datacolor

Academy

Color Theory – Part 3

Color Coordinates

Color Theory – Part 3

Color Coordinates

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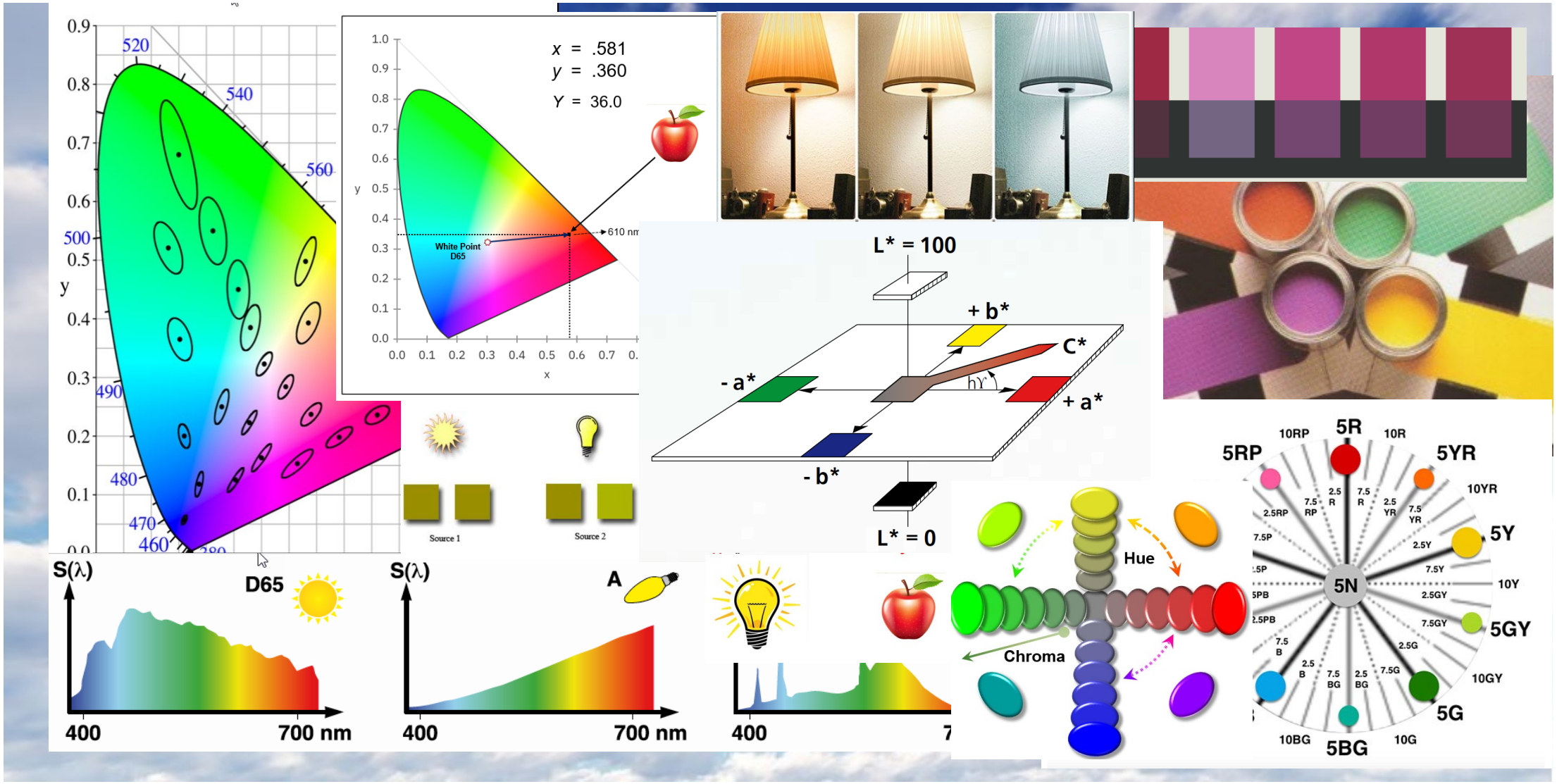

Review

Color Perception versus Color Description

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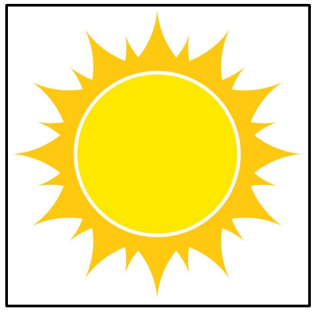
We have described the visual color perception process by showing how the light source, object and observer are together responsible for color perception.



Light Source

x

Object

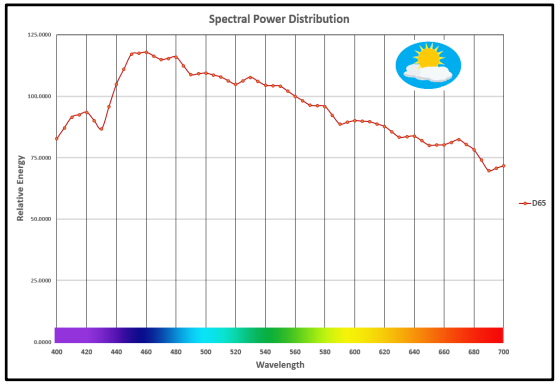
x

Observer

=

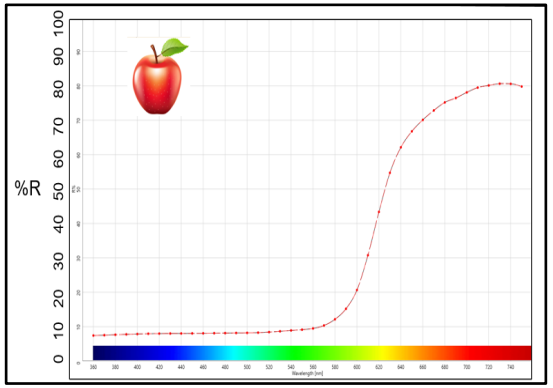
Color Perception

With the Standard Observer, we can now develop a numerical specification:



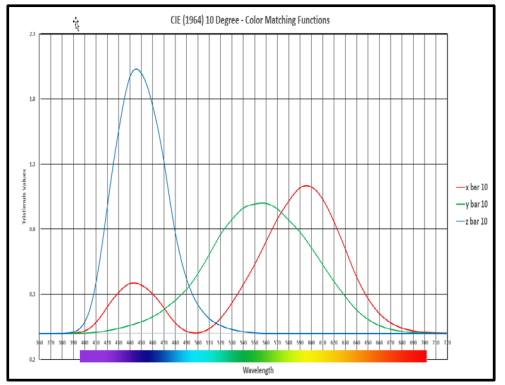
Daylight Illuminant Numerical Data

x



Reflectance Curve Numerical Data

x



CIE Standard Observer Numerical Data

=

Colorimetric Description

Review

Standard Observer / Metamerism

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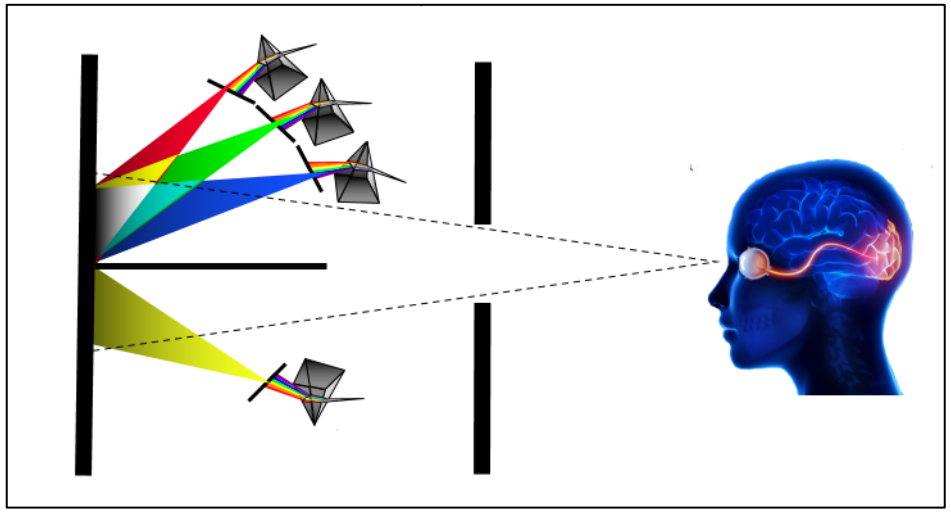

