Colorimetry

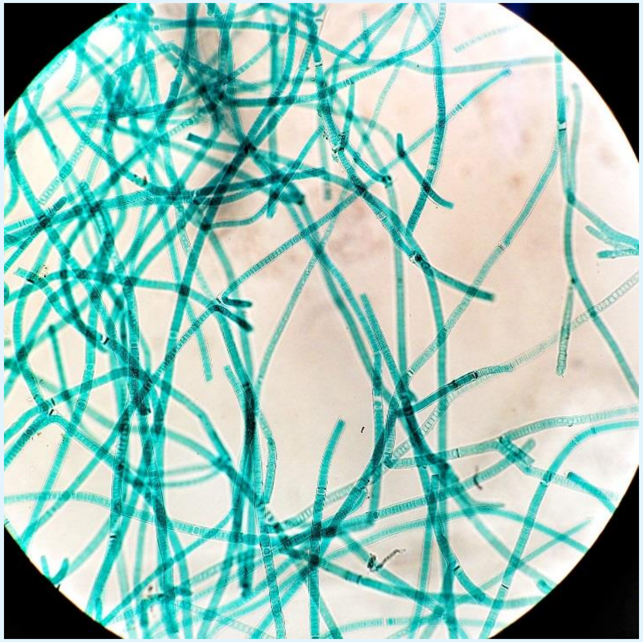
Hungarian University of Agriculture and Life Sciences

Institute of Biosystems Engineering and Process Control

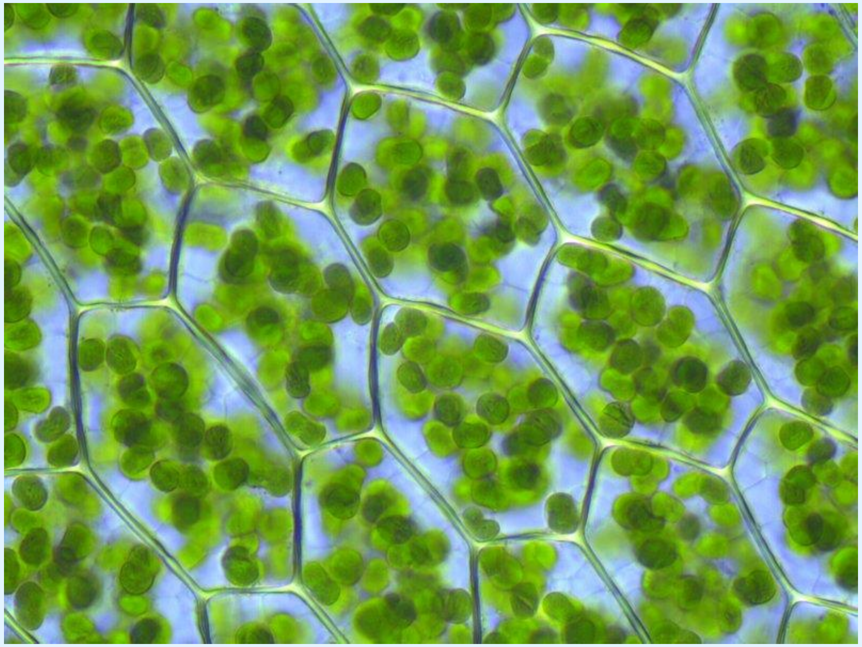
Why? When? How?

Cyanobacteria infiltrated into cells 3500 million years ago;
produced the requirements for converting of the energy (endosymbiosis)

biology



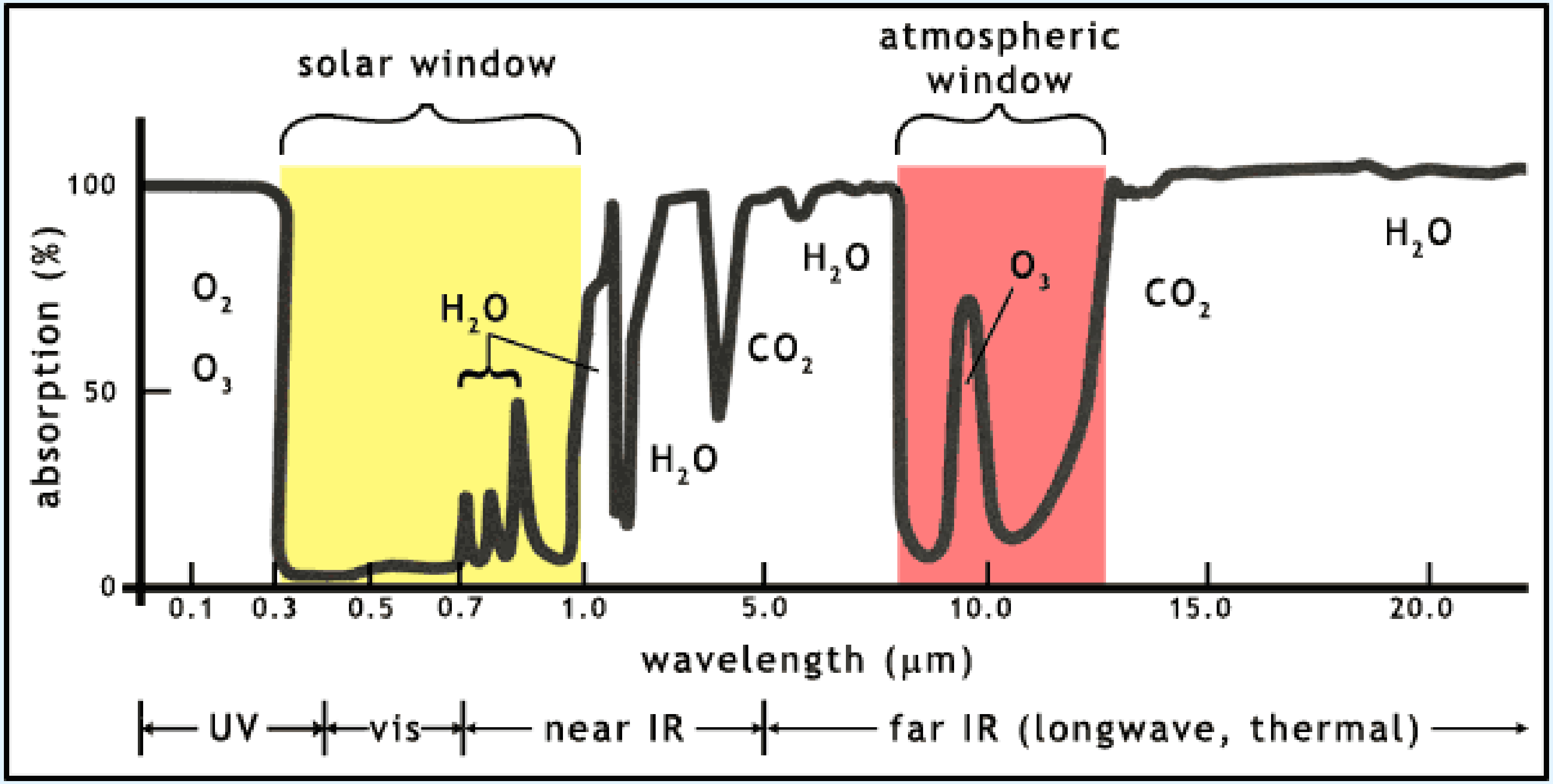
chloroplast



biology

Why? When? How?

Why even the chlorophyll?
It can make use of the window opened by the solar window



biology

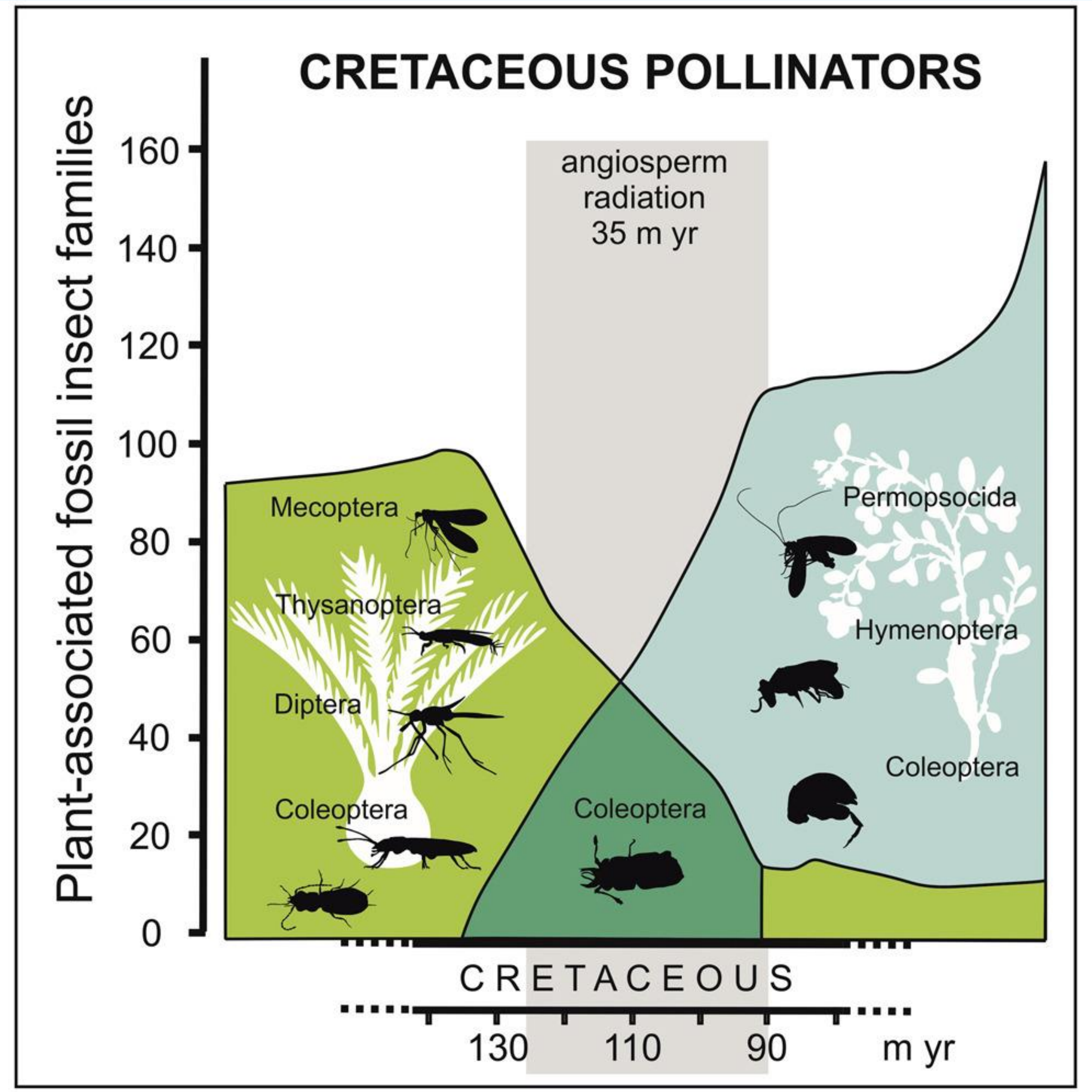
Why? When? How?

Why even the chlorophyll?
It can make use of the window opened by the atmosphere

Phototropism cold not exist in absence of photoreceptors

Flagellata
Its red spot is the photoreceptor

biology



Angiosperm related to: the colourful petal (corolla) of flowers.

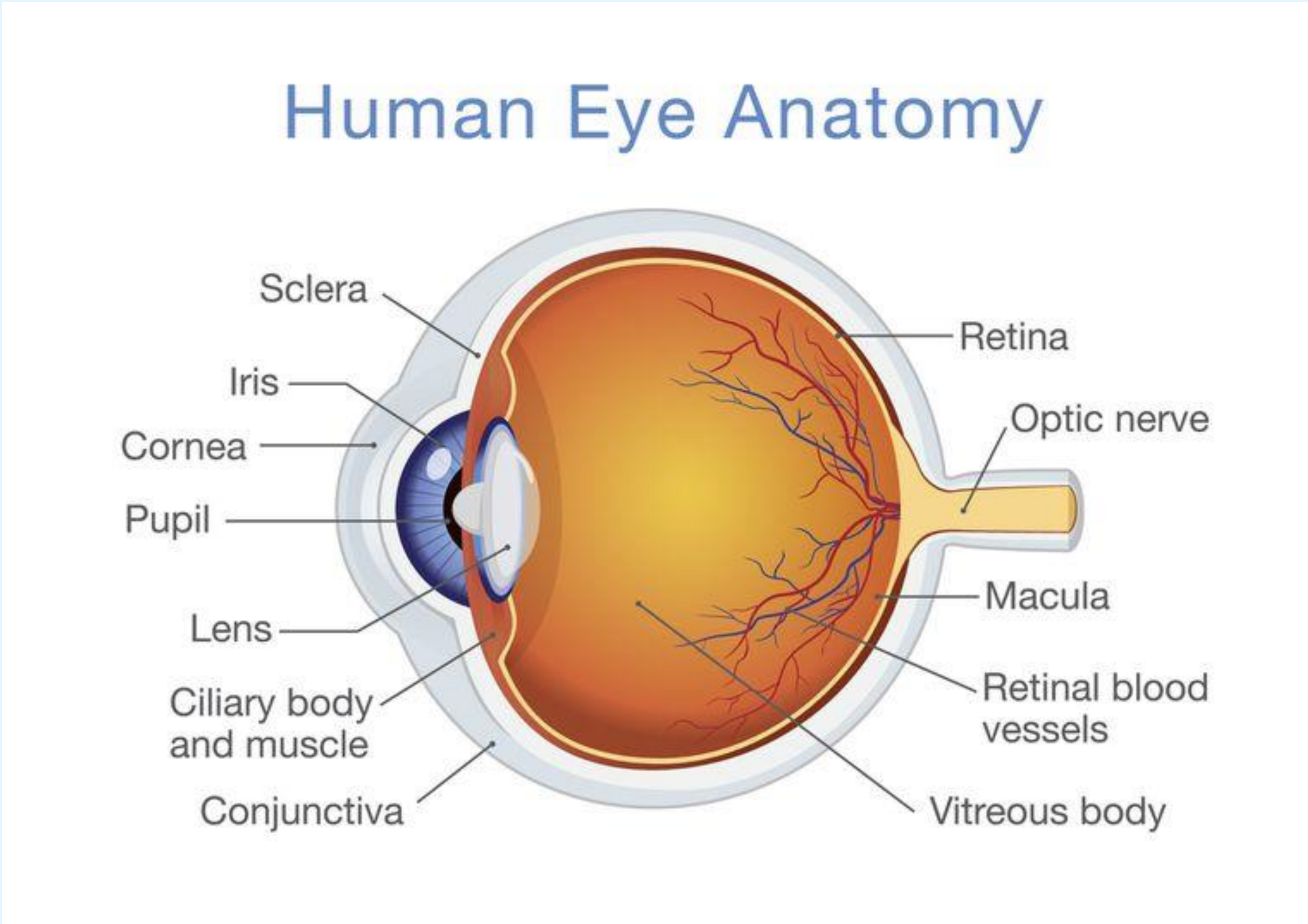
Diptera e.g. fly

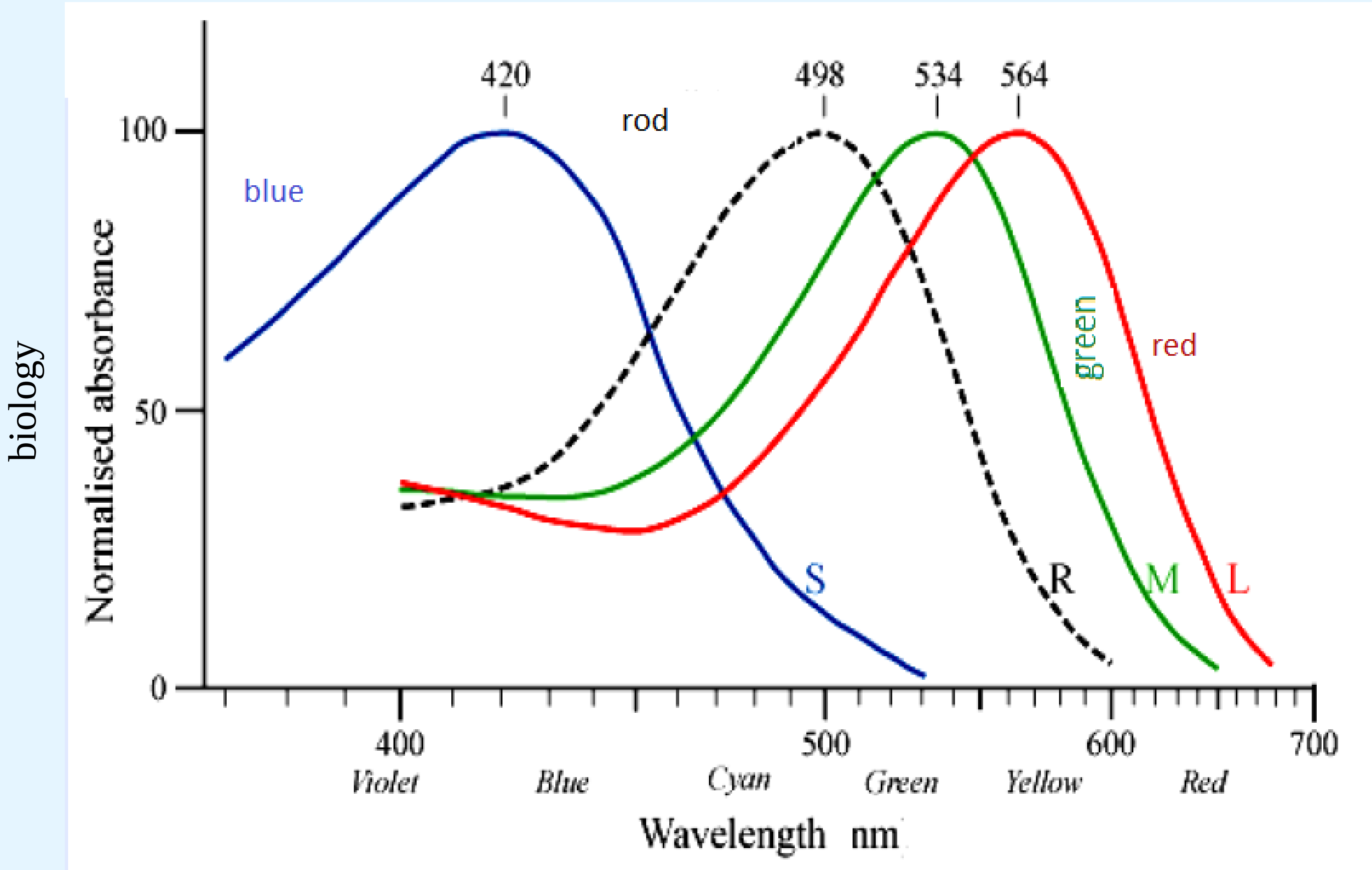
Hymenoptera e.g. bee

Pollination: to travel the pollen to another flower

The electromagnetic range of spectrum that the bugs **can see as colour** from 350 nm to 700 nm

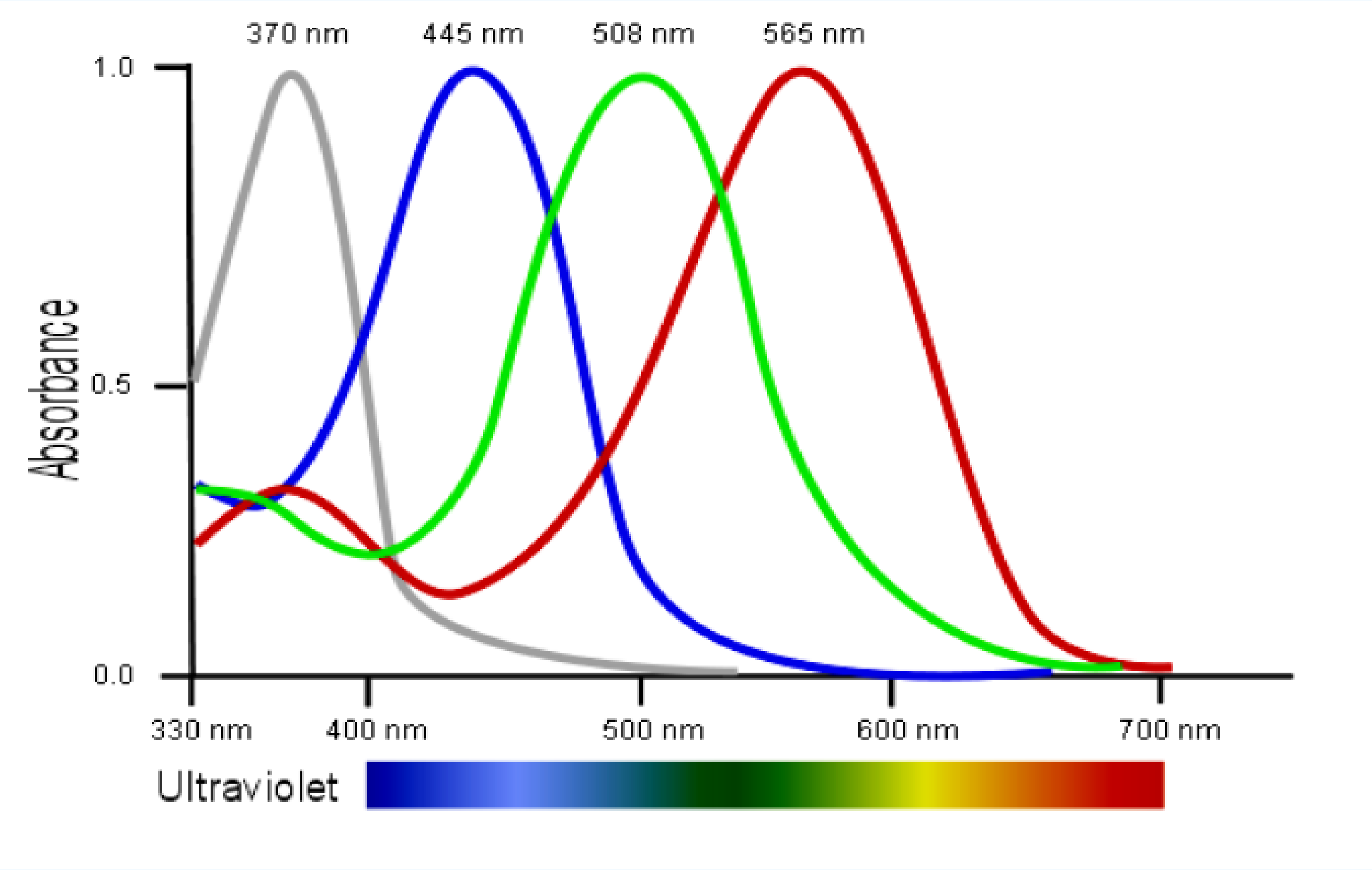
biology


Human Eye Anatomy
Sclera
Iris
Cornea
Pupil
Lens
Ciliary body and muscle
Conjunctiva
Retina
Optic nerve
Macula
Retinal blood vessels
Vitreous body


biology
Normalised absorbance
100
50
0
420
498
534
564
rod
blue
green
red
S
R
M
L
400
500
600
700
Violet
Blue
Cyan
Green
Yellow
Red
Wavelength nm

Rare case: **supervision** (tetrachromacy)

biology

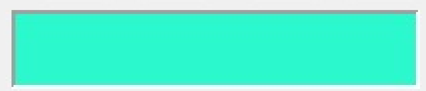


biology

Rhodopsin

Ancient Greek	ῥόδον	(rhodon, “rosy”),
	ὄψις	(opsis, “vision”)

Vertebrate RH1 500 nm circa
Skin (epidermis) RHO 505 nm circa
It is not for the colour vision:
The rhodopsin on the rods is for the scotopic vision
(vision in dark)



absorption

reflection

Opsins

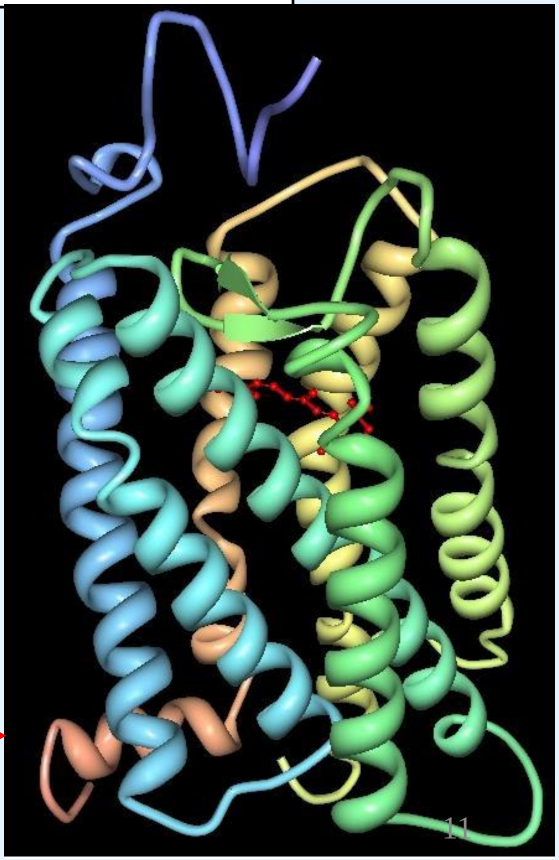
name	Sign	Range, nm	Wavelength peak. nm
OPN1SW	β	400-500	420-440
OPN1MW	γ	450-630	534-545
OPN1LW	ρ	500-700	564-580

biology

Other opsins:

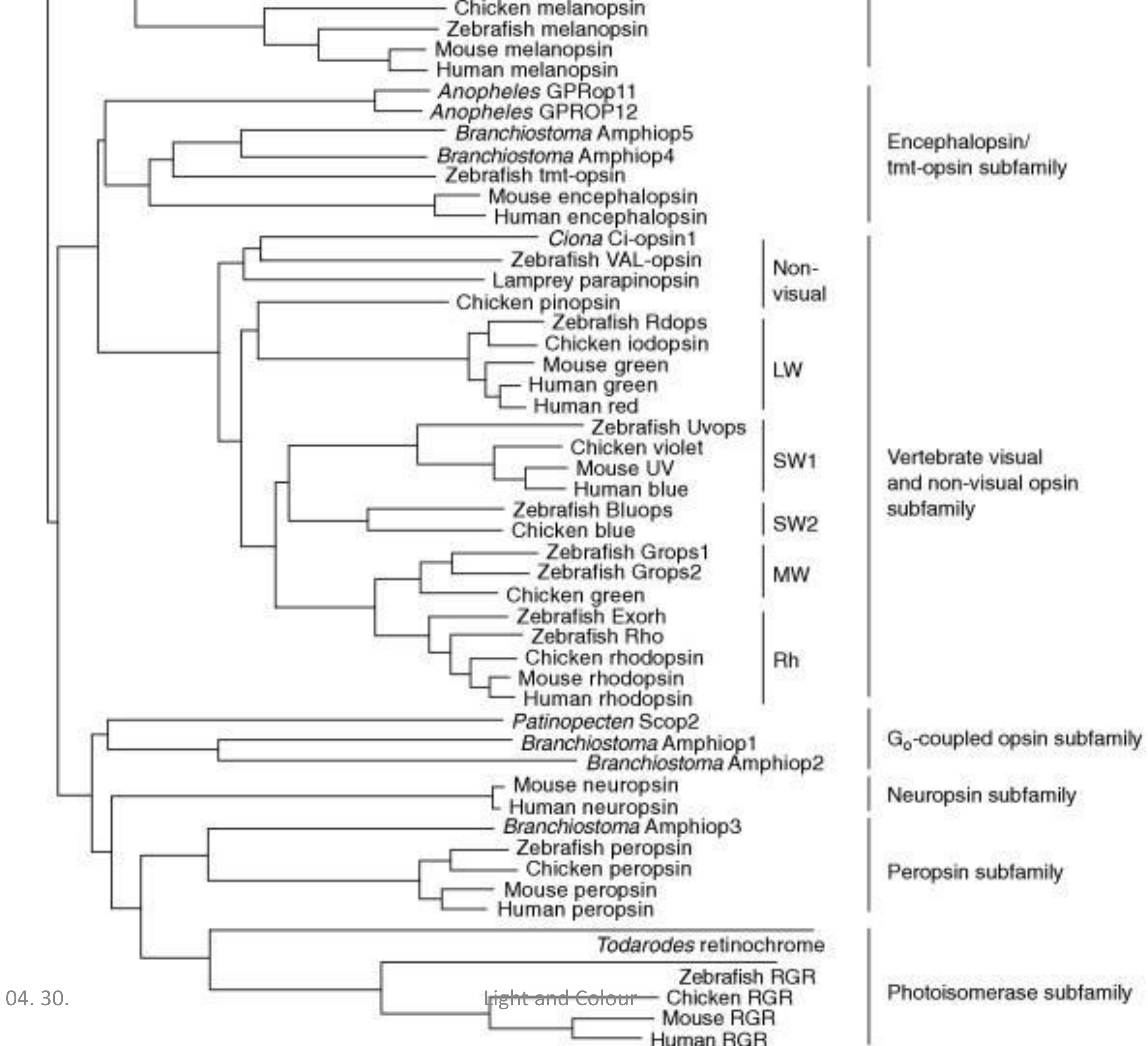
melanopsin (in brain)
rabdomer opsin (compound eye)
neuropsin (rodenta)
enkephalopsin
panopsin
peropsin

interesting: enkephalopsin can be found in brain, heart, kidney, liver, sceletal muscles, testicle, pancreas and of course in the eye

