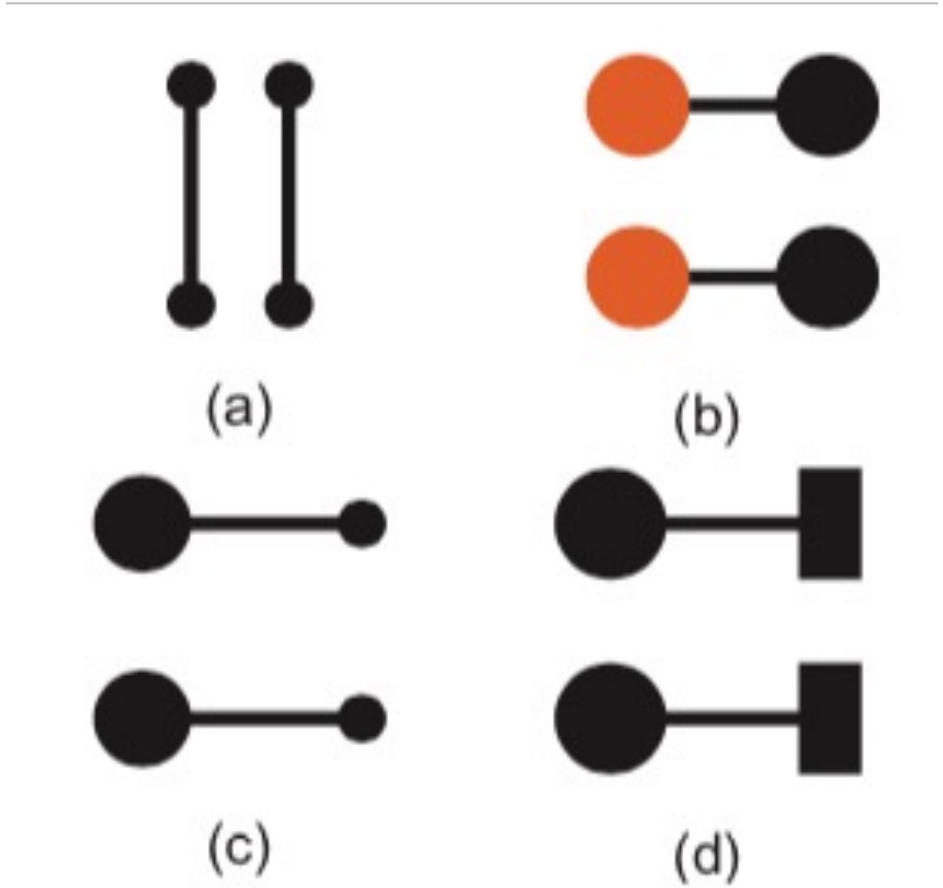




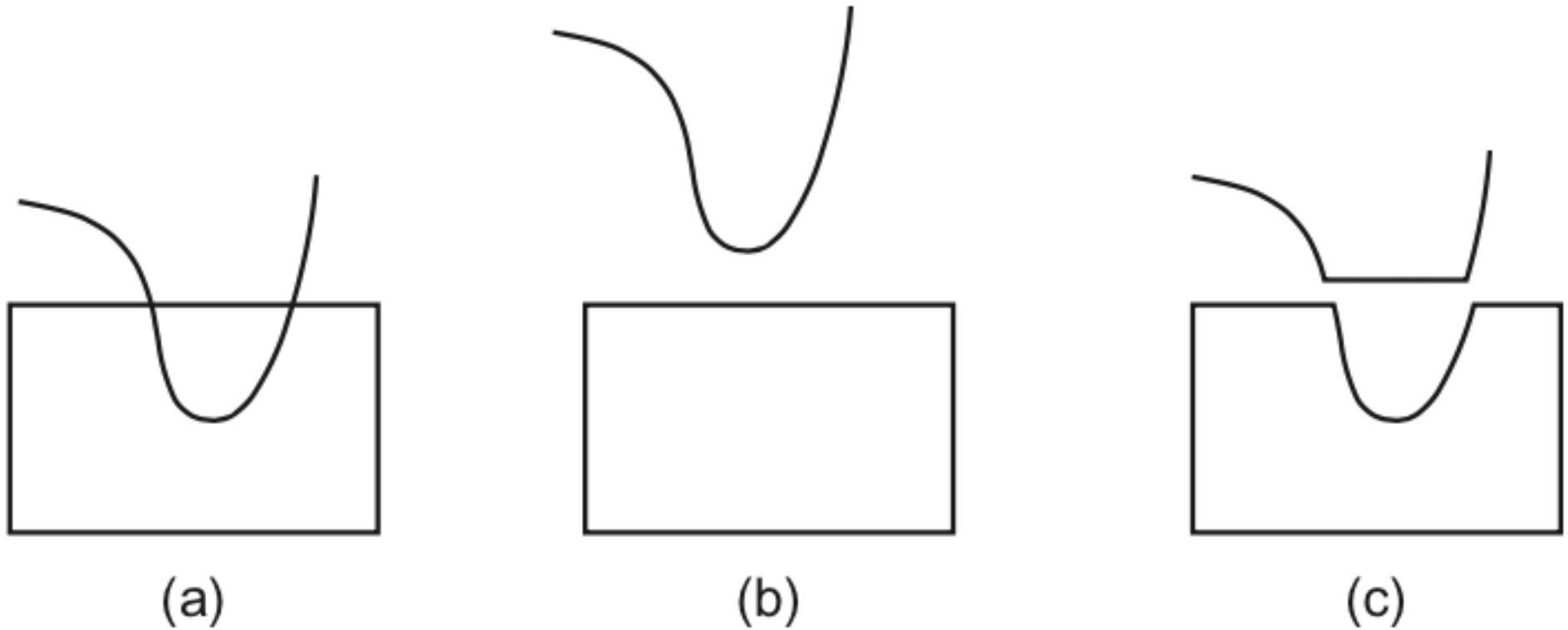
