Grand Unified (Color) Theory

Meet Roy G. Biv!

R. Scott Granneman & Jans Carton

These PDF slides can be found at granneman.com/downloads/web-dev/Design-Color.pdf

Text notes, credits, & URLs for this presentation can be found…

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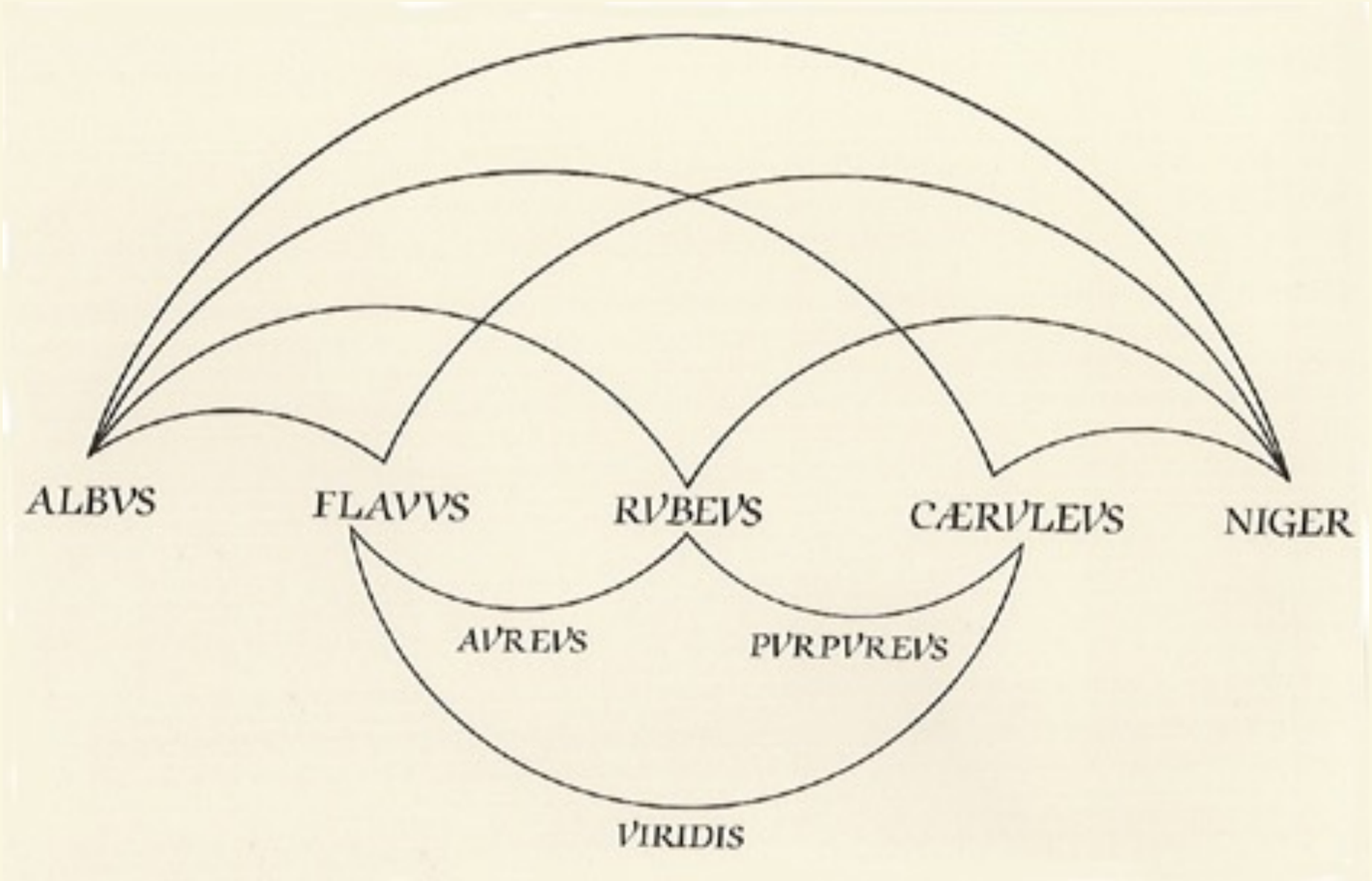
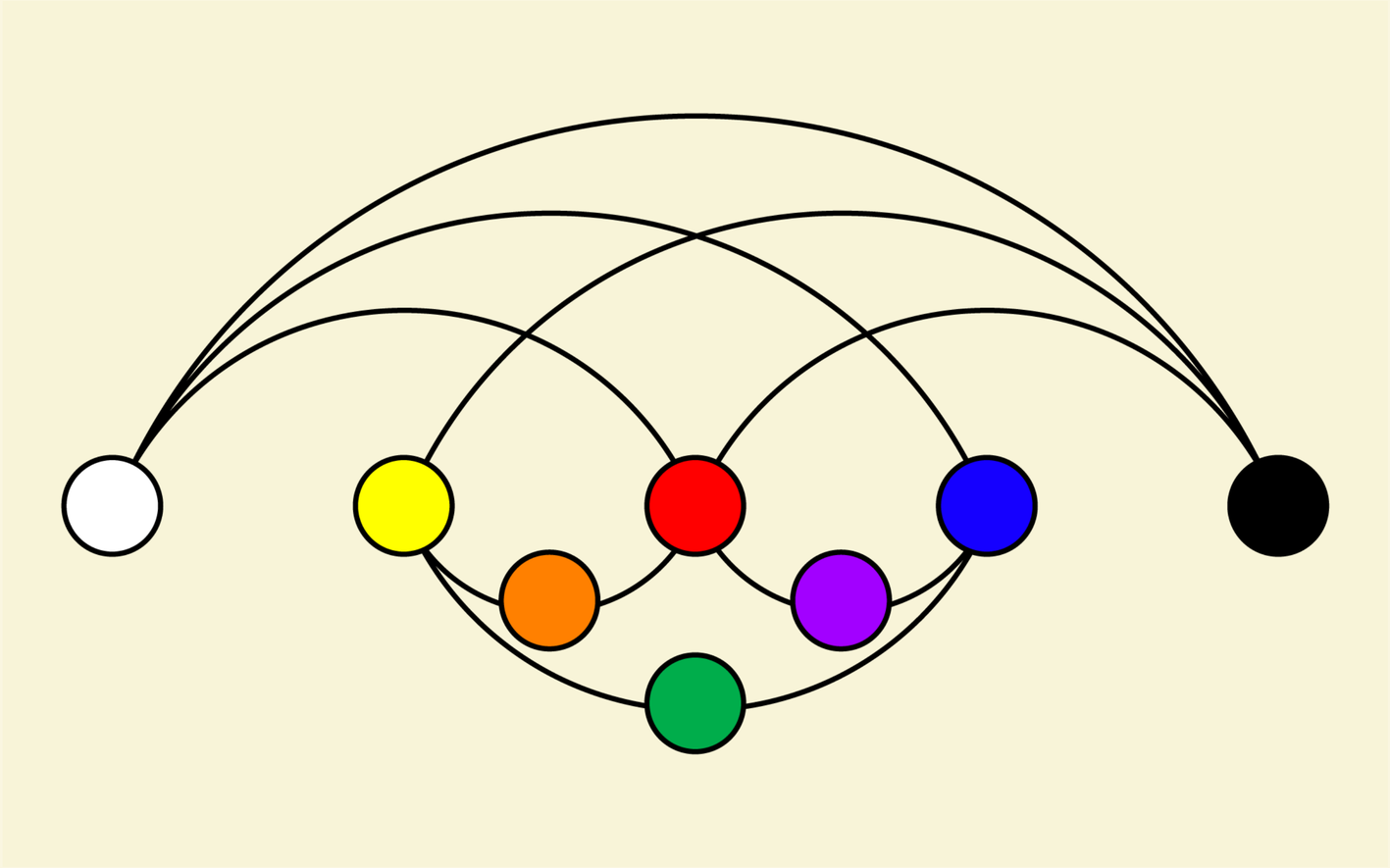
History

Aristotle’s color theories were tremendously influential

Colors sprang from the interaction of black & white & were influenced by the planets



Franciscus Aguilonius illustrated the ancient Greeks' ideas about color in 1613



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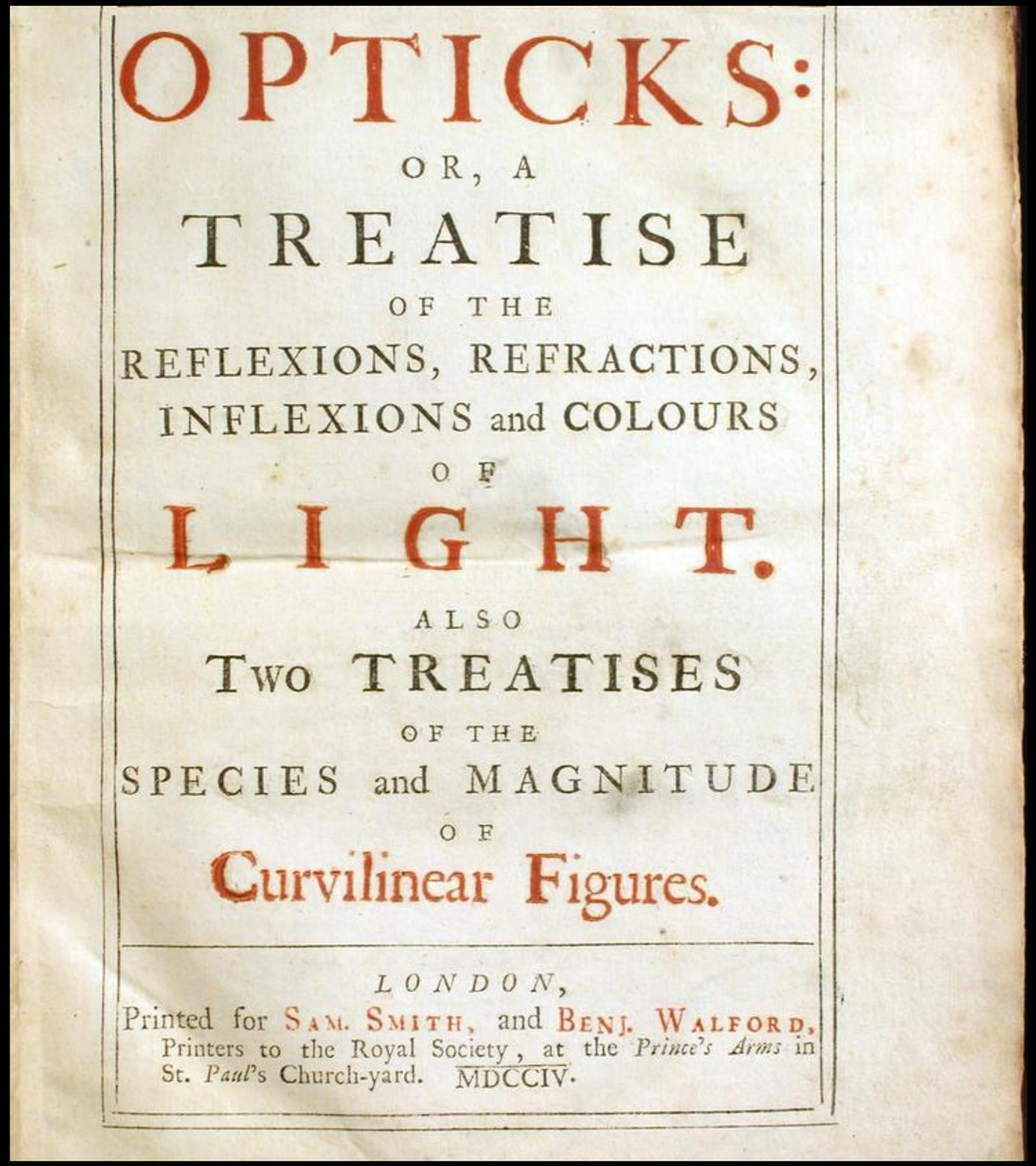


OPTICKS:

OR, A

TREATISE

OF THE

REFLEXIONS, REFRACTIONS,

INFLEXIONS and COLOURS

OF

LIGHT.

ALSO

Two TREATISES

OF THE

SPECIES and MAGNITUDE

OF

Curvilinear Figures.

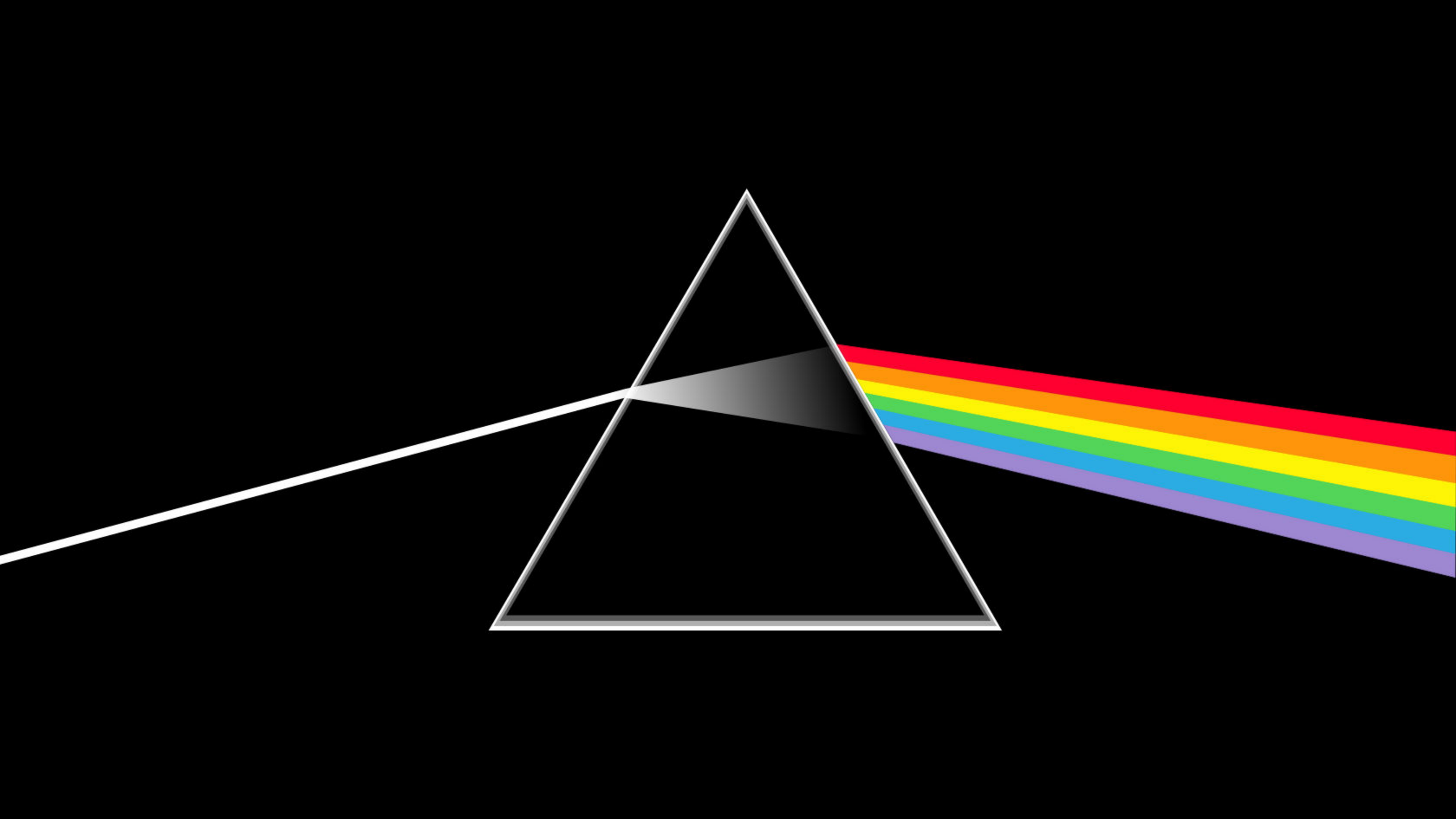
LONDON,

Printed for SAM. SMITH, and BENJ. WALFORD,

Printers to the Royal Society, at the *Prince's Arms* in

St. *Paul's* Church-yard. MDCCIV.

Isaac Newton studied color in 1666 & made major discoveries that are still important today…

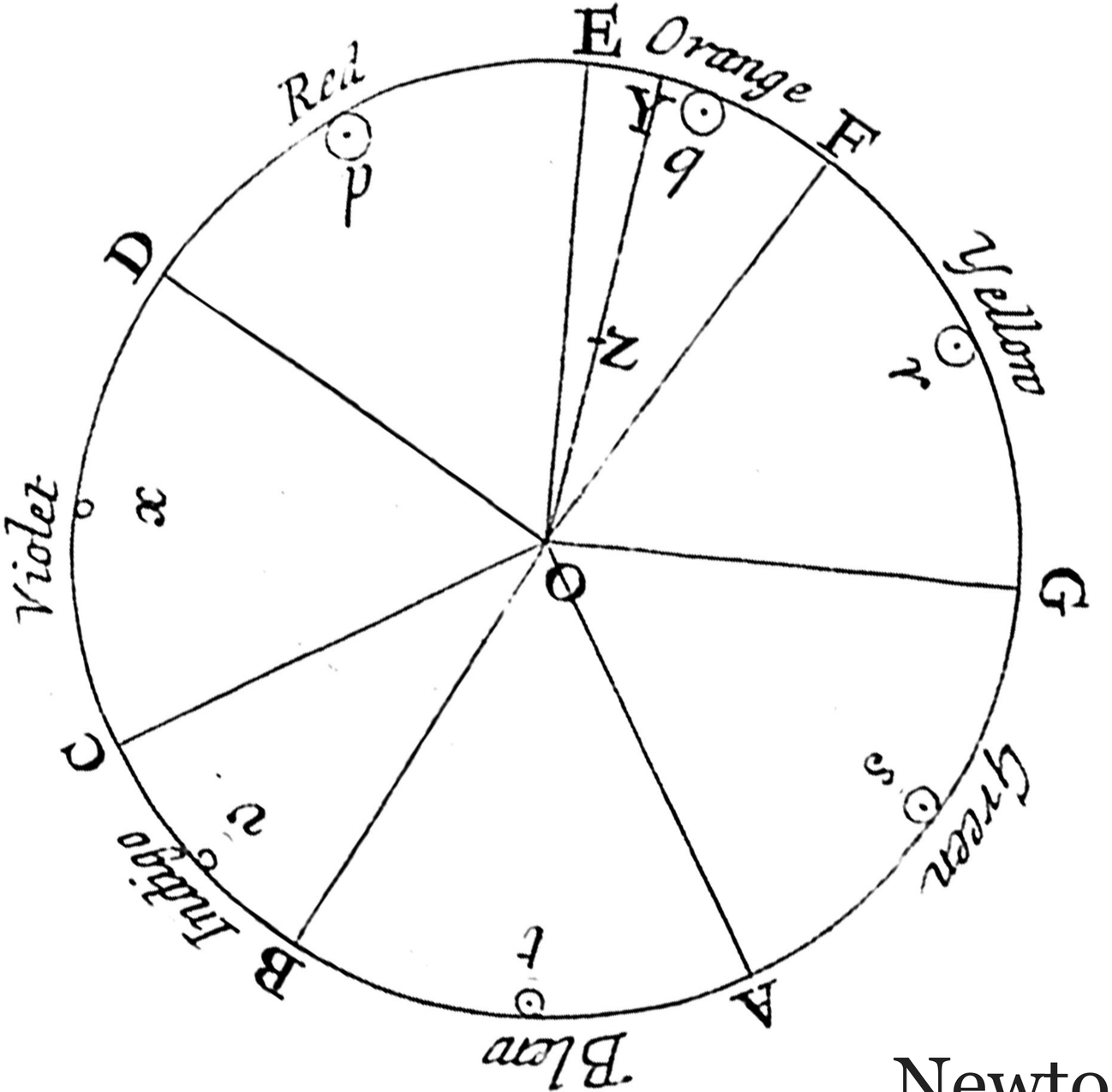


White light is made up of all the colors in the visible spectrum

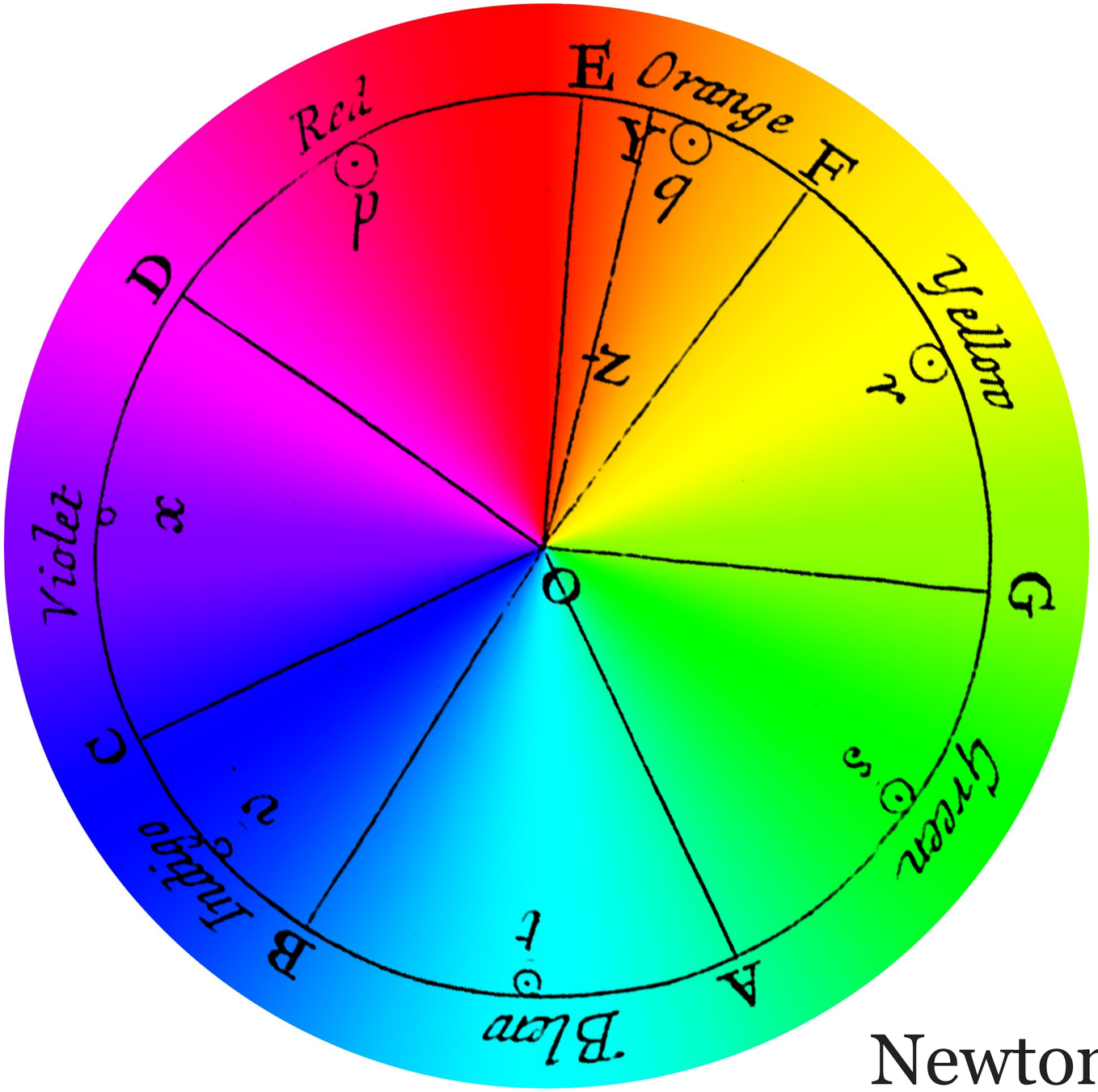
Some purples are not included in the visible spectrum

Primary colors are actually red-blue, green-blue, & yellow

Color can be conceptualized in a circle



Newton’s Color Circle

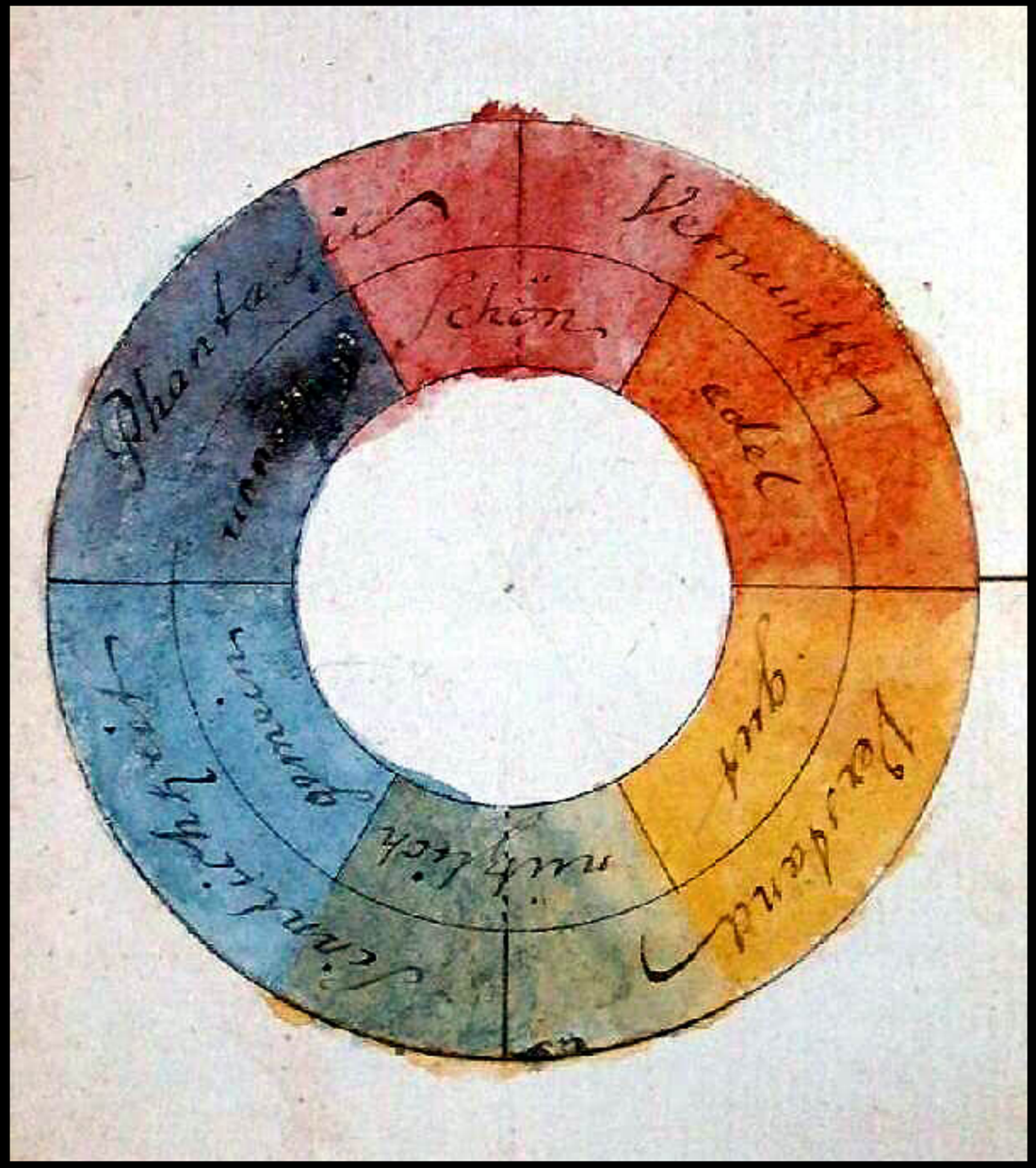


Newton’s Color Circle

Over the next 250 years, philosophers, poets, & artists rejected Newton's theories

Pre-eminent among them were Goethe, Schopenhauer, Castel, Schiffermüller, Harris, & Itten

Their teachings dominated the art world then & today



Goethe, 1809

Itten, 1961

Why did they reject Newton?

They liked the ideas of classical philosophy & preferred Aristotle’s model because it was more aesthetically pleasing

Philosophical color systems & theories have never been very useful for practical color mixing

Artists have always mixed colors from much larger palettes

Blat wijser of

W1: Bij fol: 25: is Spaens groen	W1: Bij fol: 31: is meny
W1: Bij fol: 26: is gekristallijseert Spaens groen	W1: Bij fol: 32: is roo operement of rust geel
W1: Bij fol: 27: is Berght groen	W1: Bij fol: 33: is root krijt of roodaerde
W1: Bij fol: 28: is sap groen	W1: Bij fol: 34: is roon oocker of Bruijn root
W1: Bij fol: 29: is terreverte groen	W1: Bij fol: 35: is florentijnse lack
W1: Bij fol: 30: is [illegible]	W1: Bij fol: 36: is Braesijlje [illegible]

Register.

W1: Bij fol: 25:	W1 Bij fol: 31:
W1: Bij fol: 26:	W1: Bij fol: 32:
W1: Bij fol: 27:	W1: Bij fol: 33:
W1: Bij fol: 28:	W1: Bij fol: 34:
W1: Bij fol: 29	W1: Bij fol: 35:
W1: Bij fol: 30:	W1: Bij fol: 36:

A:3:X:

Tabula Colorum Physiologica tam Mixtorum quam Simplicium, Quadrilinguis unà cum Speciminibus adjectis Regiæ Societati Londinensi humillime D.D.D. a Ric. Waller S.R.S.

			Cæ - - - - - - ru - - - - - - le - - - - - -		
			Candidu Hispan.	Montanum.	Cyprium.
			Niveus. Snow wh	Glastinus Watchet	Cyaneus Κύανε@
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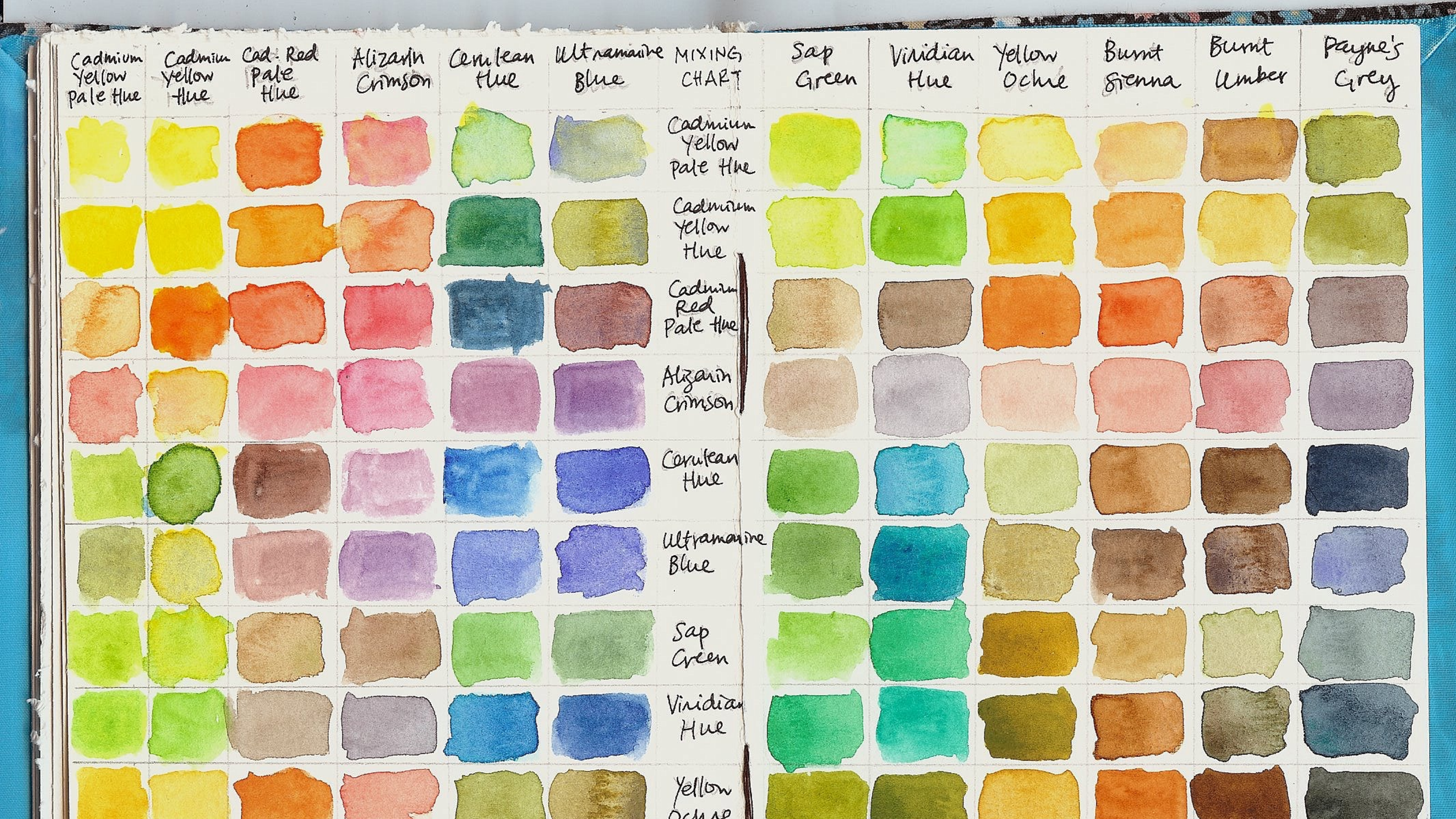
	Cerussa	Lacteus Γαλακτικός Blanc comme du lait. Milke wh	Argenteus. Ἀργύρε@ Silver Co.	Turcoinus Turcois Co	Caeruleus Ὑπουράνιος Skie Col
	- - - ces.		Lutei mixti.	Vi - - - - - - ri - - - - - -	
Lu - te - i Sim - pli -	Masticot	Limoneus Limon C	Paleus. Straw C	Cymatilis. Wave C	Saligneus Οἰσυινος Willow gr
	Gutta Gambæ	Aureus. Χρυσοειδής Couleur d'or. Gold Colour.	Luteolus. Ὑπόχλωρ@ Yellowish.	Psittaceus Poppinjay gr	Herbeus Grass green
	Ochra	Luteus. Ὠχρός. Cu d'oeuf. Clay Col.	Electricus. Ἠλέκτριν@ Amber Co.		Vitreus. Ὑάλινος Glass Co.
	Auripigmentum	Citrinus. Κίτρινος Orange Co	Byssinus. Βύσσιν@ Rawsilke C		
	b. Umbria	Fuscus. Φαιός. Brun. Browne.	Subfuscus. Dun.		
	- - - ces.		Rubei mixti.	Pur - - -	pu - - -


Cadmium Yellow Pale Hue
Cadmium Yellow Hue
Cad. Red Pale Hue
Alizarin Crimson
Cerulean Hue
Ultramarine Blue
MIXING CHART
Sap Green
Viridian Hue
Yellow Ochre
Burnt Sienna
Burnt Umber
Payne's Grey
Cadmium Yellow Pale Hue
Cadmium Yellow Hue
Cadmium Red Pale Hue
Alizarin Crimson
Cerulean Hue
Ultramarine Blue
Sap Green
Viridian Hue
Yellow Ochre

During the 20th century we…

» vastly increased our understanding of color
» devised extremely effective methods to reproduce every color we can see

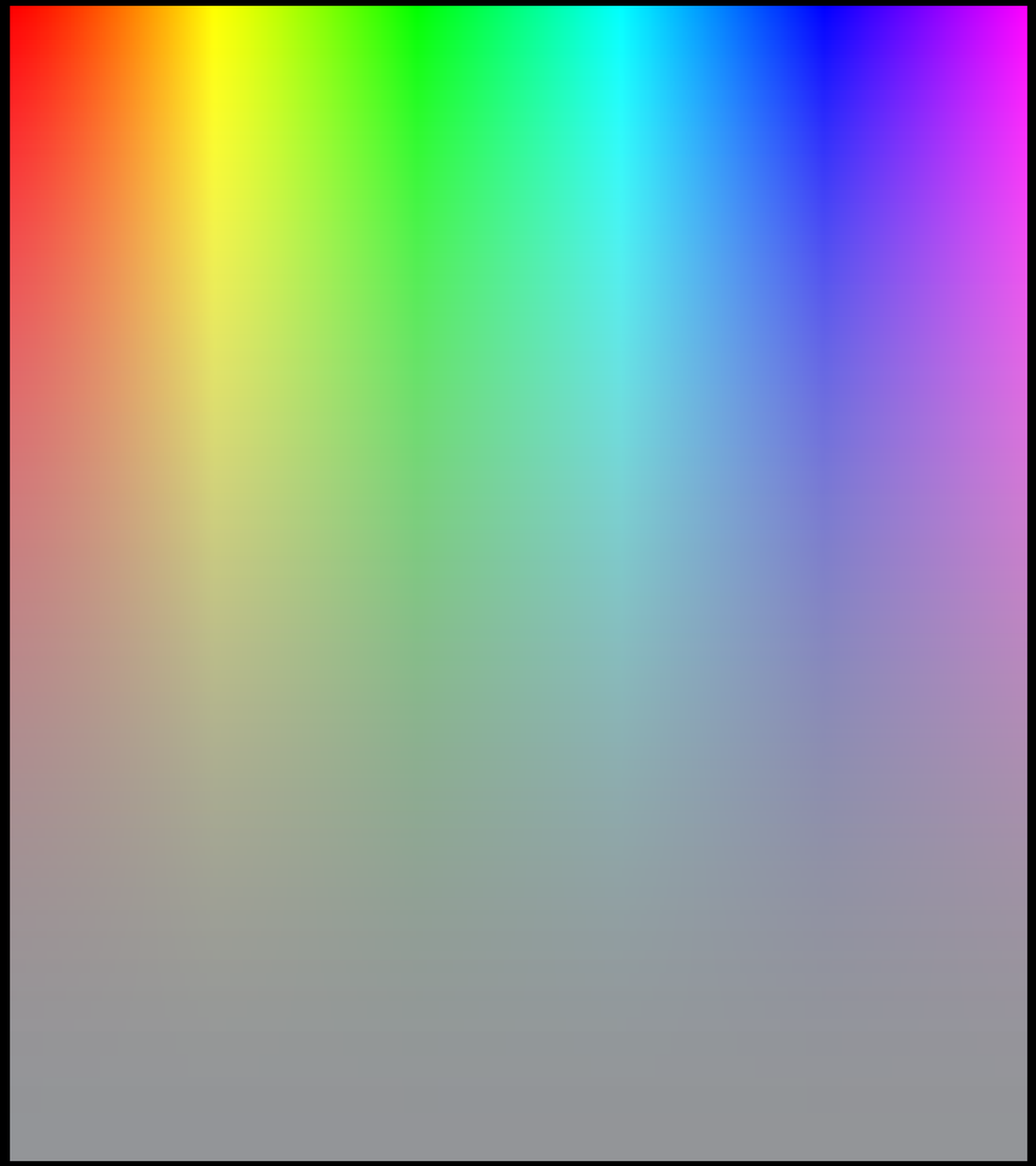

SAMSUNG

Basic Terminology

Hue

The quality that differentiates one color from another on the spectrum

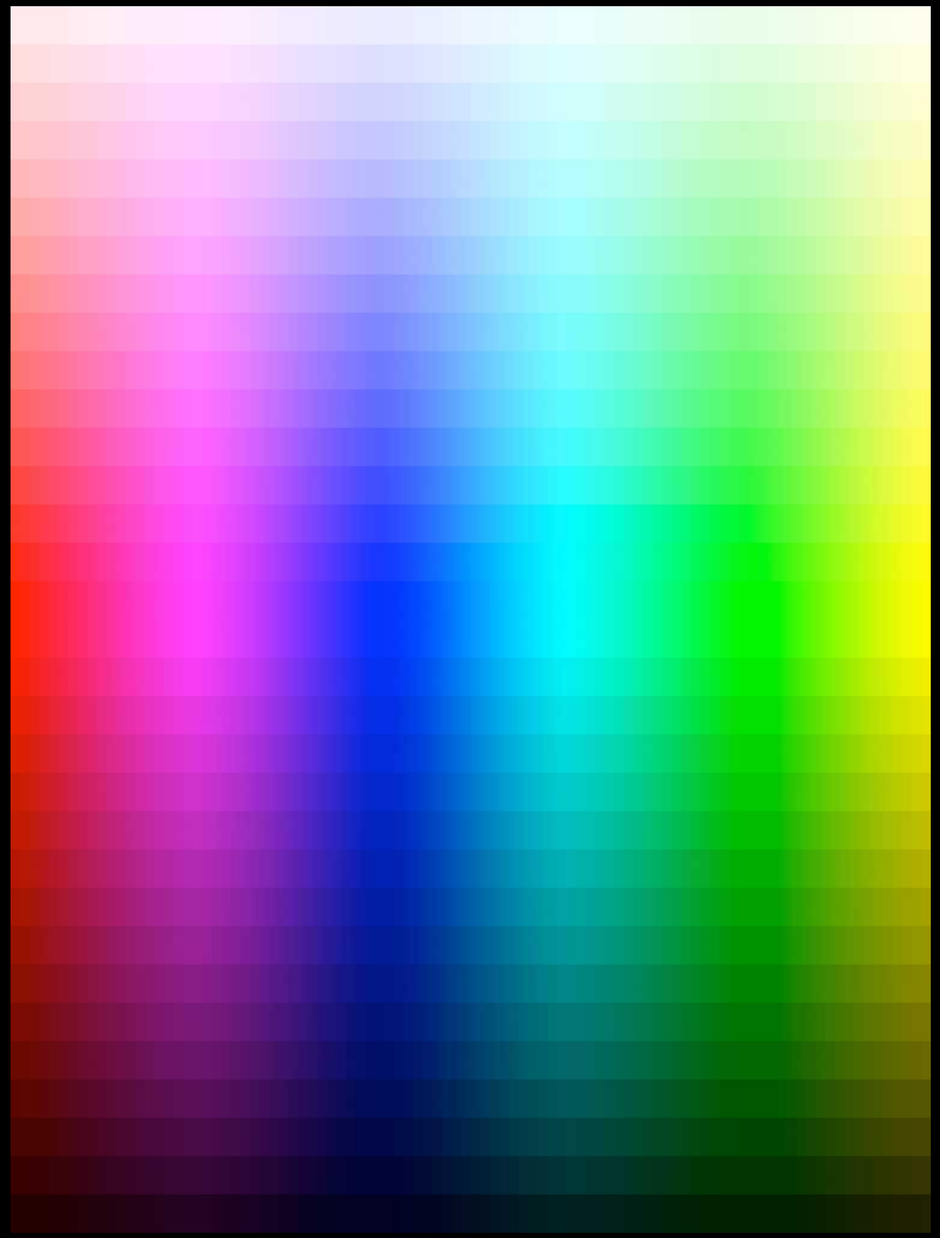
Hue is communicated by color names (green) or by degrees on a color circle (90º)



Saturation

A range from pure color to a duller color

Adding gray, black, or white to a color reduces saturation, making it more dull & muted

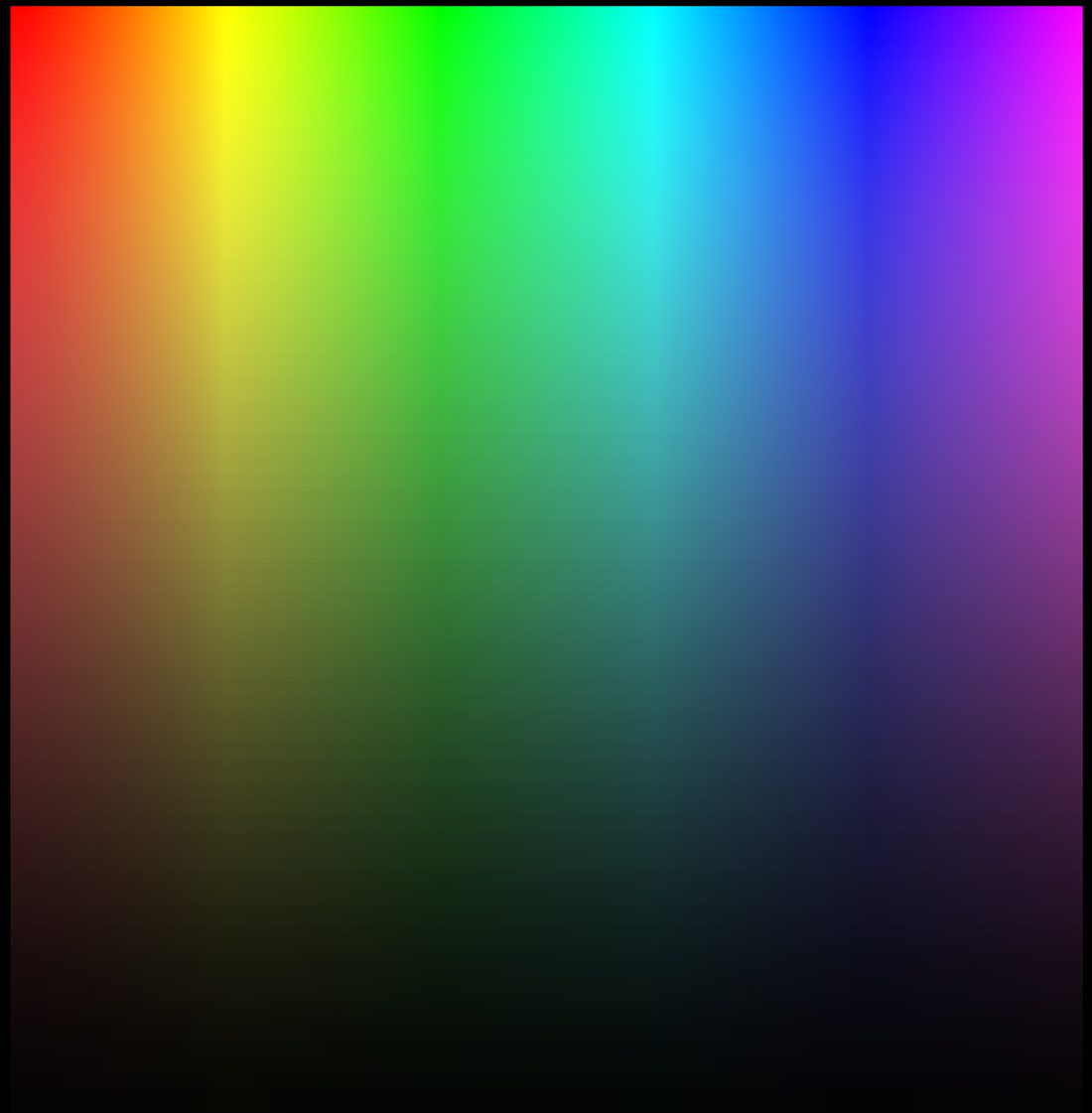


Lightness

A range from black to white

Full saturation can only be achieved at 50% lightness

Typically used in video imaging

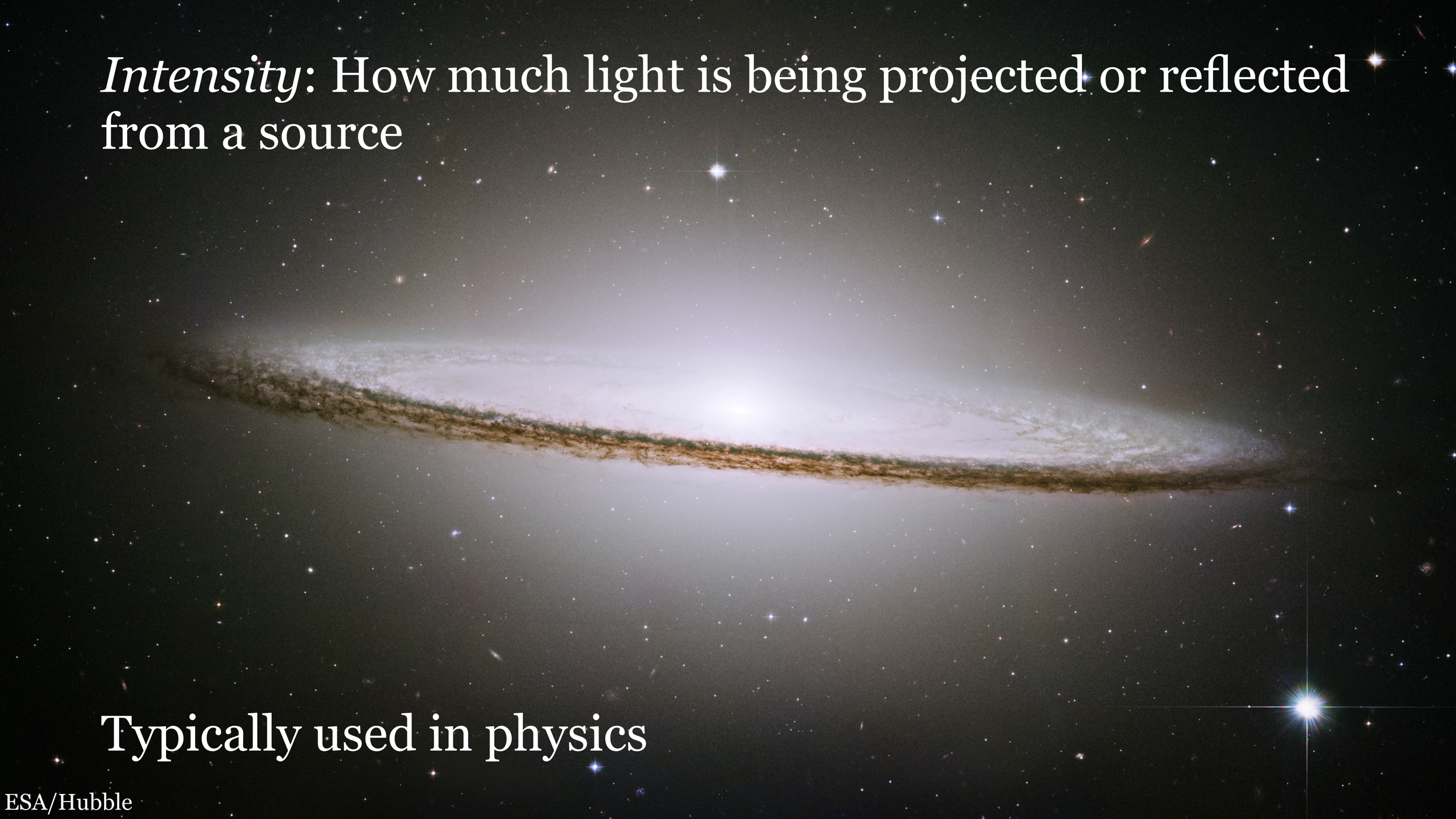


Value or *Brightness*

A range from darkness to full intensity (whatever that intensity is)

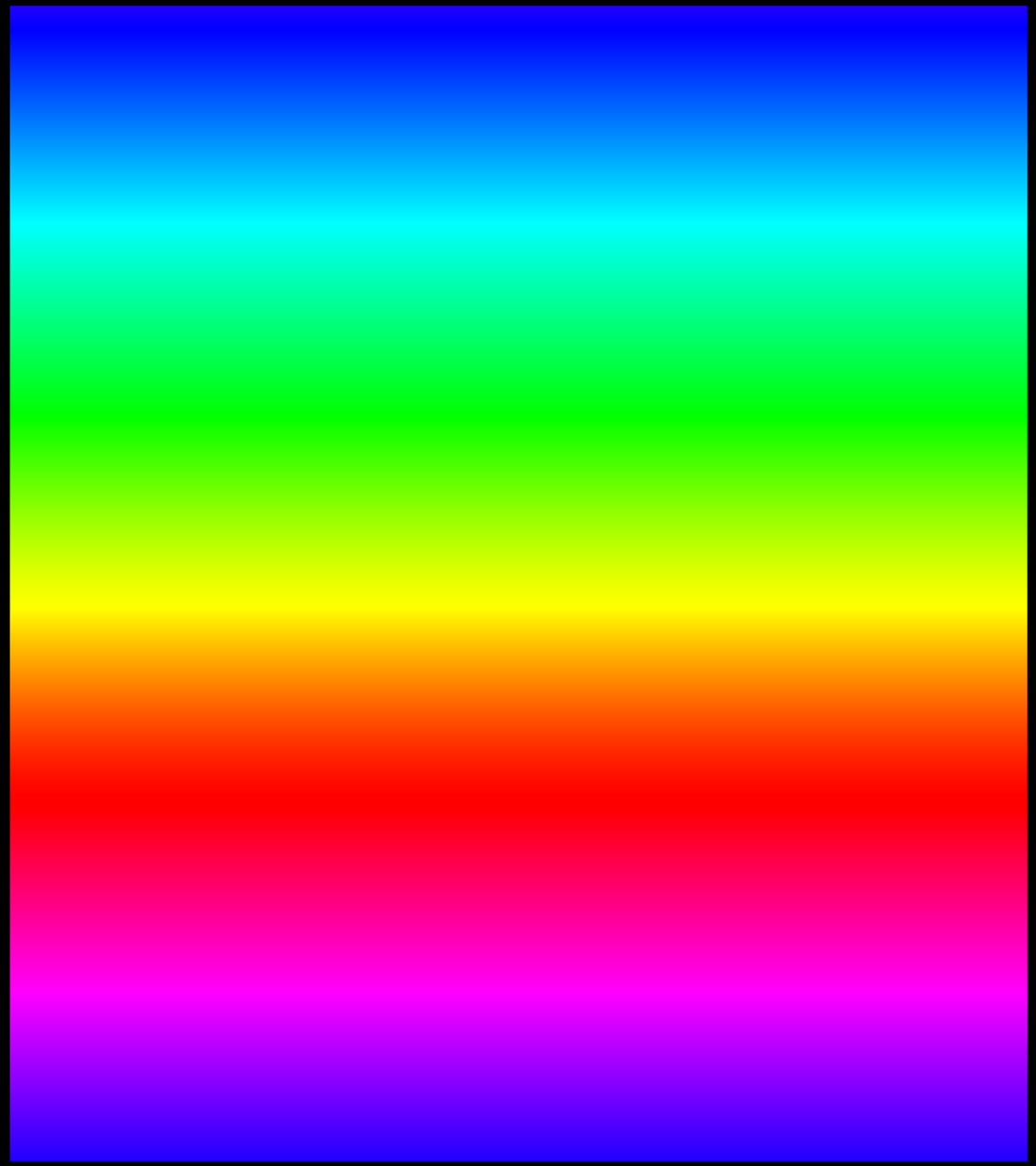
Typically used in video imaging

Intensity: How much light is being projected or reflected from a source



Typically used in physics

ESA/Hubble



Luminance

Perception of relative brightness between colors

Assume yellow & blue are at the same saturation & brightness—yellow will seem lighter

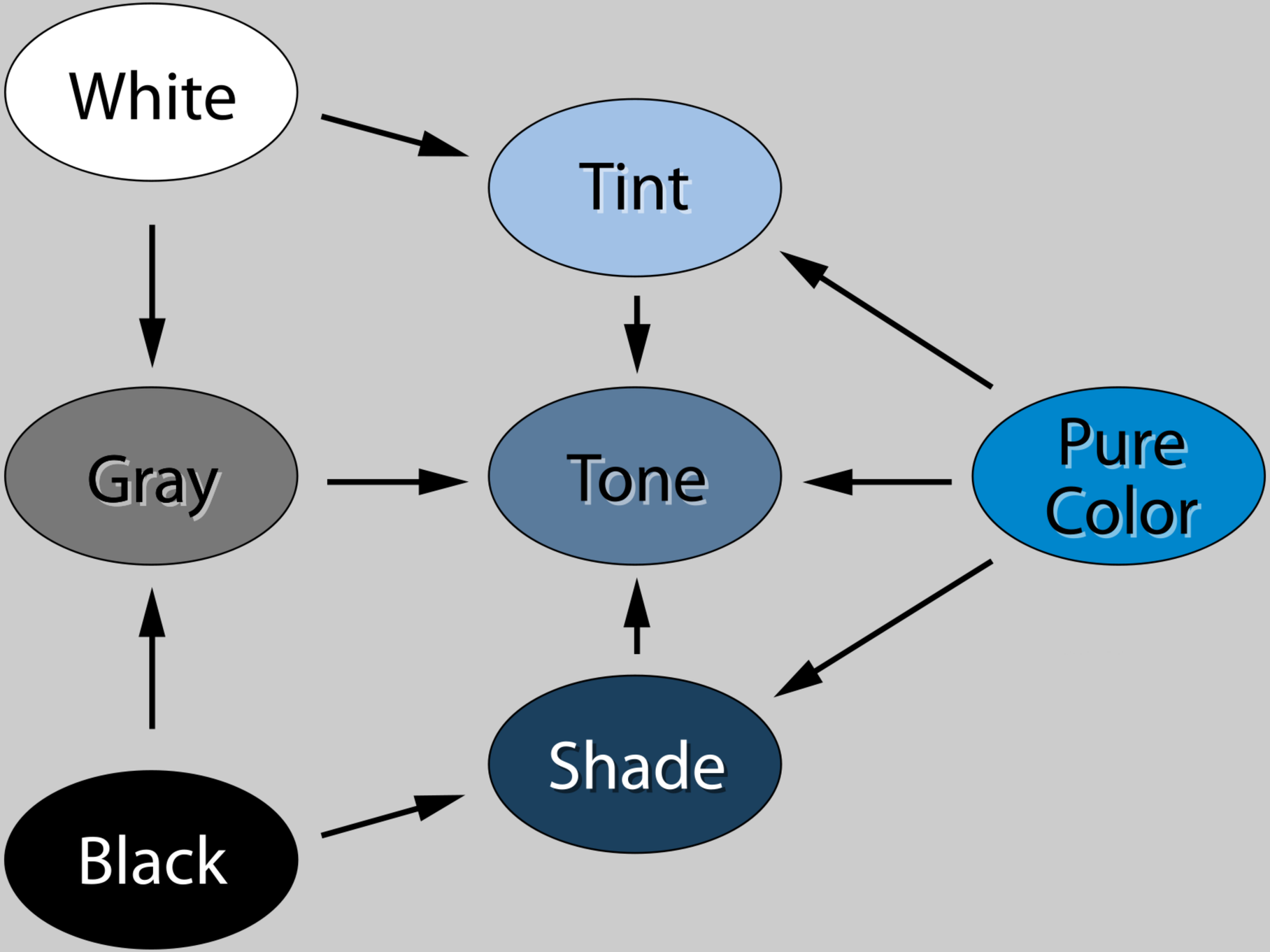
Typically used in video imaging

Tone: a color mixed with gray, black, or white

Tint: a color mixed with white

Shade: a color mixed with black

Typically used by painters

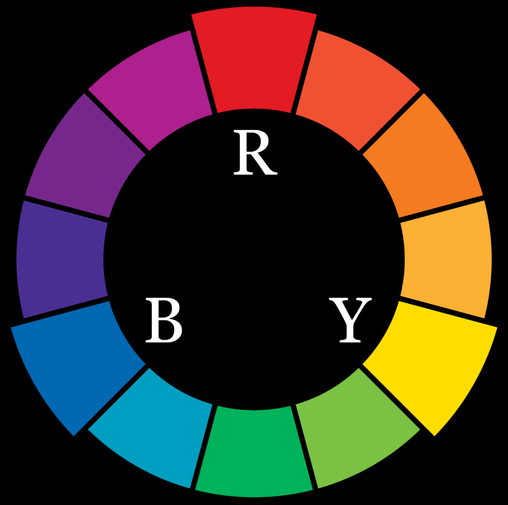

White
Tint
Gray
Tone
Pure Color
Shade
Black

Color geometry

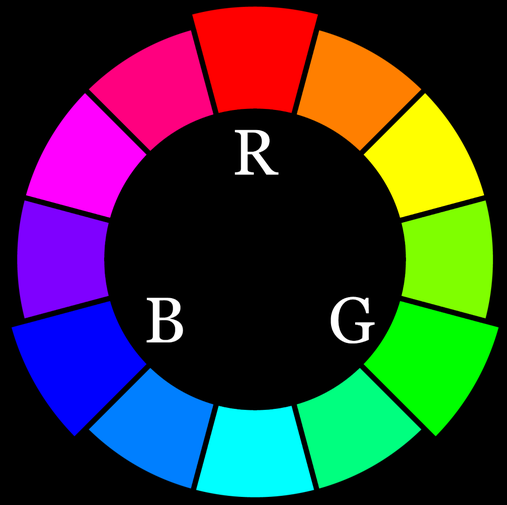
Arrangement of colors to help conceptualize their interactions & relationships with one another

Primary colors

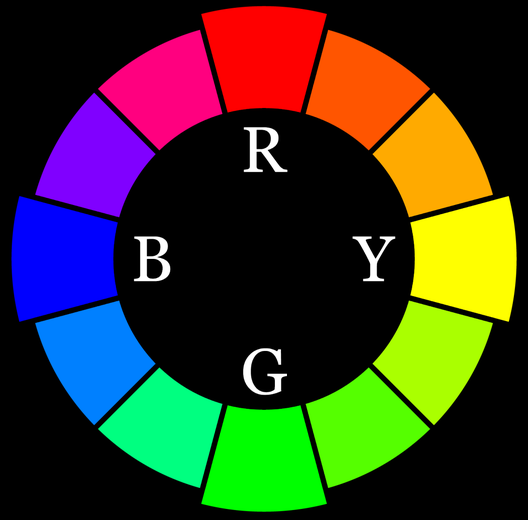
Anchor colors that define a specific color geometry



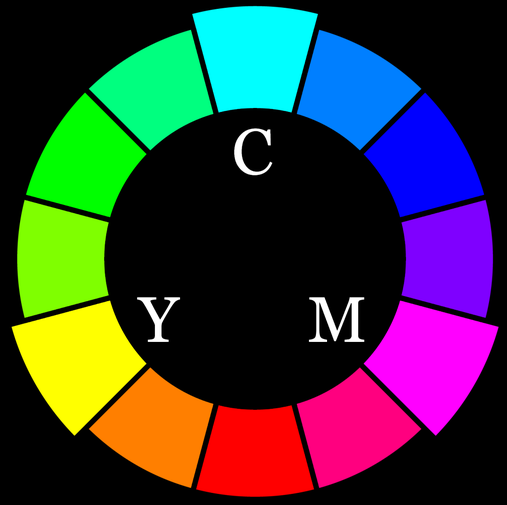
Artistic discussion



Mixing light



Color vision & psychology



Mixing pigments

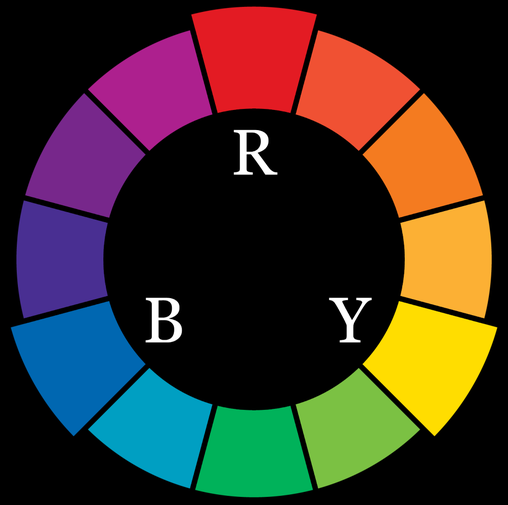
Art

Color Wheel

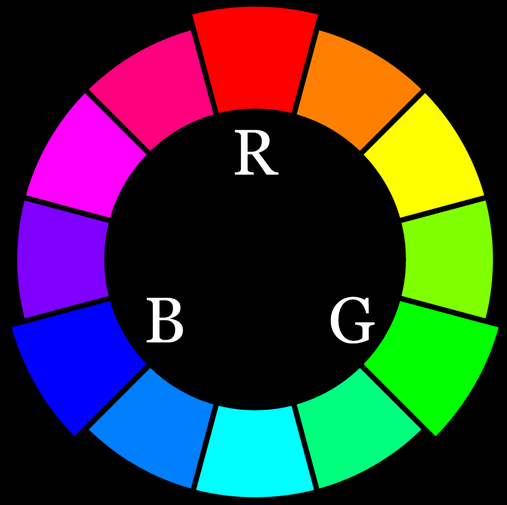
Color wheel

Model for visualizing relationships between colors in a chart

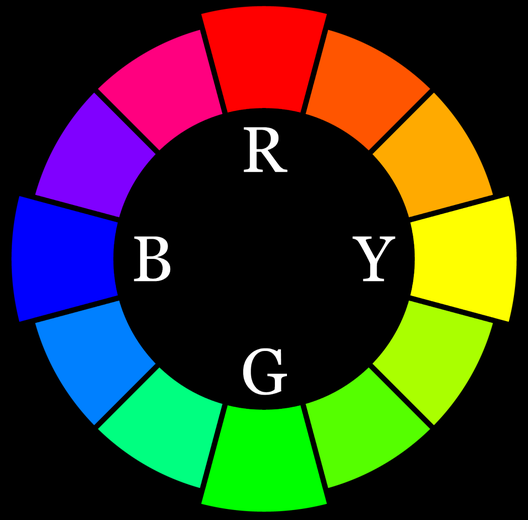
Artists refer specifically the RYB geometry model when they say “color wheel”