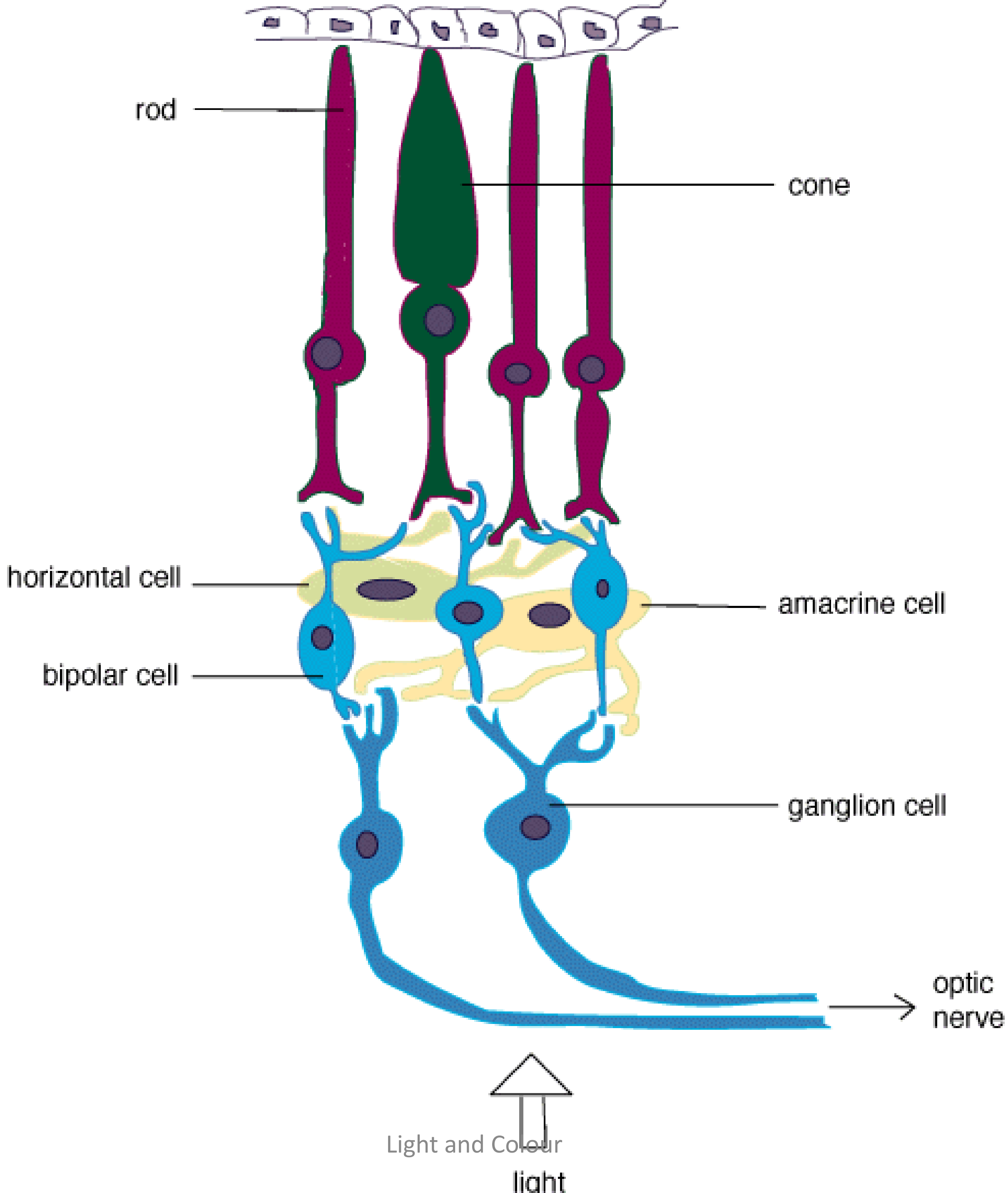


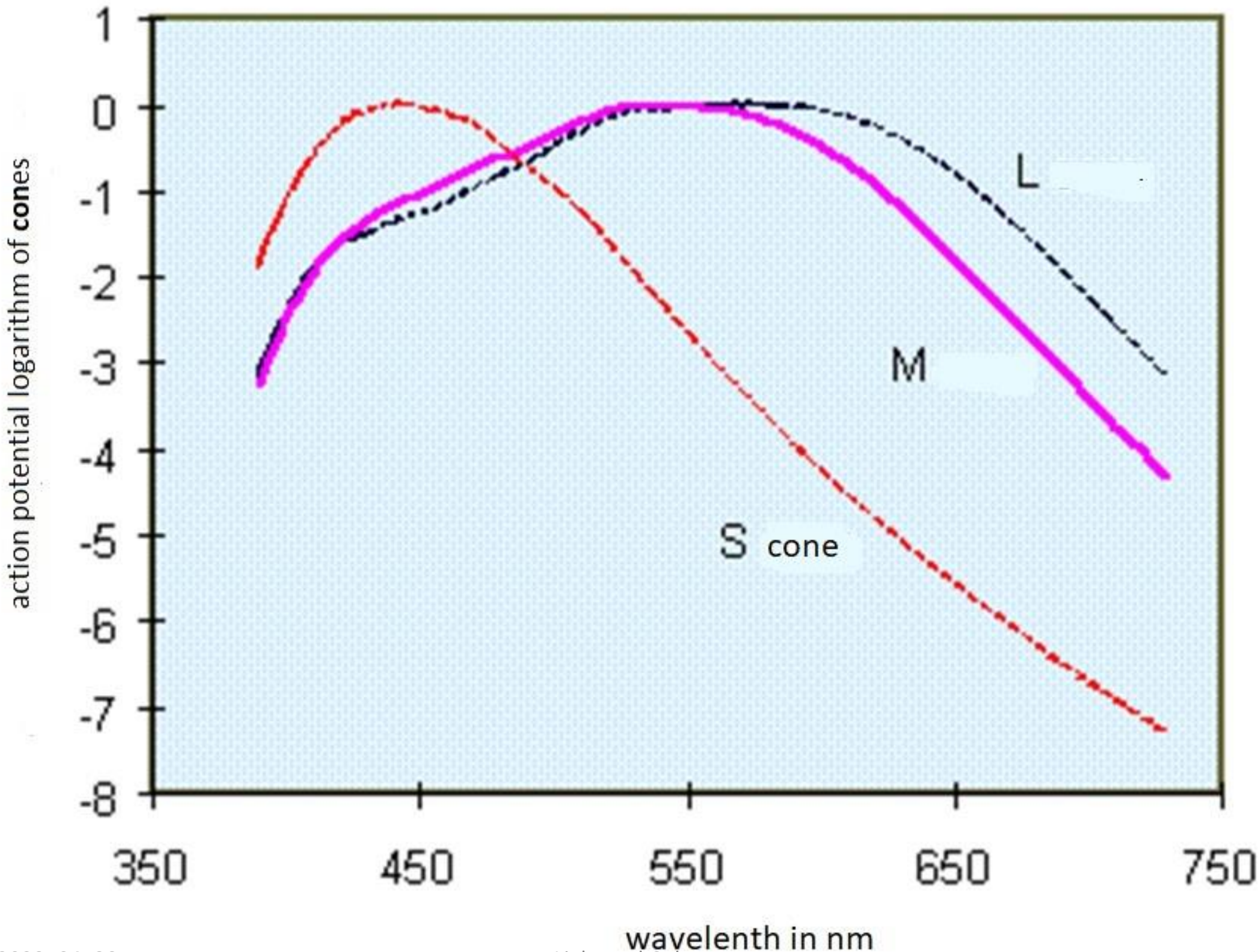
the chromophor gropus are red coloured

biology


Chicken melanopsin
Zebrafish melanopsin
Mouse melanopsin
Human melanopsin
Anopheles GPRop11
Anopheles GPROP12
Branchiostoma Amphiop5
Branchiostoma Amphiop4
Zebrafish tmt-opsin
Mouse encephalopsin
Human encephalopsin
Encephalopsin/
tmt-opsin subfamily
Ciona Ci-opsin1
Zebrafish VAL-opsin
Lamprey parapinopsin
Chicken pinopsin
Non-
visual
Zebrafish Rdops
Chicken iodopsin
Mouse green
Human green
Human red
LW
Zebrafish Uvops
Chicken violet
Mouse UV
Human blue
SW1
Zebrafish Bluops
Chicken blue
SW2
Zebrafish Grops1
Zebrafish Grops2
Chicken green
MW
Zebrafish Exorh
Zebrafish Rho
Chicken rhodopsin
Mouse rhodopsin
Human rhodopsin
Rh
Vertebrate visual
and non-visual opsin
subfamily
Patinopecten Scop2
Branchiostoma Amphiop1
Branchiostoma Amphiop2
Go-coupled opsin subfamily
Mouse neuropsin
Human neuropsin
Neuropsin subfamily
Branchiostoma Amphiop3
Zebrafish peropsin
Chicken peropsin
Mouse peropsin
Human peropsin
Peropsin subfamily
Todarodes retinochrome
Zebrafish RGR
Chicken RGR
Mouse RGR
Human RGR
Photoisomerase subfamily

biology

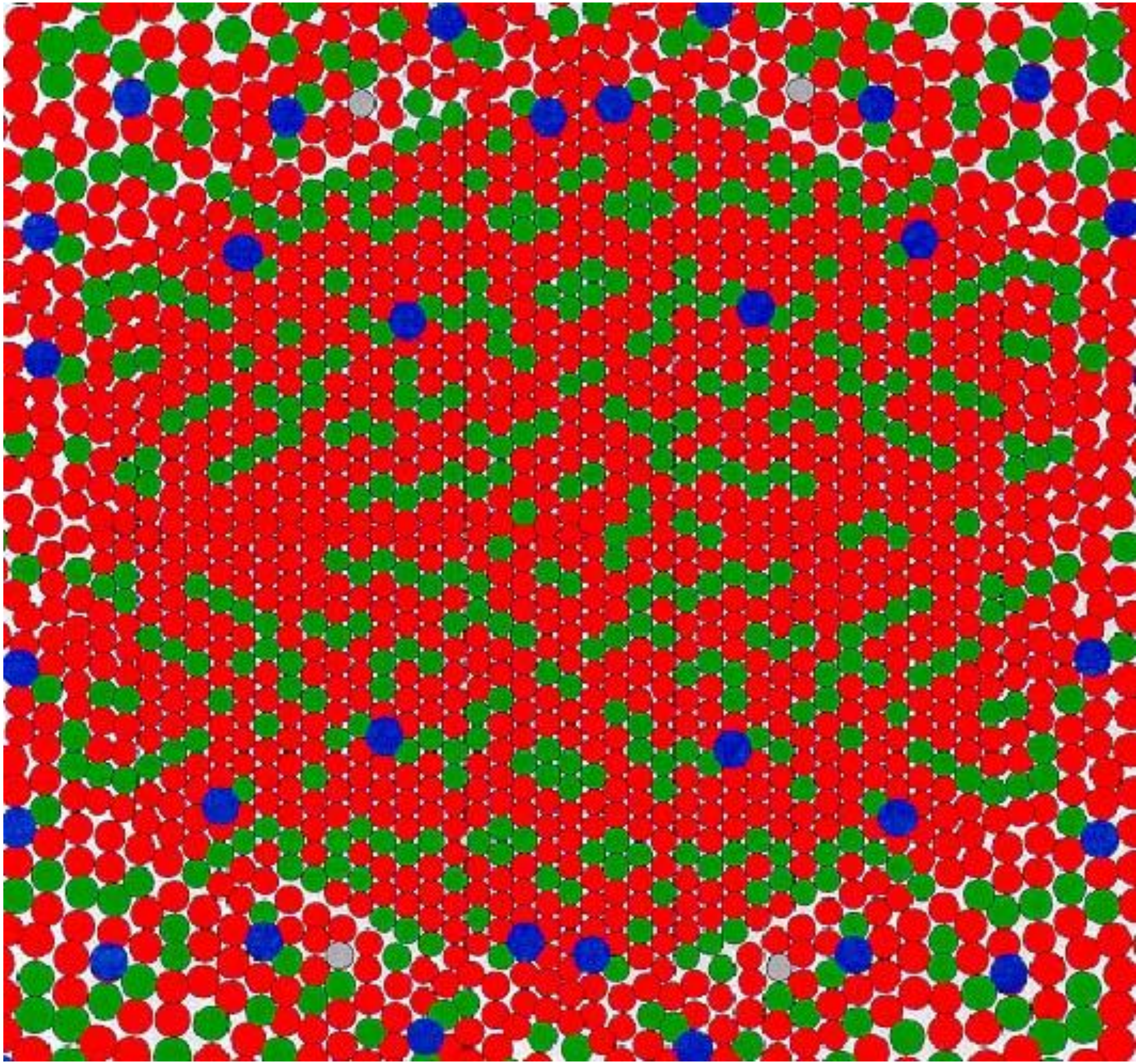

rod
cone
horizontal cell
amacrine cell
bipolar cell
ganglion cell
optic
nerve
light



action potential logarithm of **cones**
1
0
-1
-2
-3
-4
-5
-6
-7
-8
L
M
S cone
350
450
550
650
750
wavelenth in nm

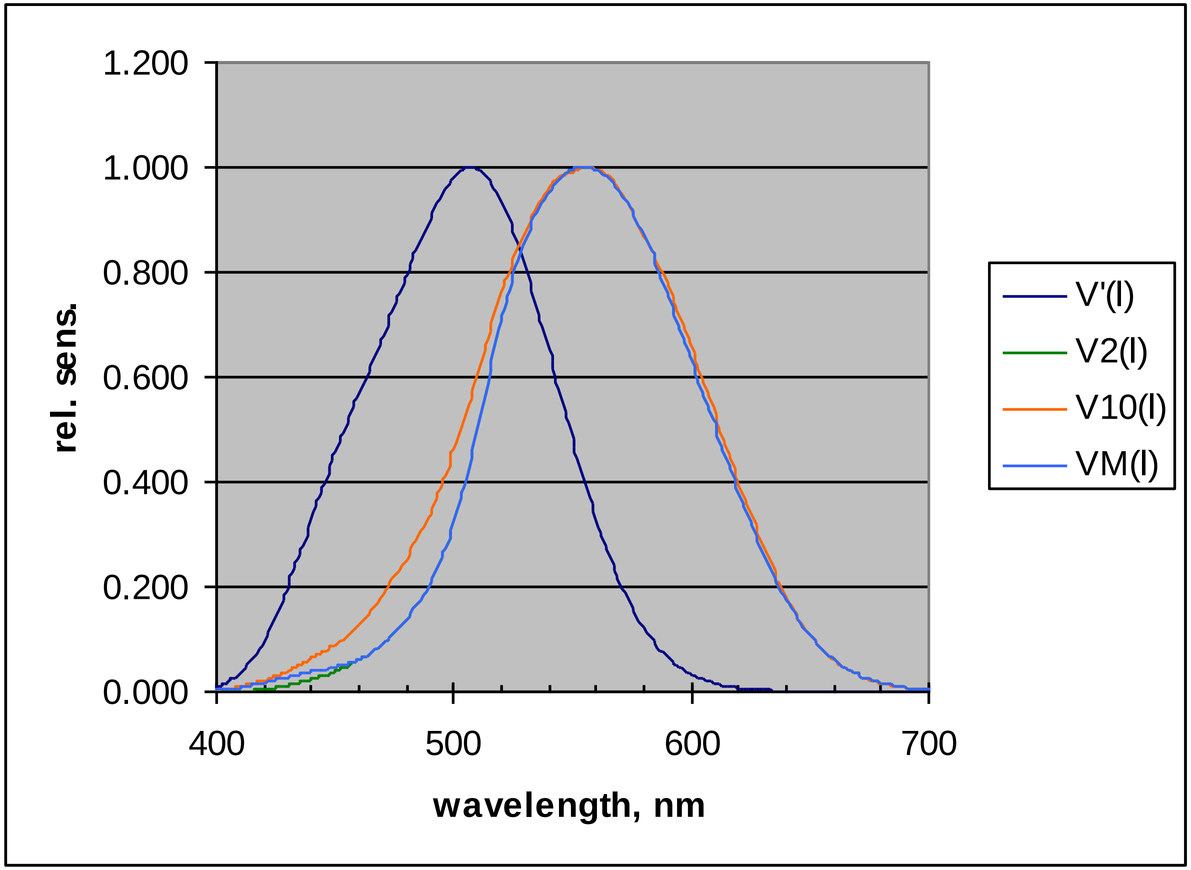
Incidence of S, M, L cones in human eye

biology



Spectral luminous efficiency

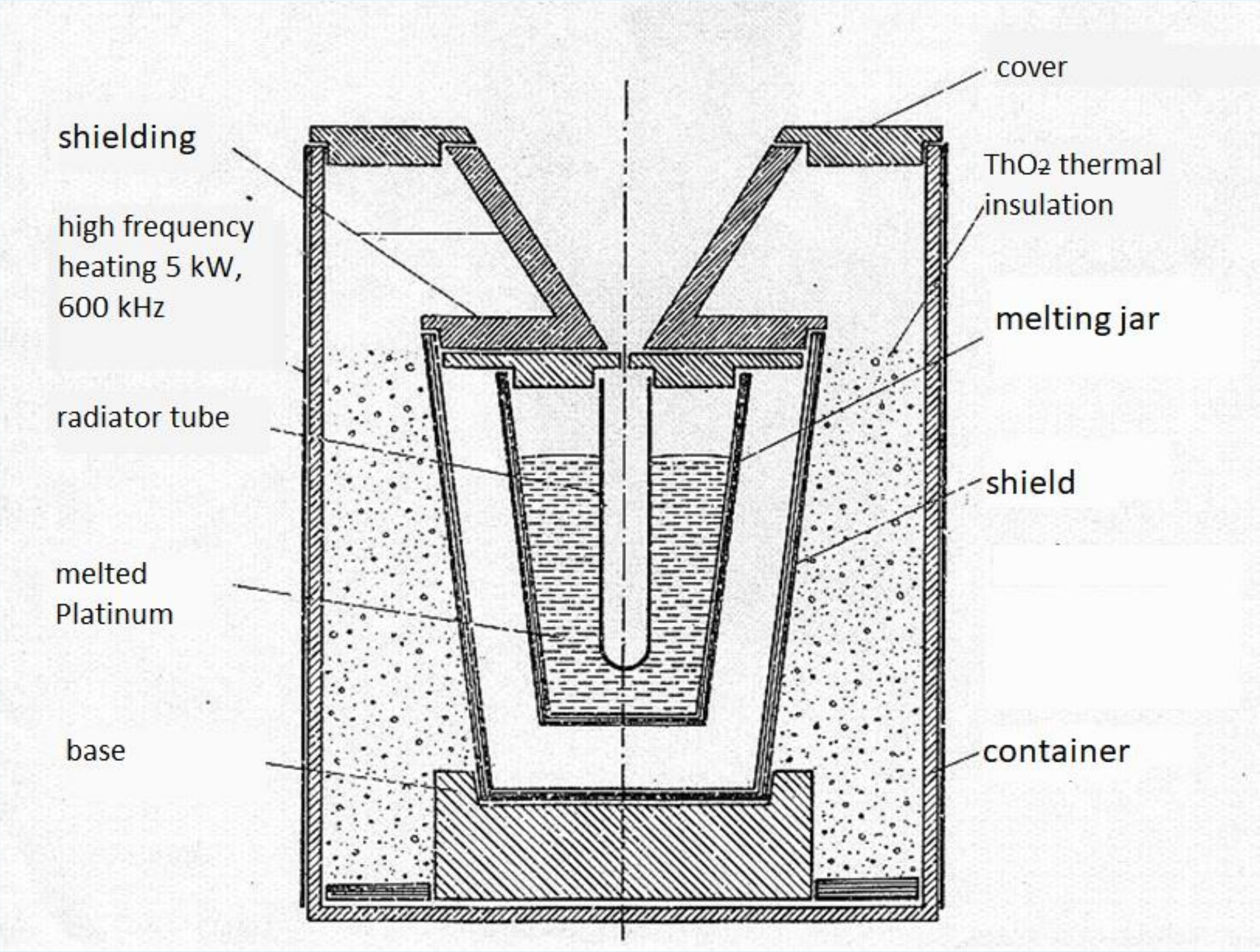
biology



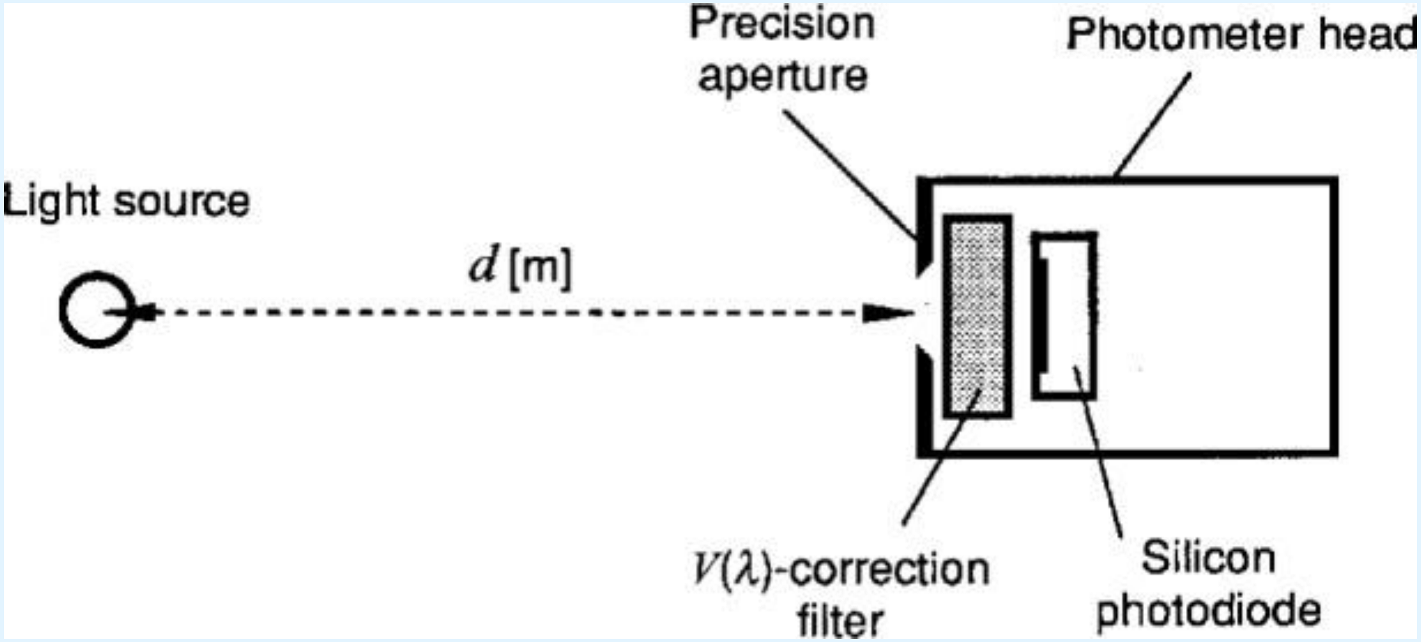
$V_M(\lambda)$ medium illuminance

(here V is for *visual*)

Cross-section of the Planckian radiator



Measuring the candela by standardised light source



Photometry

- In 1979, because of the experimental difficulties in realizing a Planck radiator at high temperatures and the new possibilities offered by radiometry, i.e. the measurement of optical radiation power, the 16th CGPM (1979, Resolution 3 ; CR , 100 and *Metrologia*, 1980, **1 6**, 56) adopted a new definition of the candela:
- **The candela is the luminous intensity, in a given direction, of a source that**
- **emits monochromatic radiation of frequency 540 ´ 10^{12} hertz and that has**
- **a radiant intensity in that direction of 1/683 watt per steradian.**

Valid up to 20th May 2019

26th meeting of the General Conference on Weights and Measures

the luminous efficacy K_{cd} of monochromatic radiation of frequency 540×10^{12} Hz is exactly 683 lumen per watt

Valid after20th May 2019

26th meeting of the General Conference on Weights and Measures

the candela, symbol cd, is the unit of luminous intensity in a given direction; its magnitude is set by fixing the numerical value of the luminous efficacy of monochromatic radiation of frequency 540 $\times 10^{12}$ Hz to be equal to exactly 683 when it is expressed in the SI unit

$m^{-2}\ kg^{-1}\ s^{3}$ cd sr, or
cd sr W^{-1}, which is equal to
lm W^{-1}.

Photometry

Candela: 1 candle from 1 m distance

The English candle used this way:
(London spermaceti candle),
height of flame 43–45 cm and
consumption 779 g per hour.

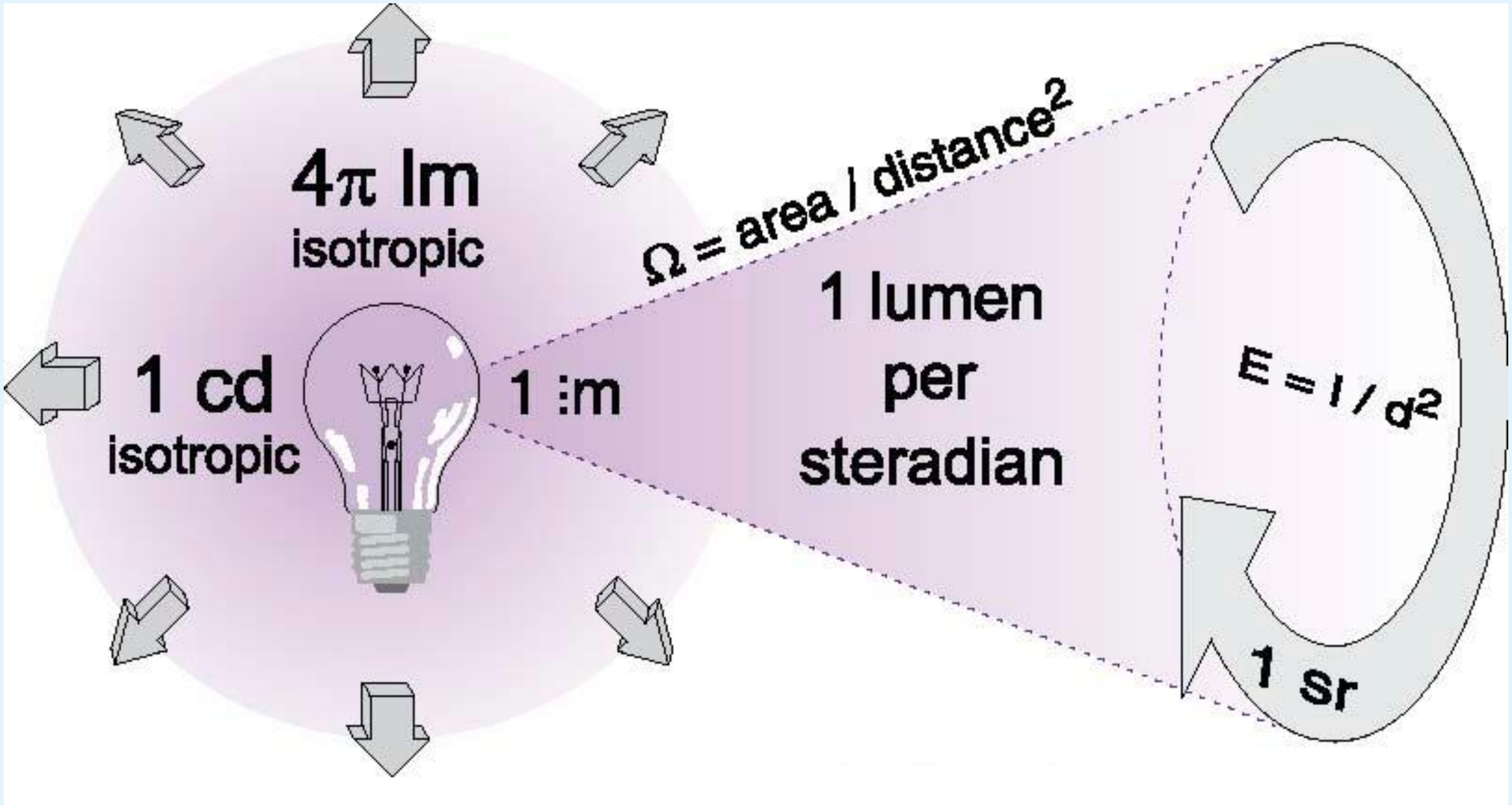
For example

Sun: 60 000 cd
Moon: 0,1 cd

Candela: Radiometric measuring

1 candela luminous intensity of monochromatic radiation at $540 \cdot 10^{12}$ Hz frequency, that radiant intensity is 1/683 Watt/steradian.