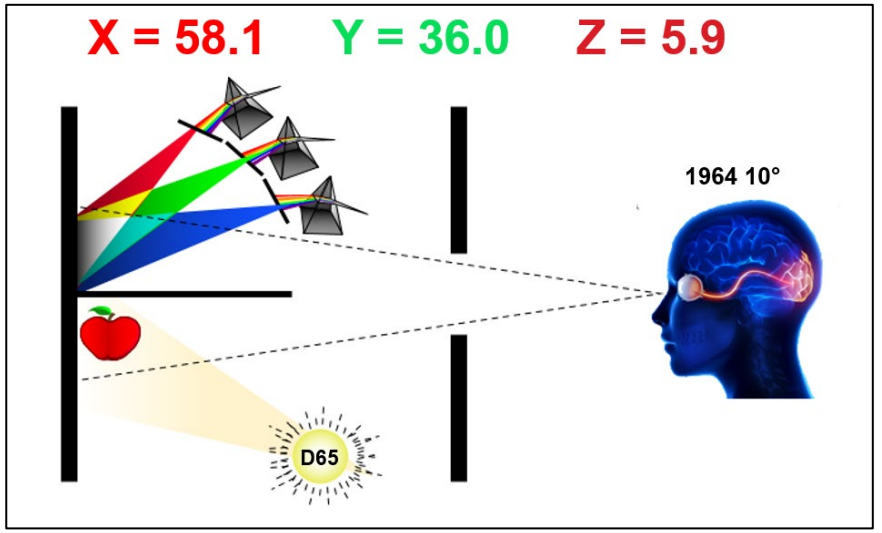

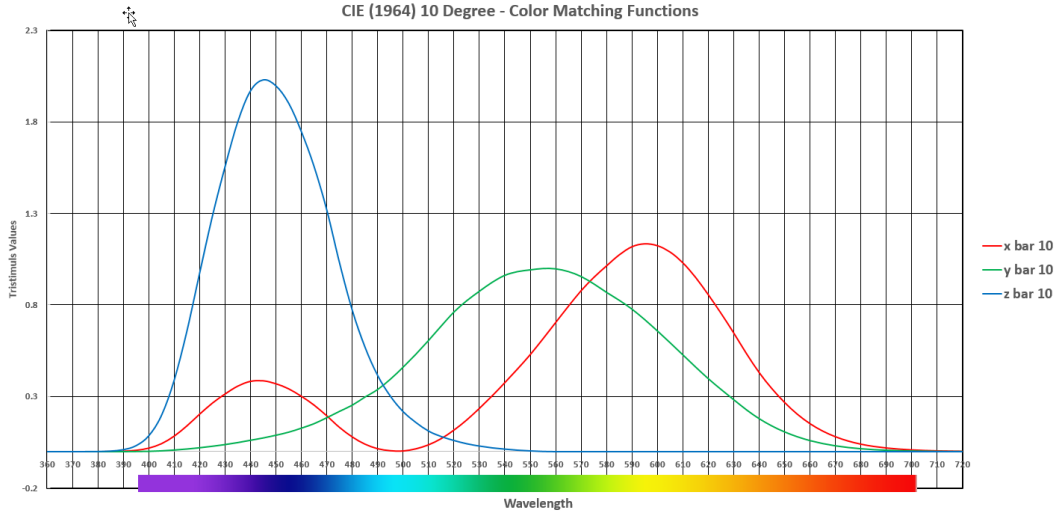

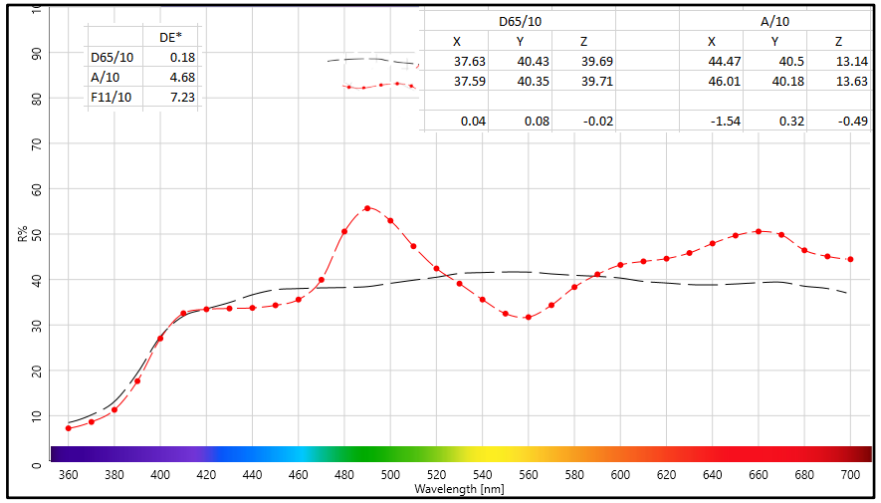

Color Order Systems

Munsell - A Visual System

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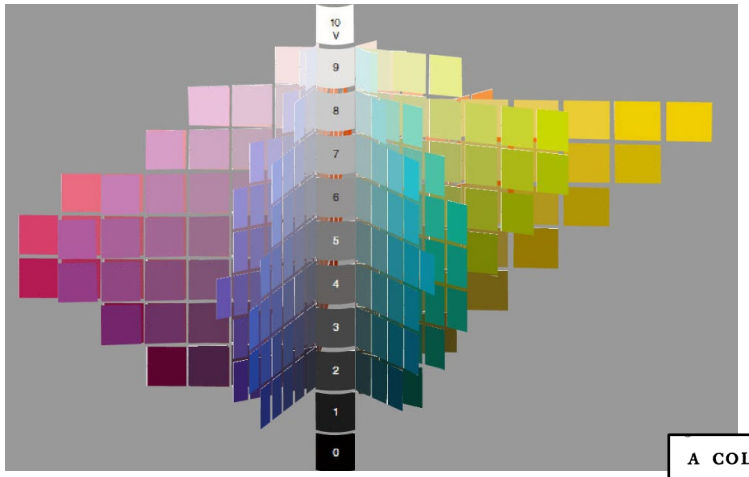
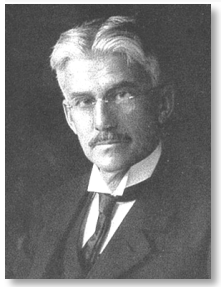
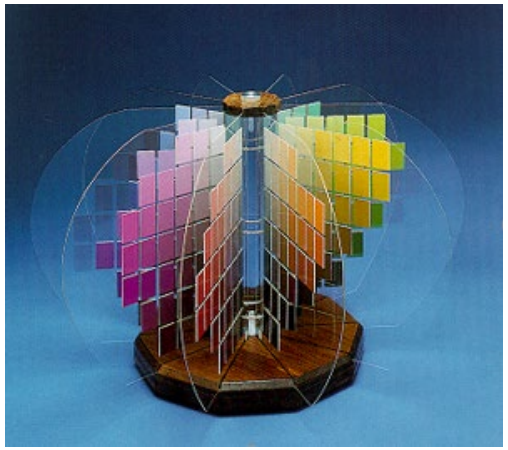
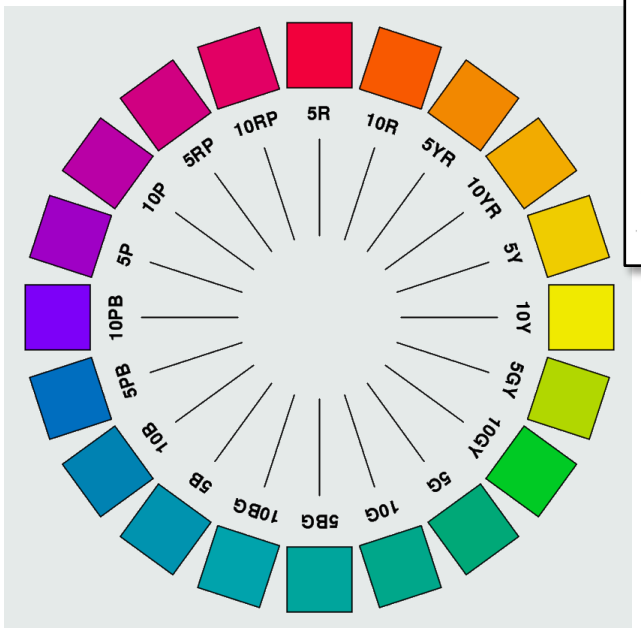








A COLOR NOTATION

By
A. H. MUNSELL

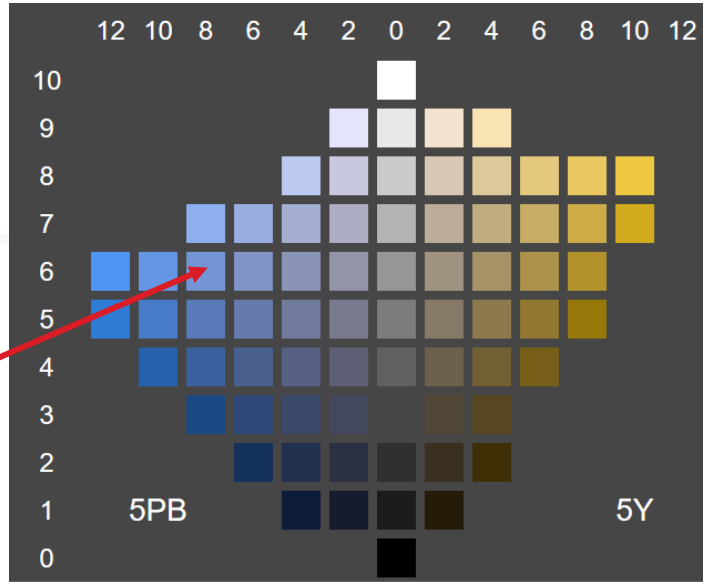
A MEASURED COLOR SYSTEM, BASED ON THE THREE QUALITIES *Hue, Value, and Chroma*
WITH
ILLUSTRATIVE MODELS, CHARTS, AND A COURSE OF STUDY ARRANGED FOR TEACHERS

GEO. H. ELLIS CO.
BOSTON
1905

Munsell Notation:

5PB 6/8

Hue Value/Chroma



NCS

Natural Color System - Opponent Color Model

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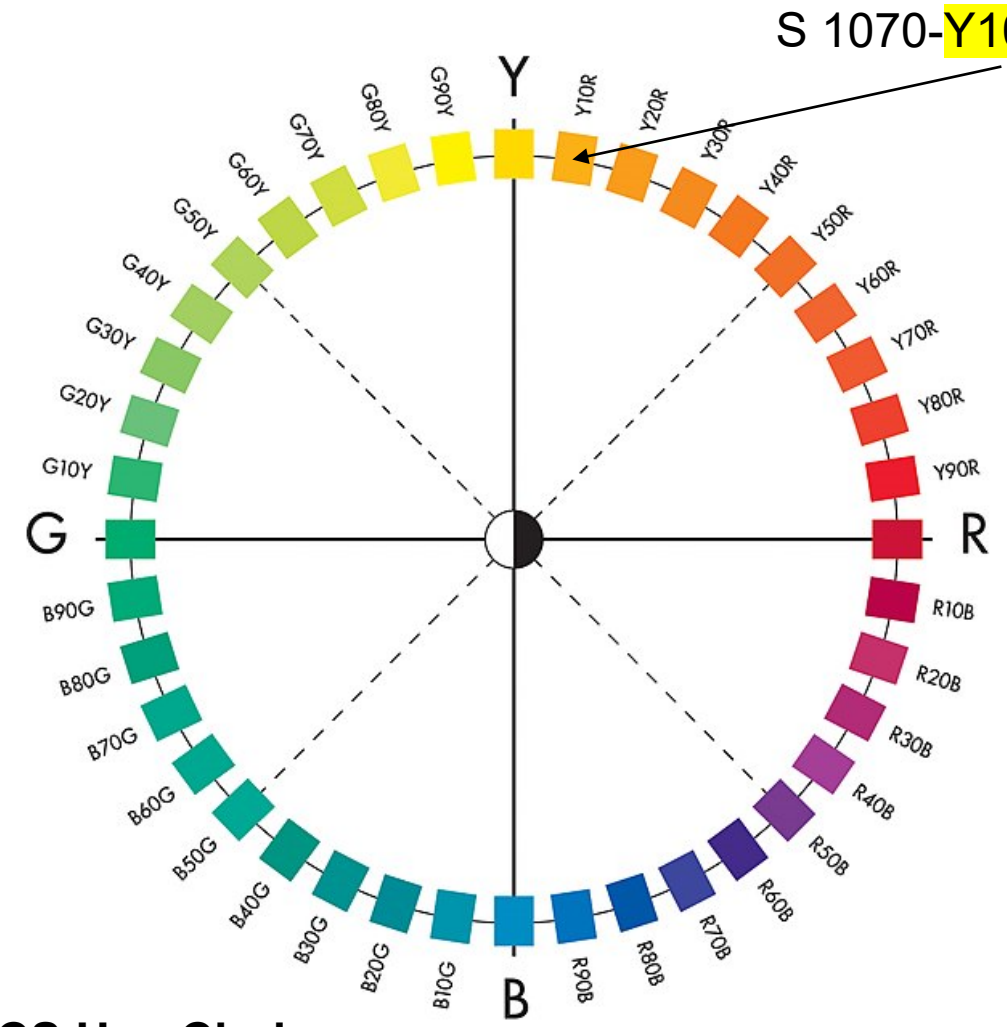
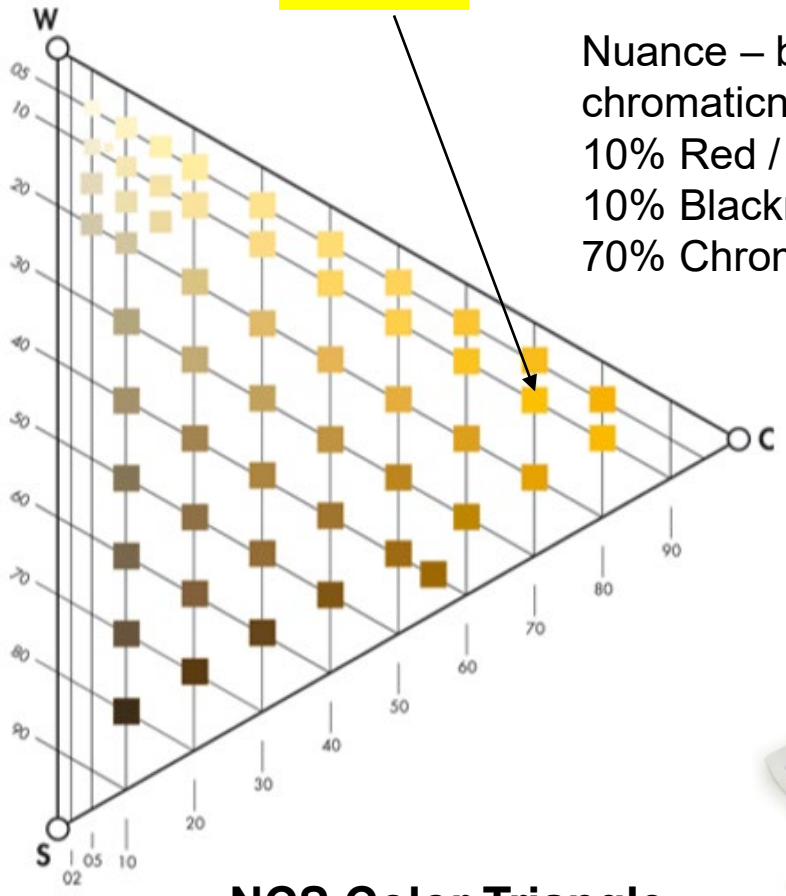


NCS Hue Circle

S 1070-Y10R

Nuance – blackness and chromaticness of a color.
10% Red / 90% Yellow
10% Blackness
70% Chromaticness



NCS Color Triangle

NCS 1950 Index

3 Dimensions of Color

Hue, Chroma, Lightness

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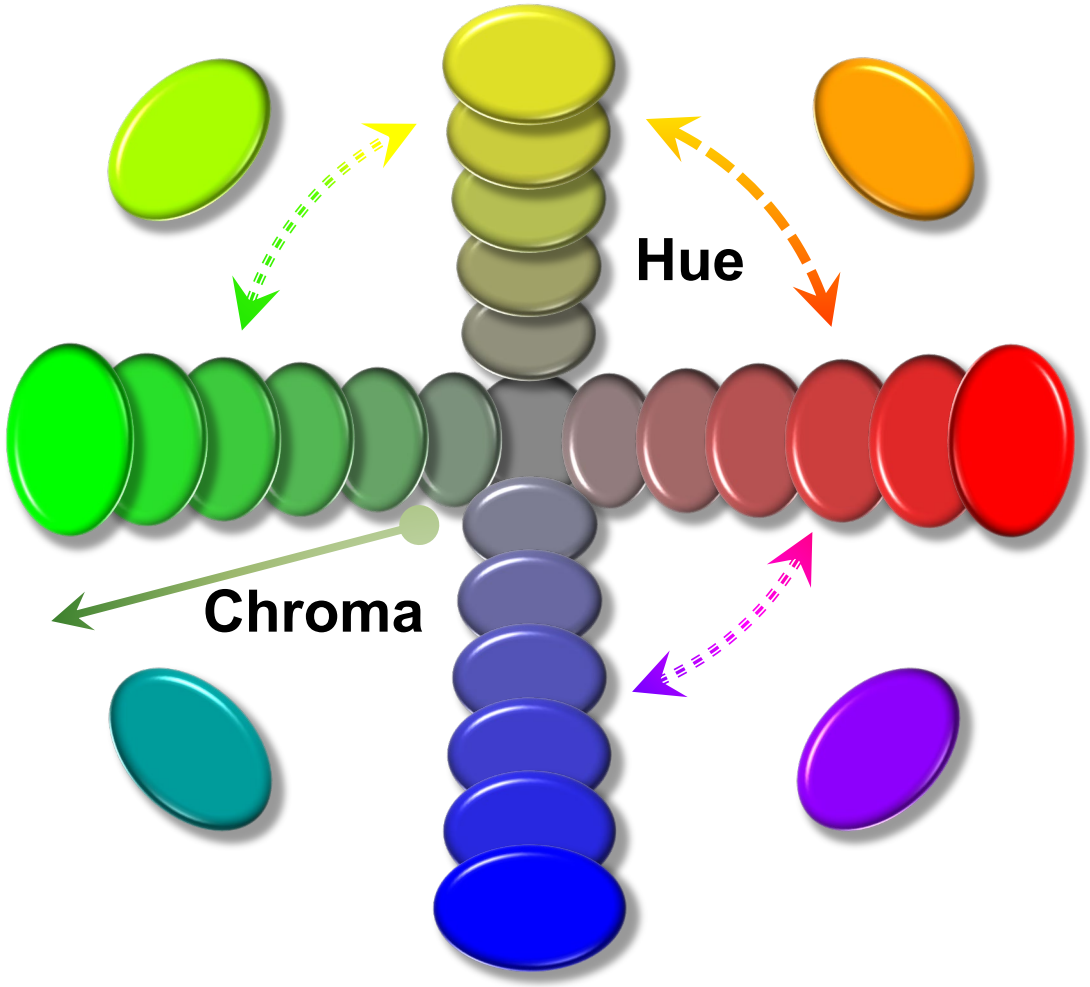

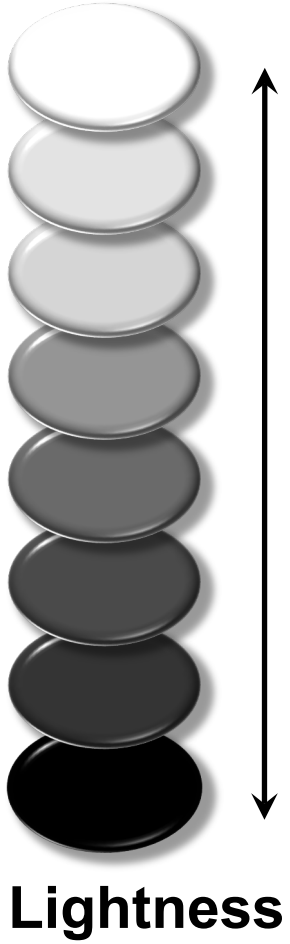

Hue is the term we use to describe a specific color like yellow, red, blue, green, violet.