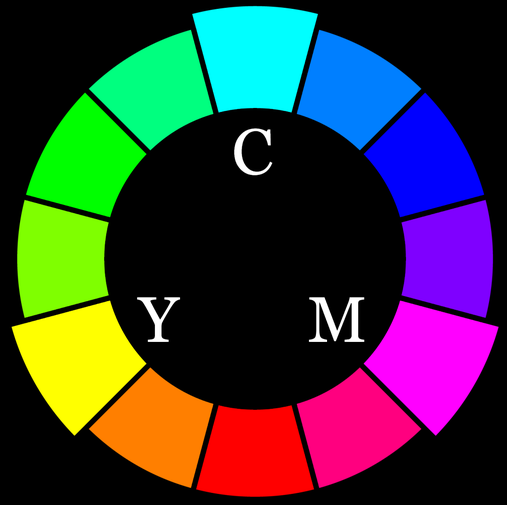
Artistic discussion



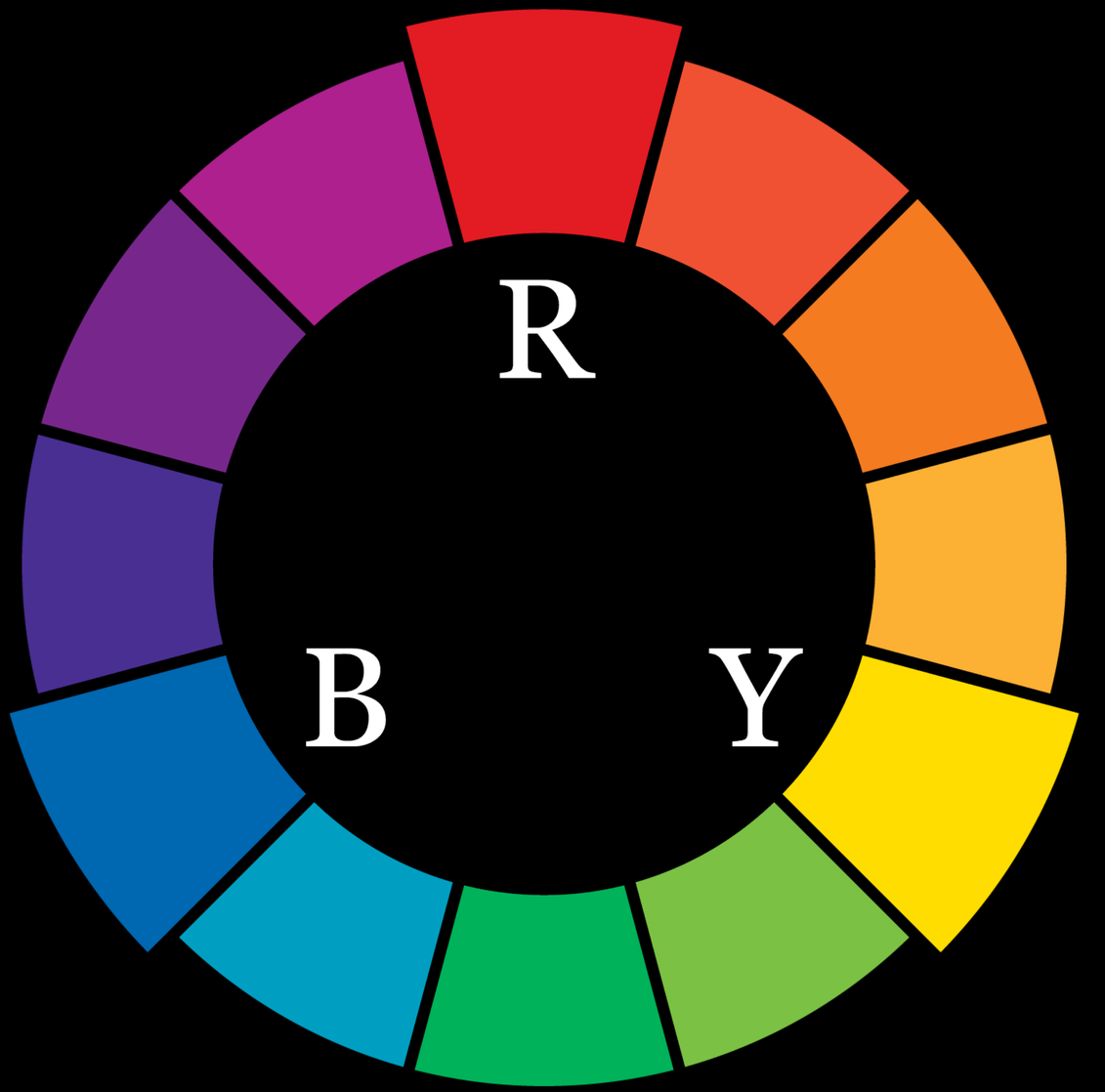
Mixing light

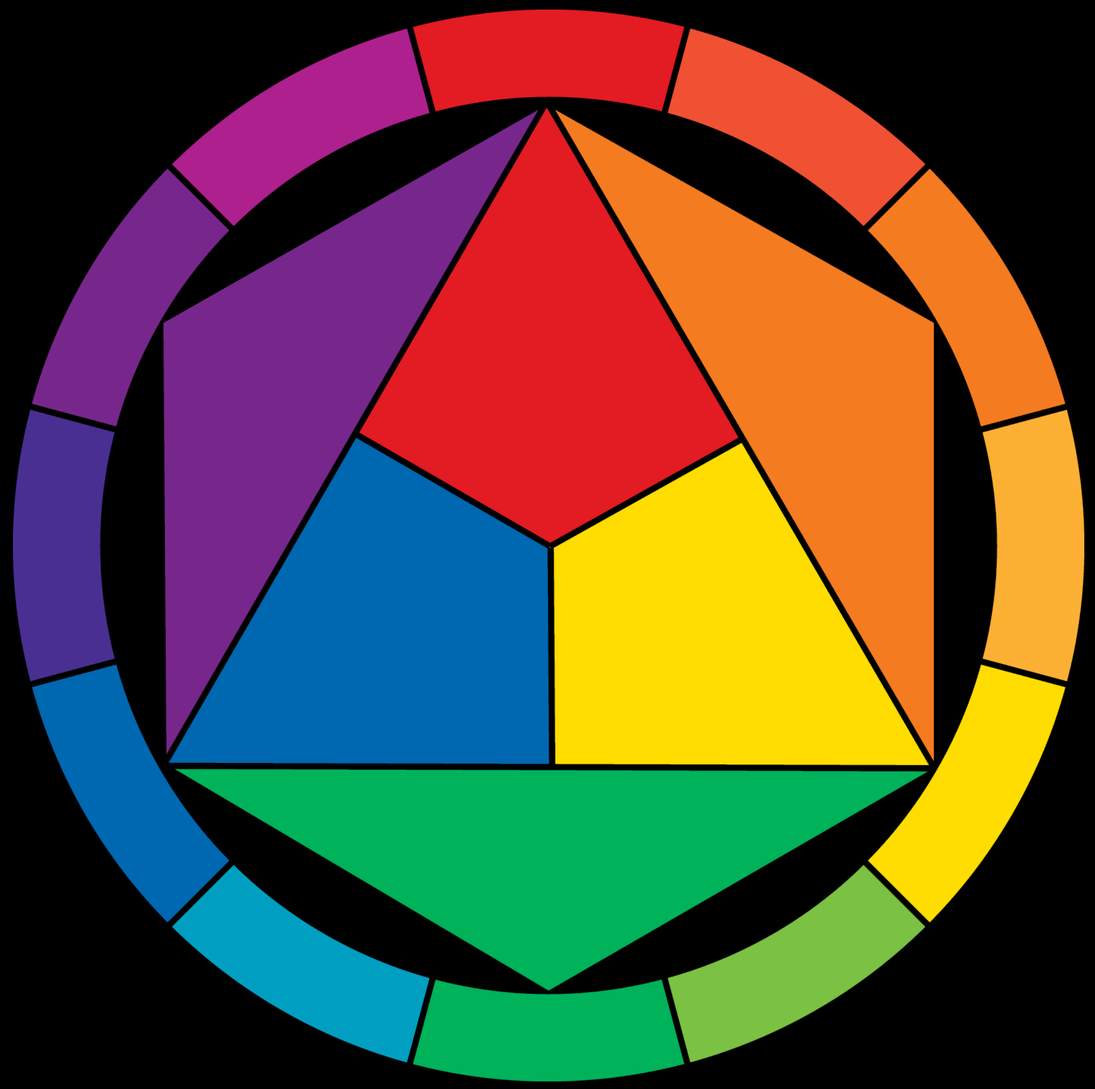


Color vision & psychology



Mixing pigments


R
B
Y



Artistic color wheel

You were probably taught this in kindergarten

In art, colors are designated by names

Primary

red

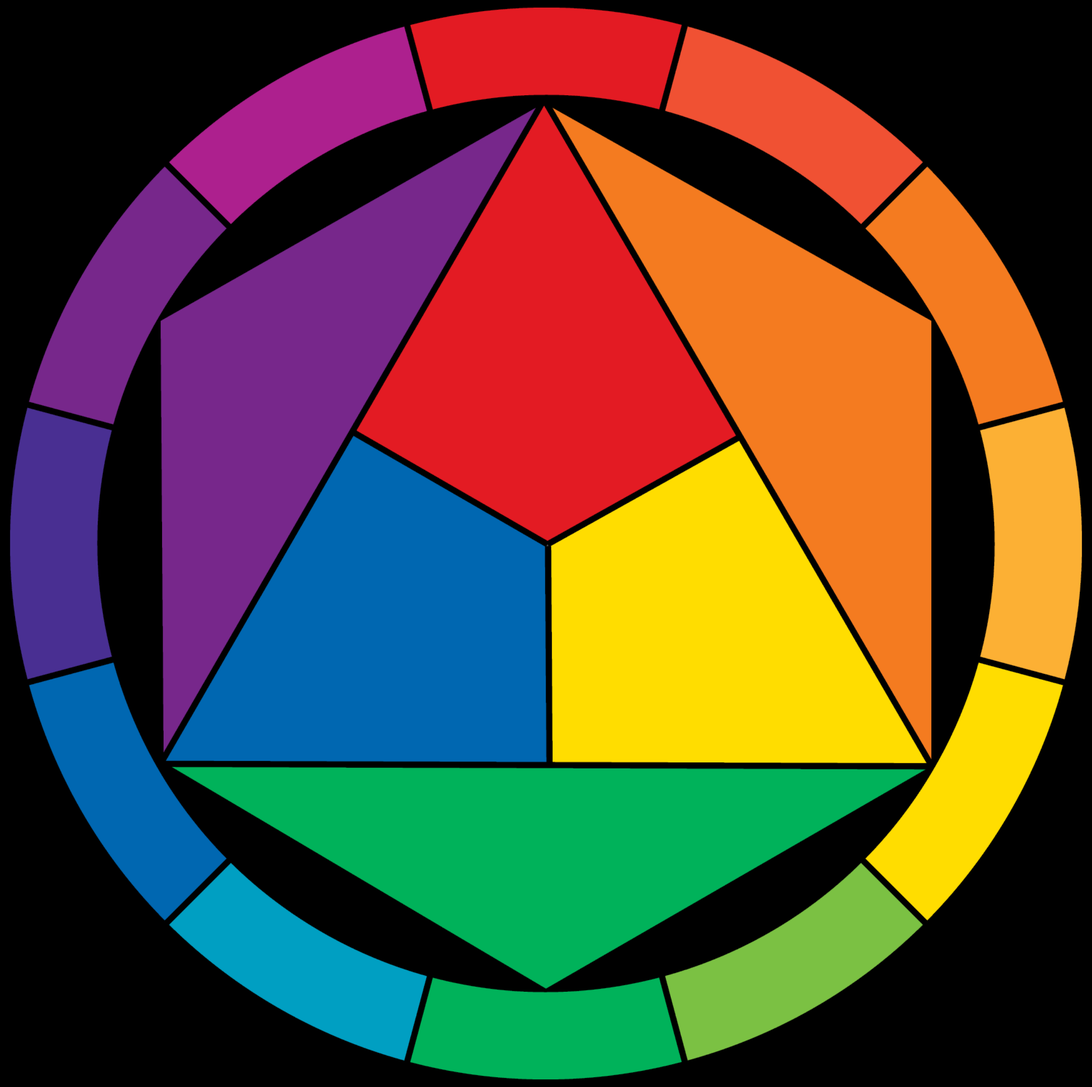
blue

yellow

Secondary

violet

orange

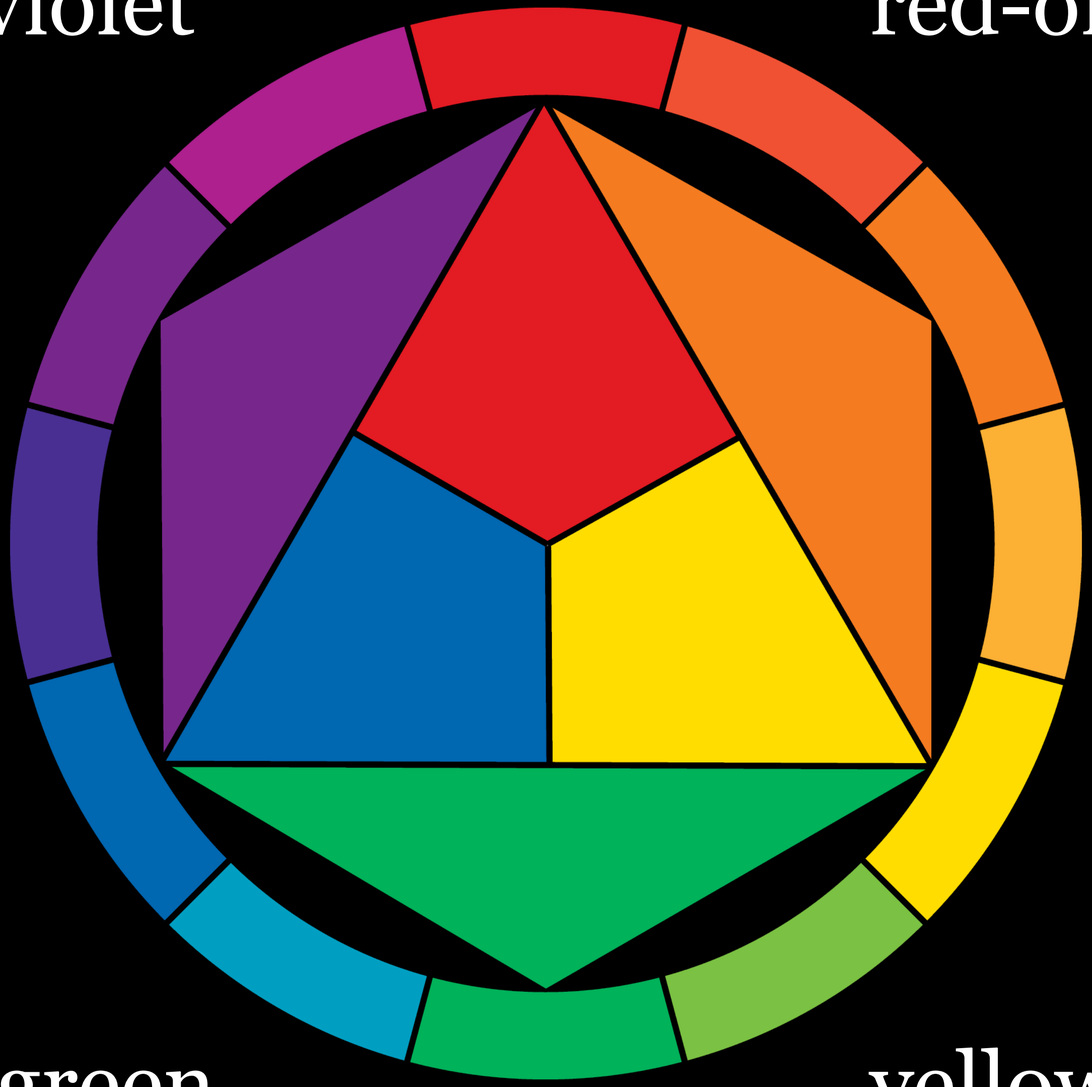


green

Tertiary

red-violet

red-orange



blue-violet

yellow-orange

blue-green

yellow-green

Functional color names came from pigments used to create them or analogous marketing terms

Alizarin Crimson
Antimony Vermilion
Antwerp Blue
Azurite
Barium Yellow
Bismuth White
Bremen Blue
Burnt Carmine
Burnt Sienna
Burnt Umber
Cadmium Orange
Cadmium Red
Cadmium Yellow
Carbon Black
Carmine
Celadon Green
Cerulean Blue
Cinnabar
Cobalt Blue
Cobalt Yellow
Cornflower Blue
Egyptian Green
Emerald Green
Indigo
Kibeni Orange
Lead White
Manganese Violet
Morin
Naples Yellow
Payne’s Grey
Prussian Blue
Realgar
Raw Sienna
Raw Umber
Red Ochre
Safflower
Saffron
Saxon Blue
Titanium White
Tyrian Purple
Ultramarine

Search the Color of Art Pigment Database

Google™ Custom Search Search

The Art is Creation,

Color of Art Pigment Database

An Artists Paint and Pigment Reference with Color Index Names, Color Index Numbers and Chemical Composition

To explore the Pigment Database, click the color menu above or If your in a hurry click here to go to the Quick Jump Chart Below

| For Important Info on the Pigment Database Click Here | For the Pigment Table Key Click Here or Scroll down |

If you are having problems with the new site design, please click here to be redirected to the old site.

Click here for the Free Art Books and eBooks page.

The Color of Art Pigment Database is a valuable reference for all artists working with color, and it is the the most complete pigment resource with color index names available for free. This collection of pigment information is an indispensable resource for all artists and art conservators interested in art restoration or making permanent works of art. Whether an artist uses oil paints, watercolor or acyclic, knowing the pigments and their properties is essential for all the visual arts from oil painting, watercolors or acrylics, to printing, and indeed, any craft or art that uses color. Artists interested in making paint in the studio should find this information useful too.

NOTE: The Pigment Database is a reference resource of pigment and paint information. I do not currently sell pigments or artist paints, but I have added some affiliate links in the pigment name column of the database that link to a pigment/paint manufacturer, or art supply, where more info can be found on the specific paint or pigment and the item purchased, sometimes at considerable discounts. Just click on the art material manufactures code next to the pigment name (for Key to the codes click here, or scroll to scroll down beneath the tables of any page). If your interested in rare, exclusive and out-of-production pigments, the following suppliers may be able to help (I have no relationship with them); Natural Pigments, Kama Pigment, Kremer Pigmente -(English site here), Sinopia Pigments, and Guerra Paint & Pigment. I hope that all oil painters as well as watercolor painters & acrylic painters and all the creative arts or crafts that use color, will find the pigment color charts useful.

Historic Orange Pigments without Color Index Names

Historic Orange Pigments Without C.I. Names | CI Natural Orange | CI Pigment Orange | Page Top^

Color Index Generic Name	CI Common or Historical Name	Common, Historic and Marketing Names	C.I. Constitution Number	Chemical Composition	Color Description † = Long Term Effects of Light	Opacity 1 = opaque 4 = trans.	Light Fastness I = excell. IV=Fugitive	Oil Absorption g/100g	☠	Side Notes
N/A	Antimony Orange	Antimony Orange; Antimony Vermilion; Golden Sulphur of Antimony; Golden Yellow; Goldschwefel; Lymphoscan; Pigment Red 107	77060	Antimony trisulphide; Sulfide of Antimony	Bright Orange	1	I	-	D	Decomposed by alkalis
N/A	Chamotte	Chamotte [KP.p]	N/A	Ground ceramic refractory brick; mostly clay, color probably from iron oxides	light red orange	-	I	-	A	used as an additive for lime mortars to increase the stability and add colour
N/A	IRGAZIN Orange 2037	IRGAZIN Orange	N/A	Diketo-pyrrolo-pyrrole/Isoindoline	Bright Orange	1	I	55	A	-
N/A	Kibeni Orange	IWA-Enogu® [KP.p]; Kibeni Orange; Vanadium-Chromite Spinel	N/A	Vanadium-Chromite Spinel; Cadmium glass powder	Mid Orange	-	I	-	-	-

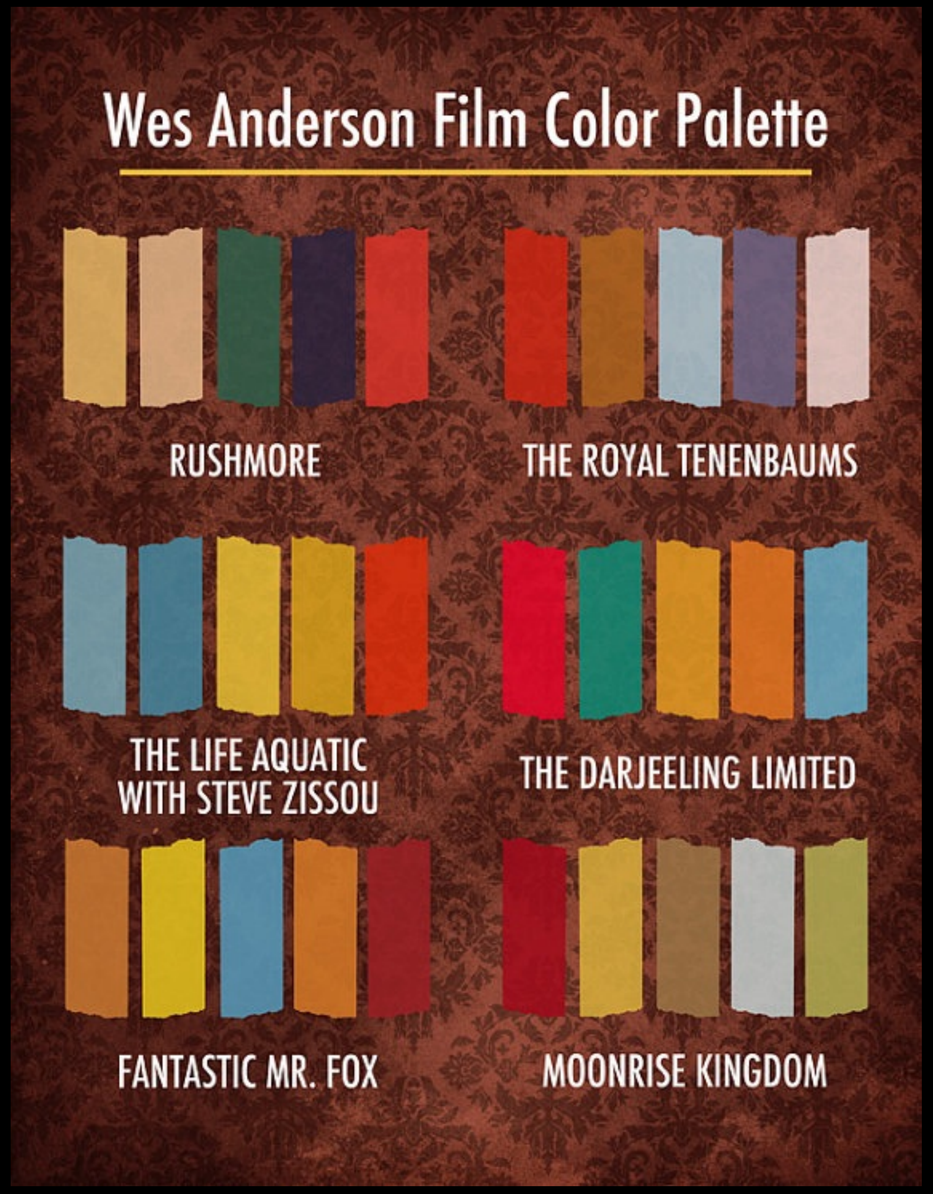
Historic Green Pigments and Mineral Pigments without Color Index Names

Color Index Generic Name	CI Common or Historical Name	Common, Historic and Marketing Names	C.I. Constitution Number	Chemical Composition	Color Description † = Long Term Effects of Light	Opacity 1 = opaque 4 = trans.	Light Fastness I = excell. IV=Fugitive	Oil Absorption g/100g	☠	Side Notes
N/A	Aegirine	Aegirine [KP.p] ; Acmite; PG23 Pigment Green 23; see Pigment Green 23	N/A	WebMineral.com (Ref at webmineral.com); Mindat.org (Ref at mindat.org); Wikipedia (Ref at wikipedia);; Chemical formula: $NaFeSi_2O_6$ "Aegirine is an iron containing silicate which forms elongated crystals. The particles are dark green and very hard." (Ref: Details from Kremer Pigments); A Sodium Silicate in which iron is present as Fe^{3+} (Ref: at wikipedia).	Dark green to greenish black, reddish brown, black	2-4*	I	-	B** MSDS	*transparency depends on source, crystal structure and impurities. **Inhalation danger
N/A Group^ Page^	Amazonite	Amazonite; Amazonite HAKUSUI-MATSU [KP.p]; Amazonite Genuine [DS.o.w]; Amazon Jade; Amazon stone	N/A	Green variety of microcline feldspar, a potassium aluminum silicate (Mineral Ref); Amazonite (Ref at Boston Fine Arts CAMEO Materials Database); Color thought to be from copper, iron or lead salts (Ref Mineral Zone), (Ref).	Light green to Blue green	-	I	-	A	-
N/A	Atacamite	Atacamit; Atacamite;	N/A	Copper oxychloride; Cupric oxychloride;	Pale green to bright deep green	-	-	-	B MSDS	-

Color Harmony

Schemes are basic arrangements for discussing harmonious & effective color combinations

Basically, design patterns for color



Created by Beth Mathews

#03ABEB	#1B346D	#F54C1A	#E6C49F	#C4CFD0


FIELD MATE

#85D5E4	#F4B6BD	#9D974A	#CDC18C	#FBD87C

6 classic color schemes

- Monochromatic
- Analogous
- Complementary
- Split Complementary
- Triadic
- Tetradic

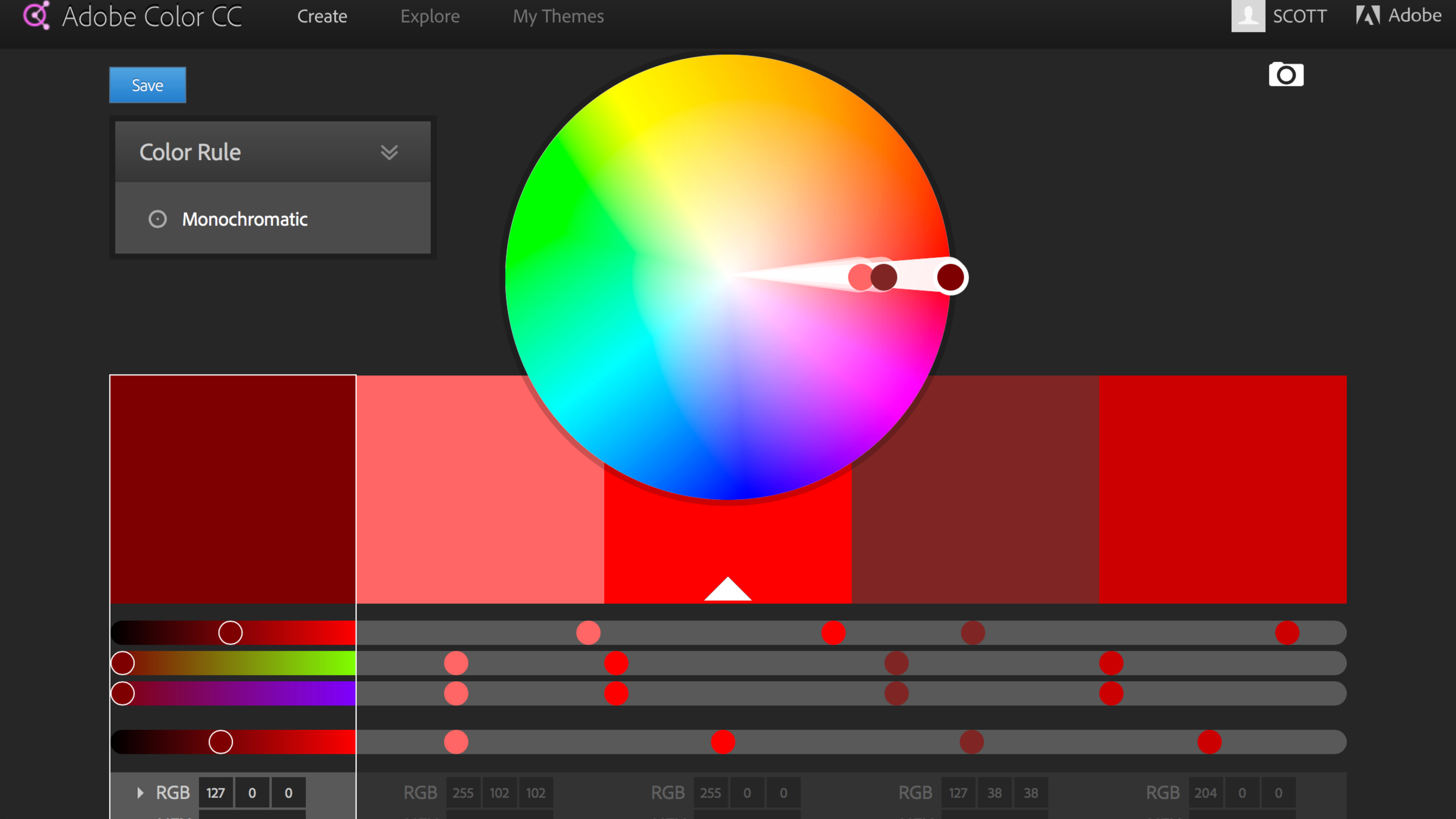
Take with a few grains of salt

Monochromatic

Single base color + any number of tints & shades

Good for moods

Sometimes hard to highlight the most important elements


Adobe Color CC
Create
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Monochromatic
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RGB 255 102 102
RGB 255 0 0
RGB 127 38 38
RGB 204 0 0

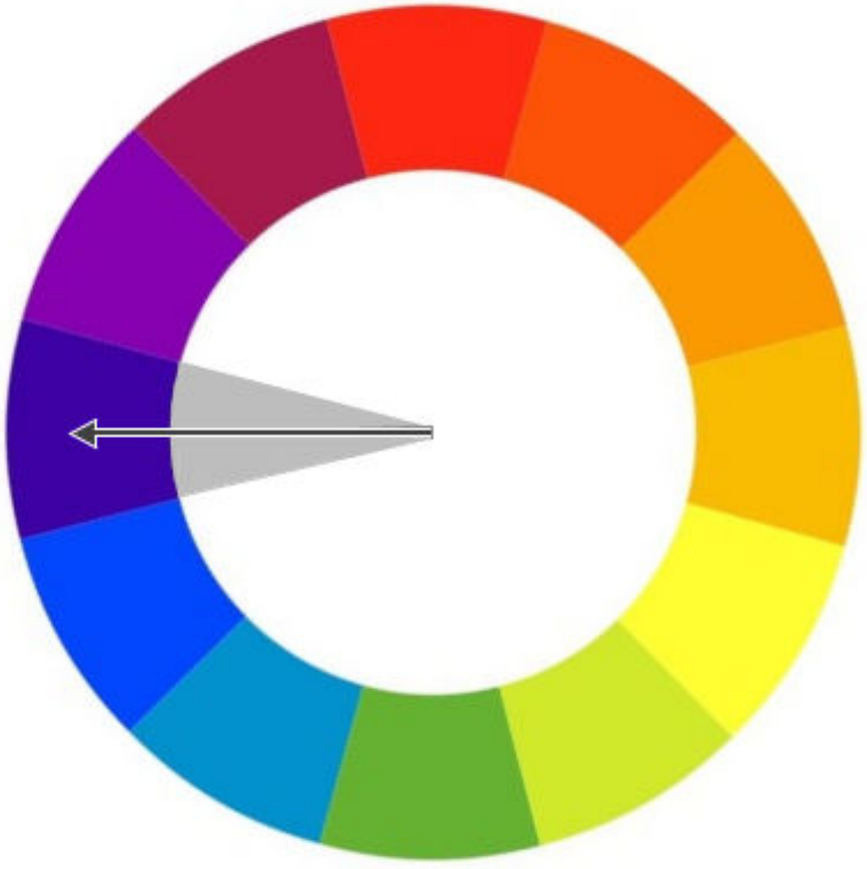

EMPYREAN ISLES
HERBIE HANCOCK
FREDDIE HUBBARD
RON CARTER
ANTHONY WILLIAMS
THE FINEST IN JAZZ SINCE 1939
4175 BLUE NOTE

1964


SOUL STATION HANK MOBLEY
WITH ART BLAKEY
WYNTON KELLY, PAUL CHAMBERS
THE FINEST IN JAZZ SINCE 1939
84031 BLUE NOTE

1960

1971

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Status
Photo
Check In
Monica Horak with Ari Grant and 3 others
Yesterday in Menlo Park, CA
Good friends, good food and a lot of laughs.
10 Likes 3 Comments
Like
Comment
Share
News Feed
Requests
Messenger
Notifications
More

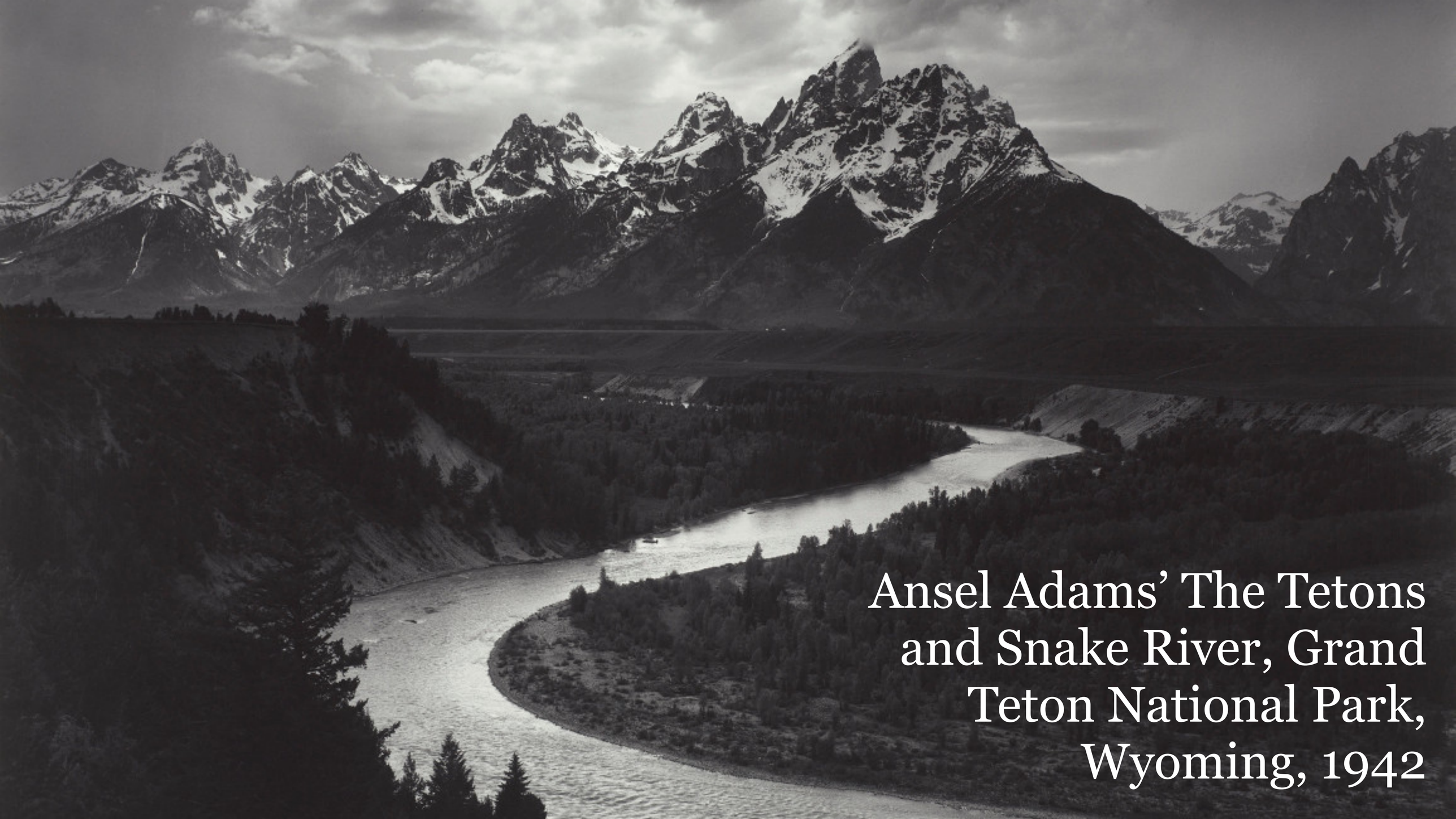
Achromatic

“Without color”

A set of colors consisting solely of black, white, & shades of gray

Bill Evans & Jim Hall's
Undercurrent

1962



Ansel Adams' The Tetons and Snake River, Grand Teton National Park, Wyoming, 1942

Diane Arbus' Identical Twins, Roselle, New Jersey, 1967

Episcopal Charities

Episcopal Charities brings to a broken world the hope for lasting change.

- Hope rooted in Episcopal vision, faith, and experience.
- Hope expressed through collective community efforts.

Investing

in organizations.

This is test content...

This is more test content...

Connecting

communities.

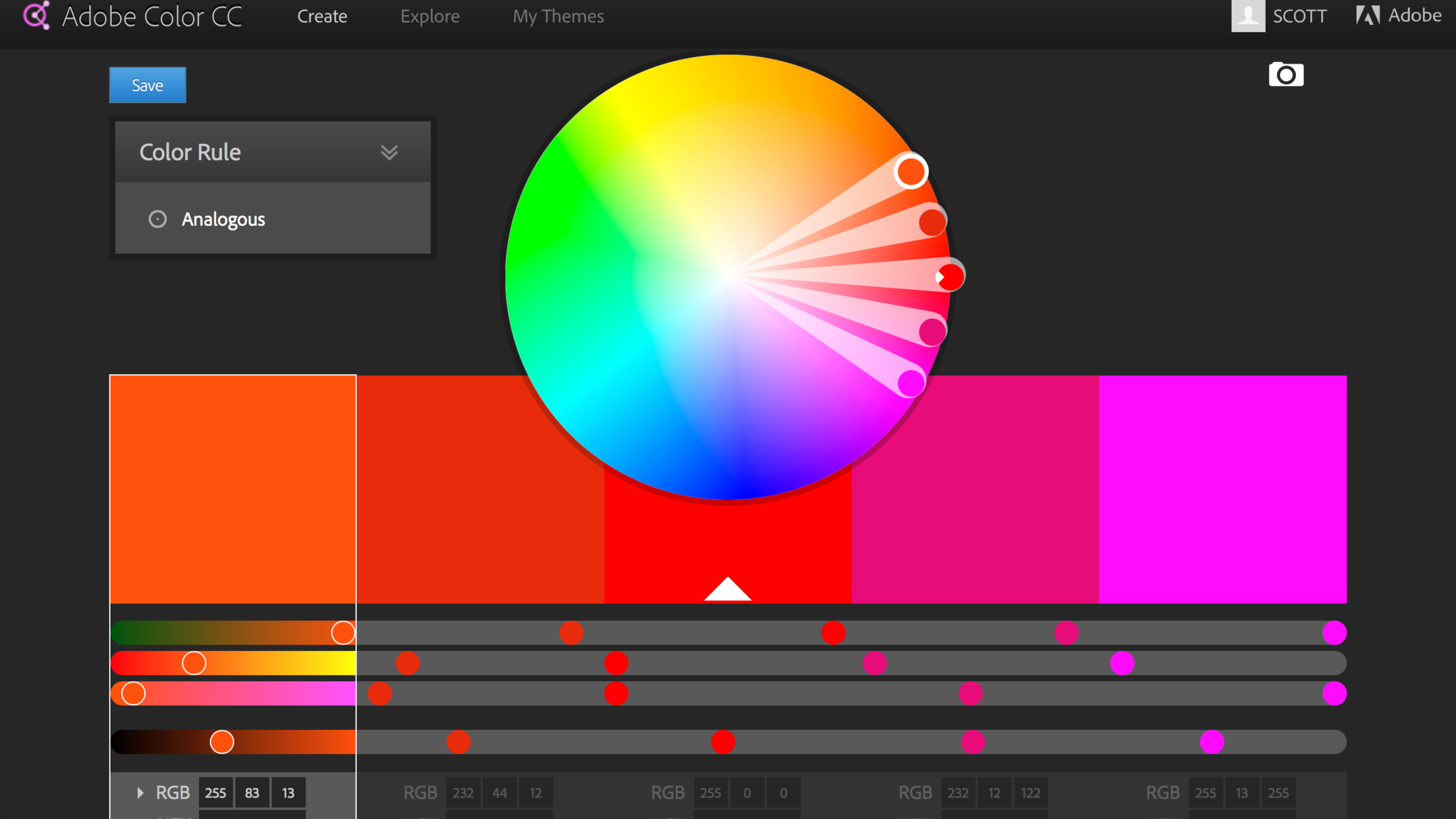
Creating

lasting change.

Analogous

Colors adjacent to one another on the color wheel

1 is dominant & others enrich it


Adobe Color CC
Create
Explore
My Themes
SCOTT
Adobe
Save
Color Rule
Analogous
RGB 255 83 13
RGB 232 44 12
RGB 255 0 0
RGB 232 12 122
RGB 255 13 255

john coltrane

BLUE TRAIN

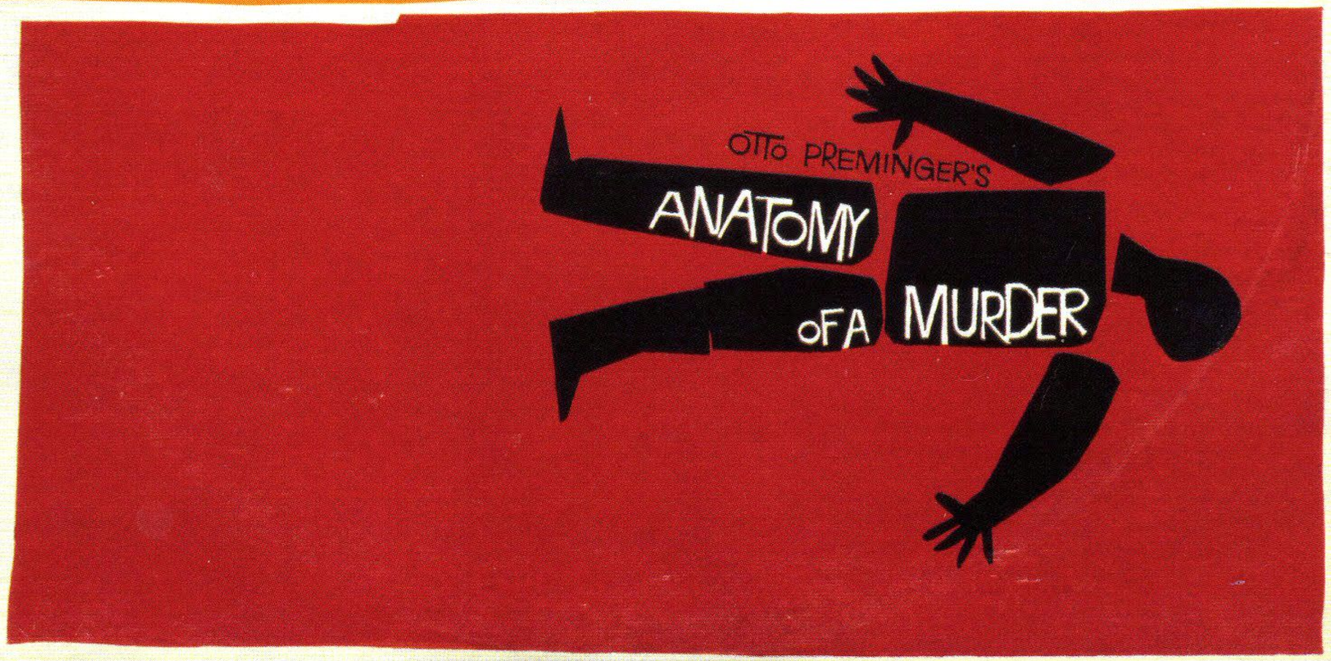
blue note 1577

1958

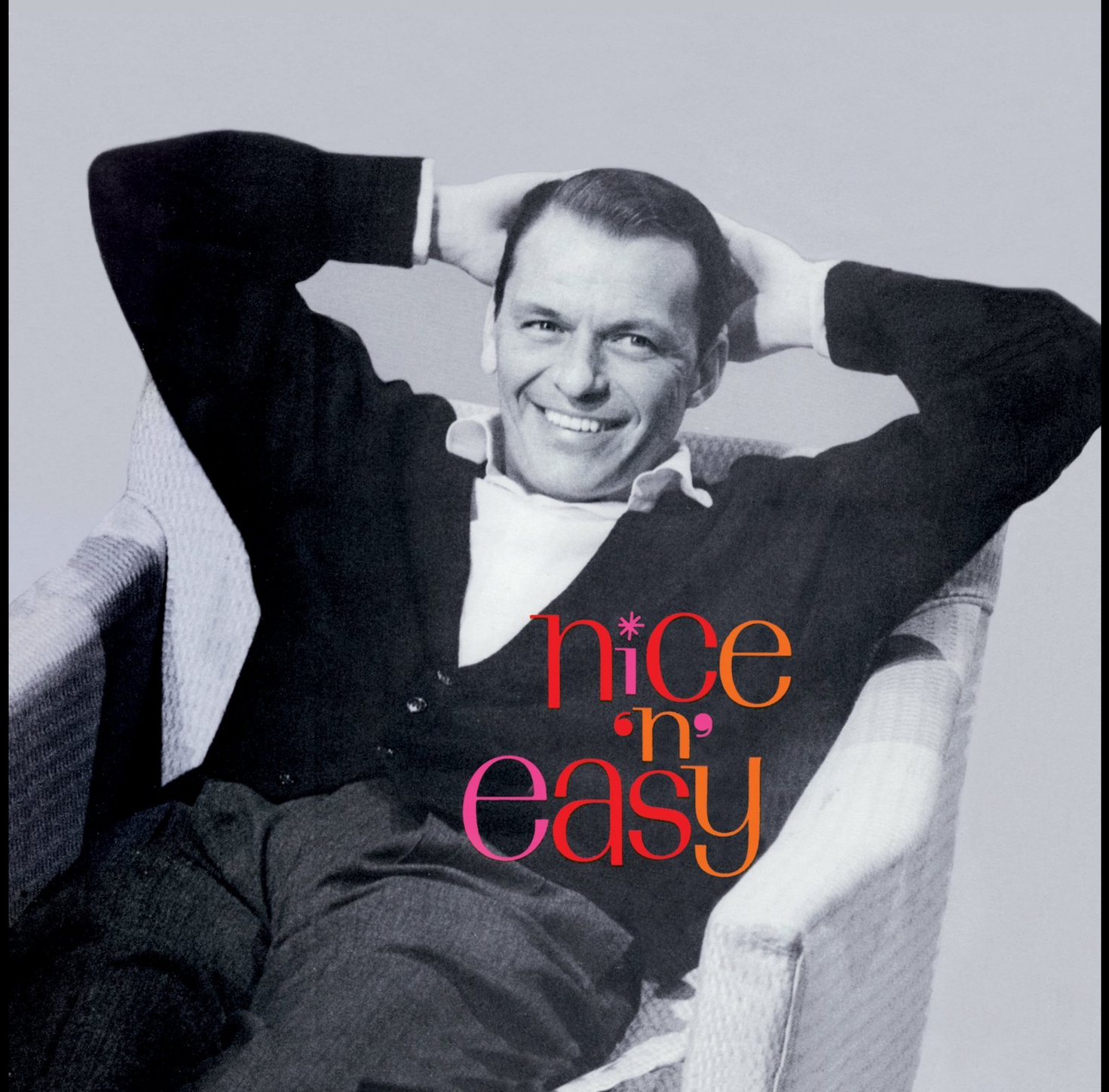
STEREO FIDELITY

COLUMBIA
GUARANTEED HIGH FIDELITY
LP

MUSIC BY DUKE ELLINGTON · FROM THE SOUND TRACK OF THE MOTION PICTURE



1959



Frank Sinatra

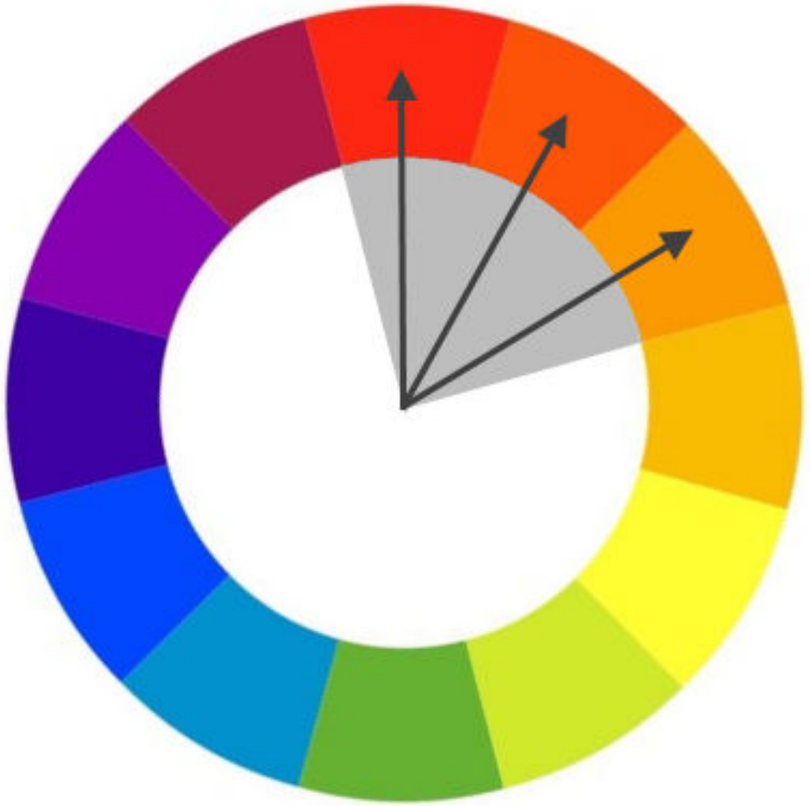
1960

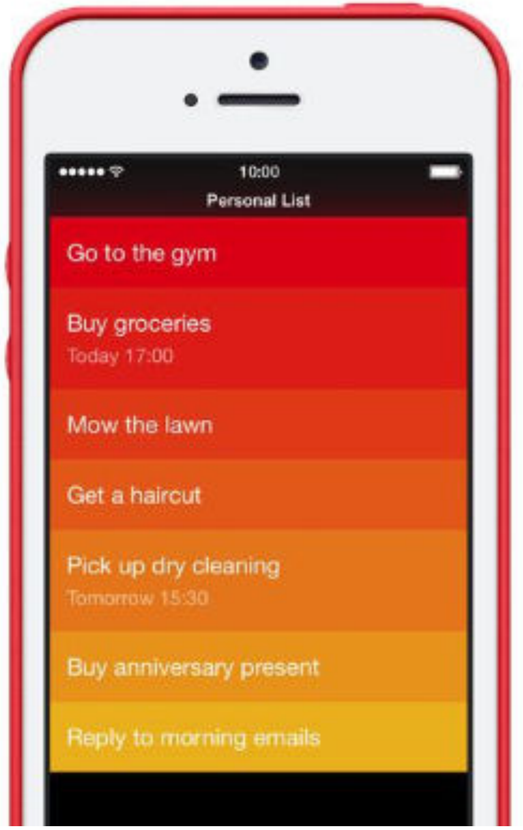
1961


STEREO
Frank Sinatra
September of my years
ARRANGED AND CONDUCTED BY GORDON JENKINS
DON'T WAIT TOO LONG / LAST NIGHT WHEN WE WERE YOUNG / SEPTEMBER SONG / ONCE UPON A TIME / HELLO, YOUNG LOVERS / I SEE IT NOW WHEN THE WIND WAS GREEN / HOW OLD AM I? / THIS IS ALL I ASK / IT WAS A VERY GOOD YEAR / IT GETS LONELY EARLY / THE MAN IN THE LOOKING GLASS
reprise RECORDS
73799

1965

Vincent van Gogh’s Still Life: Vase with Irises, 1890




10:00
Personal List
Go to the gym
Buy groceries
Today 17:00
Mow the lawn
Get a haircut
Pick up dry cleaning
Tomorrow 15:30
Buy anniversary present
Reply to morning emails


Calm

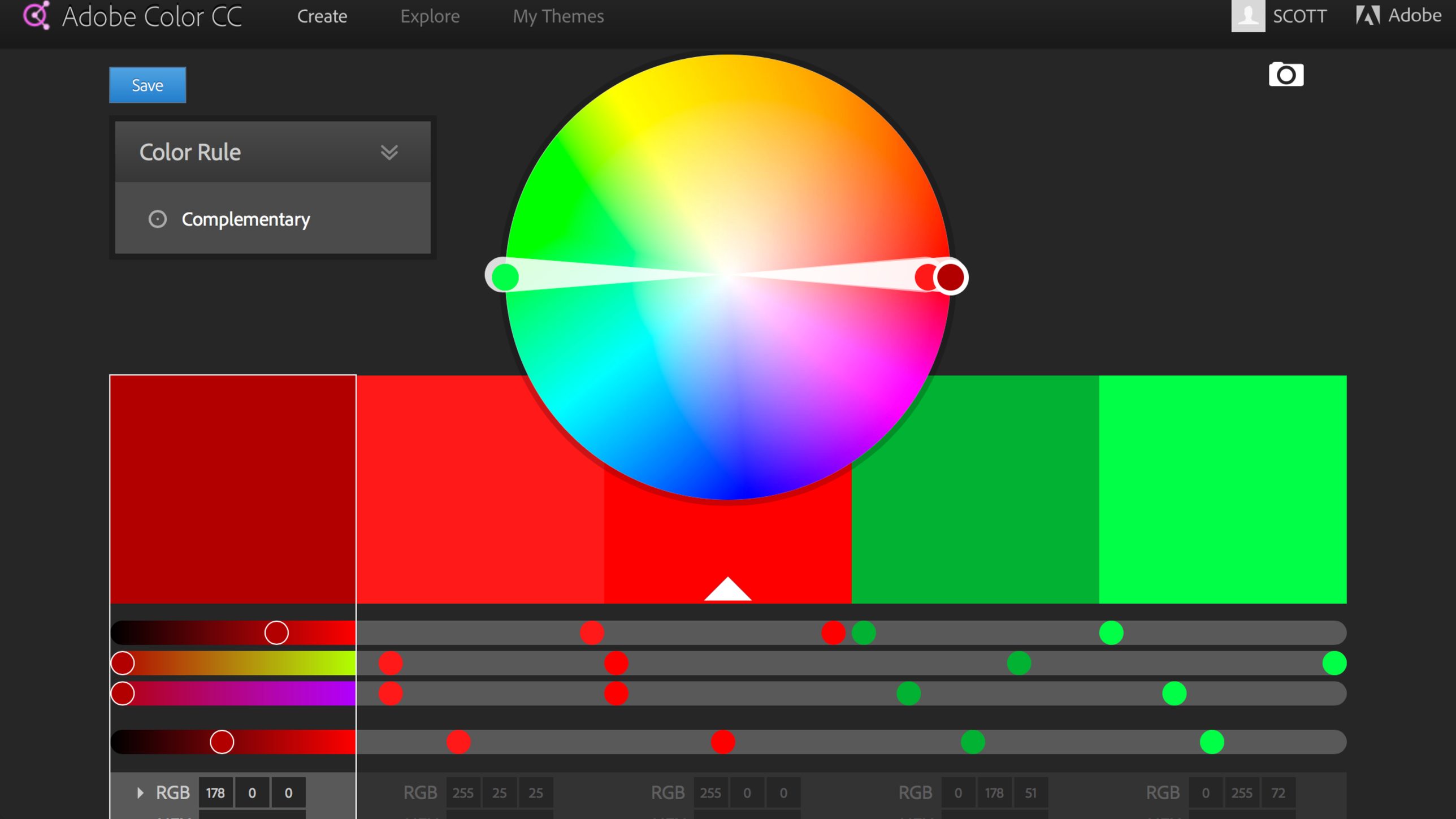
Complementary

Colors located opposite each other on the color wheel

Be careful & avoid *simultaneous contrast* when each color makes the other appear more vibrant & dominant

Make 1 color dominant & use other for accents

Best to use warm & cool


Adobe Color CC
Create
Explore
My Themes
SCOTT
Adobe
Save
Color Rule
Complementary
RGB 178 0 0
RGB 255 25 25
RGB 255 0 0
RGB 0 178 51
RGB 0 255 72

Lionel Hampton &
Stan Getz

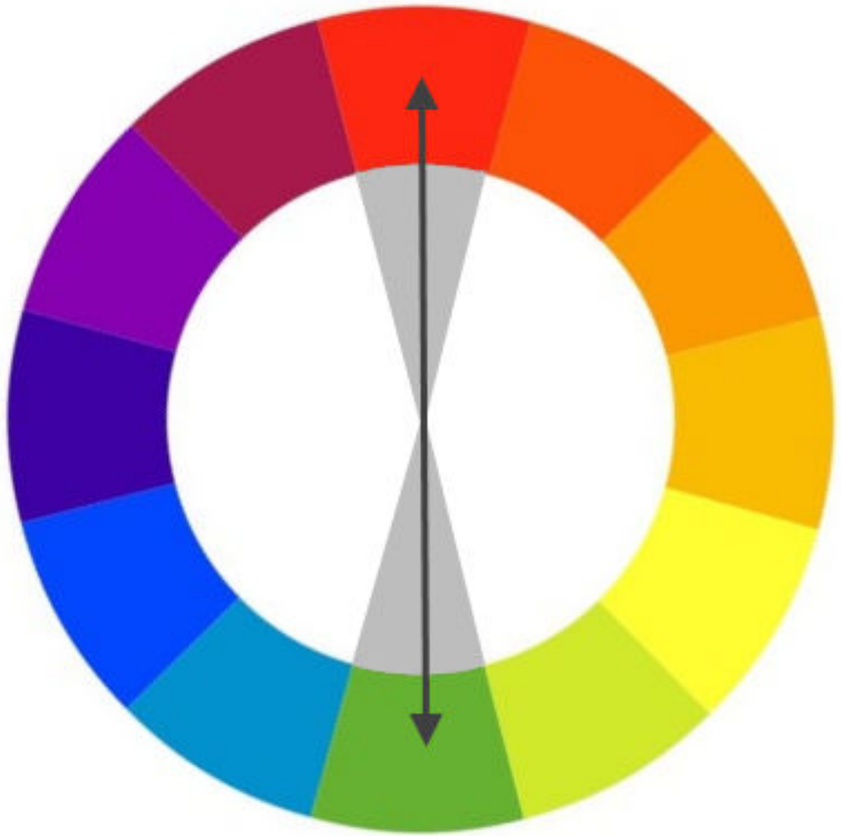
1955


out of the BLUE
THE FINEST IN JAZZ SINCE 1939
4032 BLUE NOTE
sonny RED
with Wynton Kelly, Sam Jones, Paul Chambers, Roy Brooks, Jimmy Cobb

1960

Pablo Picasso's *The Old Guitarist*, 1903–04

Georgia O’Keeffe’s *Heliconia, Crab’s Claw Ginger*, 1939

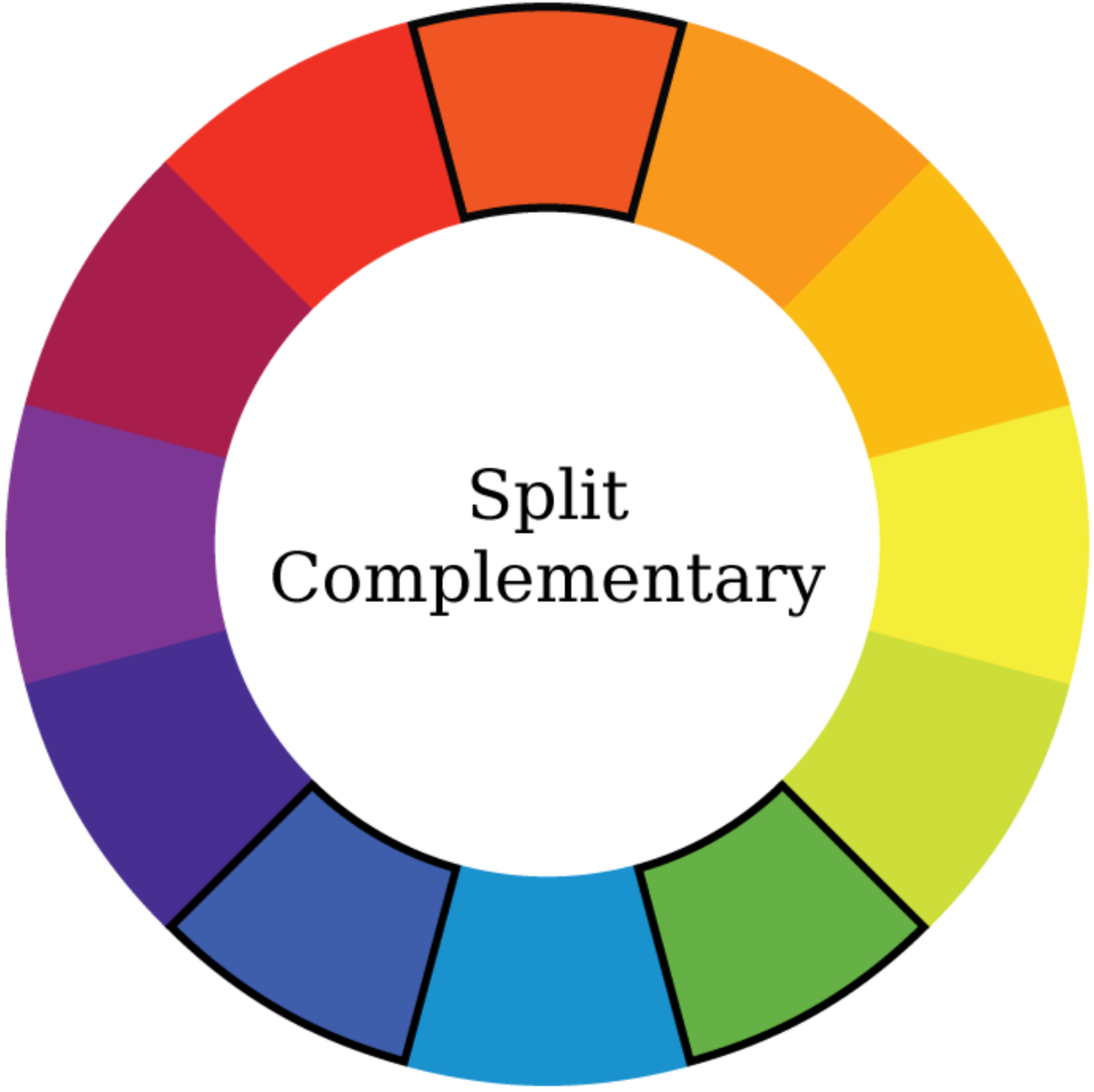



99

Split Complementary

Color + 2 colors adjacent to its complementary

High contrast without strong tension


Split
Complementary


ELLA SINGS GERSHWIN
THE BEST OF THE GEORGE AND IRA GERSHWIN SONGBOOK


ELLA SINGS ARLEN
THE BEST OF THE HAROLD ARLEN SONGBOOK


ELLA SINGS KERN
THE BEST OF THE JEROME KERN SONGBOOK


ELLA SINGS MERCER
THE BEST OF THE JOHNNY MERCER SONGBOOK

2013

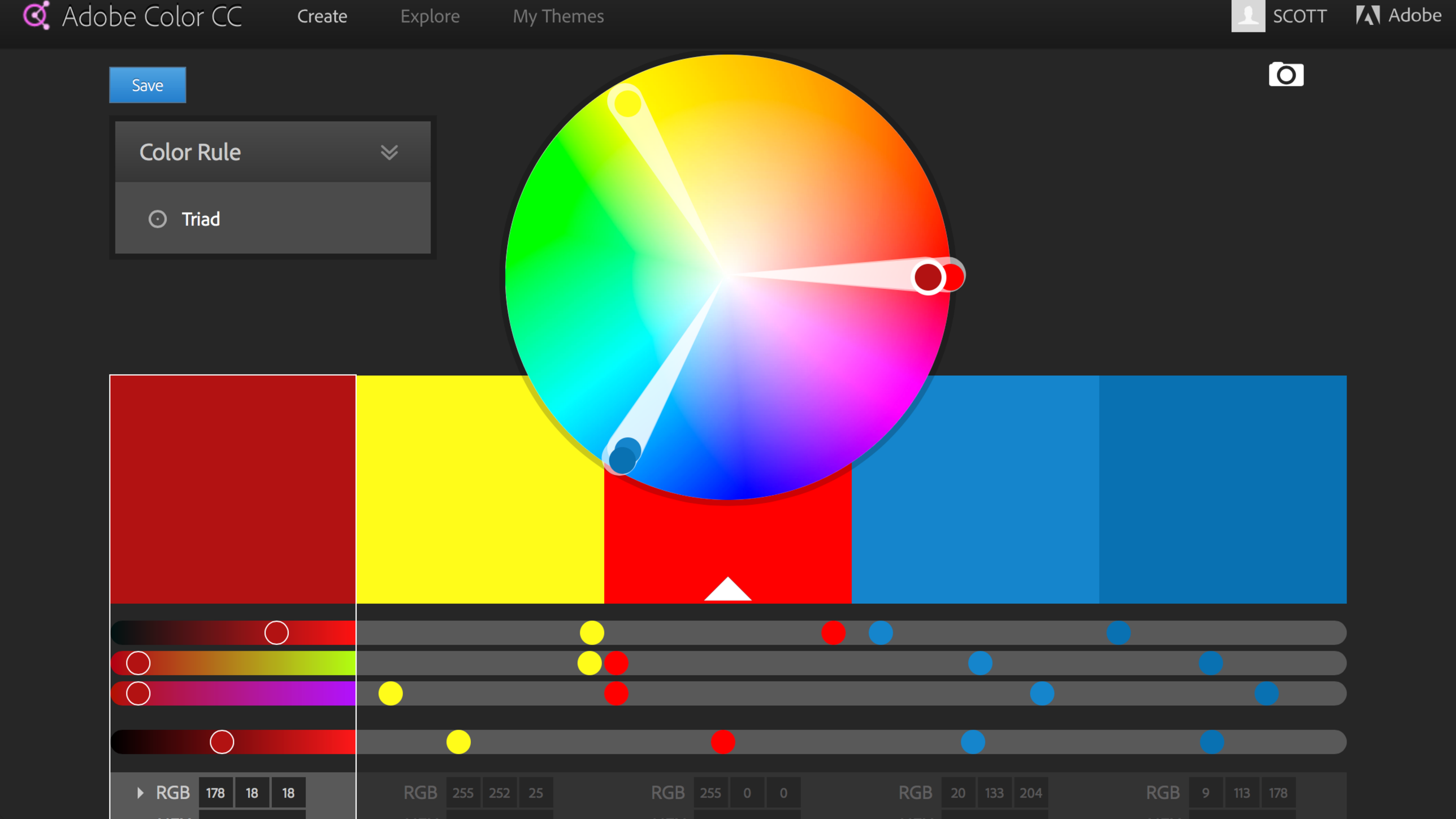
Claude Monet’s Regattas at Argenteuil, c. 1872


Claude Monet

Triadic

3 colors equally spaced around the color wheel

Strong contrast while retaining balance & harmony


Adobe Color CC
Create
Explore
My Themes
SCOTT
Adobe
Save
Color Rule
Triad
RGB 178 18 18
RGB 255 252 25
RGB 255 0 0
RGB 20 133 204
RGB 9 113 178