[~ 555nm wavelength is the peak of human (photopic) vision]



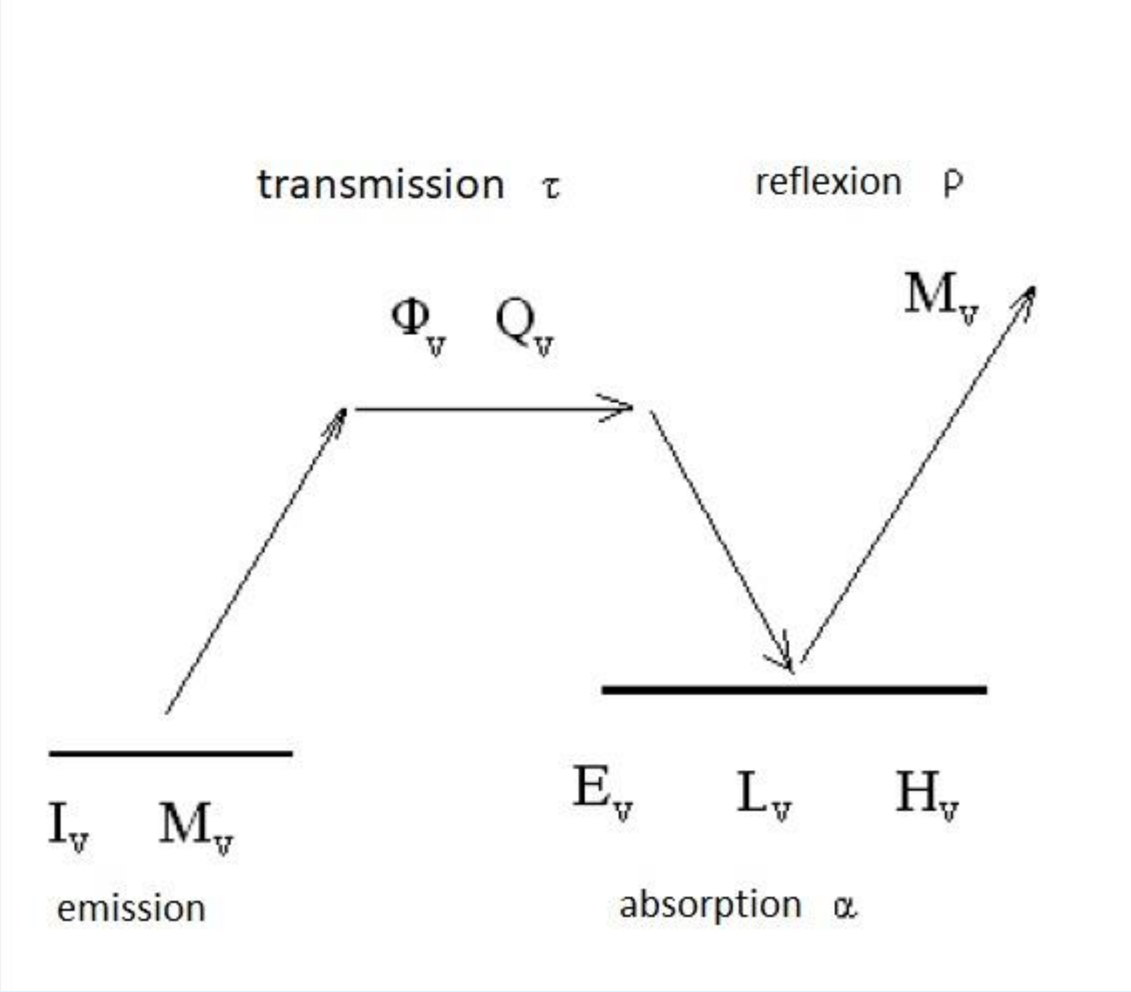
Spectral luminous efficacy: $K_m = 683 \frac{lm}{W}$

Radiant flux: Φ_e

Luminosity function for photopic vision: $V(555nm) \approx 1$

$$\Phi_V = K_m \int \frac{d\Phi_e}{d\lambda} \cdot V(\lambda) \cdot d\lambda$$

Emission of light can be originated from self-emitting light source
The surface lit can be a secondary light source.



$$\alpha+\rho+\tau=1$$

International Lighting Vocabulary, CIE, IEC 60050
http://cie.co.at/e-ilv

visual	**radiation**	**photon**	**sign**	**quantity**
Luminous intensity	Radiant intensity	Photonic intensity	I_v, I_e, I_p	cd, $W \cdot sr^{-1}$, $s^{-1} \cdot sr^{-1}$
Luminous flux	Radiant flux	Photon flux	Φ_v, Φ_e, Φ_p	lm, W, s^{-1}
Luminous energy	Radiant energy	Number of photons	Q_v, Q_e, Q_p	$lm \cdot s$, J, 1
Luminance	Radiance	Photon radiance	L_v, L_e, L_p	cd/m^2, $W \cdot m^{-2} \cdot sr^{-1}$, $s^{-1} \cdot m^{-2} \cdot sr^{-1}$
Luminous exitance	Radiant exitance	Photon exitance	M_v, M_e, M_p	lm/m^2, $W \cdot m^{-2}$, $m^{-2} \cdot s^{-1}$
illuminance	irradiance	Photon irradiance	E_v, E_e, E_p	lx, $W \cdot m^2$, $m^{-2} \cdot s^{-1}$
Luminous exposure	Radiant exposure	Photon exposure	H_v, H_e, H_p	$lx \cdot s$, $J \cdot m^{-2}$, m^{-2}

International Lighting Vocabulary, CIE, IEC 60050
https://cie.co.at/e-ilv

English	Русский	portugués	IEC 60050	CIE (EILV)
Luminous intensity	сила света	intensidade luminosa	834-21-045	17-21-045
Luminous flux	световой поток	fluxo luminoso	834-21-039	17-21-039
Luminous energy	световая енергия	enegia luminosa	834-21-037	17-21-037
Luminance	яркость	luminância	834-21-050	17-21-050
Luminous exitance	светимость	emitância luminosa	834-21-081	17-21-081
illuminance	освещённость	iluminância	834-21-060	17-21-060
Luminous exposure	световая экспозиция	exposição luminosa	834-21-072	17-21-072

Международная комиссия по освещению   Comissão Internacional de Iluminação

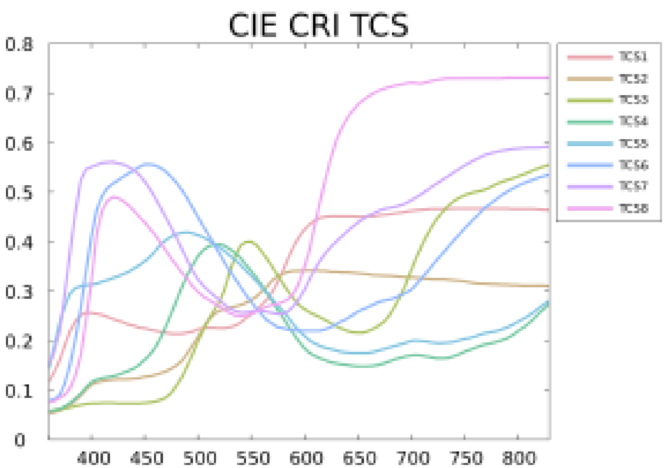
Luminous efficacy of light sources

Light source	Luminous efficacy, lm/W
Incandescent or halogen bulb	14,4; 17
LED	60 … 150
Fluorescent lamp	85
High pressure sodium metal lamp	90
High pressure Na-lamp	116
Low pressure Na-lamp	206

Coluor rendering index

Test color samples

As specified in (CIE 1995), the original test color samples (TCS) are taken from an early edition of the Munsell Atlas. The first eight samples, a subset of the eighteen proposed in (Nickerson 1960), are relatively low saturated colors and are evenly distributed over the complete range of hues.[8] These eight samples are employed to calculate the general color rendering index R_a. The last seven samples provide supplementary information about the color rendering properties of the light source; the first four for high saturation, and the last three as representatives of well-known objects. The reflectance spectra of these samples may be found in (CIE 2004),[9] and their approximate Munsell notations are listed aside.[10]



Name	Appr. Munsell	Appearance under daylight	Swatch
TCS01	7,5 R 6/4	Light greyish red	
TCS02	5 Y 6/4	Dark greyish yellow	
TCS03	5 GY 6/8	Strong yellow green	
TCS04	2,5 G 6/6	Moderate yellowish green	
TCS05	10 BG 6/4	Light bluish green	
TCS06	5 PB 6/8	Light blue	
TCS07	2,5 P 6/8	Light violet	
TCS08	10 P 6/8	Light reddish purple	
TCS09	4,5 R 4/13	Strong red	
TCS10	5 Y 8/10	Strong yellow	
TCS11	4,5 G 5/8	Strong green	
TCS12	3 PB 3/11	Strong blue	
TCS13	5 YR 8/4	Light yellowish pink (skin)	
TCS14	5 GY 4/4	Moderate olive green (leaf)	
TCS15	1 YR 6/4	Asian skin	

light colour designation

New quality measure mainly for LED light sources

light colour designation IEC 845-27-133

Example: 835

First figure: first figure of the colour rendering index (now 8)

Its meaning: the colour rendering index can be found 80 and 89

Next figures: first two digits of the *colour temperature* (now35)

Its meaning: 3500 K (moderately cold)

It is not signed for incandescent light sources, their colour rendering index is maximum: 100, colour temperature is 2700 K *light colour designation* CIE S 017:2020 ILV

17-27-133

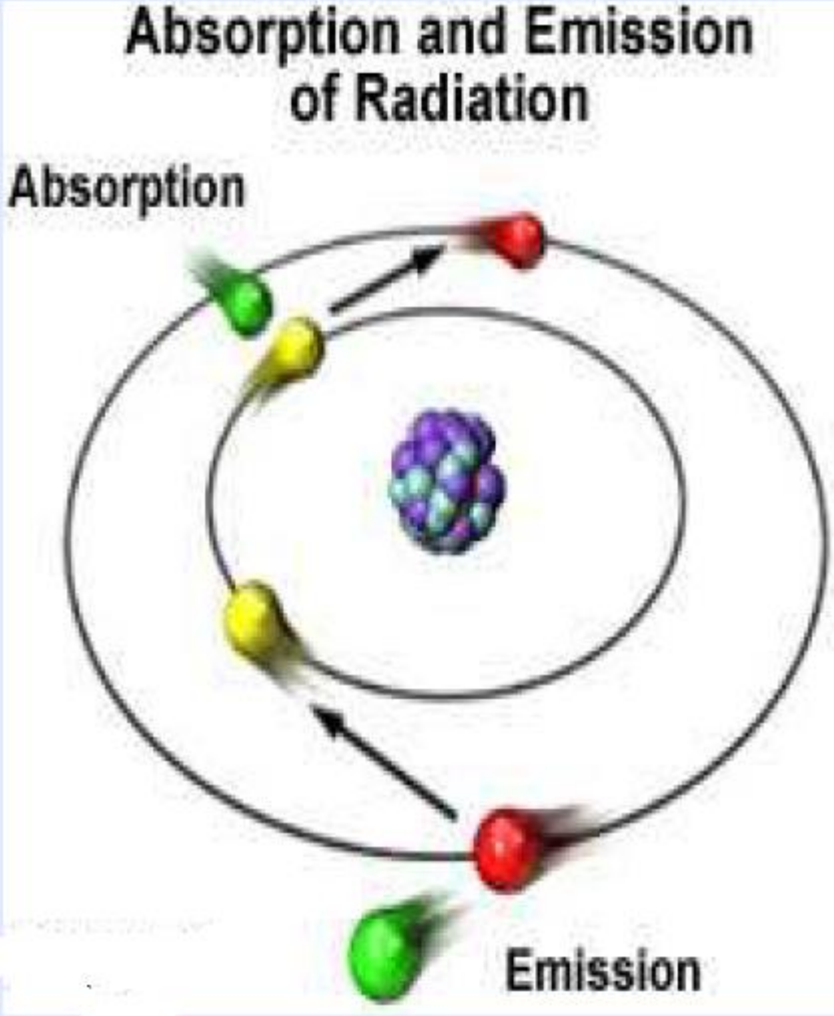
Correlated colour temperature

In the picture: compact fluorescent tube 3000K (above)

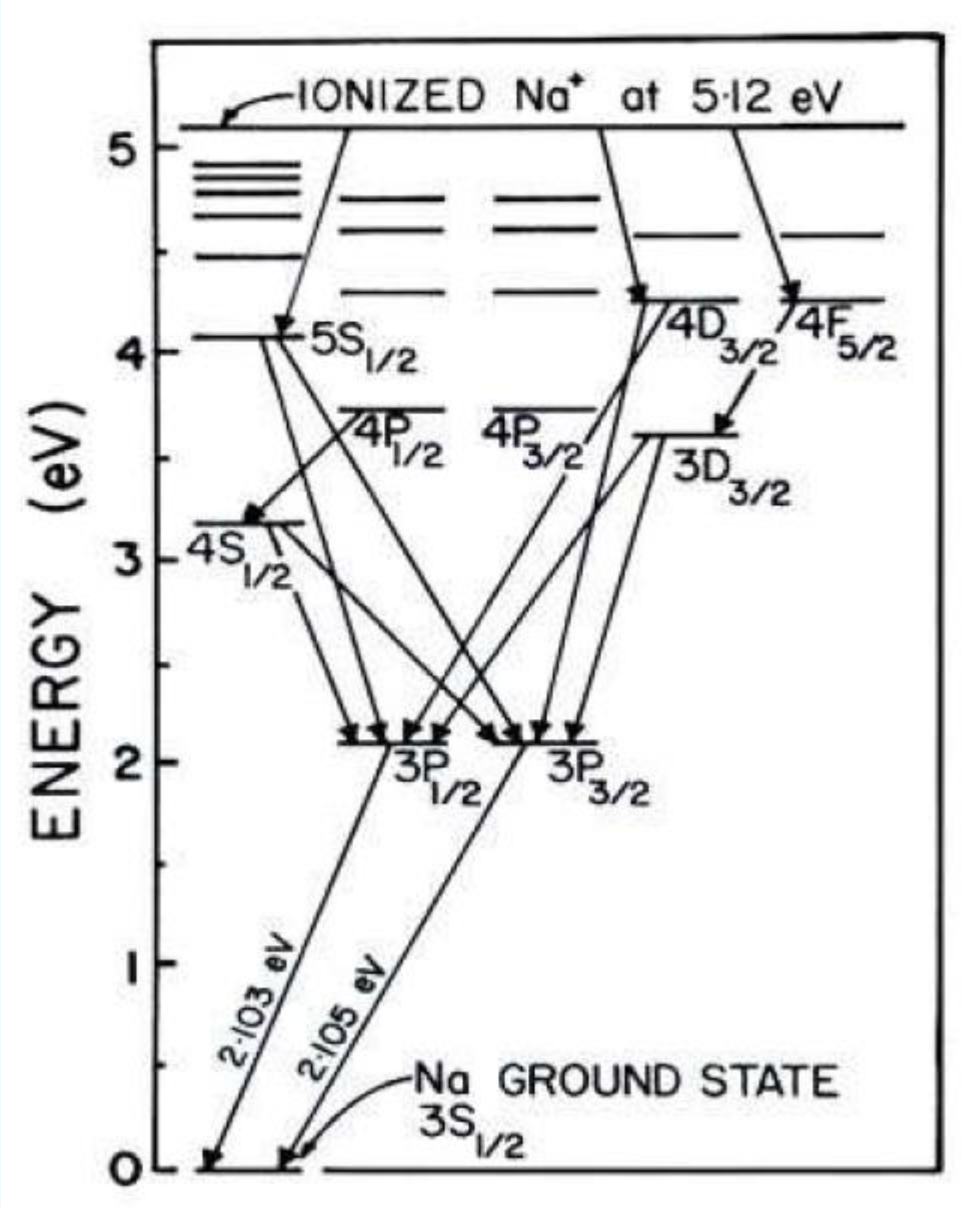
Traditional incandescent lamp 2700 K (left)

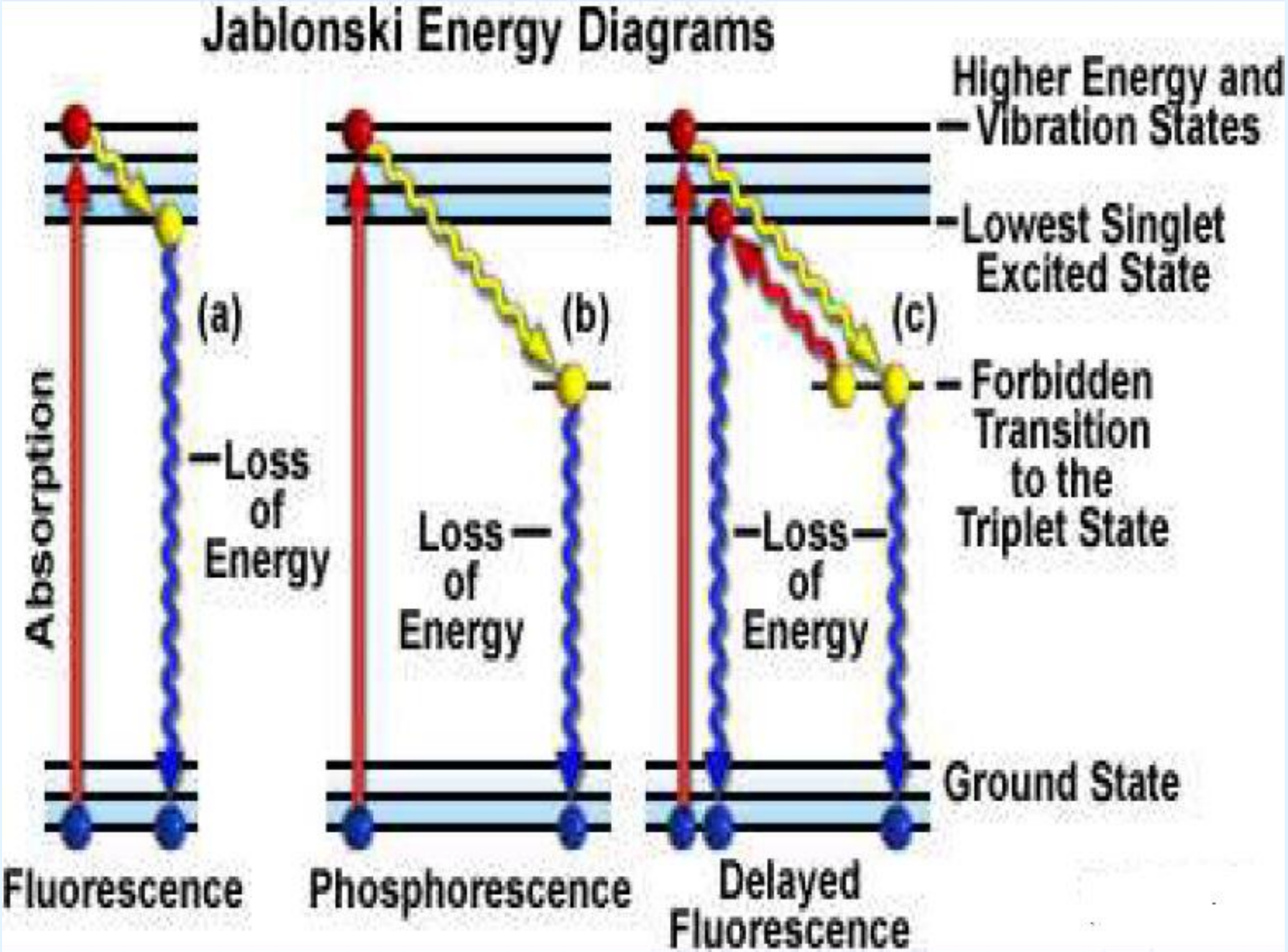
LED light source 4000 K (right)

colour rendering index and the colour temperature

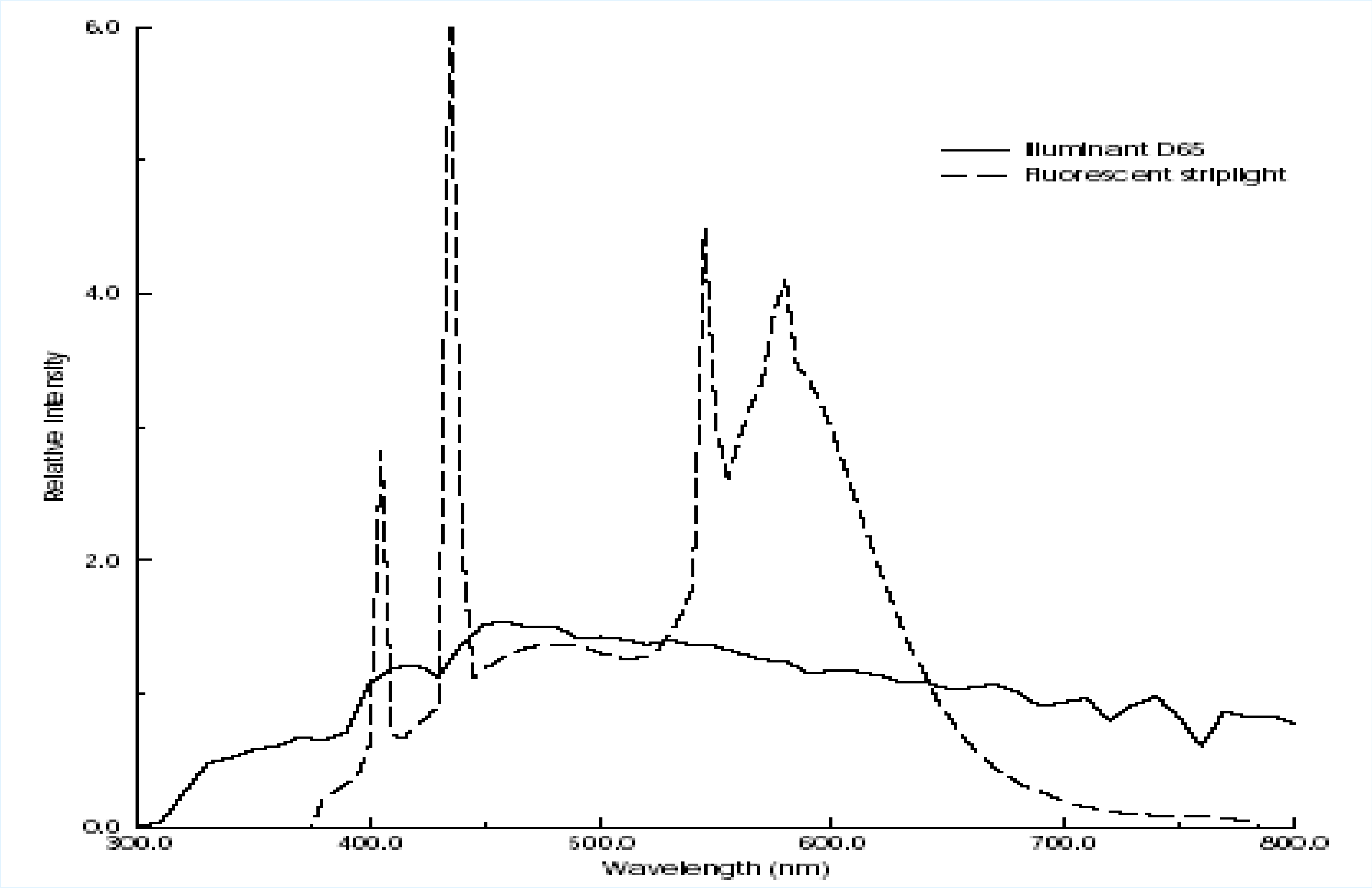


Excited emission:




Jablonski Energy Diagrams
Higher Energy and Vibration States
Lowest Singlet Excited State
Forbidden Transition to the Triplet State
Ground State
Absorption
(a)
(b)
(c)
Loss of Energy
Loss of Energy
Loss of Energy
Fluorescence
Phosphorescence
Delayed Fluorescence

spectrum of a fluorescent lamp



Colured phenomaena

- Excitation (e.g. sodium lamp)
- Metal binding (crystal contamination)
- Charge combination at organic molecules
- Energy change in valence band , or band gap (semiconductor)
- Geometric origin (diffraction, interferency)

Sources

- SI (Bureau International de Poids et Measures)
- National Institute of Satandards and Technology
- Commission Internationale de l'Éclairage
- Commission Électrotechnique Internationale
- Code of Federal Regulations, Food and Drug administration, FDA
- EINECS European Inventory of Existing Commercial Chemical Substances
  INS International Numbering System for Food Additives

Betanin, permitted colorant E162

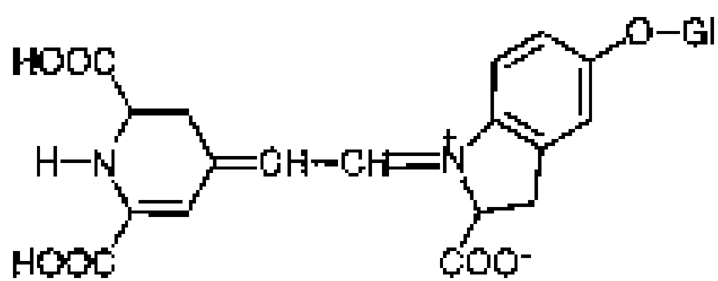
Colour Index 2.0 - Colour Index Base Set

File Search... Text Report View Windows Help

Beetroot Powder 42047

C.I. 75840 **C.I. Natural Red 33** Disclosed by DFA

Common name Betanine



Present, with the agylcone, in red beetroot (*beta vulgaris*).

Sources

- ISO 23539:2005 Photometry
- MSz 7300 COLOROID
- CIE Publ. S 017:2020 (IEC 845) International Lighting Vocabulary
- ISO 13300-1:2006 Sensory analysis. General guidance
- Colour Index Constitution Number
- Chemical Abstract Registry number (CAS)

Sources

- Colour Index International
- Society of Dyers and Colourists SDC
- American Association of Textile Chemists and Colorists AATCC
  - Colour Index Generic Names
  - Colour Index Constitution Numbers

Sources

- International Standards Organisation (ISO)
- European Colour Fastness Establishment (ECE)
- European Committee for Standardisation (CEN)
- Commission International de l'Éclairage (CIE)
- British Standards Institute (BSI)
- (Budapest Capital Government Office), Department of Metrology:
  Division of electrical, thermophysical and optical measuring

Sources

- ICS 67.160.10 Alcoholic beverages. Beer
- **ISO 12824:2016** Sugar and sugar products
- **ISO 7541:1989** Ground paprika. Determination of total natural colouring matter content
- **ISO 3864-2:2016** Graphical symbols. Safety colours and safety signs
- **ISO 3668:2017** Paints and varnishes — Visual comparison of colour of paints
- **ISO 19026:2015** Accessible design — Shape and colour of a flushing button and a call button

Sources

- MSZ 1361:2009
- A nemzeti zászló és lobogó követelményei
- Requirements for national flag and waving
- ICS 59.080 Products of the Textile Industry
- *Red* 18-1660 Munsell 4,6R 4,4/15
- *White* Berger whitness index: W_{BE}=100
- *Green* 18-6320 Munsell 1,25G 4,2/5

Sources

- http://elfiz2.kee.hu
- http://physics2.kee.hu
- http://elfiz2.kee.hu/aic/doc
- https://efiz.alarmix.net/aic/doc
- http://physics2.kee.hu/hallgato (en)
- http://www.mik.uni-pannon.hu

UV-C	100-280 nm
UV-B	280-315 nm
UV-A	315-400 nm
violett	380-440 nm
blue	440-495 nm
green	495-558 nm
yellow	558-640 nm
red	640-780 nm
IR-A	780-1400 nm
IR-B	1400-3000 nm
IR-C	3000-1000000 nm

Lukács Gyula, 2003 Coloristics Symposium:

According it the word „colour” shouldn’t be used because of misunderstanding. Instead of it we should use

- Perceived colour: attribute of visual **perception** consisting of any combination of chromatic and achromatic content. This attribute can be described by chromatic colour names such as yellow, orange, brown, red, pink, green, blue, purple, etc.