Chroma is the amount or intensity of a specific hue. The saturation or difference from gray.

Lightness is the total amount of light coming from a sample independent of hue and chroma.

CIELAB

Non-linear Transformation of CIE xyY Color Space

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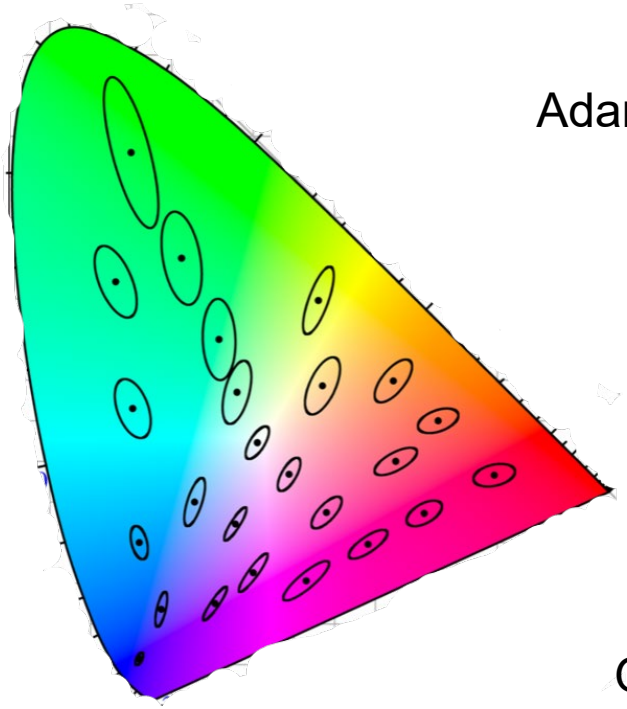
CIE xyY



Munsell System

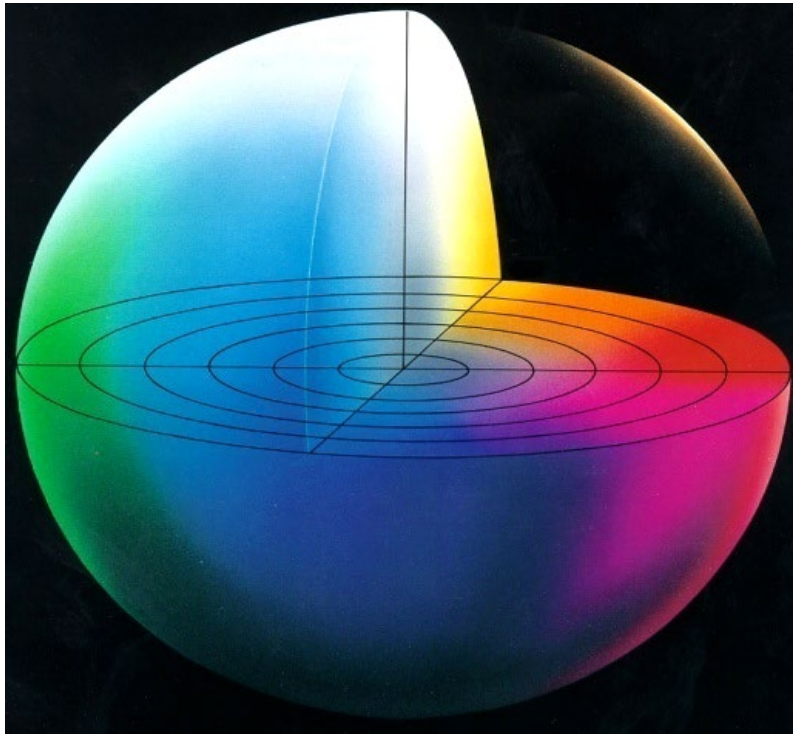
Adams Chromatic Value
1942

Adams-Nickerson
ANLab
1944, 1950

Glasser –Reilly
Cube Root
1958

CIE 1976

CIE L*a*b*



Opponent Color Model

CIELAB

*CIE L*a*b* Color Space*

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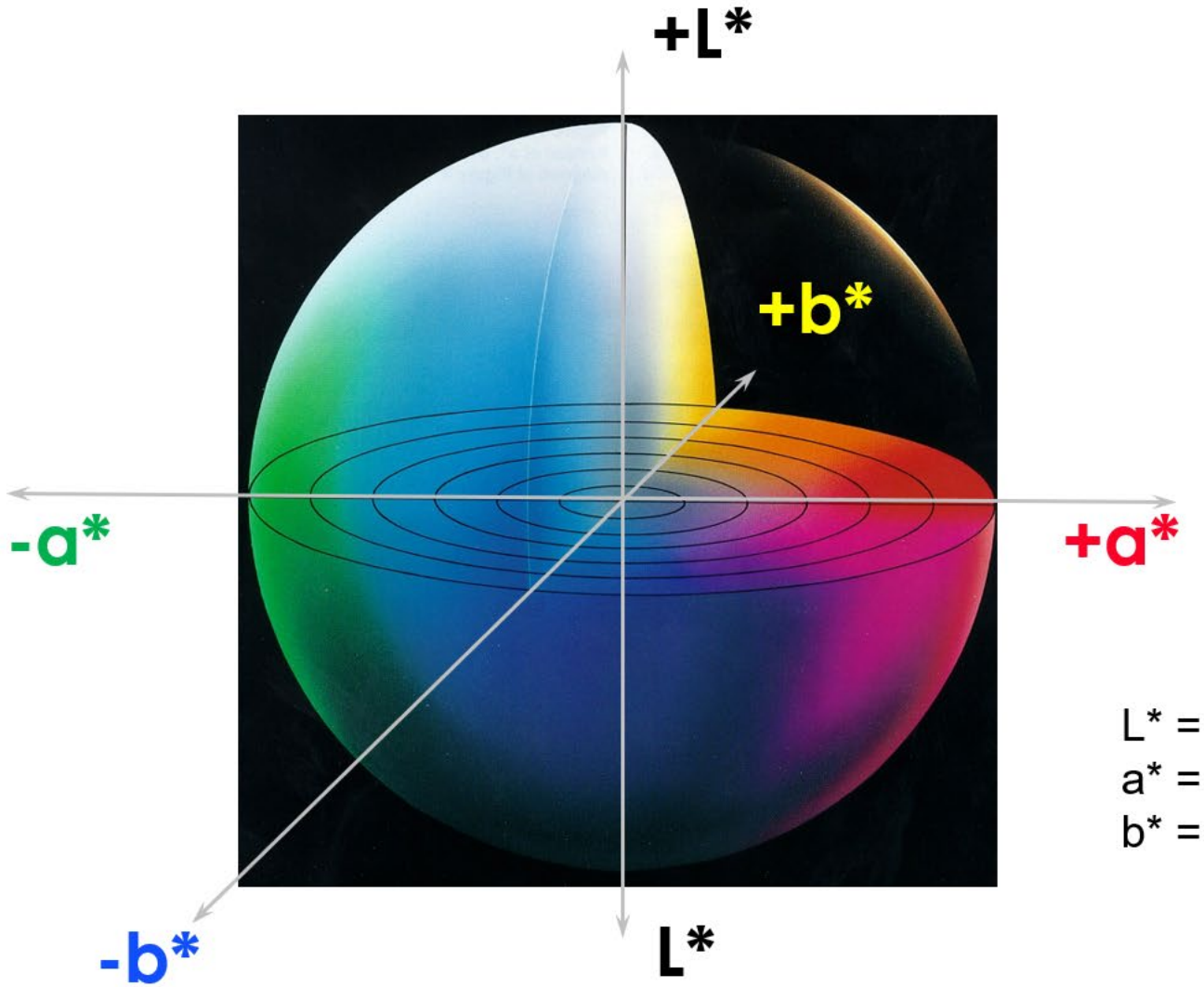

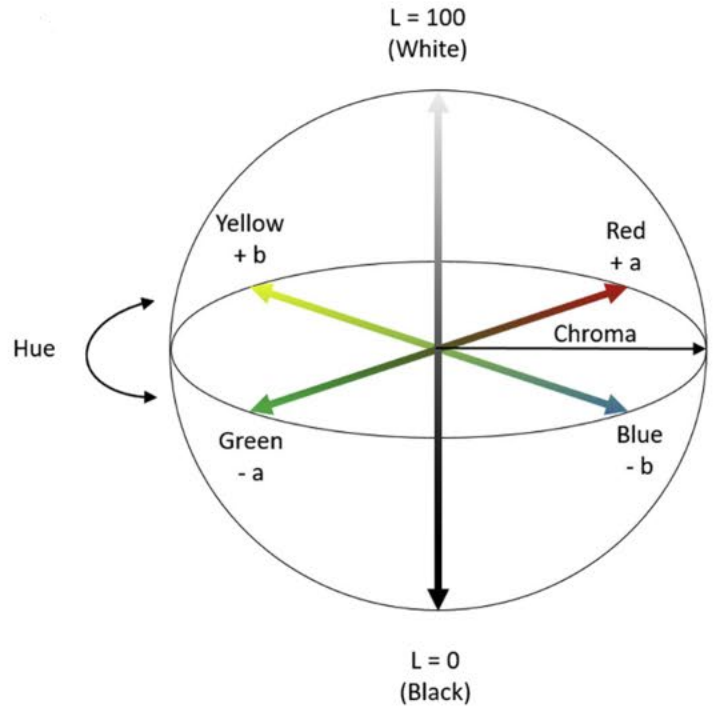

L* = Lightness
a* = red-green axis +a* (red) -a* (green)
b* = yellow-blue axis +b* (yellow) -b* (blue)

Opponent Color Model

CIELAB

*CIE L*a*b* Color Space*

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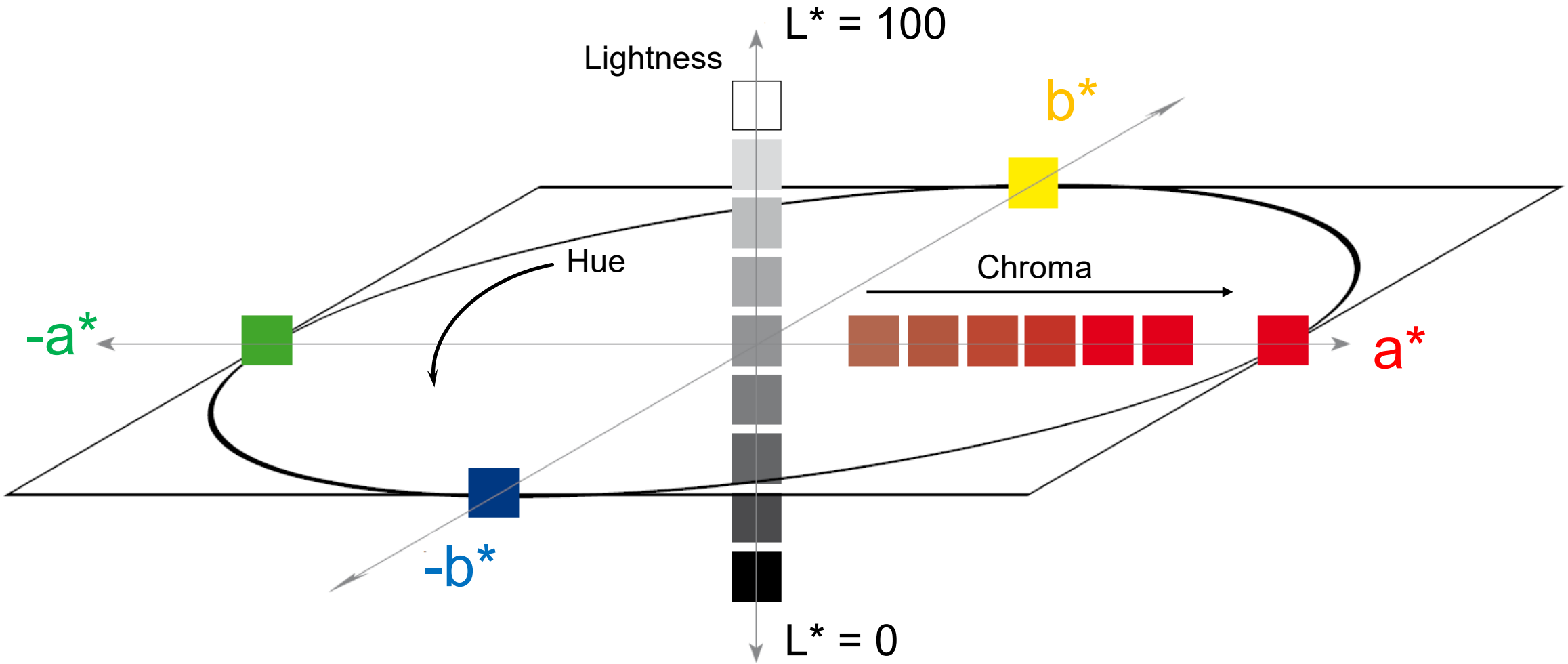