FRIDAY NIGHT
MILES DAVIS
IN PERSON
AT THE BLACKHAWK,
SAN FRANCISCO
VOLUME I
fontana

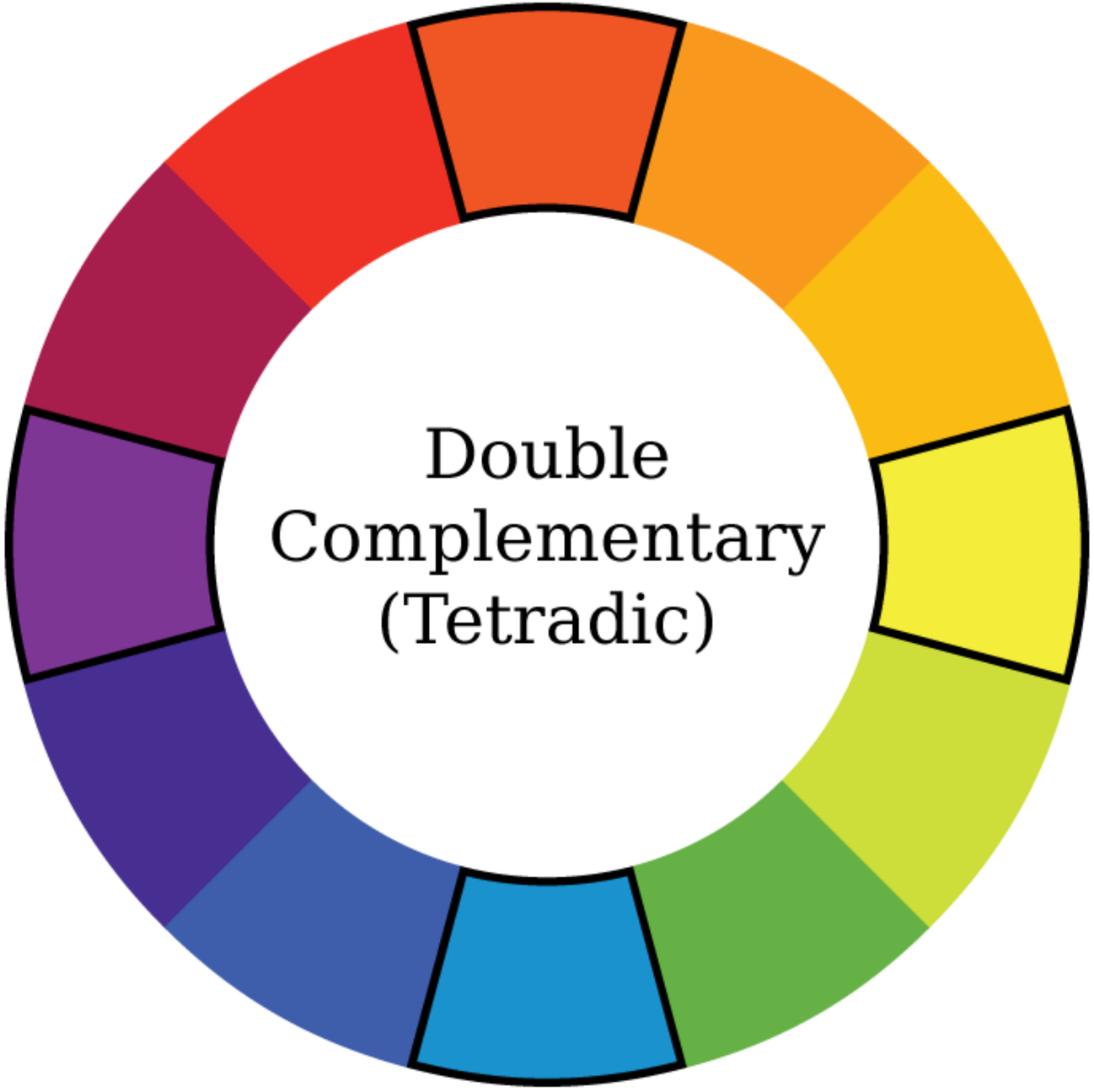
1961

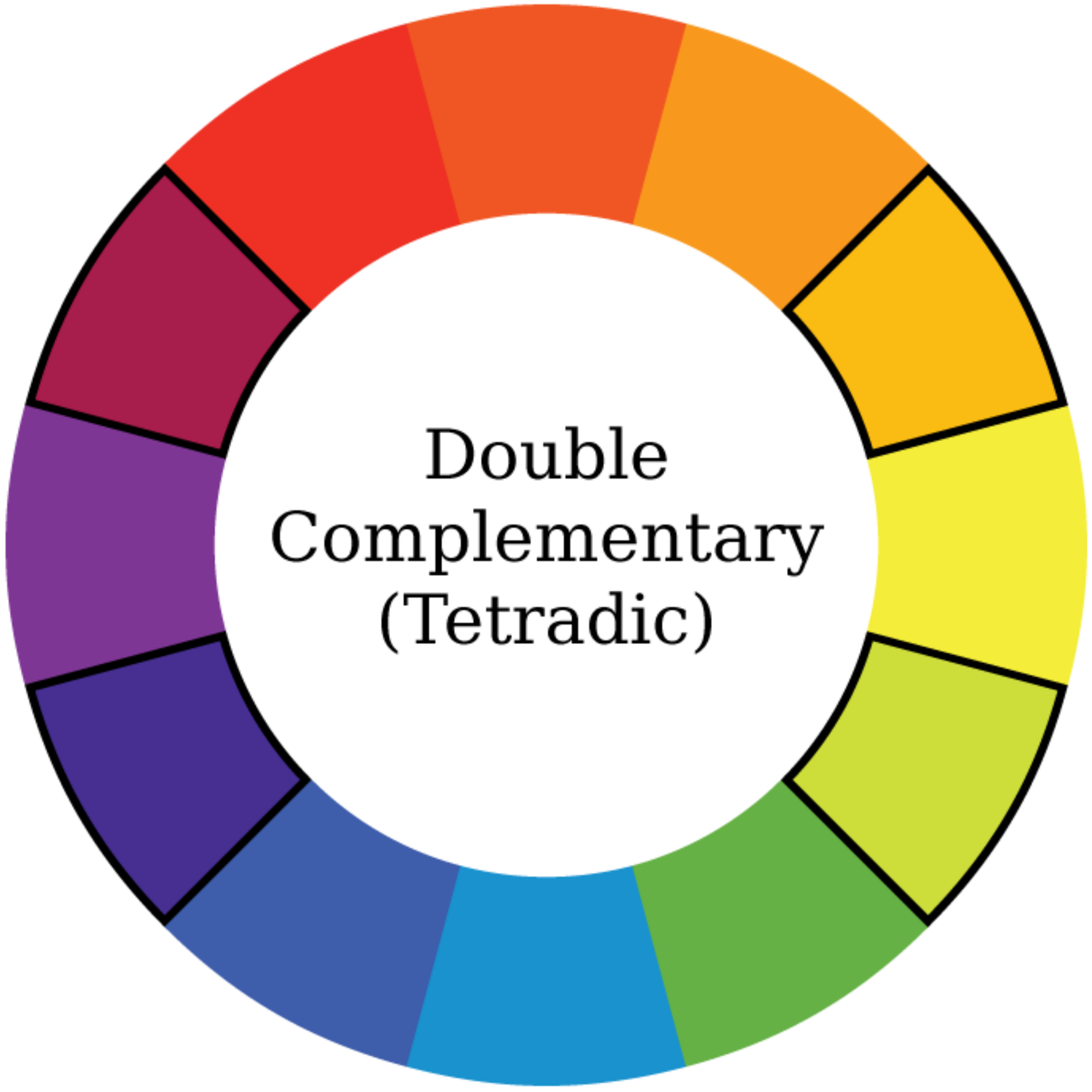
Tetradic

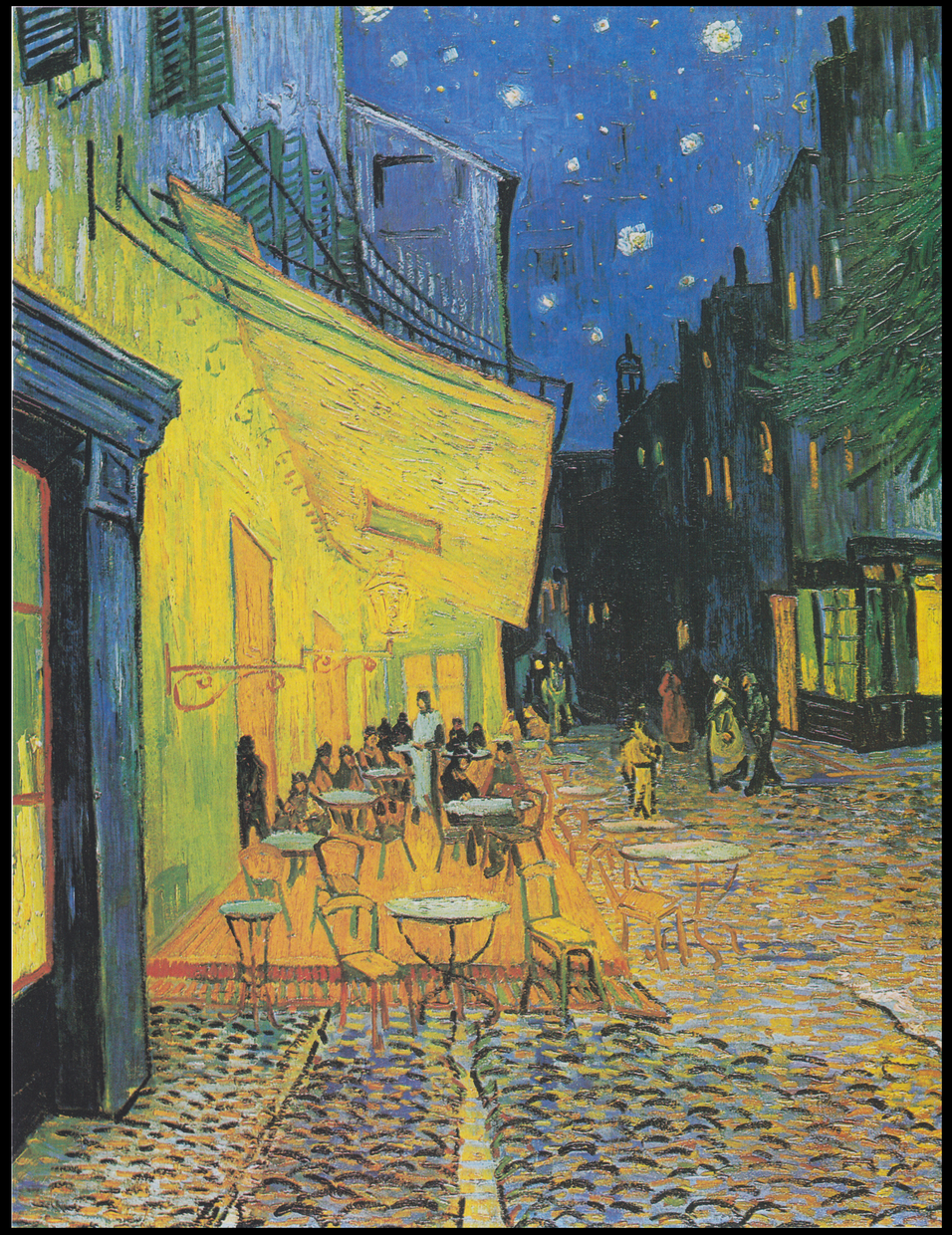
AKA *Double Complementary*

4 colors arranged into 2 complementary color pairs

Richest of all schemes but choose 1 color to be dominant or it may look unbalanced


Double
Complementary
(Tetradic)

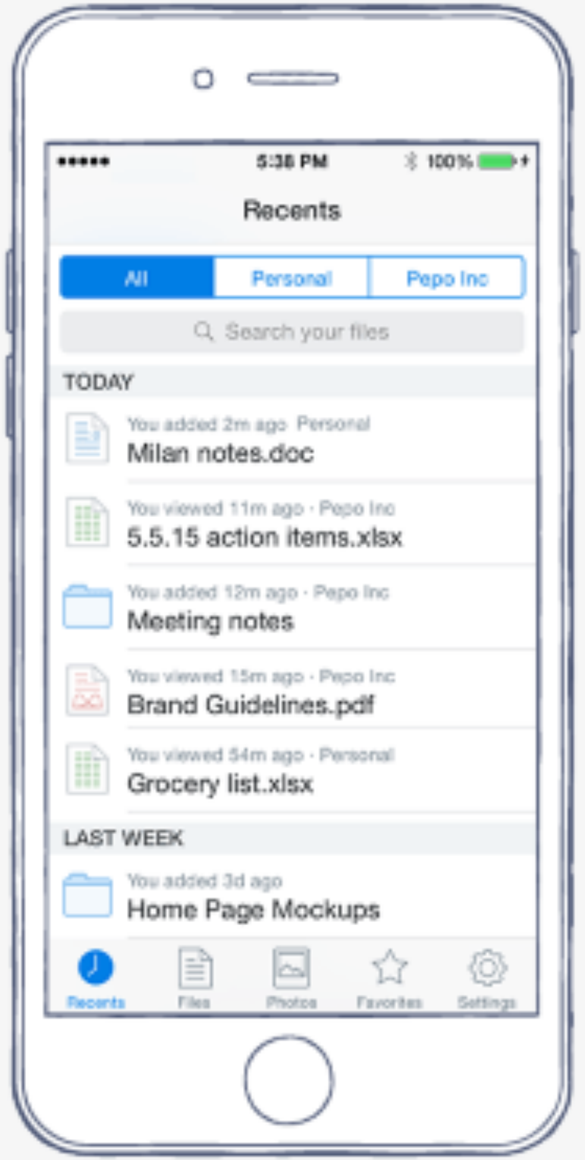

Double
Complementary
(Tetradic)



Vincent van Gogh's
Terrace of the café on the Place du Forum in Arles in the evening, 1888

Custom

A simple trick to create a nice custom color palette: add a bright accent color into an otherwise neutral palette


5:38 PM
100%
Recents
All
Personal
Pepo Inc
Search your files
TODAY
You added 2m ago Personal
Milan notes.doc
You viewed 11m ago · Pepo Inc
5.5.15 action items.xlsx
You added 12m ago · Pepo Inc
Meeting notes
You viewed 15m ago · Pepo Inc
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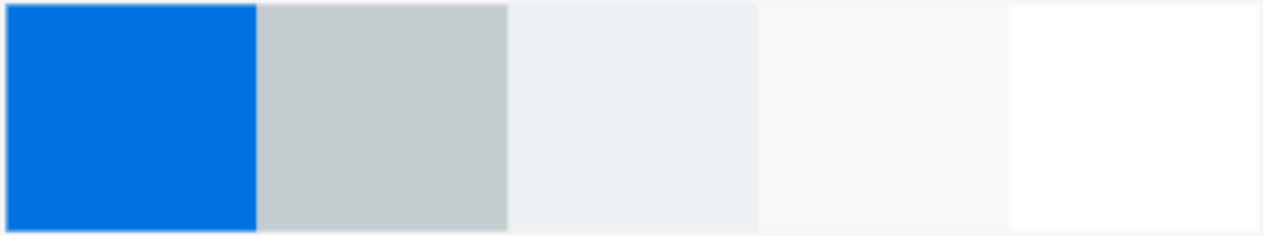
Recents
Files
Photos
Favorites
Settings



Most Used

sandy stone beach o... 9K+ 9K+ 339

Firenze 9K+ 9K+ 186

Neutral Blue 9K+ 9K+ 54

Johnny Cash Tribute 9K+ 957 242

Cherry Cheesecake 9K+ 5K+ 107

Japanese Garden 9K+ 3K+ 80

1944mustang 9K+ 5K+ 49

Watermelon 9K+ 5K+ 151

Granny Smith Apple 9K+ 3K+ 91

Aspirin C 9K+ 6K+ 29

Phaedra 9K+ 7K+ 18

Flat UI 9K+ 5K+ 17

Most Popular

sandy stone beach o... 9K+ 9K+ 339

Firenze 9K+ 9K+ 186

Neutral Blue 9K+ 9K+ 54

Phaedra 9K+ 7K+ 18

Honey Pot 9K+ 6K+ 50

Aspirin C 9K+ 6K+ 29

1944mustang 9K+ 5K+ 49

Sea Wolf 8K+ 5K+ 41

Vitamin C 9K+ 5K+ 40

Flat UI 9K+ 5K+ 17

Cherry Cheesecake 9K+ 5K+ 107

Watermelon 9K+ 5K+ 151


But...

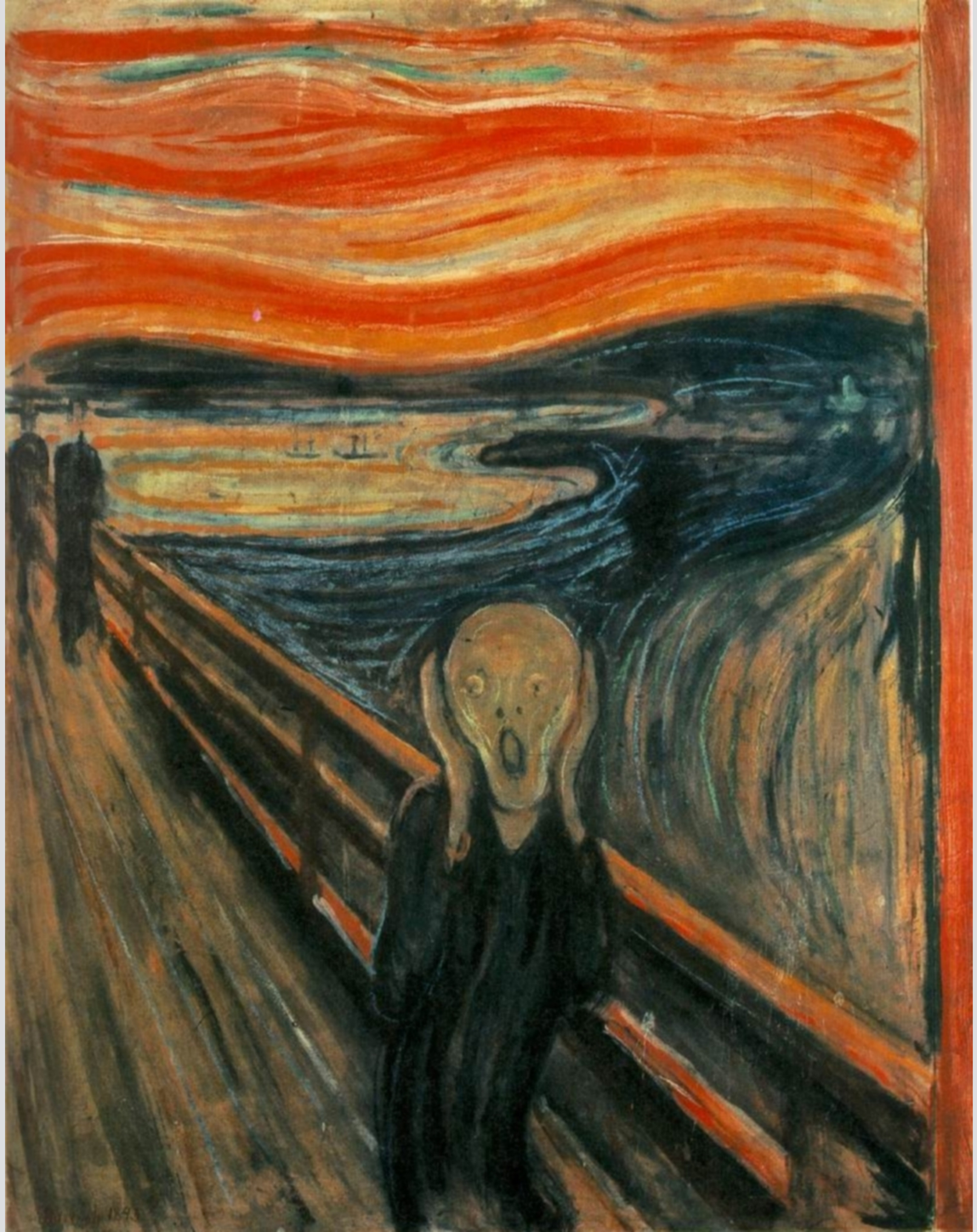
Schemes by themselves are not harmonious

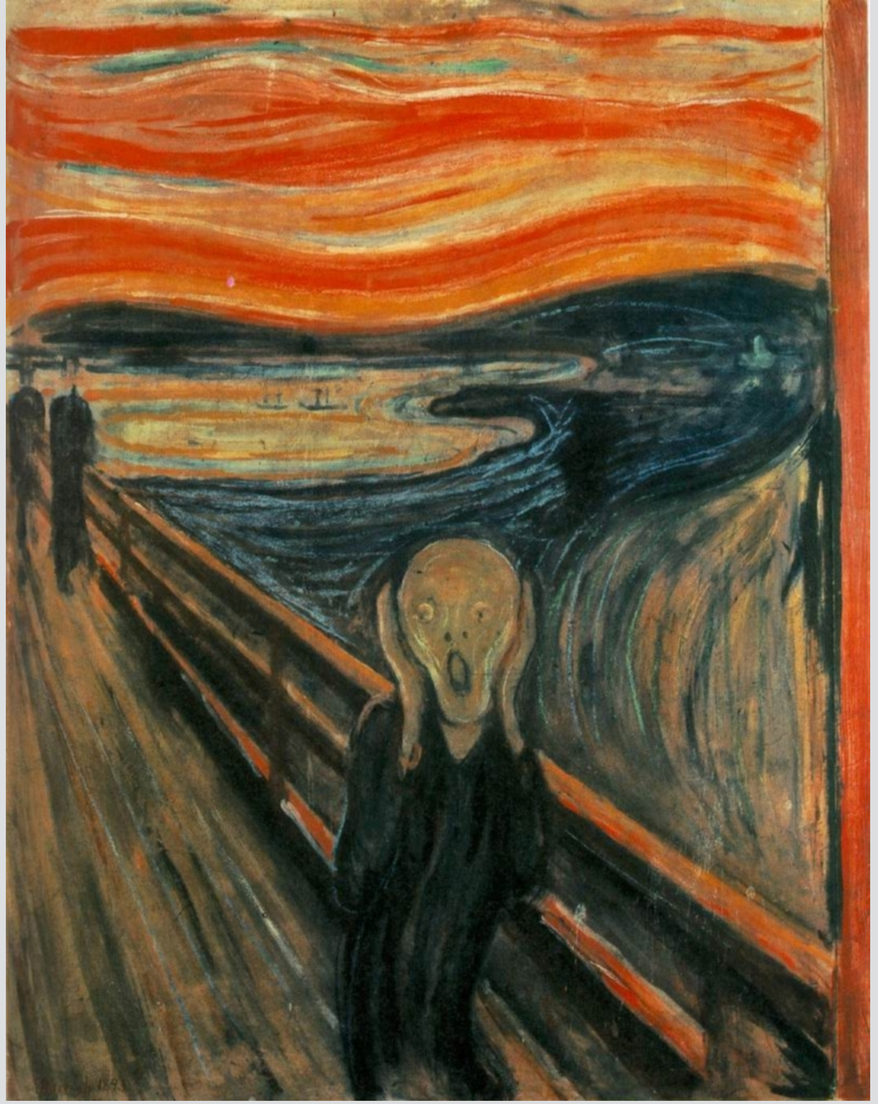
Harmony is dependent upon composition & context

#263C8B	#4E74A6	#BDBF78	#BFA524	#2E231F

#514264	#527E8E	#8D80A7	#989A55	#255C3F

#593202	#47421D	#346C36	#A1700F	#F2C641





#4D7186	#284253	#E0542E	#F4A720	#EF8C12

Modern Color Reproduction

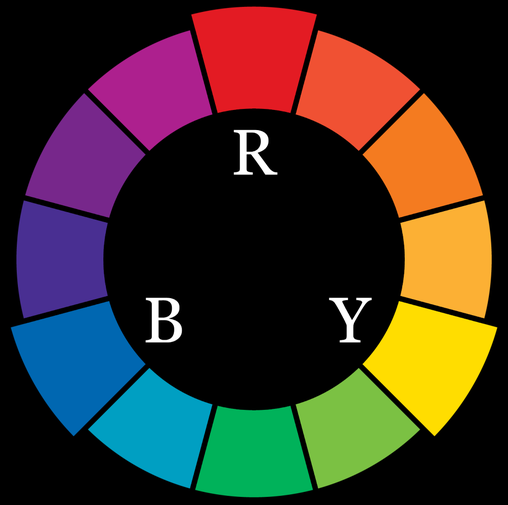
Color model

A mathematical model for representing colors as groups of numbers, typically as three or four values, each representing a color component

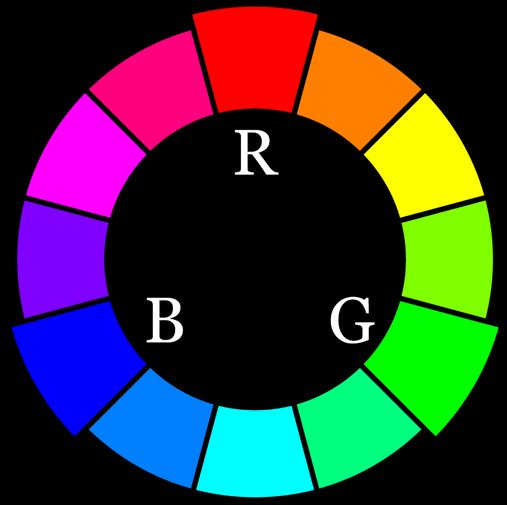
Used with RGB & CMY only

Descriptor	Value
Keywords	`magenta`
RGB 6-character hexadecimal	`#FF0033`
RGB 3-character hexadecimal	`#F03`
RGB functional notation (integer)	`rgb(255,0,51)`
RGB functional notation (%)	`rgb(100%,0%,20%)`
Red, Green, Blue, Alpha	`rgba(255,0,51,0.7)`
Hue, Saturation, Lightness	`hsl(348,100%,50%)`
Hue, Saturation,Lightness, Alpha	`hsla(348,100%,50%,0.7)`

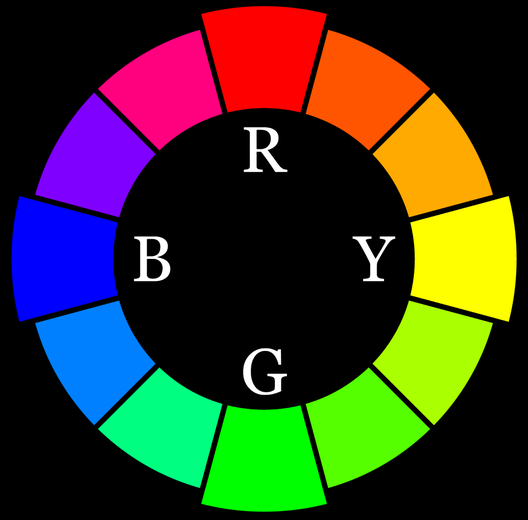
RGB



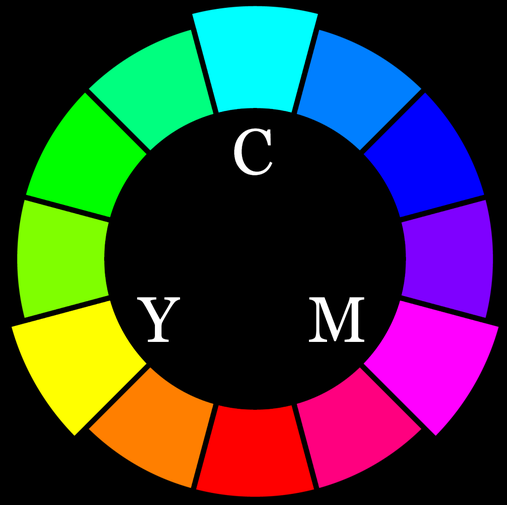
Artistic discussion



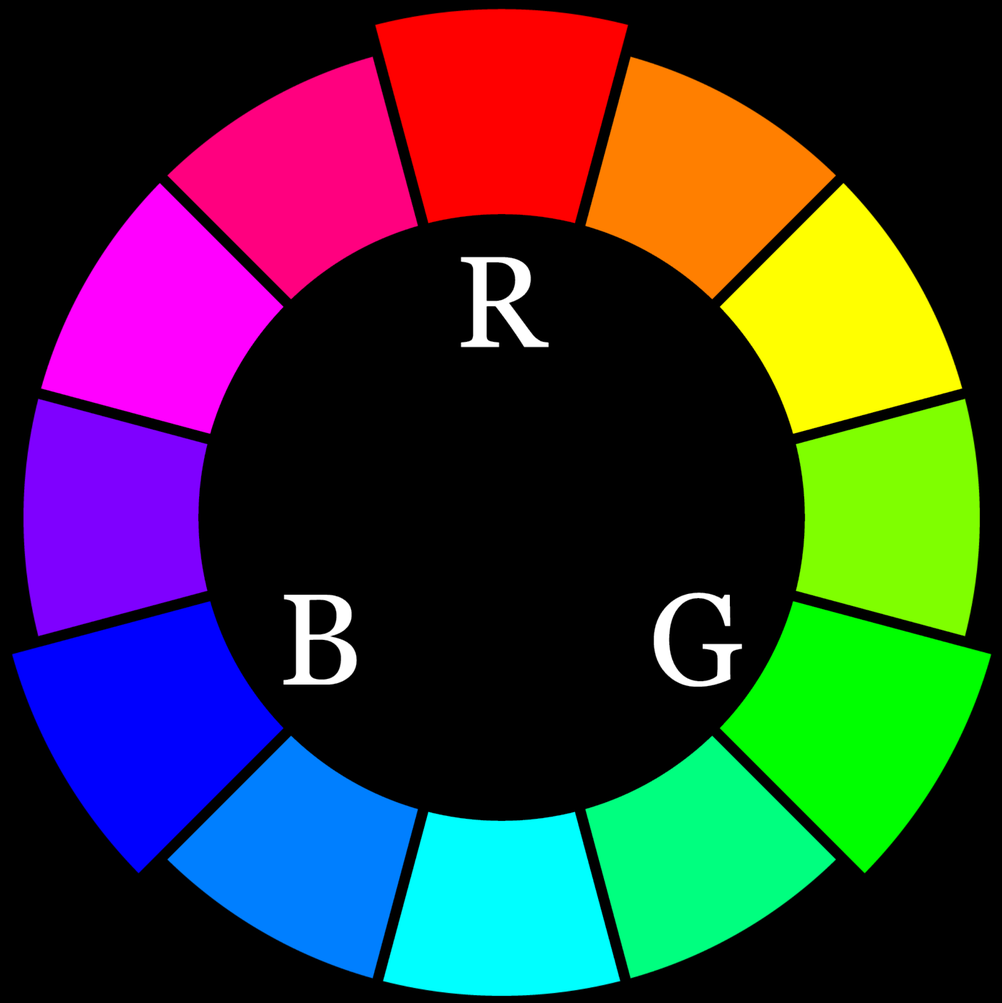
Mixing light



Color vision & psychology

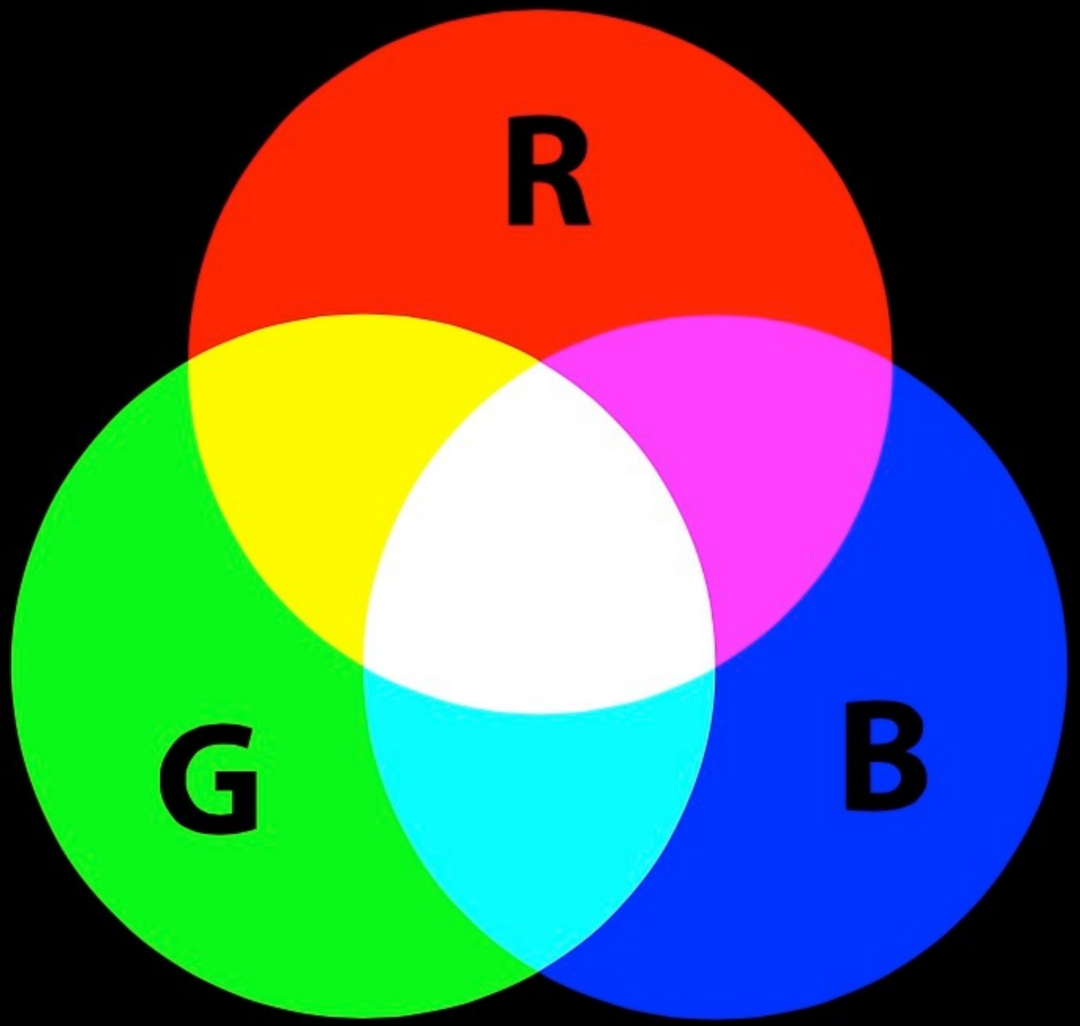


Mixing pigments

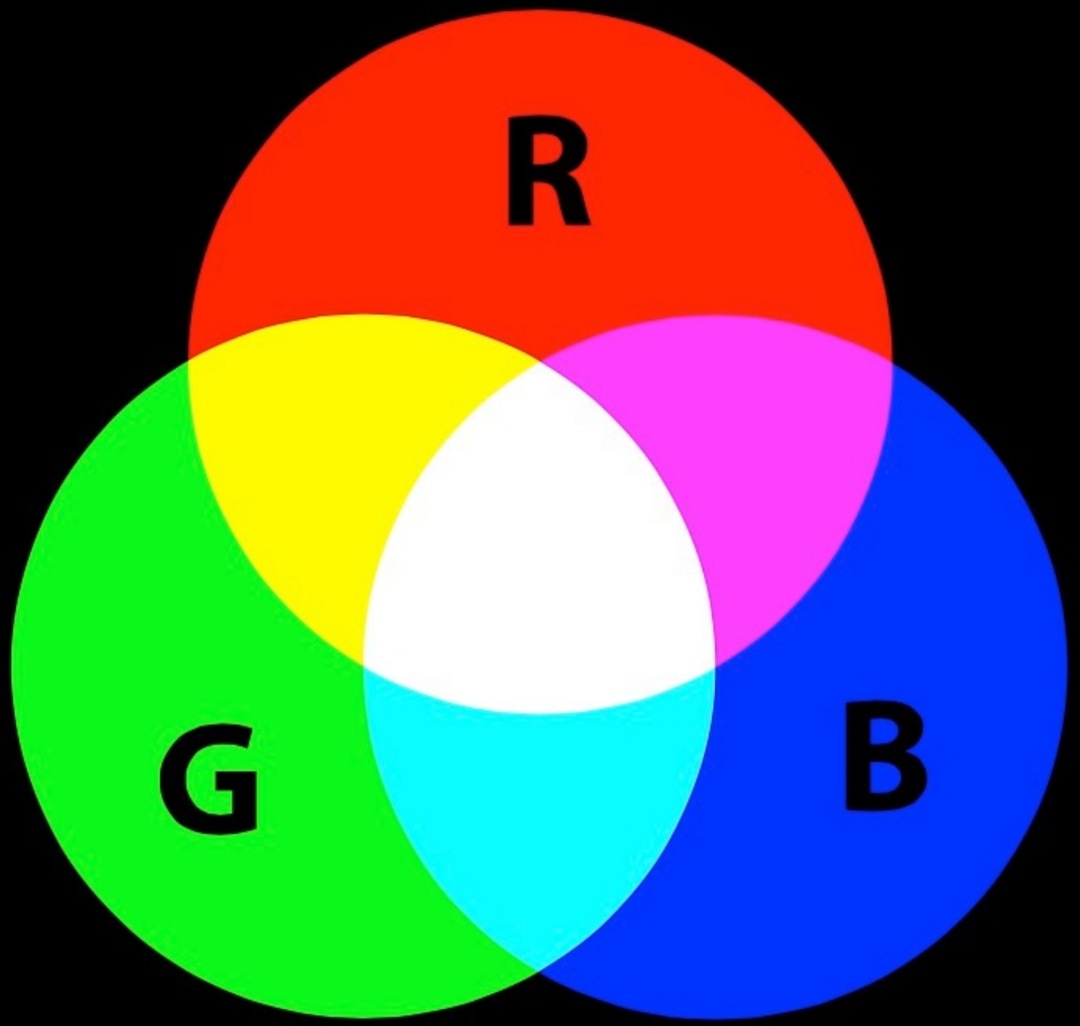


RGB color model combines red, green, & blue *light* to produce a wide range of colors

RGB are the lowest points of luminance in this color geometry



Mixing RGB colors of light equally produces white



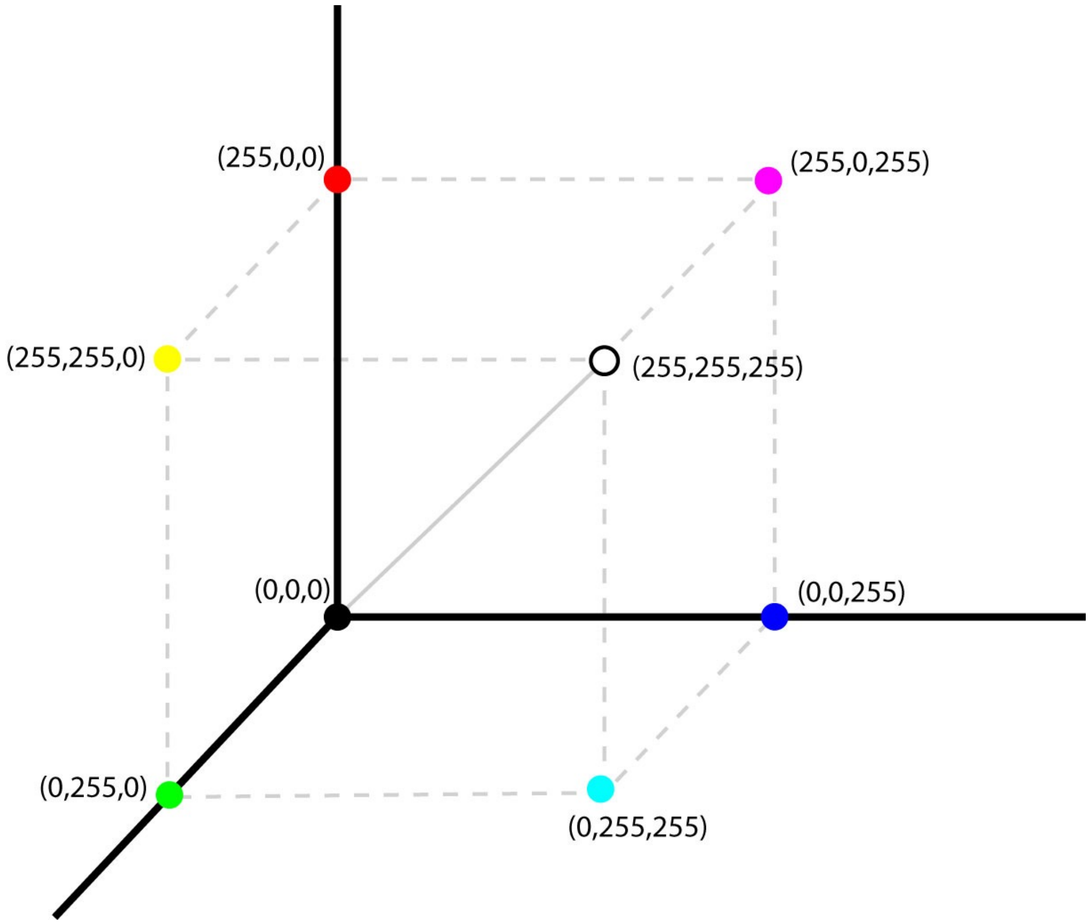
Additive color

Adding light to darkness; e.g., a monitor emitting light or a movie screen reflecting light

When primary colors are combined, the result is more luminous (which appears lighter)

RGB color model can be visualized as a variety of 3D spaces

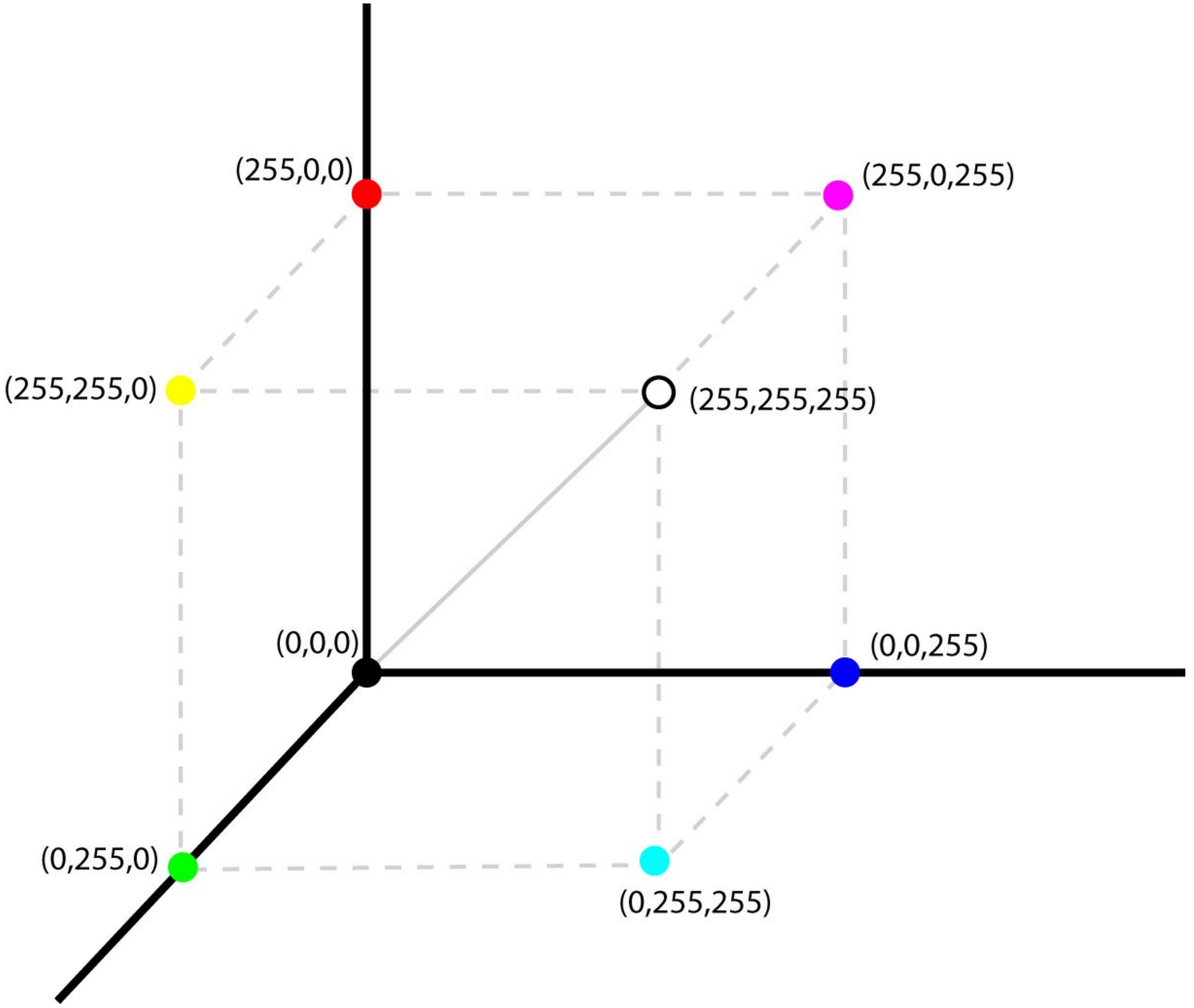
The three dimensions are used to depict hue, saturation, & lightness



The simplest color space to to comprehend is a cube

Very computationally efficient

The problem is that the result of combining RGB values is difficult to visualize

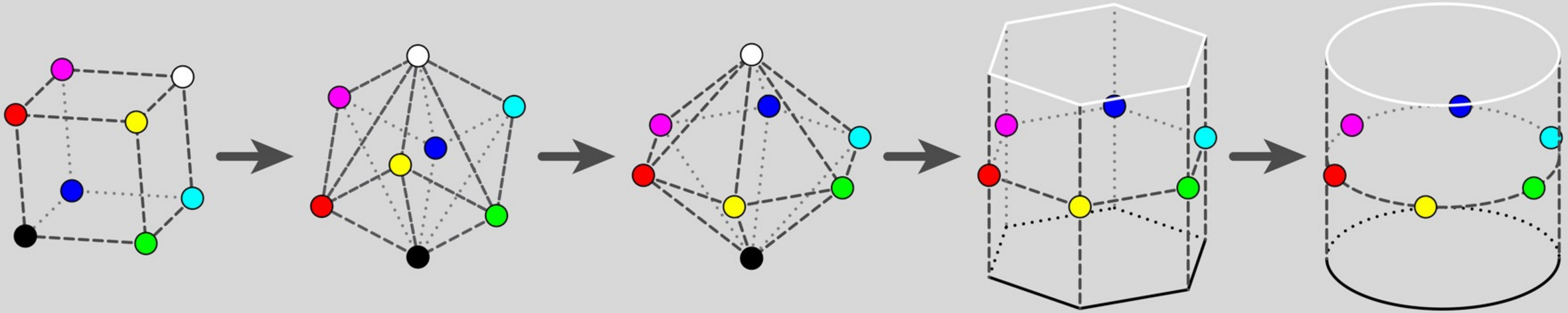

(255,0,0)
(255,0,255)
(255,255,0)
(255,255,255)
(0,0,0)
(0,0,255)
(0,255,0)
(0,255,255)

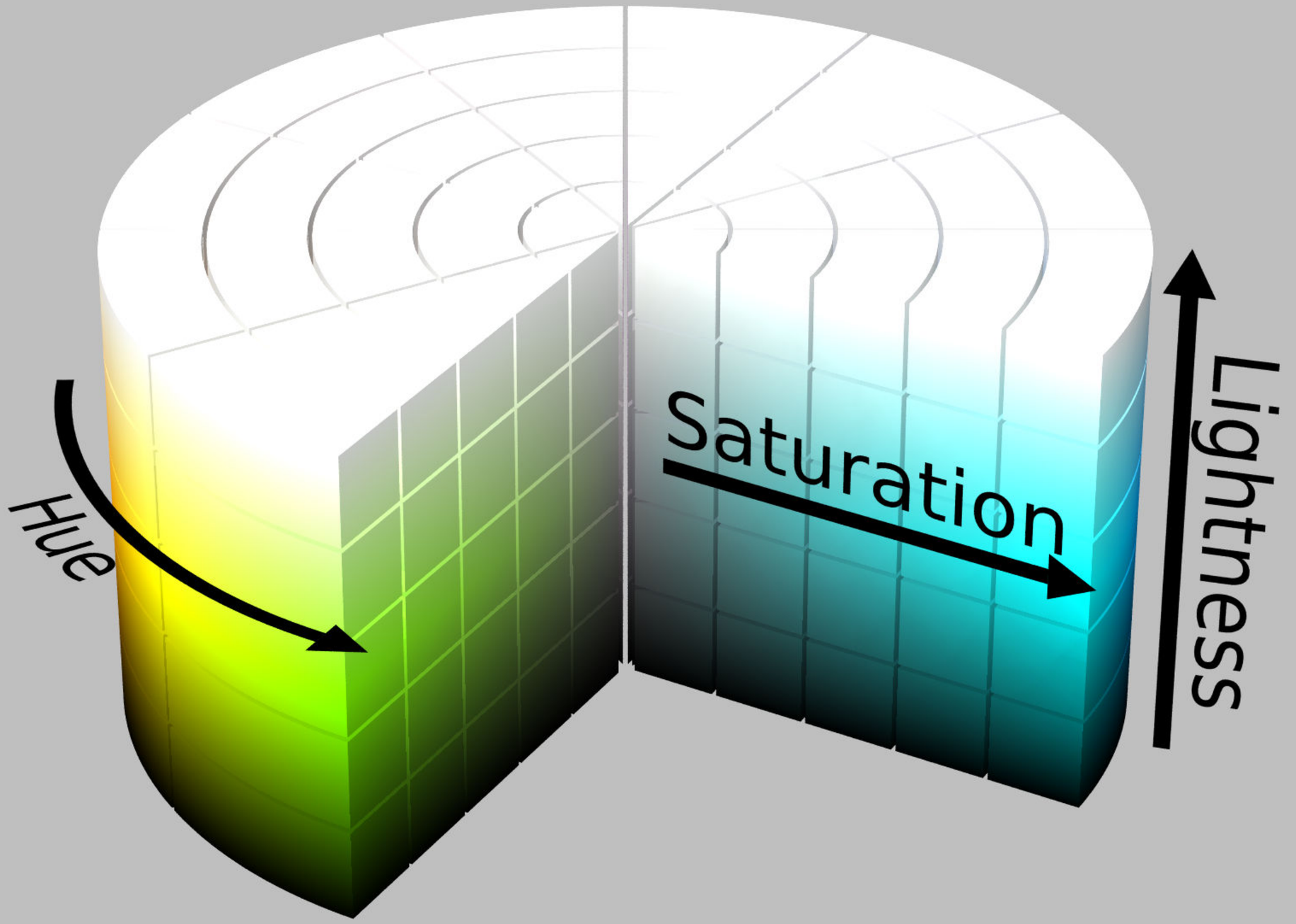
HSL transformation of the RGB cube is more intuitive & perceptually relevant than the RGB cube alone

Computationally efficient

Transforms the cube into a “double hexcone” cylinder

Lacks perceptual uniformity

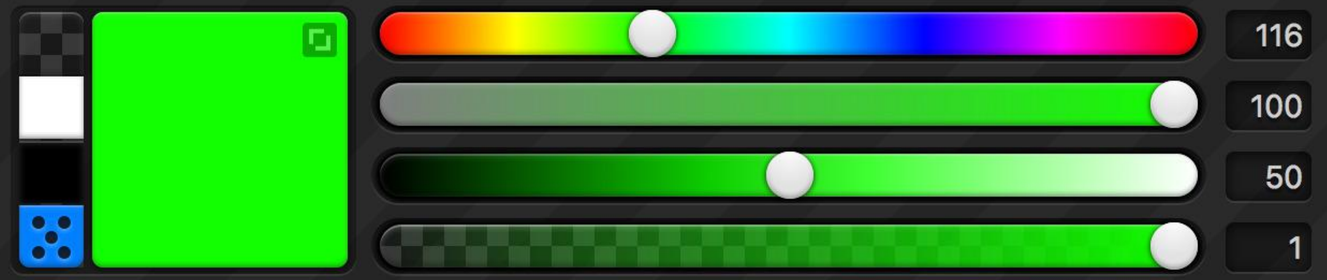



Hue
Saturation
Lightness

A MOST EXCELLENT

HSL COLOR PICKER

CREATED FOR YOUR ENJOYMENT, BY BRANDON MATHIS

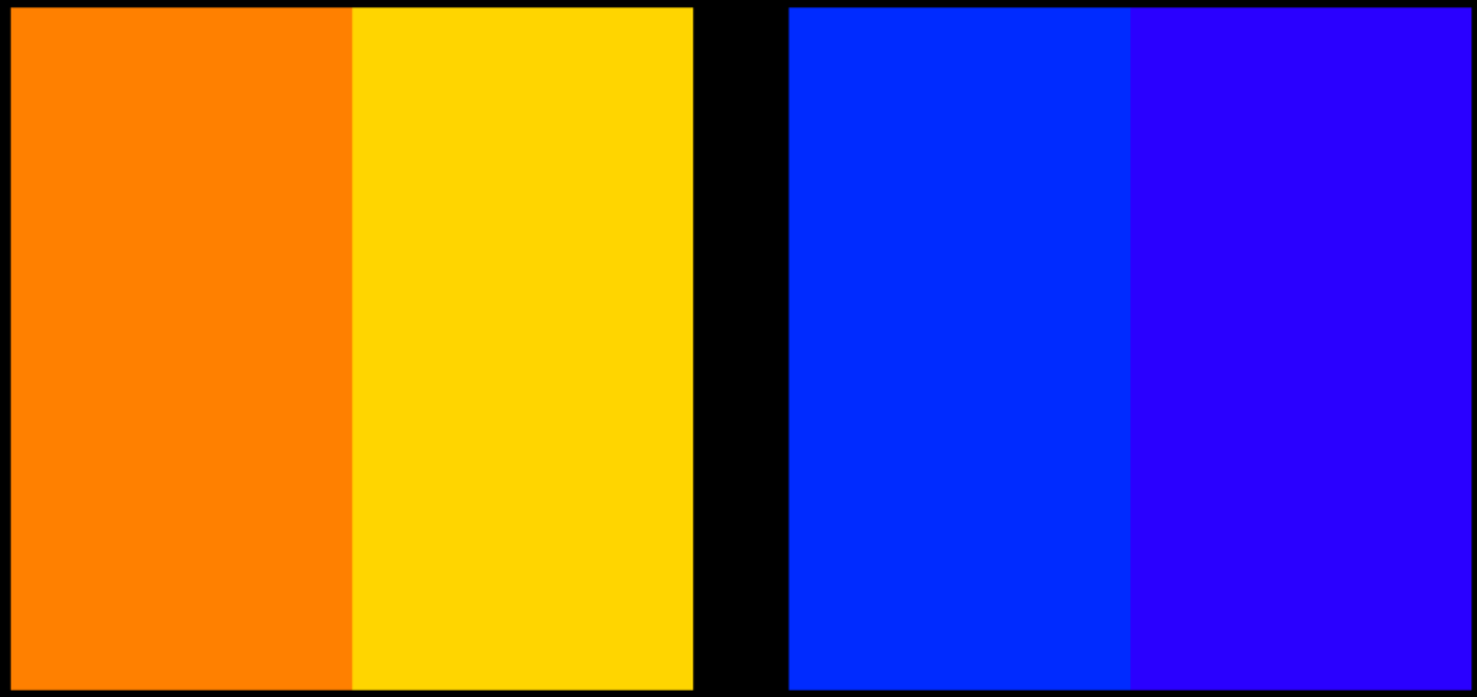


#1f0 | rgba(17, 255, 0, 1) | hsla(116, 100%, 50%, 1)

 | What's HSL? | Source

So what’s the problem?

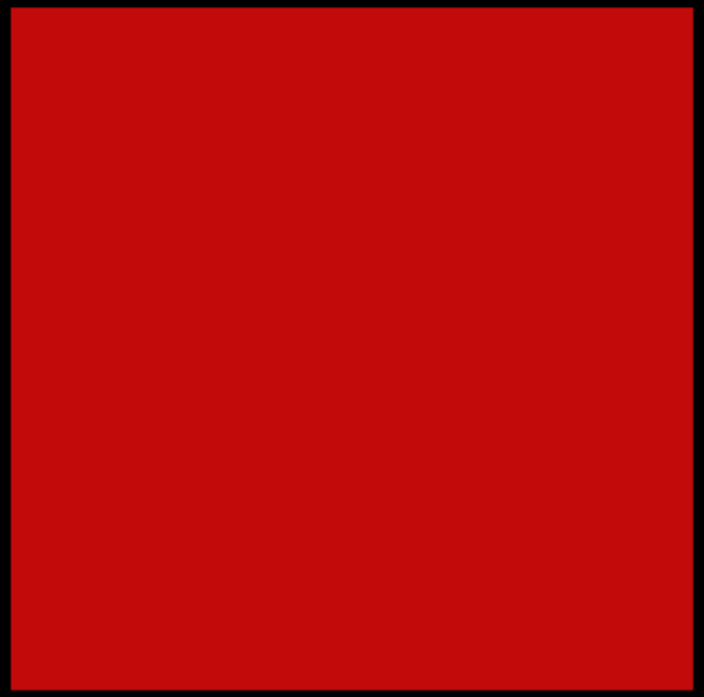
Changes in distance (numerical values) don’t match perceived changes in hue, saturation, & lightness



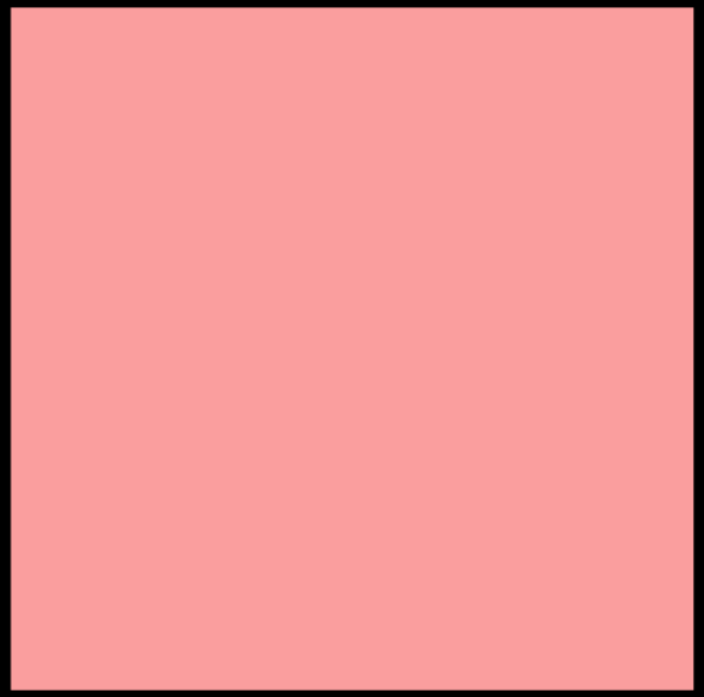
Hue: 30° to 50°
Saturation: 100%
Lightness: 50%

Hue: 230° to 250°
Saturation: 100%
Lightness: 50%

HSL equal hue change

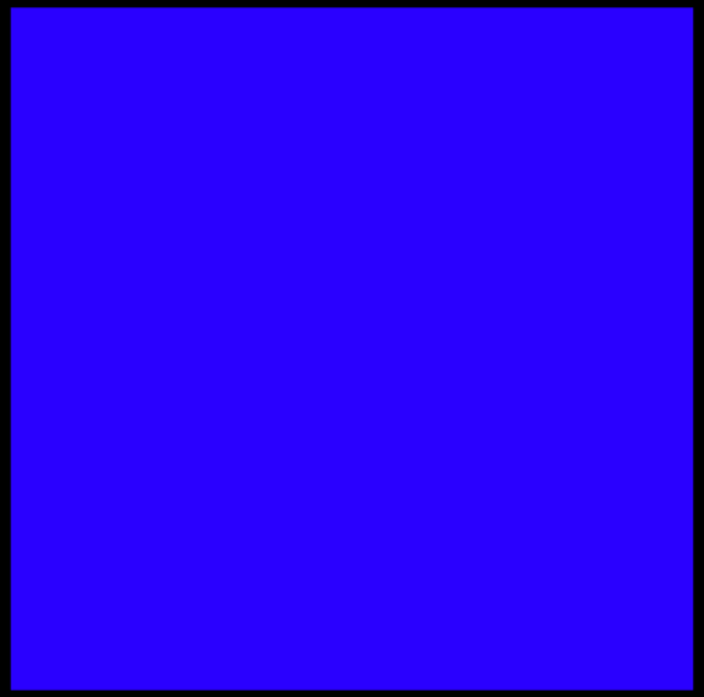


Hue: 0°
Saturation: 90%
Lightness: 40%

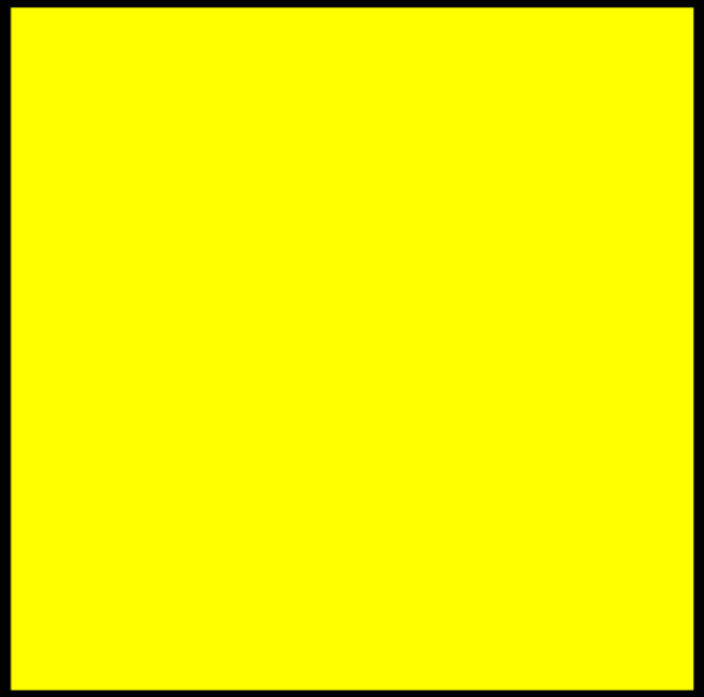


Hue: 0°
Saturation: 90%
Lightness: 80%

HSL equal saturation



Hue: 250°
Saturation: 100%
Lightness: 50%

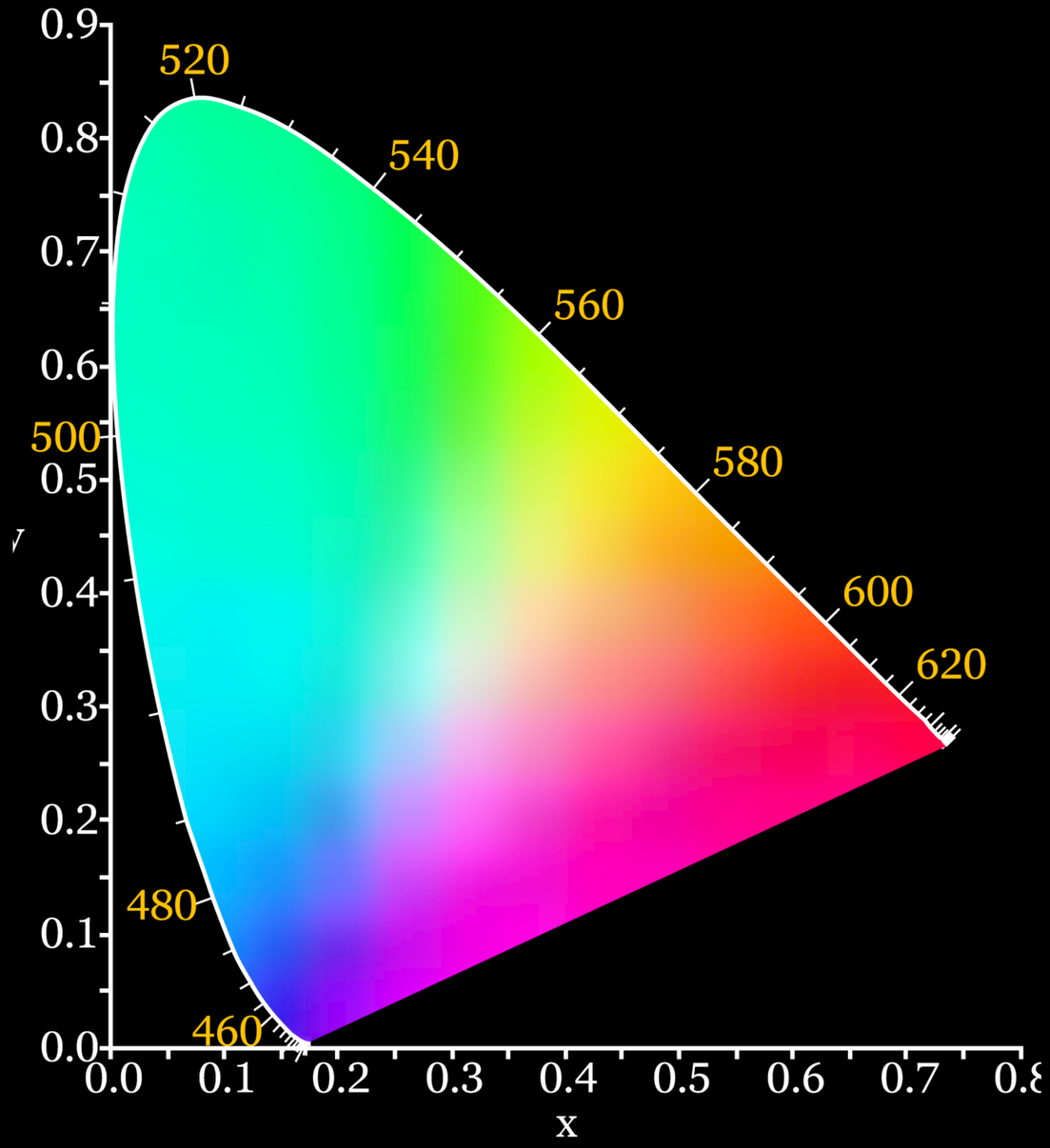


Hue: 60°
Saturation: 100%
Lightness: 50%

HSL equal lightness

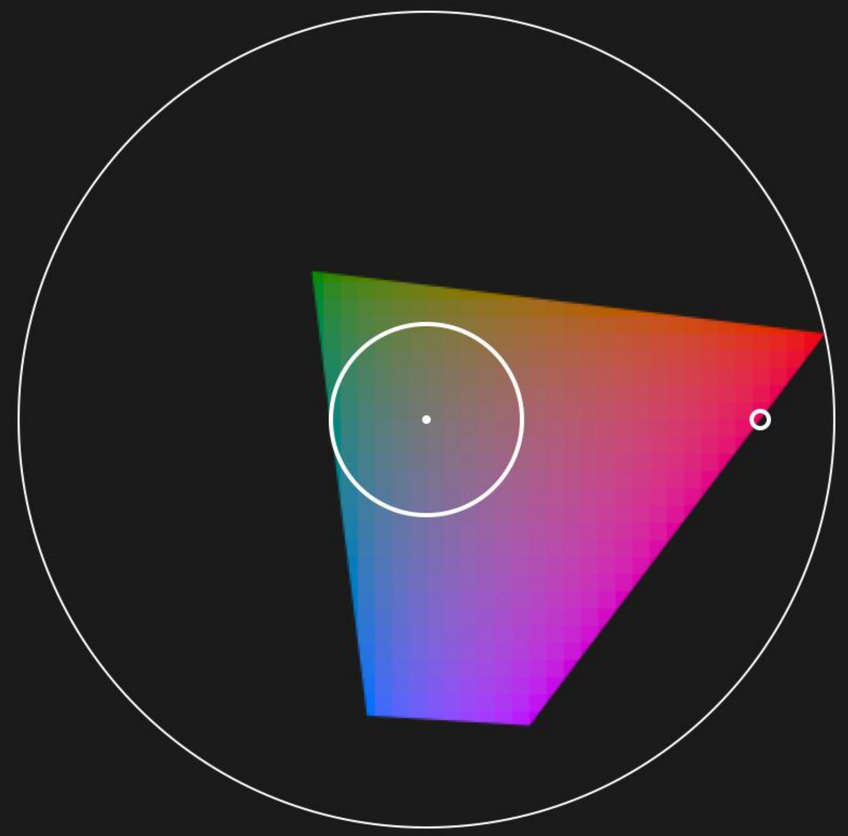
The answer? Mapping human perception by using color appearance models, which seek uniformity by mapping human perception

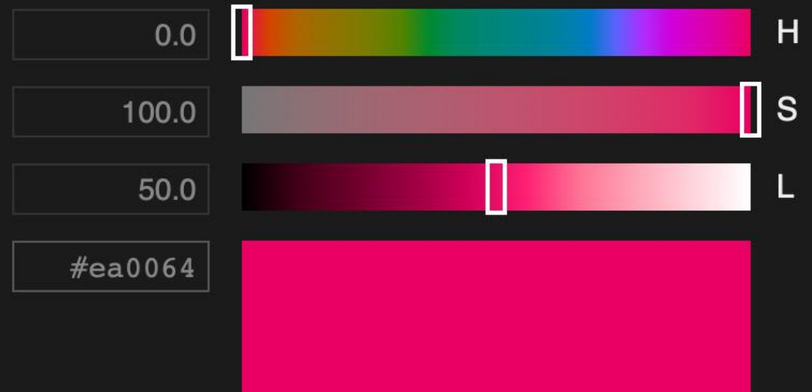
- 1931: CIE
- 1976: CIE LAB
- 1976: CIE LUV (CIE Lch)
- 1980s–1995: Hunt model
- 1997: CIECAM97s
- 2002: CIECAM02
- 2012: HUSL → HSLuv



CIE Color Chart

Developed in 1931 to show full range of color humans can perceive & relationship between those perceptions





HSL$_{uv}$ is a human-friendly alternative to HSL.