- Colur stimulus: visible **radiation energy** entering the eye and producing a sensation of colour, either chromatic or achromatic

International Lighting Vocabulary

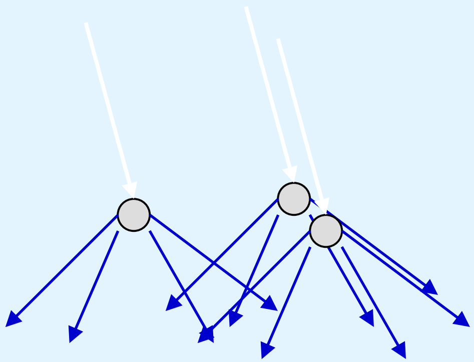
Physical quantities	Psychophysical quantities		Colour sensation
radiometry	photometry	Metrology of colour stimuli	Properties in psychology
Optical radiation (1 nm<λ<1 mm)	Visual radiation (380 nm <λ<780 nm)	Colour stimulus CIE 1931 (1964)	Visual appearance
	spectral luminous efficiency, V(λ), V'(λ)	Tristimulus values X, Y, Z	
Radiant intensity	Luminous intensity	CIELAB colour space L*, a*, b*	Colour perception
Radiant flux	Luminous flux		
radiance	luminance		
irradiance	illuminance		
		CIE 1976 lightness, L* CIELAB hue angle, h_{ab} CIELAB chroma, C_{ab}*	luminousness hue colourfulness
		CIELAB colour difference, ΔE_{ab}*	Colour perception sensitivity

Dark – light

Pale – vivid

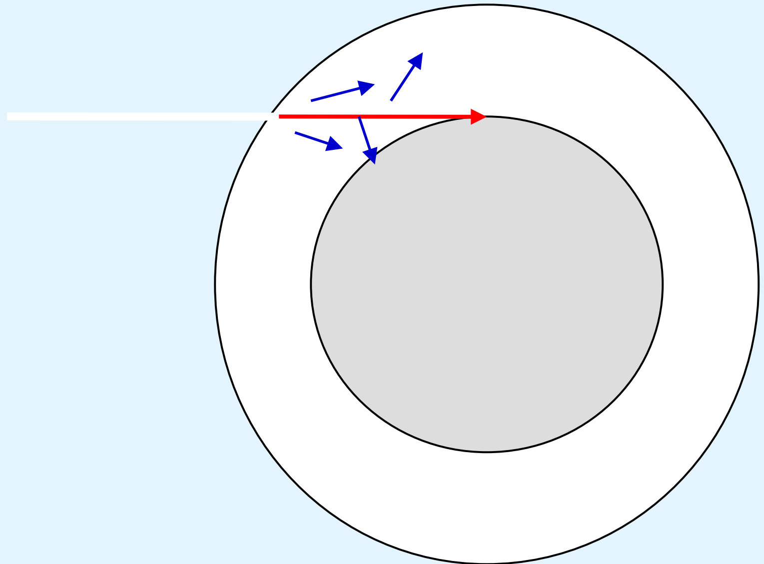
Grassmann's Law

- To specify a colour match three independent variables are necessary and sufficient
- For an additive mixture of colour stimuli only their tristimulus values are relevant, not their spectral composition
- In additive mixtures of colour stimuli, if one or more components of the mixture are gradually changed, the resulting tristimulus values also change gradually

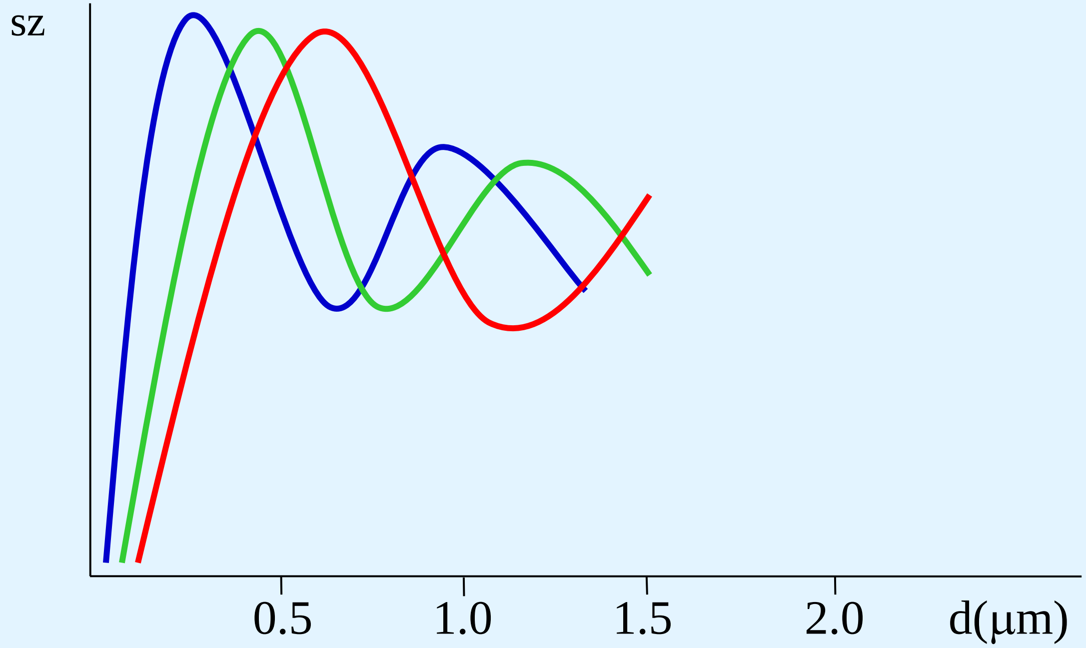


Rayleigh-scattering: the scattering reverse function of the wavelenth of its fourth power (~ λ^{-4}), if the size of the particle smaller than the wavelength (d << λ).

Results: a) the sky is blue in the daytime
b) The sky is red at sunrise and sunset



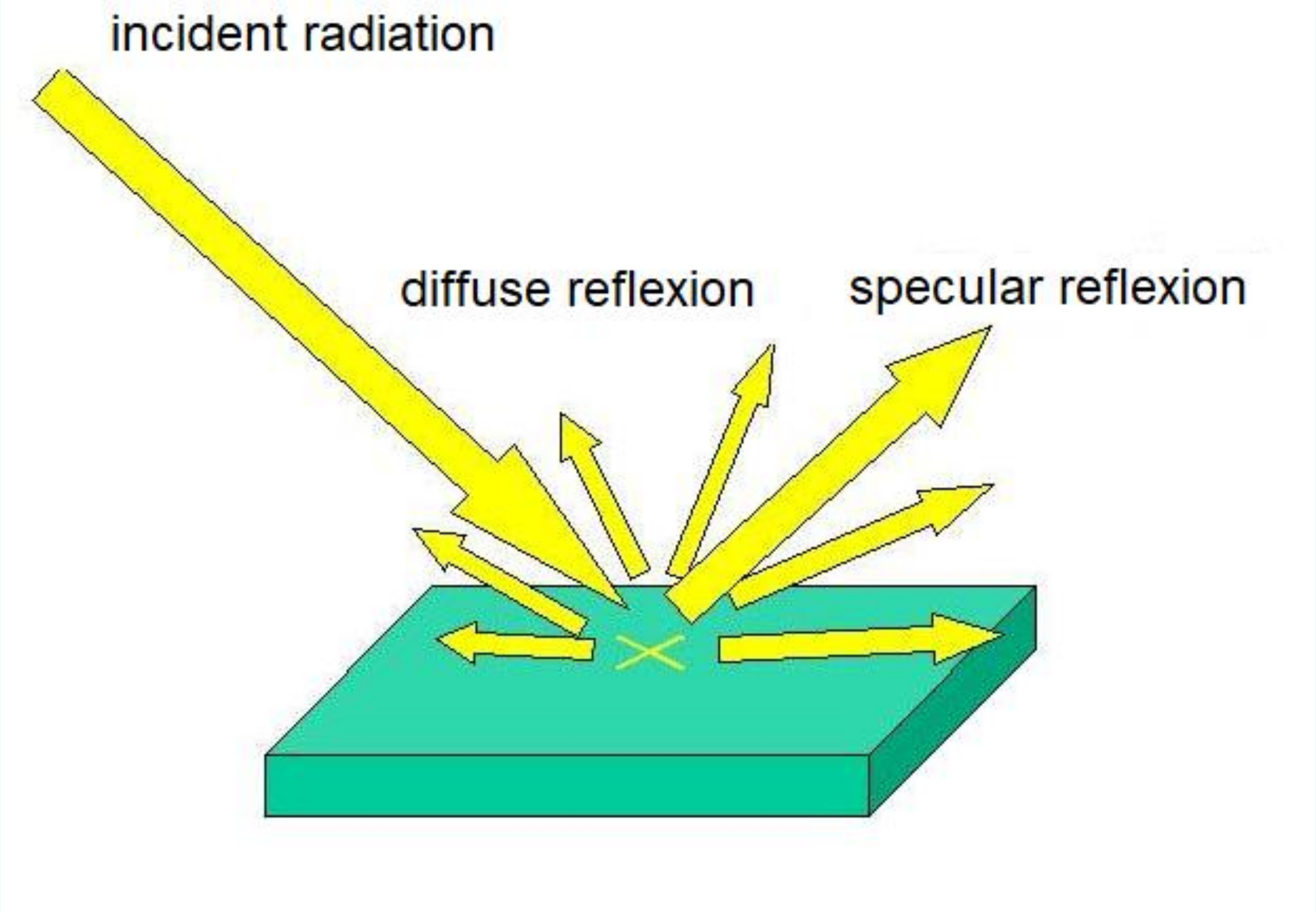
Mie-scattering (d > λ) **Gustav Adolf Feodor Wilhelm Ludwig Mie**



The type of scattering depends on the wavelength and the size of the particle too.

Why the clouds are white:

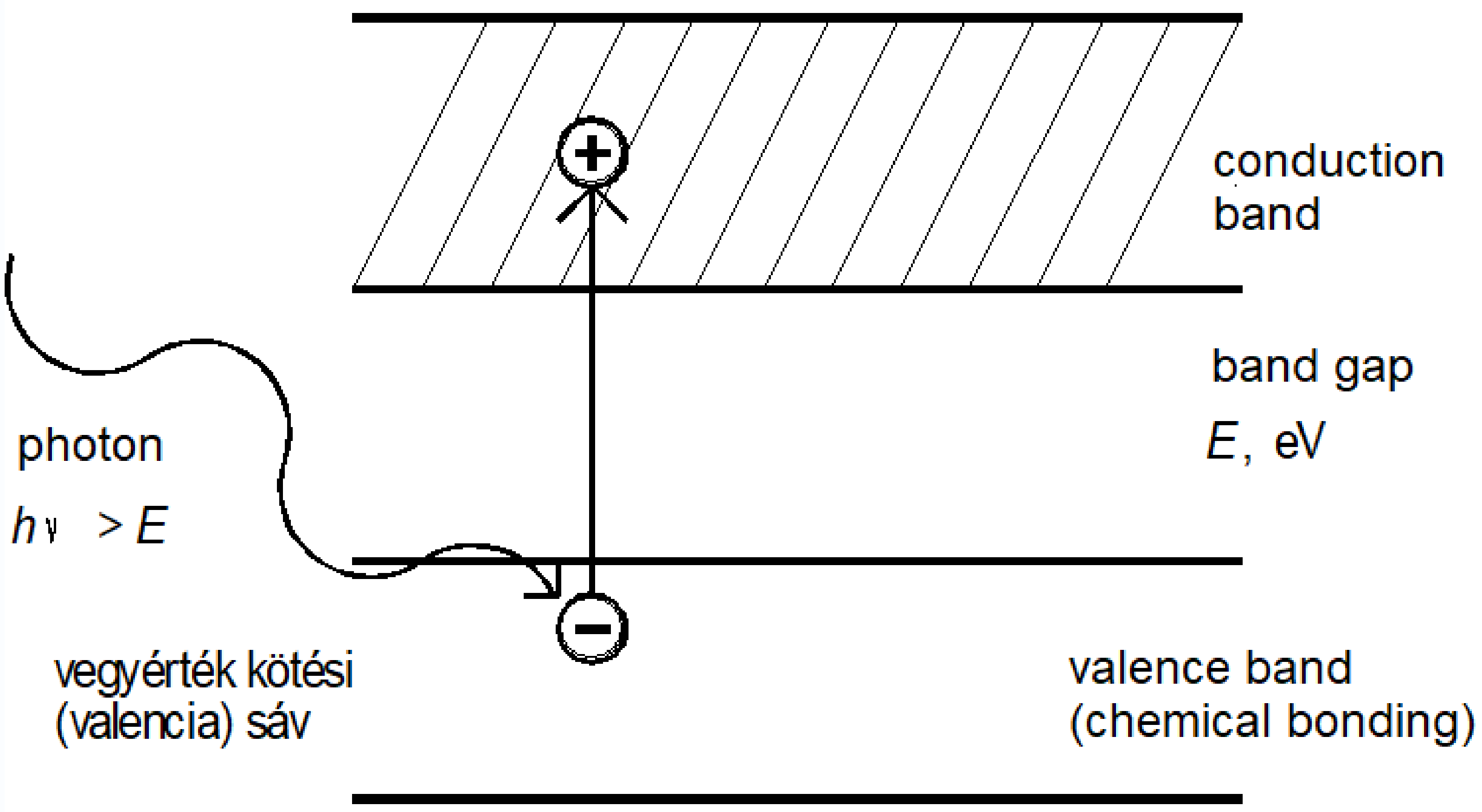
particles with great diameter (d > 10 μm) causes scattering at all wavelength.


incident radiation
diffuse reflexion
specular reflexion

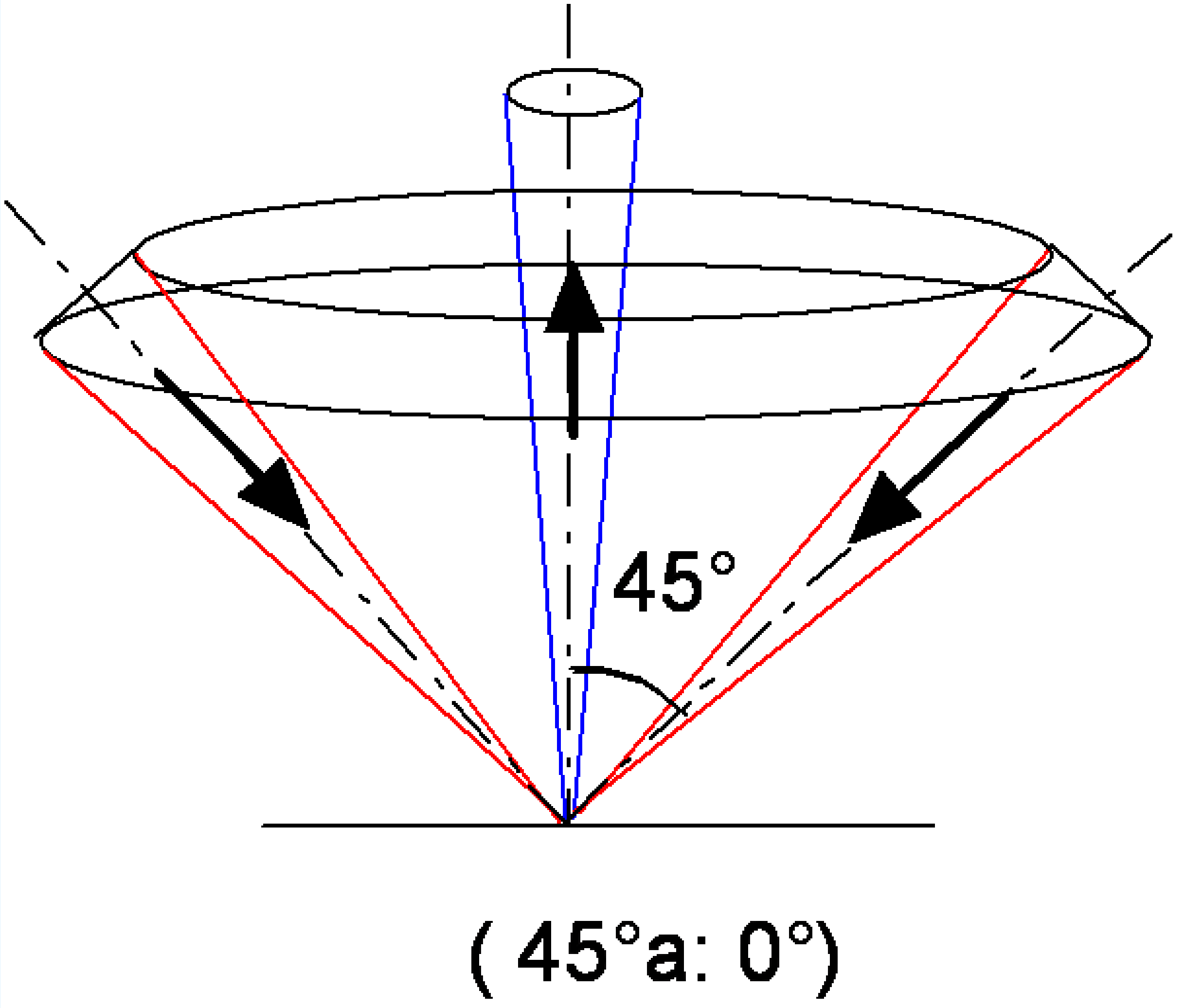
Photodetectors

- Photoconductivity (Indium-antimonid, InSb, CdS, CdSe)
- p-n junction: photoelement (Si, Ge, GaAsP), photodiodes, phototransistors (Si), avalanche photodiode, CCD (Charge Coupled Device), CMOS (Charge Coupled Metal Oxide Semiconductor), Se, photo-FET (field effect transistors)
- photocathode (AgOCs, CsNaK), photocell, photomultiplier (vacuum tubes)
- Thermal detector (Seebeck-effect), pyroelectric cell (polyvinyl-fluoride)

Photoconductive cell



Geometry of 1931 CIE Standard observer



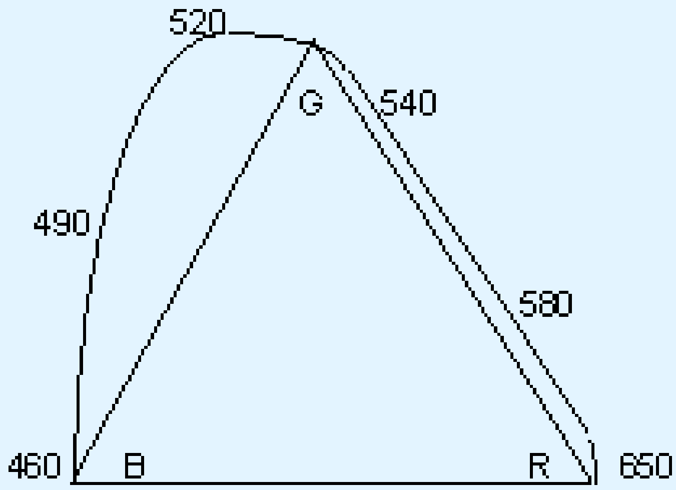
CIE standard illuminant A

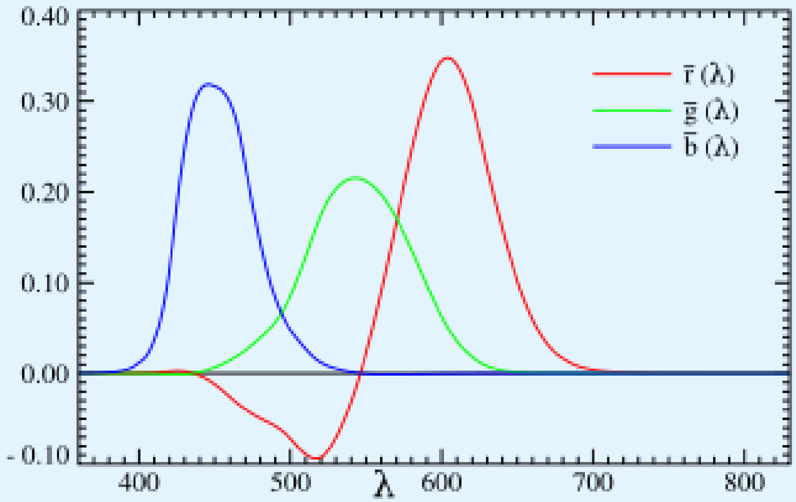
The relative spectral power distribution $S_A(\lambda)$ is defined by the equation

$$S_A(\lambda) = 100\left(\frac{560}{\lambda}\right)^5 \times \frac{\exp\dfrac{1{,}435\times10^7}{2\,848\times560} - 1}{\exp\dfrac{1{,}435\times10^7}{2\,848\,\lambda} - 1}$$

where λ is the vacuum wavelength in nanometres and the numerical values in the two exponential terms are definitive constants originating from the first definition of Illuminant A in 1931.

This spectral power distribution is normalized to the value 100 (exactly) at the vacuum wavelength 560 nm (exactly).





Origin of the CIE 1931 RGB
(based upon Maxwell's RGB)

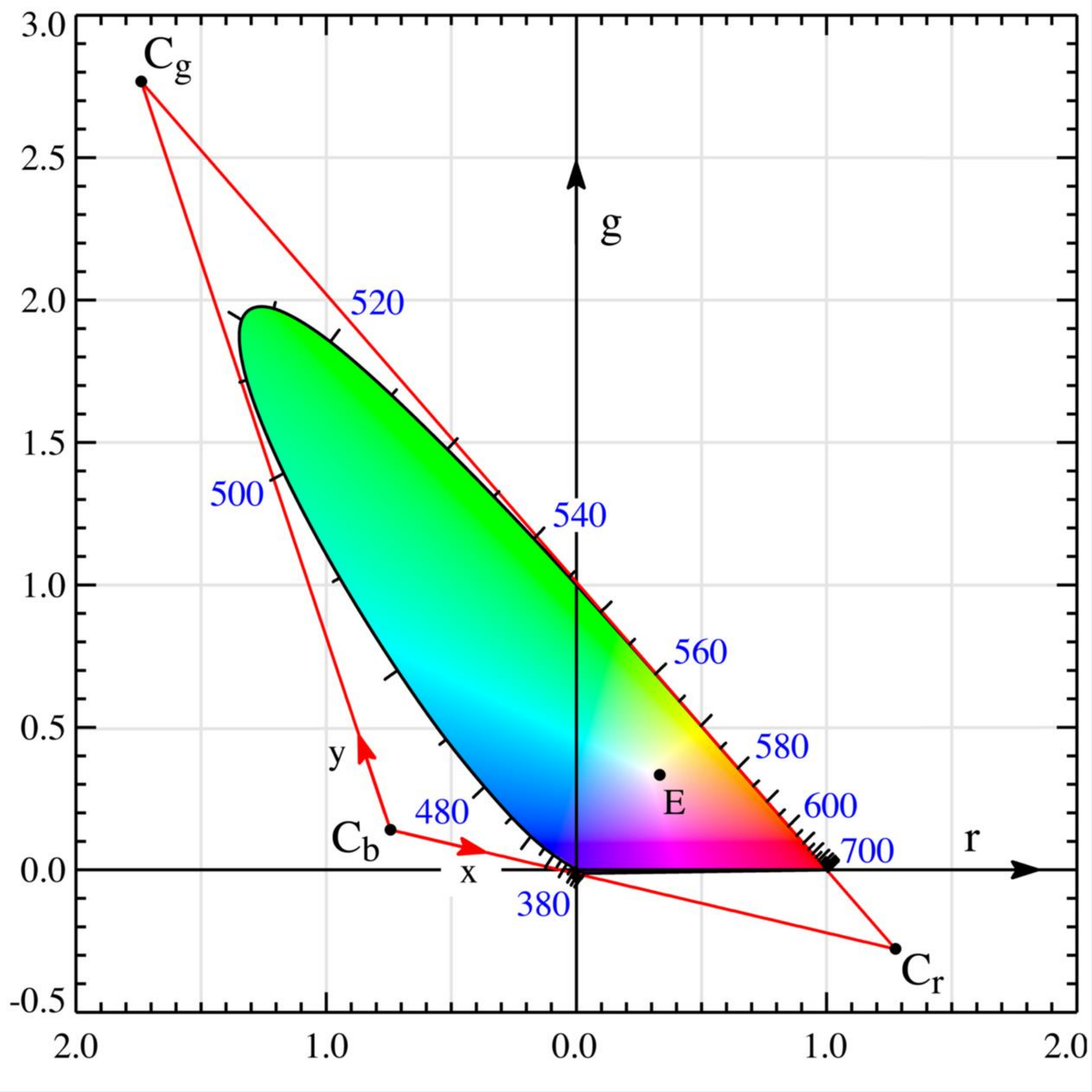
RGB - XYZ matrix transformation

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} 2{,}76888 & 1{,}75175 & 1{,}13016 \\ 1{,}00000 & 4{,}59070 & 0{,}06010 \\ 0{,}00000 & 0{,}05651 & 5{,}59427 \end{vmatrix} \cdot \begin{vmatrix} R \\ G \\ B \end{vmatrix}$$

Az inverse transformació:

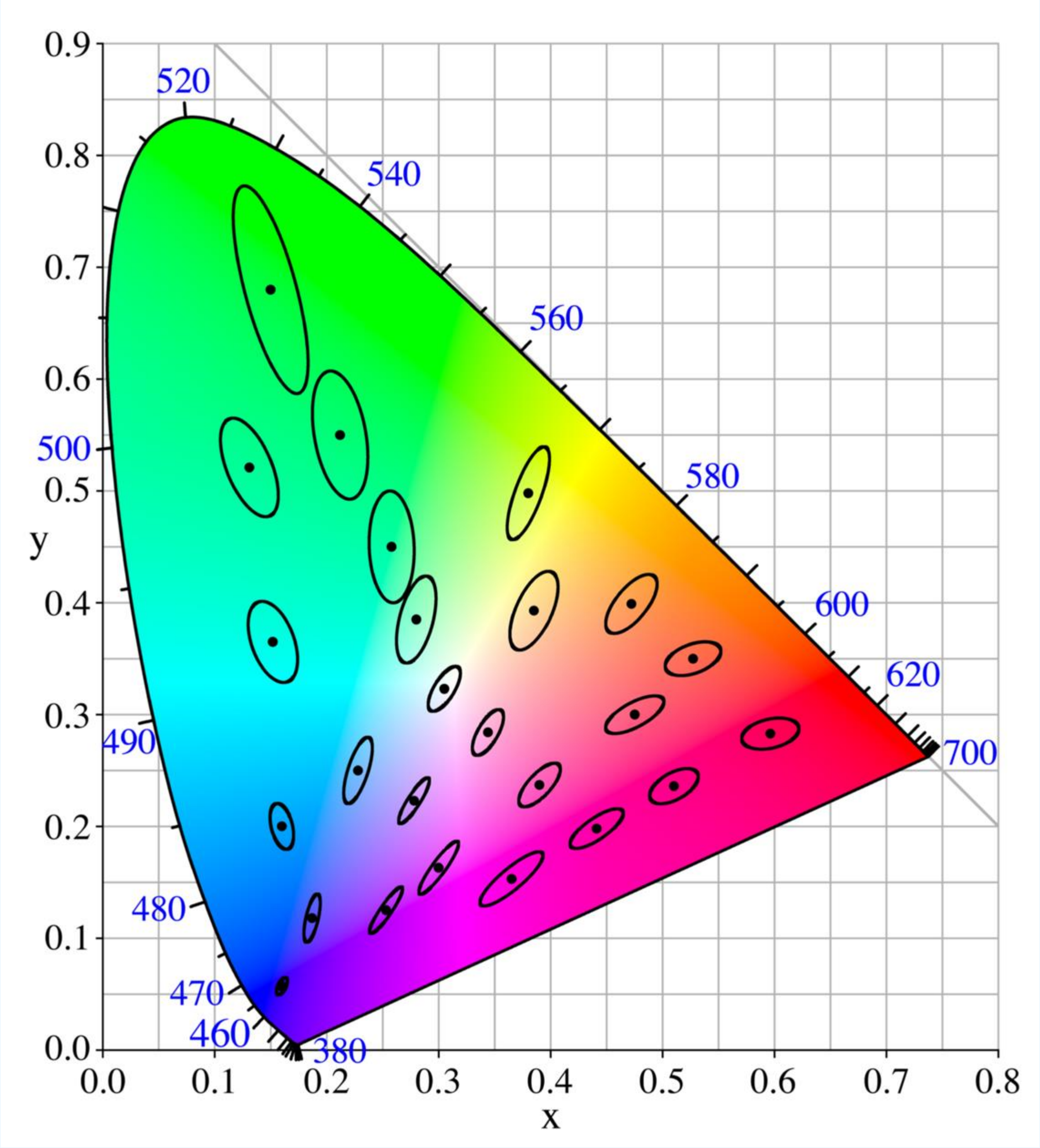
$$\begin{vmatrix} 0{,}41846 & -0{,}15866 & -0{,}08283 \\ -0{,}09117 & 0{,}25243 & 0{,}01571 \\ 0{,}00092 & -0{,}00255 & 0{,}17860 \end{vmatrix}$$

Source: dr Schanda János, Pannon Egyetem



Colour triangle of the CIE 1931 RGB

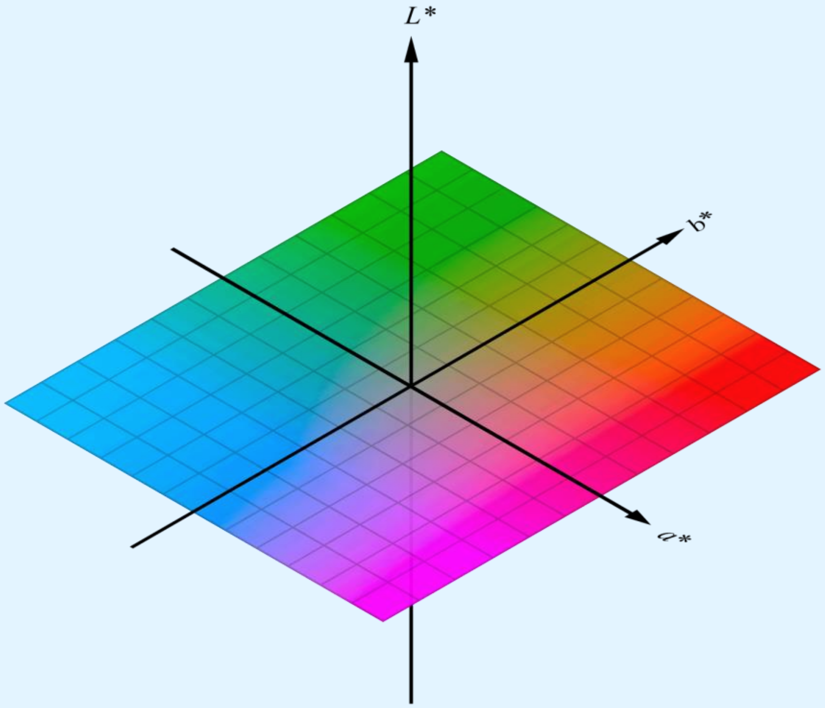
(the xy is coloured in the middle)



MacAdam tolerancy ellipses

CIE 1976 L*a*b*

- Basic colour difference



$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a*)^2 + (\Delta b*)^2}$$

CIE 1976 L*u*v*

Basic colour difference

u_n and v_n are the standard (normal) illuminant

$$u' = \frac{4X}{X + 15Y + 3Z} \qquad v' = \frac{9Y}{X + 15Y + 3Z}$$

$$u^* = 13L^*\left(u' - u_n'\right) \qquad v^* = 13L^*\left(v' - v_n'\right)$$

$$\Delta E = \sqrt{\left(\Delta L\right)^2 + \left(\Delta u^*\right)^2 + \left(\Delta v^*\right)^2}$$

CIE 1976 L*u*v*

Chroma

$$C^* = \sqrt{(u^*)^2 + (v^*)^2}$$

Chromacity angle

$$h_{uv} = arctan \frac{v^*}{u^*}$$

CIE colour difference equation

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{k_L S_L} \right)^2 + \left(\frac{\Delta C'}{k_C S_C} \right)^2 + \left(\frac{\Delta H'}{k_H S_H} \right)^2 + \left(R_T \left(\frac{\Delta C'}{k_C S_C} \right) \left(\frac{\Delta H'}{k_H S_H} \right) \right) \right]^{1/2}$$

$$L' = L^*$$

$$a' = a^*(1+G)$$

$$b' = b^*$$

$$G = 0{,}5 \left(1 - \sqrt{\frac{\overline{C}{}^{*7}_{ab}}{\overline{C}{}^{*7}_{ab} + 25^7}} \right)$$

CIE colour difference equation (explained)

$$S_L = 1 + \frac{0{,}015\left(\overline{L}'-50\right)^2}{\sqrt{20+\left(\overline{L}'-50\right)^2}}$$

$$S_C = 1 + 0{,}045\overline{C}'$$

$$S_H = 1 + 0{,}015\overline{C}'T$$

$$T = 1 - 0{,}17\cos\left(\overline{h}'-30\right) + 0{,}24\cos\left(2\overline{h}'\right) + 0{,}32\cos\left(3\overline{h}'+6\right) - 0{,}20\cos\left(4\overline{h}'-63\right)$$

CIE Whiteness Index

$$W = Y + 800(x_n - x) + 1700(y_n - y)$$

$$W_{10} = Y_{10} + 800(x_{n,10} - x_{10}) + 1700(y_{n,10} - y_{10})$$

$$T_w = 1000(x_n - x) - 650(y_n - y)$$

$$T_{w,10} = 900(x_{n,10} - x_{10}) - 650(y_{n,10} - y_{10})$$

where *Y* is the *Y*-tristimulus value of the sample, *x* and *y* are the *x*, *y* chromaticity coordinates of the sample, and x_n, y_n are the chromaticity coordinates of the perfect diffuser, all for the CIE 1931 standard colorimetric observer; *Y*10, *x*10 , *y*10, $x_{n,10}$ and $y_{n,10}$ are similar values for the CIE 1964 standard colorimetric observer.