Similarity



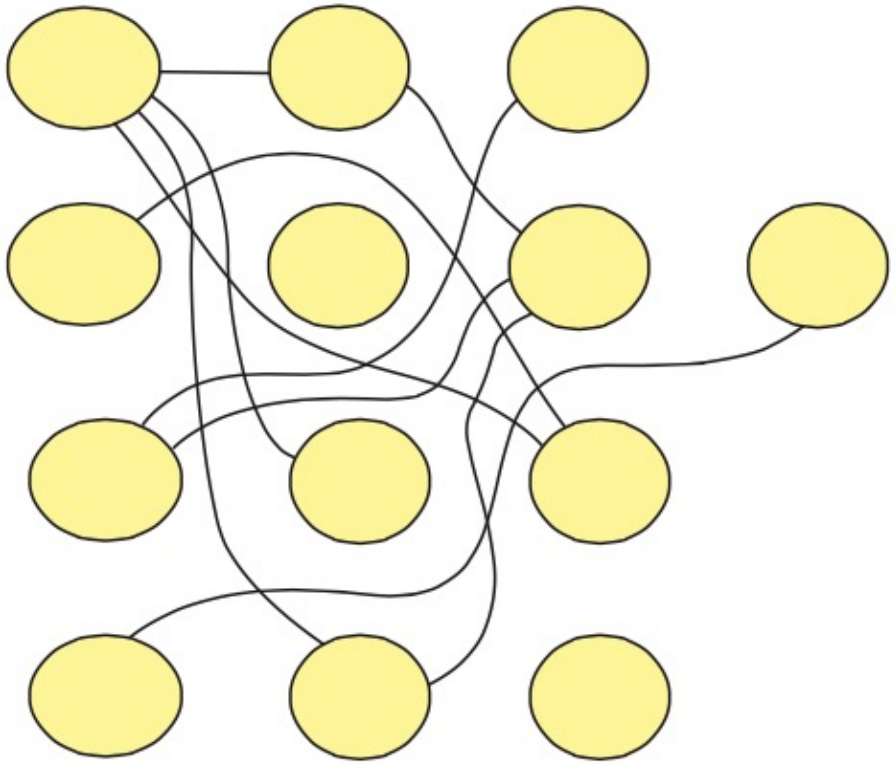
Connectedness



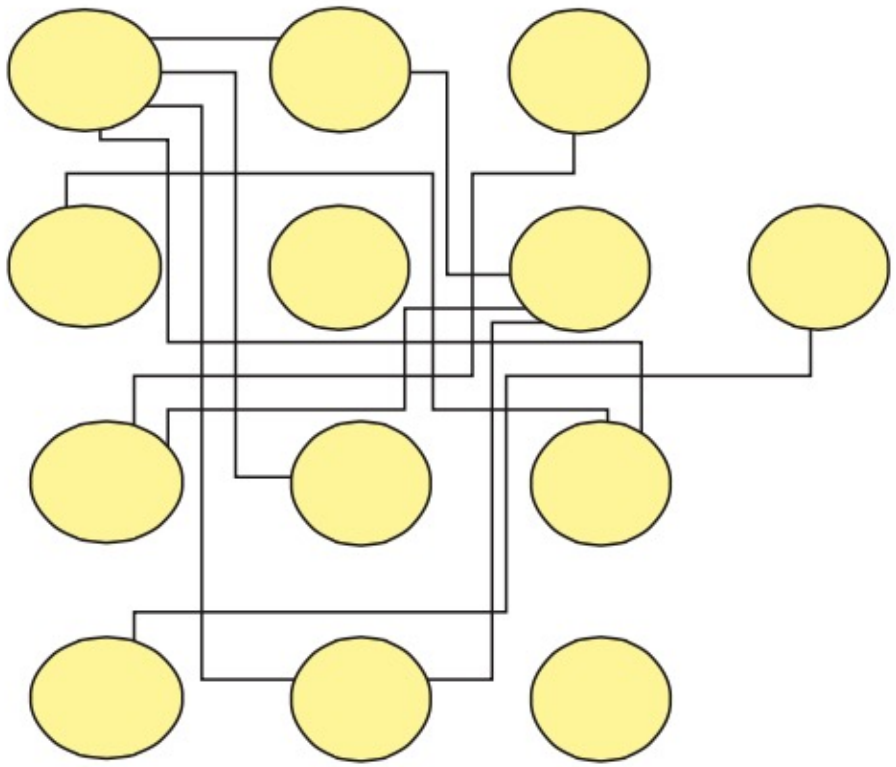