Here you can see CIELUV, a color space designed for perceptual uniformity based on human experiments. When accessed by polar coordinates, it becomes functionally similar to HSL with a single problem: its chroma component doesn't fit into a specific range.

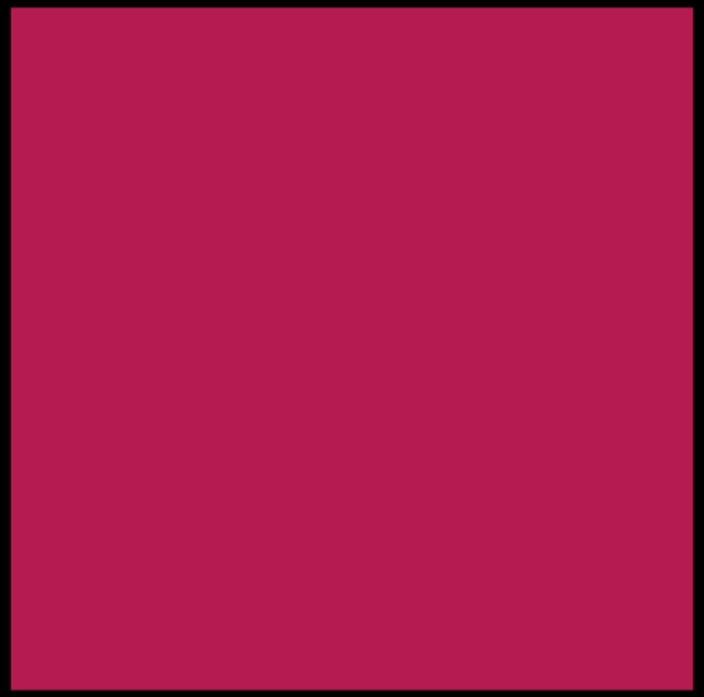
HSL$_{uv}$ extends CIELUV with a new saturation component that allows you to span all the available chroma as a neat percentage.

If you know CSS, you can only use HSL, not HSLuv!

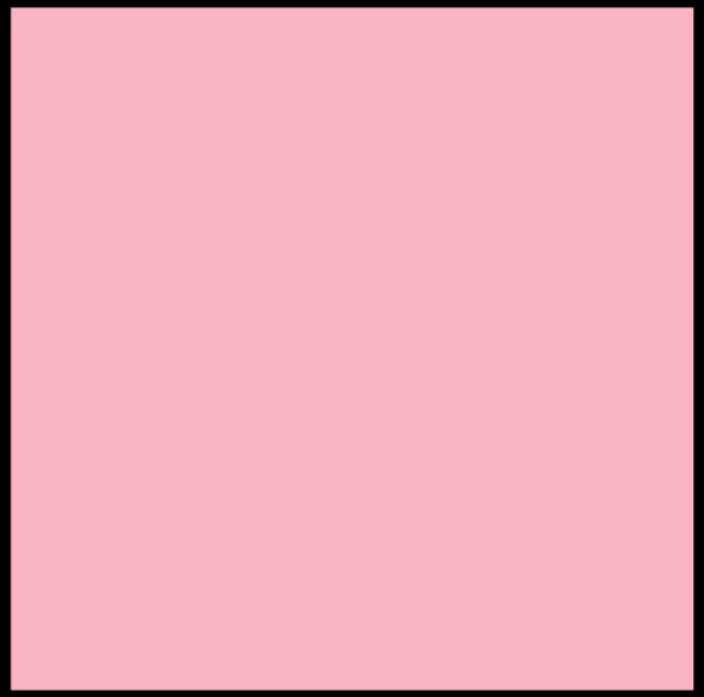
Hue: 30° to 50°
Saturation: 100%
Lightness: 50%

Hue: 230° to 250°
Saturation: 100%
Lightness: 50%

HUSL equal hue change

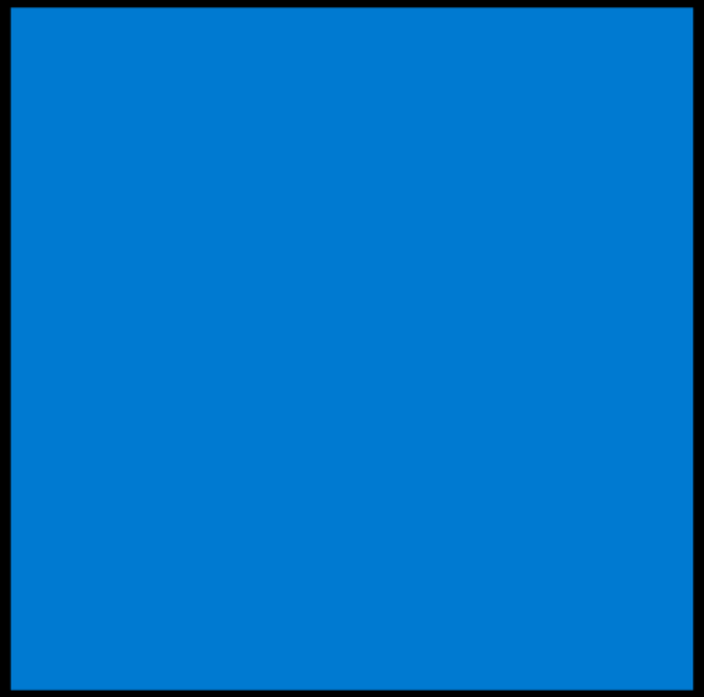


Hue: 0°
Saturation: 90%
Lightness: 40%

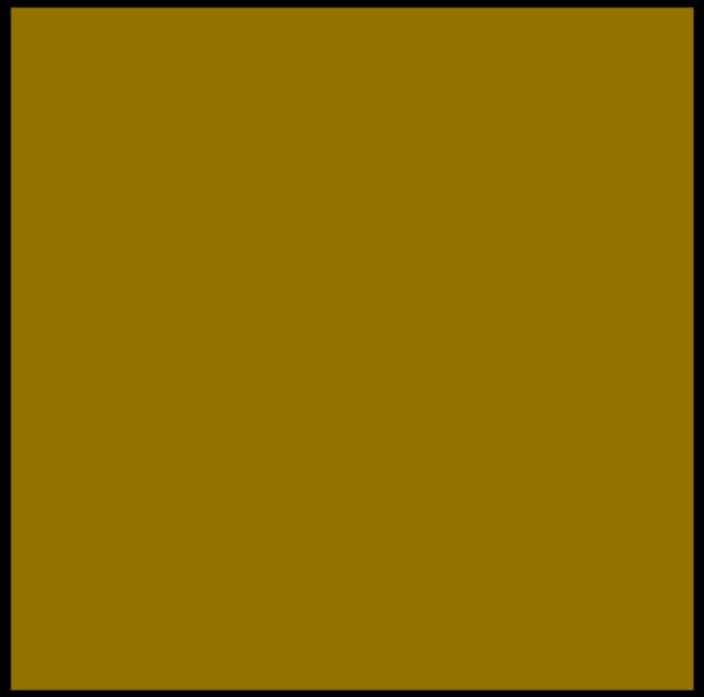


Hue: 0°
Saturation: 90%
Lightness: 80%

HUSL equal saturation

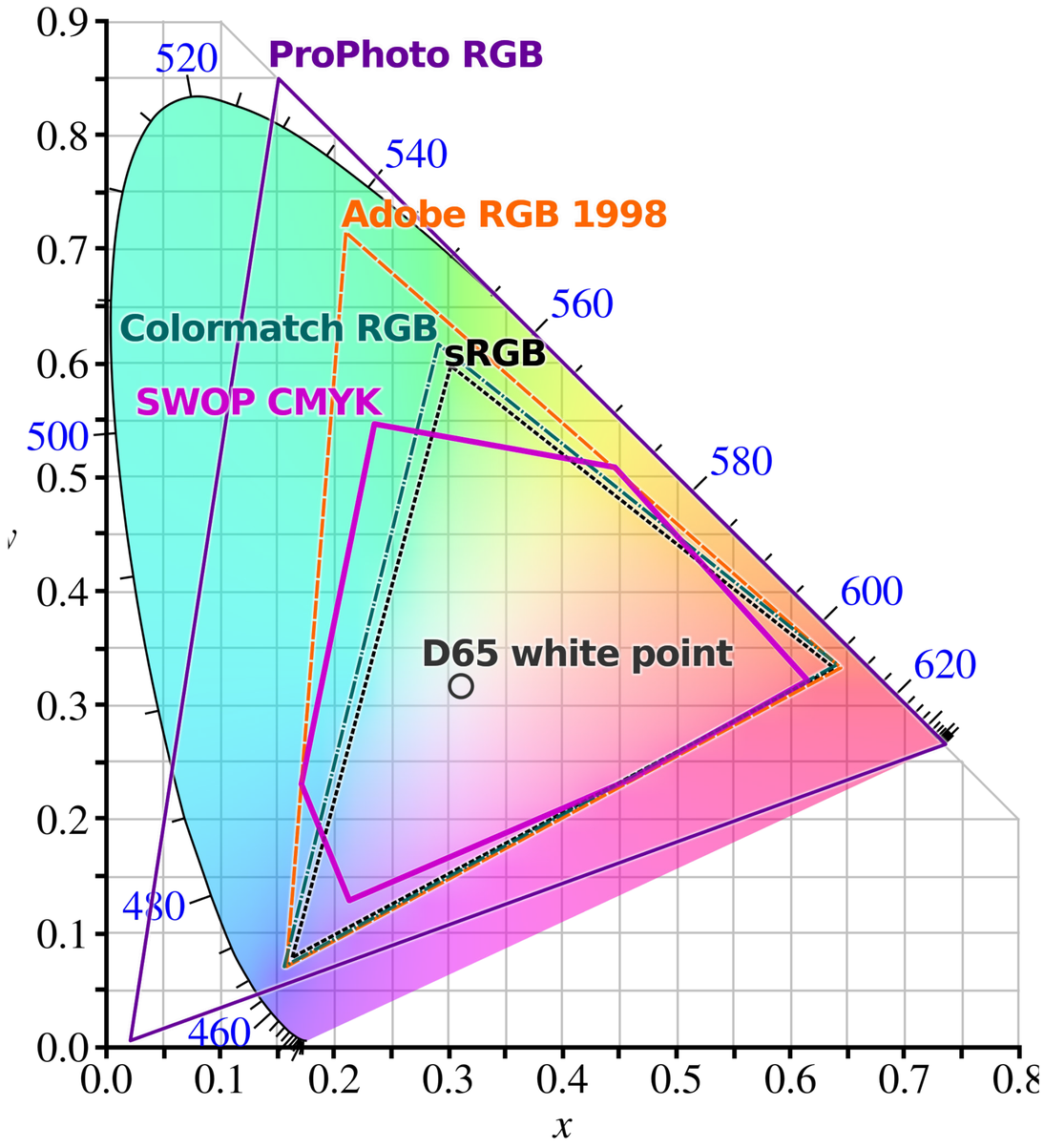


Hue: 250°
Saturation: 100%
Lightness: 50%



Hue: 60°
Saturation: 100%
Lightness: 50%

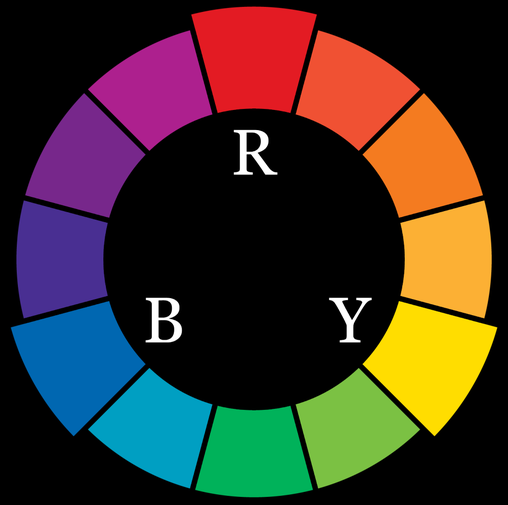
HUSL equal lightness



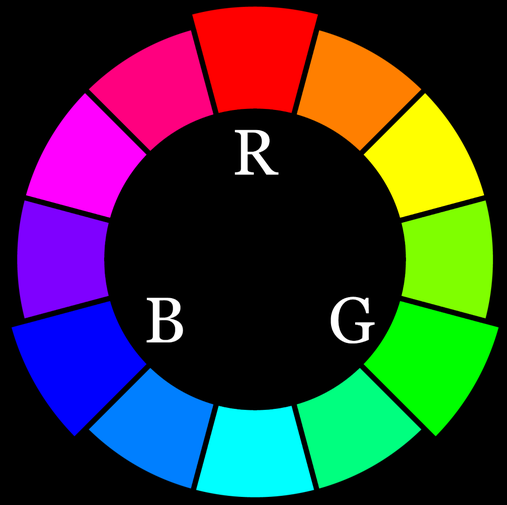
Gamut

The full range of colors that a particular implementation of a color model can reproduce

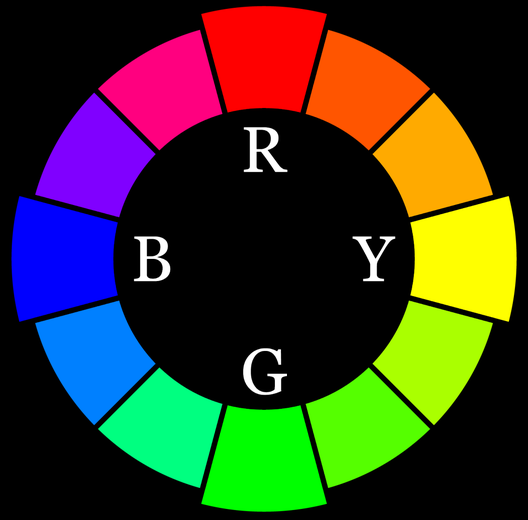
CMY



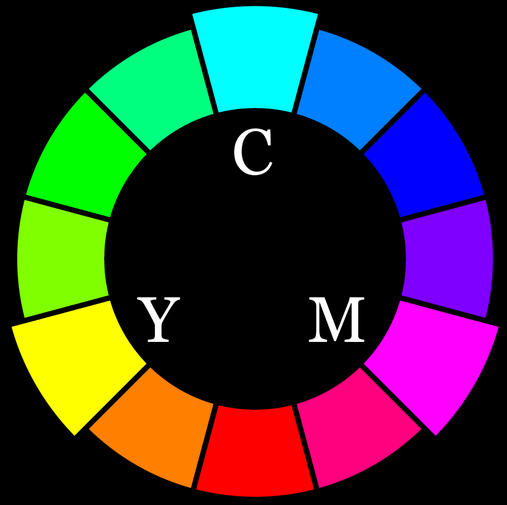
Artistic discussion



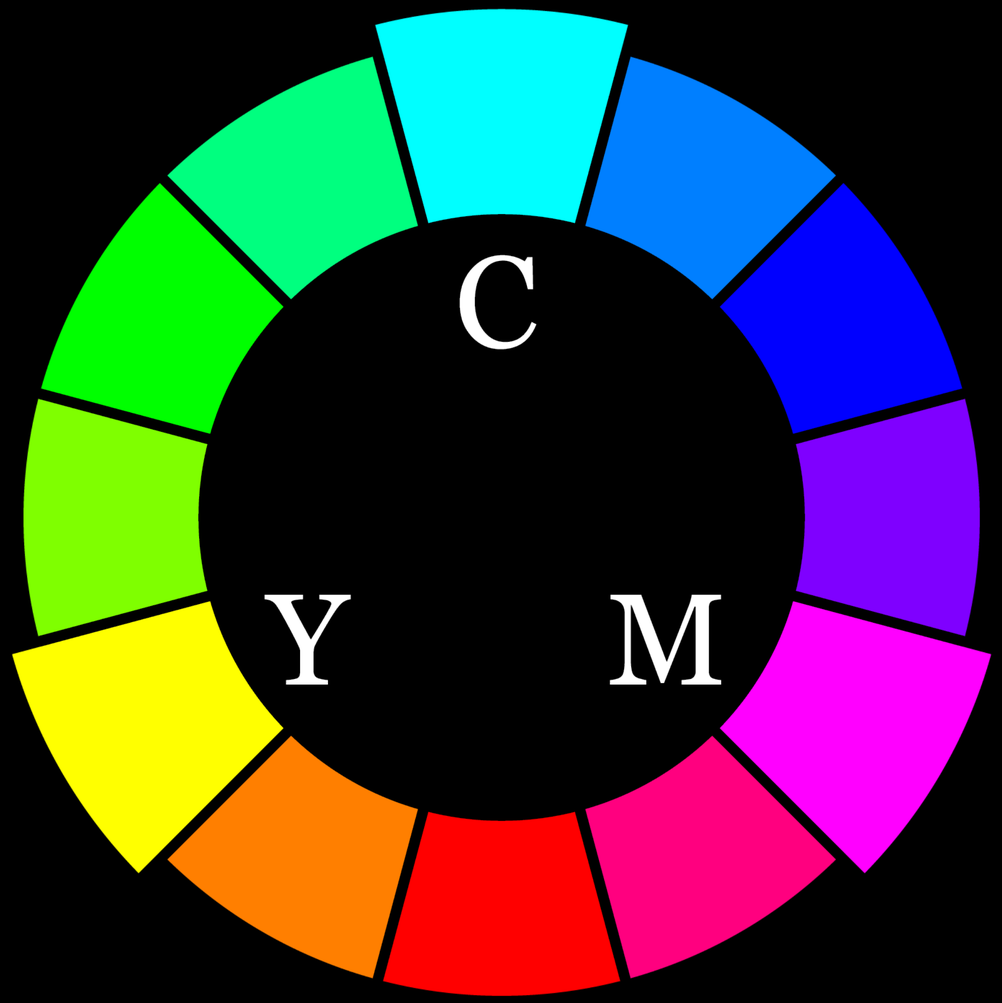
Mixing light



Color vision & psychology



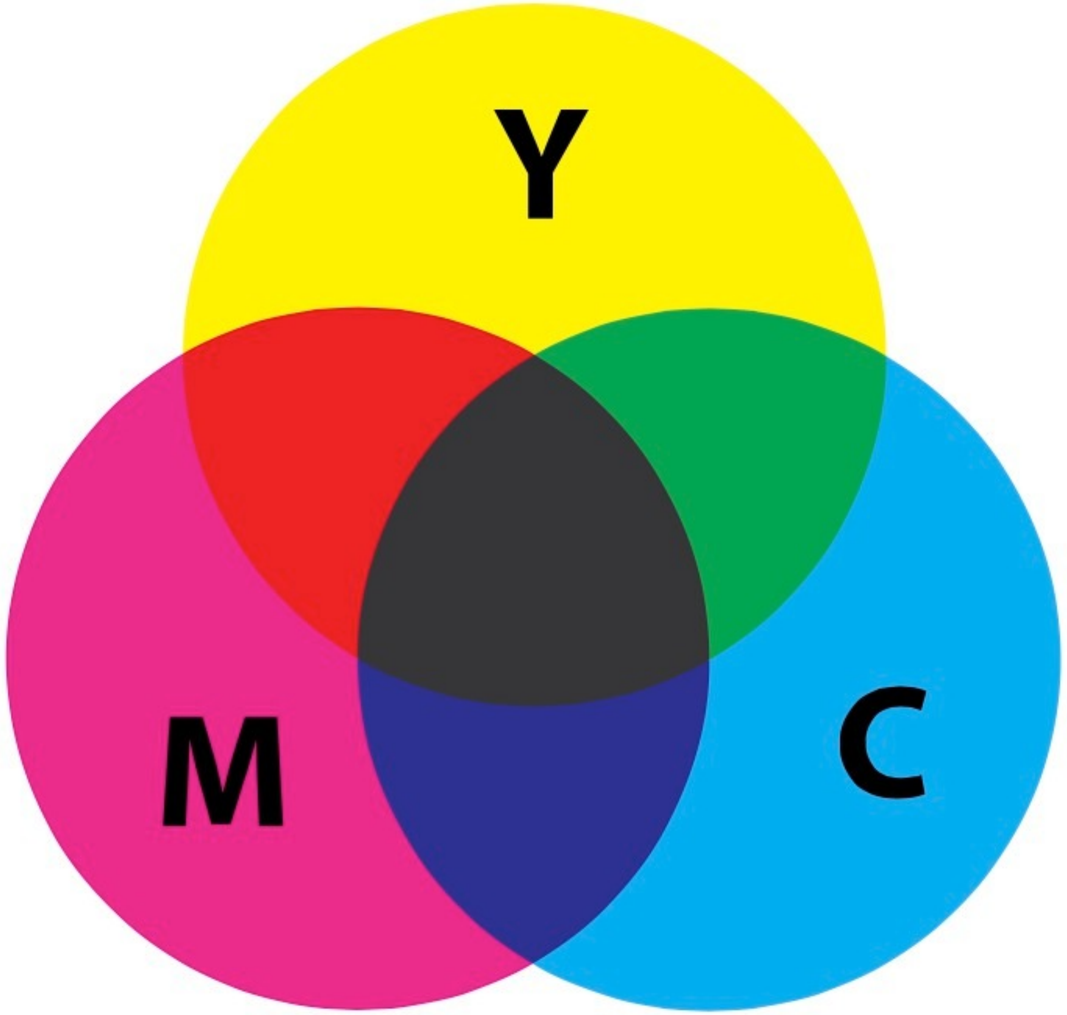
Mixing pigments



CMY color model combines cyan, magenta, & yellow *pigments** like paints, inks, & dyes to produce a wide range of colors

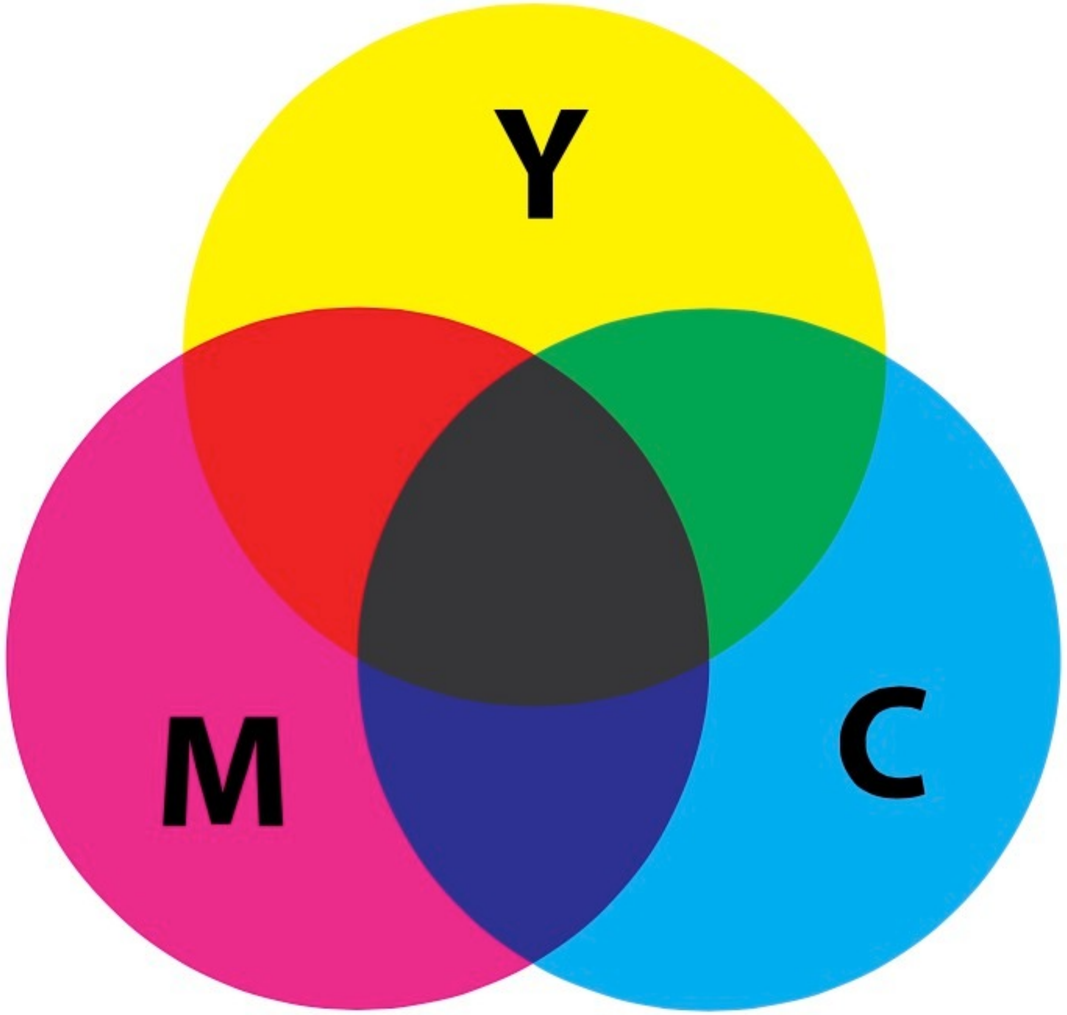
CMY are the highest points of luminance in this color geometry

* Not lights — that's RGB!



Mixing CMY pigment colors equally produces black

Results in the widest gamut possible when mixing 3 pigments



Subtractive color

Removing colors from white light; e.g., pigments absorb (remove or subtract) some colors & reflect others

When primary colors are combined, the result is less luminous (which appears darker)

Why CMY*K*?

CMY has a limited gamut & since pigments don’t absorb light perfectly, additional colors are needed to produce a wider range of colors

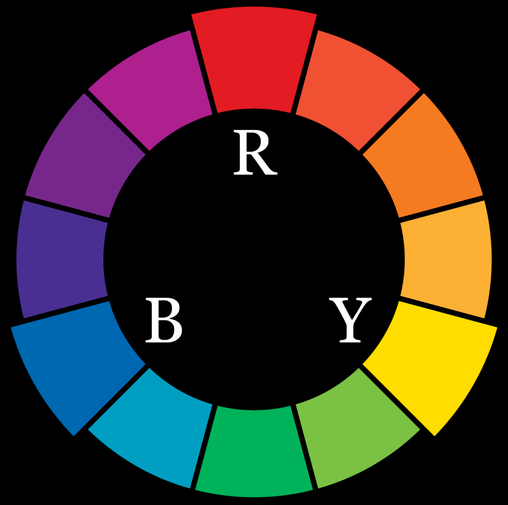
Black (or Key, hence the *K*) ink is always used for this purpose

Green & orange ink are also commonly used as additional spot colors

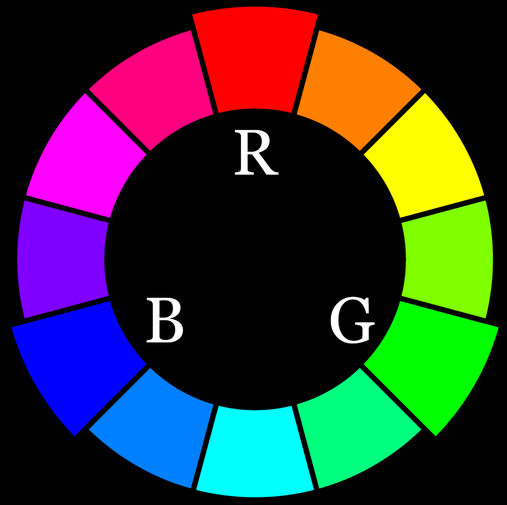
Computers & screens always combine light & cannot remove light

Computers & screens therefore always use the RGB (additive) model

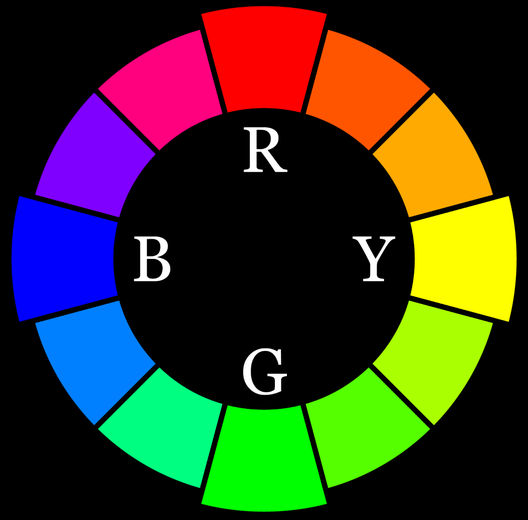
Perceiving Color



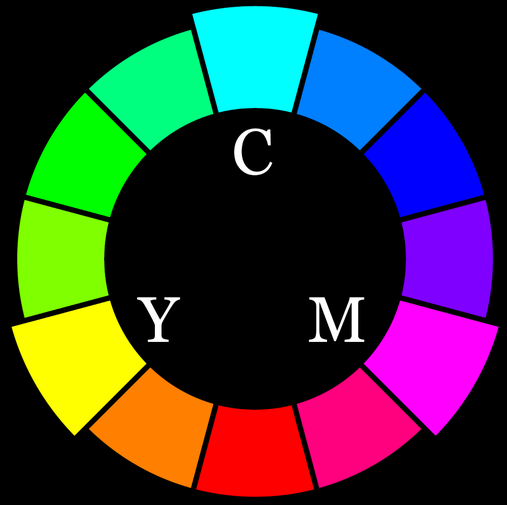
Artistic discussion



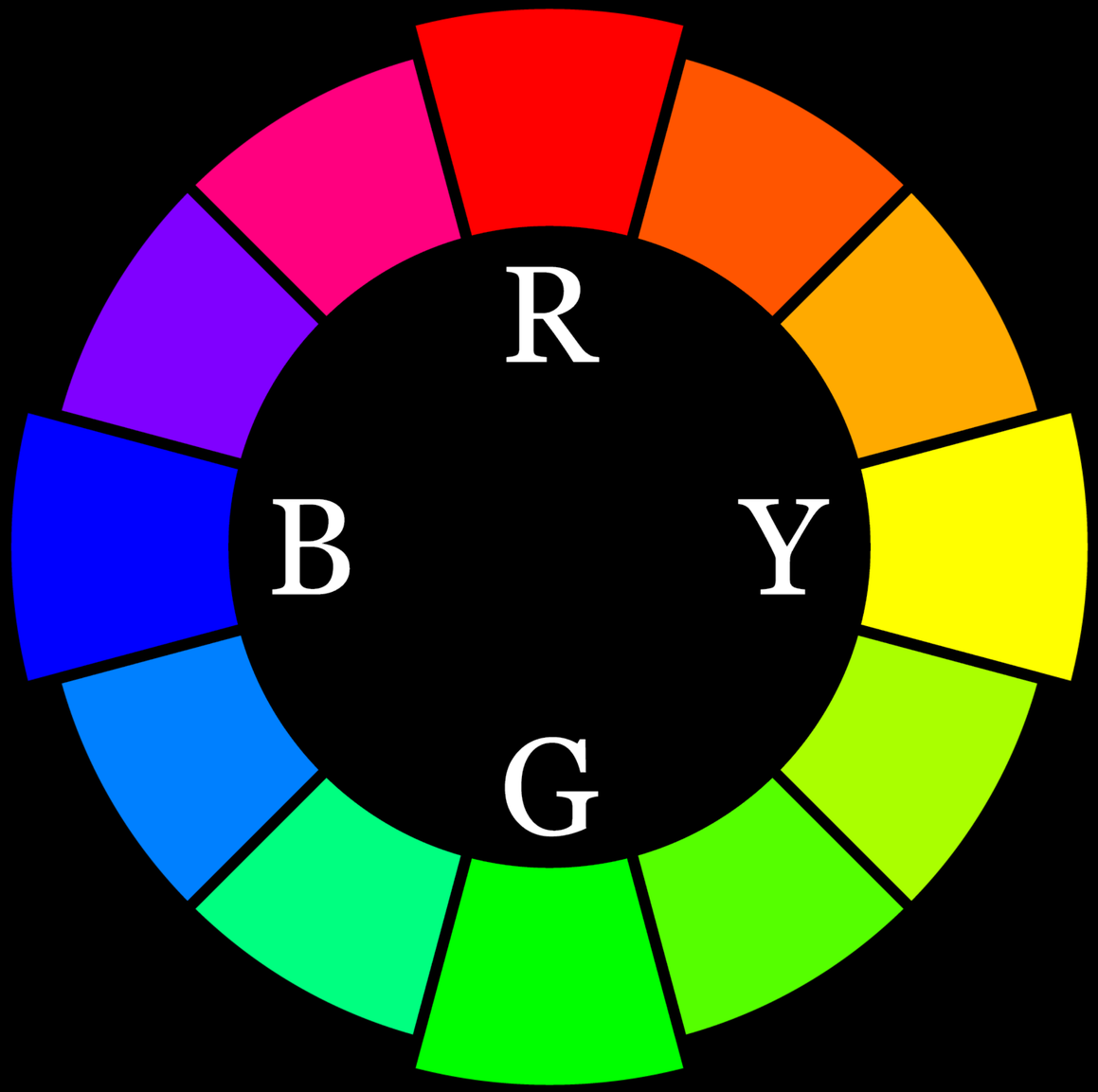
Mixing light



Color vision & psychology



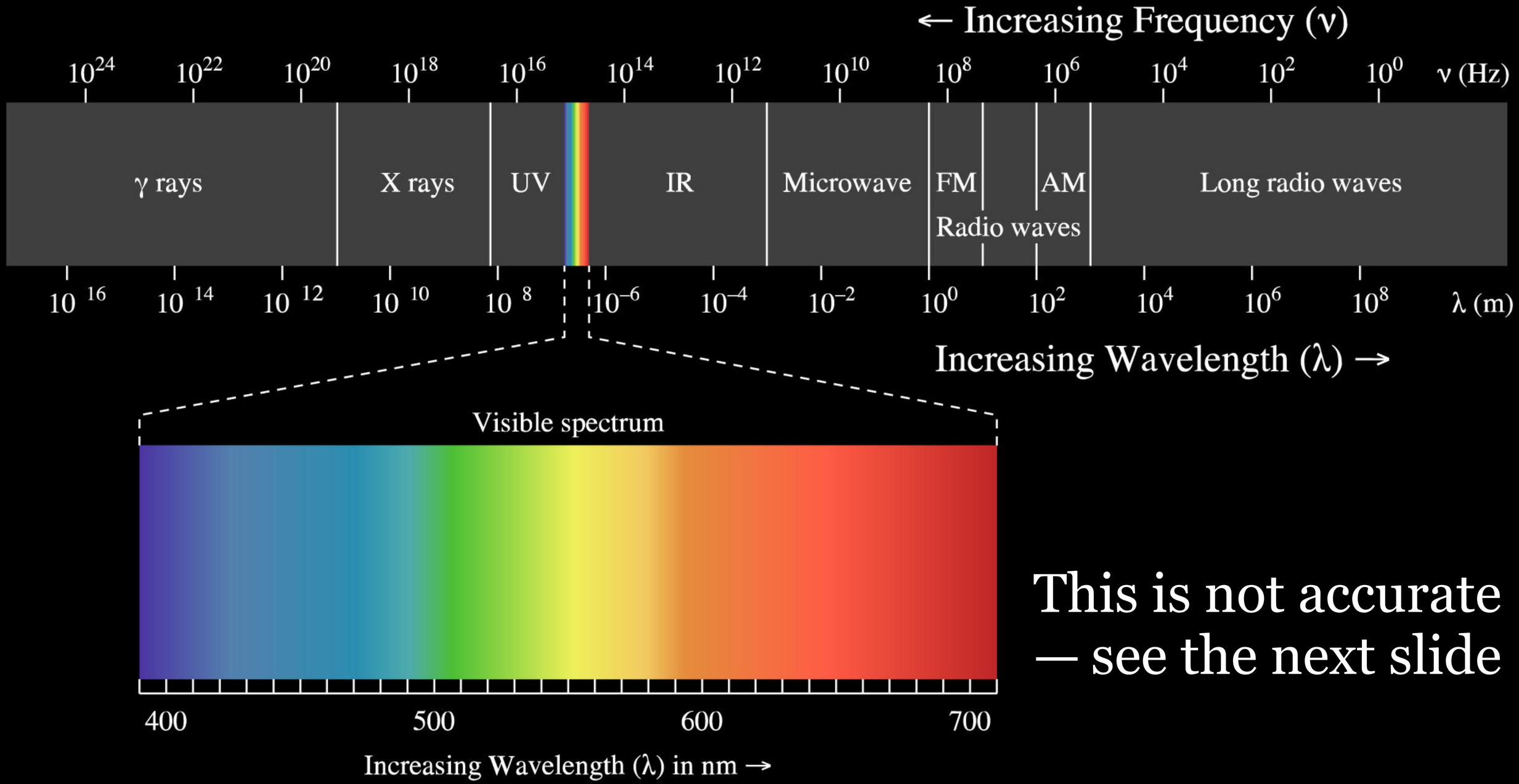
Mixing pigments


R
B
Y
G

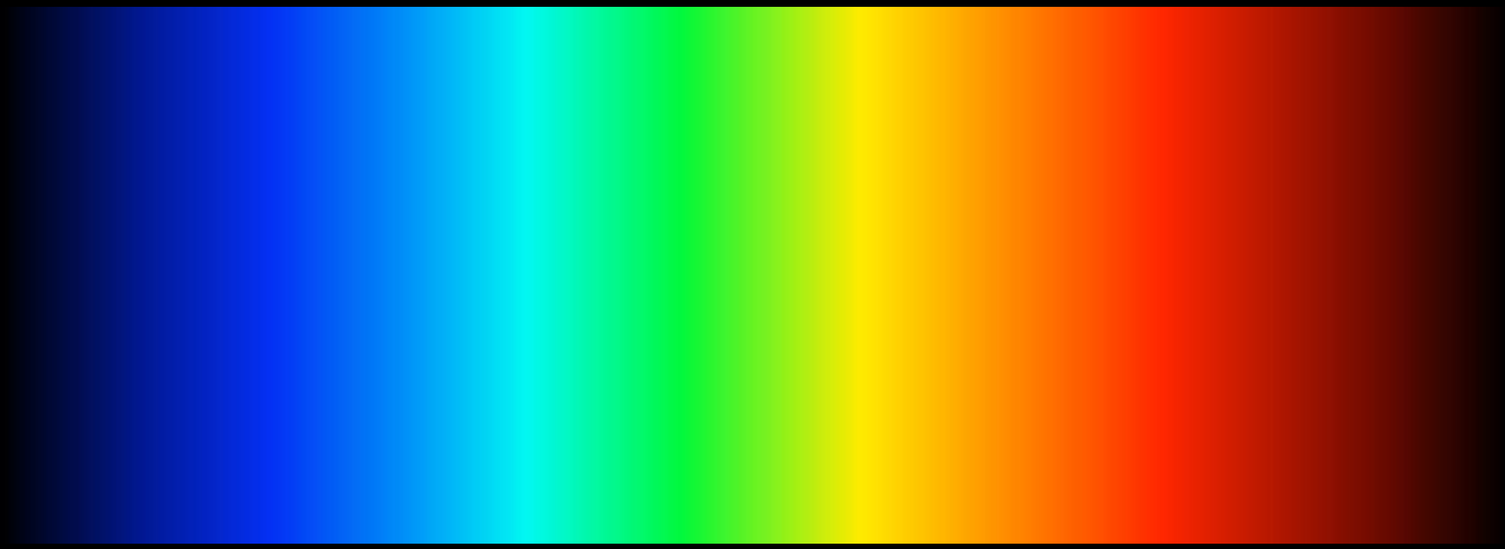
The Visible Spectrum (aka The Physics)

One of Newton’s 4 discoveries: humans can see only certain wavelengths of the electromagnetic spectrum, which we perceive as colors

However, our brains perceive *extraspectral colors* that are not included in the visible spectrum



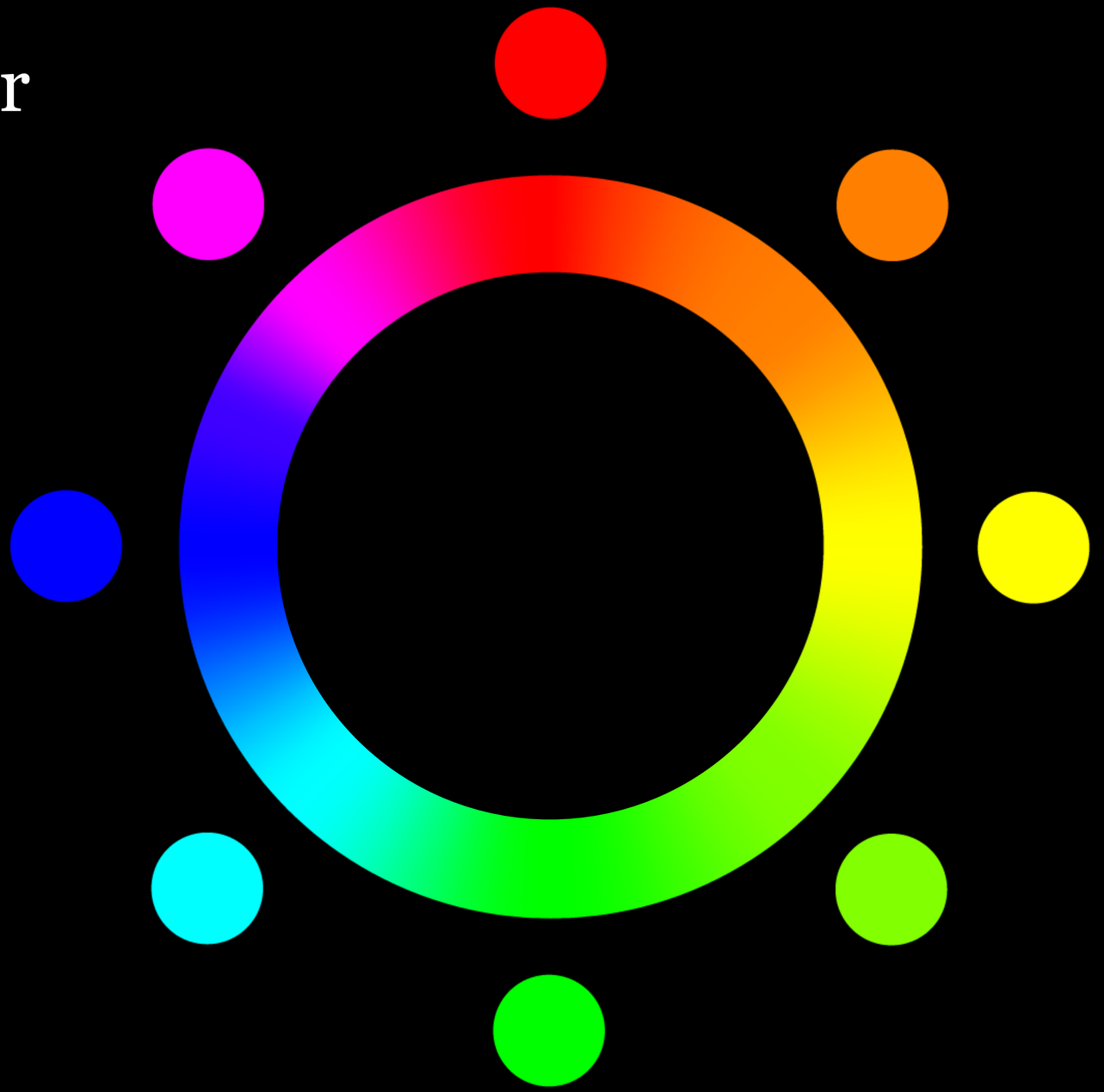
This is not accurate — see the next slide



This is a much truer representation of the visible spectrum

If we wrap the visible spectrum into a circle, what color is missing?

The brain creates the color magenta when it receives a mixture of red & blue light



How We See Colors

Theory

The *opponent process*: *two* color signals are sent to the brain so it can process & determine hue

One signal sent to the brain is either yellow or blue

The other signal sent to the brain is red or green

The visual cortex processes blue/yellow & red/green signals into all hues

Biology

We see by sensing light

In the eye, *rods* & *cones* are the cells that sense light

Cones (~4.5 million in the retina) allow us to perceive color

Rods (~92 million in the retina)

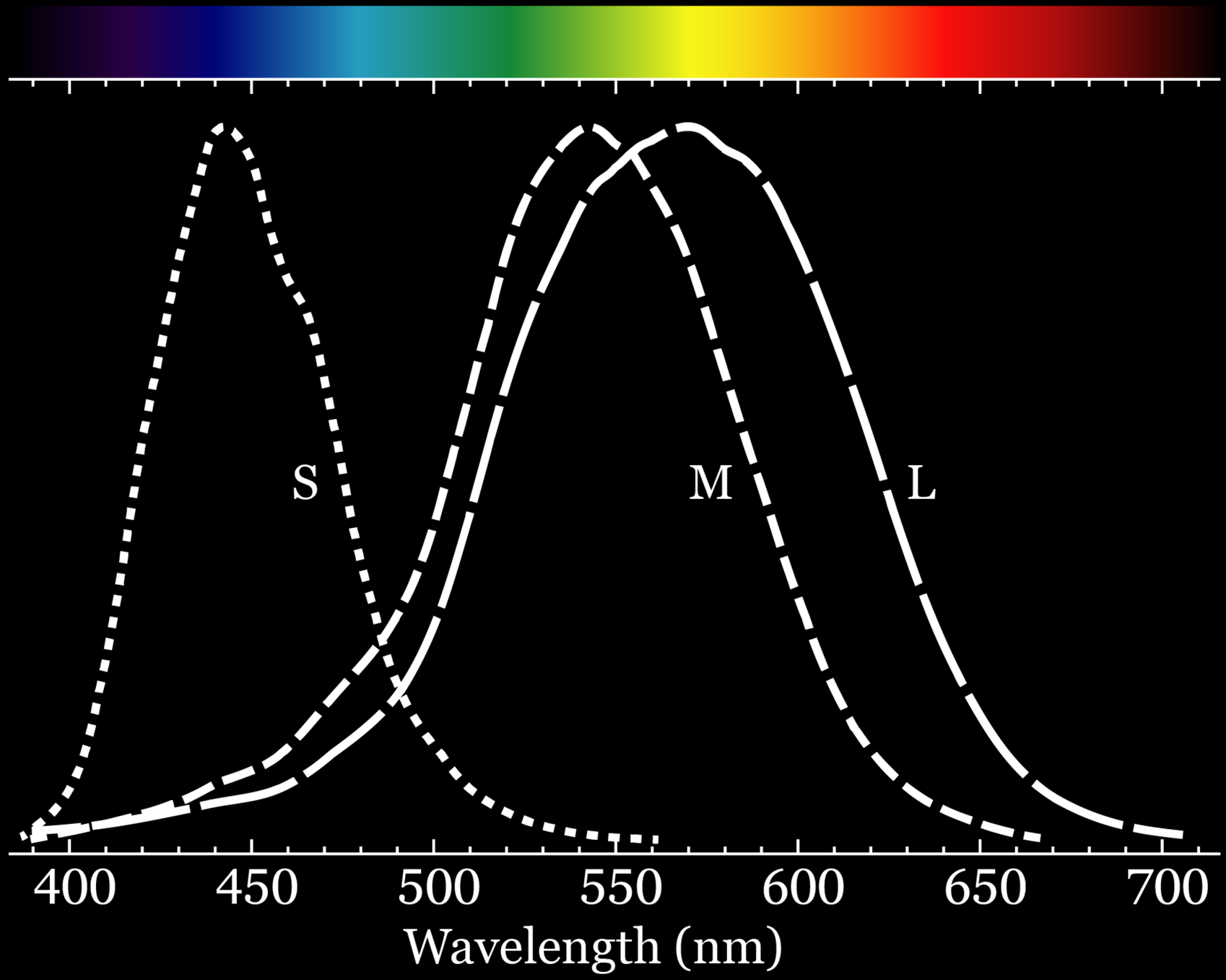
- Have little role in color vision
- Much smaller than rods so more tightly packed
- Primarily responsible for perceiving fine detail & contrast (amount of light)
- Almost entirely responsible for night vision

Rod Stewart

Cone Stewart

3 cones, each responding to visible light

- L (*long* λ): most strongly to the "red" end
- M (*medium* λ): most strongly to the "green" range
- S (*short* λ): only to the "blue" end


S
M
L
400
450
500
550
600
650
700
Wavelength (nm)

No one cone can detect a particular color

For example, an L cone responds equally to…

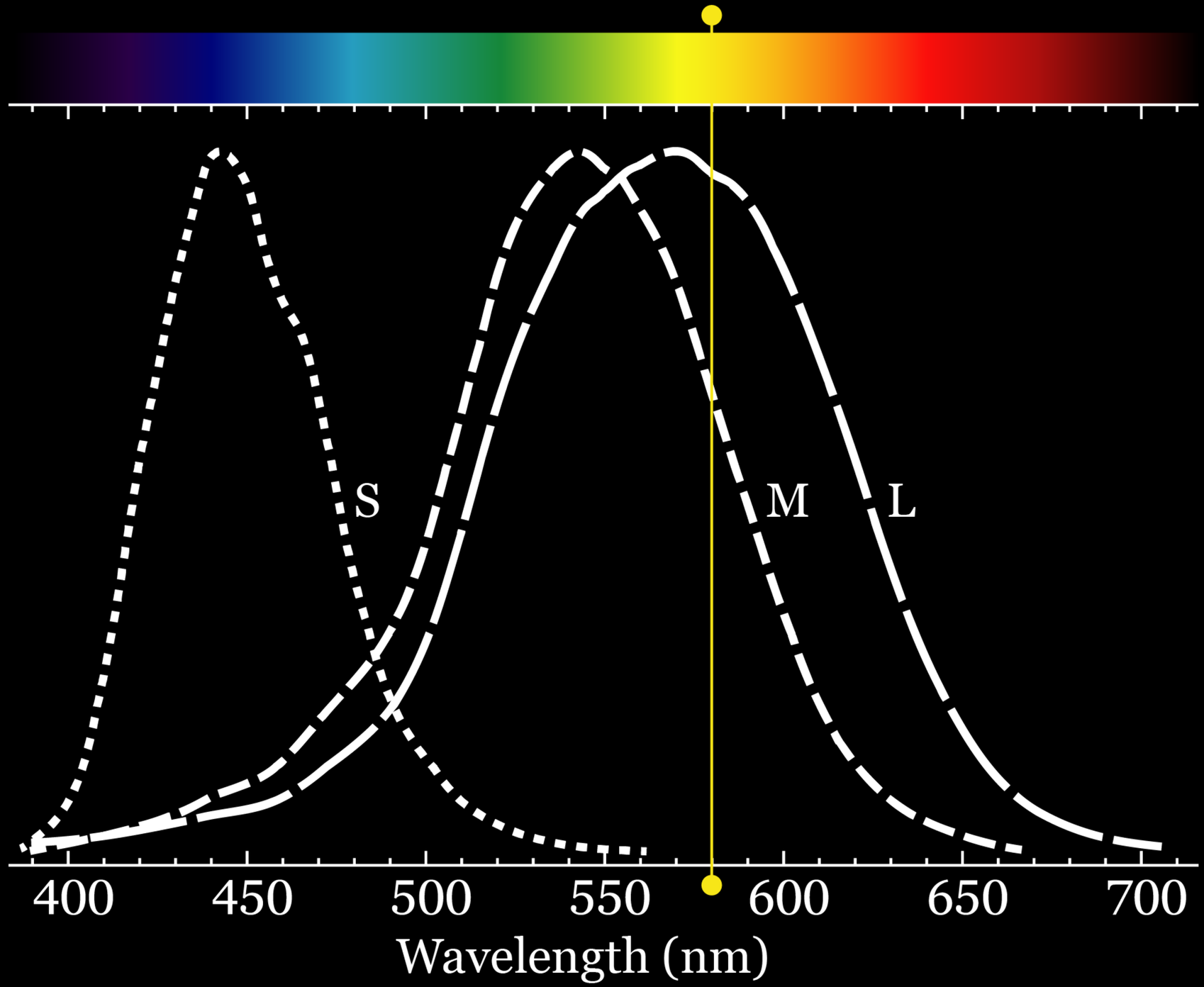
» a small amount of yellow (570 nm) light, or
» double that amount of green (510 nm) light

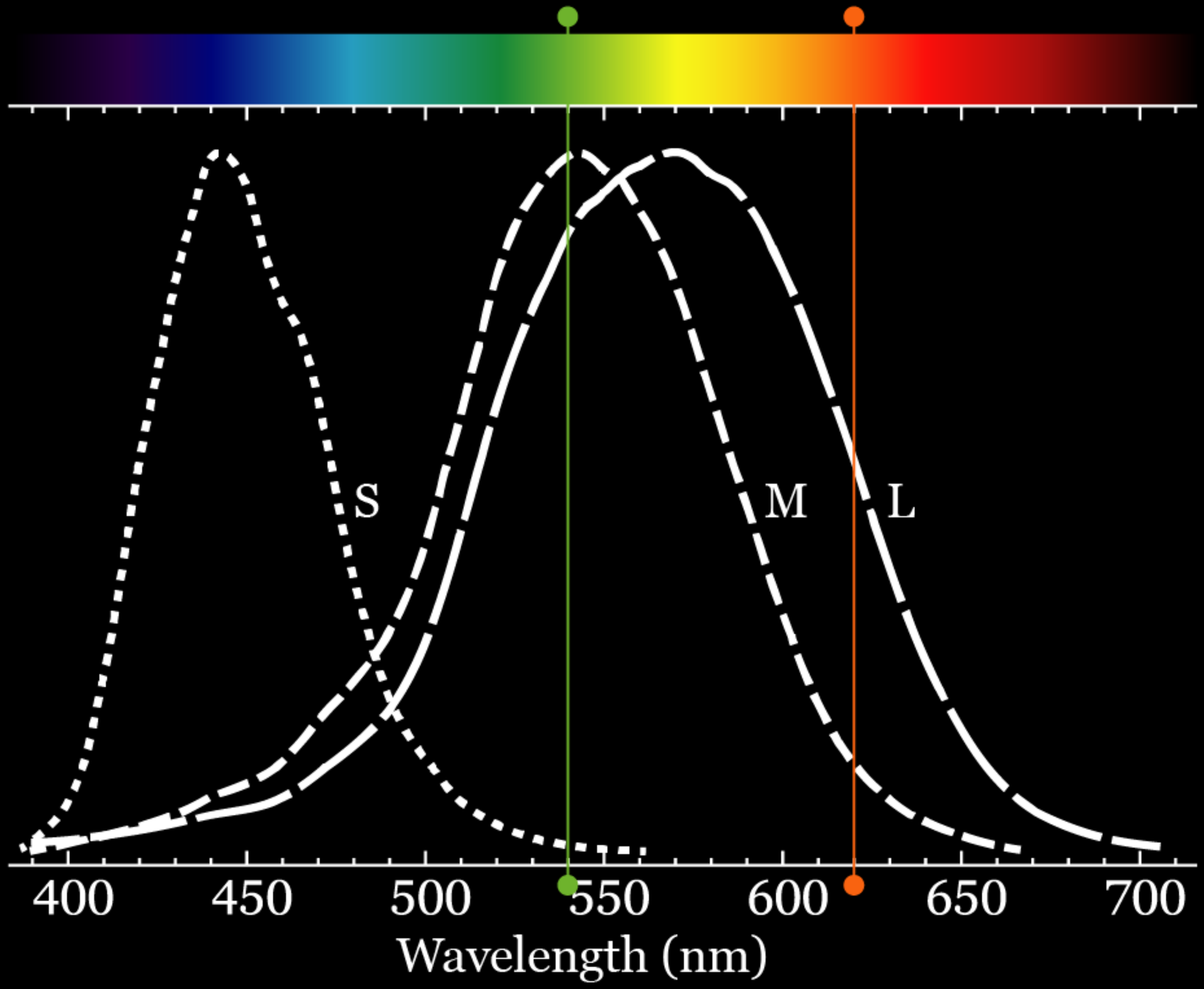
Our eyes produce color signals by comparing how the L, M, & S cones respond to light

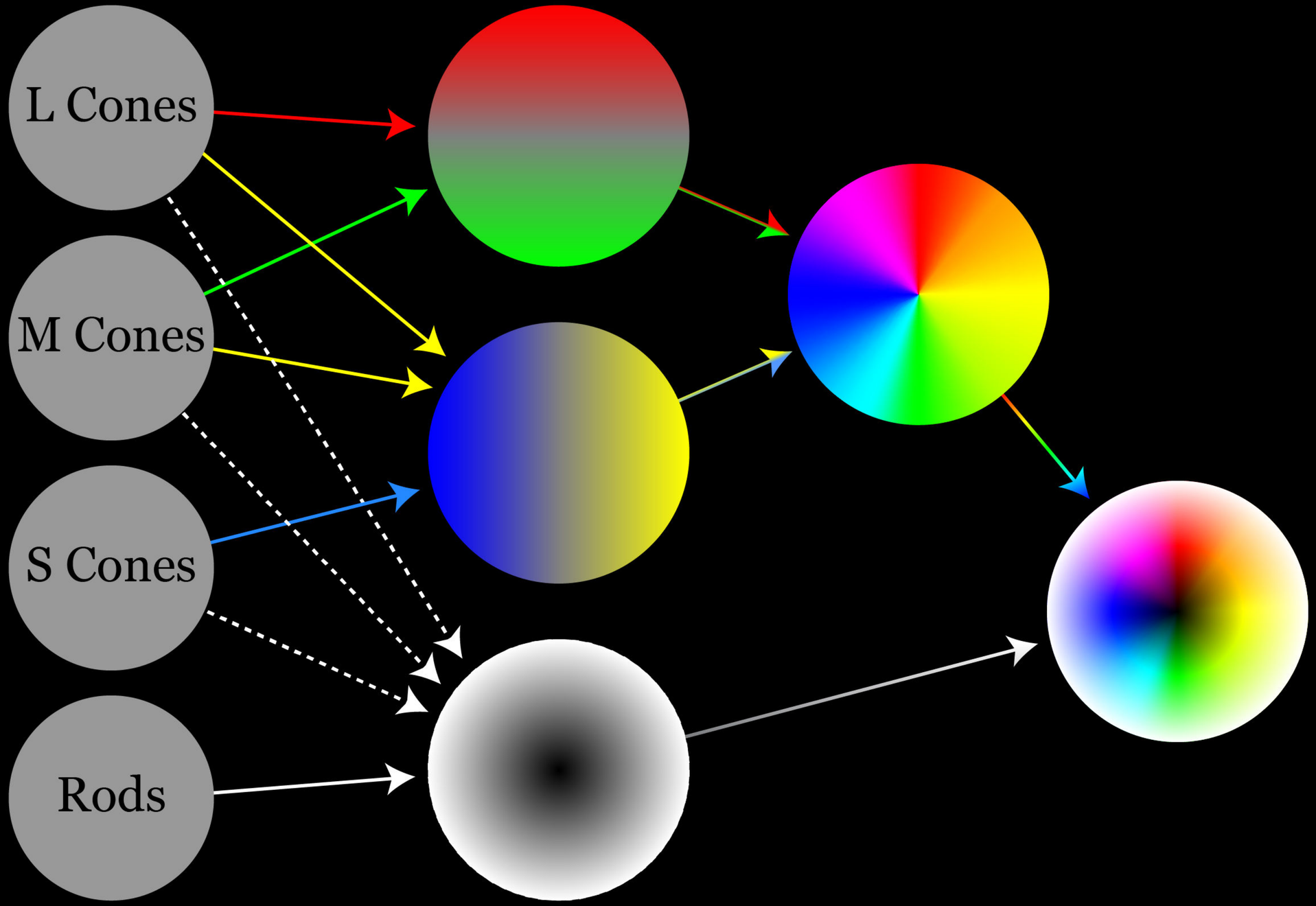
For example, when we see 580 nm light…

- L cone response is high
- M cone response is moderate
- S cone response is nil

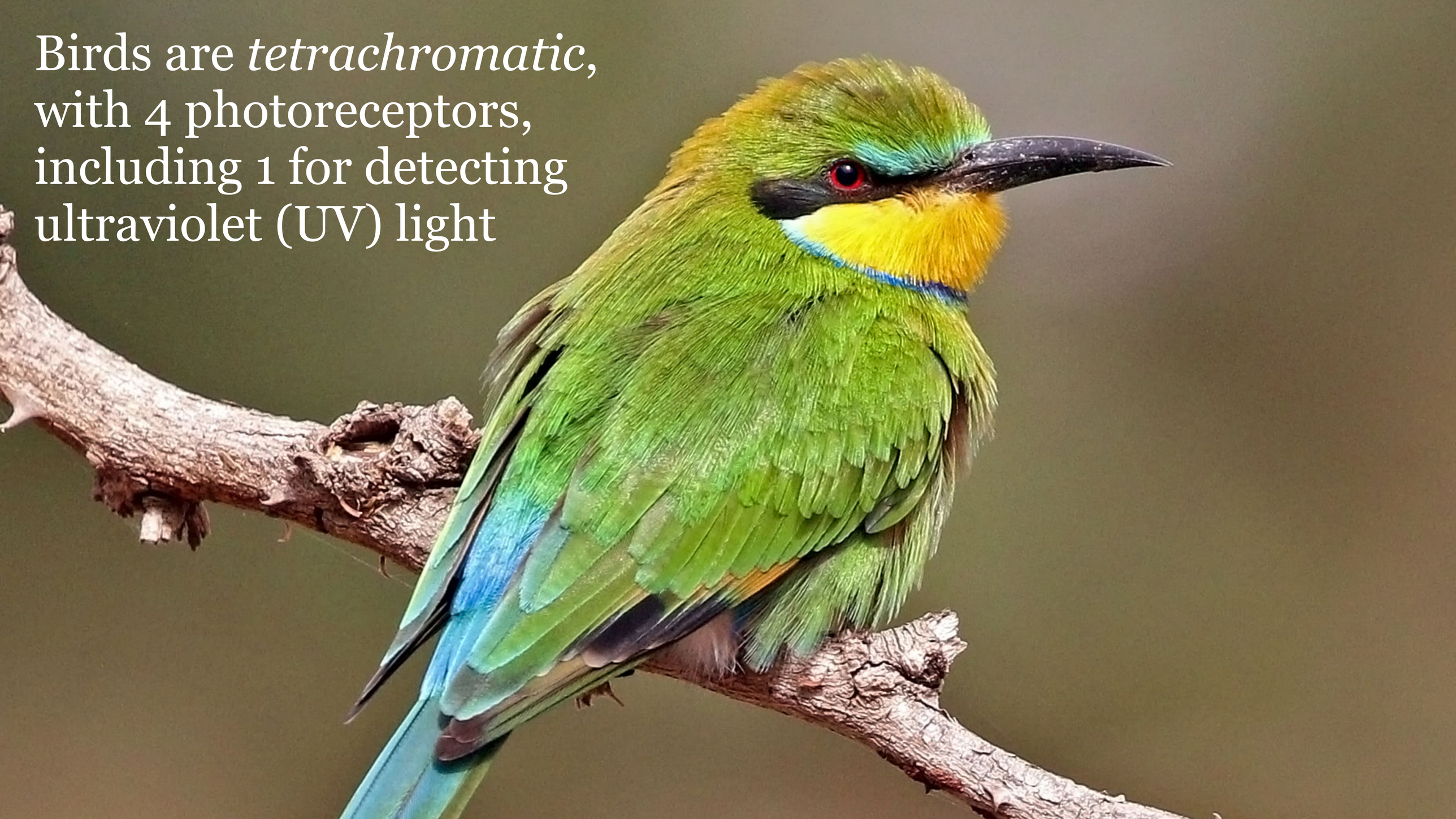
Resulting in a yellow color signal sent to the brain

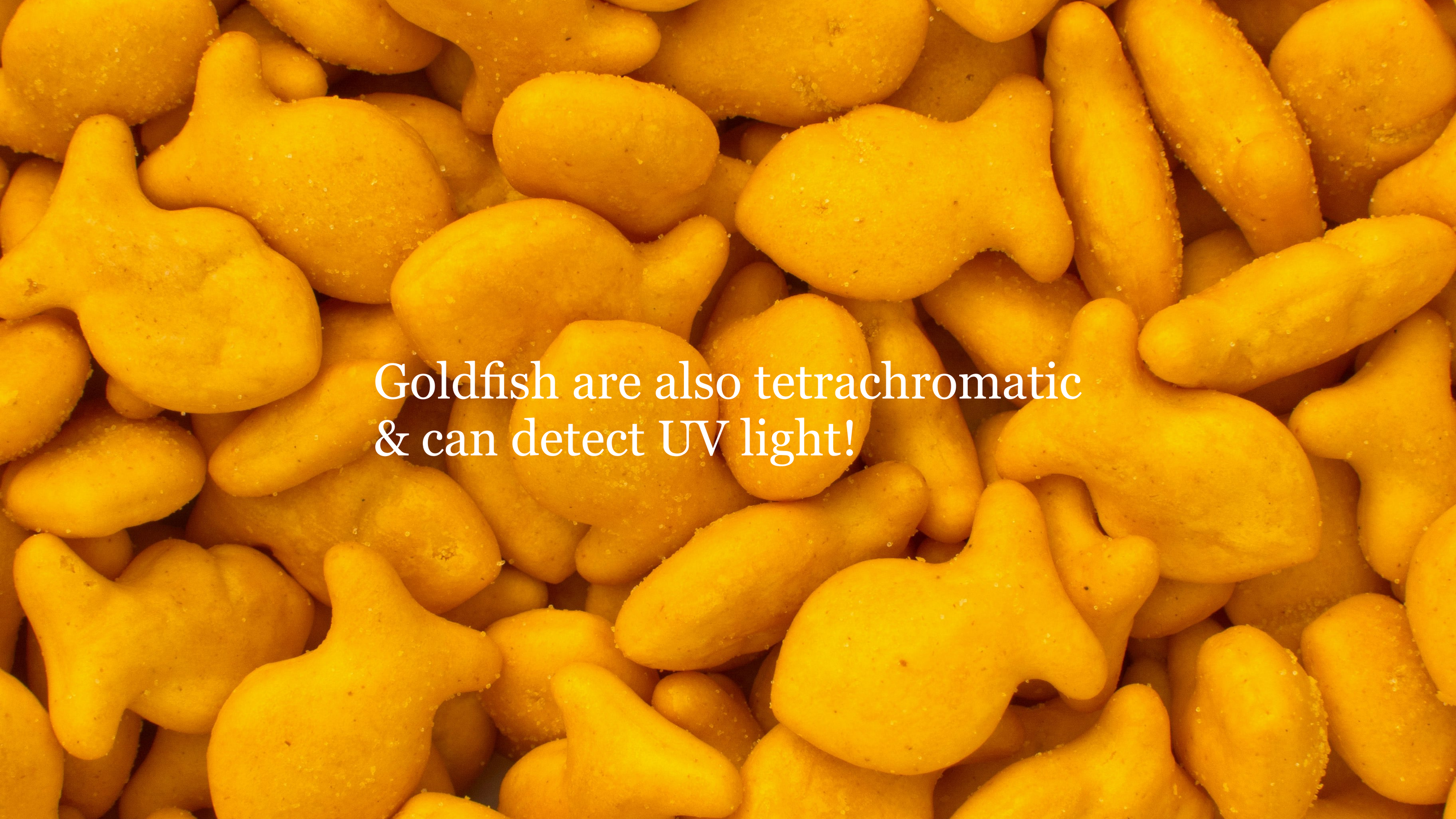

S
M
L
400
450
500
550
600
650
700
Wavelength (nm)


S
M
L
400
450
500
550
600
650
700
Wavelength (nm)

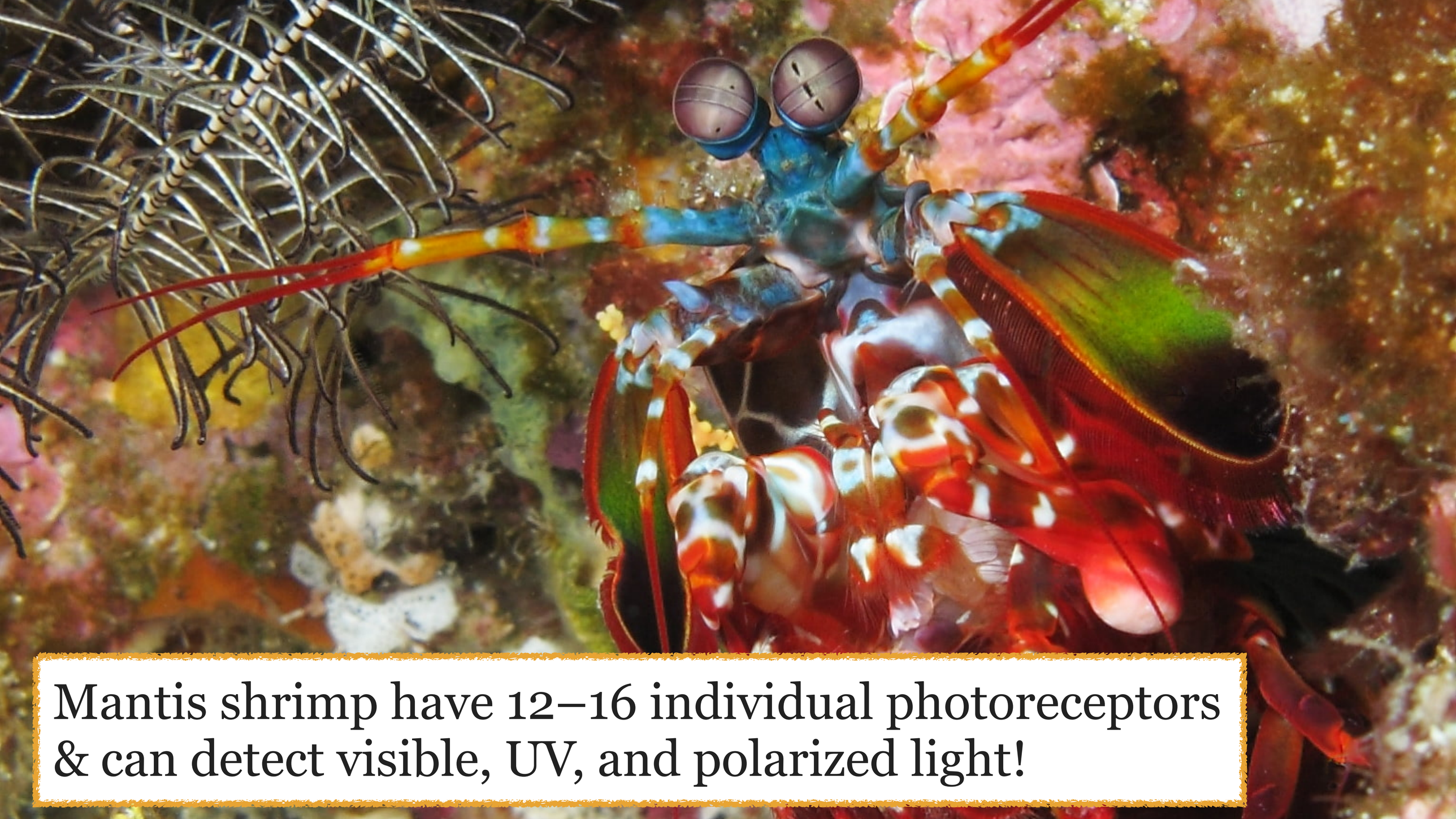

L Cones
M Cones
S Cones
Rods


Dogs have just 2
photoreceptors:
green & blue


Birds are *tetrachromatic*,
with 4 photoreceptors,
including 1 for detecting
ultraviolet (UV) light


Goldfish are also tetrachromatic
& can detect UV light!