Tint: difference from the ideal white (or achromatic)

CIE Whiteness Index

$$W_{CIE\text{-}L^*a^*b^*} =$$

$$2.41L^* - 4.45b^*[1 - 0.009(L^* - 96)] - 141.4$$

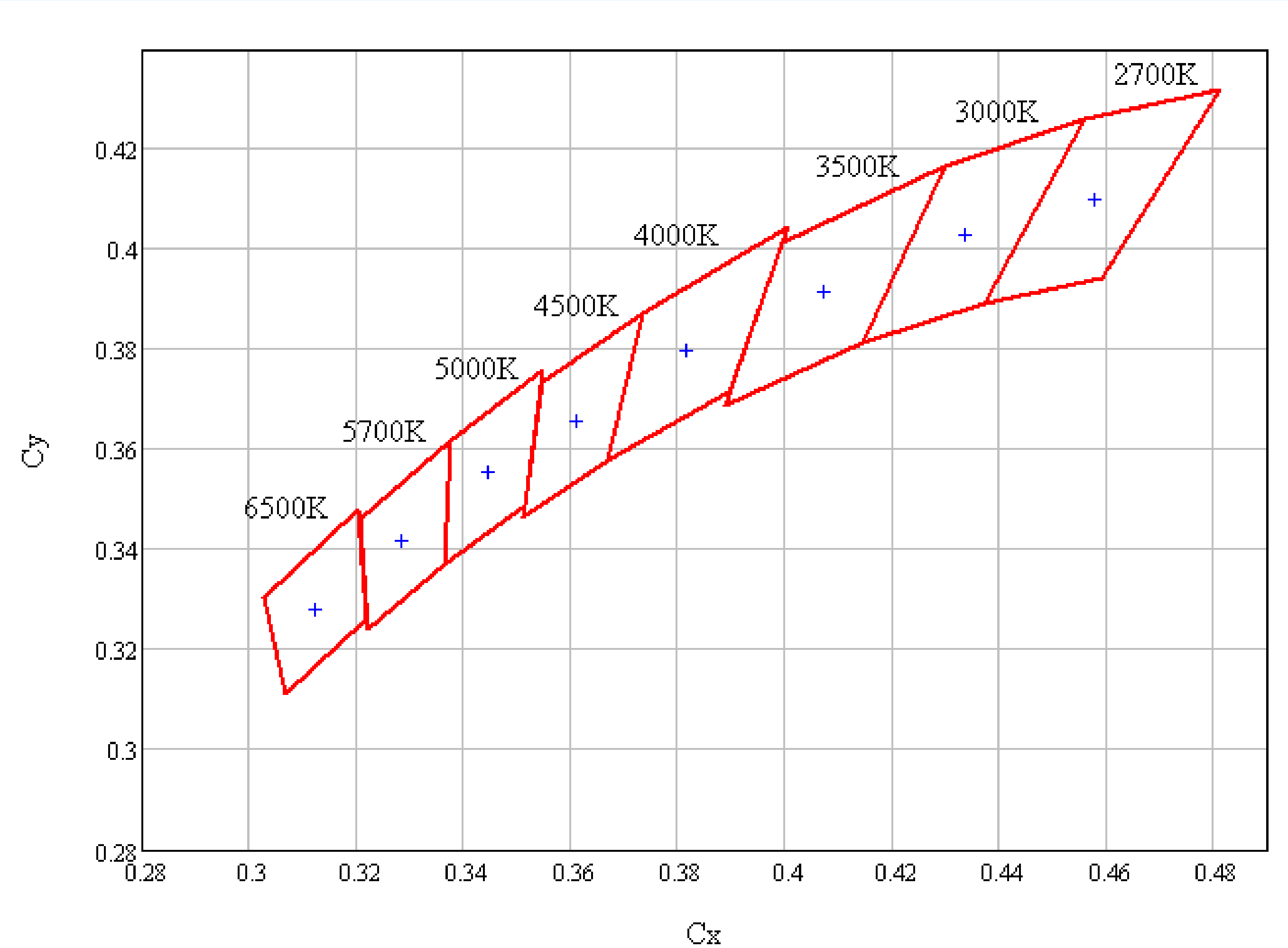
Whiteness Index

- ASTM American Society for Testing and Materials
  - Color and Appearance E12

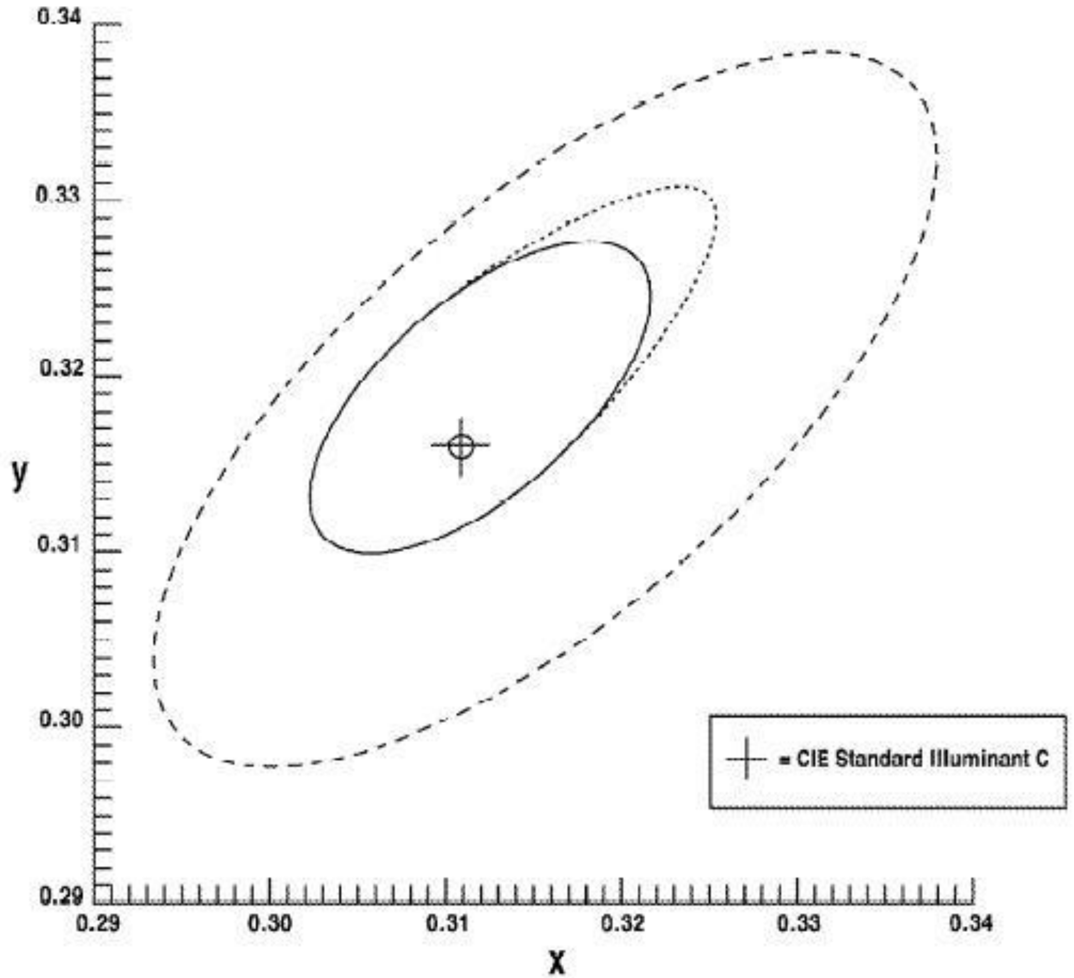
Whiteness Indices

- ASTM E313-98 Standard Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates
- $WI=3{,}388Z-3Y$
- $W_{Taube}=G-4(G-B)$ BASF
- $WI_{Leukometer}=2R_{459}-R_{614}$ Carl Zeiss, Jena

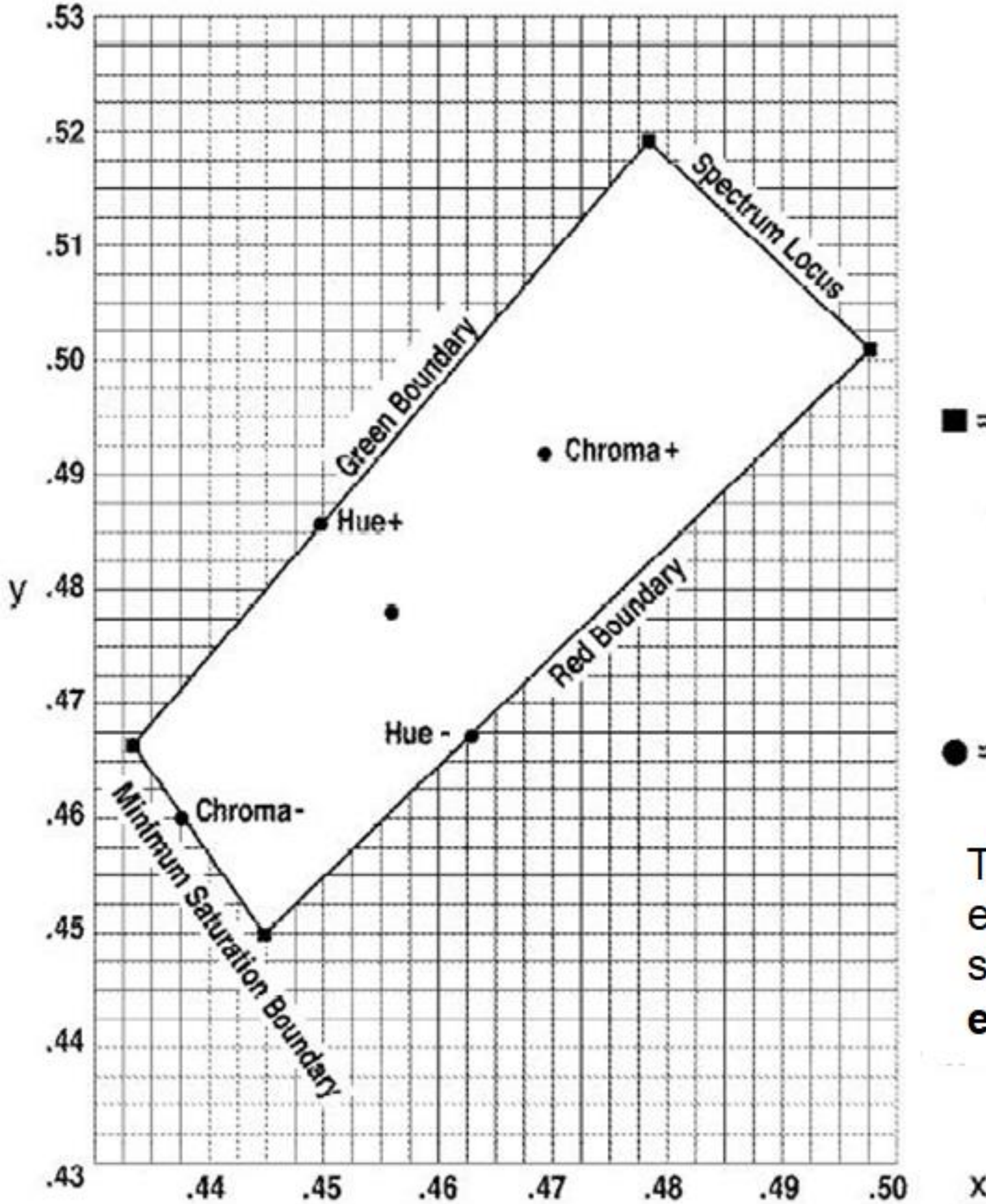
Tolerances for white illumination according ANSI



Tolerance of white, grey and black according the ANSI Z5351



Legend	Color	Munsell Value	Munsell Chroma Tolerance
	White	N 9	/0.5 to /1.0
	Grey	N 5	/0.5
	Black	N 1.5	/0.5



This diagram shows the relationship between the permissible color region for Safety Yellow as shown in Figure 1 tolerance limits for Safety Yellow described in the CIE data found in Table 1.

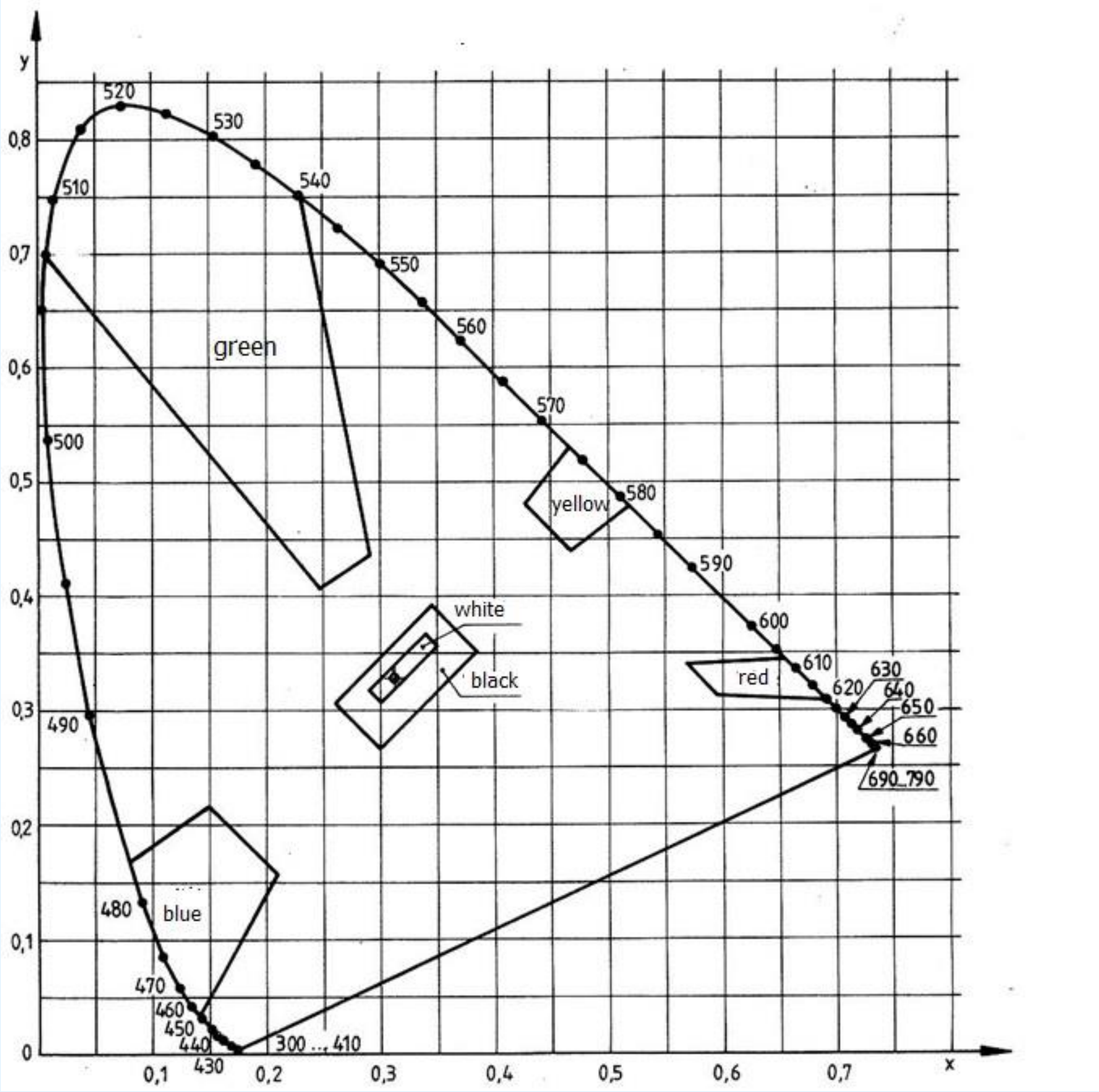
■ = Corner Points of Acceptable Color Tolerance Region

● = Color Tolerance Chart Colors

The proper expression for saturation is **exitation purity**

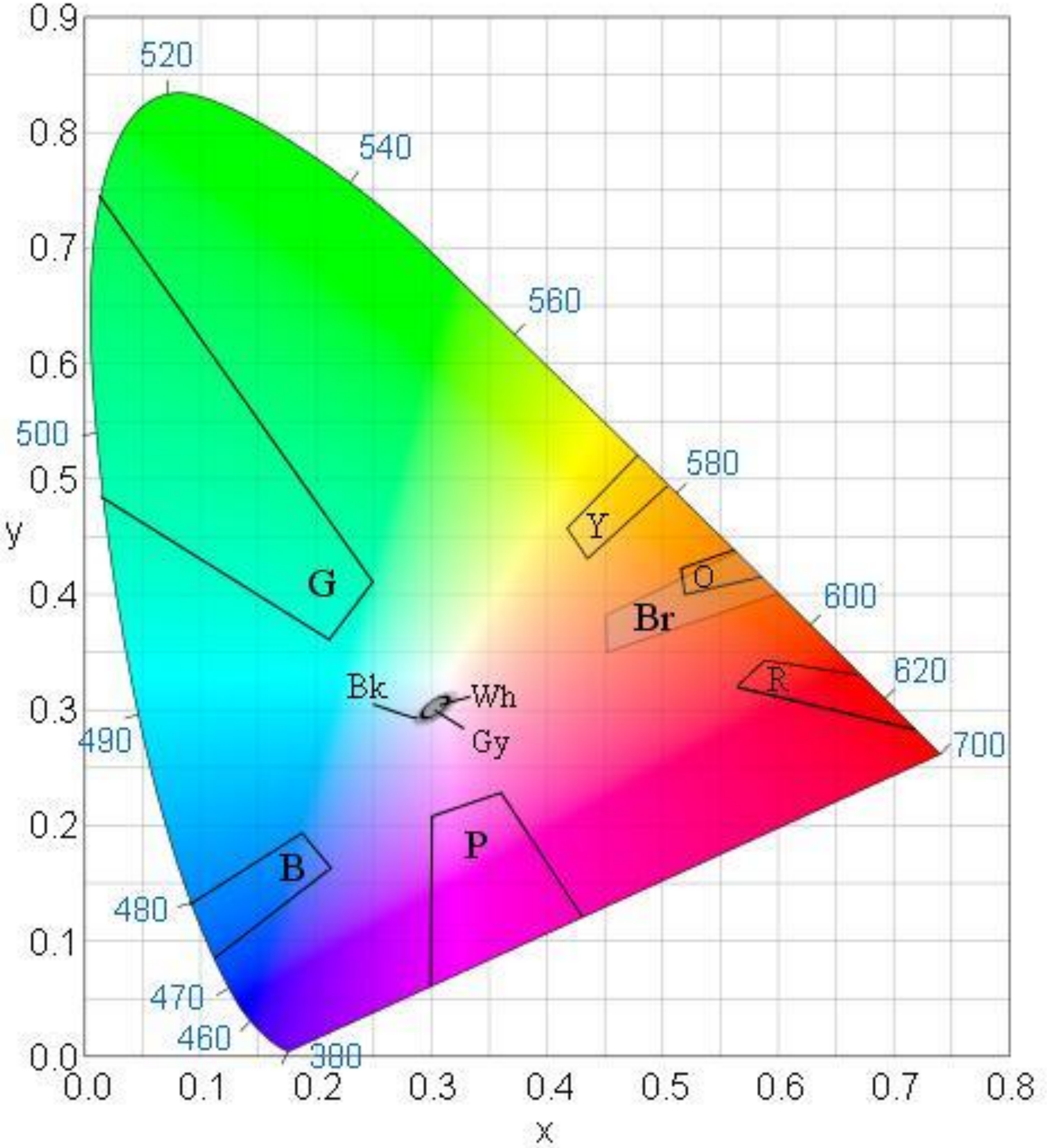
ISO 3864

colour	Corner points of chromacity coordinates Standard D65 illumination, 45°/0° geometry					illuminating factor, β		
						regular materials	retroflecting materials	
		1	2	3	4		type 1	type 2
red	x y	0,690 0,310	0,595 0,315	0,569 0,341	0,655 0,345	≥0,07	≥0,05	≥0,03
blue	x y	0,078 0,171	0,150 0,220	0,210 0,160	0,137 0,038	≥0,05	≥0,01	≥0,01
yellow	x y	0,519 0,480	0,468 0,442	0,427 0,483	0,465 0,534	≥0,45	–	–
retroflecting yellow	x y	0,545 0,454	0,487 0,423	0,427 0,483	0,465 0,534	–	≥0,27	≥0,16
green	x y	0,230 0,754	0,291 0,438	0,248 0,409	0,007 0,703	≥0,12	–	–
retroflecting green	x y	0,007 0,703	0,248 0,409	0,177 0,362	0,026 0,399	–	≥0,04	≥0,03
white	x y	0,350 0,360	0,300 0,310	0,290 0,320	0,340 0,370	≥0,75	–	–
retroflecting white	x y	0,350 0,360	0,300 0,310	0,285 0,325	0,335 0,375	–	≥0,35	≥0,27
black	x y	0,385 0,355	0,300 0,270	0,260 0,310	0,345 0,395	≥0,03	–	–



ISO 3864

International safety signs



ANSI Z535.1

Safety Color Code

ANSI Z535.4 Product Safety Signs

Table 2 – Colour-coding for push-button actuators and their meanings

Colour	Meaning	Explanation	Examples of application
RED	Emergency	Actuate in the event of a hazardous situation or emergency	Emergency stop Initiation of emergency function (see also 10.2.1)
YELLOW	Abnormal	Actuate in the event of an abnormal condition	Intervention to suppress abnormal condition Intervention to restart an interrupted automatic cycle
BLUE	Mandatory	Actuate for a condition requiring mandatory action	Reset function
GREEN	Normal	Actuate to initiate normal conditions	(See 10.2.1)
WHITE	No specific meaning assigned	For general initiation of functions except for emergency stop	START/ON (preferred) STOP/OFF
GREY			START/ON STOP/OFF
BLACK			START/ON STOP/OFF (preferred)

Emergency abnormal

Intervention

initiate normal mandatory

The other colours: at choice

Safety of machinery –
Electrical equipment of machines
Part 1: General requirements1

10.3.2 Colours

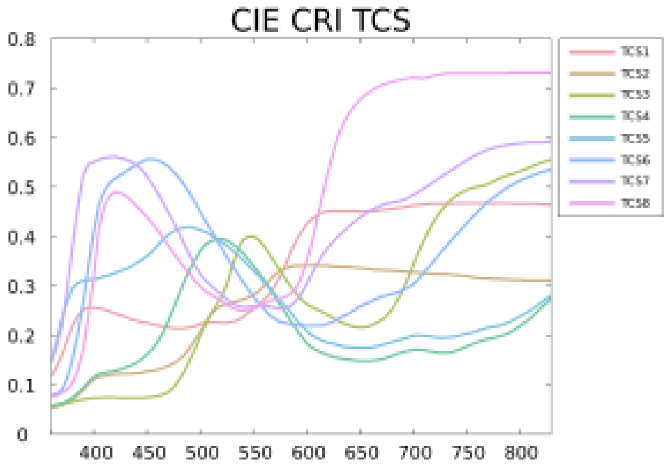
Unless otherwise agreed between the supplier and the user (see Annex B), indicator lights shall be colour-coded with respect to the condition (status) of the machine in accordance with Table 4.