CIELAB Equations

L , Lightness - Darkness*

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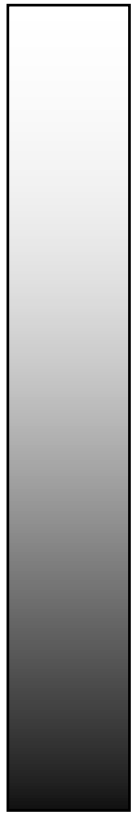
L* = 100 White

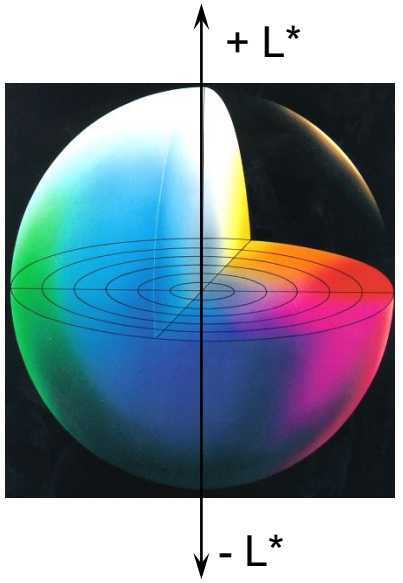


L* = 0 Black

$$L^* = 116\,(Y/Y_n)^{1/3} - 16$$

Y_n = Tristimulus Value of White
Valid for Y/Y_n > or = 0.01

$X_n = 94.81$; $Y_n = 100.0$; $Z_n = 107.3$ For D65/10



CIELAB Equations

a , red - green*

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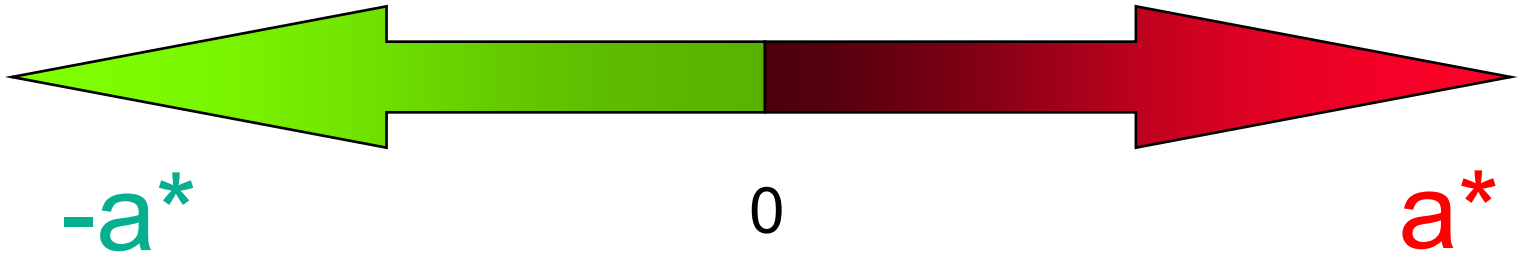

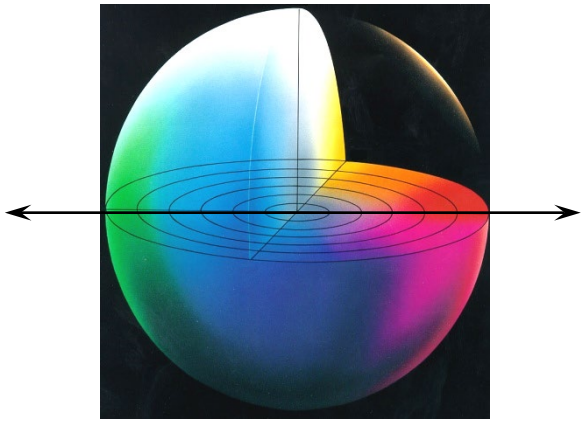

$$a^* = 500\ (X/X_n)^{1/3} - 500\ (Y/Y_n)^{1/3}$$

Valid for X/X_n & Y/Y_n > or = 0.01

$X_n = 94.81$; $Y_n = 100.0$; $Z_n = 107.3$ For D65/10

CIELAB Equations

b , yellow - blue*

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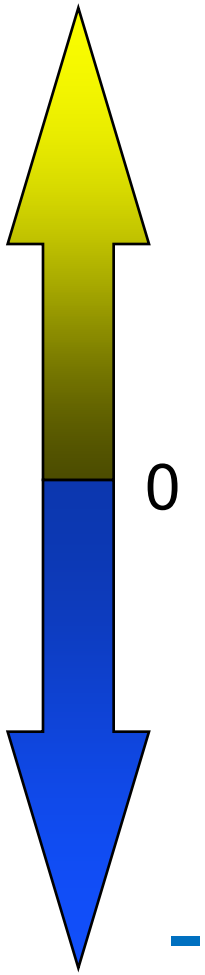
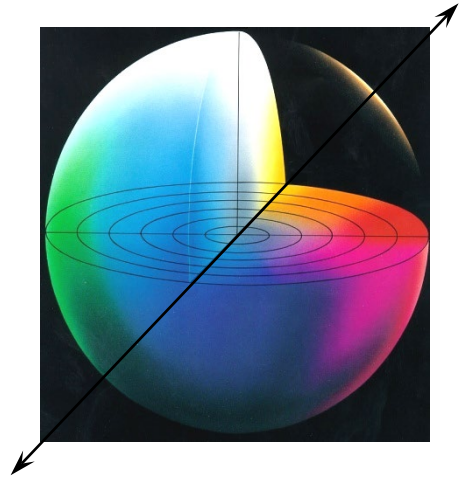


$$b^* = 200\,(Y/Y_n)^{1/3} - 200\,(Z/Z_n)^{1/3}$$

Valid for Z/Z_n & Y/Y_n > or = 0.01

$X_n = 94.81$; $Y_n = 100.0$; $Z_n = 107.3$ For D65/10



CIELAB

3 Dimensions of Color – Hue, Chroma, Lightness

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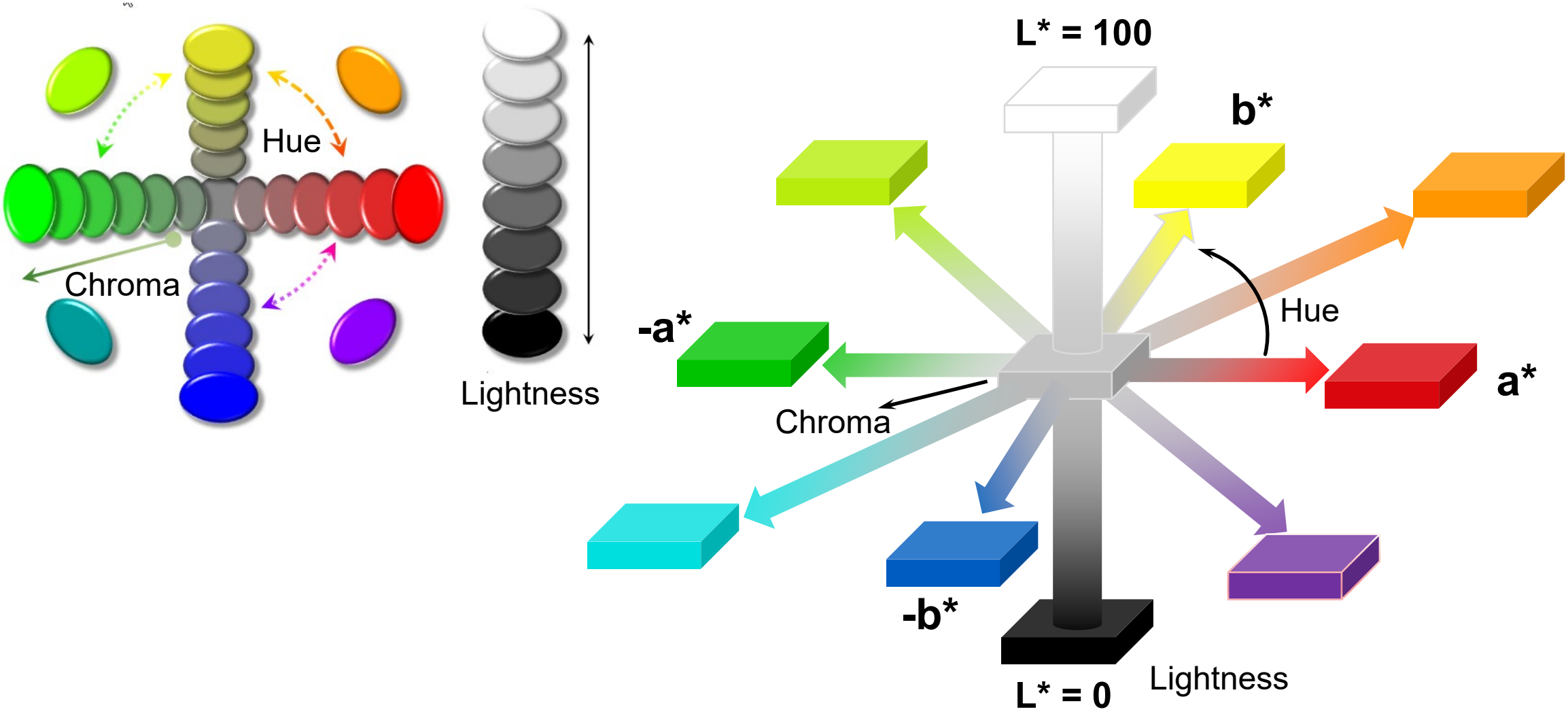

CIE L*a*b*

*L*a*b* Coordinates*

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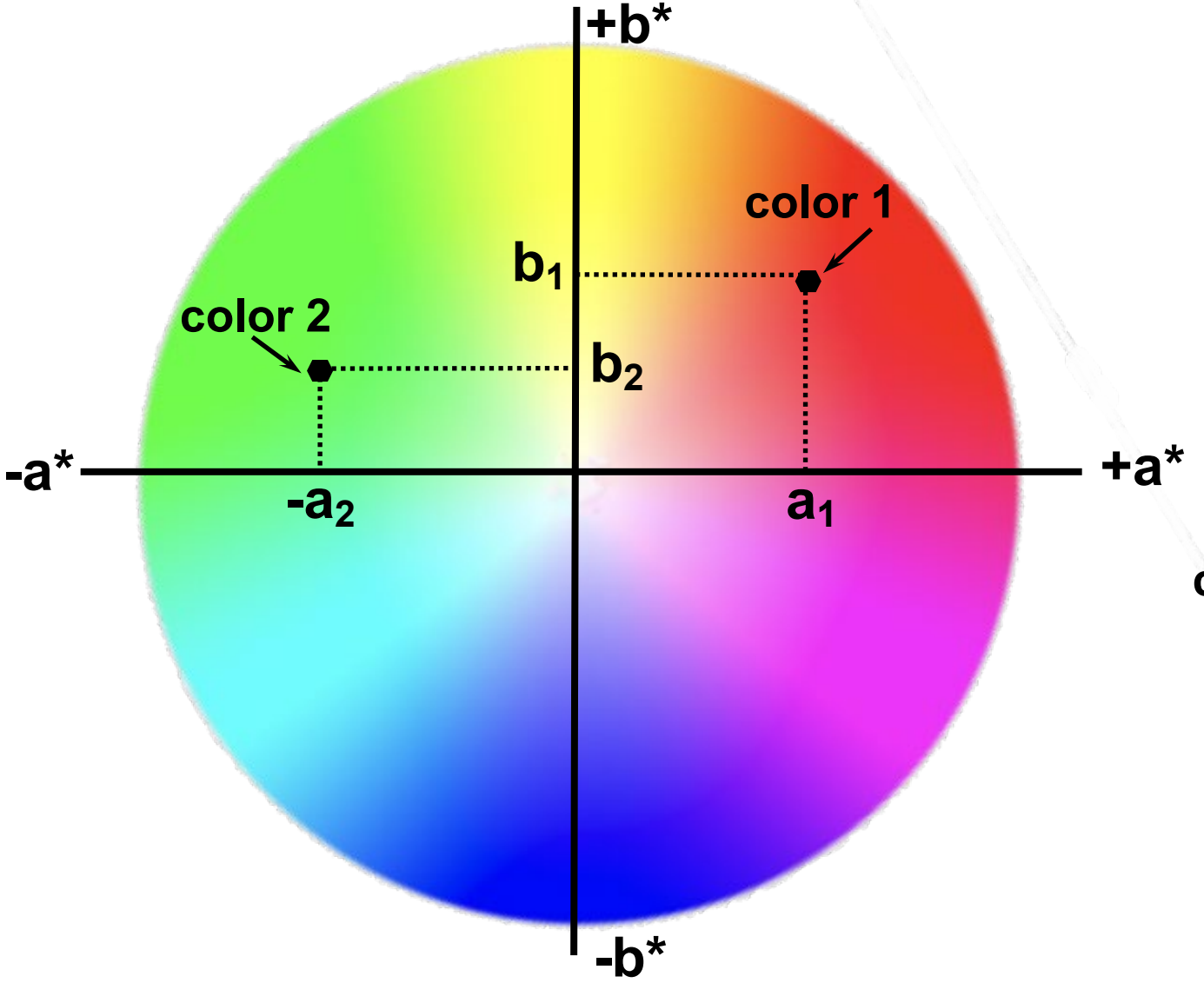
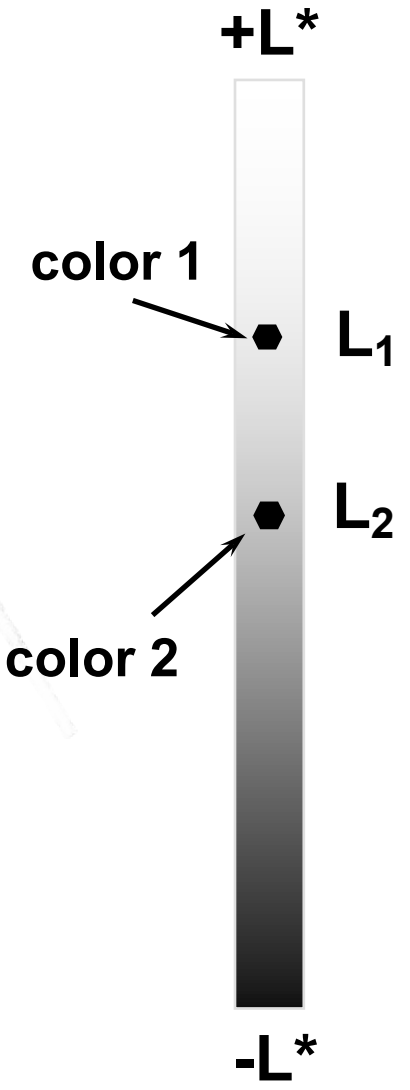
Color 1
L* = +65
a* = +10
b* = +10