Octopuses can detect polarized light, &
may be able to see colors even though
they have only 1 photoreceptor



Mantis shrimp have 12–16 individual photoreceptors & can detect visible, UV, and polarized light!

Mantis shrimp have 12–16 individual photoreceptors & can detect visible, UV, and polarized light!

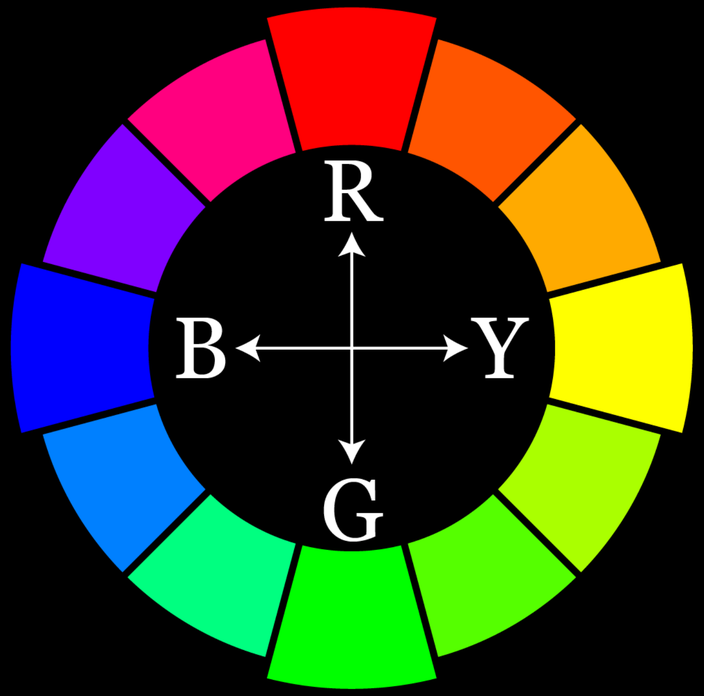
Color Blindness

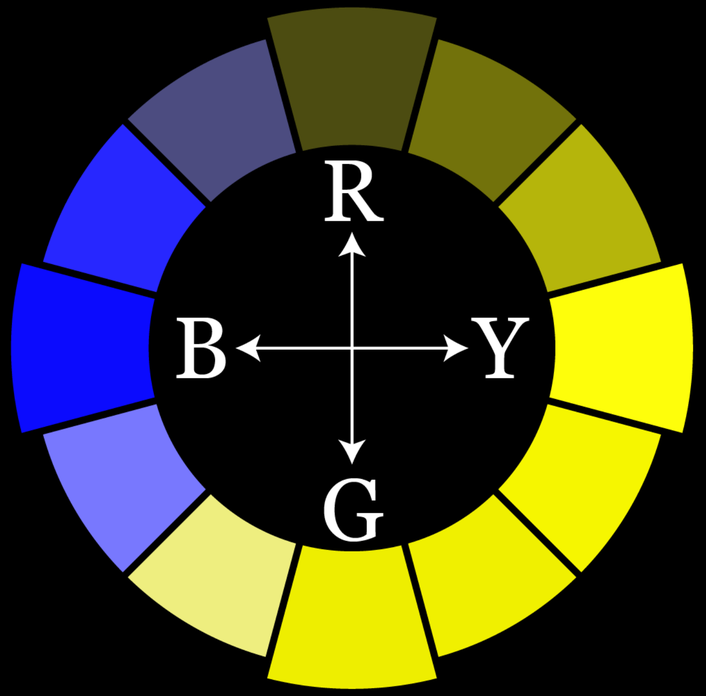
Color blindness is a complex, nuanced condition, not a black & white absolute

It’s not “I can’t see red at all & instead see gray!”

Instead it’s “I have trouble telling the difference between some greens & some reds”

Normal

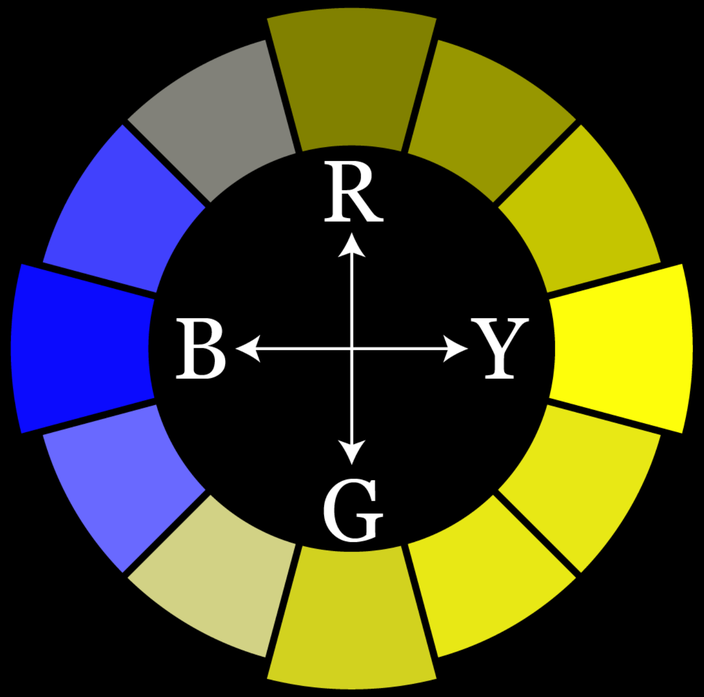


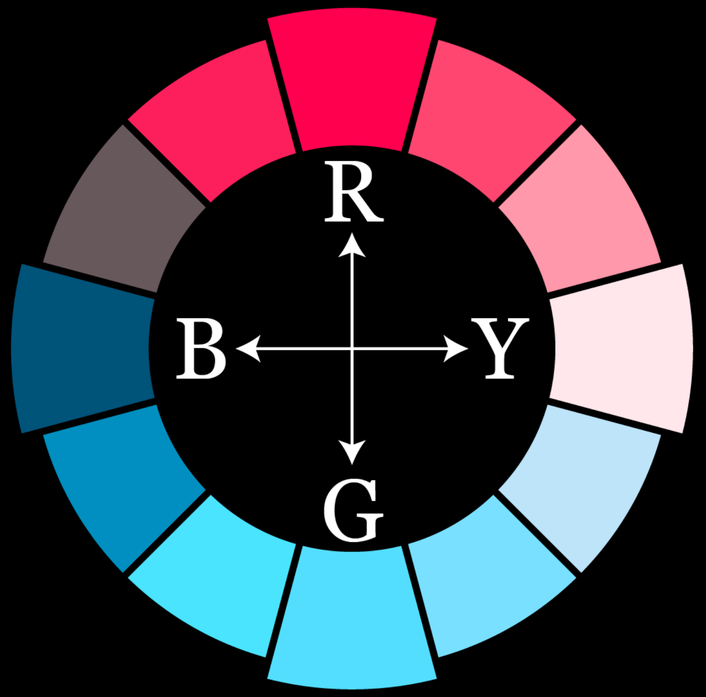


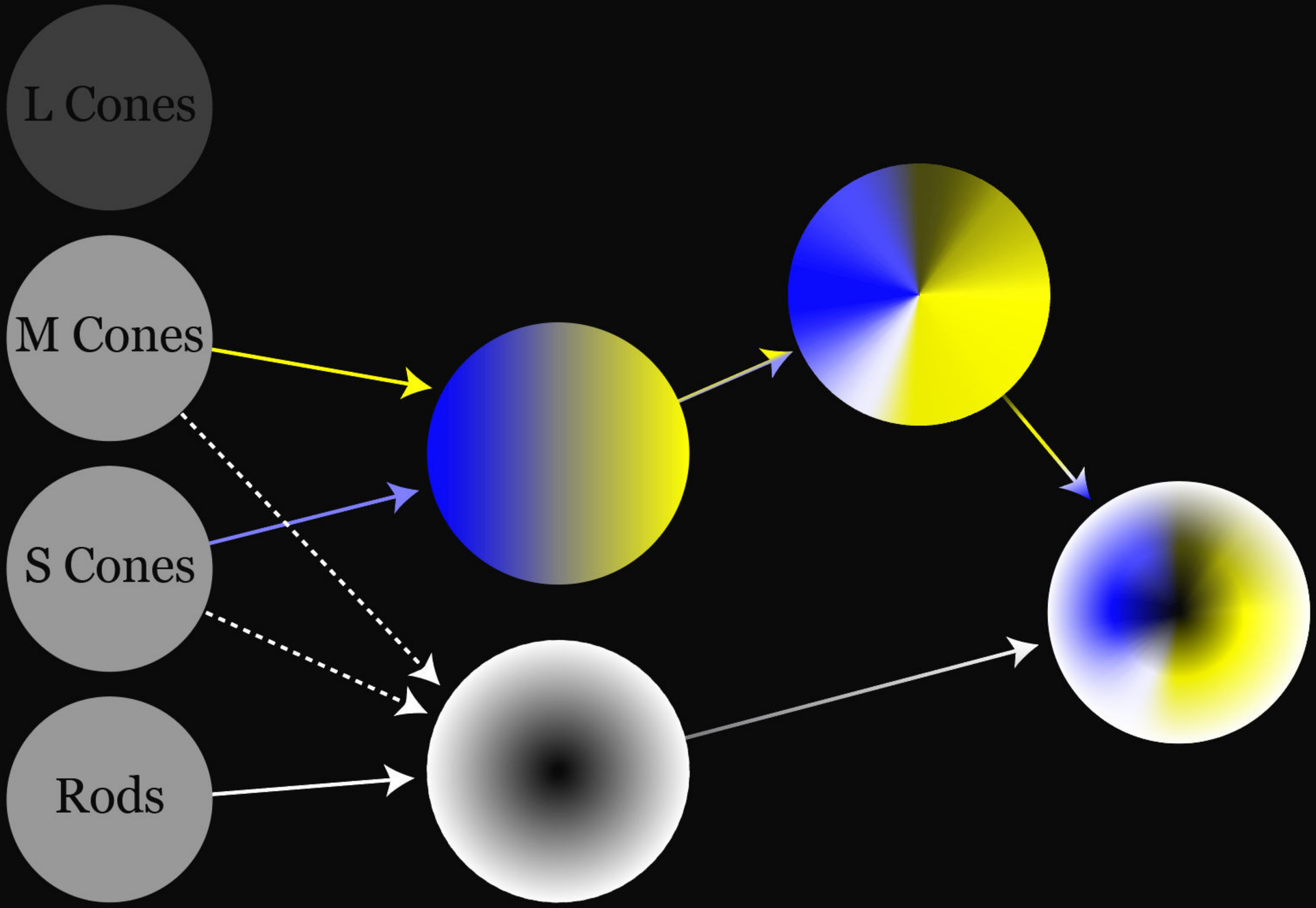
Deuteranopia

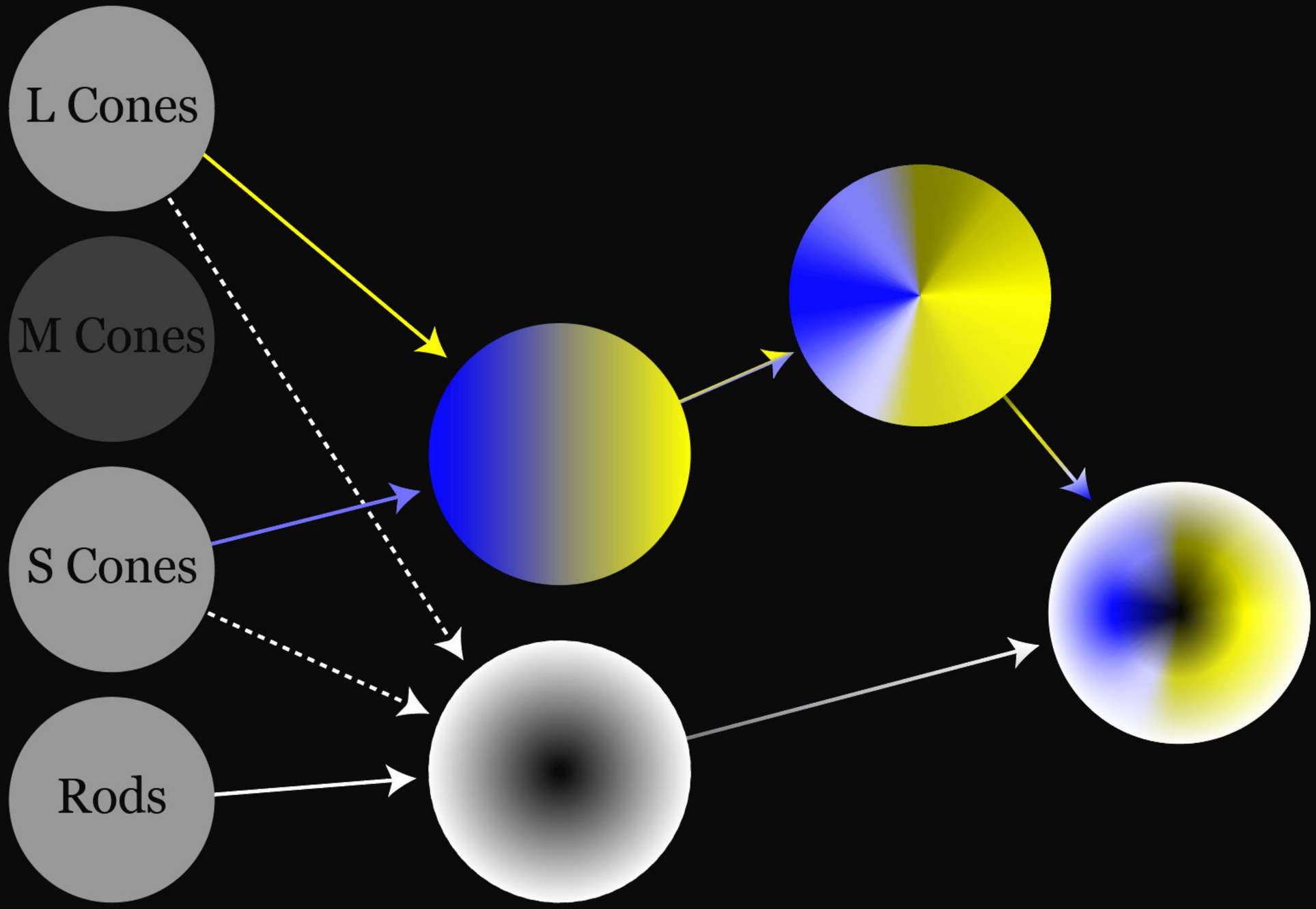
No M cone

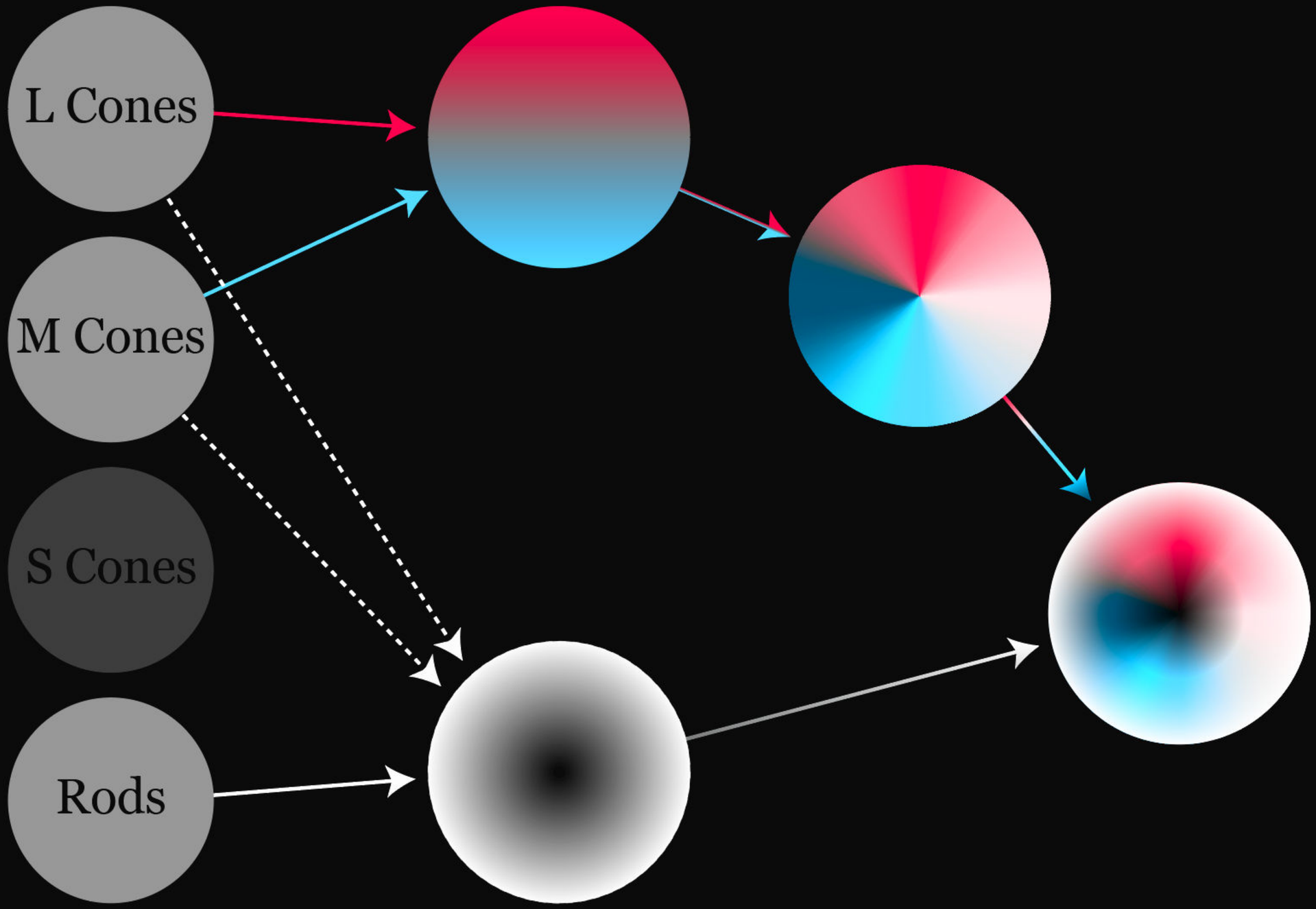
~~Green-blind~~






L Cones
M Cones
S Cones
Rods


L Cones
M Cones
S Cones
Rods

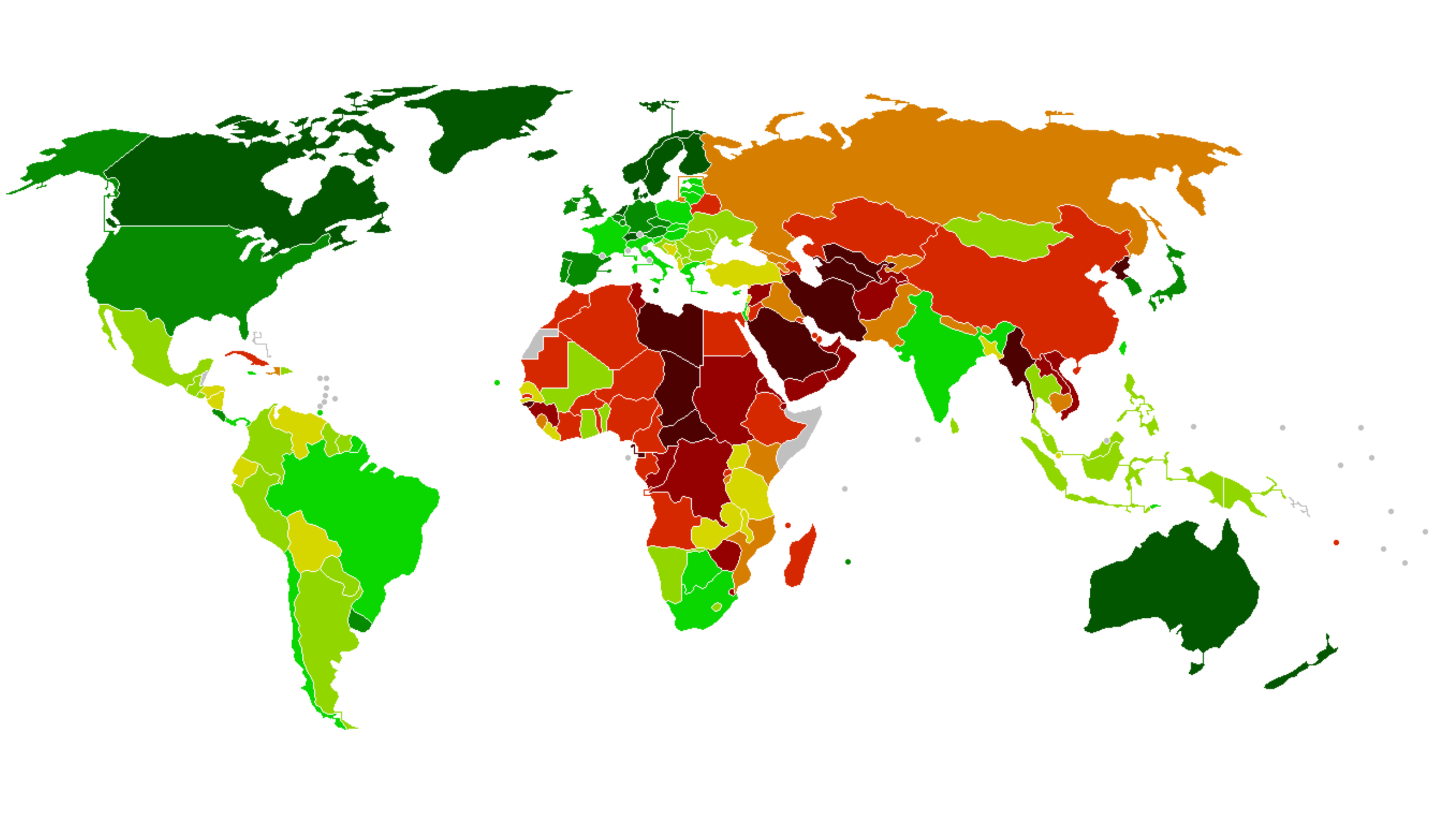

L Cones
M Cones
S Cones
Rods

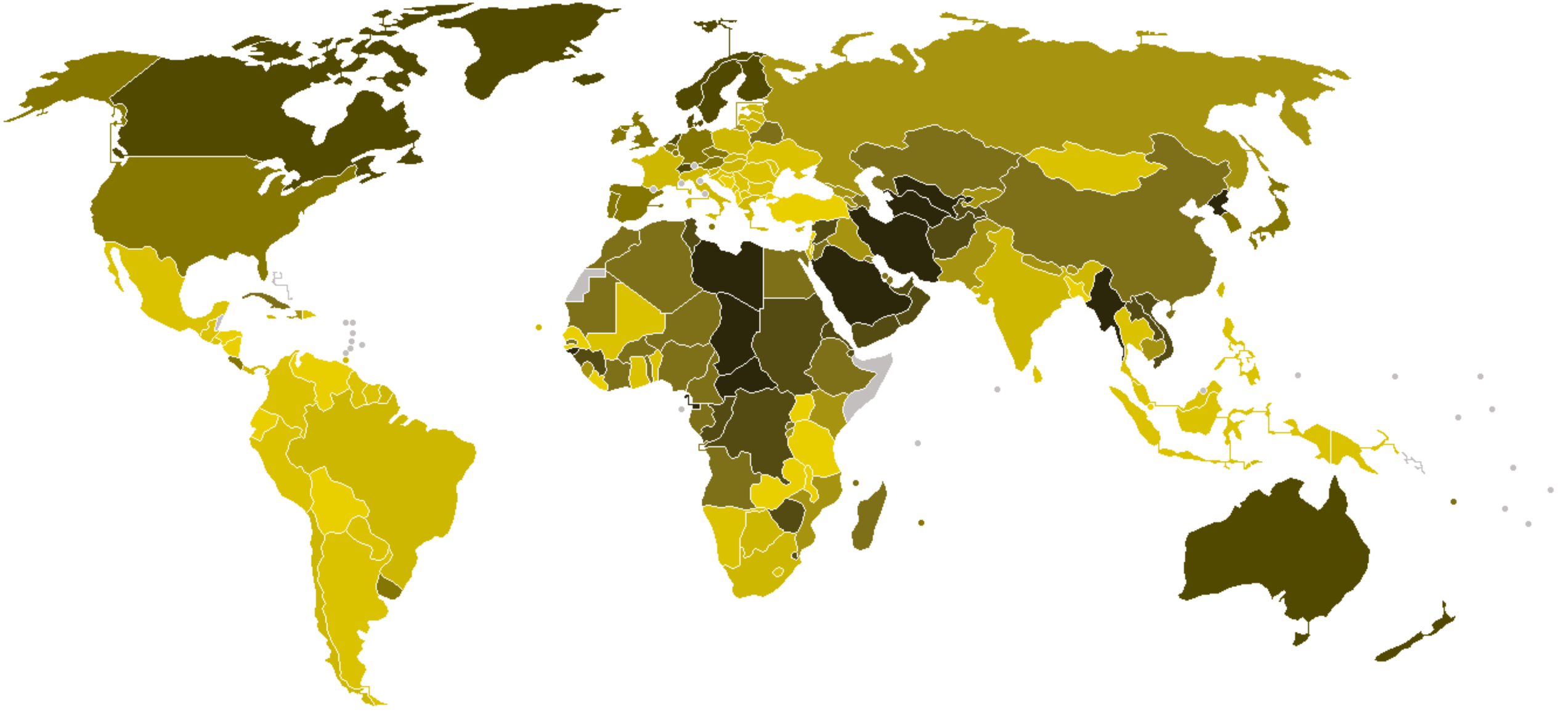
Color blindness is on a continuum: some people are heavily affected, some are barely affected, & most are in between

Type	Deficiency	Males	Females
Protanopia	L cone absent	1.3%	0.02%
Deuteranopia	M cone absent	1.2%	0.01%
Tritanopia	S cone absent	0.001%	0.03%
Total		2.4%	0.03%
Protanomaly	L cone deficient	1.3%	0.02%
Deuteranomal	M cone deficient	5%	0.35%
Tritanomaly	S cone deficient	0.0001%	0.0001%
Total		6.3%	0.37%

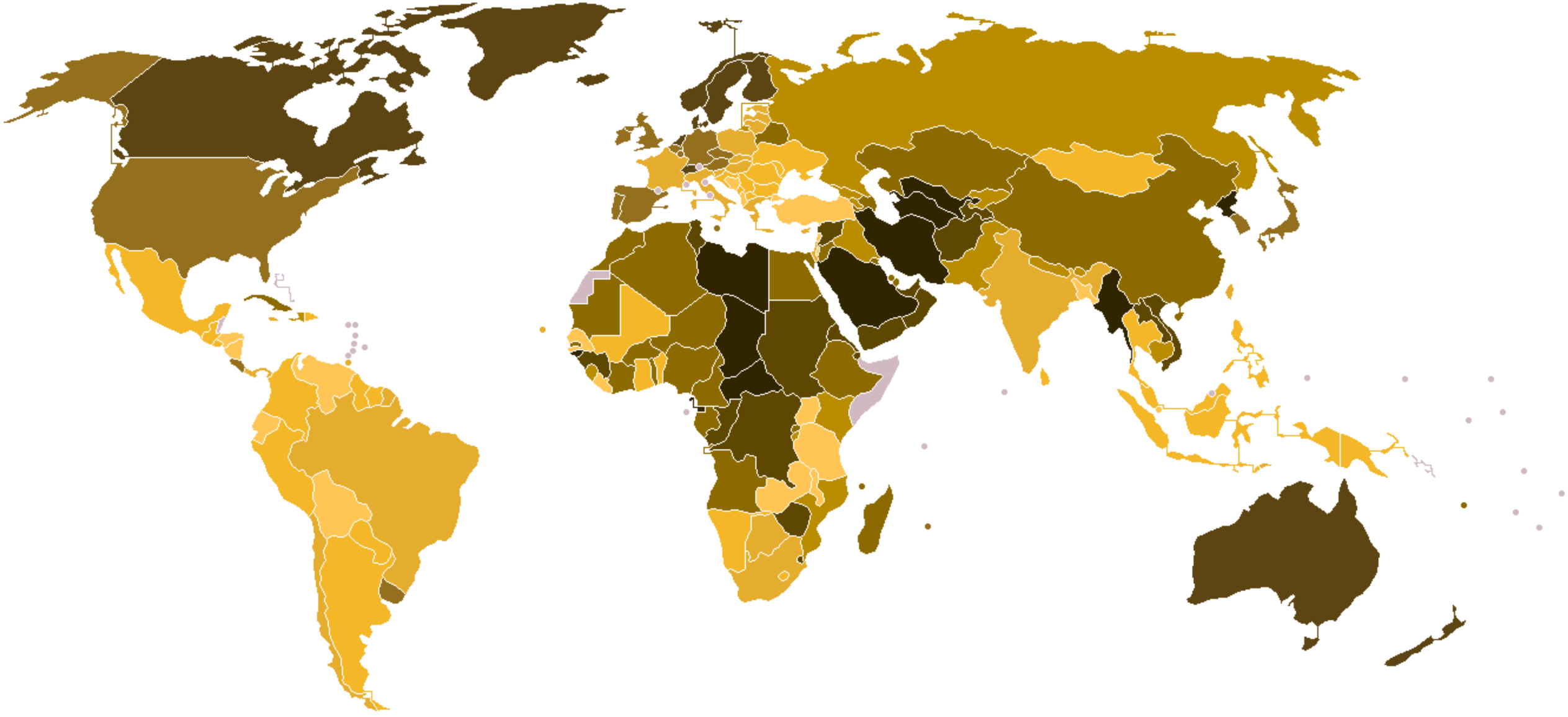
If you’re a designer, avoid red-green color contrast for differentiation

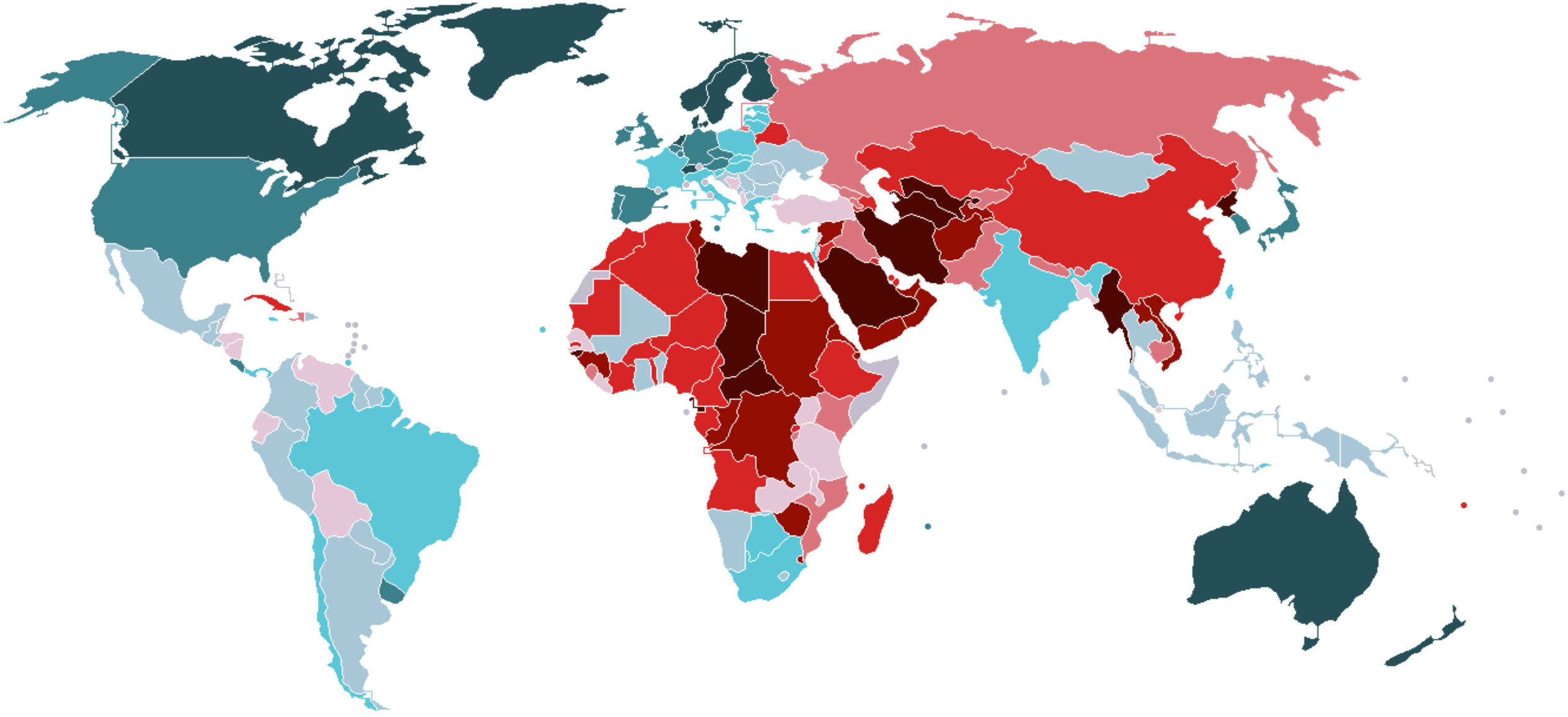
Instead, depend upon lightness contrast & use blue





P





Test for color blindness

Colorblind Web Page Filter

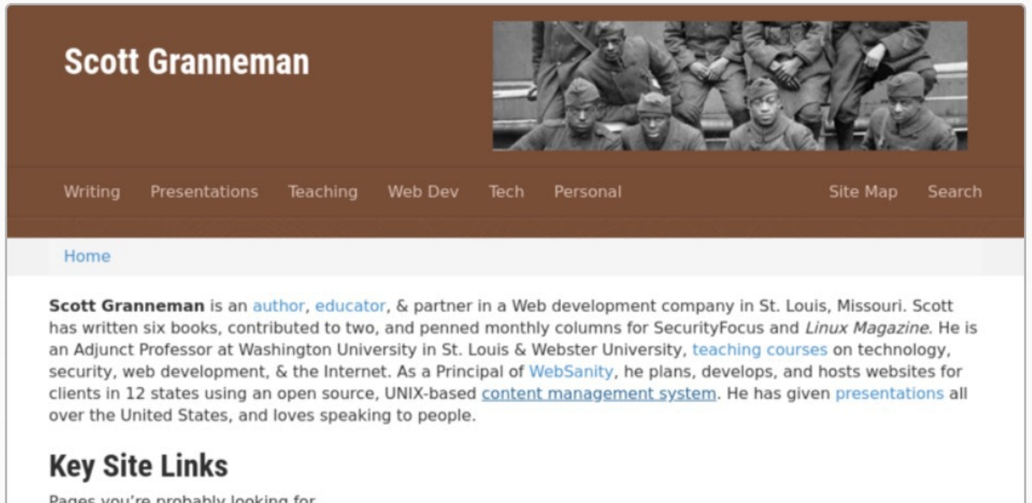
What are color blind anomalies? ⓘ

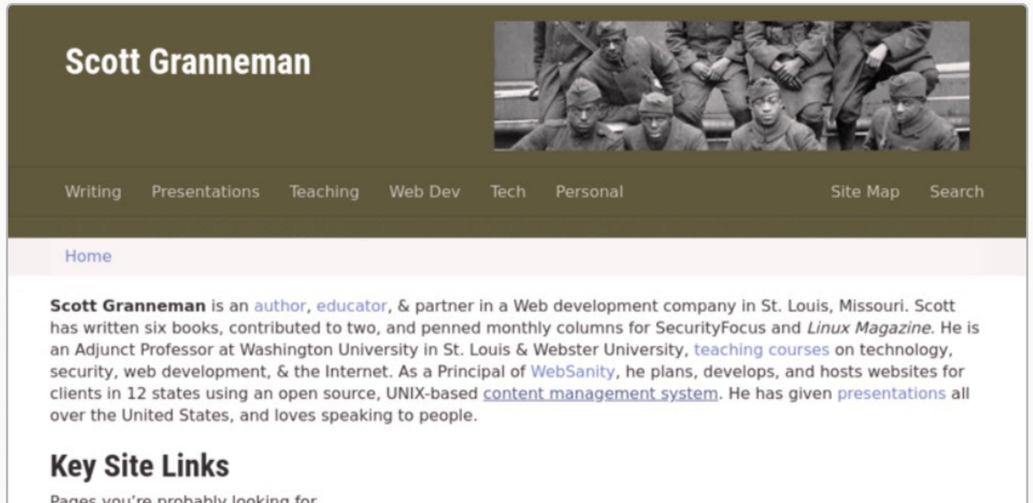
Please indicate a resource to be viewed, and a color filter to be applied to that resource.

Type a URL:
https://granneman.com

And then pick a color filter:
Protanopia

FETCH AND FILTER!





Colorblind Web Page Filter

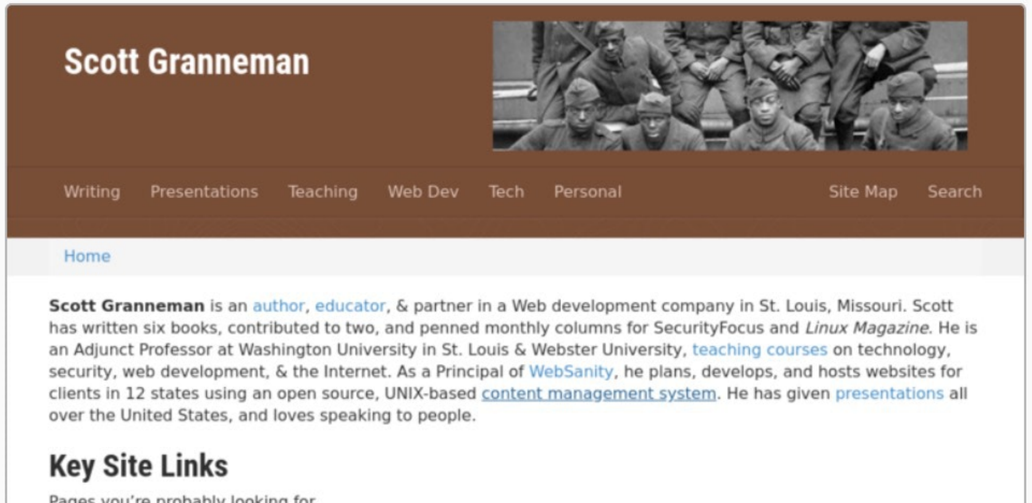
What are color blind anomalies? ⓘ

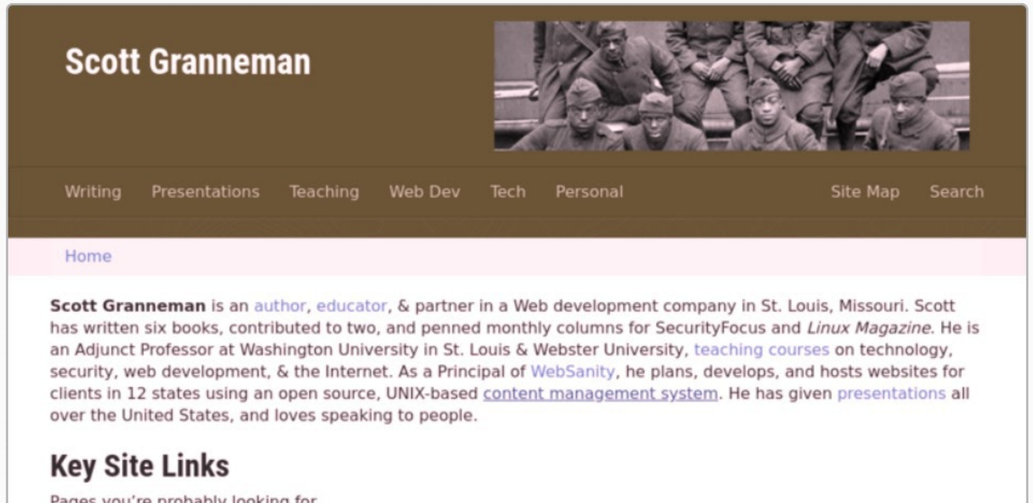
Please indicate a resource to be viewed, and a color filter to be applied to that resource.

Type a URL:
https://granneman.com

And then pick a color filter:
Deutanopia

FETCH AND FILTER!





Colorblind Web Page Filter

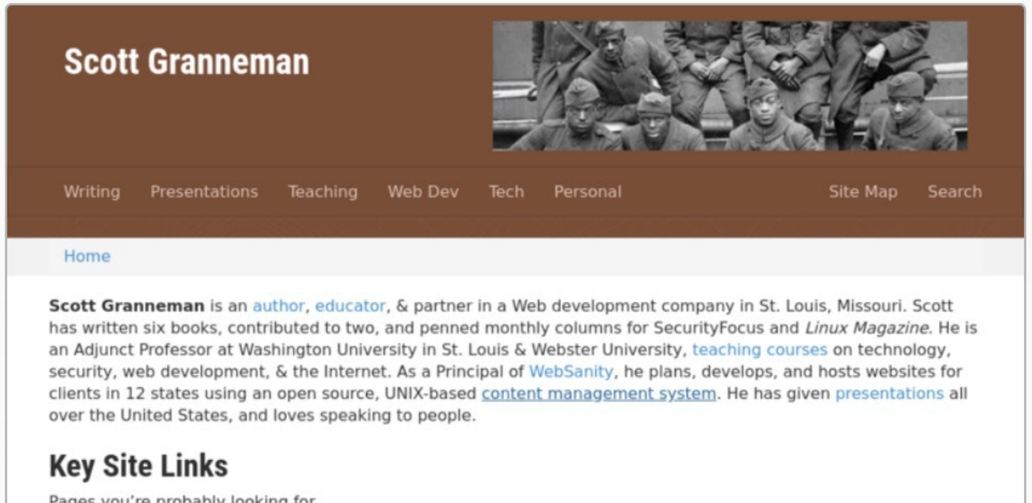
What are color blind anomalies? ⓘ

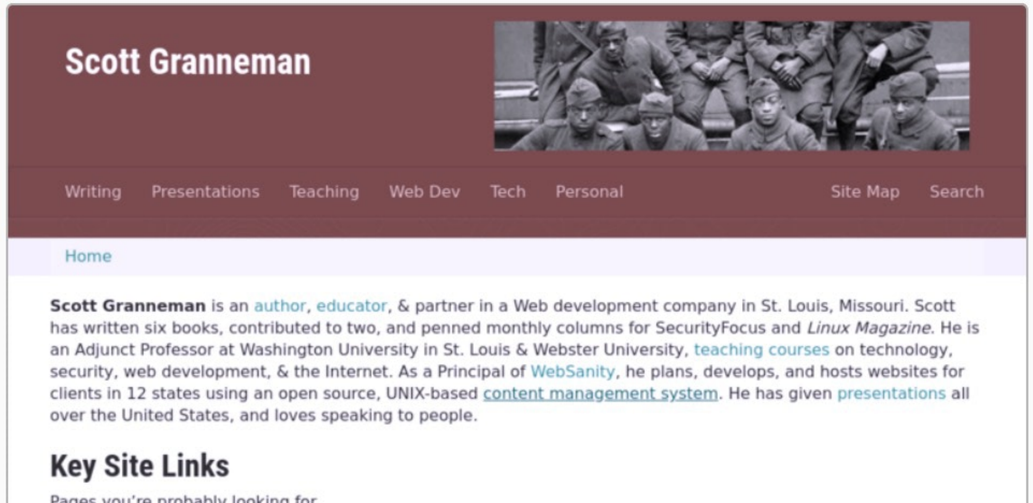
Please indicate a resource to be viewed, and a color filter to be applied to that resource.

Type a URL:
https://granneman.com

And then pick a color filter:
Tritanopia

FETCH AND FILTER!





Colorblind Web Page Filter

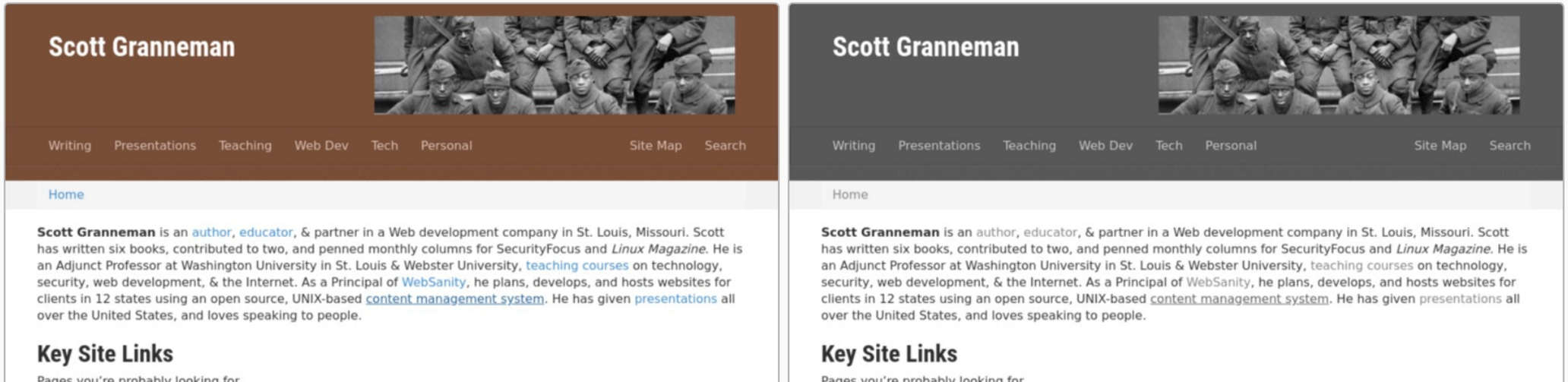
What are color blind anomalies? ⓘ

Please indicate a resource to be viewed, and a color filter to be applied to that resource.

Type a URL:
https://granneman.com

And then pick a color filter:
Greyscale/achromatopsia

FETCH AND FILTER!



Sim Daltonism

The color blindness simulator.

Sim Daltonism for iOS

Sim Daltonism for Mac

From the perspective of a color blind person, some colors are impossible to distinguish. Sim Daltonism lets you visualize colors as they are perceived with various types of color blindness. Use the camera on your iOS device, or use the Mac app to filter a region of the screen.

Sim Daltonism is open source. Take a look and contribute code if you like.

Color Oracle

Design for the Color Impaired

Color Oracle is a free color blindness simulator for Windows, Mac and Linux. It takes the guesswork out of designing for color blindness by showing you in real time what people with common color vision impairments will see.

Color Oracle applies a full screen color filter to art you are designing, independently of the software in use. Eight percent of all males are affected by color vision impairment – make sure that your graphical work is readable by the widest possible audience.

Download

Version 1.3, May 5, 2018.

macOS Windows Linux

Colour Oracle for Windows and Linux requires Java 6 or higher.

macOS 10.15 Catalina users, please see the manual for fixing a common issue.

Read this article for more information: Color Design for the Color Vision Impaired

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Saint Louis Zoo
Animals Always®

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FEATURES

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  8 a.m. to 5 p.m. Mon-Thurs;
  8 a.m. to 7 p.m. Fri-Sun & holidays
- McDonnell Polar Bear Point is OPEN!
- Adopt a polar bear!

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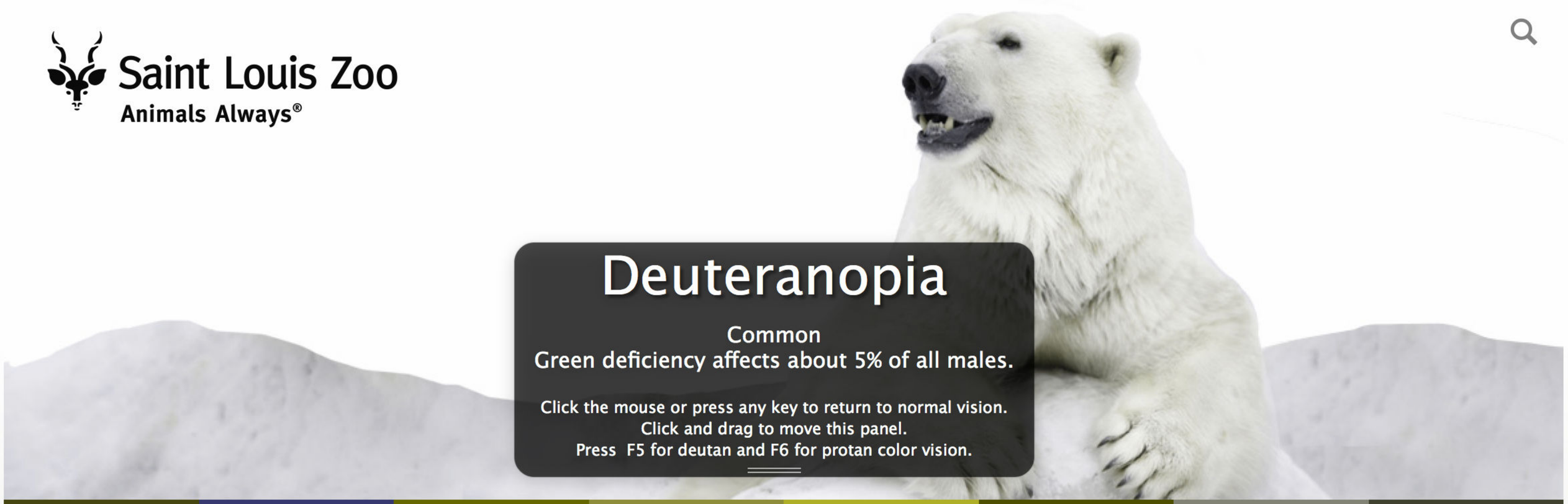


Deuteranopia

Common
Green deficiency affects about 5% of all males.

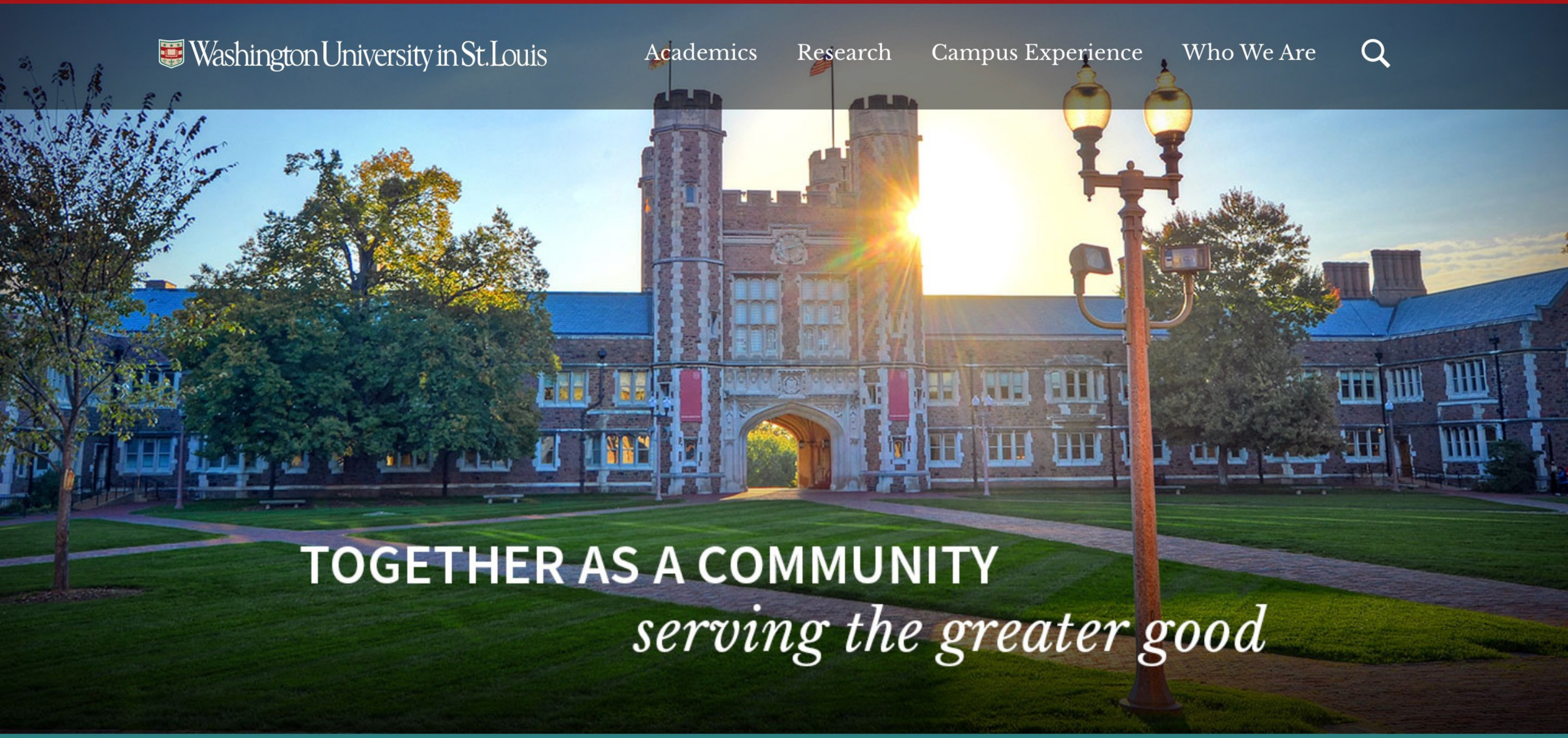
Click the mouse or press any key to return to normal vision.
Click and drag to move this panel.
Press F5 for deutan and F6 for protan color vision.

Save with a Safari Pass!

Enjoy a full day of Zoo fun including the Children's Zoo, Zooline Railroad, Stingrays at Caribbean Cove,

FEATURES

- Summer Hours
  8 a.m. to 5 p.m. Mon-Thurs;
  8 a.m. to 7 p.m. Fri-Sun & holidays
- McDonnell Polar Bear Point is OPEN!
- Adopt a polar bear!



For the latest information about our response to COVID-19, visit covid19.wustl.edu.