Table 4 – Colours for indicator lights and their meanings with respect to the condition of the machine

Colour	Meaning	Explanation	Action by operator
RED	Emergency	Hazardous condition	Immediate action to deal with hazardous condition (for example switching off the machine supply, being alert to the hazardous condition and staying clear of the machine)
YELLOW	Abnormal	Abnormal condition Impending critical condition	Monitoring and/or intervention (for example by re-establishing the intended function)
BLUE	Mandatory	Indication of a condition that requires action by the operator	Mandatory action
GREEN	Normal	Normal condition	Optional
WHITE	Neutral	Other conditions; may be used whenever doubt exists about	Monitoring

Test color samples

As specified in (CIE 1995), the original test color samples (TCS) are taken from an early edition of the Munsell Atlas. The first eight samples, a subset of the eighteen proposed in (Nickerson 1960), are relatively low saturated colors and are evenly distributed over the complete range of hues.[8] These eight samples are employed to calculate the general color rendering index R_a. The last seven samples provide supplementary information about the color rendering properties of the light source; the first four for high saturation, and the last three as representatives of well-known objects. The reflectance spectra of these samples may be found in (CIE 2004),[9] and their approximate Munsell notations are listed aside.[10]



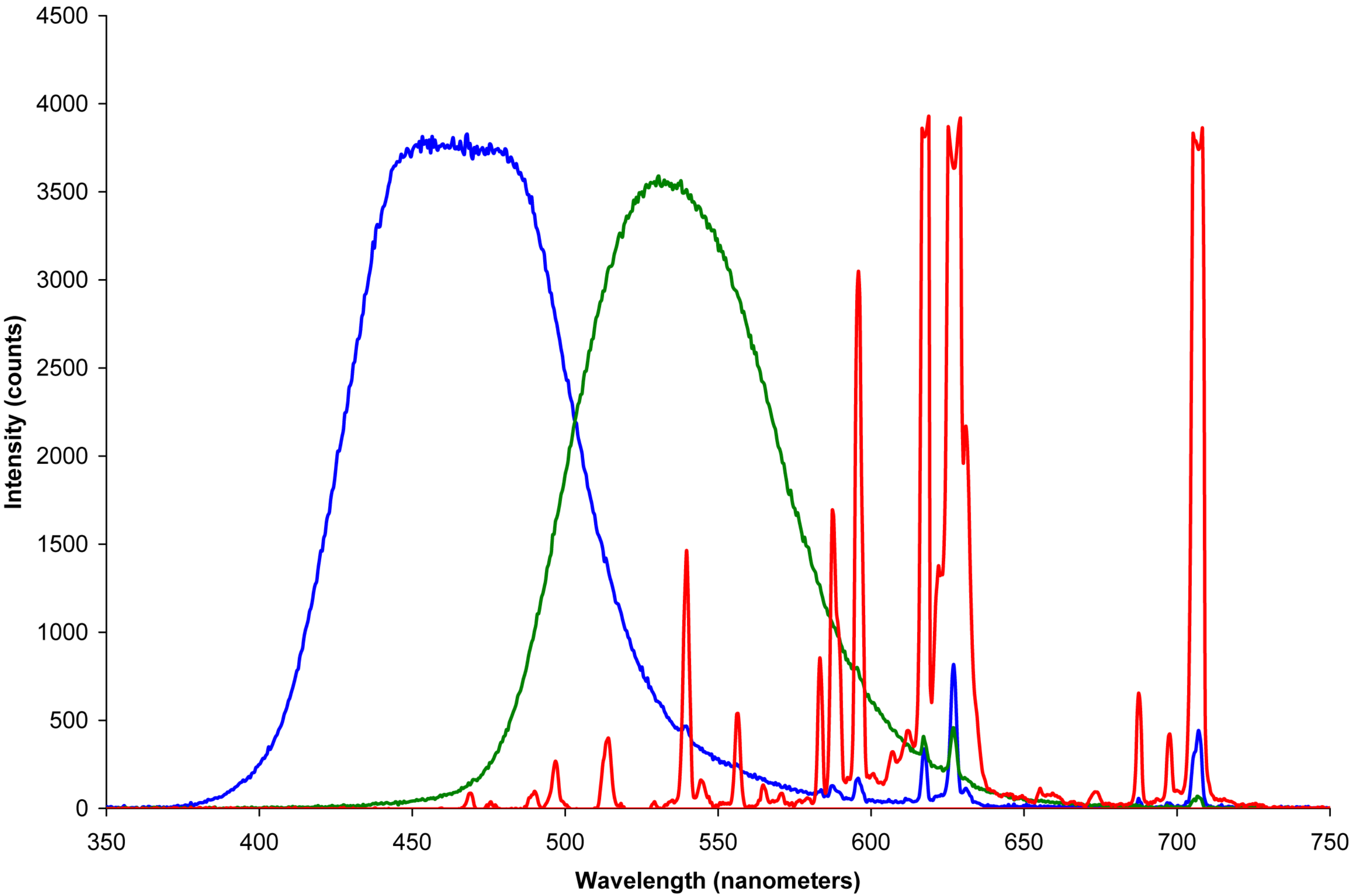
Name	Appr. Munsell	Appearance under daylight	Swatch
TCS01	7,5 R 6/4	Light greyish red	
TCS02	5 Y 6/4	Dark greyish yellow	
TCS03	5 GY 6/8	Strong yellow green	
TCS04	2,5 G 6/6	Moderate yellowish green	
TCS05	10 BG 6/4	Light bluish green	
TCS06	5 PB 6/8	Light blue	
TCS07	2,5 P 6/8	Light violet	
TCS08	10 P 6/8	Light reddish purple	
TCS09	4,5 R 4/13	Strong red	
TCS10	5 Y 8/10	Strong yellow	
TCS11	4,5 G 5/8	Strong green	
TCS12	3 PB 3/11	Strong blue	
TCS13	5 YR 8/4	Light yellowish pink (skin)	
TCS14	5 GY 4/4	Moderate olive green (leaf)	
TCS15	1 YR 6/4	Asian skin	

How to control the colour rendering index of the light sources

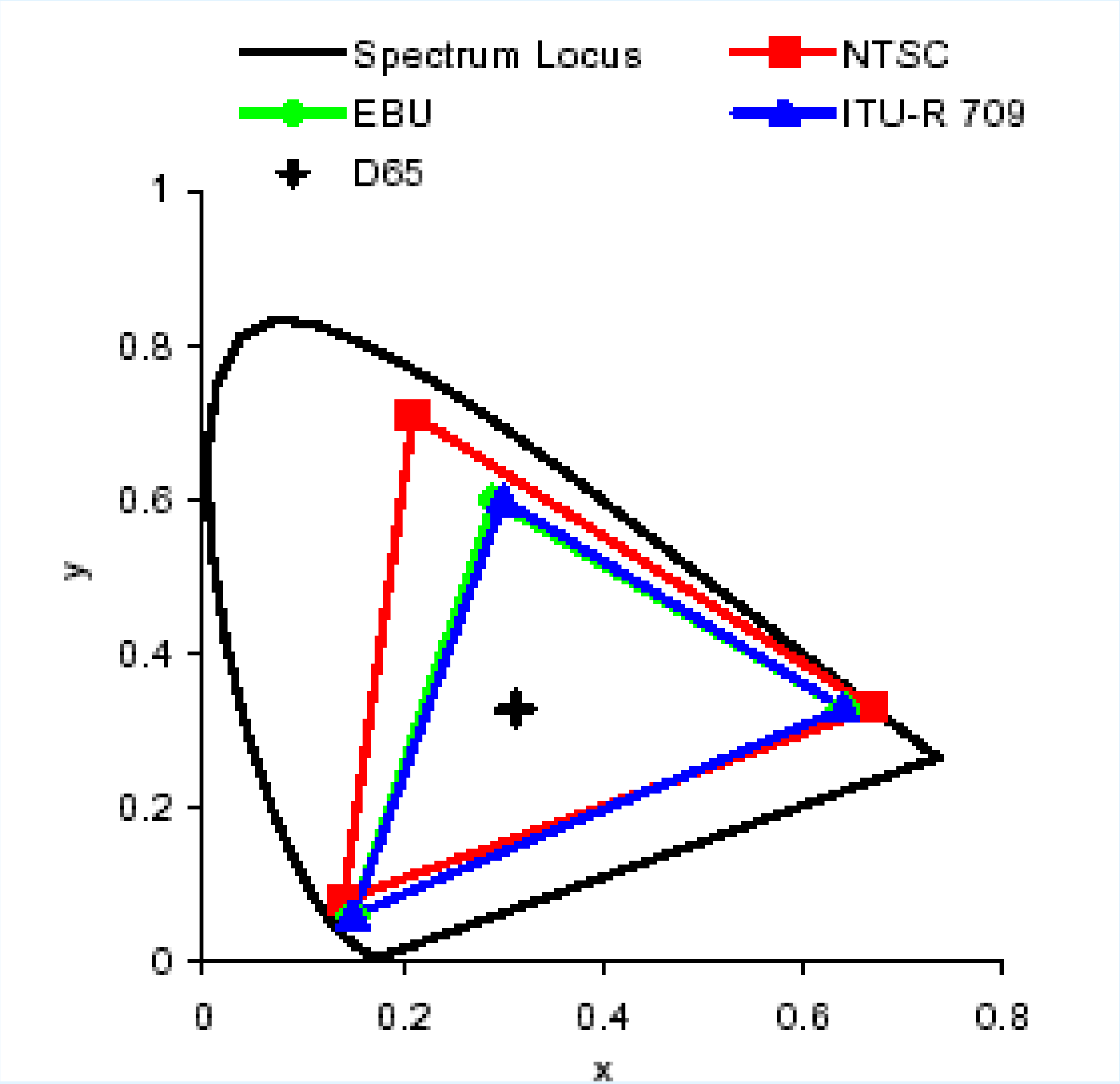
Table 1: Attributes of standard RGB color spaces

Color Space	Type	Encoding	Gamut	White Point	Primaries			Specified Dynamic Range and Viewing Conditions
						x	y	
ISO RGB	Unrendered	8-bit nonlinear	Limited	floating	floating			No
Extended ISO RGB	Unrendered	10- to 16-bit nonlinear	Unlimited (signed)	floating	floating			No
sRGB	Rendered	8-bit nonlinear	CRT	D65	R	0.64	0.33	Yes; reference viewing environment defined, with D50 as ambient white point
					G	0.30	0.60	
					B	0.15	0.06	
ROMM RGB	Rendered	8-bit nonlinear, 12-, 16-bit optional	Wide	D50	R	0.7347	0.2653	Yes; reproduction viewing environment defined
					G	0.1596	0.8404	
					B	0.0366	0.0001	
Adobe RGB 98	Rendered	8-bit nonlinear	Extended CRT	D65	R	0.64	0.34	No
					G	0.21	0.71	
					B	0.15	0.06	
Apple RGB	Rendered	8-bit nonlinear	CRT	D65	R	0.625	0.34	No
					G	0.28	0.595	
					B	0.155	0.070	
NTSC RGB	Rendered	Nonlinear	CRT	Ill. C	R	0.67	0.33	partial gamma correction to compensate for destination viewing conditions
					G	0.21	0.71	
					B	0.14	0.08	
EBU RGB (CCIR 601)	Rendered	Nonlinear	CRT	D65	R	0.64	0.33	No
					G	0.29	0.60	
					B	0.15	0.06	
ITU-R BT.709	Rendered	Nonlinear	CRT	D65	R	0.64	0.33	No
					G	0.30	0.60	
					B	0.15	0.06	

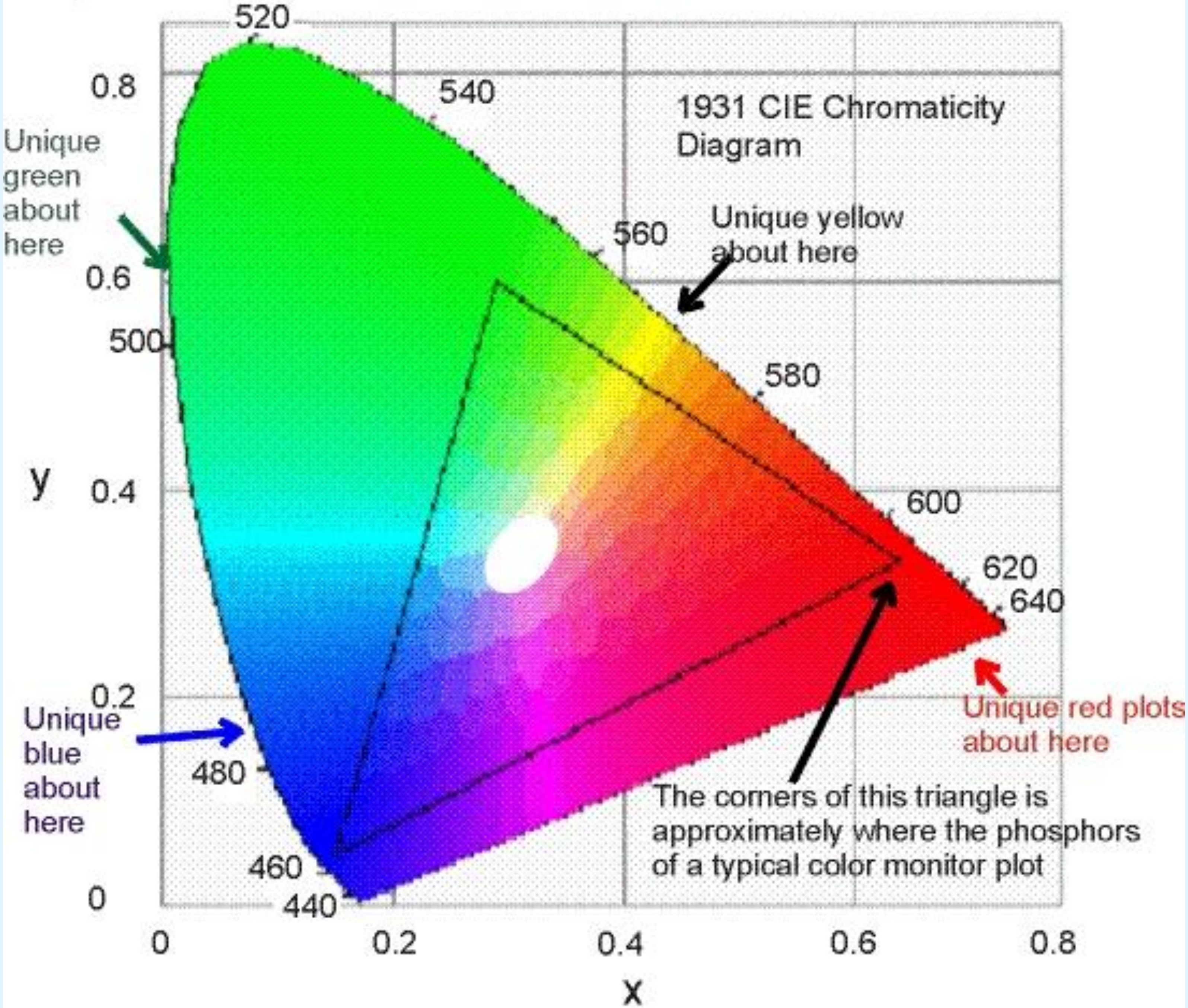
How many RGB systems are exist? Which one we really call standard?



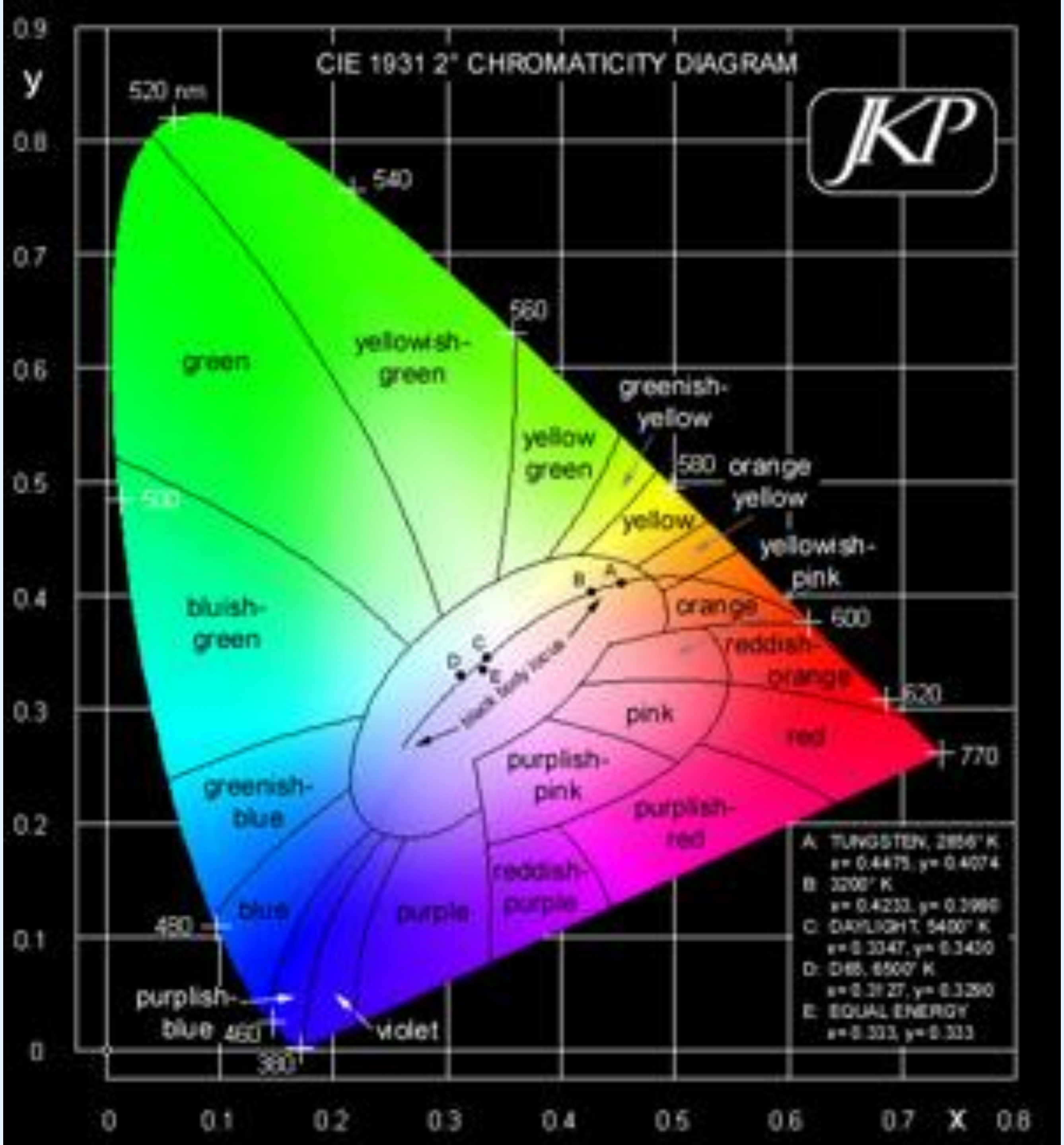
Spectra of colour displays



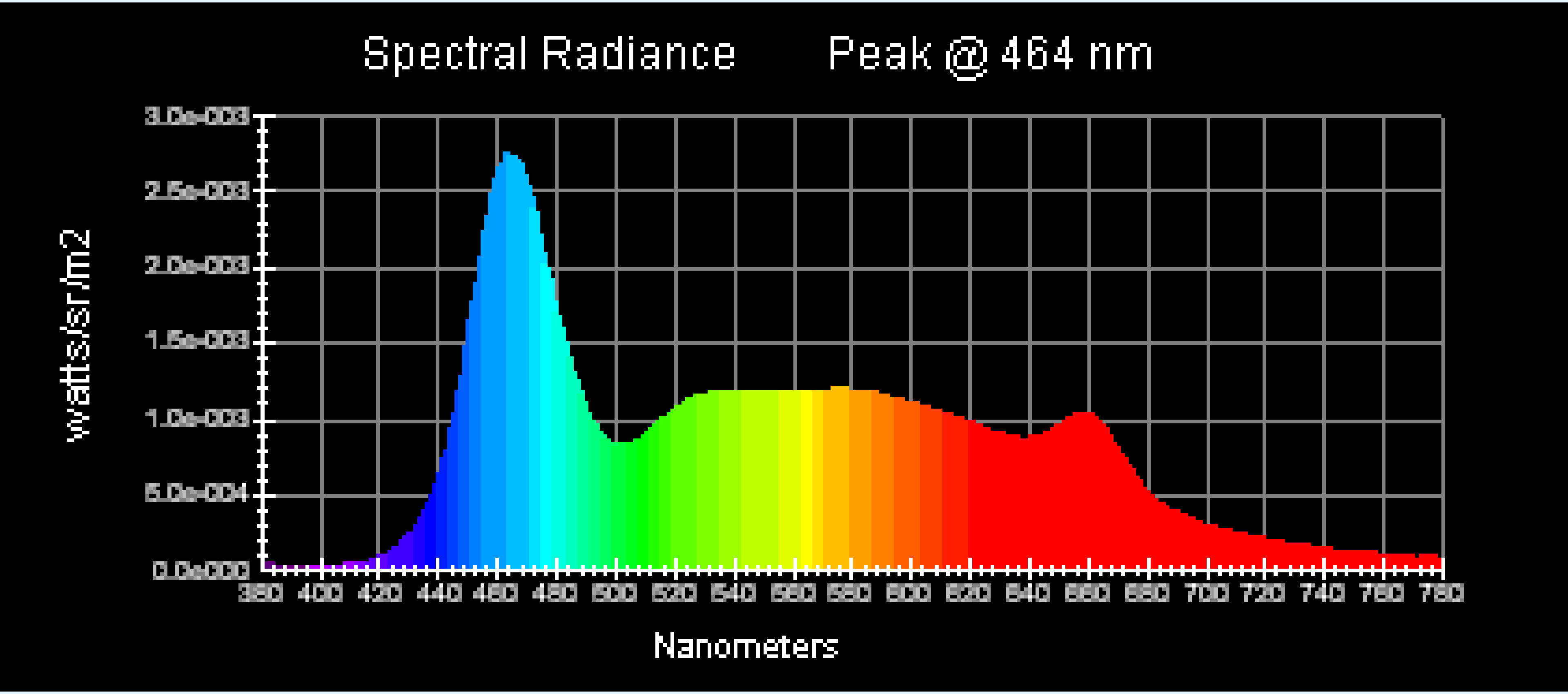
ITU = International Telecommunical Union. The displayable colours exist only inside the gamut



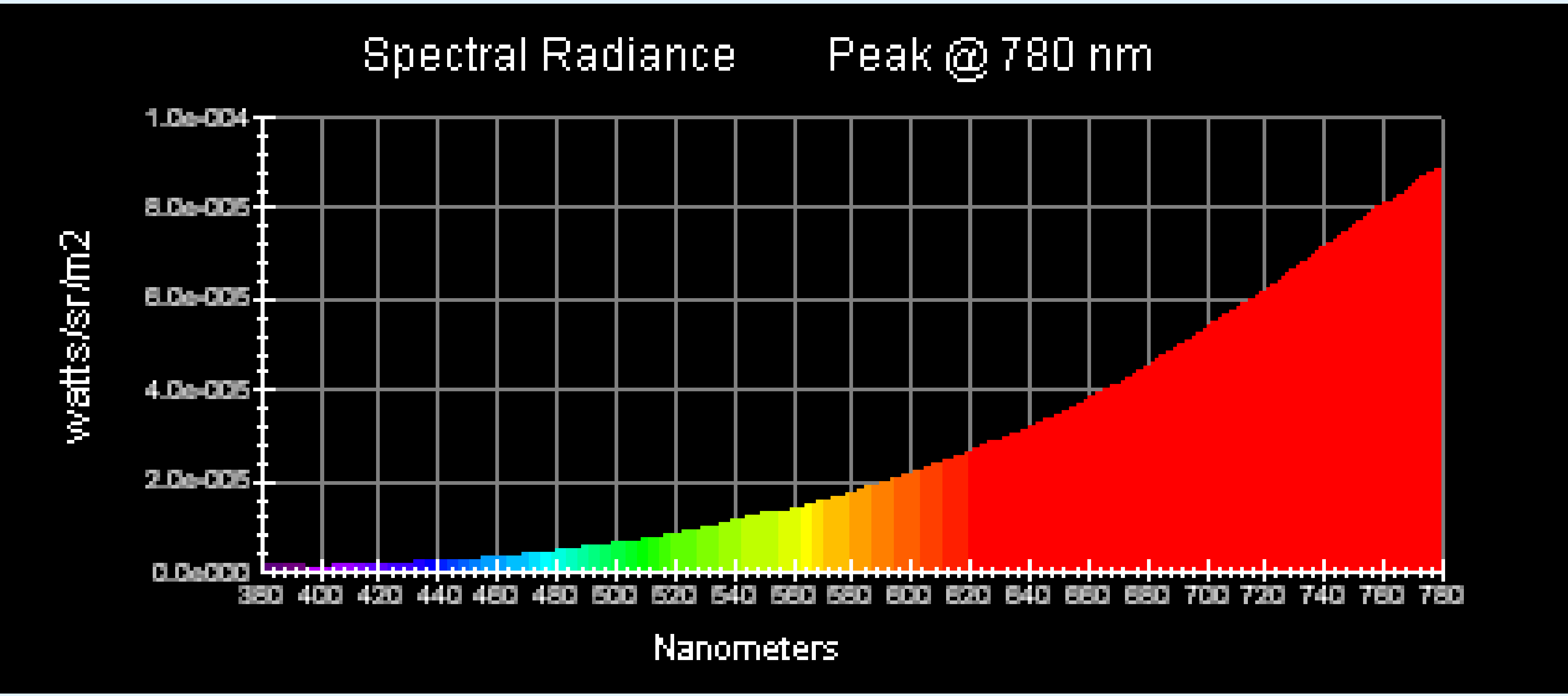
1931 CIE Chromaticity Diagram
520
540
560
580
600
620
640
500
480
460
440
Unique green about here
Unique yellow about here
Unique blue about here
Unique red plots about here
The corners of this triangle is approximately where the phosphors of a typical color monitor plot
y
x
0
0.2
0.4
0.6
0.8


CIE 1931 2° CHROMATICITY DIAGRAM
JKP
y
x
520 nm
540
560
580
600
620
770
500
480
460
380
green
yellowish-
green
yellow
green
greenish-
yellow
orange
yellow
yellow
yellowish-
pink
orange
reddish-
orange
red
pink
purplish-
pink
purplish-
red
reddish-
purple
purple
bluish-
green
greenish-
blue
blue
purplish-
blue
violet
A: TUNGSTEN
B: 3200° K
C: DAYLIGHT, 5400° K
D: D65, 6500° K
E: EQUAL ENERGY
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

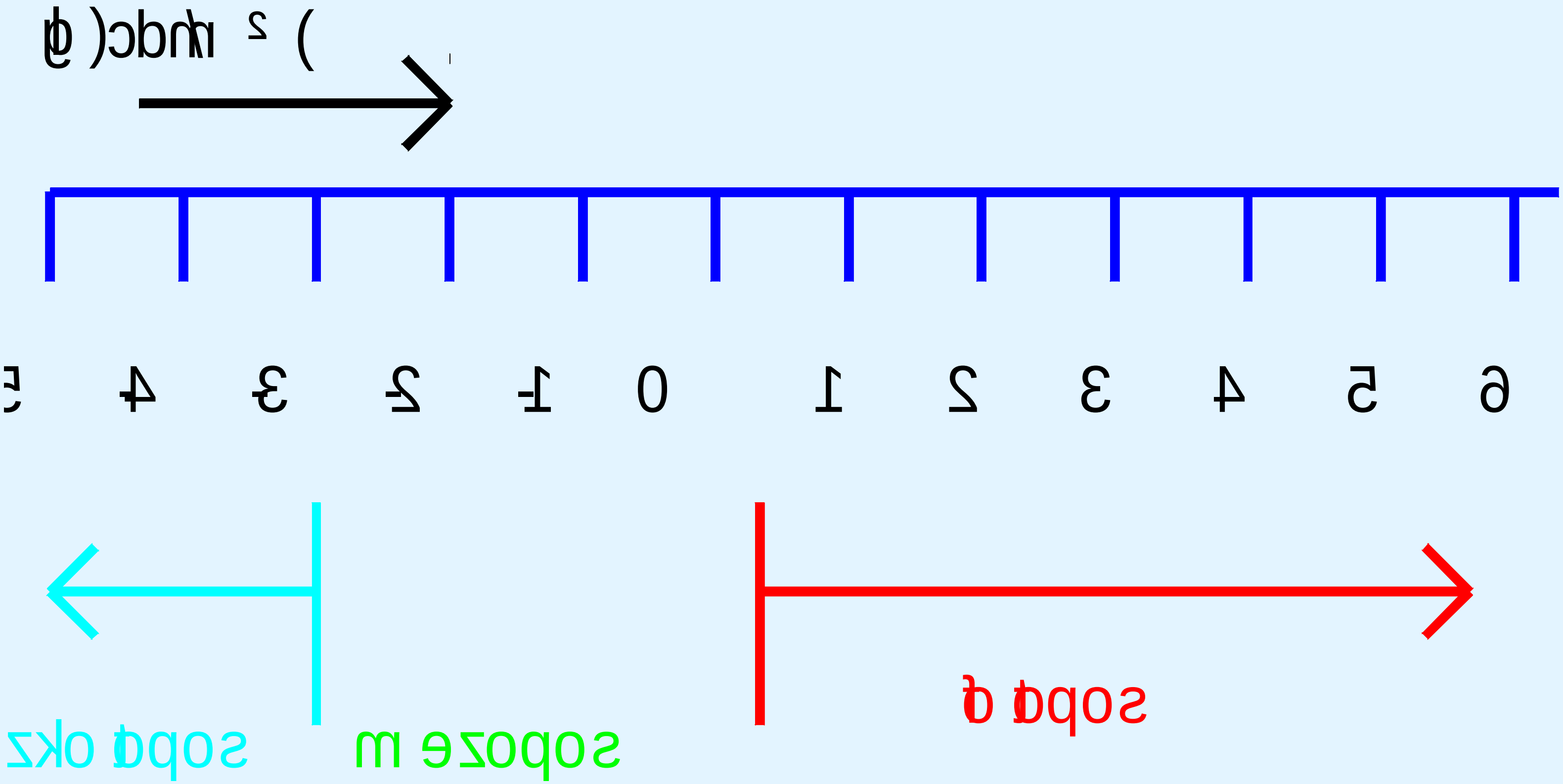
A sample spectrum of daylight modelling

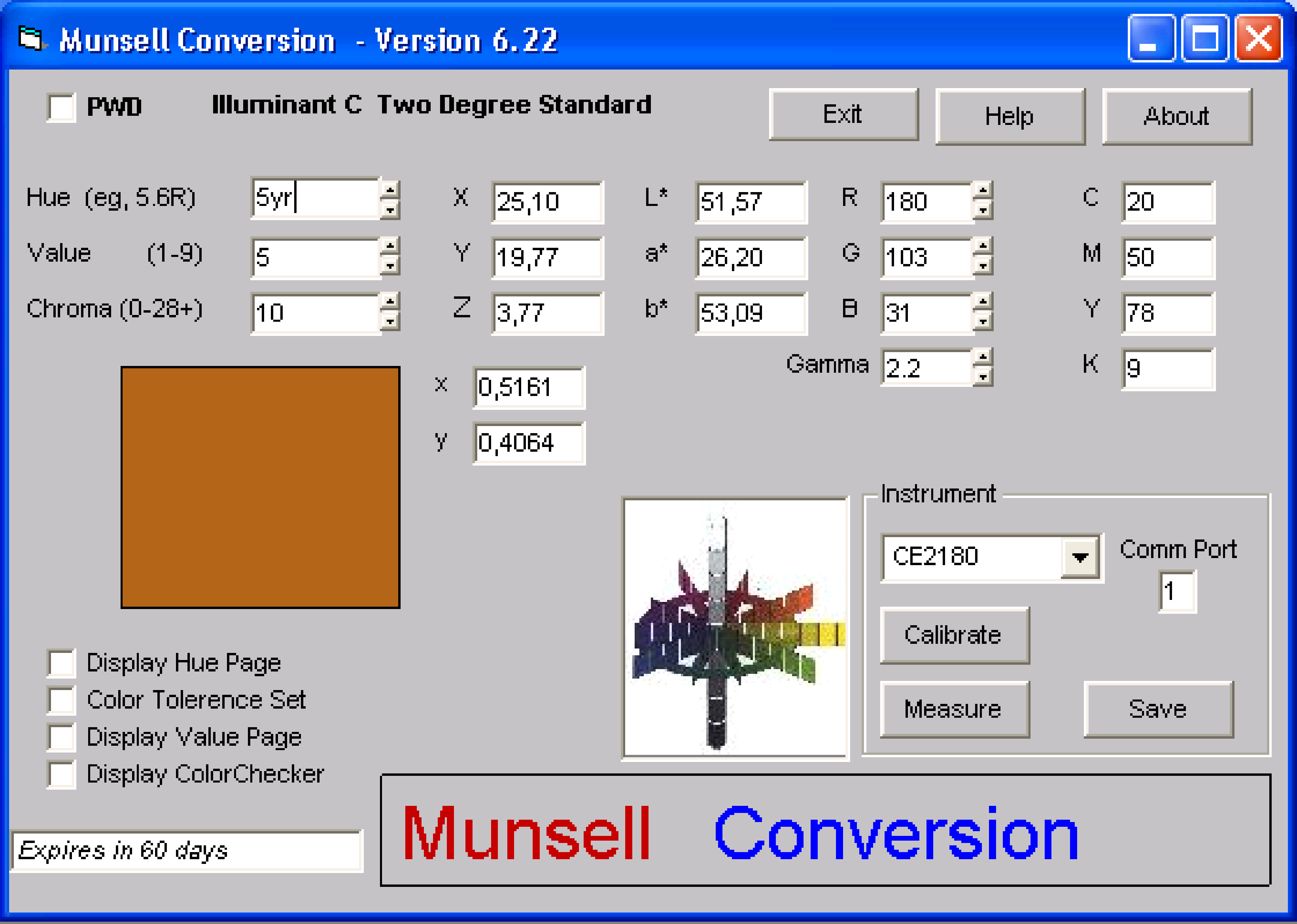


Thermal radiation, a model of the CIE A spectral distribution (illuminant A).