Color 2
L* = +50
a* = -10
b* = +5





C* / h

Metric Chroma – Metric Hue Angle

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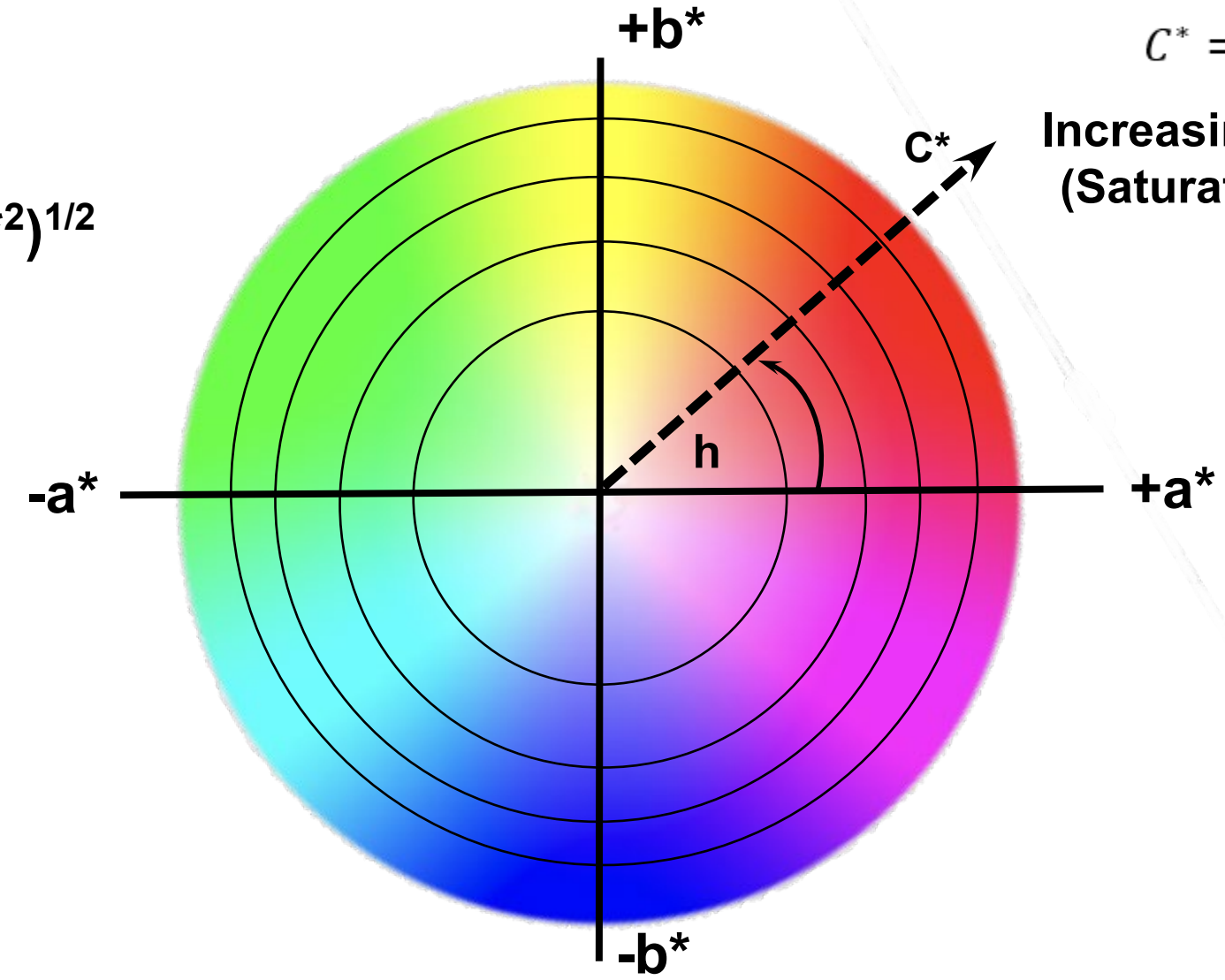
L*,C*,h

$C^* = (a^{*2} + b^{*2})^{1/2}$

$h = \tan^{-1}(b^*/a^*)$

$$C^* = \sqrt{a^{*2} + b^{*2}}$$

Increasing C* (Saturation)



Color Difference

CIELAB Rectangular Coordinates – Da, Db*, DL**

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$DE^* = (DL^{*2} + da^{*2} + db^{*2})^{1/2}$

$dE^* = \sqrt{dL^2 + da^2 + db^2}$

$DL^* = L^*_{BAT} - L^*_{STD}$

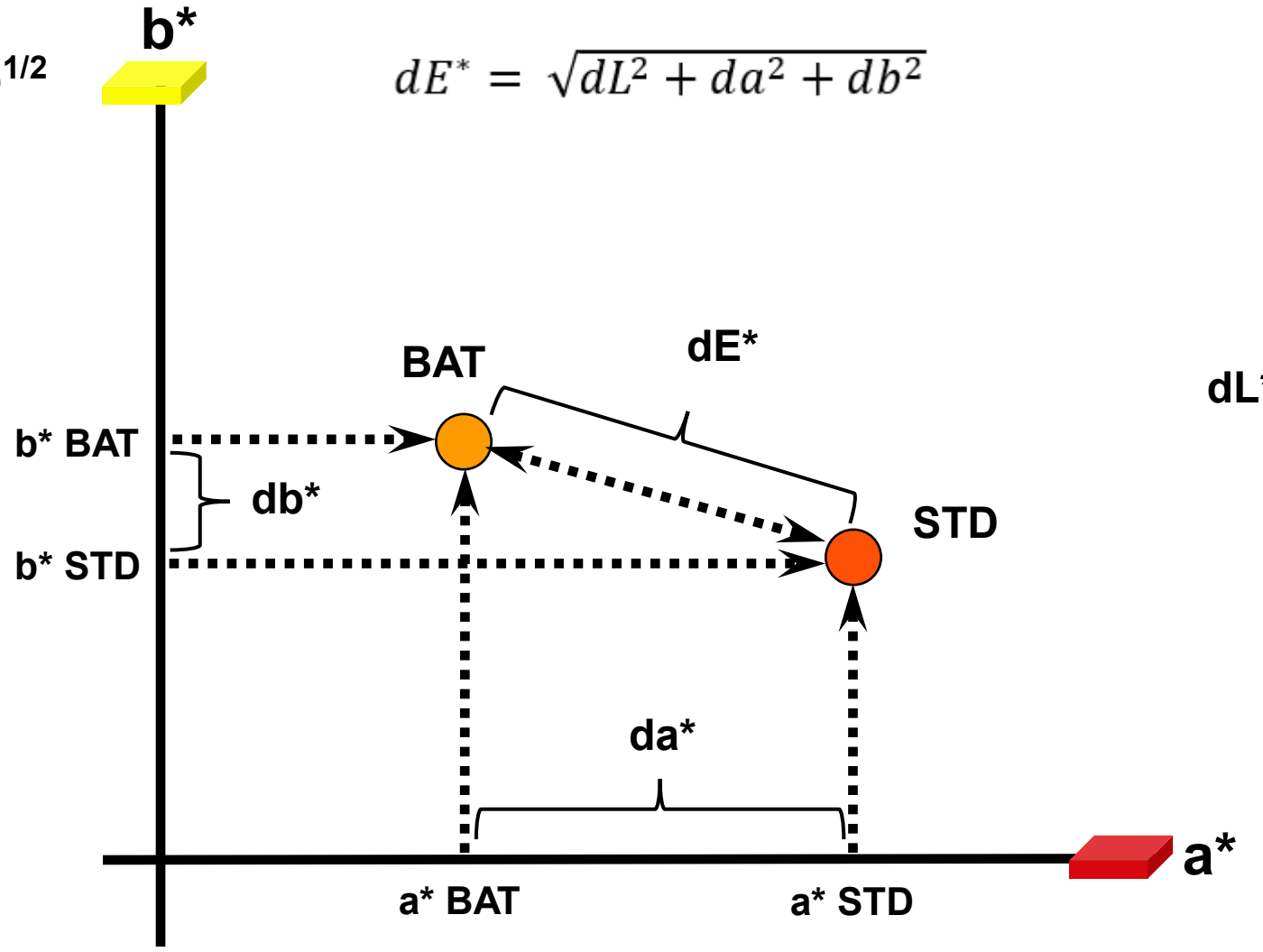
(+ is lighter)
(- is darker)

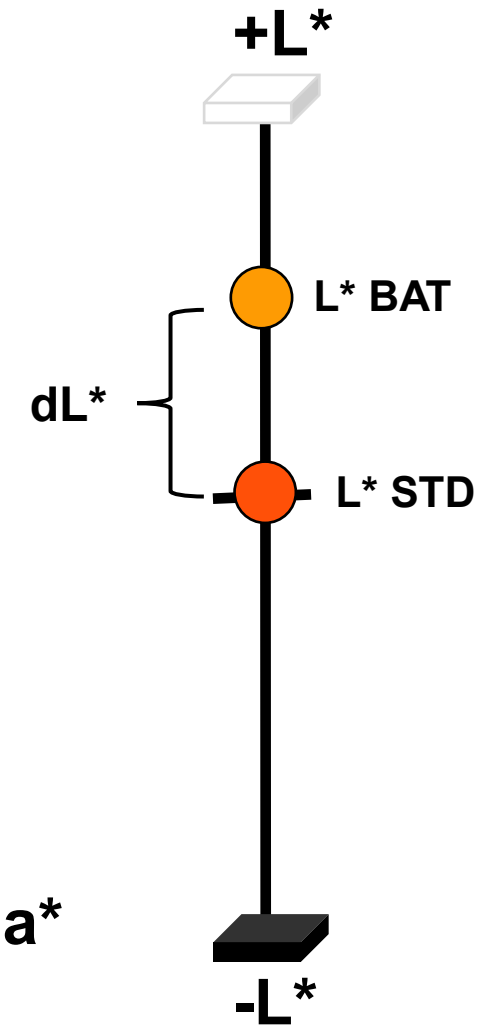
$da^* = a^*_{BAT} - a^*_{STD}$

(+ is redder, less green)
(- is greener, less red)

$db^* = b^*_{BAT} - b^*_{STD}$

(+ is yellower, less blue)
(- is bluer, less yellow)





Color Difference

CIELAB Polar Coordinates – DL, DC*, DH* Metric Hue Angle*

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$C^* = (a^{*2} + b^{*2})^{1/2}$

$h = \tan^{-1}(b^*/a^*)$

$DL^* = L^*_{BAT} - L^*_{STD}$

(+ is lighter)

(- is darker)