Continuity



Continuity

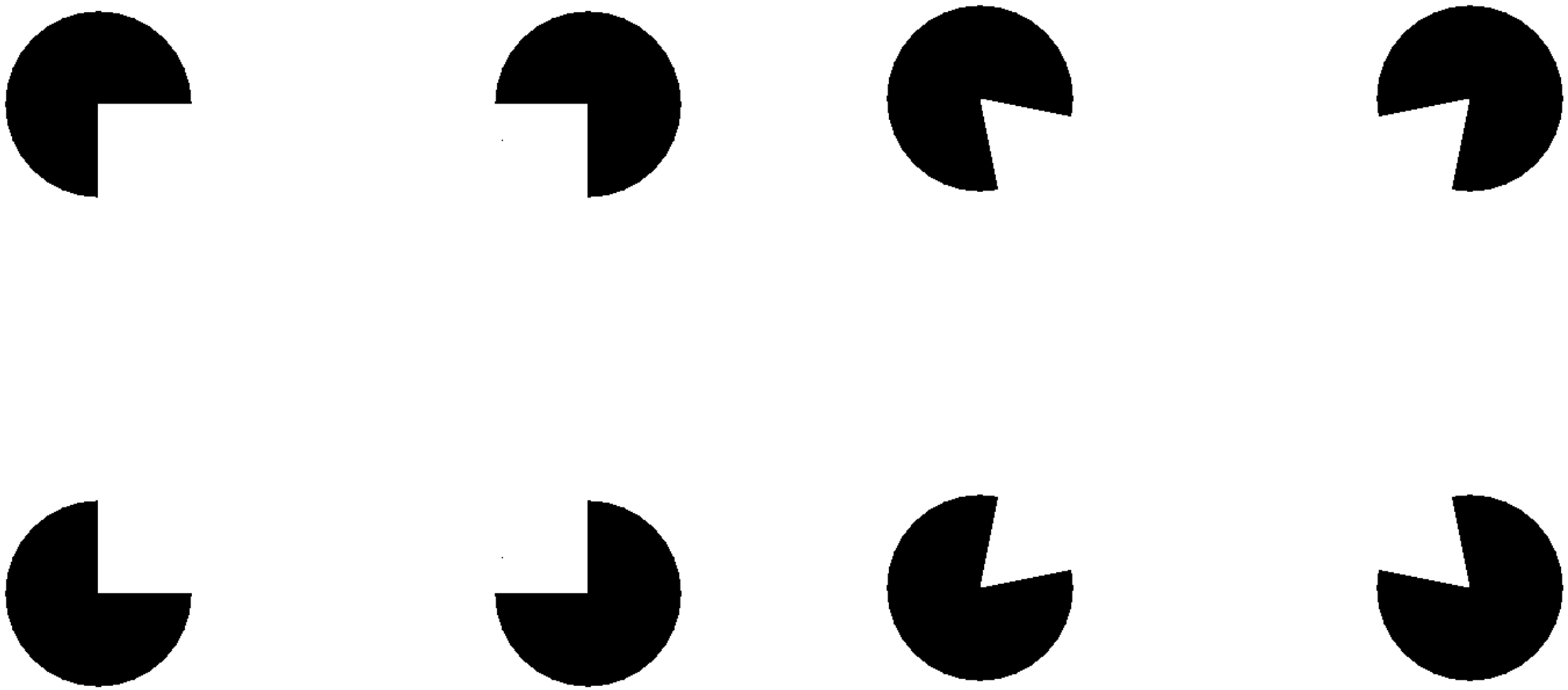


(a)