Photopic, mesopic and scotopic vision. Chromatic adaptation




Munsell Conversion - Version 6.22
PWD
Illuminant C Two Degree Standard
Exit
Help
About
Hue (eg, 5.6R)
5yr
Value (1-9)
5
Chroma (0-28+)
10
X
25,10
Y
19,77
Z
3,77
x
0,5161
y
0,4064
L*
51,57
a*
26,20
b*
53,09
R
180
G
103
B
31
Gamma
2.2
C
20
M
50
Y
78
K
9
Instrument
CE2180
Comm Port
1
Calibrate
Measure
Save
Display Hue Page
Color Tolerence Set
Display Value Page
Display ColorChecker
Expires in 60 days
Munsell Conversion

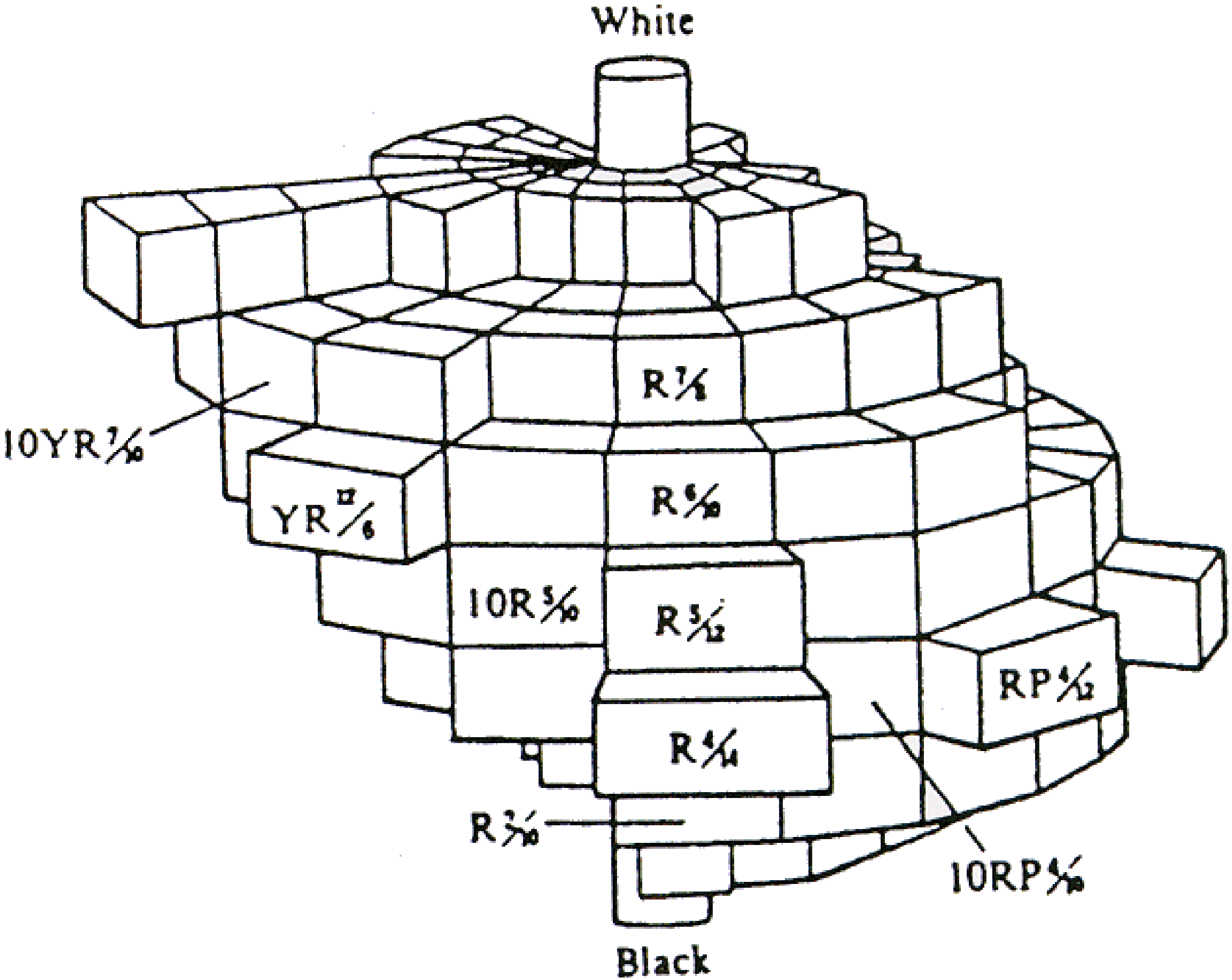


Figure 10.6.1 Munsell color system

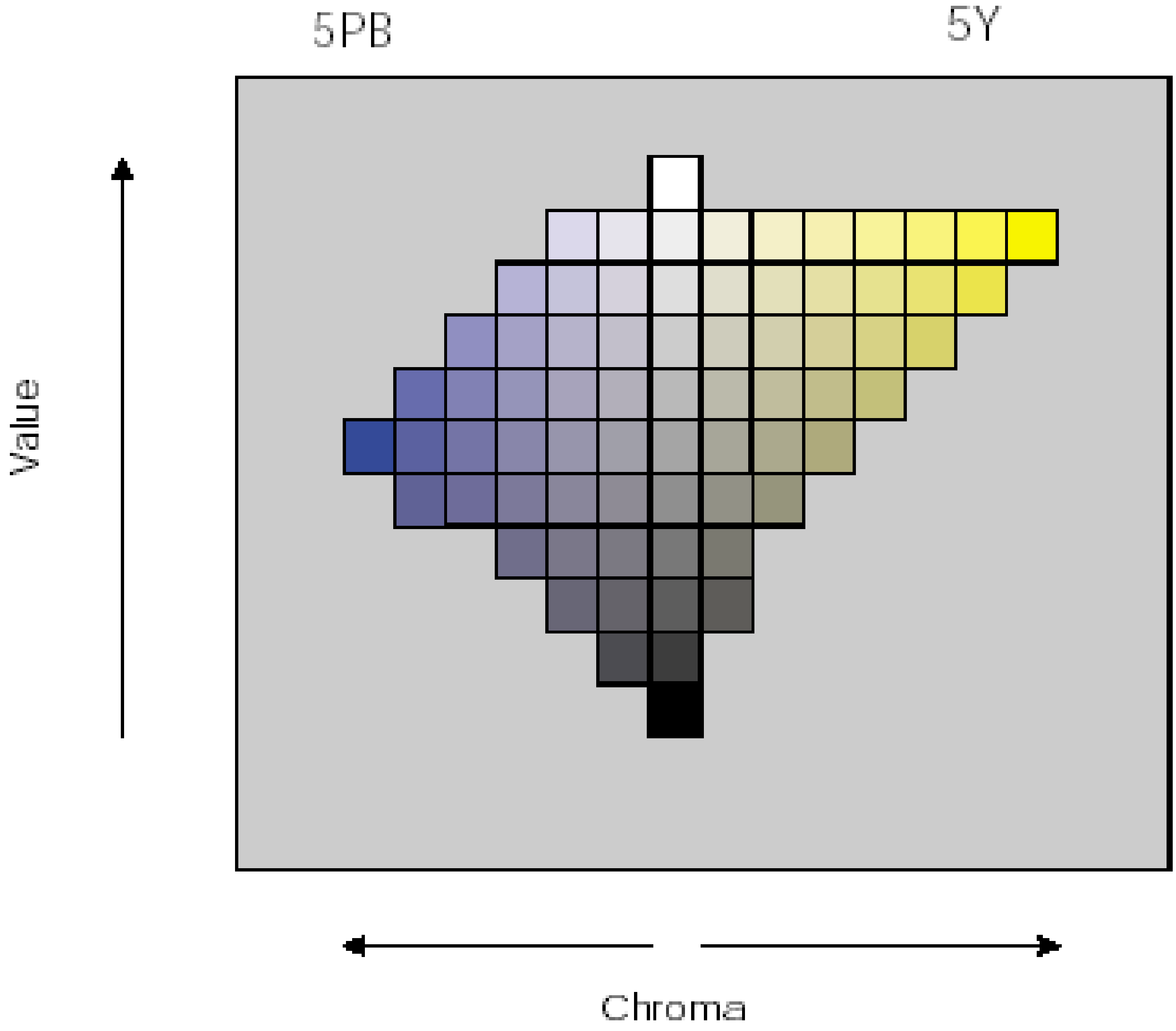
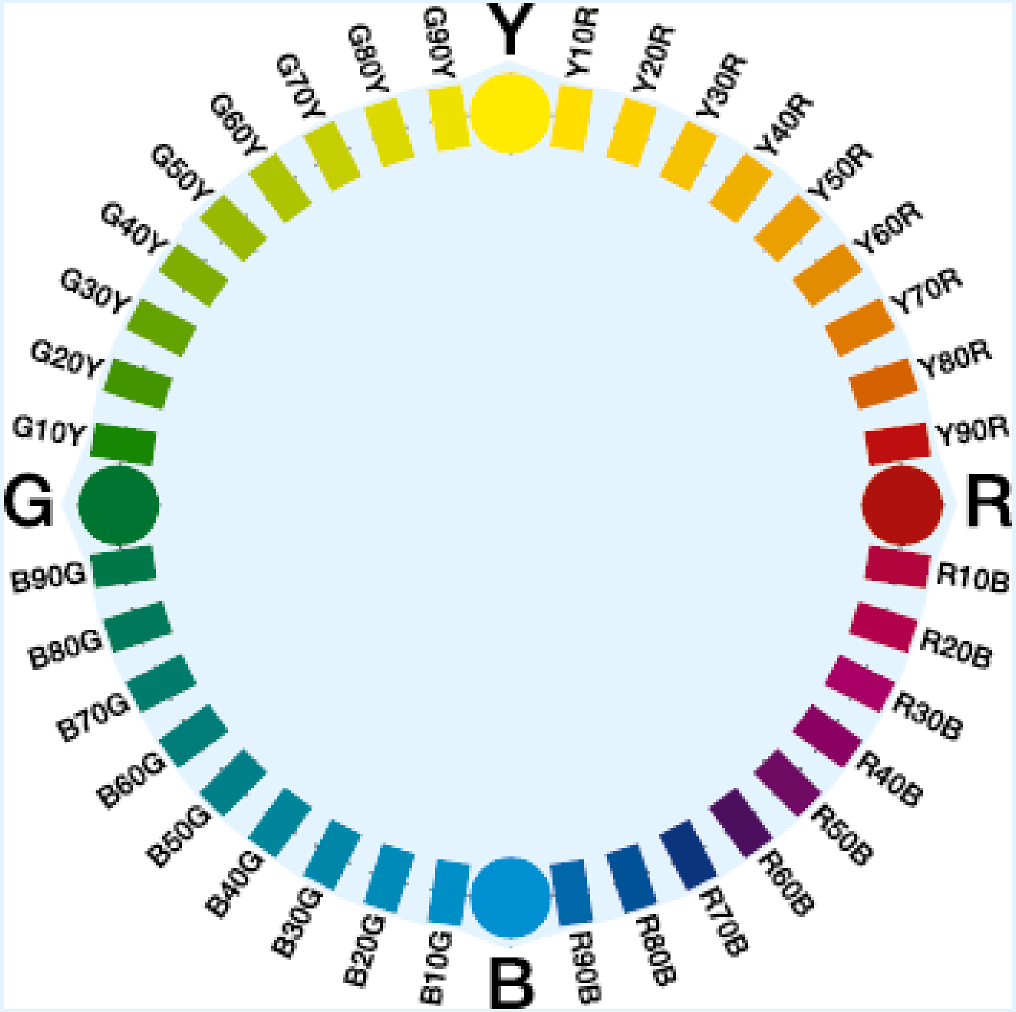


Figure 38: A pair of leaves from the Munsell system

Natural Colour System

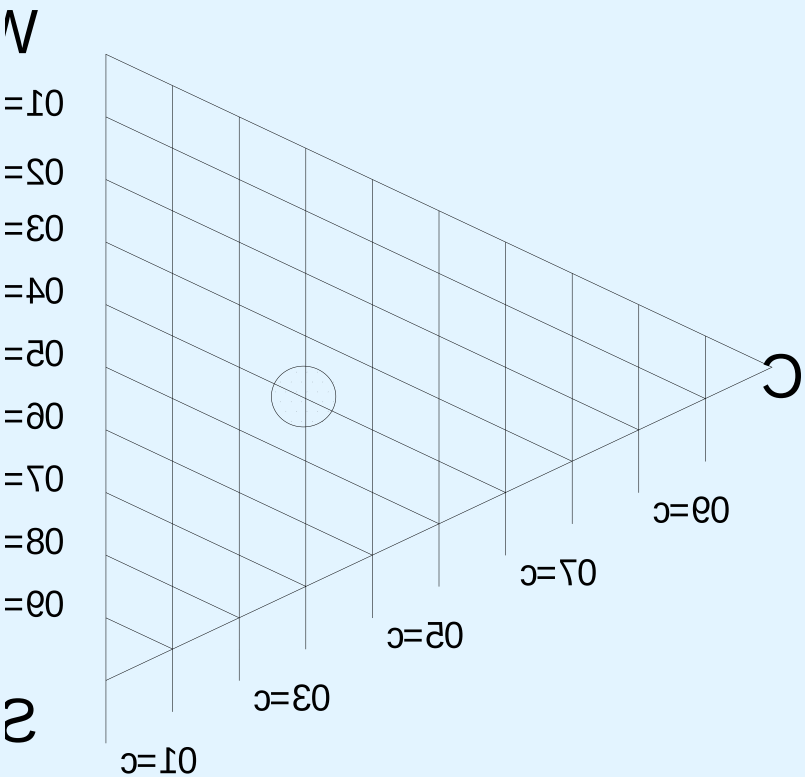
NCS colour wheel (Royal Swedish Academy of Sciences).

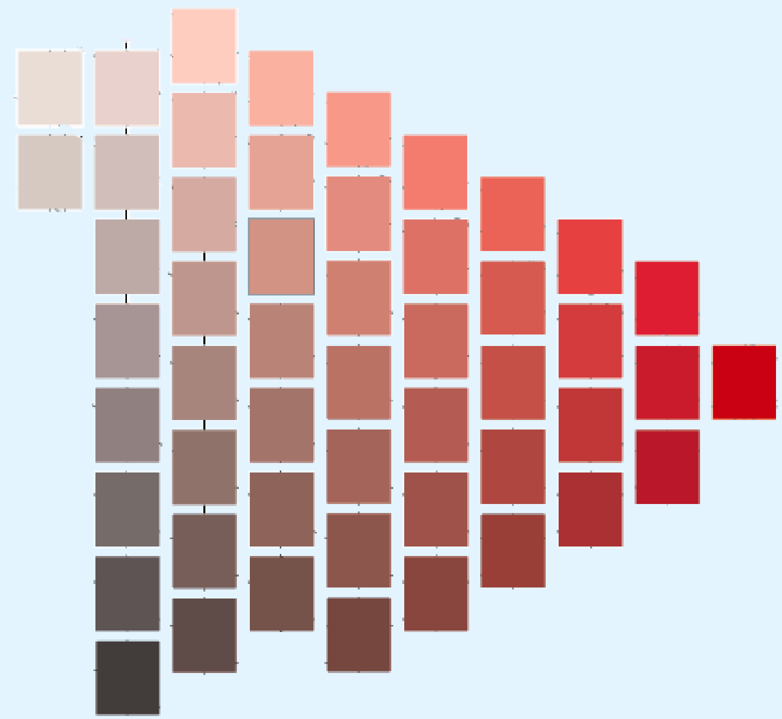
Derived from the Opponent colour system



Y ≈ 576.5 nm
R ≈ 629 nm

NCS colour collection





S 4030 - Y80R (≈ 608 nm)

The **Natural Coluor System**, Leonardo da Vinci, Herring

Φ hue, s schwarz, c chromaticness, w white, b blackness

lime green Y35G = 65% yellow + 35% green

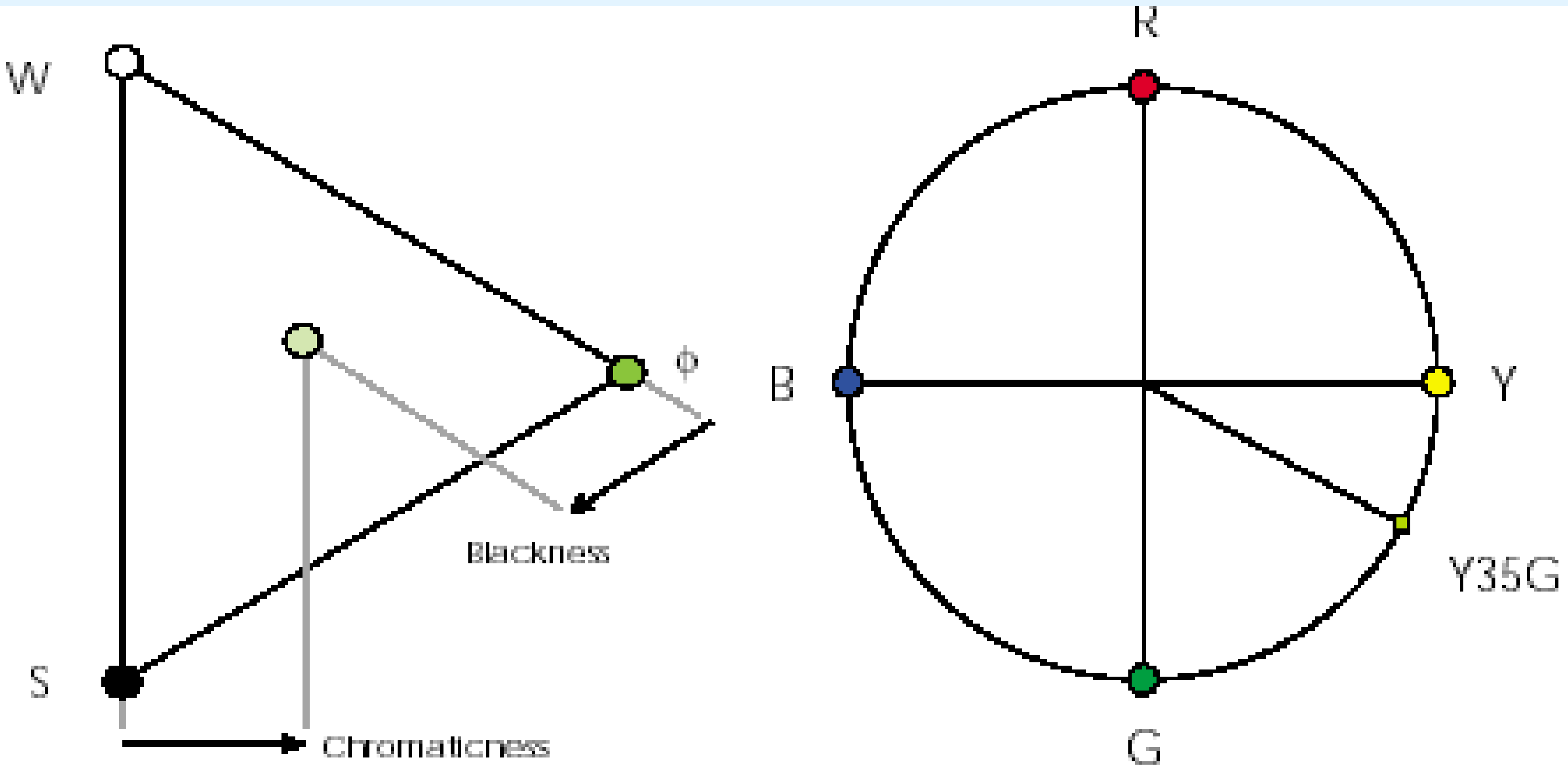
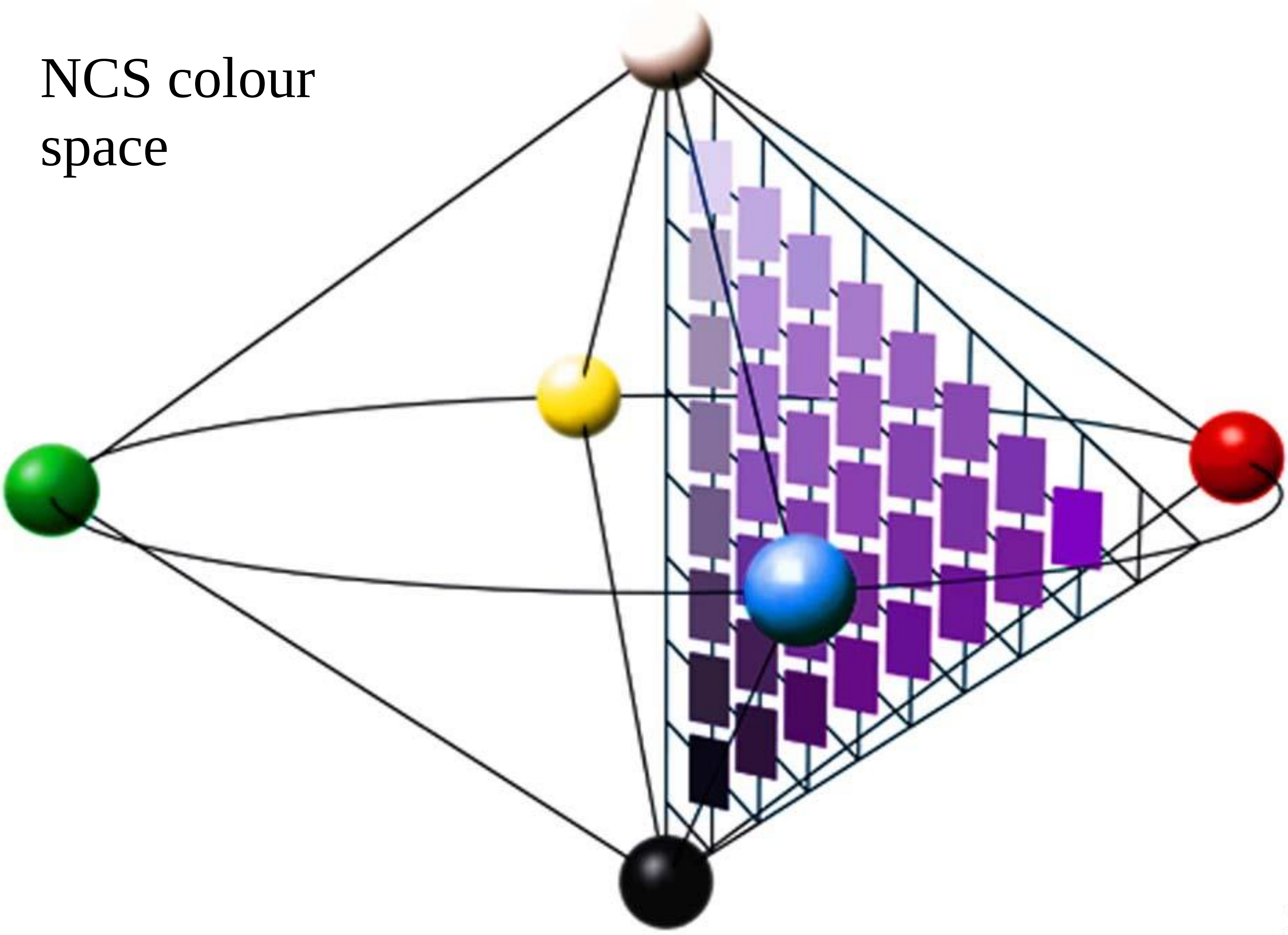


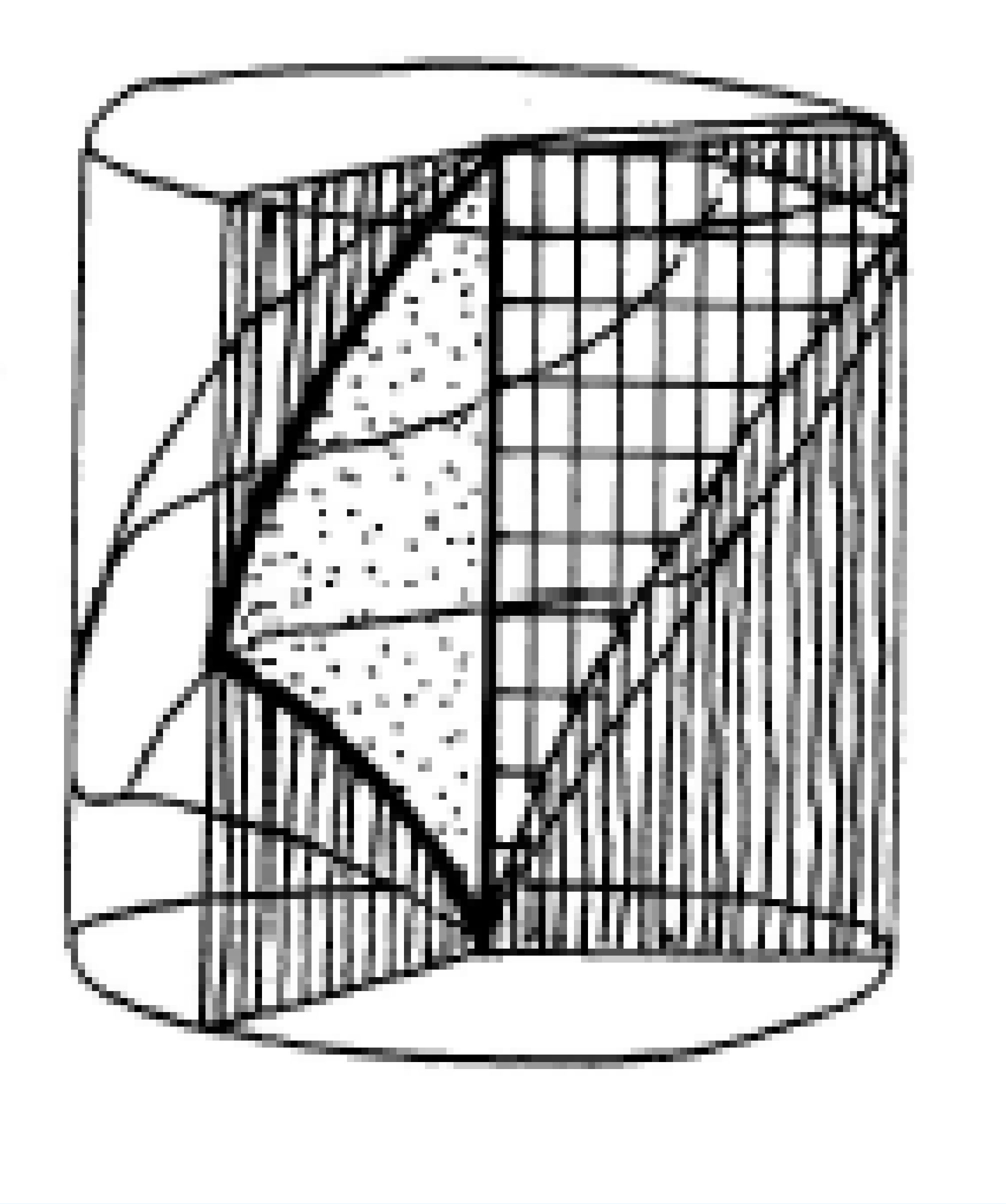
Figure 39: The Swedish NCS

NCS colour space



COLOROID colour space.