University flag at half-staff: Nancy Rubin

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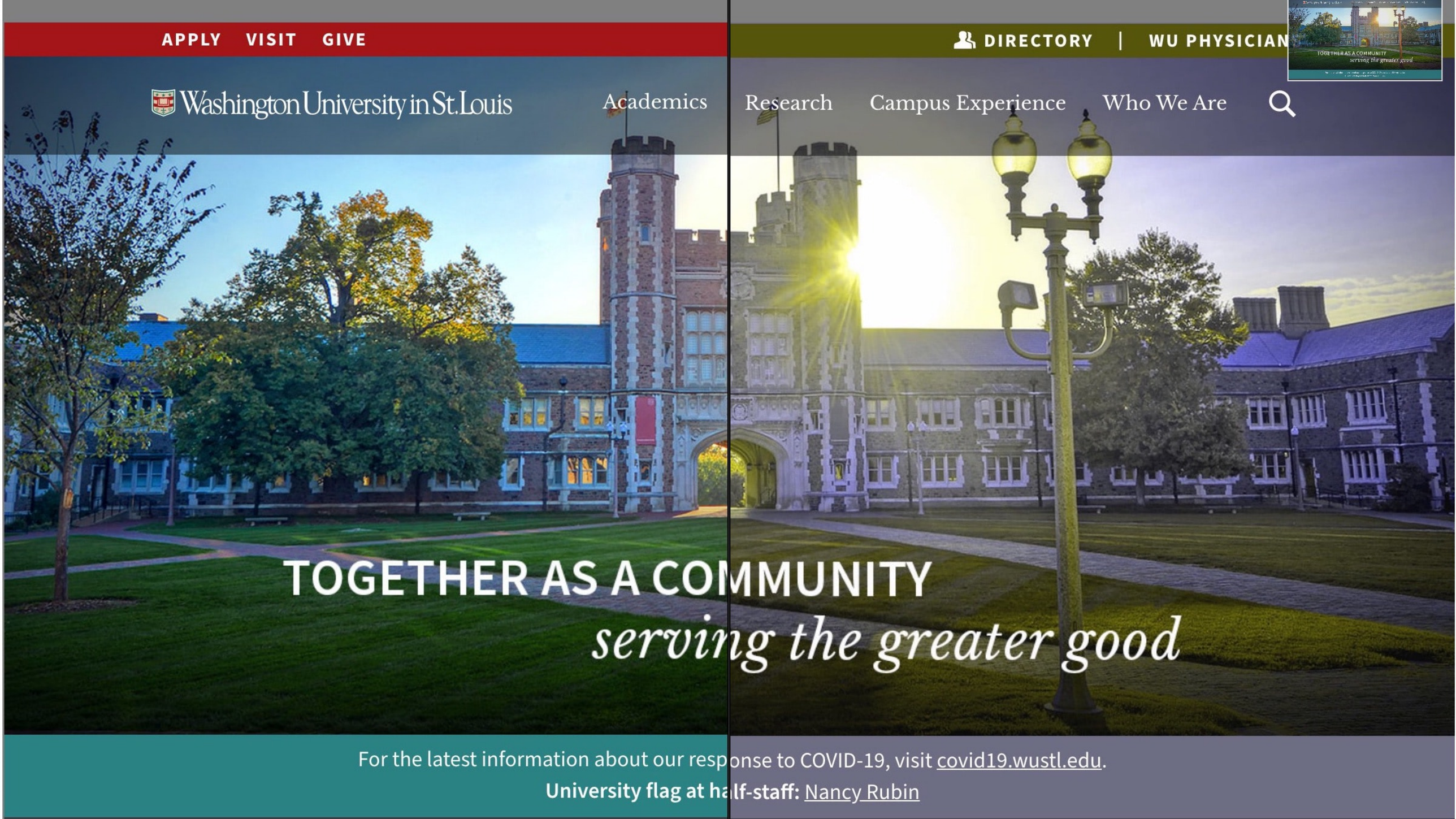
APPLY VISIT GIVE
DIRECTORY | WU PHYSICIAN
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Research
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Who We Are
TOGETHER AS A COMMUNITY
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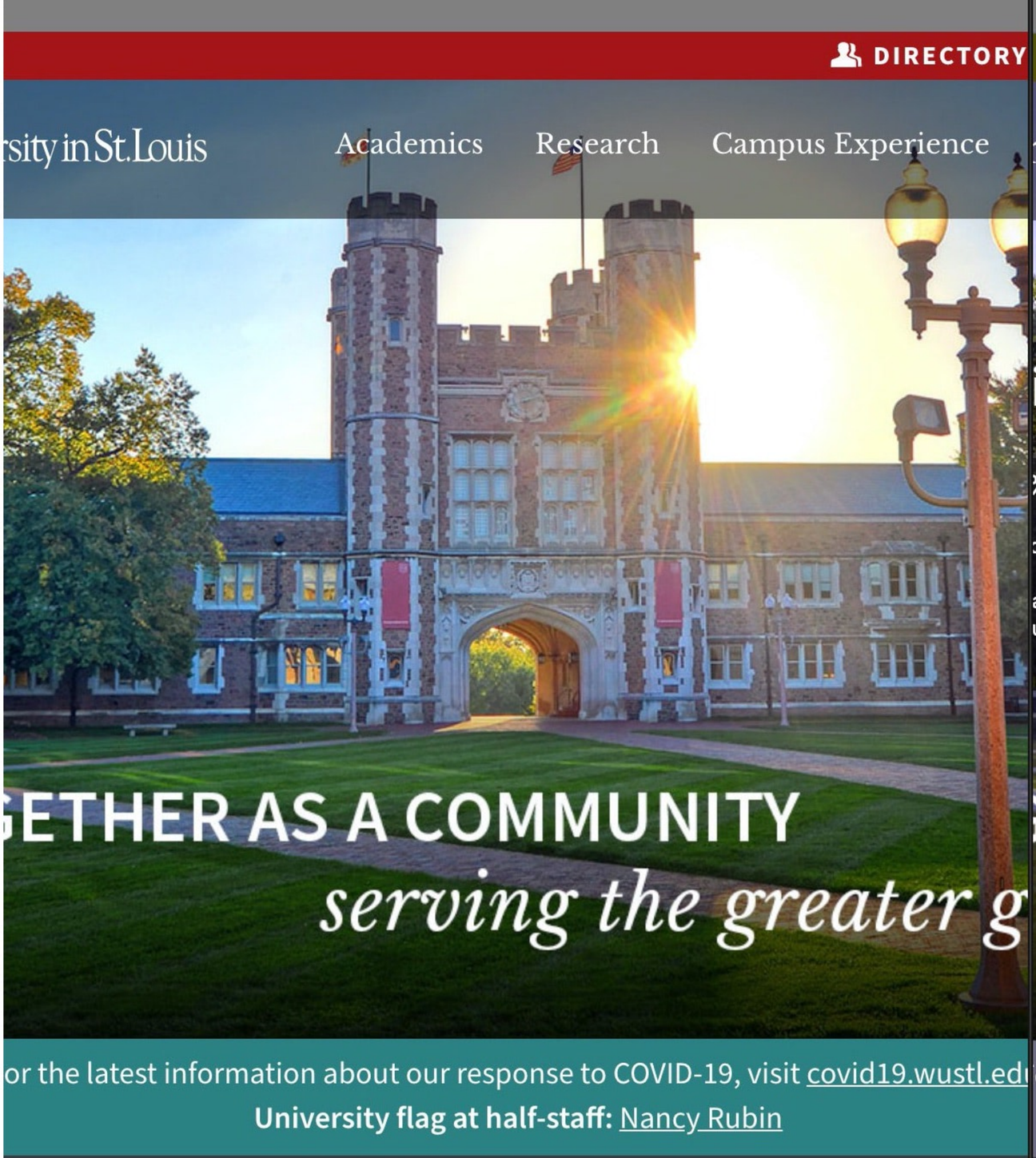
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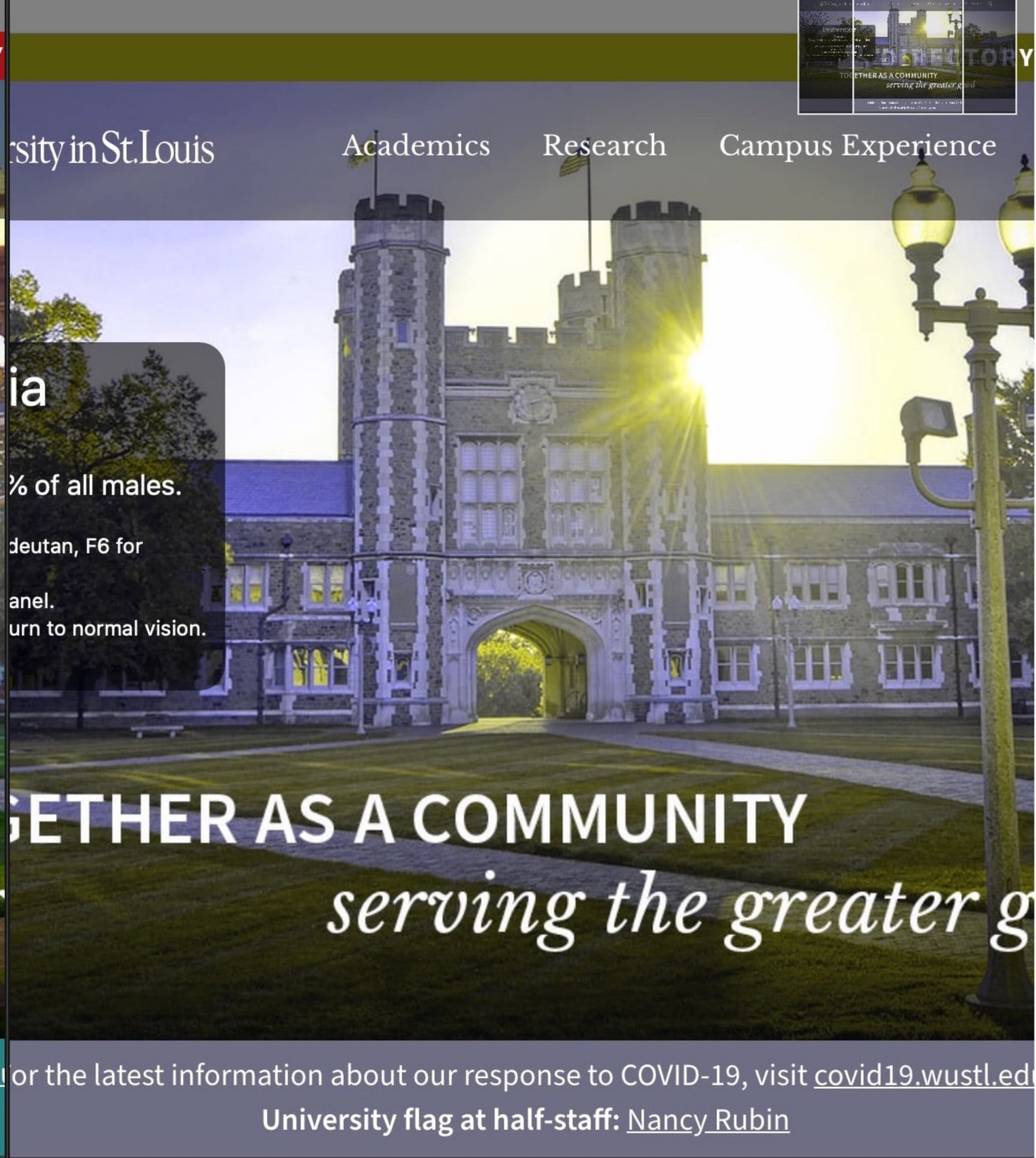
ia
% of all males.
deutan, F6 for
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Academics
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Campus Experience
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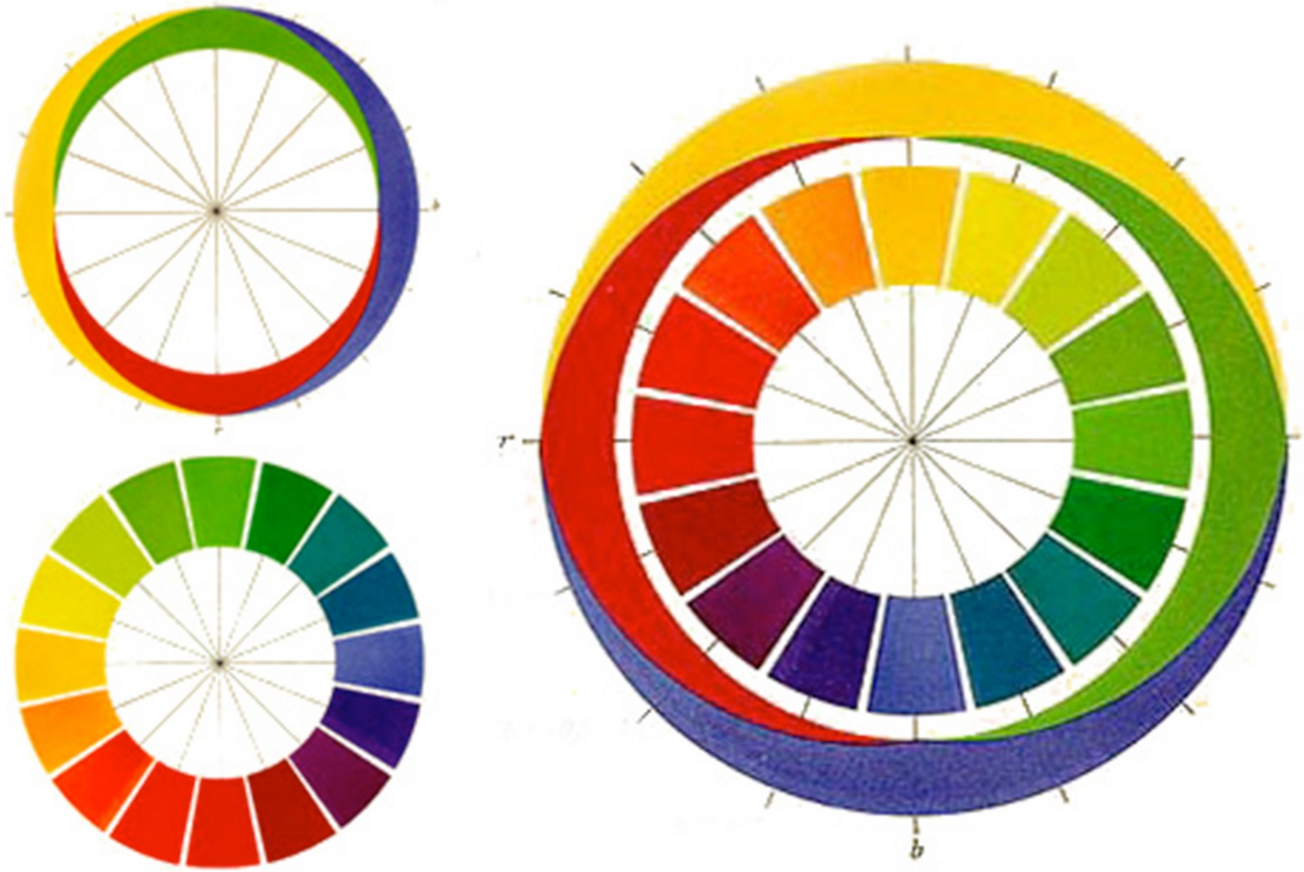
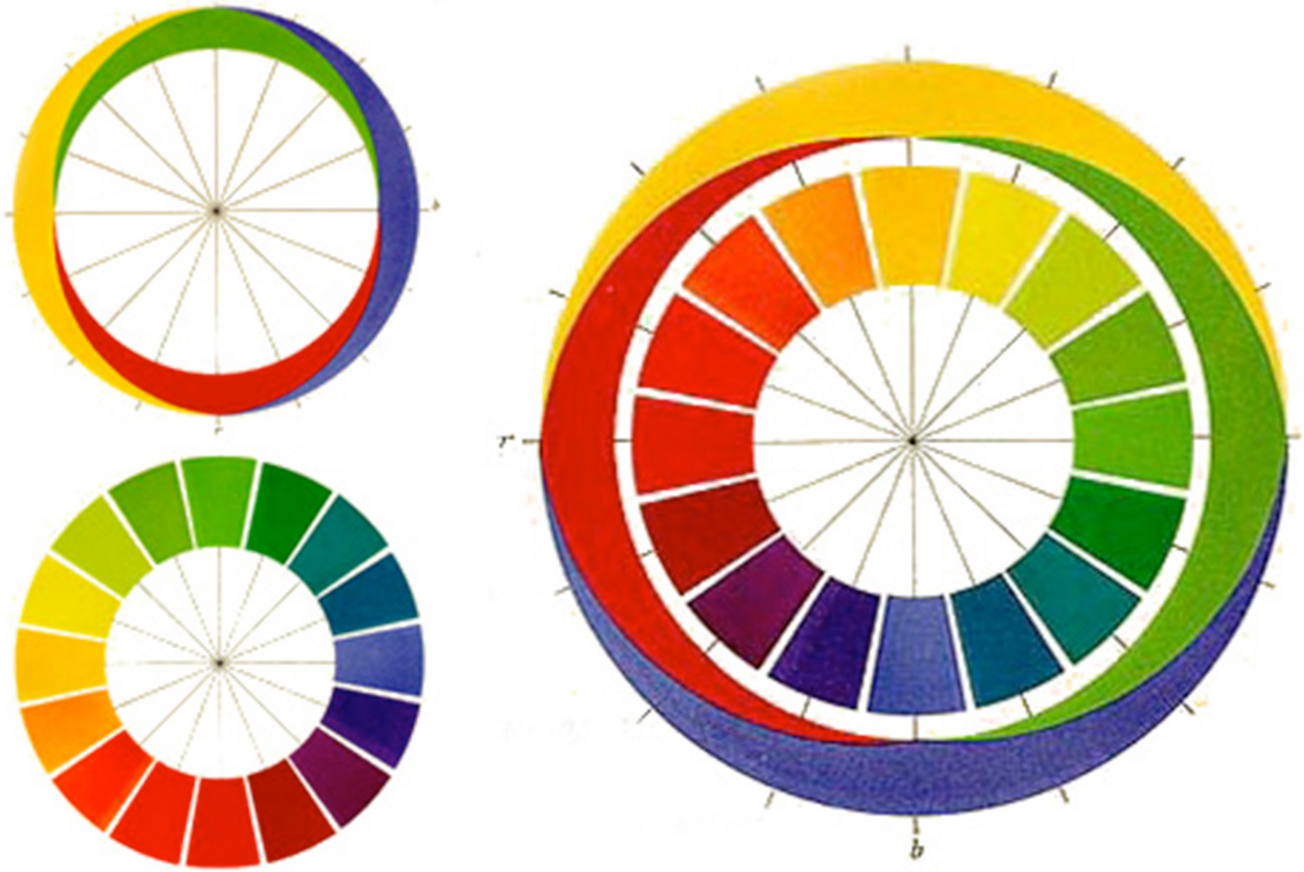
Mind Games

Psychological Primary Colors

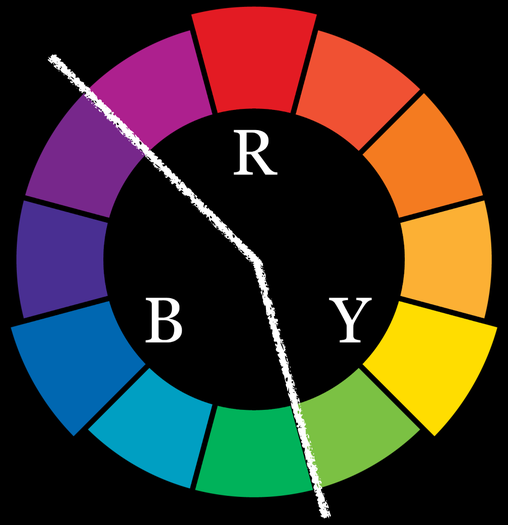
Leonardo da Vinci (1452–1519) classified yellow, blue, red, & green as “simple” colors

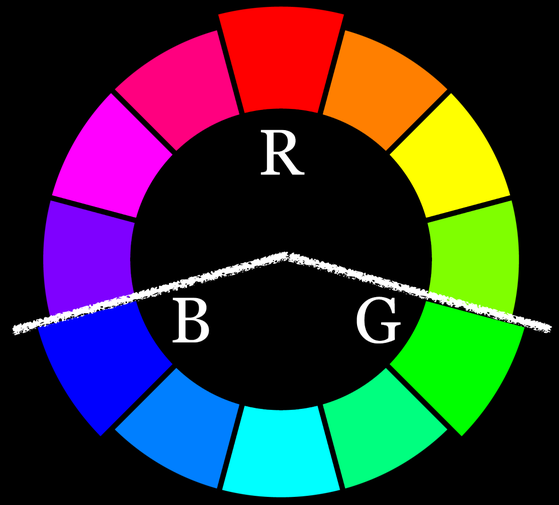


Ewald Hering (1834–1918) created the 4-primary color wheel in 1878

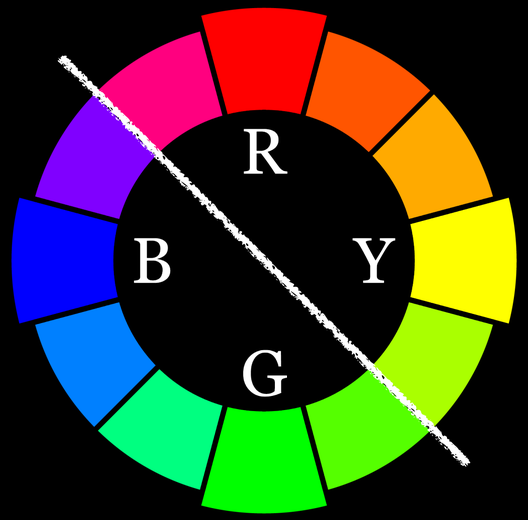


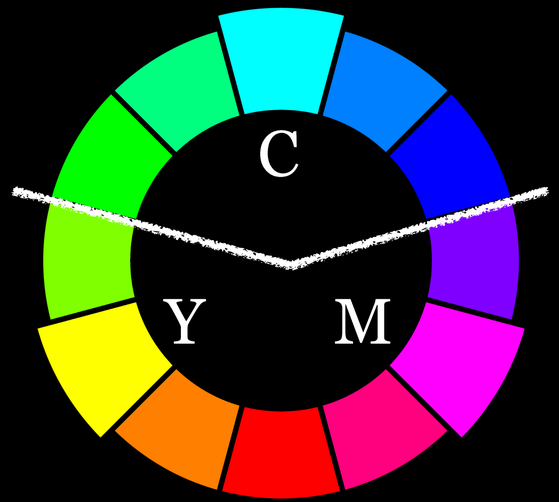
Outer ring shows that every primary color group (yellow, blue, red, & green) has a warm & cool side

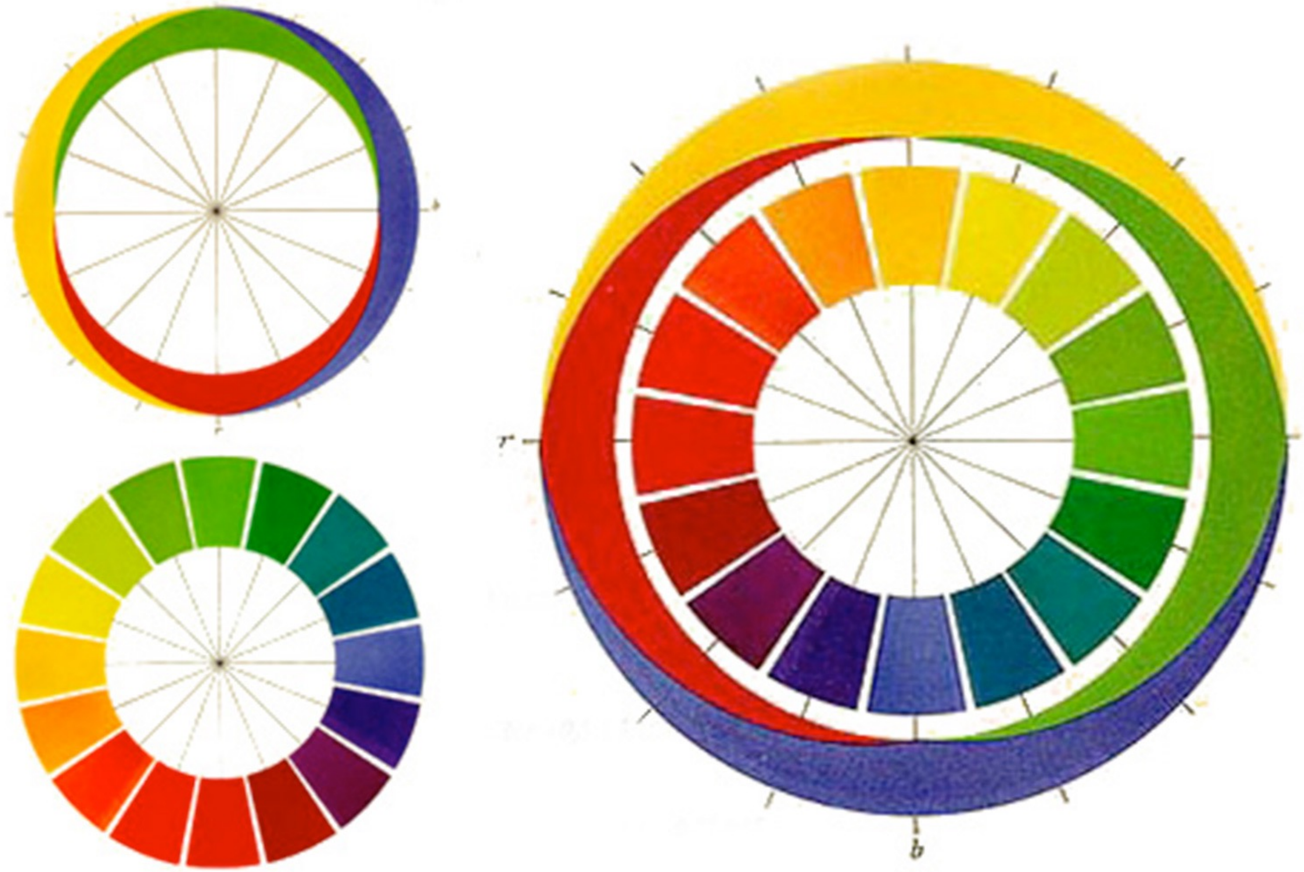




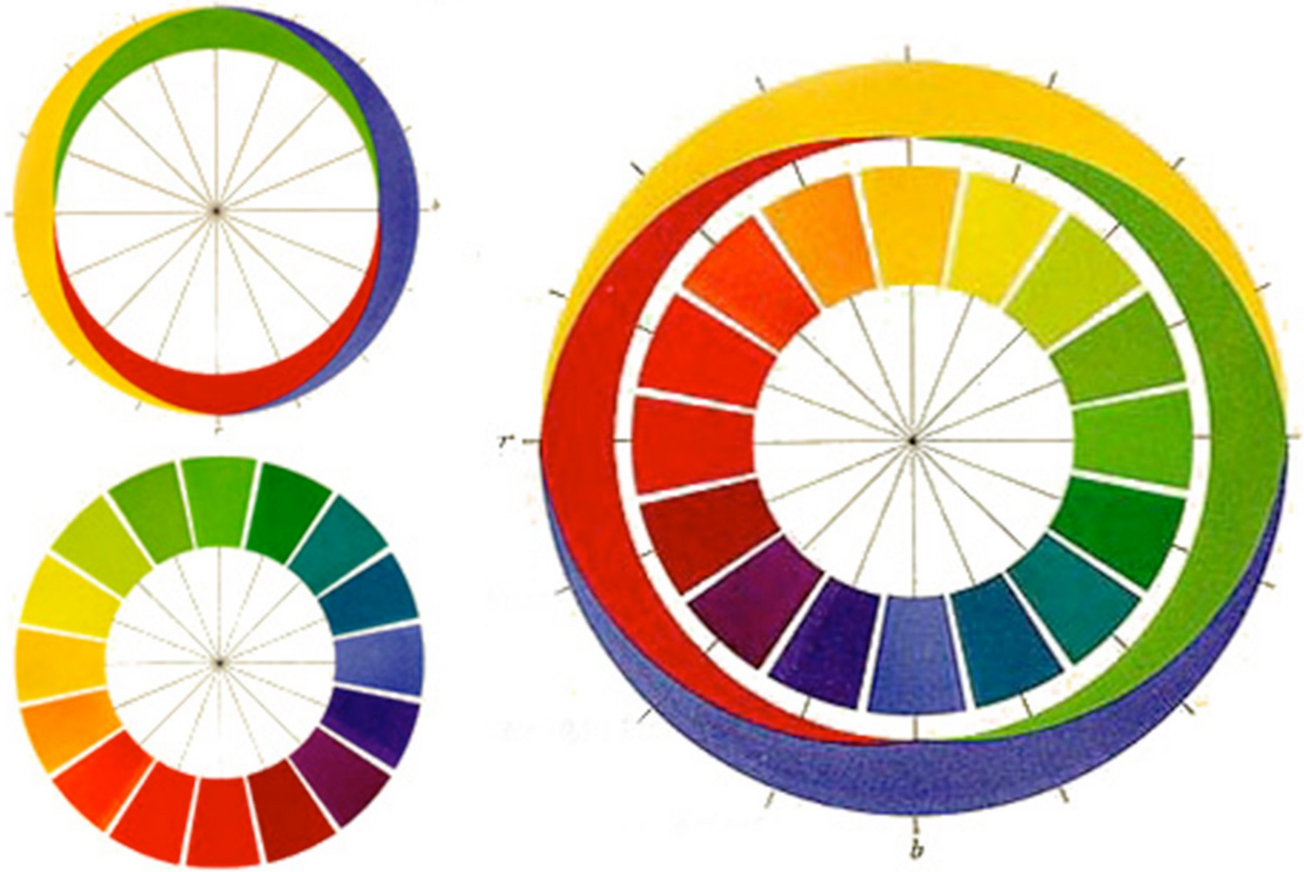
You can easily divide into warm & cool with Hering's 4-primary color geometry, but with a 3-primary version you can't really draw a straight line







Opposing colors can’t be part of one another: red & green, blue & yellow, black & white



Hering’s wheel is used as the model when testing psychological response to color

Perceptual and Motor Skills, 1975, 41, 207-210.

EFFECTS OF FOUR PSYCHOLOGICAL PRIMARY COLORS ON ANXIETY STATE

KEITH W. JACOBS AND JAMES F. SUESS[1]

University of Southern Mississippi

Summary.—Effects of the four psychological primary colors were assessed by randomly assigning 40 undergraduates (13 male, 27 female) to 4 treatment groups, with each group receiving either red, yellow, green, or blue illumination. Anxiety state was assessed at 5-min. intervals using the State-Trait Anxiety Inventory. The red and yellow groups had significantly higher A-state scores than the blue and green groups, and these values did not change significantly during the 15-min. testing session.

For several years psychologists have been interested in a number of

Color Symbolism


26 °C
STOP
START
Bypass
OFF
MGI SUBSTRAT

People have been trying to map colors to emotions forever

Colors can definitely be associated with emotions, but it’s not simple or cut & dried

WHAT COLOR EMOTION DOES YOUR FRONT DOOR EVOKE?

OPTIMISM

CLARITY

WARMTH

FRIENDLY

CHEERFUL

CONFIDENCE

EXCITEMENT

YOUTHFUL

BOLD

CREATIVE

WISE

IMAGINITIVE

TRUST
DEPENDABLE
STRENGTH

PEACEFUL
GROWTH
HEALTH

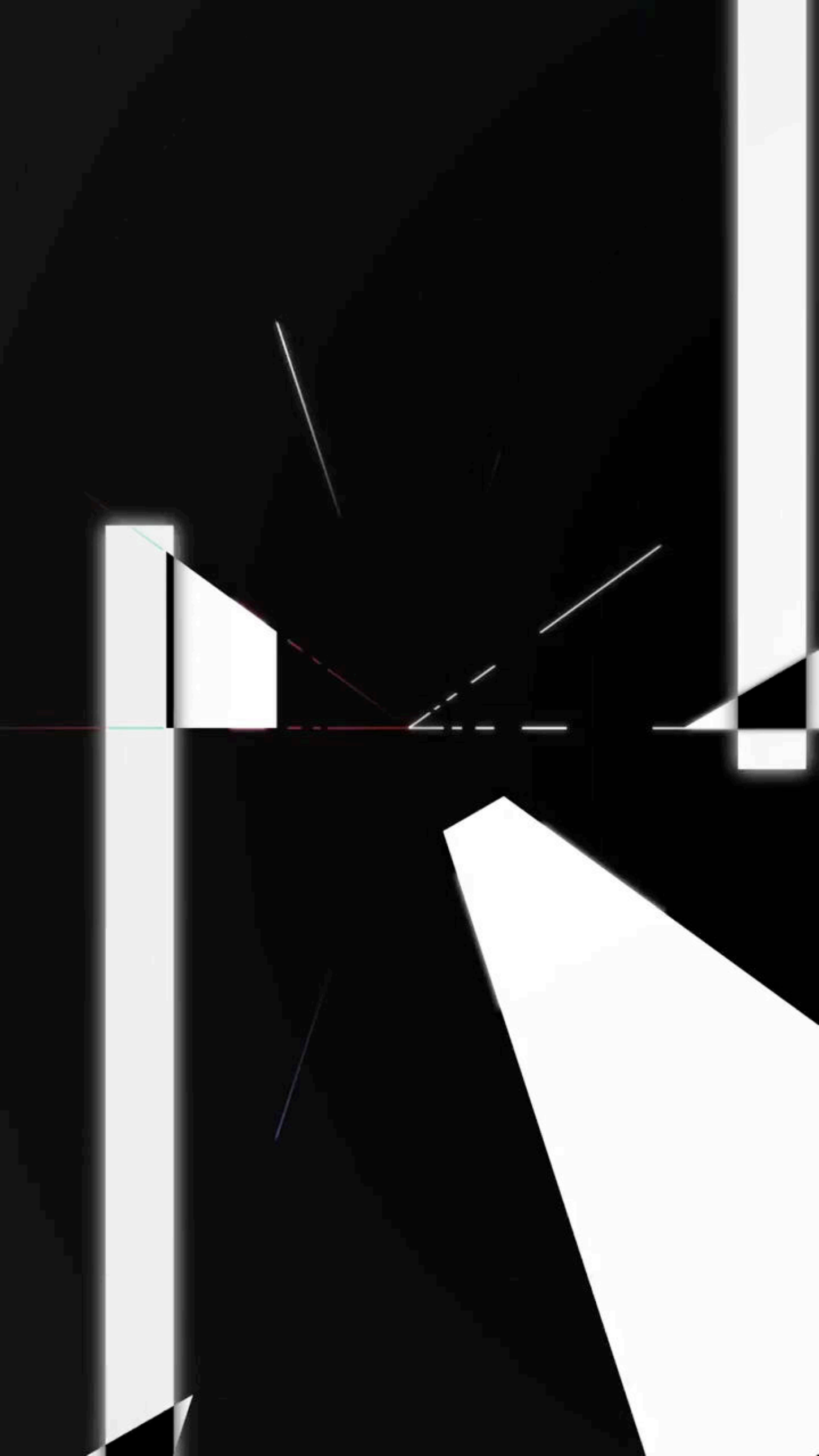


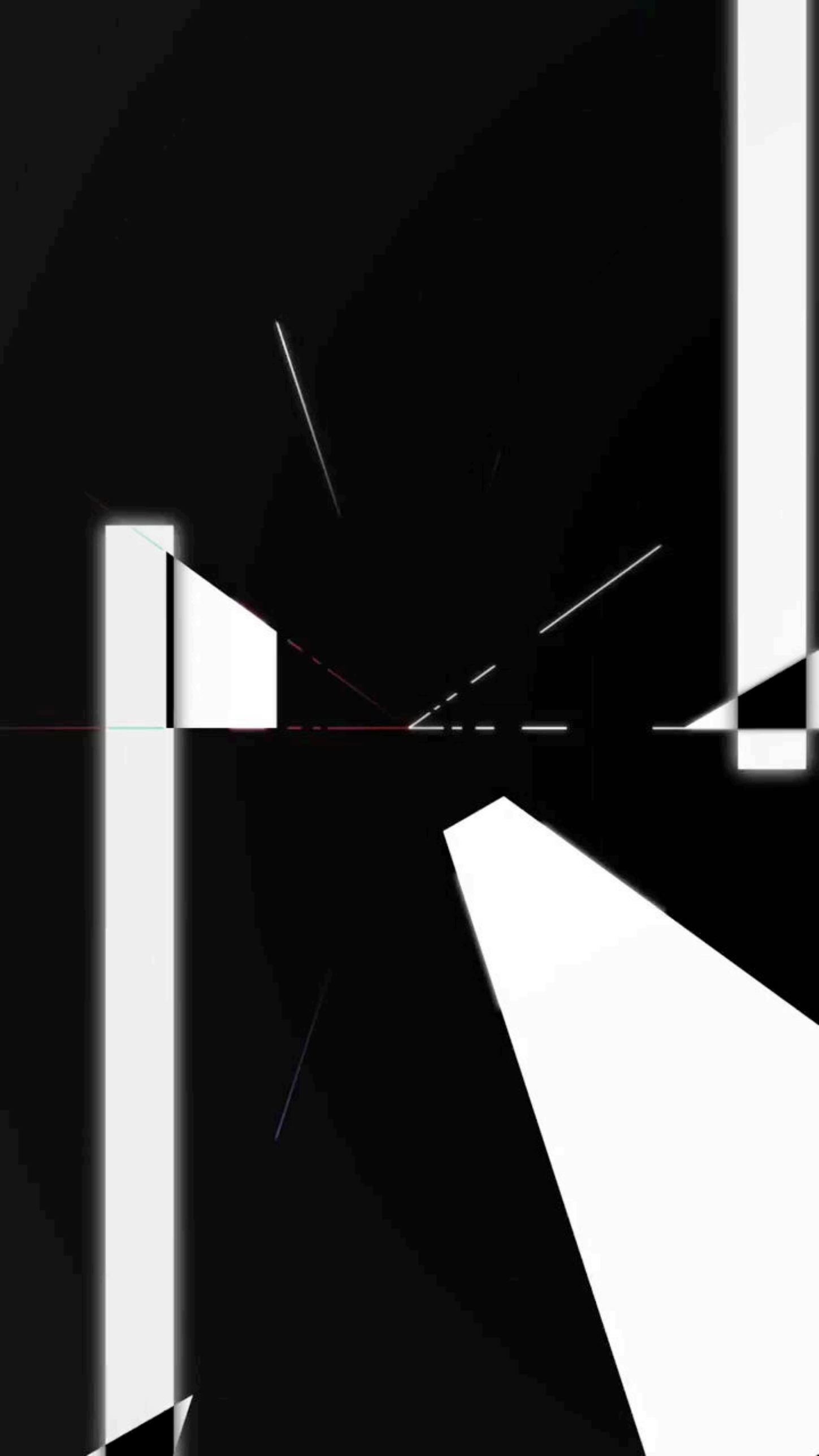





BALANCE
NEUTRAL
CALM

BuildDirect™





Red

Excitement!

Passion!

Drama!

Blood!

Romance!

Sex!

Magic!

Love!

Heat!

Anger!

Hate!

Stop! (traffic lights)

Burgundy & Maroon

Rich indulgence

Brownish Red

Autumn harvest

Pink

Femininity

Pigs

Cherry blossoms

Gay pride

Panthers & Floyds

Orange

Happiness

Sunrise & sunset

Enthusiasm

Creativity

Metabolism

Appetite

Fire

Citrus

Autumn

Halloween

Cheetos

Energy

Doesn’t show up often in nature, so it tends to jump out at us when we see it

- Life jackets
- Traffic cones
- Hunting vests (some animals can’t distinguish between green & orange, however)

Yellow

Happiness	Caution
Energy	Canaries
Sunshine	Eggs
Warmth	Sponge Bob Squarepants
Cowardice	Madness
Urine	Jaundice

Highly visible, so seen on…

» Busses
» Taxicabs
» Caution signs

Green

Nature

Growth

Freshness

Hope

Wealth

Stability

Education

Luck

Envy

Seasickness

Extraterrestrials

Go (traffic lights)


Green on Black = Nerds!

Blue

Open

Intelligence

Faith

Calm

Water

Sky

Sadness

Stability

Denim

Cold

Spirituality

Most often cited as favorite color

Safest color to use as a default

Reduces appetite (not many blue foods in nature!)

Purple

Royalty

Luxury

Power

Wealth

Extravagance

Flowers

Gems

Wine

Bravery (Purple Heart)

Barney

Tinky Winky

Prince

White

Perfection	Smoke
Light	Baby powder
Purity	Snow
Weddings	Milk & cream
Clean	Bones
Ghosts	Vanilla

Death & mourning in China

Black

Death

Evil

Power

Elegance

Strength

Formality

Solemnity

Night

Burned wood

Space

Shadows

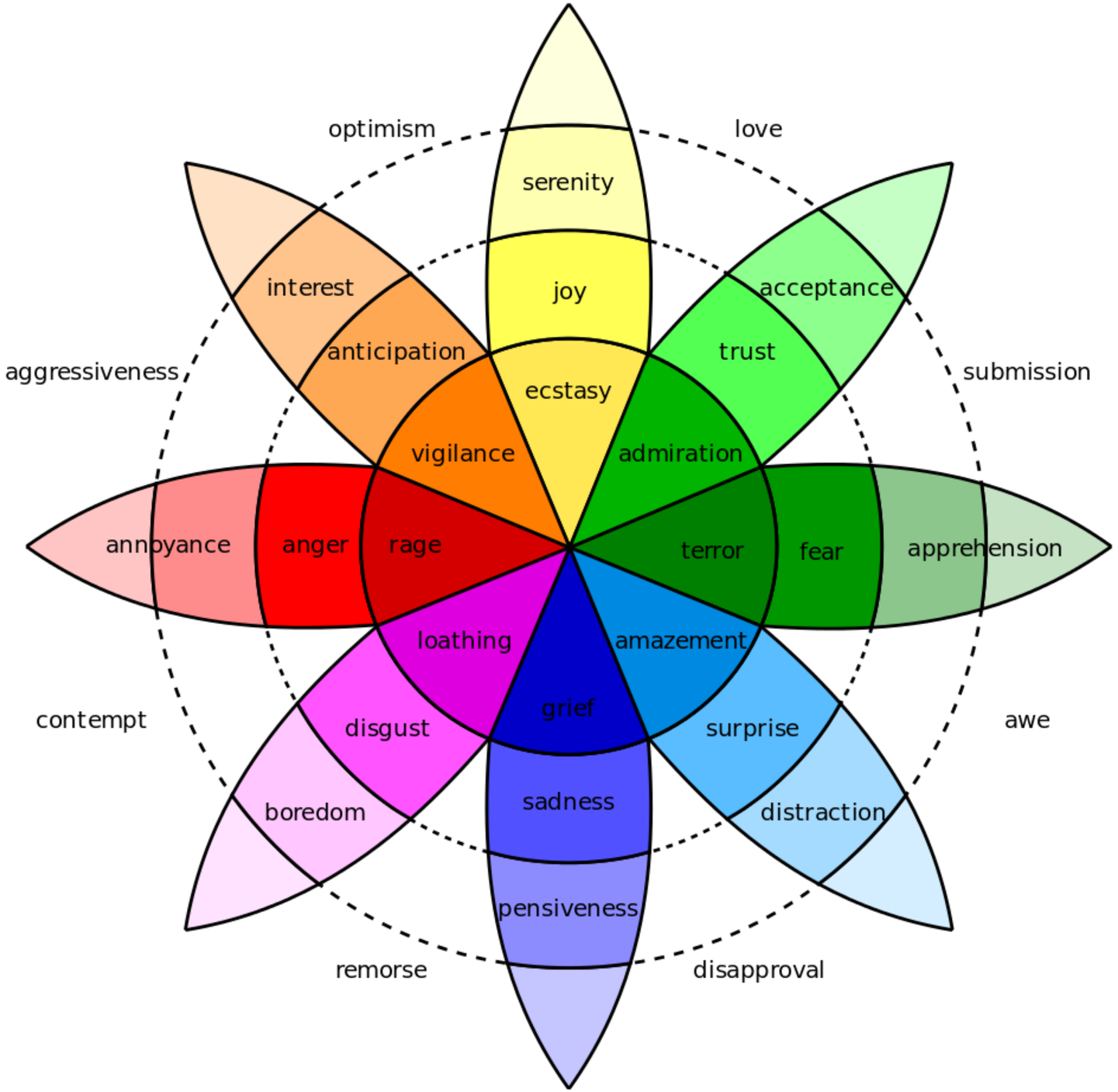
Licorice 🤮

Darth Vader

Black Panther

People have associated colors with emotions

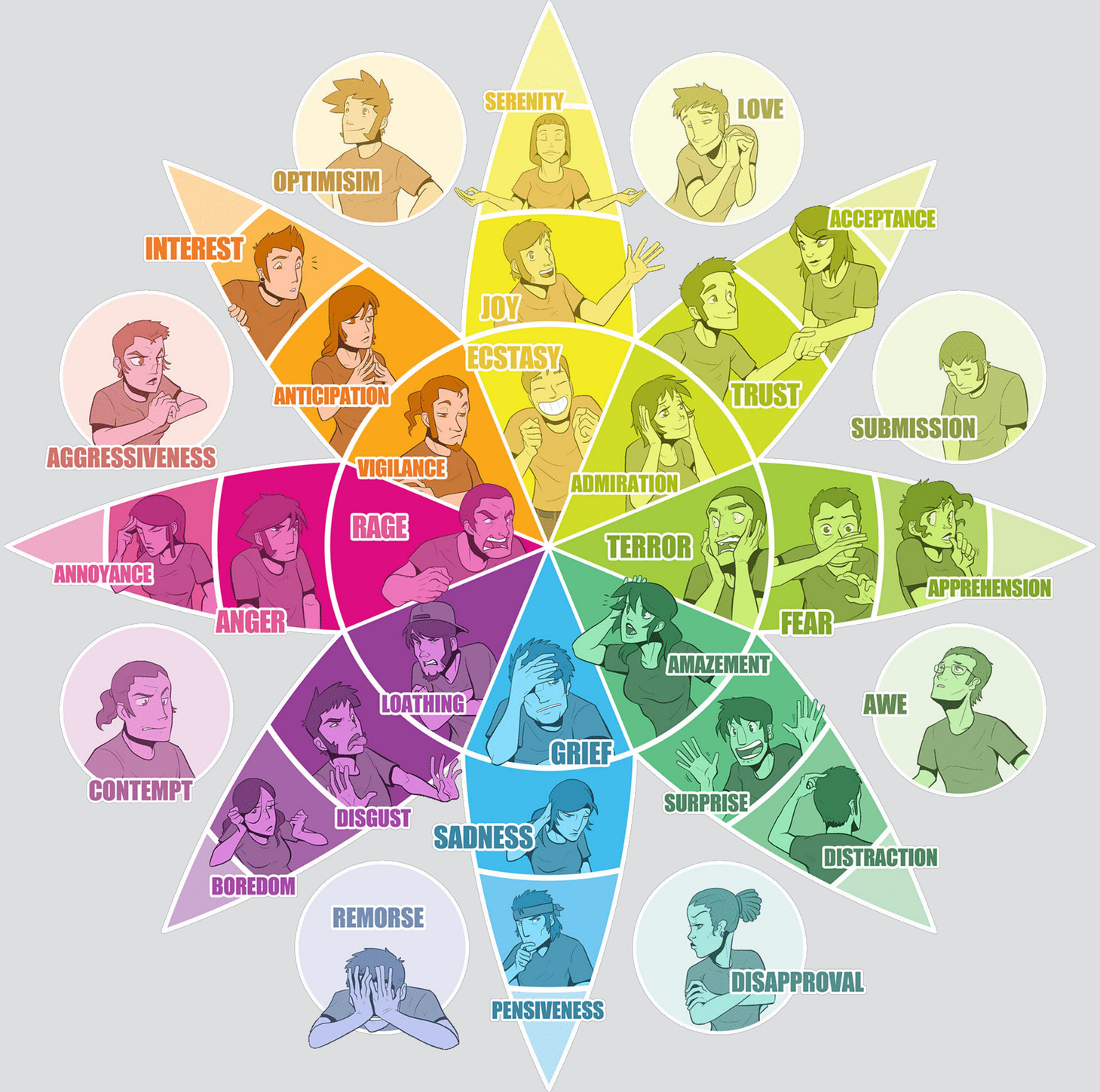
Now people set up systems of emotions using the color wheel model to illustrate that system

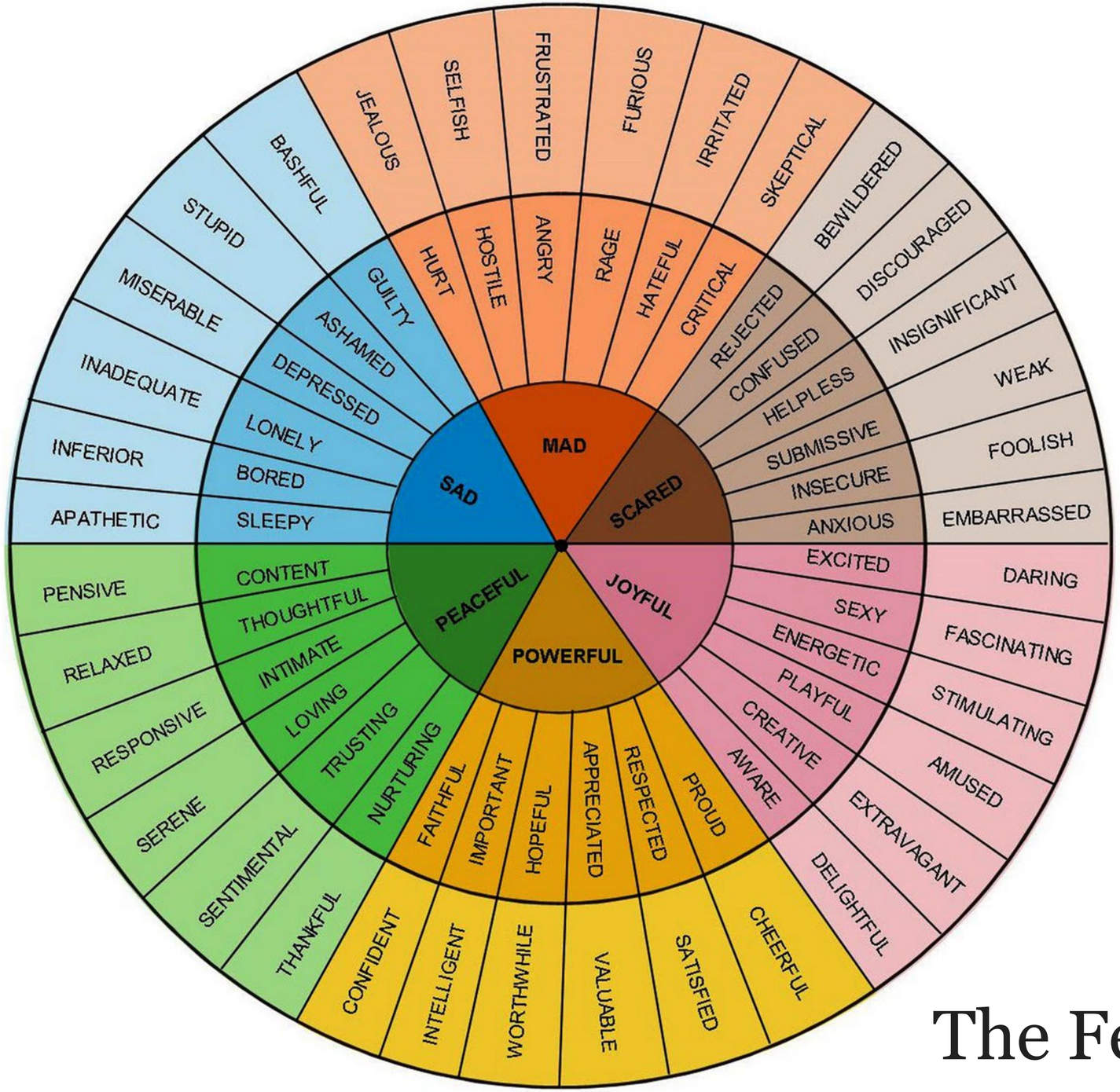


Plutchik's Wheel of Emotions

8 basic emotions + 8 derivative emotions, each composed of 2 basic ones

Plutchik has arranged emotions like a color wheel, but not mapped the colors to emotions


SERENITY
LOVE
OPTIMISIM
INTEREST
ACCEPTANCE
JOY
ECSTASY
TRUST
ANTICIPATION
SUBMISSION
AGGRESSIVENESS
VIGILANCE
ADMIRATION
RAGE
TERROR
ANNOYANCE
APPREHENSION
ANGER
FEAR
AMAZEMENT
CONTEMPT
AWE
LOATHING
GRIEF
SURPRISE
DISGUST
SADNESS
DISTRACTION
BOREDOM
REMORSE
DISAPPROVAL
PENSIVENESS



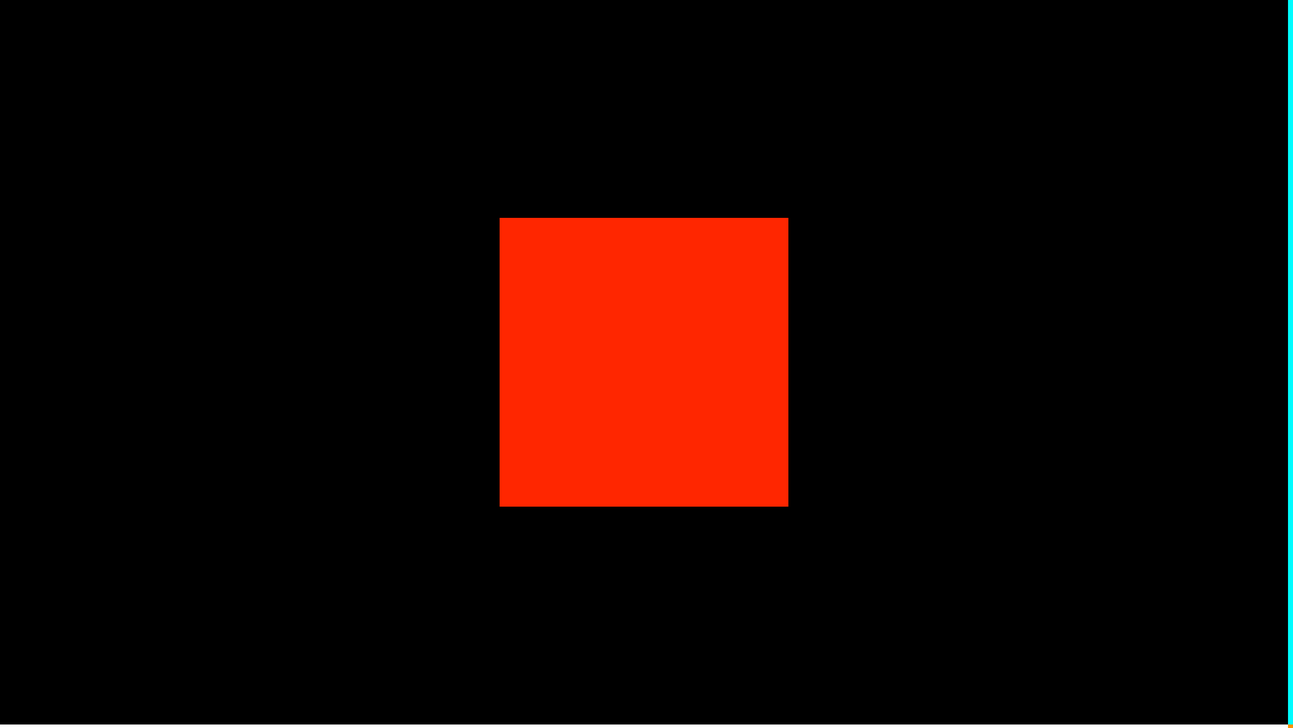
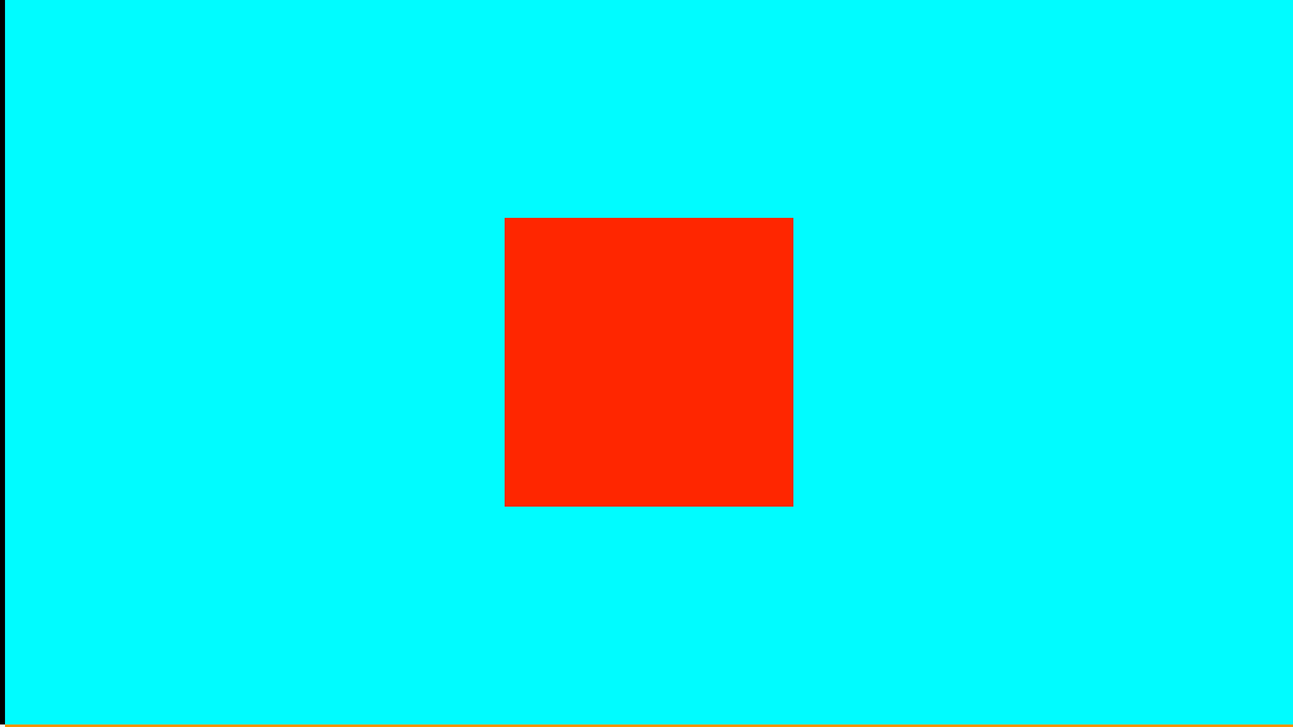
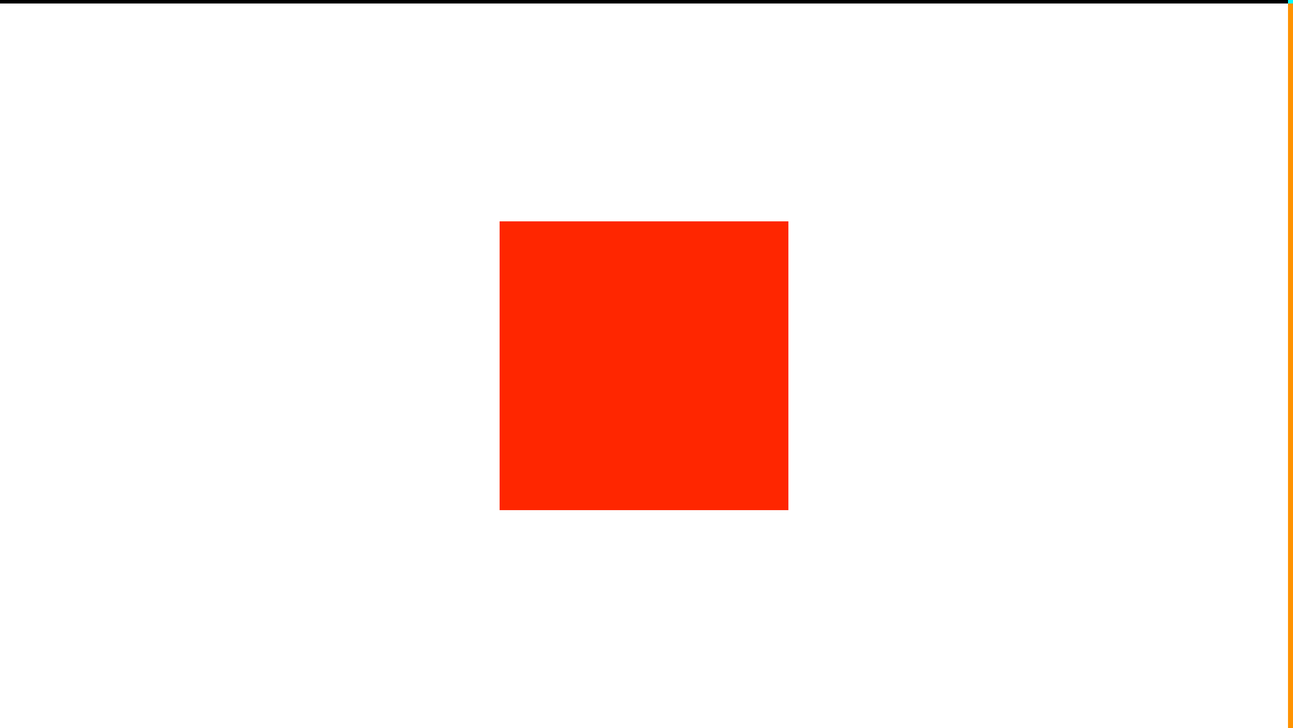
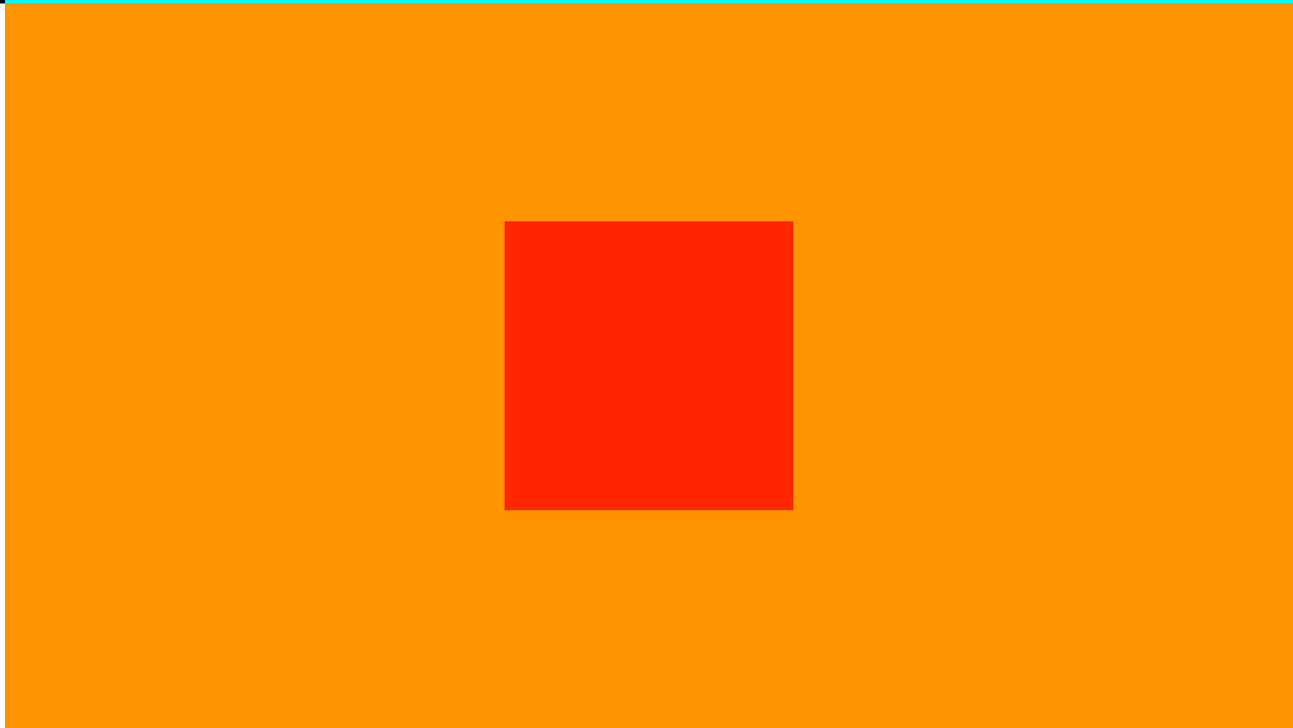
The Feelings Wheel


But...

A big caveat: context matters

- Color pairings
- Culture
- Generations
- Settings
- Personal taste & experience

Pairing colors will change perceptions about them

Happy Halloween!