$DC^* = C^*_{BAT} - C^*_{STD}$

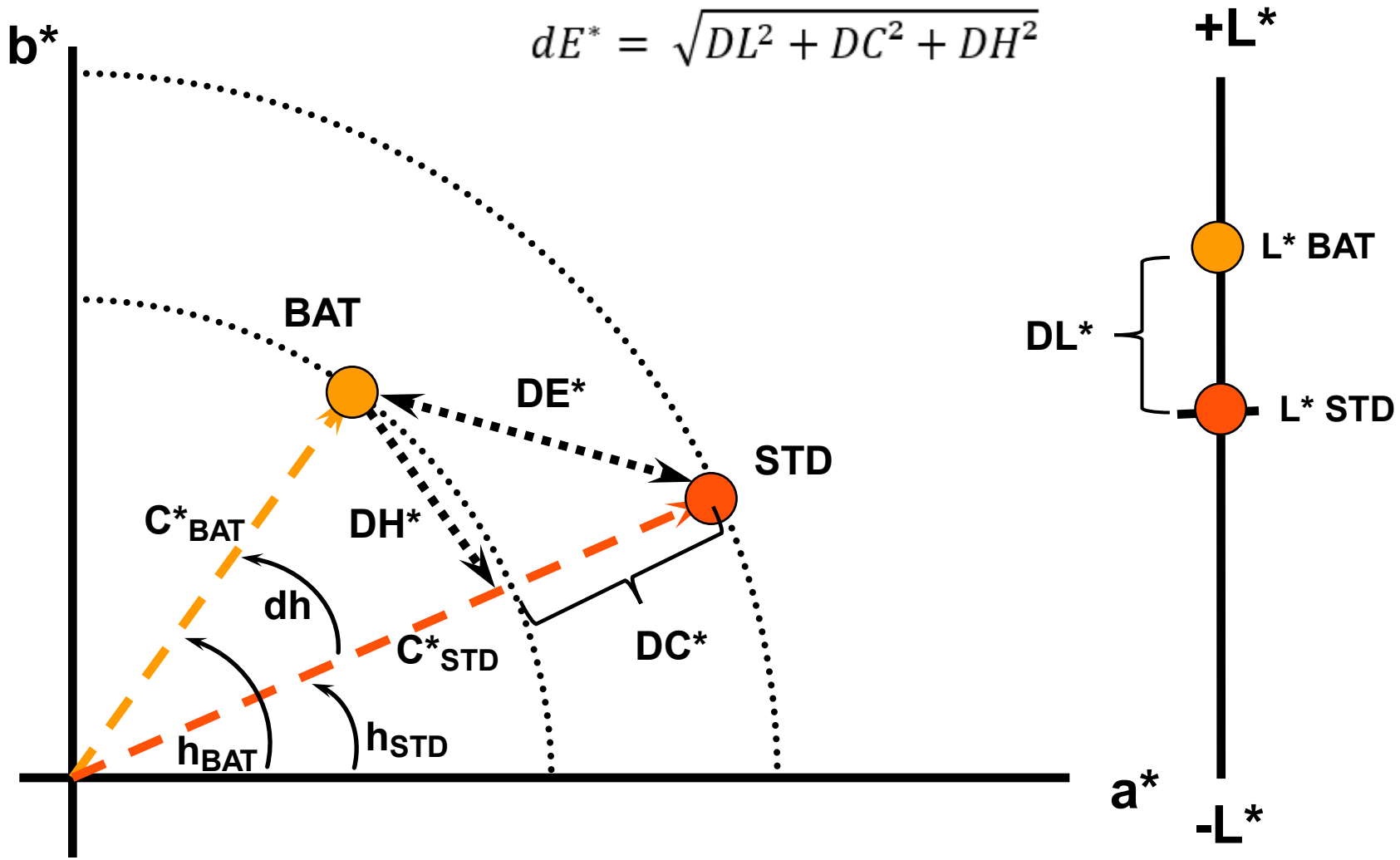
(+ is more chroma)

(- is less chroma)

$DH^* = 2(C^*_{STD} * C^*_{BAT})^{1/2} \sin(dh/2)$

(+ is counter-clockwise)

$DE^* = (DL^2 + DC^2 + DH^2)^{1/2}$



CIELAB

Rectangular and Polar Coordinates

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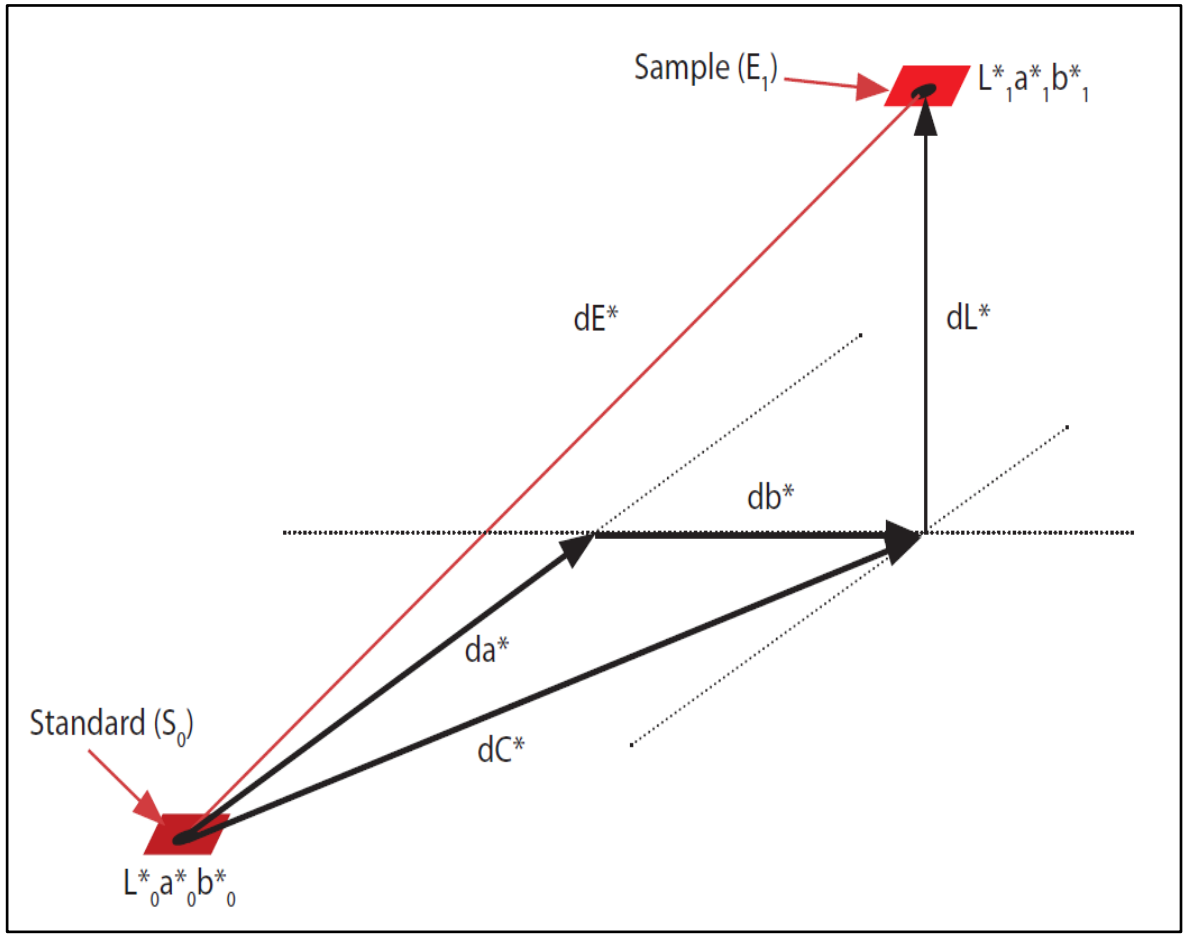
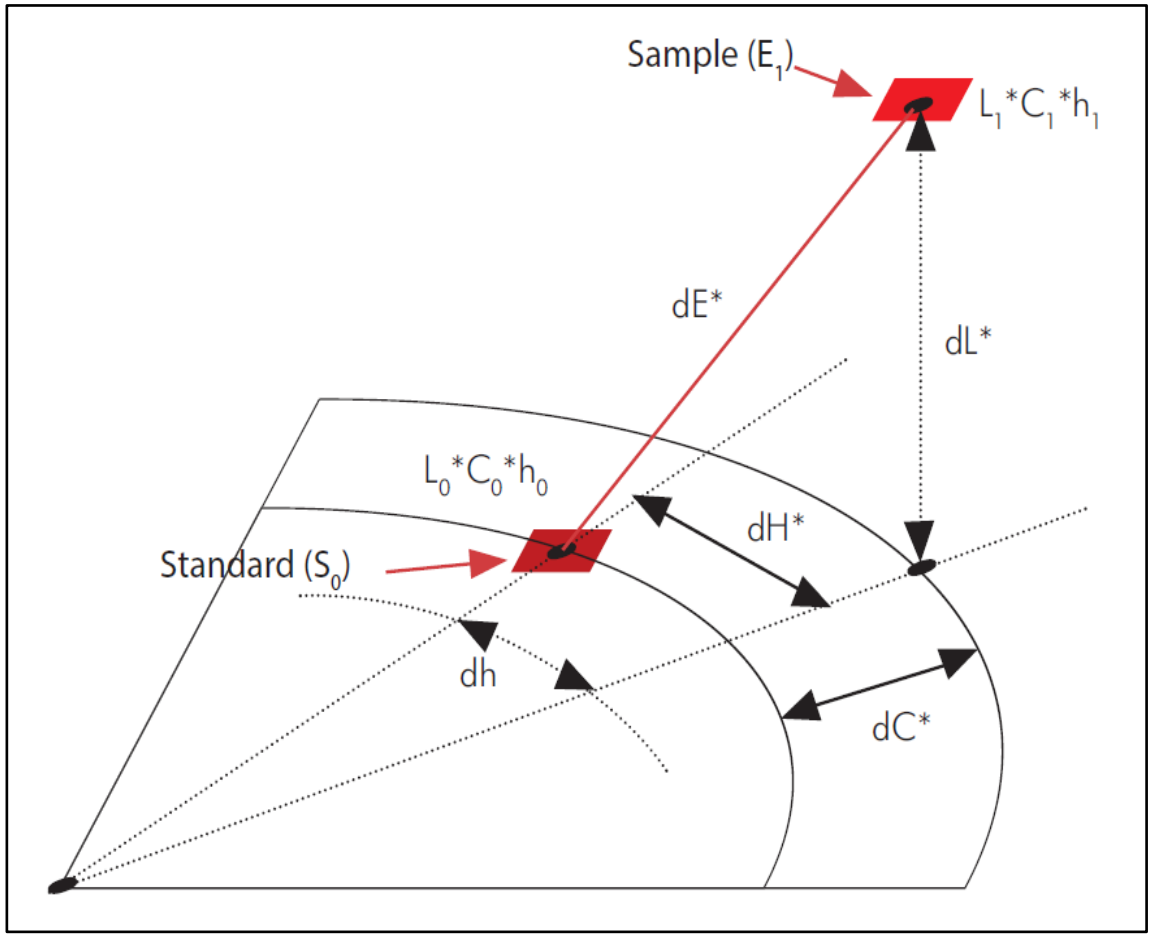
$$dE^* = \sqrt{dL^2 + da^2 + db^2}$$

$$dE^* = \sqrt{DL^2 + DC^2 + DH^2}$$





Color Difference

*CIELAB L*a*b* vs L*C*H**

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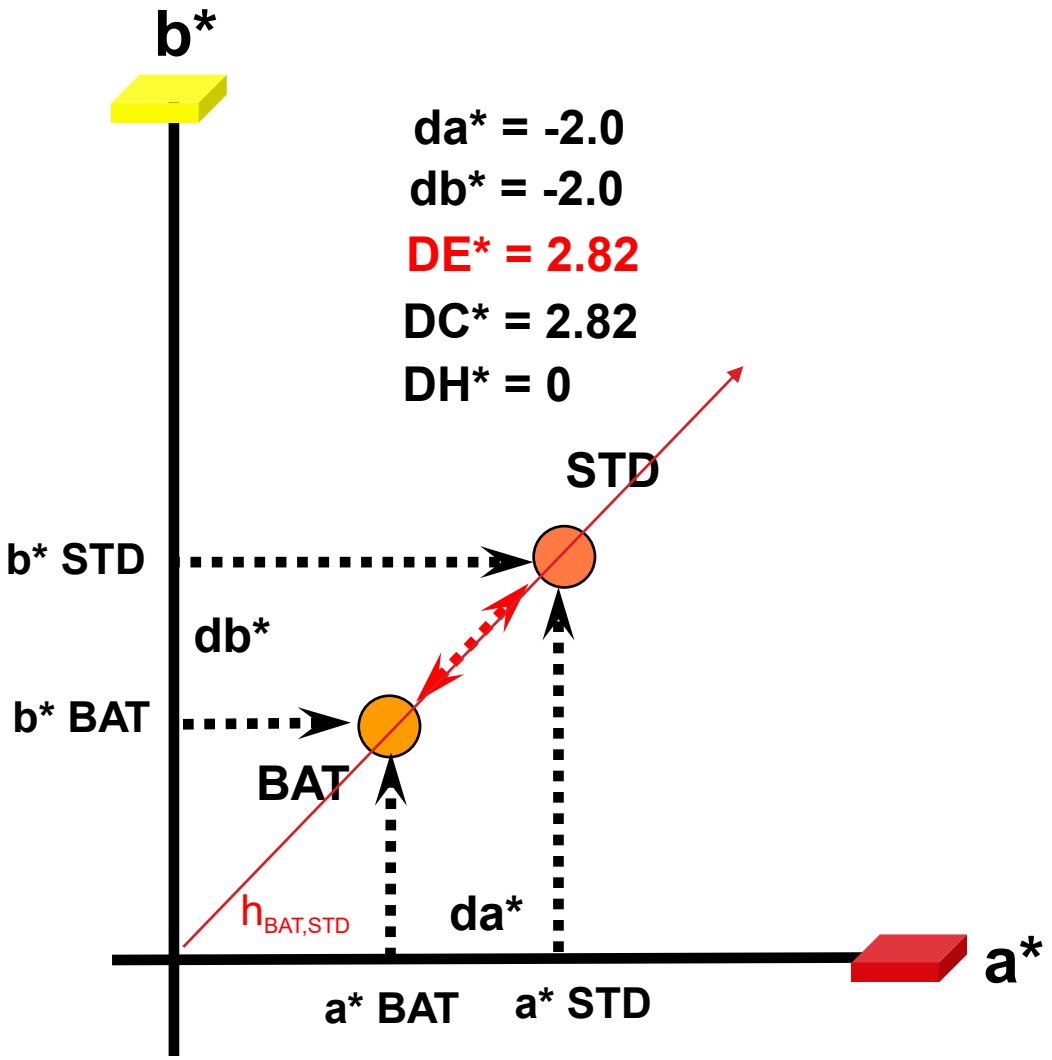