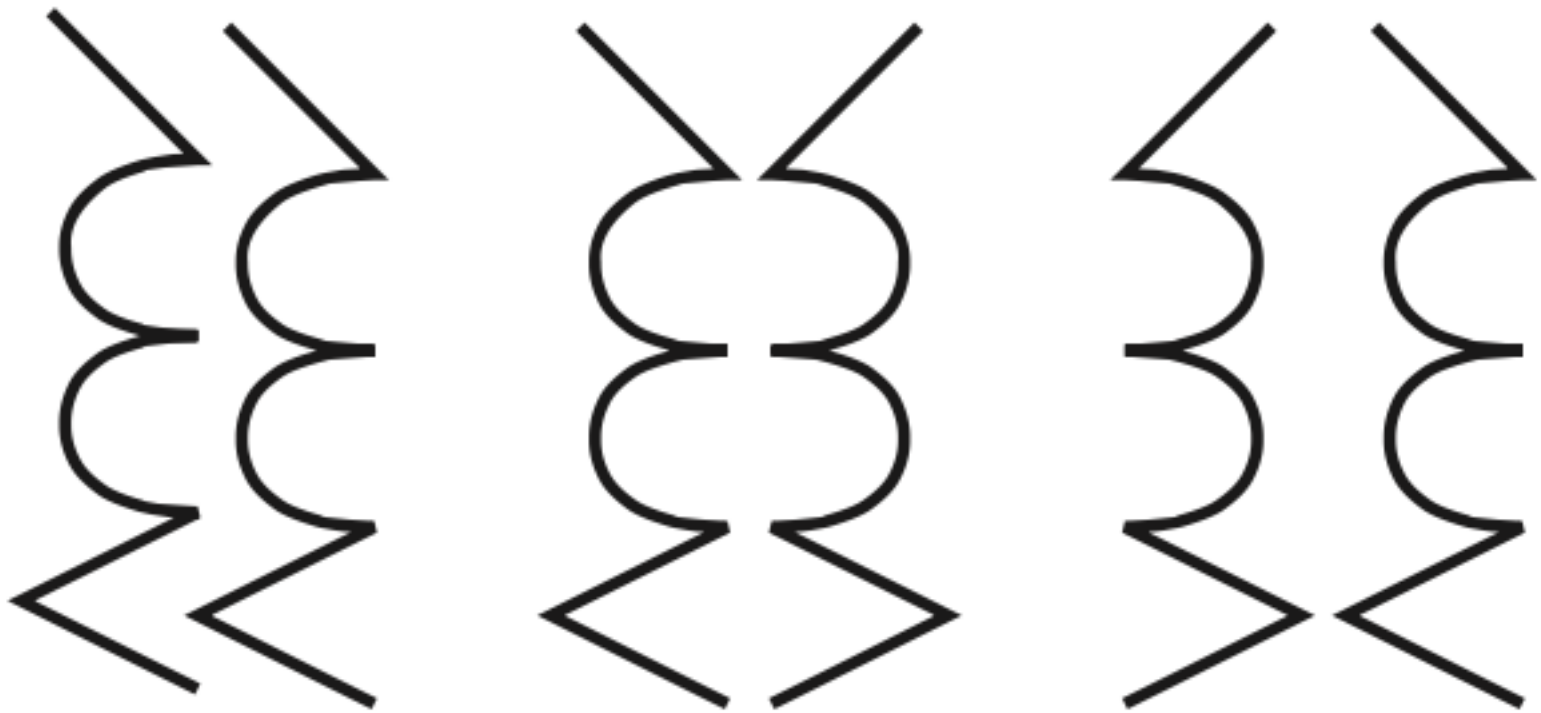


(b)

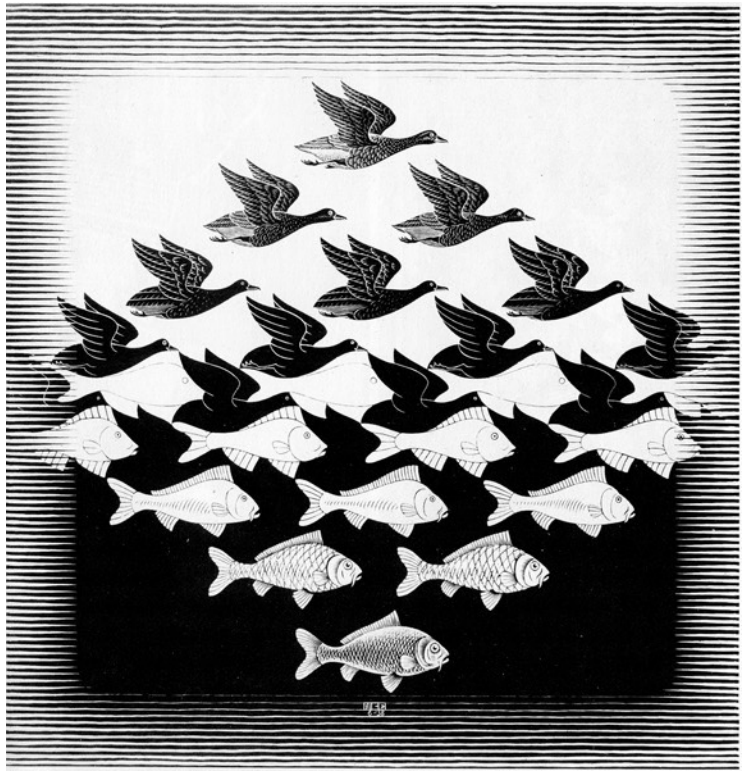
Closure



Symmetry



Figure/ground



Rules of Thumb

- Color
  - ‘Get it right in black & white’
  - Do no harm (use color sparingly)
  - Optimize for brightness, not hue
  - Limited hue palette, be selective
  - Avoid high contrasts and saturation
- Use preattentive processing for most important task
- Gestalt theory
  - Design towards proximity
  - Distinguish background and elements
  - Make connections continuous, avoid hard edges
  - Design elements towards arrangements