People in different cultures have different associations with colors


Cardinals

DIST. CULLYBACKEY
No. 20
CO.
PORTGLENONE

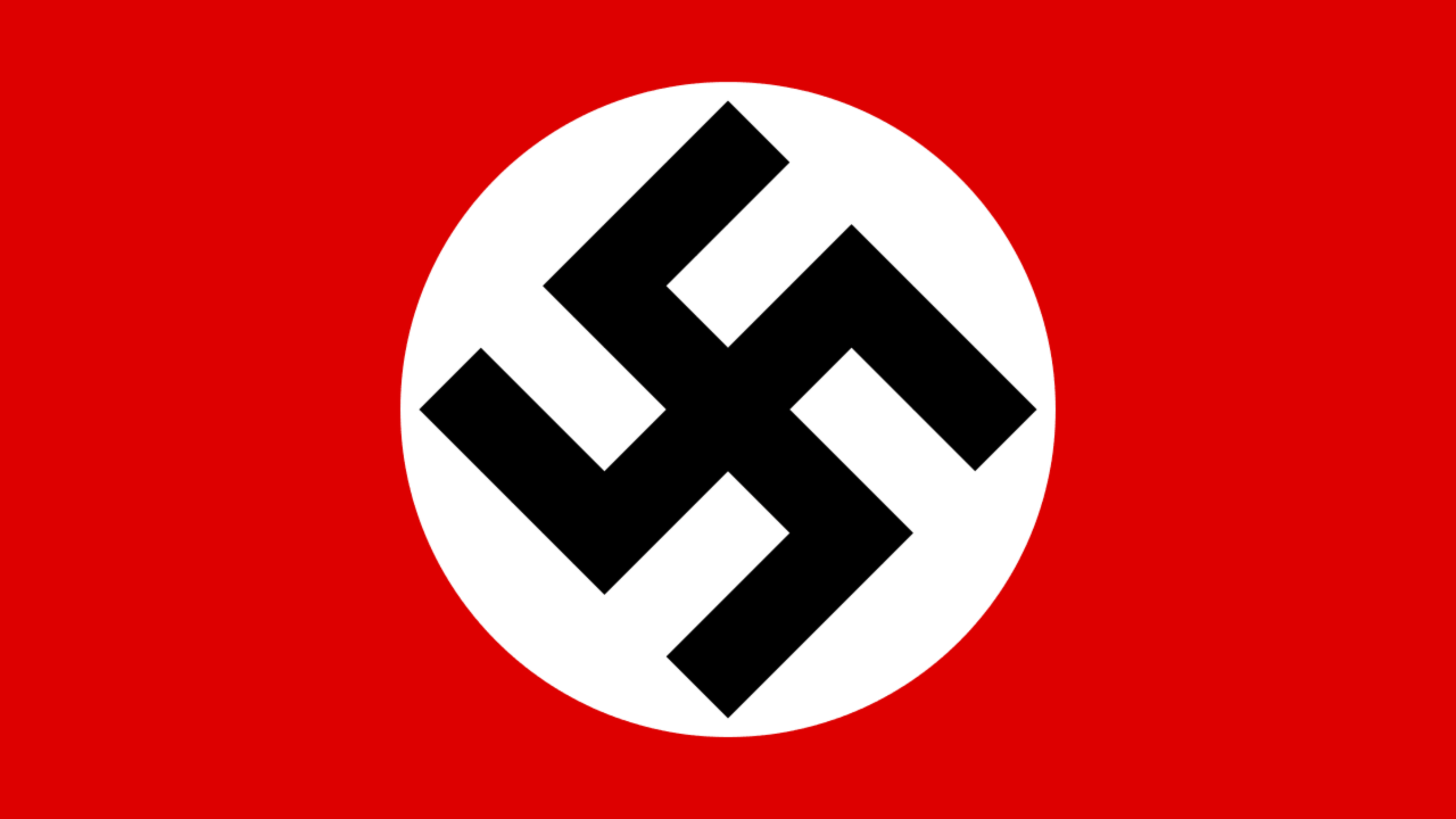

Kiss Me
I'm Irish

Generational

Different generations have different associations with colors & designs

Sometimes these can range over hundreds (or even thousands) of years


peter max©



Queen Anne (Edmund Lilly, 1703)

Queen Anne & Prince George (Charles Boit, 1706)

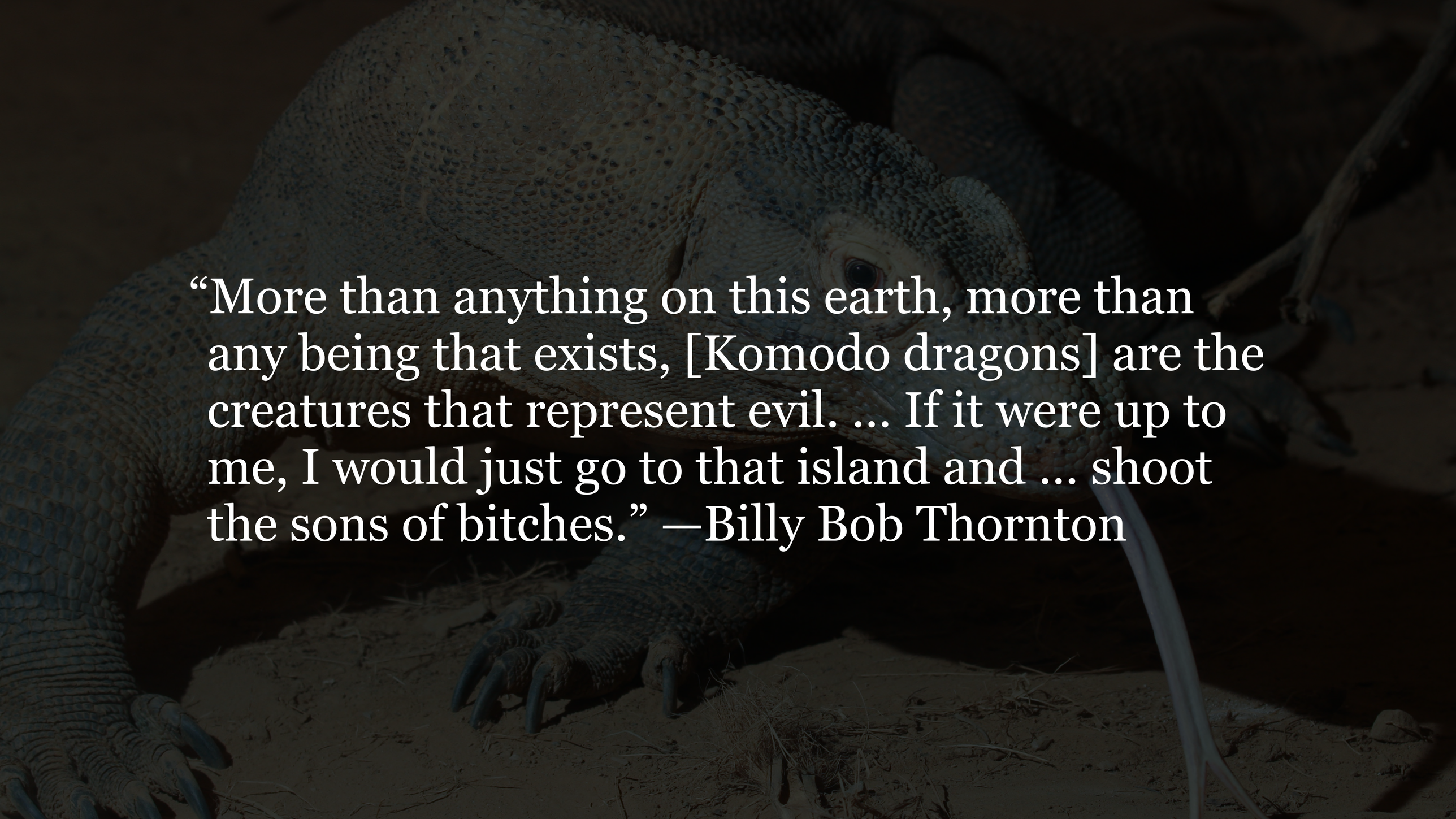
Settings

The same colors can have different meanings in different industries or fields

Personal taste & experience


Chromophobia:
fear of bright colors


Chromophobia:
fear of bright colors

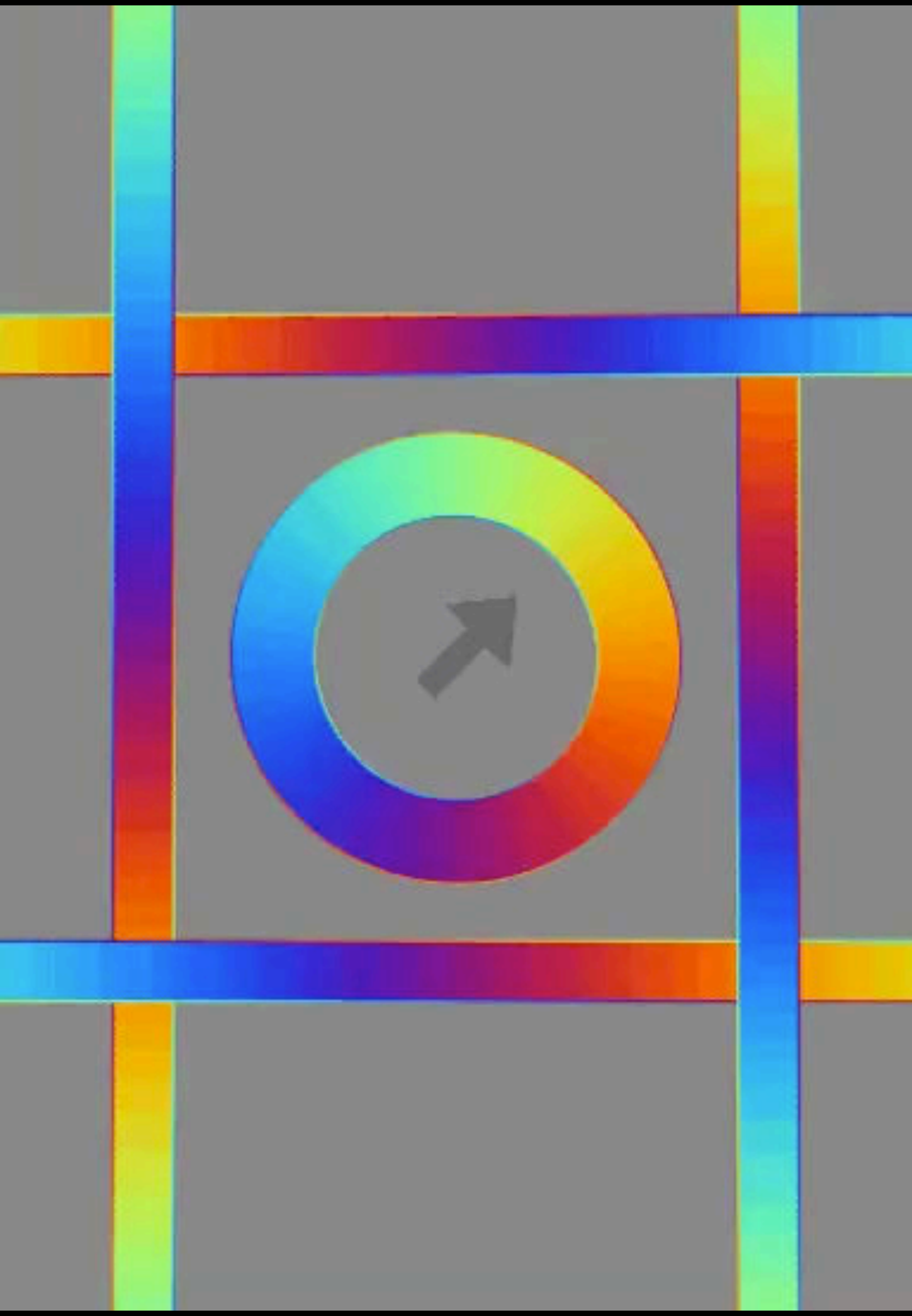

“More than anything on this earth, more than any being that exists, [Komodo dragons] are the creatures that represent evil. … If it were up to me, I would just go to that island and … shoot the sons of bitches.” —Billy Bob Thornton

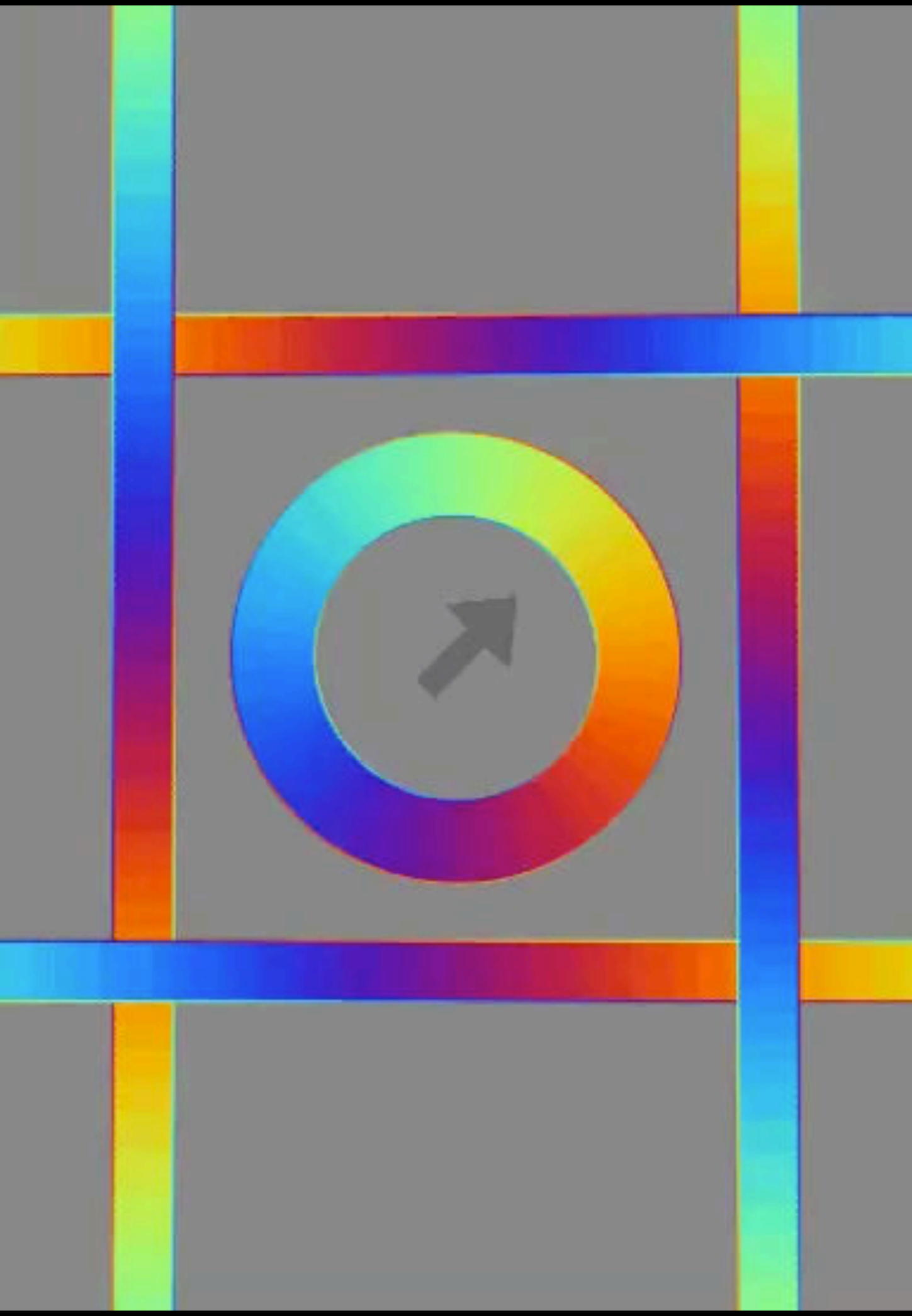
Illusion

2 things affect optical illusions

- *Cognition*: Your brain incorrectly interprets input from your eyes
- *Physiology*: Your brain gets bad input because your eyes send false signals

Motion





Animation is an illusion of motion that occurs when you see multiple images shown rapidly one after the other

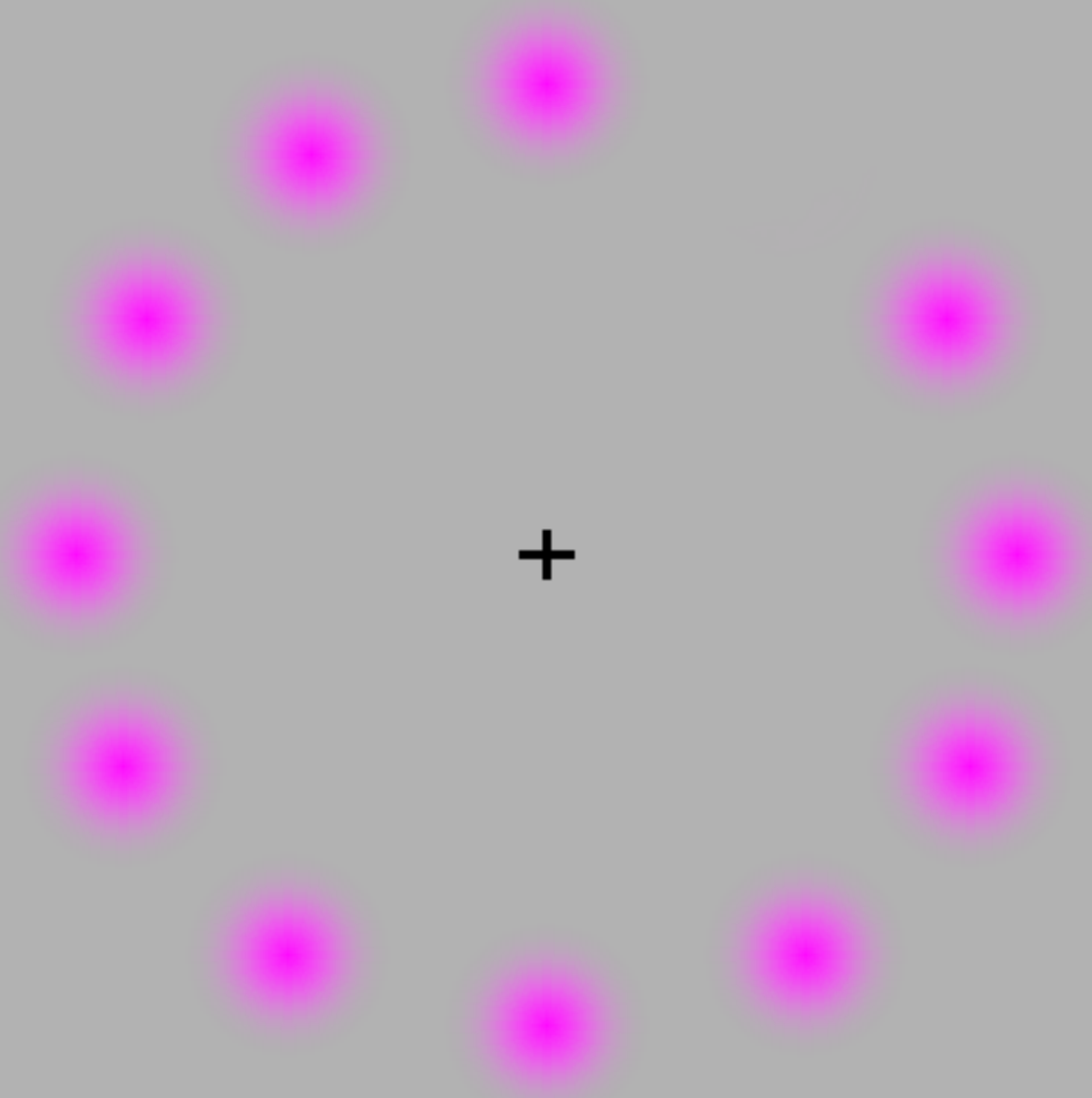
Beta movement: series of static images presented at > 10–12 frames per second appear to be in motion

Phi phenomenon: your brain fills in blanks when it sees lights going off & on at constant intervals

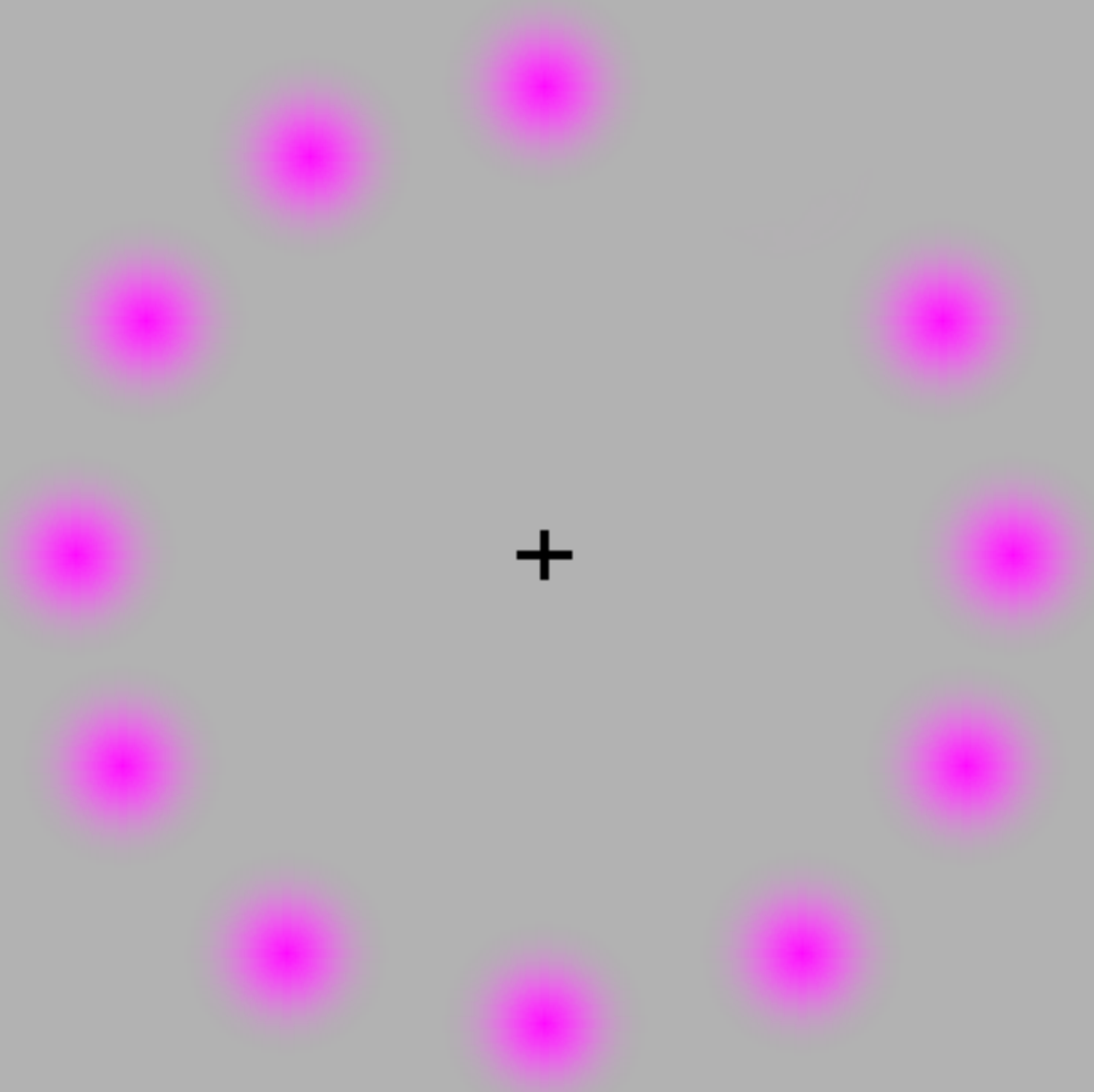
Beta movement in action

Beta movement in action

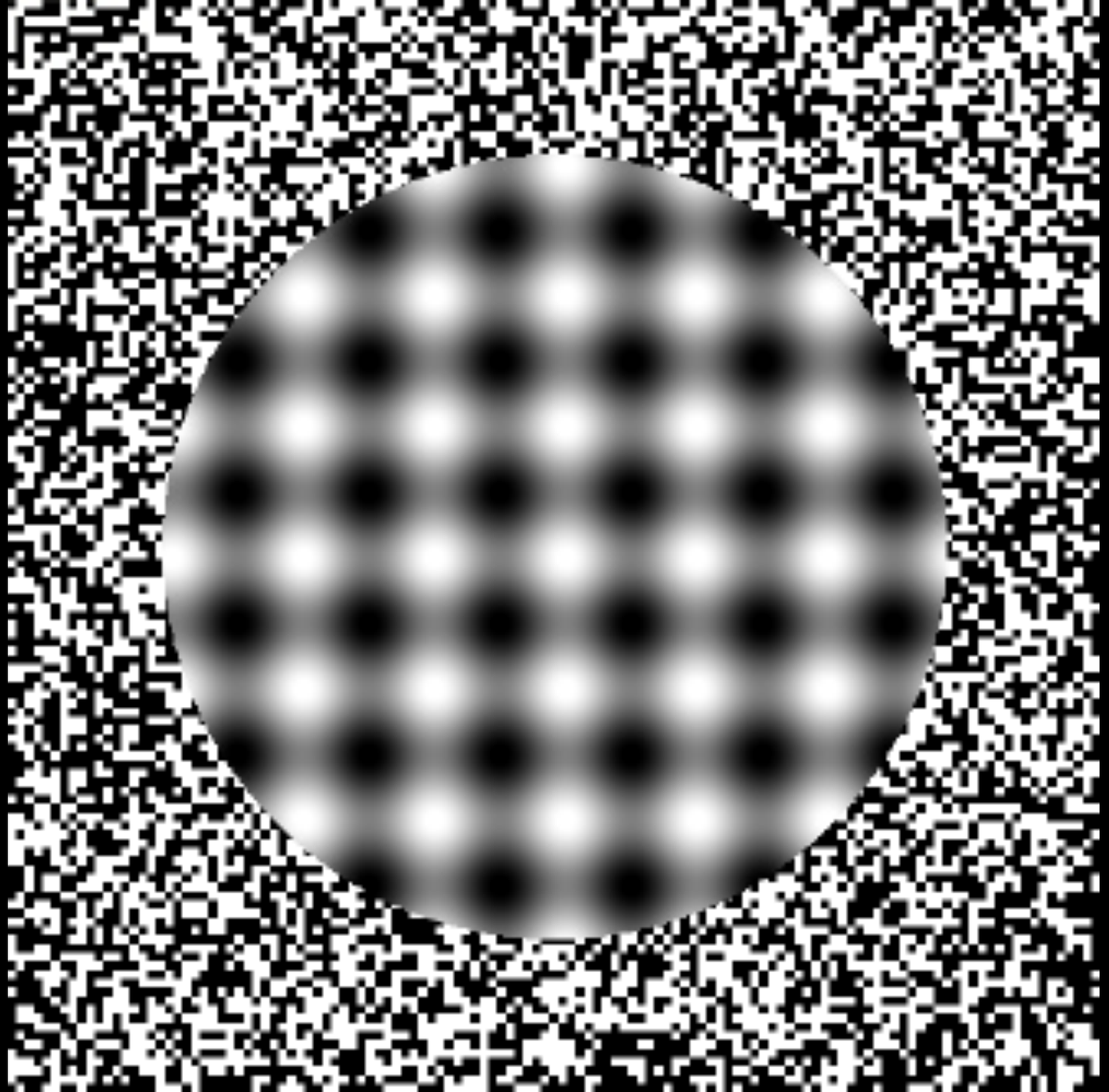
The lilac chaser

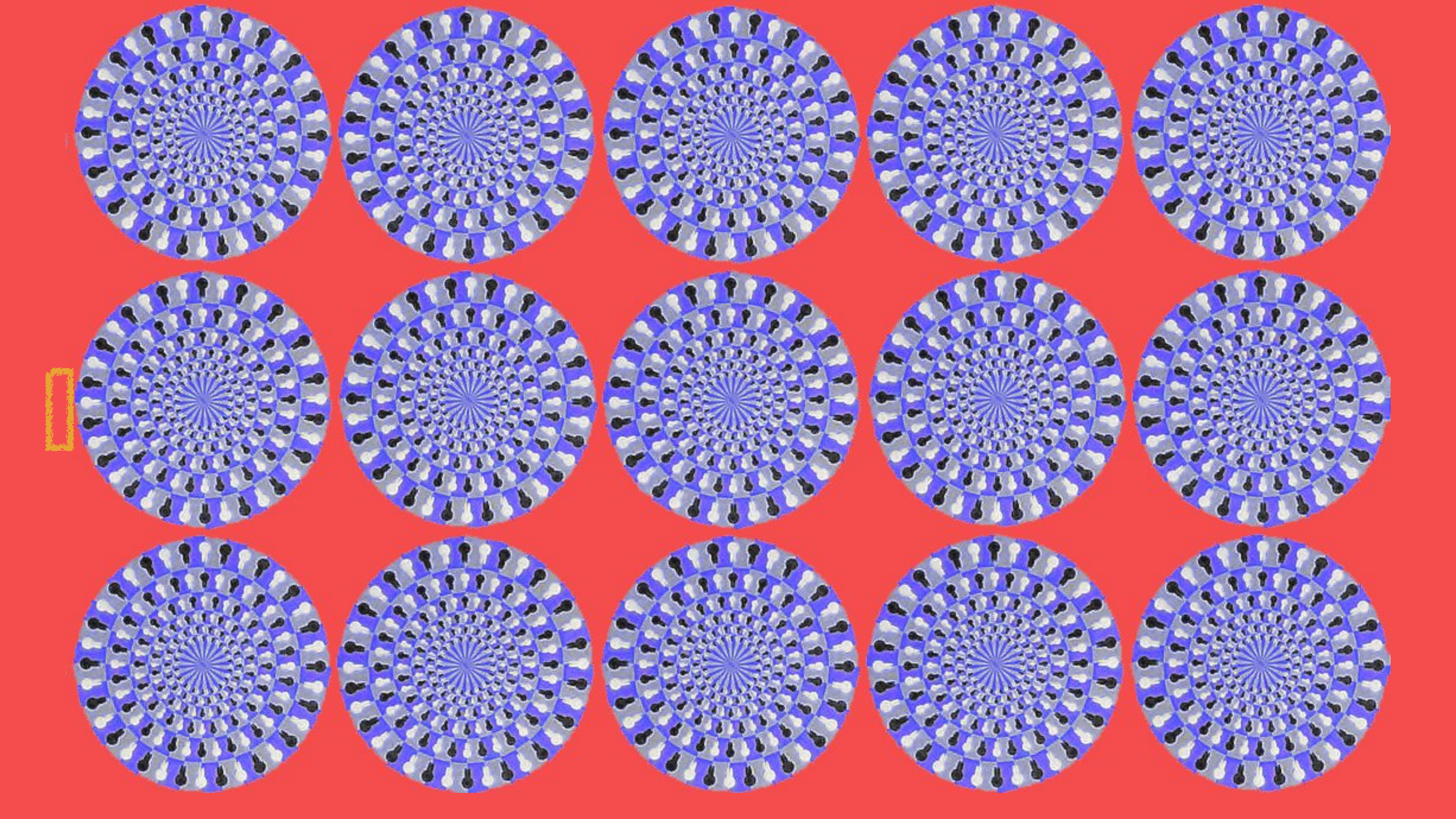


Stare at the +
in the center

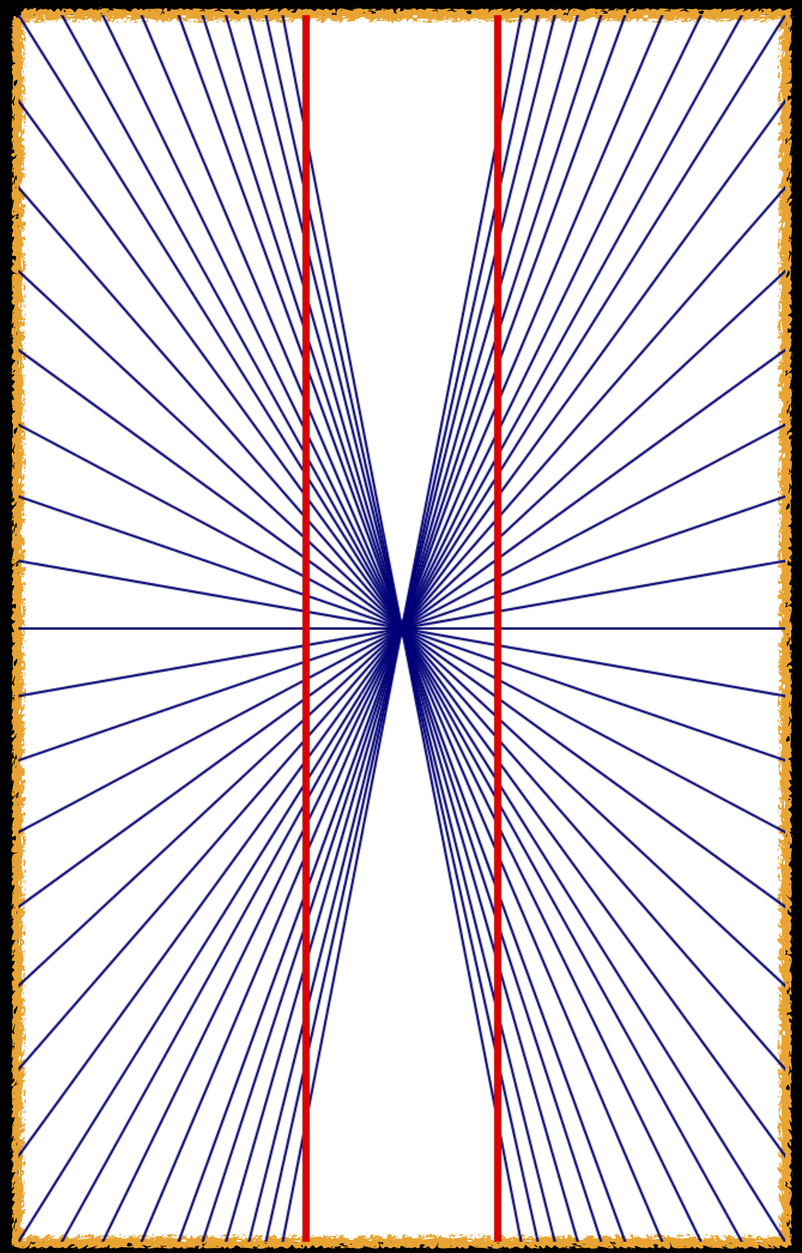


Peripheral drift is “generated by the presentation of a sawtooth luminance grating in the visual periphery”

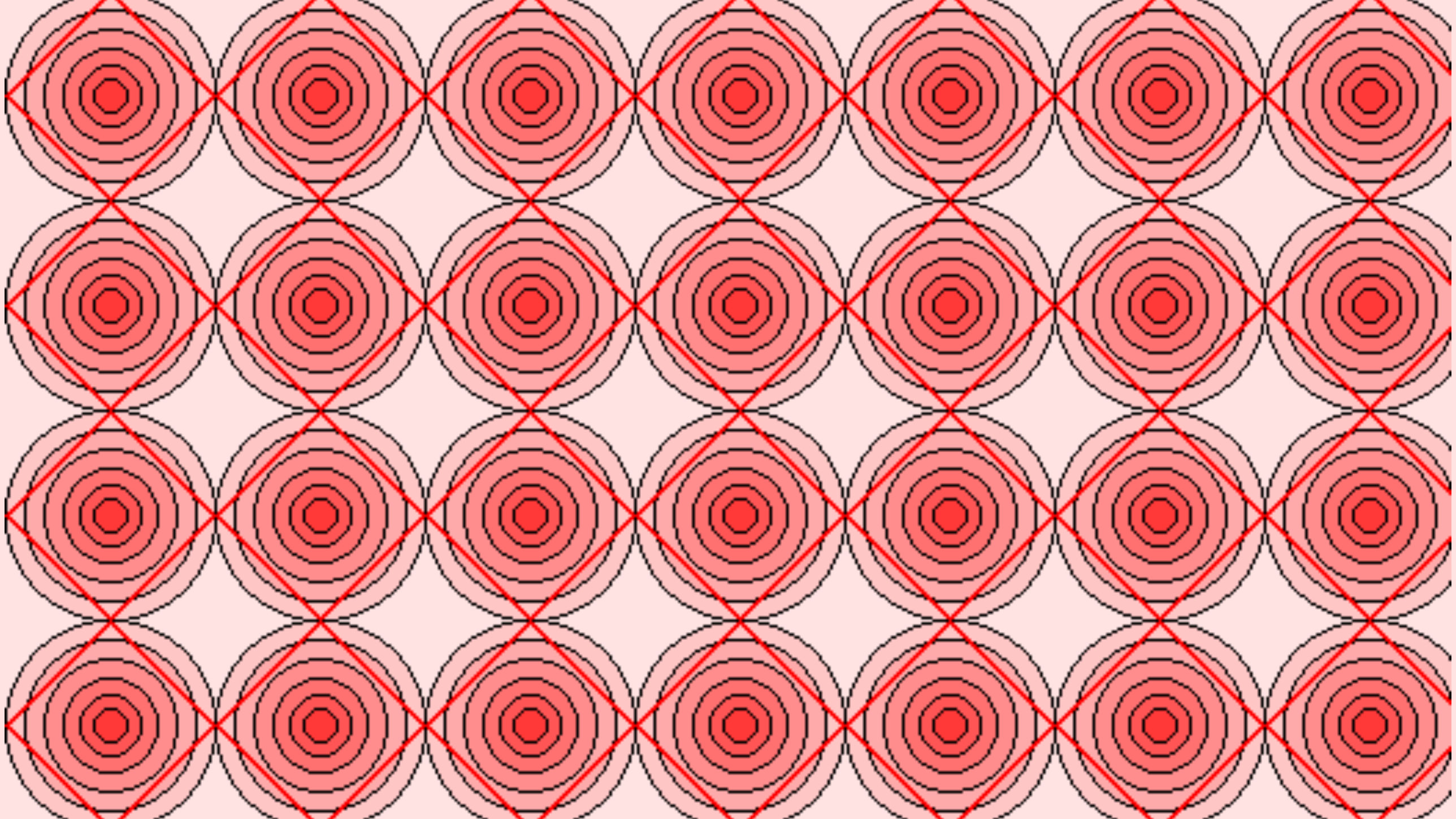


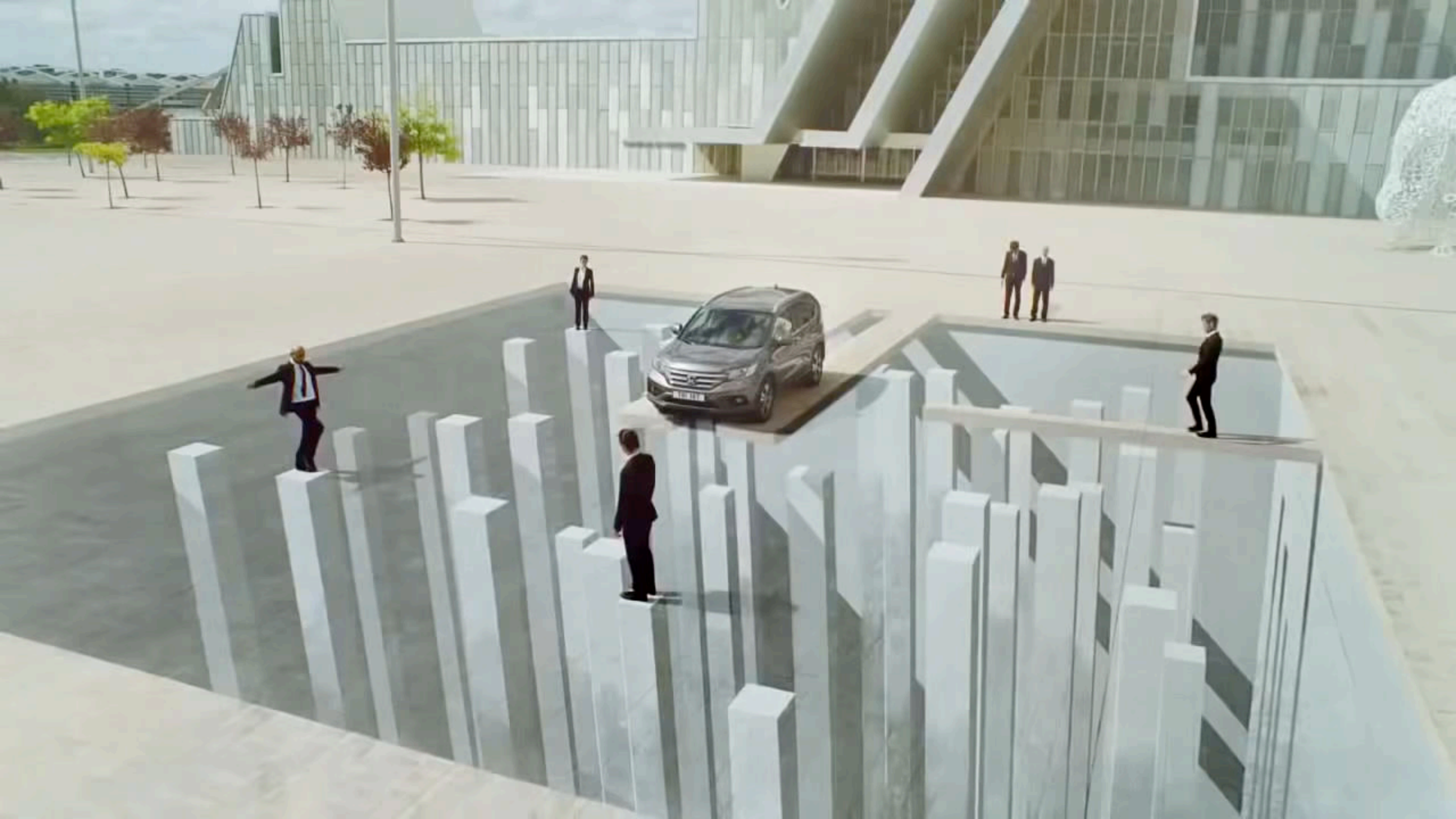


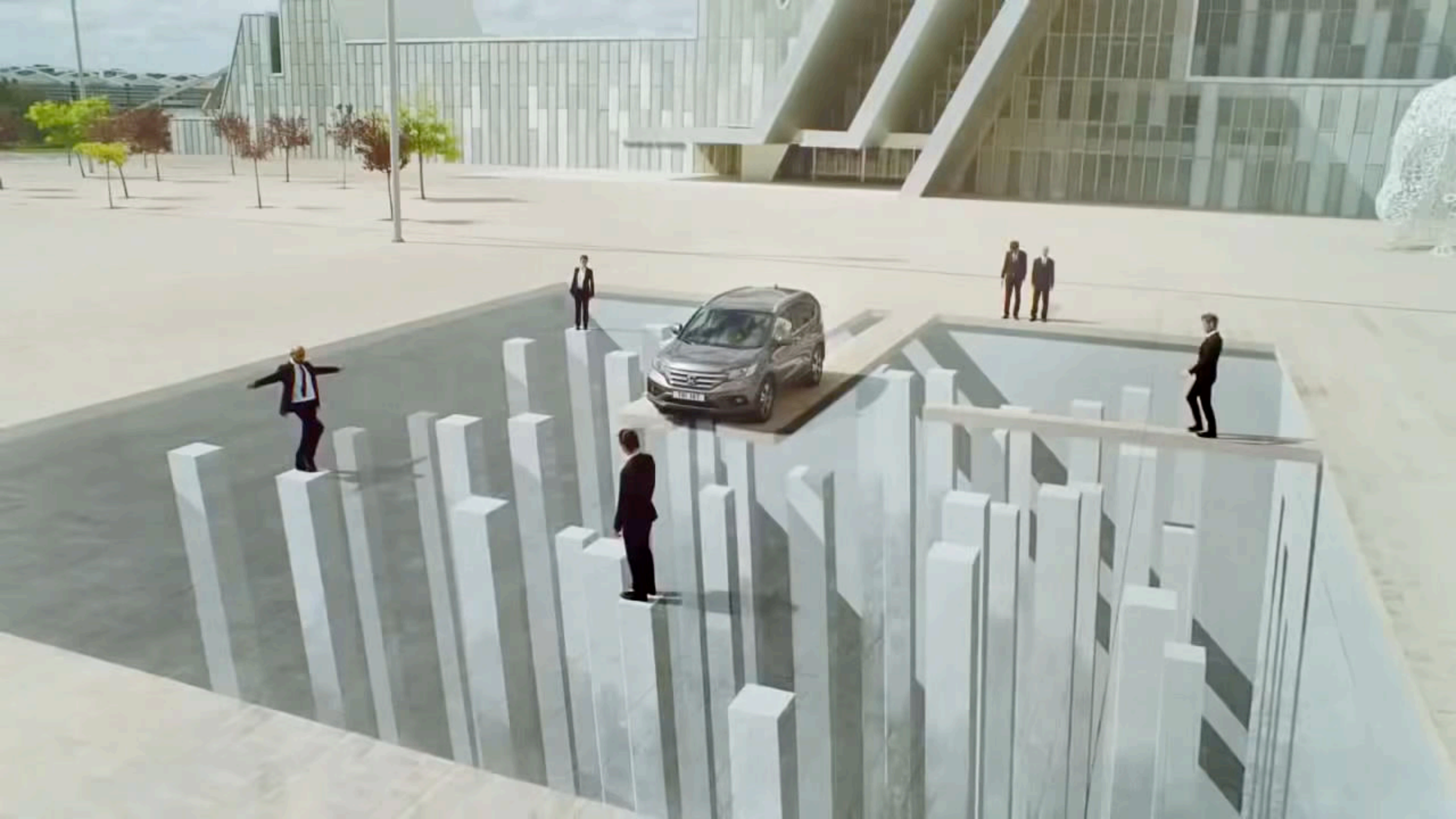
Perspective



Ewald Hering Illusion





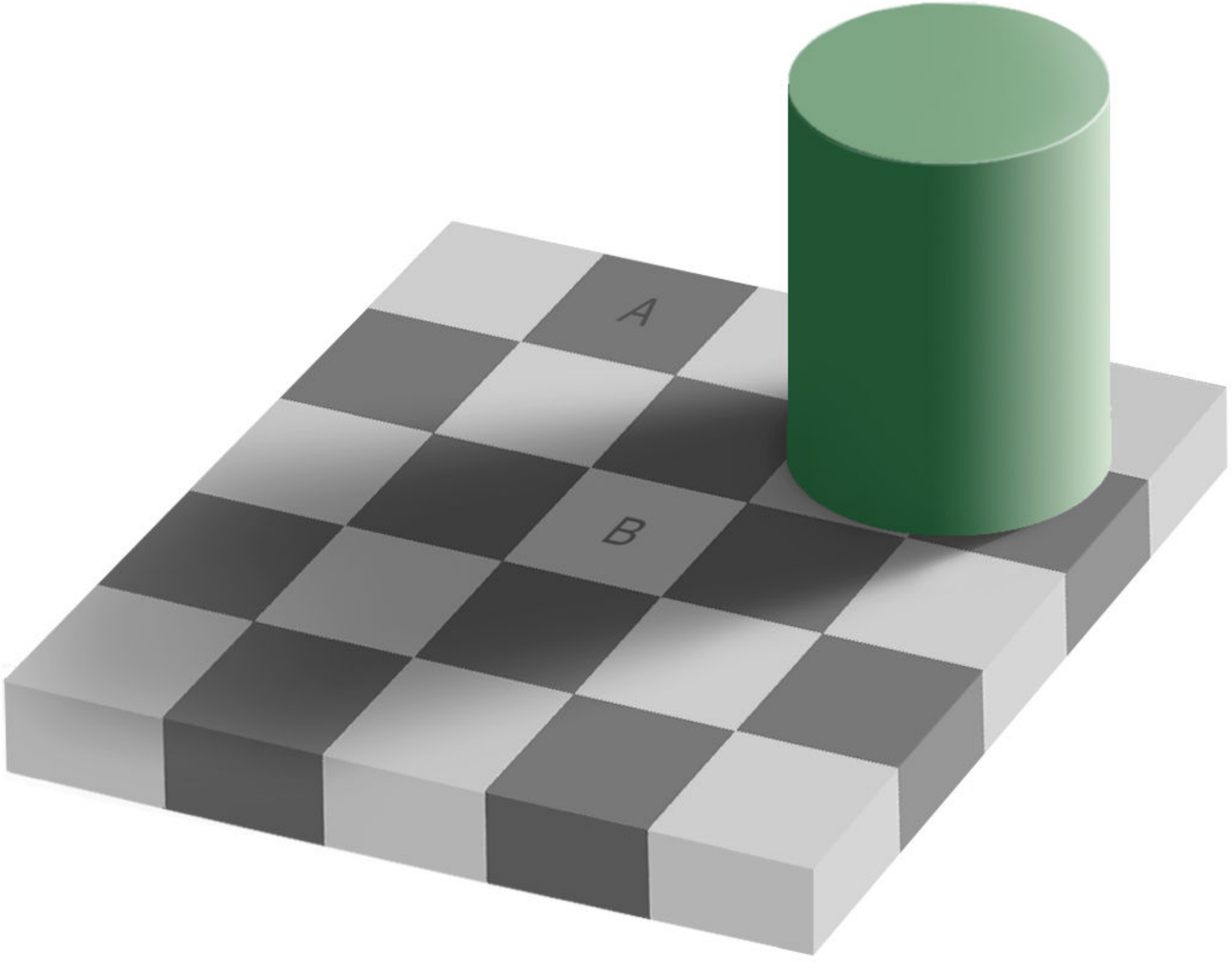


Color

Color constancy is the perception of color as constant even though our sensation of the color changes due to lighting

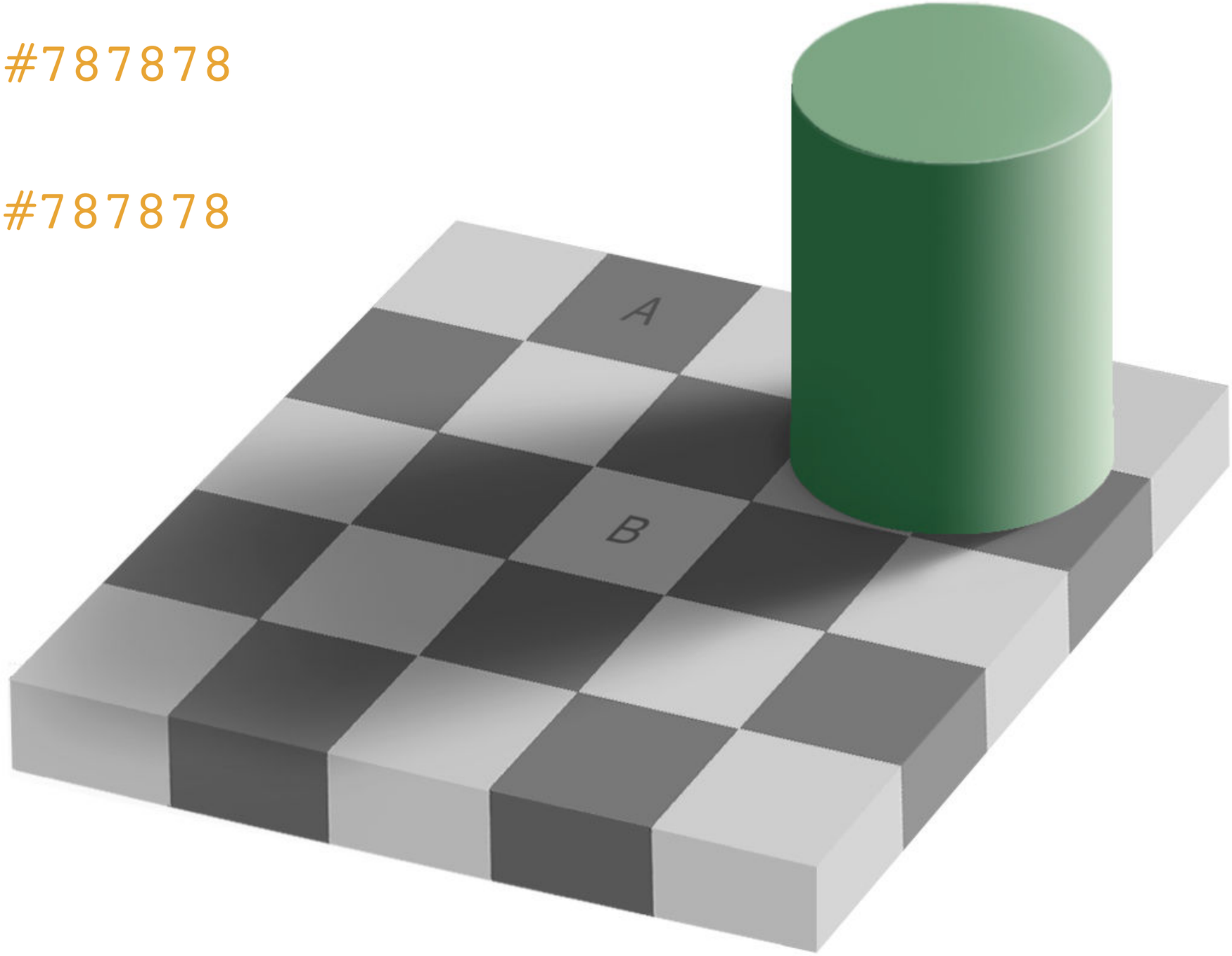
For example, we don’t think of a person as changing colors when they move from sunlight into shade

However, the color of the light reflected from their skin has changed!


A
B

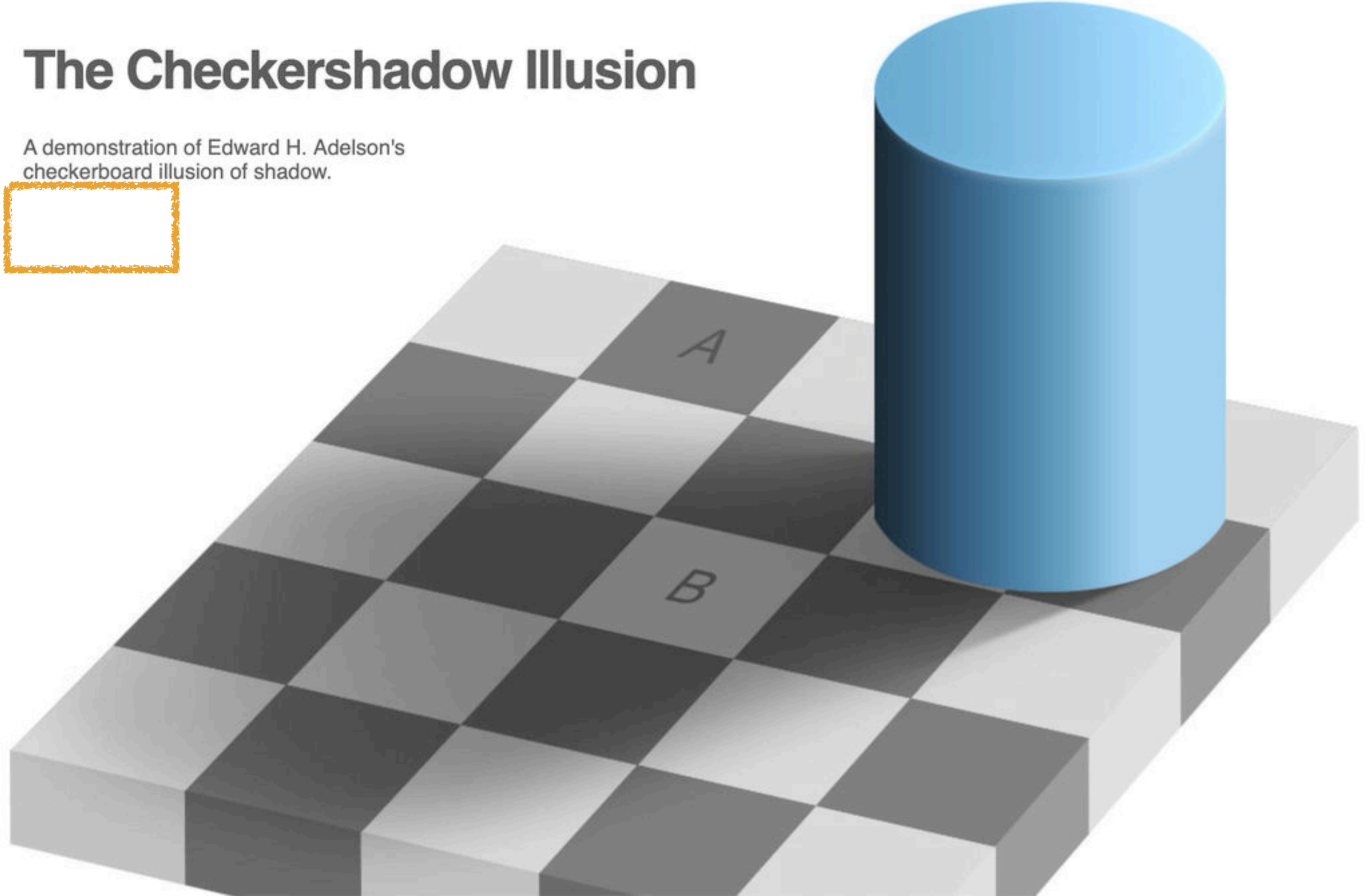
A = ● = #787878

B = ● = #787878



The Checkershadow Illusion

A demonstration of Edward H. Adelson's checkerboard illusion of shadow.



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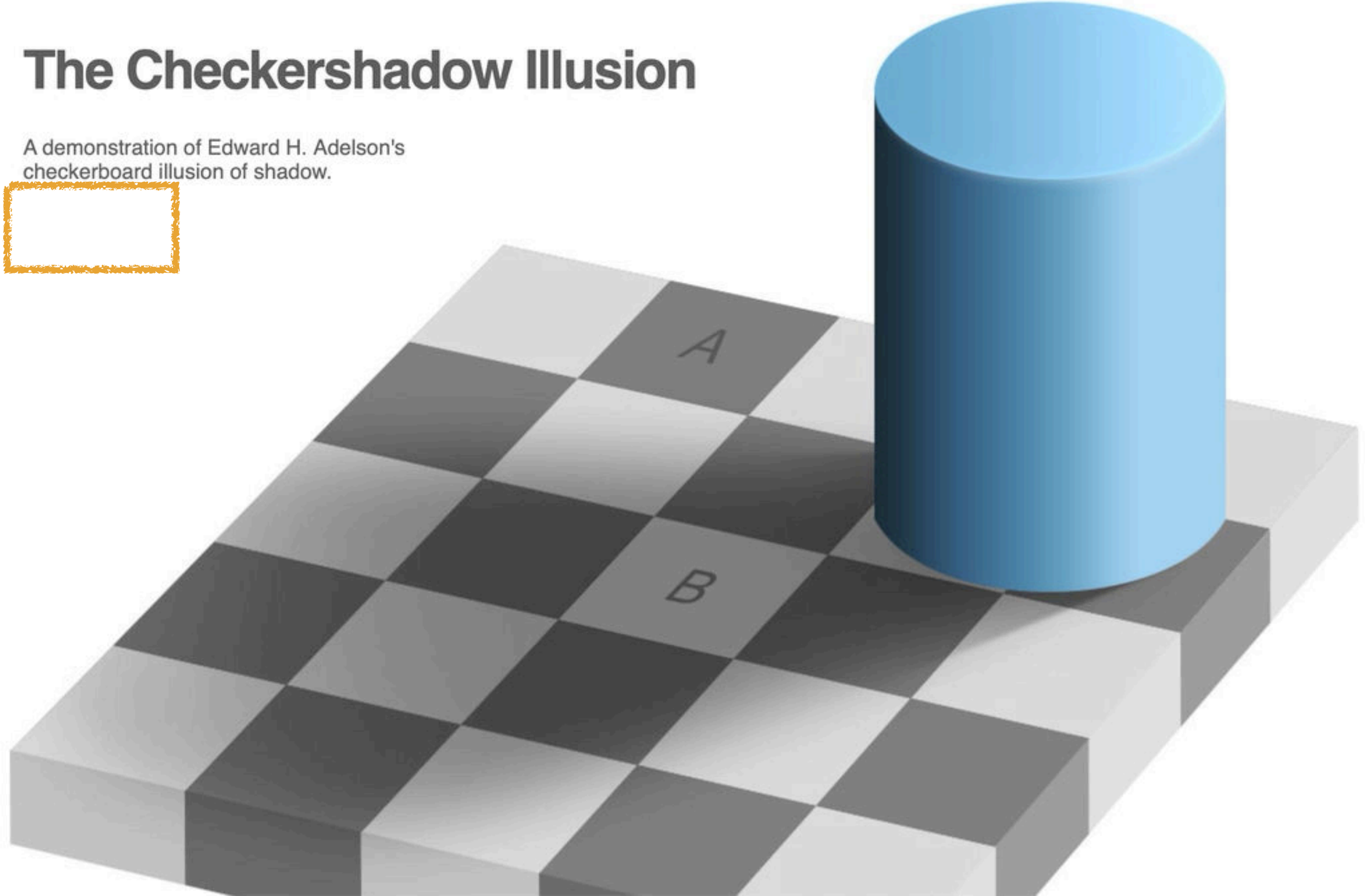
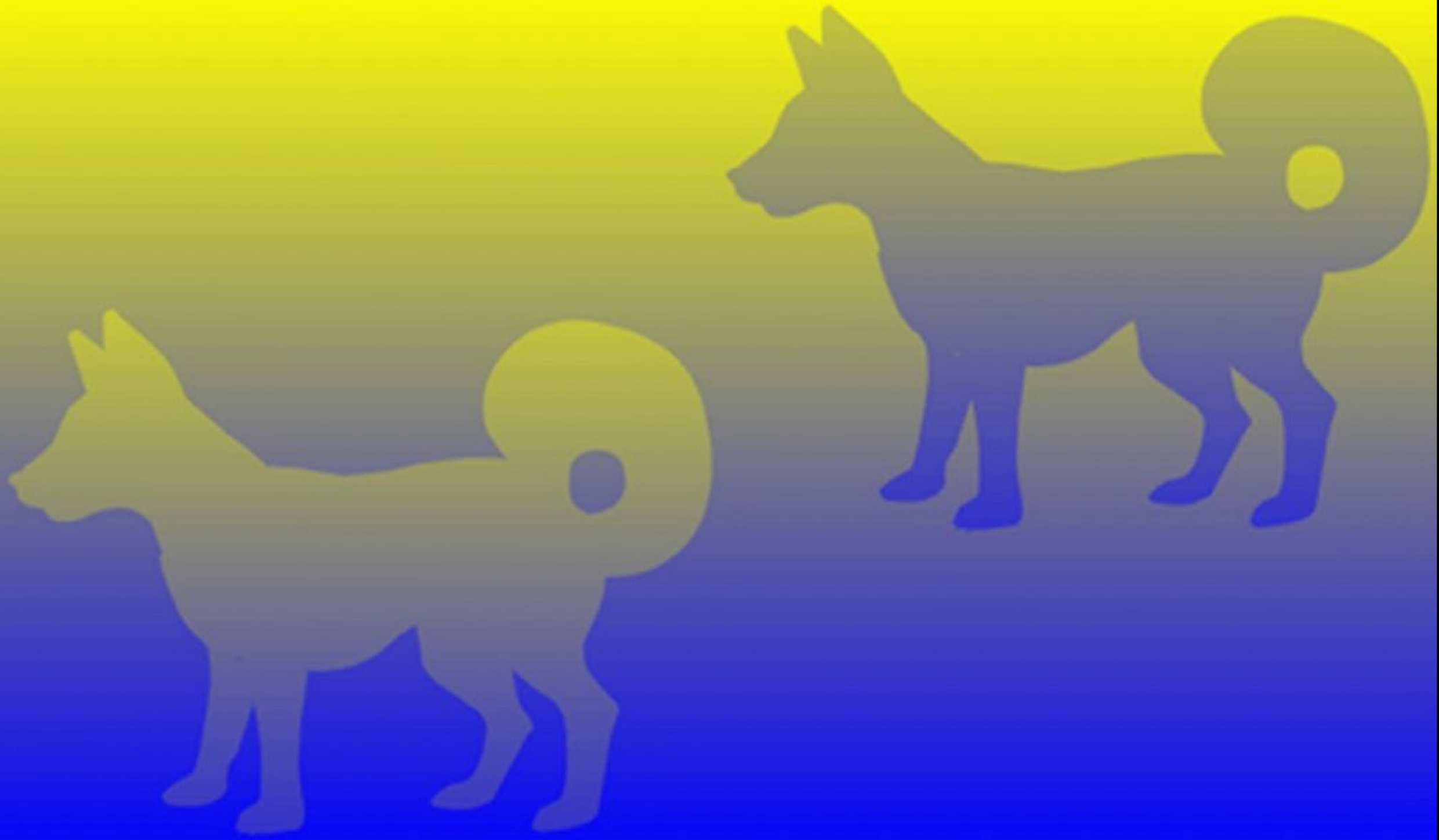
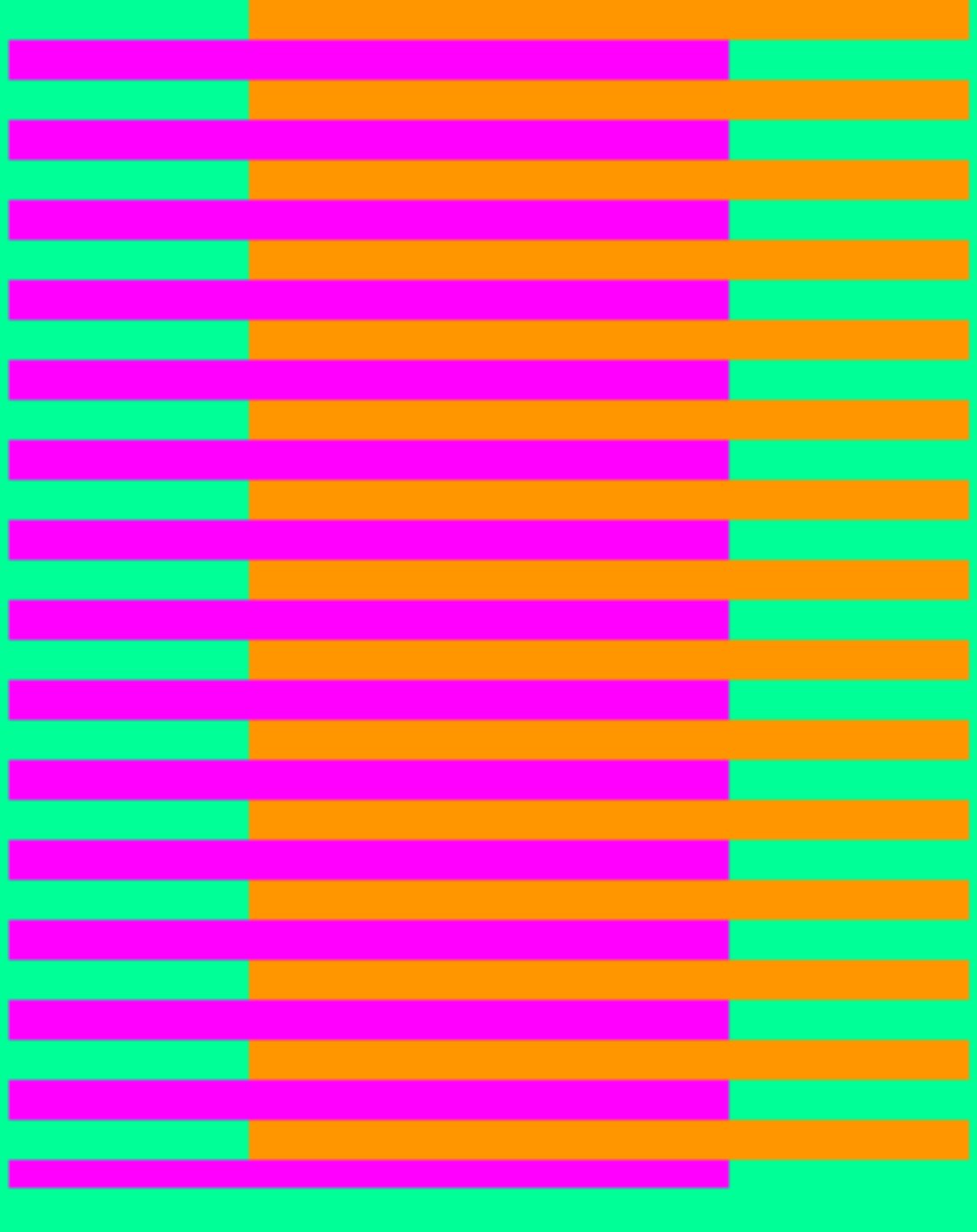
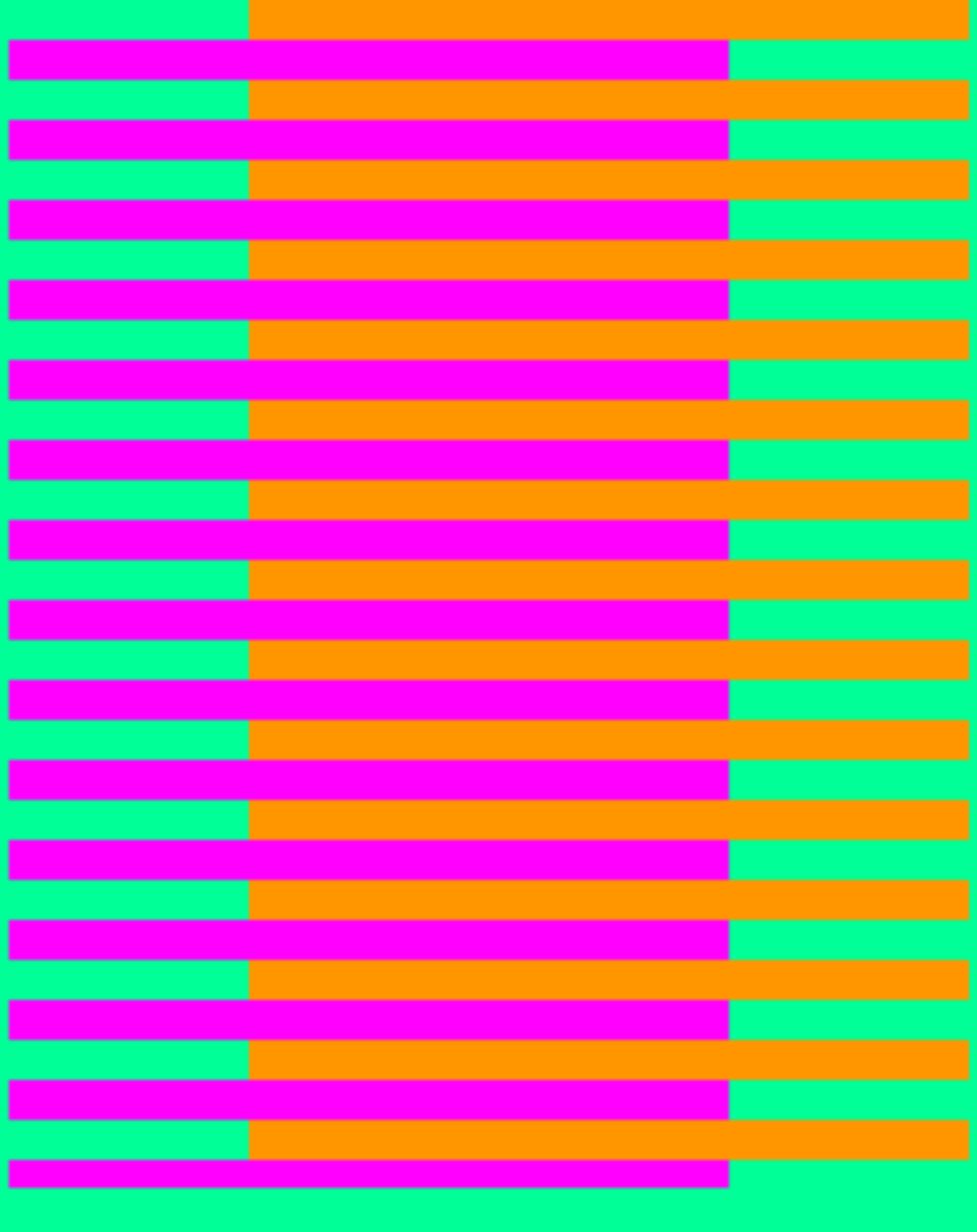


Color comparison



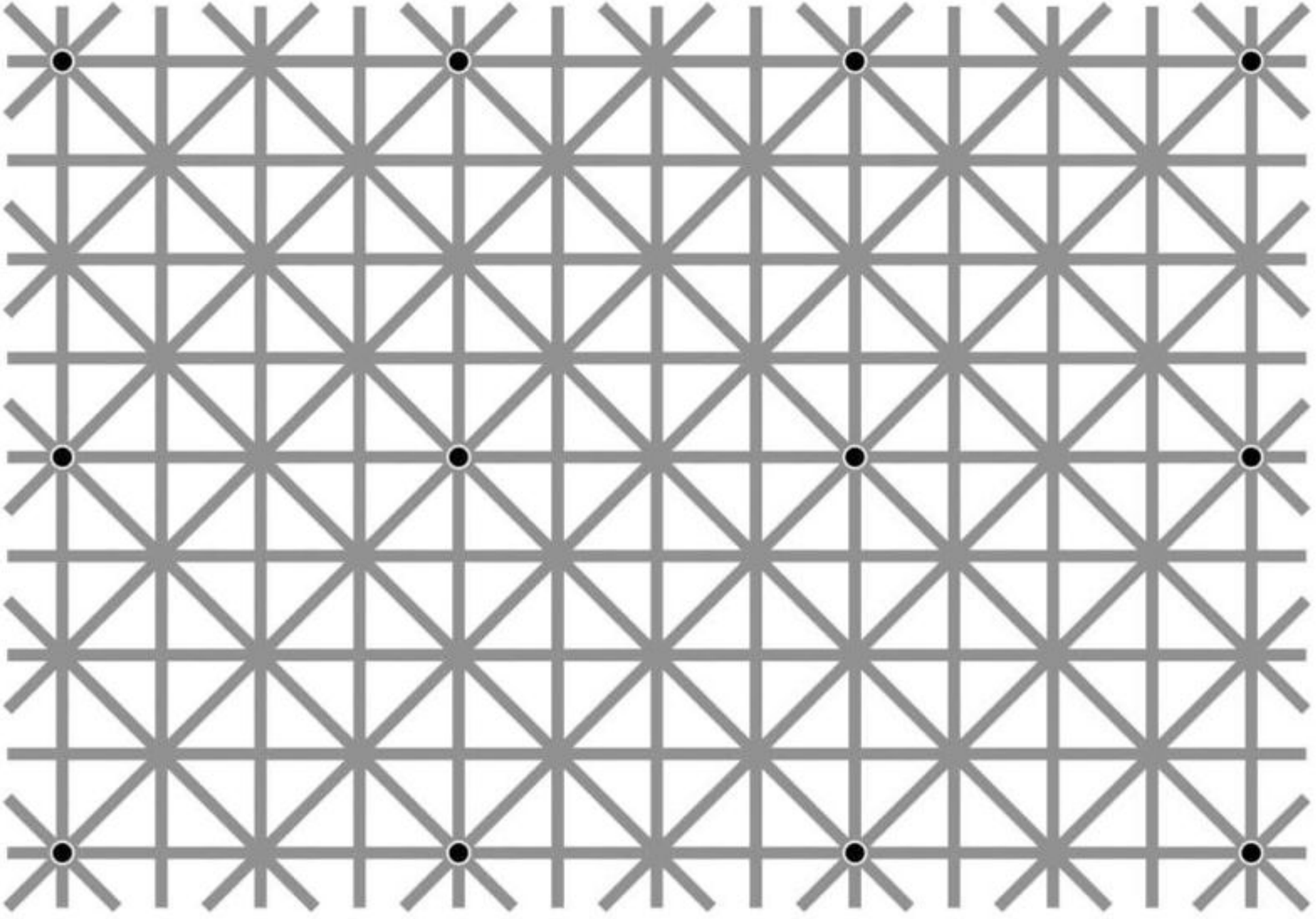





Blue & green are the same color

Others

Blind spot illusion

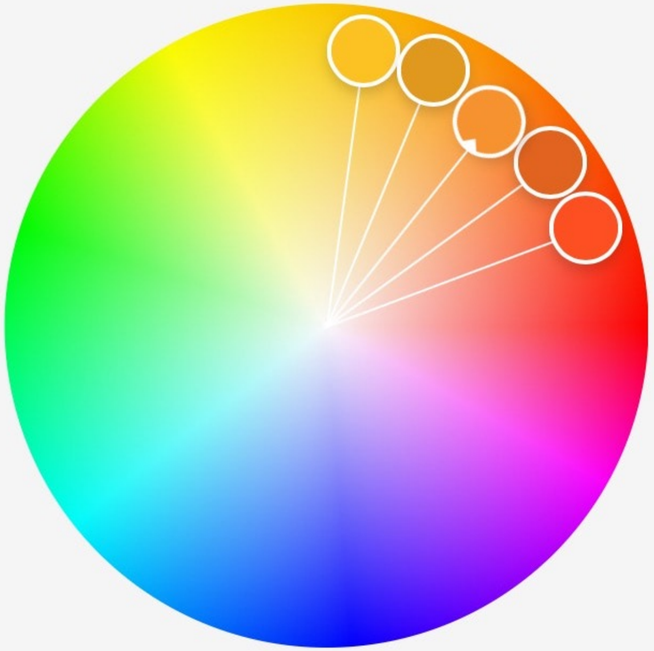


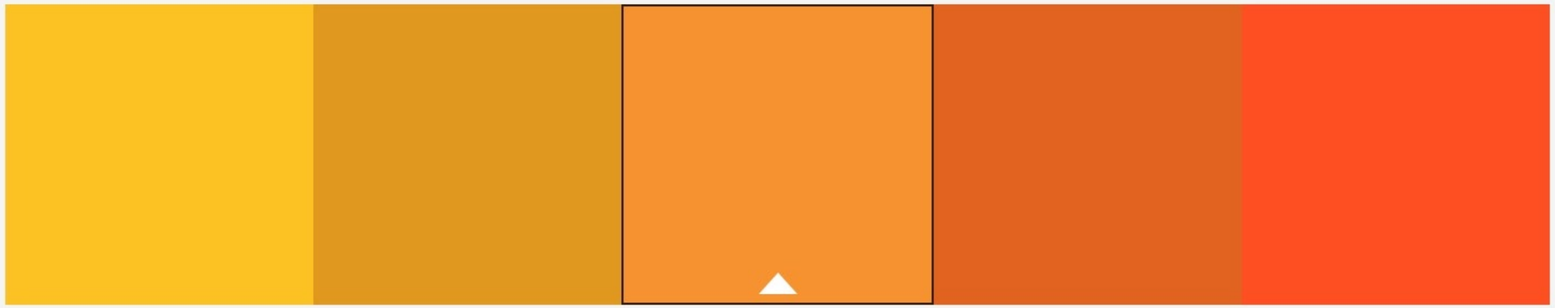
Tools

Color Wheel | Extract from an Image

Apply Color Harmony Rule

- (•) Analogous
- ( ) Monochromatic
- ( ) Triad
- ( ) Complementary
- ( ) Compound
- ( ) Shades
- ( ) Custom





#FCC123 #E0981F #F79230 #E0641F #FC5023

Color Mode

Save to Palettes from ...