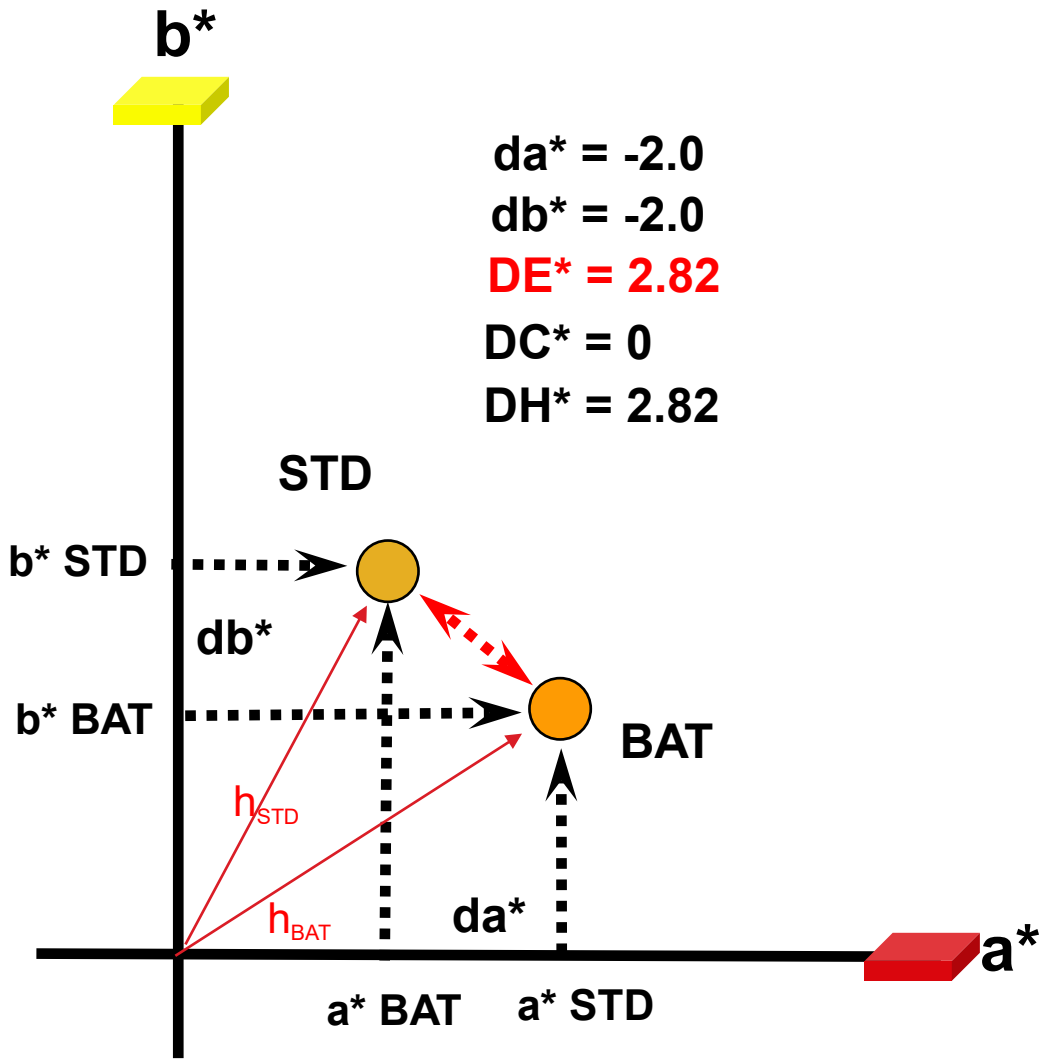

CIELAB Color Difference

Red Apple 1 and Red Apple 2

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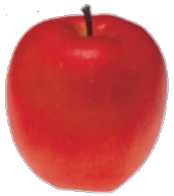
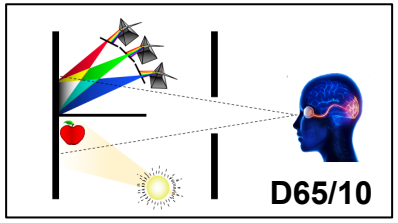
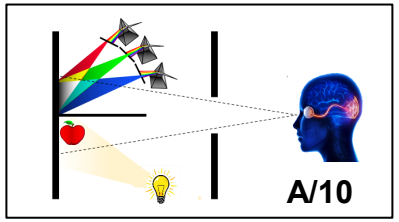
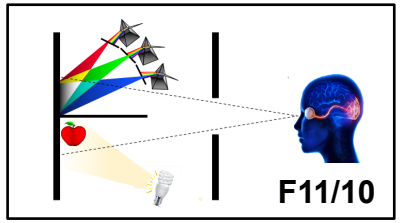
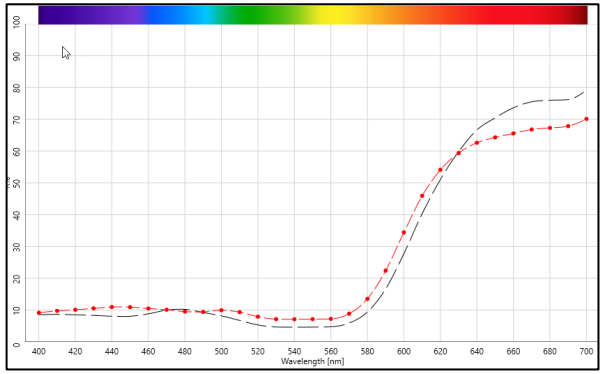


Red Apple 1



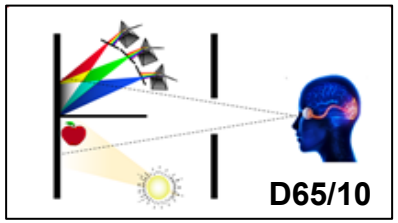


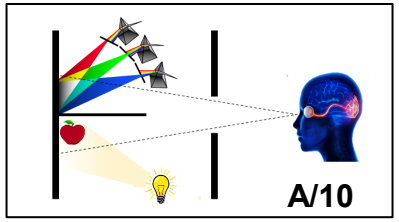


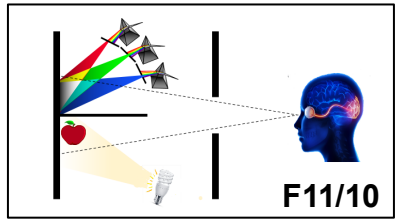


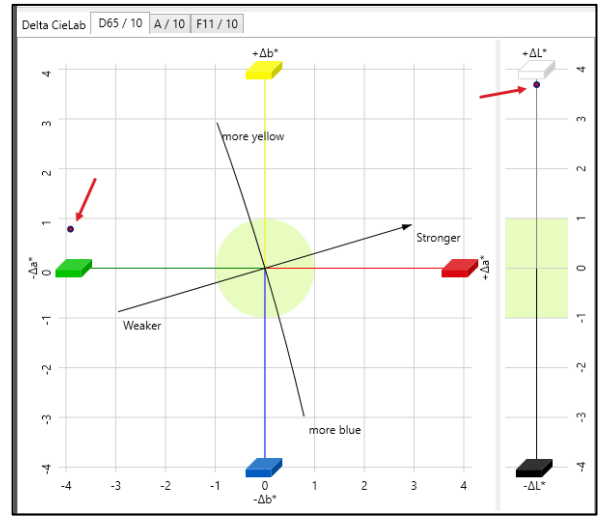
Current Illumi	Std. Name	Std. CIE X	Std. CIE Y	Std. CIE Z	Std. CIE L	Std. CIE a	Std. CIE b	Std. CIE C	Std. CIE h
D65 10 Deg	Red Apple 1	21.65	13.60	9.29	43.65	48.50	14.38	50.58	16.51
A 10 Deg		34.21	18.83	3.06	50.49	51.01	26.02	57.26	27.03
F11 10 Deg		26.83	15.91	5.58	46.86	47.48	20.42	51.68	23.27

Red Apple 2









Current Illumi	Batch Name	Batch CIE X	Batch CIE Y	Batch CIE Z	Batch CIE L	Batch CIE a	Batch CIE b	Batch CIE C	Batch CIE h
D65 10 Deg	Red Apple 2	24.30	16.28	11.16	47.34	44.58	15.16	47.09	18.78
A 10 Deg		37.04	21.62	3.62	53.62	46.57	26.30	53.49	29.45
F11 10 Deg		30.77	19.11	6.90	50.82	45.29	20.79	49.84	24.66

CIELAB Color Difference – DL*, Da*, Db*, DC*, DH*, DE*

Current Illumi	Batch Name	CIE DL	CIE Da	CIE Db	CIE DC	CIE DH	CIE DE
D65 10 Deg	Red Apple 2	3.69	-3.92	0.78	-3.50	1.93	5.44
A 10 Deg		3.13	-4.44	0.28	-3.78	2.34	5.44
F11 10 Deg		3.96	-2.19	0.37	-1.85	1.23	4.54

CMC Color Difference Equation

Ellipsoidal Tolerancing

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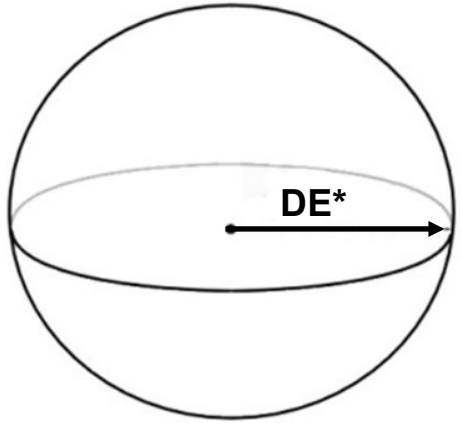
DE*



$$\Delta E^*_{CMC(l:c)} = \left[\left(\frac{\Delta L^*}{l S_L}\right)^2 + \left(\frac{\Delta C^*_{ab}}{c S_C}\right)^2 + \left(\frac{\Delta H^*_{ab}}{S_H}\right)^2\right]^{1/2}$$

S_L = Lightness Tolerance

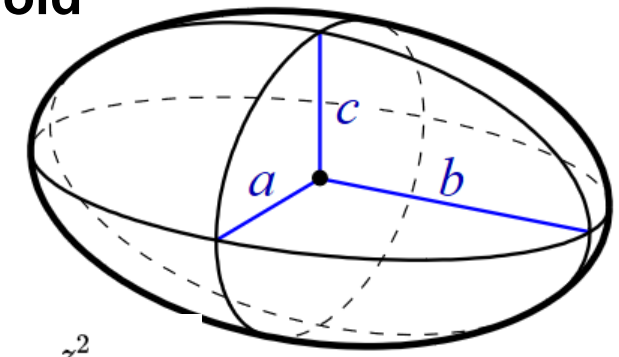
S_C = Chroma Tolerance

S_H = Hue Tolerance

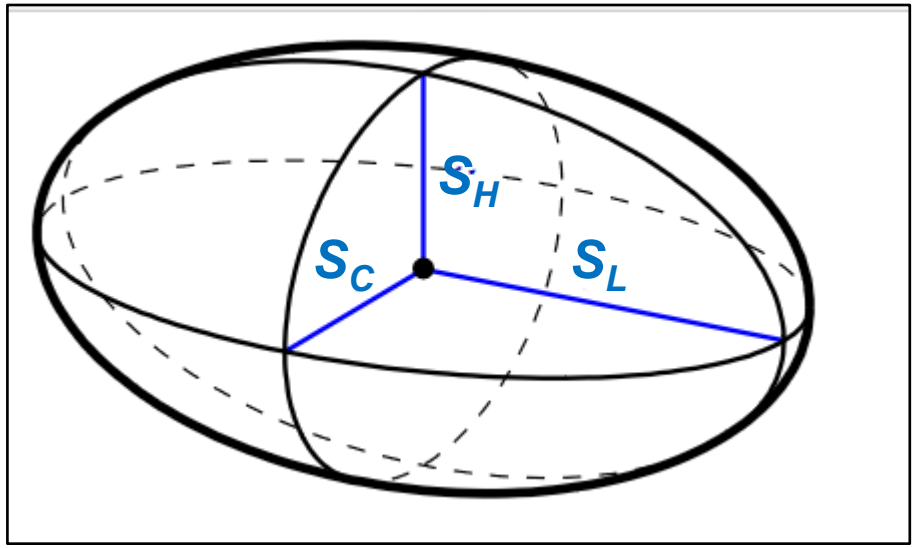
l = Lightness Adjustment Factor

c = Chroma Adjustment Factor

Ellipsoid



$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$



CMC Color Difference Equation

Meaning of the Value of the CMC DE

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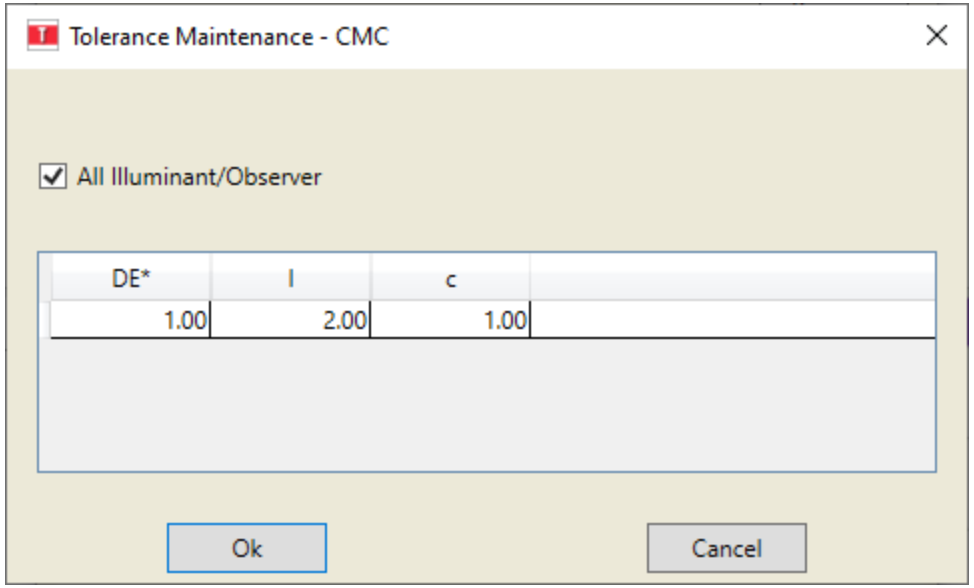

$$\Delta E^*_{CMC(l:c)} = \left[\left(\frac{\Delta L^*}{l S_L}\right)^2 + \left(\frac{\Delta C^*_{ab}}{c S_C}\right)^2 + \left(\frac{\Delta H^*_{ab}}{S_H}\right)^2\right]^{1/2}$$

l = Lightness Factor

Allows adjustment of DL* Semi-axis

c = Chroma Factor

Allows adjustment of DC* Semi-axis

$DE^*_{CMC} = 1.0$

Batch is on surface of ellipsoid.