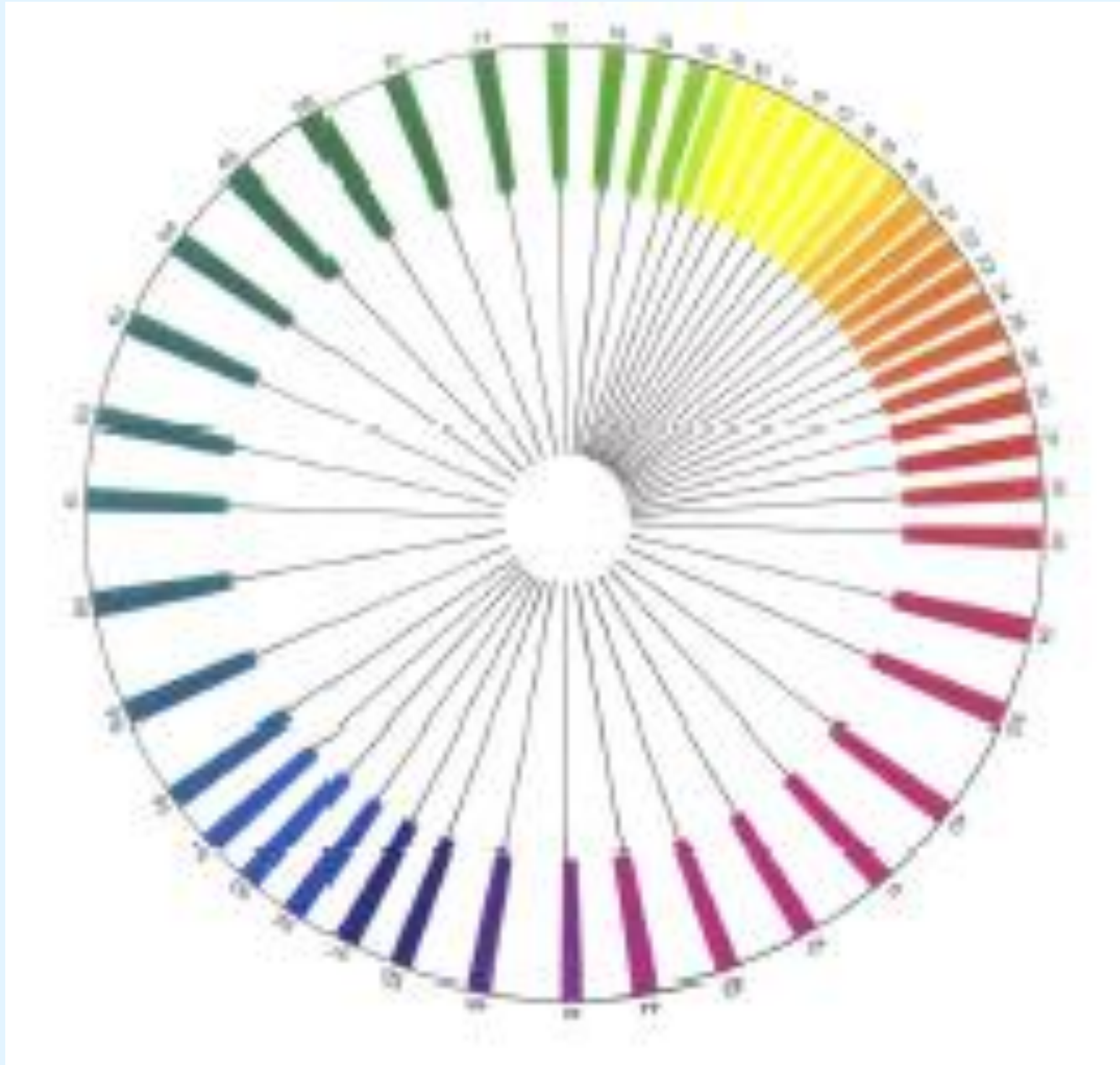
Equal colour excitation purity. Border line and cross section (*between the blue and yellow range).*



COLOROID
colour wheel

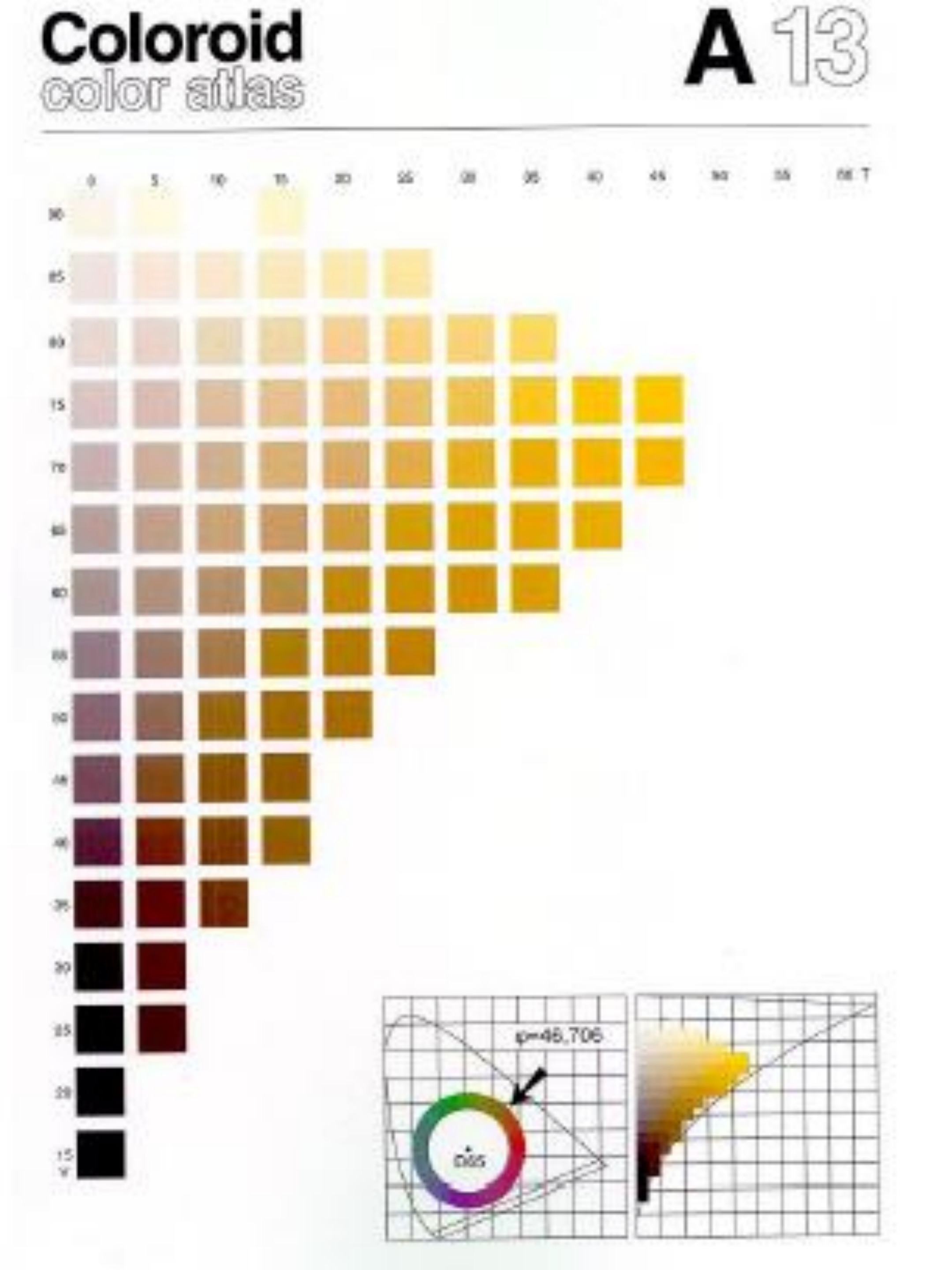
hue

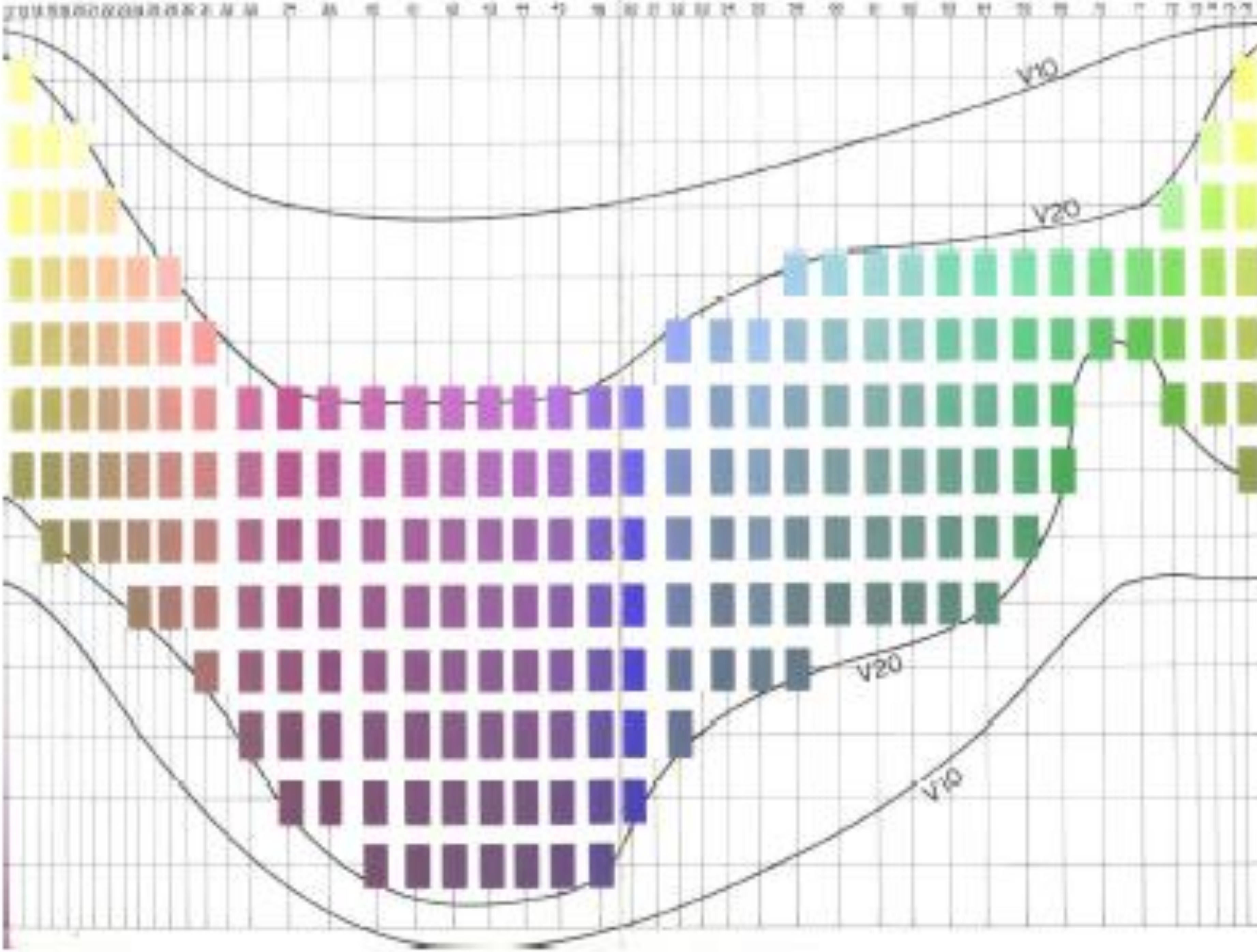
from A10 to A76



Sample page from COLOROID collection of colours

A13 mustard-yellow




V10
V20
V20
V10

Coloroid

Hue

$$tg\varphi = \frac{y - y_0}{x - x_0}$$

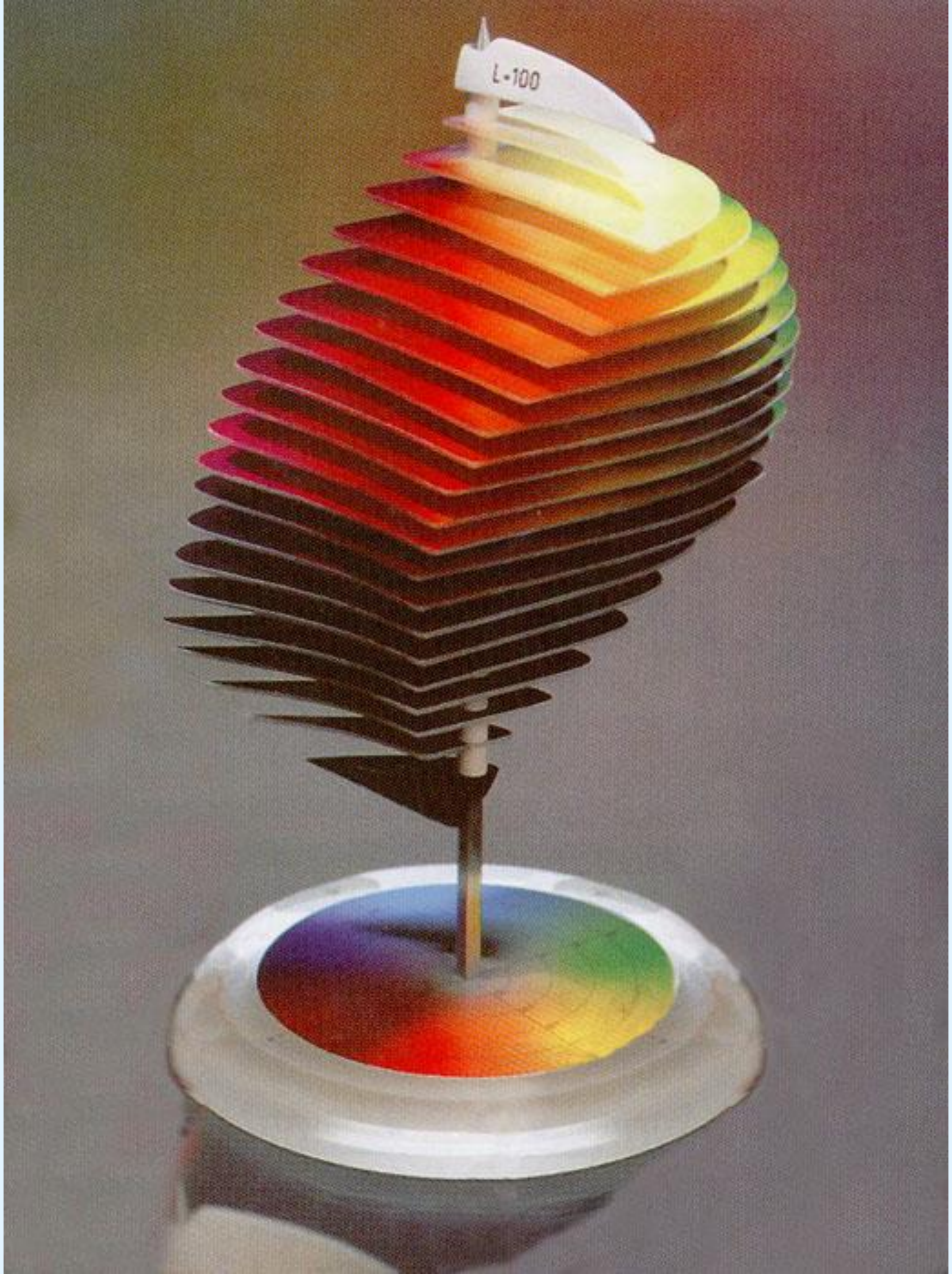
Excitation purity

$$T = 100\frac{Y\left(1 - y\varepsilon_w\right)}{100\left(y\varepsilon_\lambda - y_\lambda\varepsilon_\lambda\right) + Y_\lambda\left(1 - y\varepsilon_w\right)}$$

Lightness

$$V = 10\sqrt{Y}$$

The CIELAB colour space



Codex Alimentarius Commission

ESSENTIAL COMPOSITION AND QUALITY FACTORS

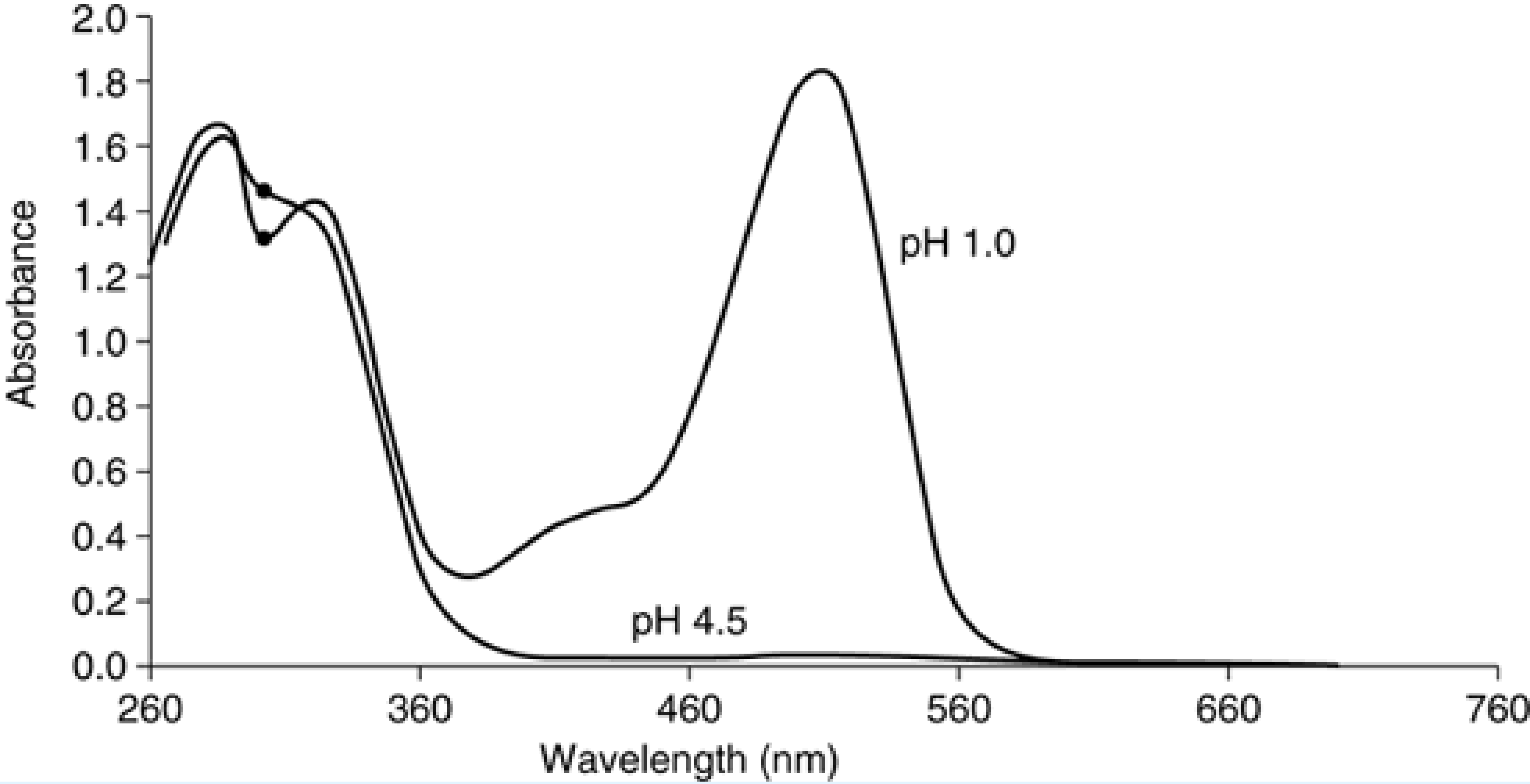
This section should contain all quantitative and other requirements as to composition including, where necessary, identity characteristics, provisions on packing media and requirements as to compulsory and optional ingredients. It should also include quality factors which are essential for the designation, definition or composition of the product concerned. Such factors could include

the quality of the raw material, with the object of protecting the health of the consumer, provisions on **taste, odour, colour and texture** which may be apprehended by the senses, and basic quality criteria for the finished products, with the object of preventing fraud. This section may refer to tolerances for defects, such as blemishes or imperfect material, but this information should be contained in an appendix to the standard or in another advisory text.

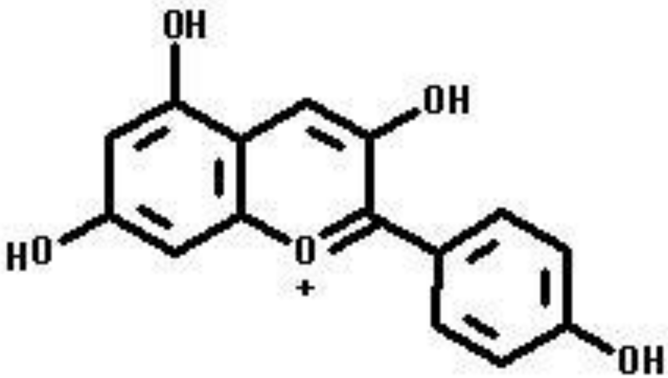
Food colorants originated from plants

genus	species	name
solanacae	lycopersicon esculantum	tomato
	solanum tuberosum	potato
	capsicum annuum	paprika
	nicotiana tabacum	tobacco
	solanum nigrum	solanum

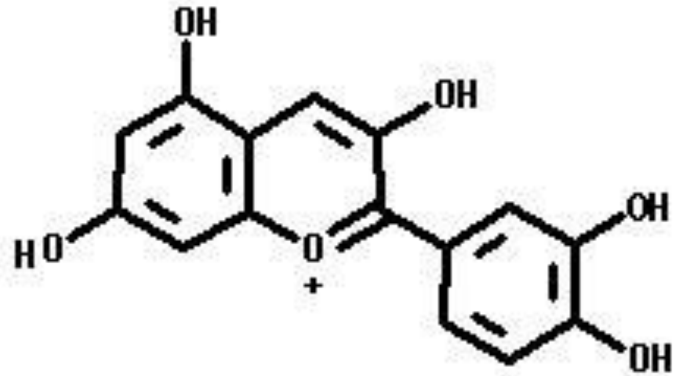
pH-dependency of anthocyanines



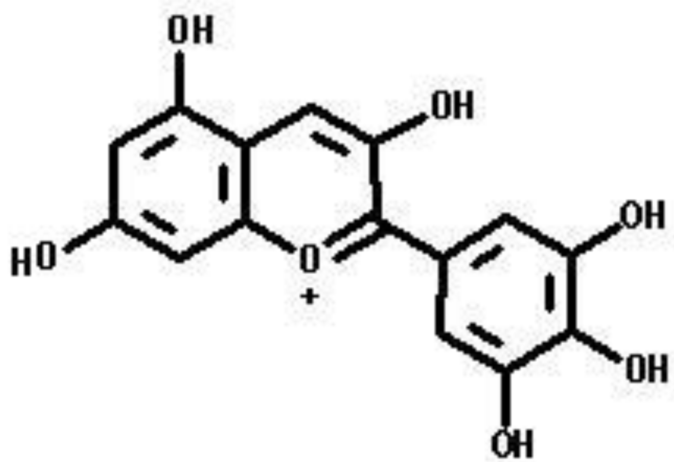
ANTHOCYANIDINS



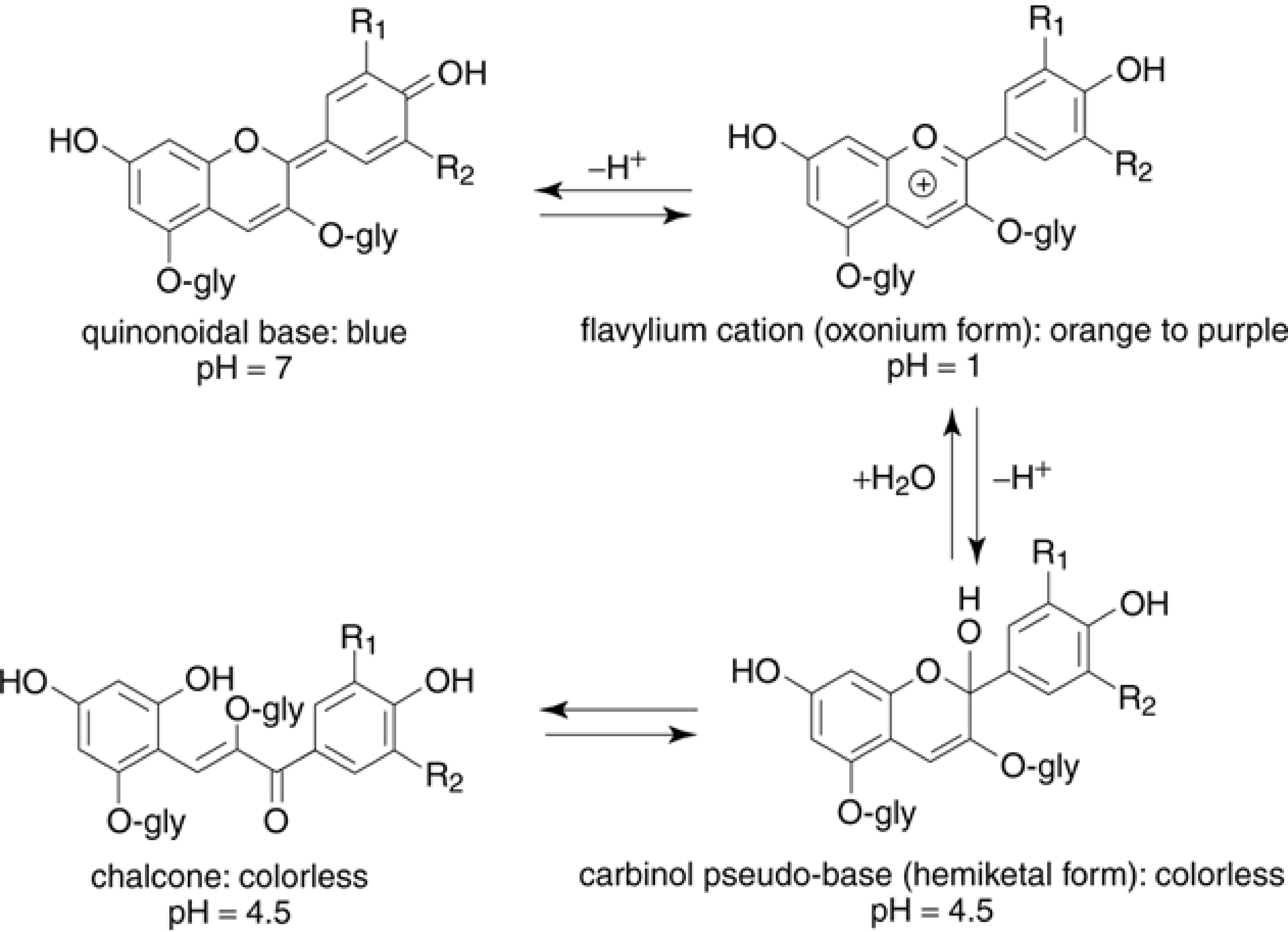
Pelargonidin



Cyanidin



Delphinidin


R1
OH
HO
O
R2
O-gly
O-gly
quinonoidal base: blue
pH = 7
−H+
R1
OH
HO
O
+
R2
O-gly
O-gly
flavylium cation (oxonium form): orange to purple
pH = 1
+H2O
−H+
R1
H
O
OH
HO
O
R2
O-gly
O-gly
carbinol pseudo-base (hemiketal form): colorless
pH = 4.5
R1
HO
OH
OH
O-gly
R2
O-gly
O
chalcone: colorless
pH = 4.5

Anthocyanins (E163)

Cyanidin-3-galactoside

Cyanidin-3-glucoside

Delphinidin-3-glucoside

Malvidin-3,5-diglucoside

Pelargonidin-3-glucoside

Peonidin-3-arabinoside

Petunidin-3,5-diglucoside

Carotenoid pigments (E161)

antheraxanthin	astaxanthin	canthaxanthin
α-carotene	β-carotene E160	ε-carotene
γ-carotene	ζ-carotene	α-cryptoxanthin
diatoxanthin	7,8-didehydro-astaxanthin	fucoxanthin
fucoxanthinol	lactucaxanthin	lutein E161b
lycopene E160d	neoxanthin	neurosporene
peridinin	phytoene	rhodopin
rhodopin glucoside	siphonaxanthin	spheroidene
spheroidenone	spirilloxanthin	uriolide
uriolide acetate	violaxanthin	zeaxanthin

E 100 CURCUMIN magyar neve:kurkumin

Synonyms CI Natural Yellow 3, Turmeric Yellow, Diferoyl Methane *(a turmeric tiltott, az oleoresin Amerikában is)*

Definition Curcumin is obtained by solvent extraction of turmeric i.e. the ground rhizomes of natural strains of *Curcuma longa* L. In order to obtain a concentrated curcumin powder, the extract is purified by crystallization. The product consists essentially of curcumins; i.e. the colouring principle (**1,7-bis(4-hydroxy-3-methoxyphenyl)hepta-1,6-dien-3,5-dione**) and its two desmethoxy derivatives in varying proportions. Minor amounts of oils and resins naturally occuring in turmeric may be present.

Class Dicinnamoylmethane

Colour Index No 75300 Einecs 207-280-5 CAS 458-37-7

Chemical names **I** 1,7-Bis(4-hydroxy-3-methoxyphenyl)hepta-1,6-diene-3,5-dione

II 1-(4-Hydroxyphenyl)-7-(4-hydroxy-3-methoxyphenyl-) hepta-1,6-diene-3,5-dione

III 1,7-Bis(4-hydroxyphenyl)hepta-1,6-diene-3,5-dione

Curcuma flower

Curcuma rhizome (rootstalks)

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