Name My Color Theme

Tags

Enter or Select from below

Peach + Orange +

Coral + Skin +

Pink +

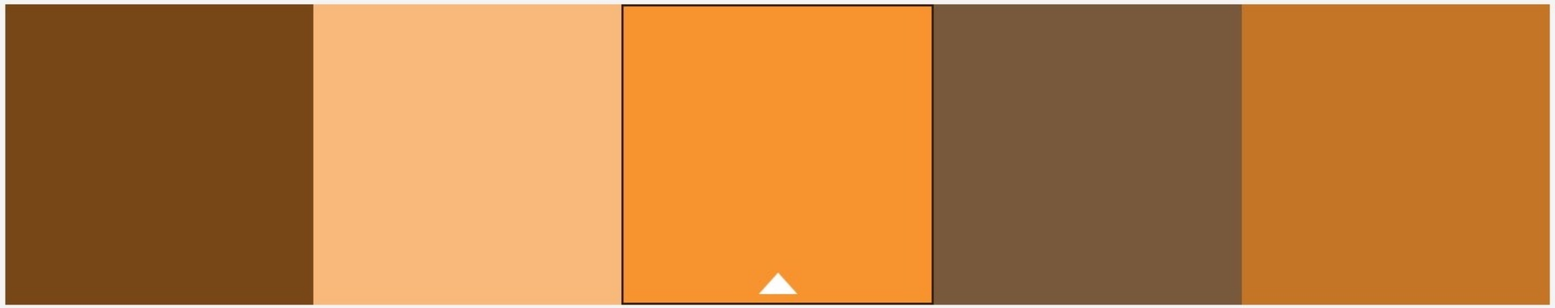
Publish to Color

Save

Color Wheel | Extract from an Image

Apply Color Harmony Rule

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



#784717 #F9B97A #F7932F #78593B #C47525

Color Mode

Save to Palettes from ...

Name My Color Theme

Tags

Enter or Select from below

Peach + Orange +

Coral + Skin +

Pink +

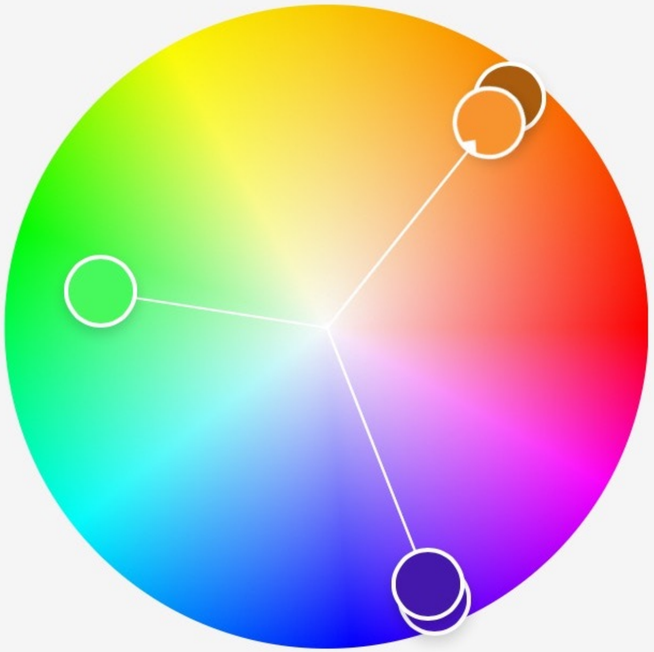
Publish to Color

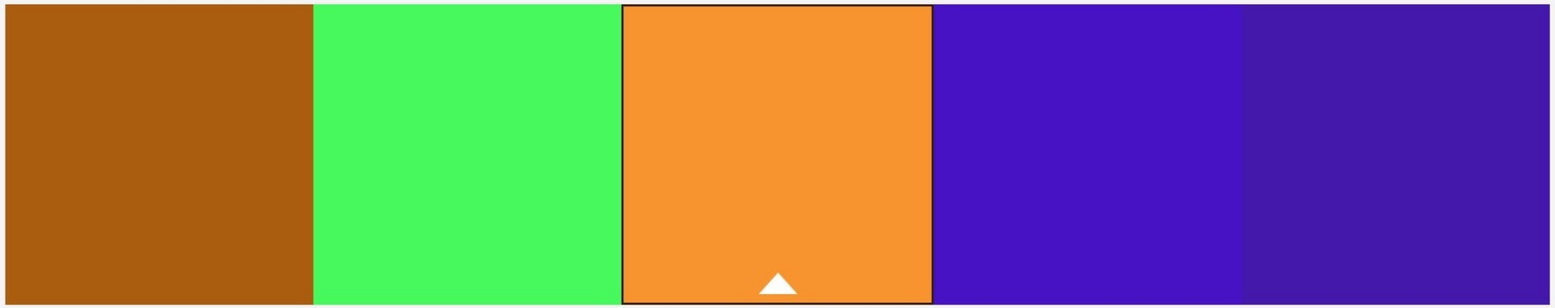
Save

Color Wheel | Extract from an Image

Apply Color Harmony Rule

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





#AB5D0F #48F95E #F7932F #4712C4 #4418AB

Color Mode

Save to Palettes from ...

Name My Color Theme

Tags

Enter or Select from below

Peach + Orange +

Coral + Skin +

Pink +

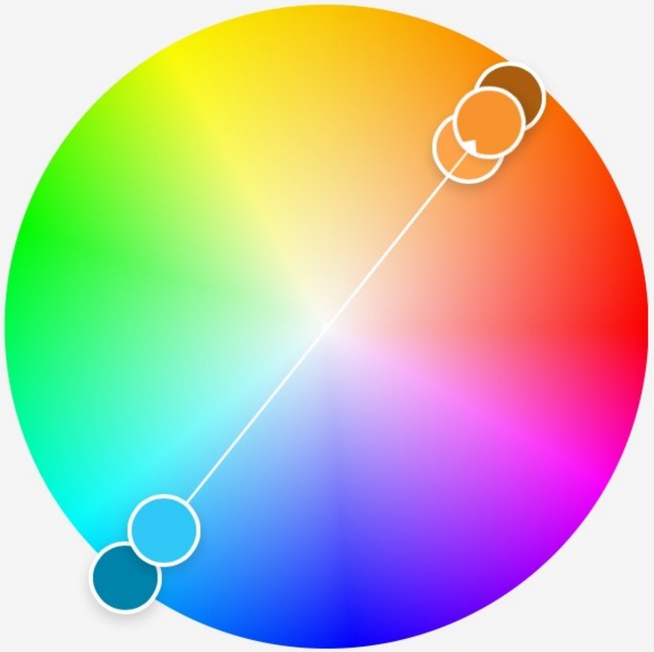
Publish to Color

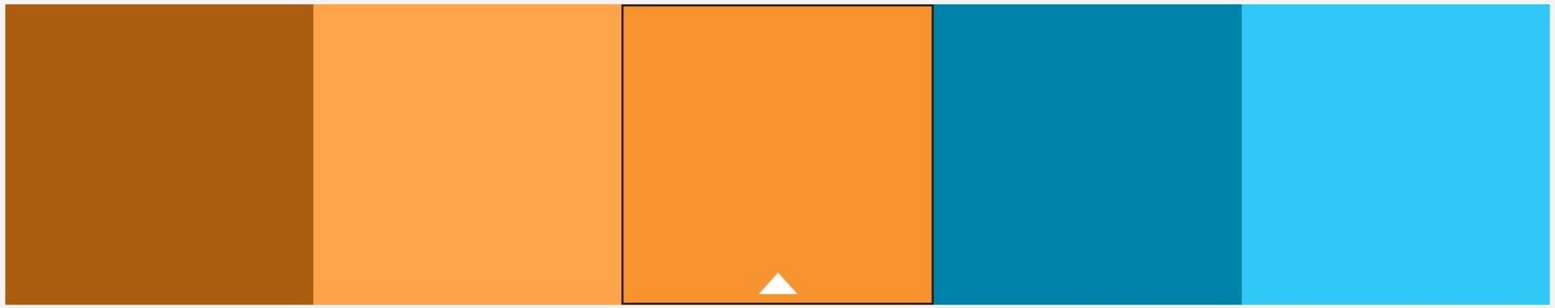
Save

Color Wheel | Extract from an Image

Apply Color Harmony Rule

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





#AB5E10 #FFA44A #F7932F #0083AB #2FC8F7

Color Mode

Save to **Palettes from ...**

Name My Color Theme

Tags

Enter or Select from below

Blue + Bright +

Neon + Green +

Orange +

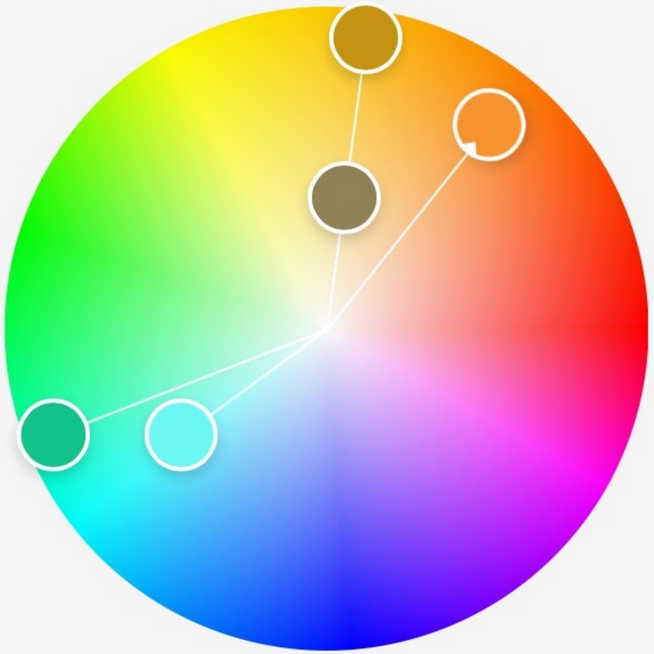
Publish to Color

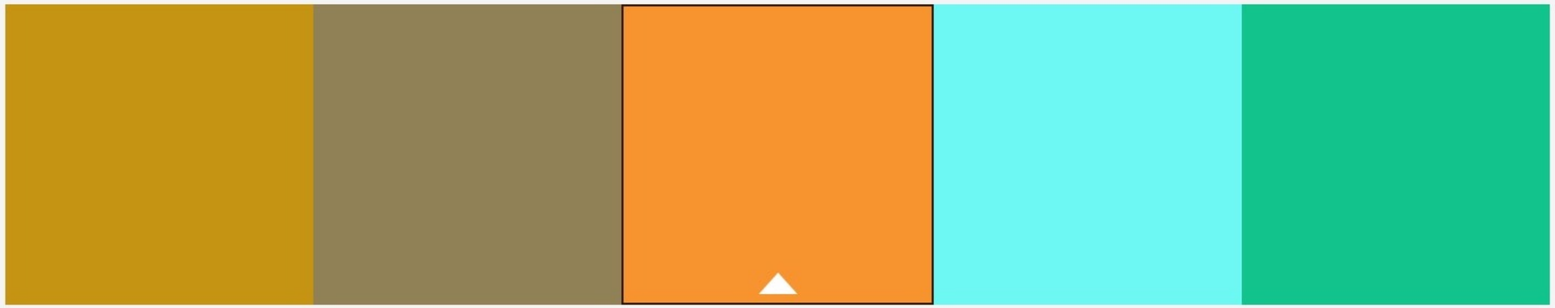
Save

Color Wheel | Extract from an Image

Apply Color Harmony Rule

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





#C49412 #918156 #F7932F #6DF8F4 #12C48C

Color Mode

Save to Palettes from ...

Name My Color Theme

Tags

Enter or Select from below

Blue + Bright + Neon + Green + Orange +

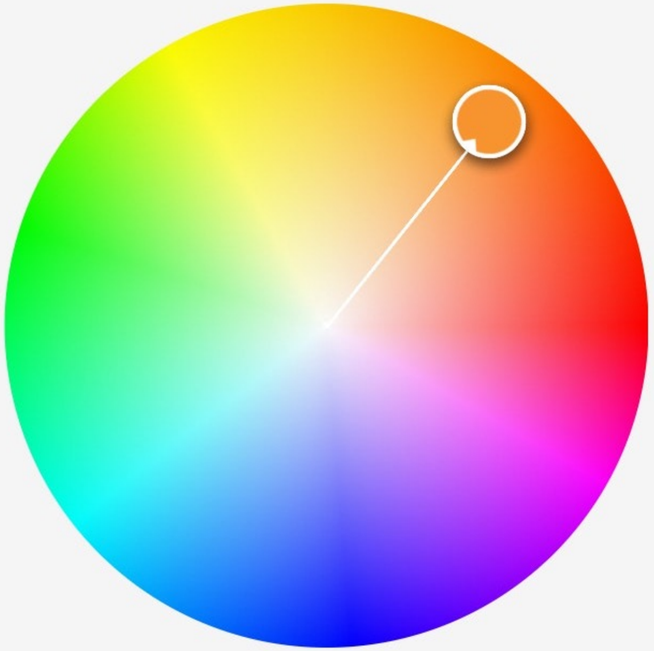
Publish to Color

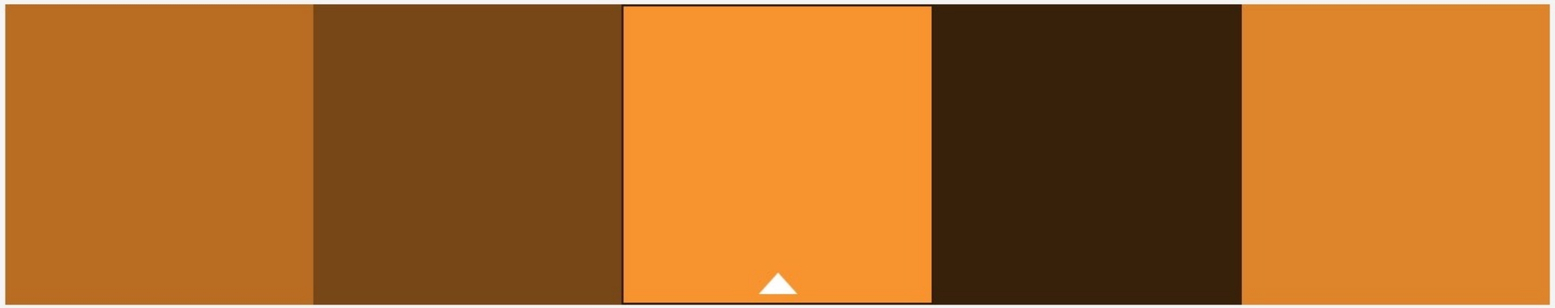
Save

Color Wheel | Extract from an Image

Apply Color Harmony Rule

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





#B86D23 #784717 #F7932F #38210B #DE842A

Color Mode

Save to **Palettes from ...**

Name My Color Theme

Tags

Enter or Select from below

Orange + Blue + Summer + Green +

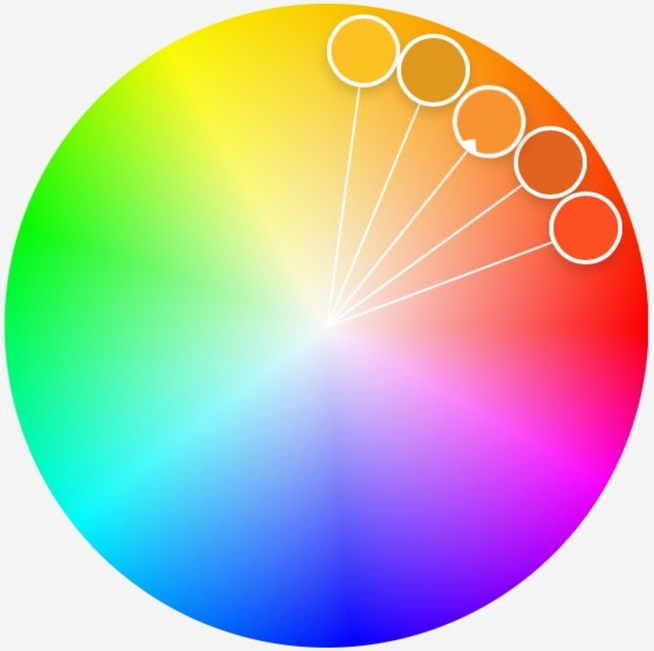
Publish to Color

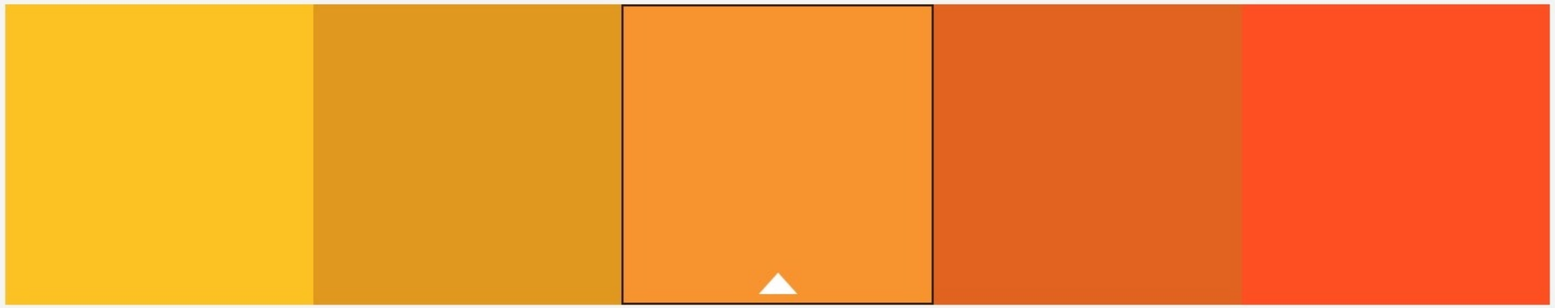
Save

Color Wheel | Extract from an Image

Apply Color Harmony Rule

- (•) Analogous
- ( ) Monochromatic
- ( ) Triad
- ( ) Complementary
- ( ) Compound
- ( ) Shades
- ( ) Custom





#FCC123 #E0981F #F7932F #E0641F #FC5023

Color Mode

Save to My Library

Name Orange Splash

Tags

Orange × Enter or Select fro...

Sun + Yellow +

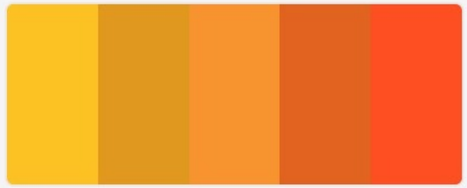
Fire + Fall +

Publish to Color

Save

Sort Libraries by Last Modified

MY LIBRARY 1 THEMES



Orange Splash

PALETTES FROM PIX 4 THEMES

Color Wheel | Extract from an Image

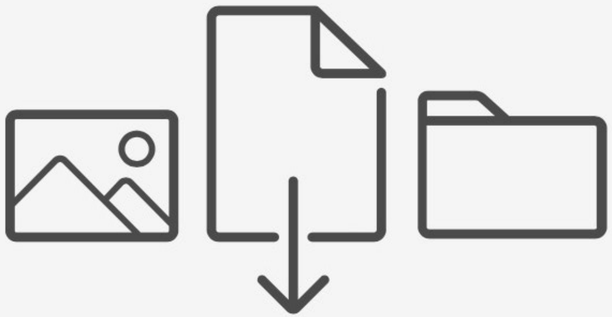
Replace

Save to My Library

Name *Enter theme name*

Publish to Color

Save

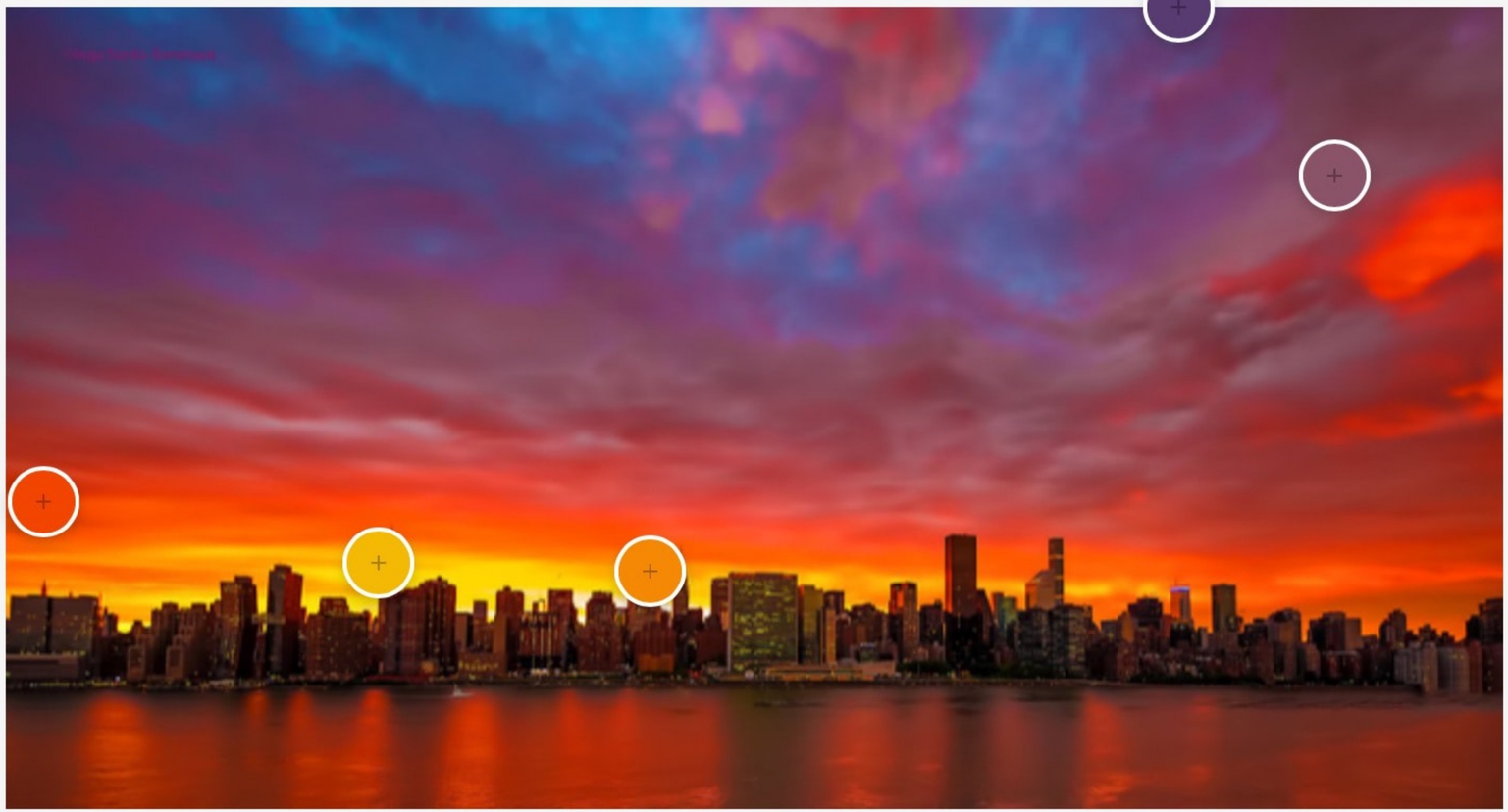


Drag and Drop Your File

or Select a File from your computer

Extract using Color Mood

- (•) Colorful
- ( ) Bright
- ( ) Muted
- ( ) Deep
- ( ) Dark
- ( ) None



Save to My Library

Name City sunset

Tags

Enter or Select from below

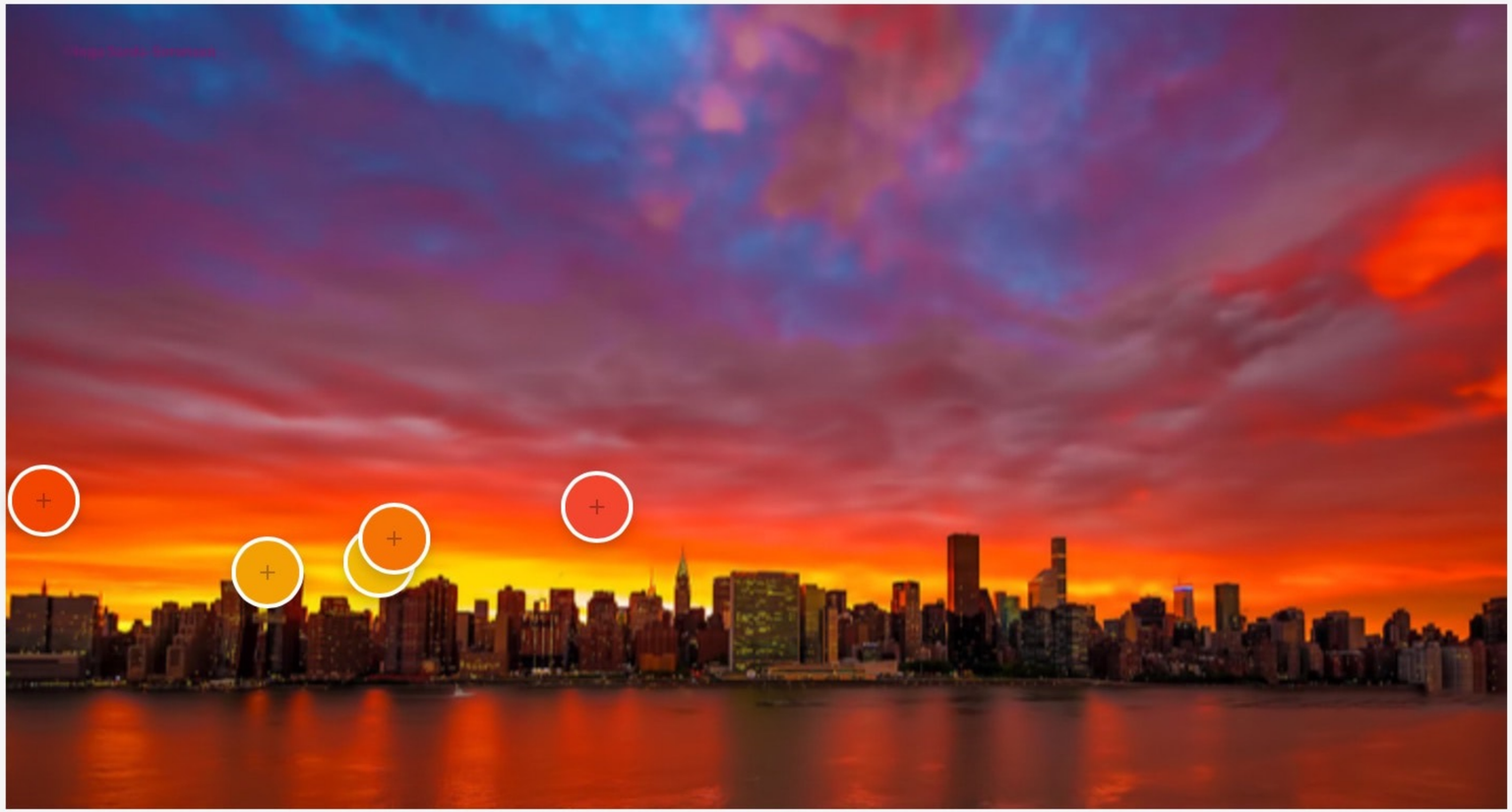
Skin + Tones + Pastel + Light +

Publish to Color

Save

Extract using Color Mood

- Colorful
- Bright
- Muted
- Deep
- Dark
- None



Save to My Library

Name City sunset

Tags

Enter or Select from below

Skin + Tones +

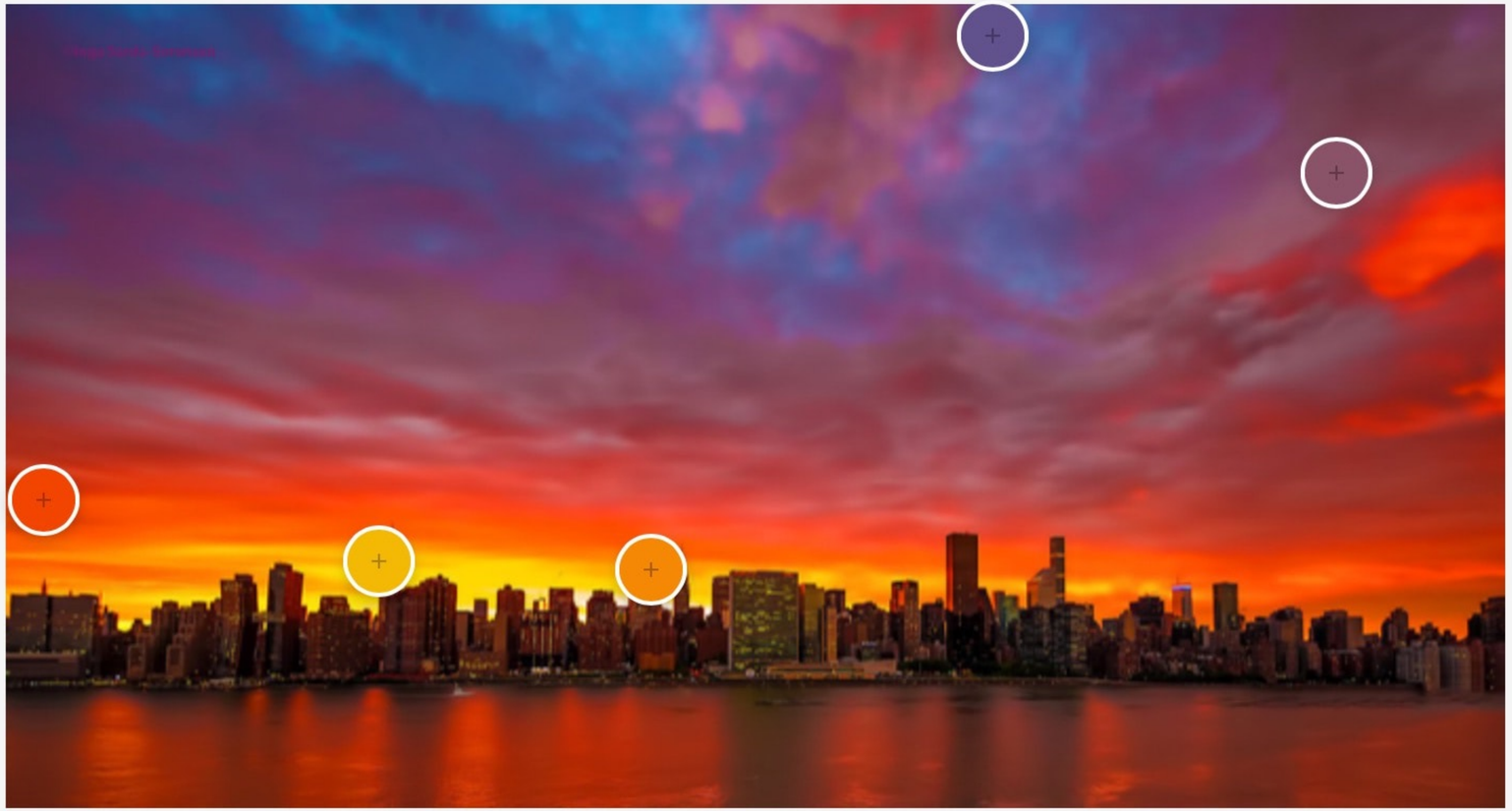
Pastel + Light +

Publish to Color

Save

Extract using Color Mood

- Colorful
- Bright
- Muted
- Deep
- Dark
- None



Save to My Library

Name City sunset

Tags

Enter or Select from below

Skin + Tones +

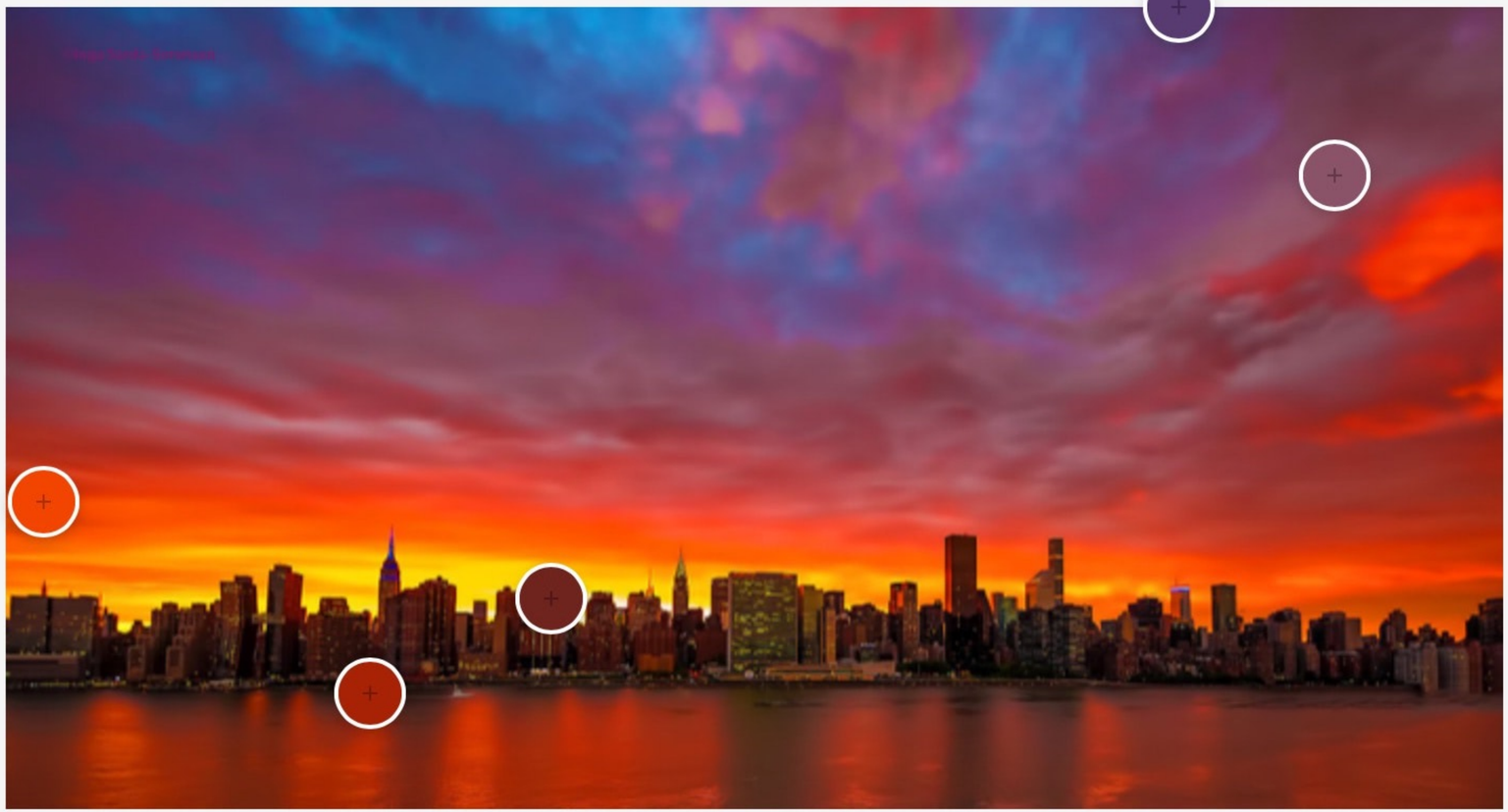
Pastel + Light +

Publish to Color

Save

Extract using Color Mood

- Colorful
- Bright
- Muted
- Deep
- Dark
- None



Save to My Library

Name City sunset

Tags

Enter or Select from below

Skin + Tones +

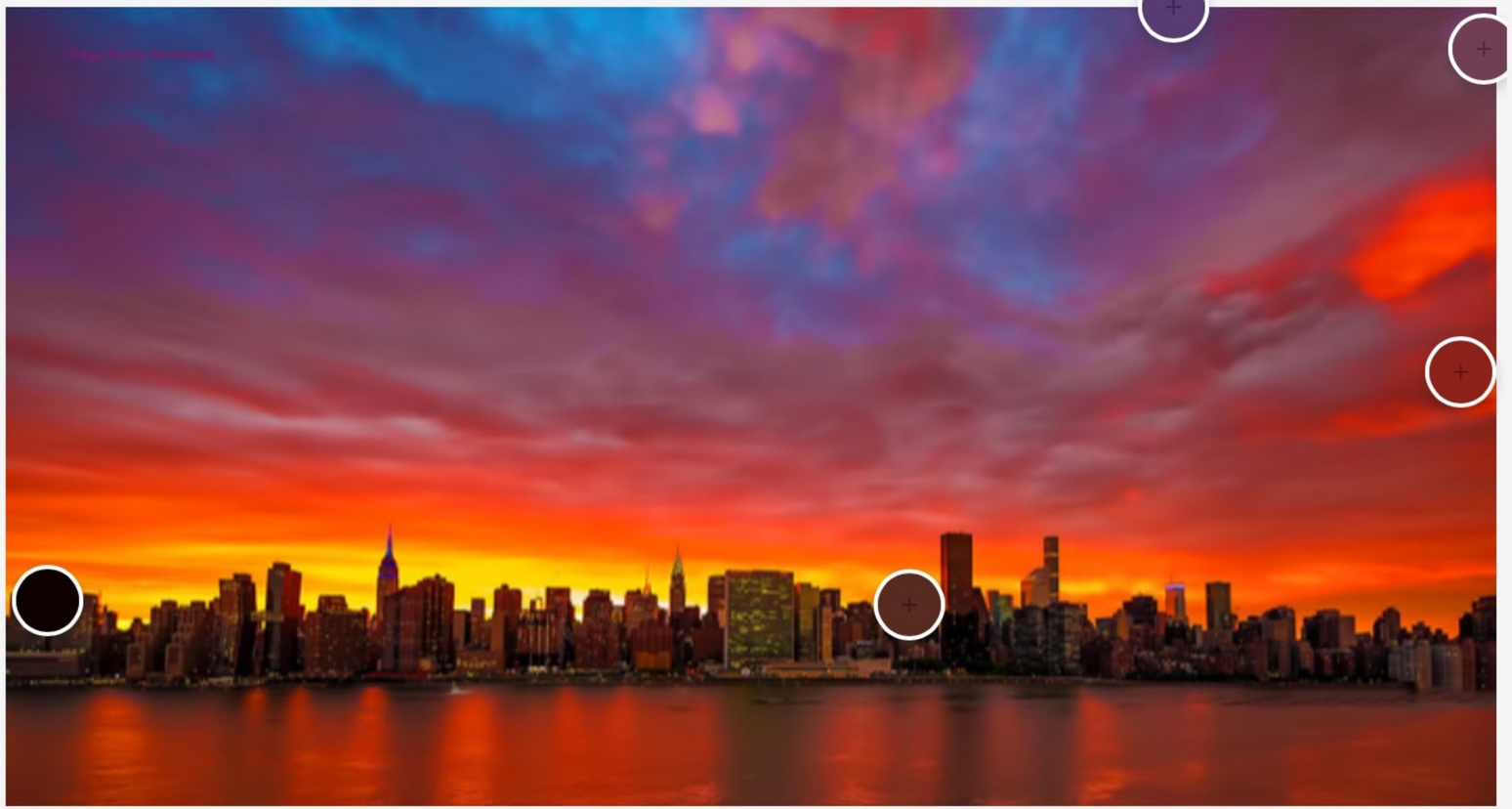
Pastel + Light +

Publish to Color

Save

Extract using Color Mood

- Colorful
- Bright
- Muted
- Deep
- Dark
- None



Save to My Library

Name City sunset

Tags

Enter or Select from below

Skin + Tones +

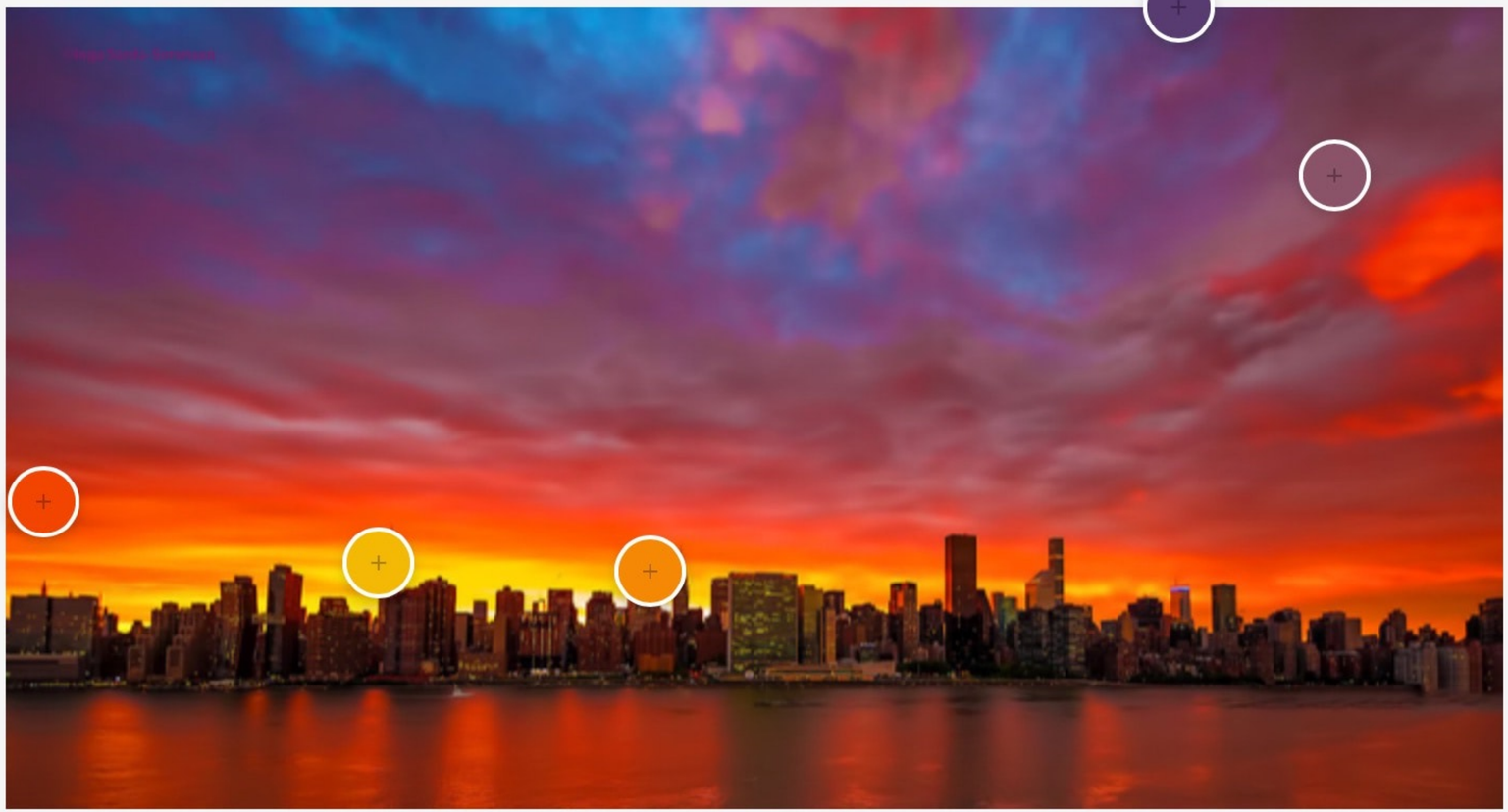
Pastel + Light +

Publish to Color

Save

Extract using Color Mood

- (•) Colorful
- ( ) Bright
- ( ) Muted
- ( ) Deep
- ( ) Dark
- ( ) None



Save to My Library

Name City sunset - Colorful

Tags

Sunset

Blue + Orange +

Bright + Yellow +

Bold +

Publish to Color

Save

Sort Libraries by Last Modified

PALETTES FROM PIX

3 THEMES

Mountains lake trees

Rossy at the beach

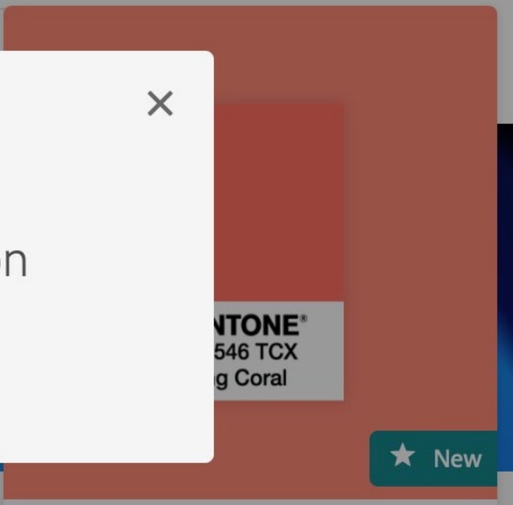
City sunset - Colorful

MY LIBRARY

1 THEMES

Search with co

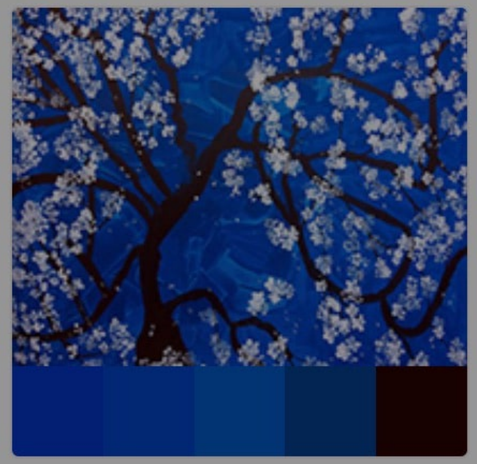
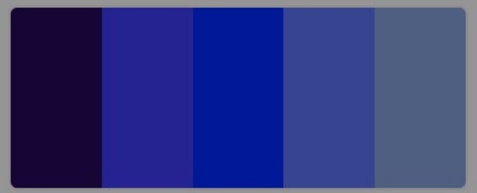
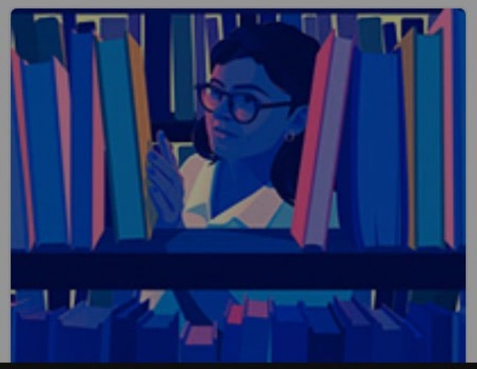
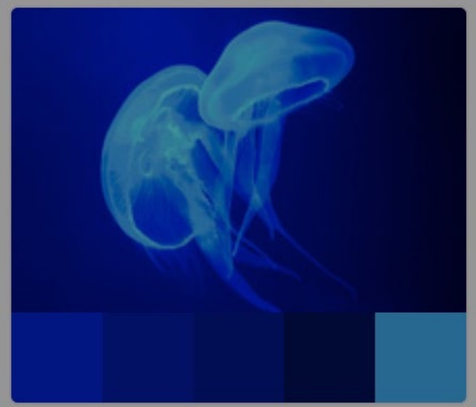
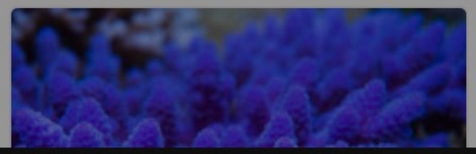
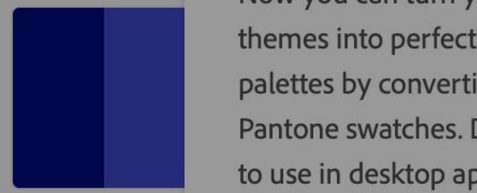
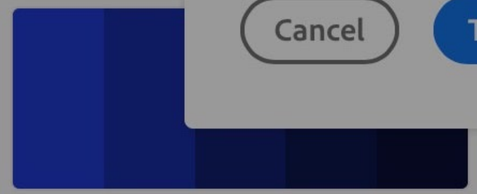
Your color exploration journey starts here, with beautiful themes from the best in Adobe Stock and Behance imagery. You can change the filter to refine the inspiration source, or use colors and keywords to target your searches.



Pantone Match

Now you can turn your color themes into perfect print palettes by converting them to Pantone swatches. Download to use in desktop applications.

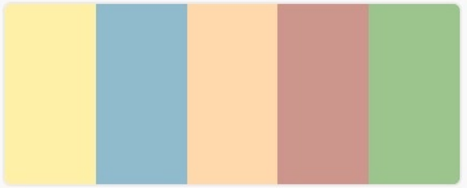
Cancel Try it out

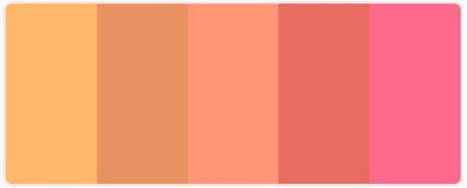








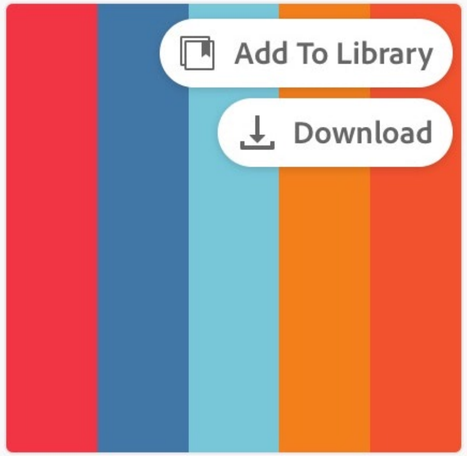

desert

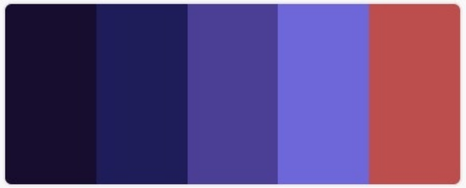
Palettes fr...

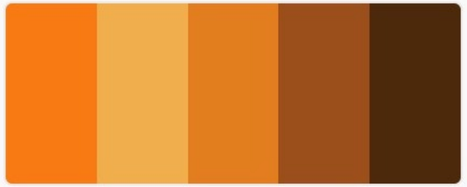
View All Sources











Search with colors, moods or keywords like ocean, wine, moonlight, lucky, water...

My Library

Discover current color trends in different industries from the creative communities on Behance and Adobe Stock.

Fashion

Explore color through cutting-edge fashion with looks from boho natural to vibrant haute couture curated from Behance.

Architecture

Build your color story from architectural elegance on Behance from residential interiors to the cities of the future.

View More >

Game Design

Level up your color game by analyzing the latest color trends of your fellow game designers on Behance.

Flavour

Explore color so rich you can taste it through the latest trends in Adobe Stock food photography.

View More >

Travel

Find your perfect beach blue, or sea green with inspiring palettes curated from the best Adobe Stock travel imagery.

App Store Preview

Adobe Capture 4+

Asset Creation for Designers

Adobe Inc.

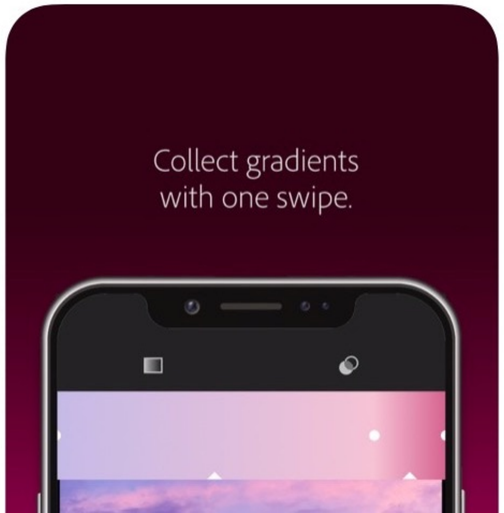
#155 in Productivity

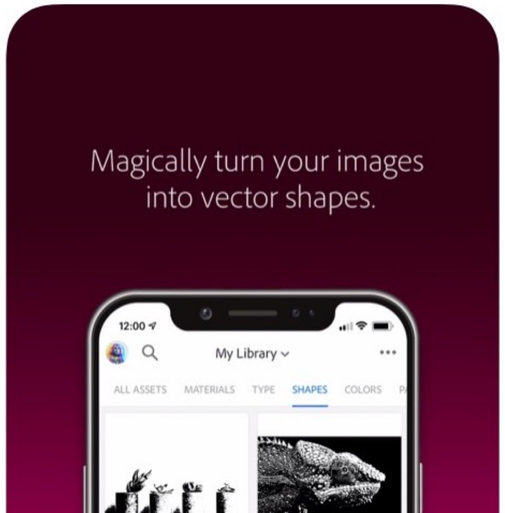
★★★★★ 4.8, 11.6K Ratings

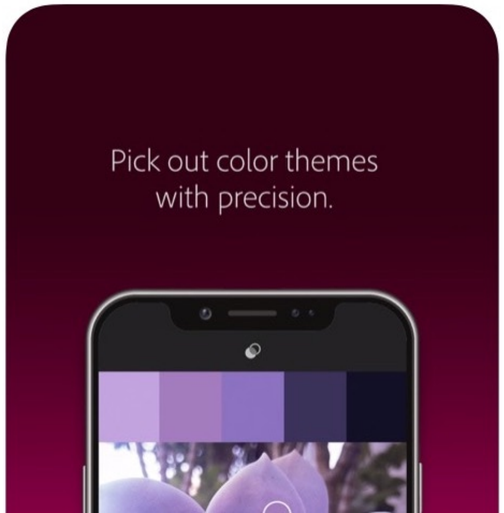
Free · Offers In-App Purchases

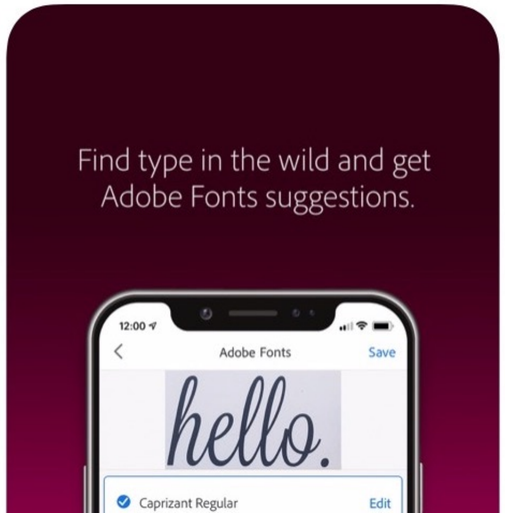
Screenshots

iPhone iPad



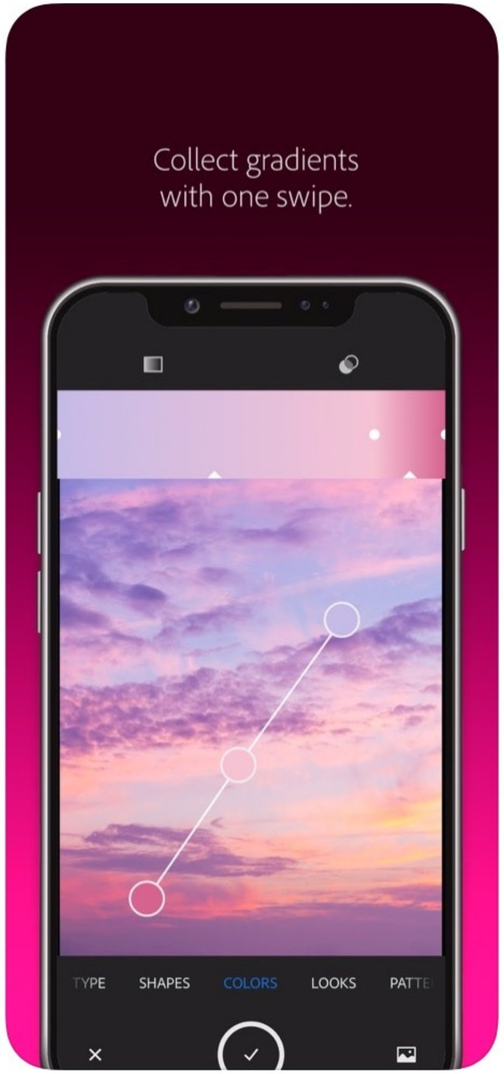


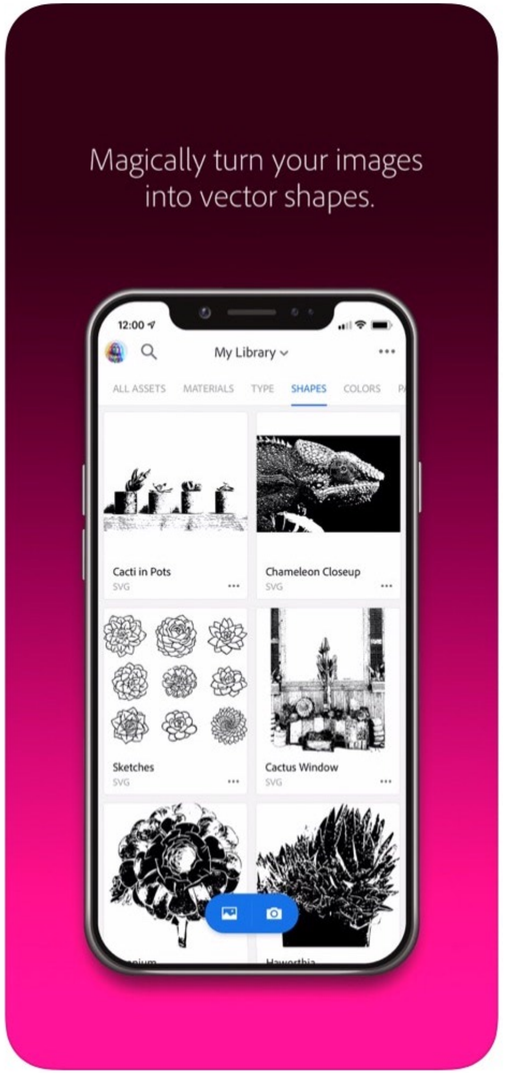


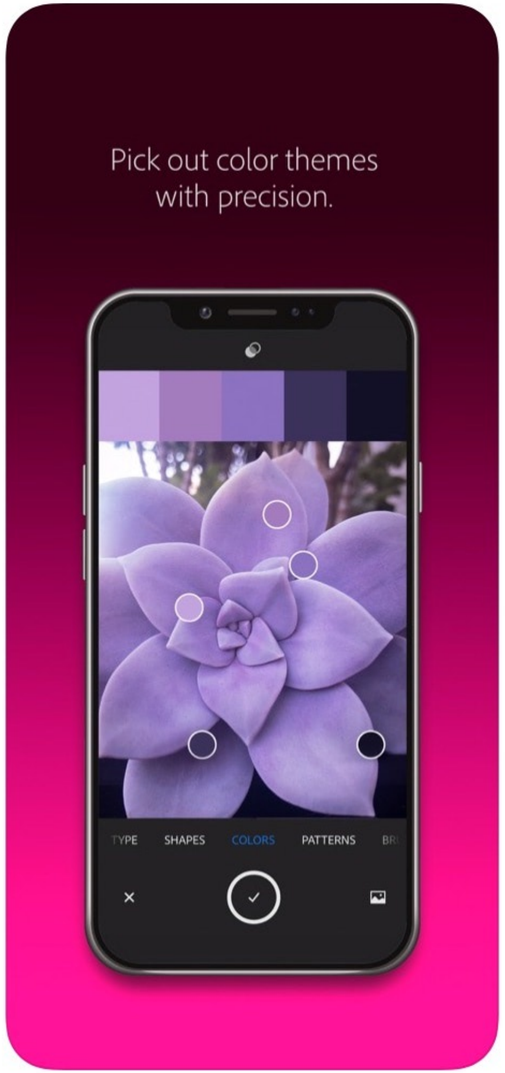


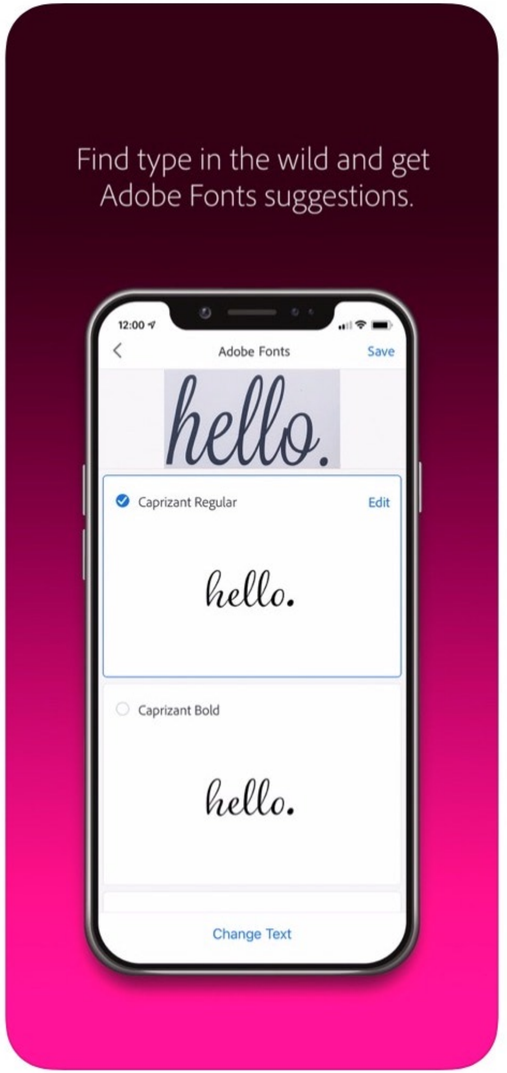
Screenshots

iPhone iPad









Adobe Capture turns your iPhone and iPad into a creation machine.

Final Thoughts

Thank you!

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@scottgranneman

jans@websanity.com
websanity.com

Grand Unified (Color) Theory

Meet Roy G. Biv!

R. Scott Granneman & Jans Carton

Changelog

2021-08-03 2.8: Updated theme to Granneman 1.7; fixed minor formatting issues; added 2 optical illusion videos

2020-07-26 2.7: Updated screenshot of Color Oracle home page; added screenshots of WUSTL's webpage taken using Color Oracle; added URL for The Dress; added animals under *Biology*

Changelog

2019-08-17 2.6: Added many jazz album covers to illustrate *Color Harmony*

2019-08-14 2.5: Added more optical illusions & re-ordered them; better diagrams & charts in Color Blindness; changed title to *Grand Unified (Color) Theory*; added diagram showing how multiple wavelengths can produce 1 color; completely updated all of *Tools*

Changelog

2019-07-10 2.4: Fixed *hue* illustration; combined *intensity* slides; changed *Basic Concepts* to *Basic Terminology*; cleaned up tints, tones, & shades & primary colors; re-did color geometries illustrations; all hex values now use lining numbers instead of old style; changed *Color Models* to *Modern Color Reproduction*; changed *Color Vision* to *Perceiving Color*; rearranged *The Visible Spectrum*; minor wording fixes everywhere

Changelog

2018-10-24 2.3: Fixed screenshot of HSLuv; added HSL Color Picker

2017-08-05 2.2: Added more color examples under Color Harmony; added color names under Color Wheel; labeled Color Blindness examples; added Adobe Capture & hid Adobe Kuler; fixed Nazi flag; updated theme to Granneman 1.5; fixed formatting errors

Changelog

2016-10-12 2.1: Added Sim Daltonism to Color Blindness; fixed missing font on slides about red in Pairing Colors; added Plutchik & more to Color Symbolism; switched theme to Granneman 1.2; fixed formatting

2015-06-24 2.0: Completely re-did the whole thing!

2014-08-10 1.1: Changed to new theme

2013-11-04 1.0: Final refinements

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