$DE^*_{CMC} < 1.0$

Batch is inside ellipsoid (Pass)

$DE^*_{CMC} > 1.0$

Batch is outside ellipsoid (Fail)

CMC Color Difference Equation

Changing the Value of the CMC Adjustment Factor

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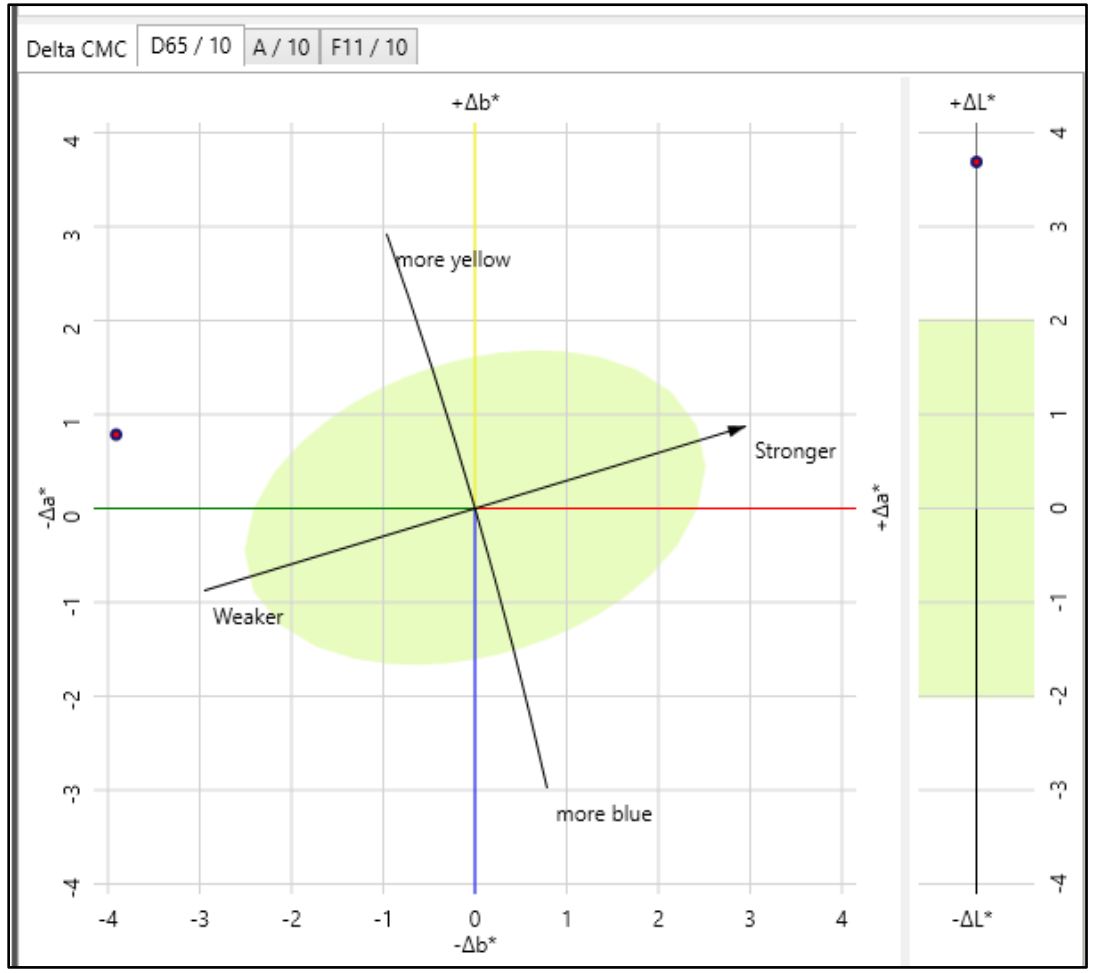
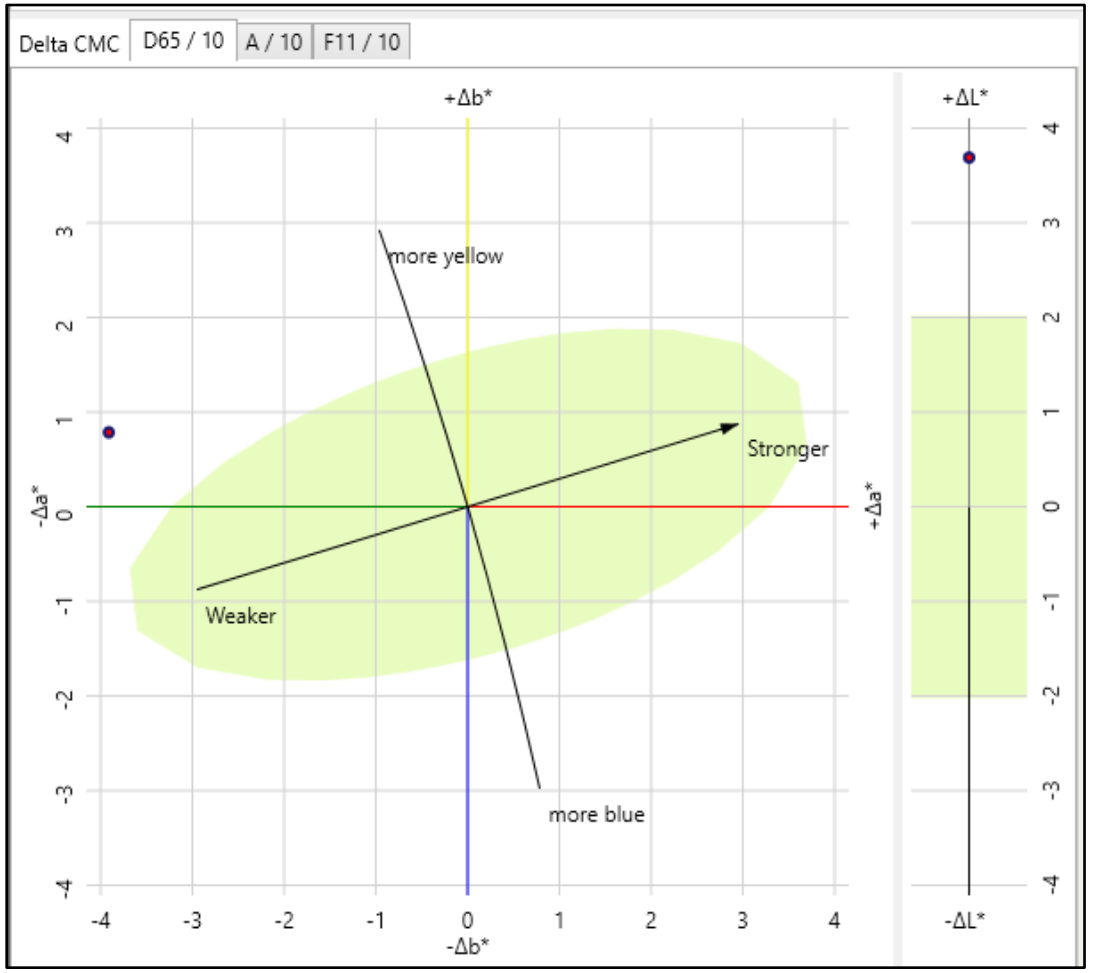
$l = 2$ $c = 1$



$l = 2$ $c = 1.5$



CIE 2000 Color Difference Equation

Meaning of the Value of the CIE 2000 DE

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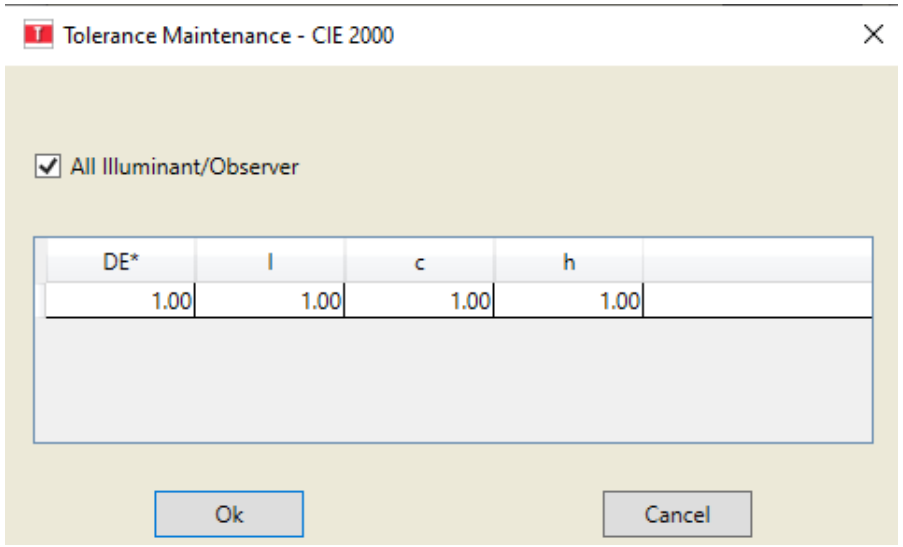

$$\Delta E_{00}^{*} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C} \frac{\Delta H'}{k_H S_H}}$$

Includes lightness, chroma and hue weighting factors
Improved gray colors
Improved performance for blue colors using rotational factor

K_L = Lightness Factor
Allows adjustment of DL* Semi-axis

K_C = Chroma Factor
Allows adjustment of DC* Semi-axis

K_H = Hue Factor
Allows adjustment of DH* Semi-axis

S_L = Lightness Tolerance

S_C = Chroma Tolerance

S_H = Hue Tolerance

DE^*_{00} = 1.0
Batch is on surface of ellipsoid.

DE^*_{00} < 1.0
Batch is inside ellipsoid (Pass)

DE^*_{00} > 1.0
Batch is outside ellipsoid (Fail)

Webinar – Final Comments

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Questions

Next session:

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We will talk about color tolerances

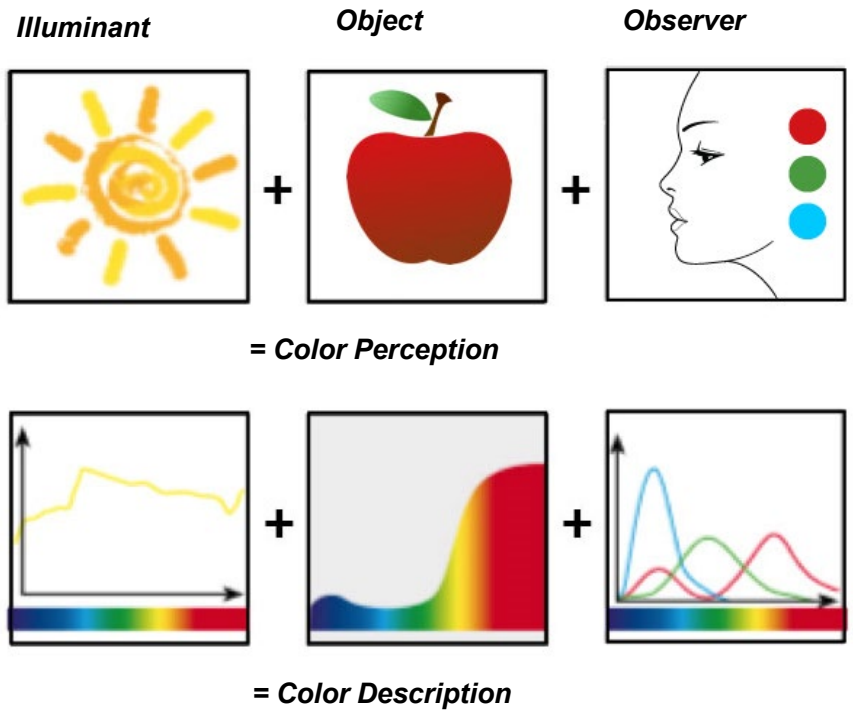
Color Tolerances

DE

Rectangular

Ellipsoidal

AI Tolerancing



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Some useful reading material:

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