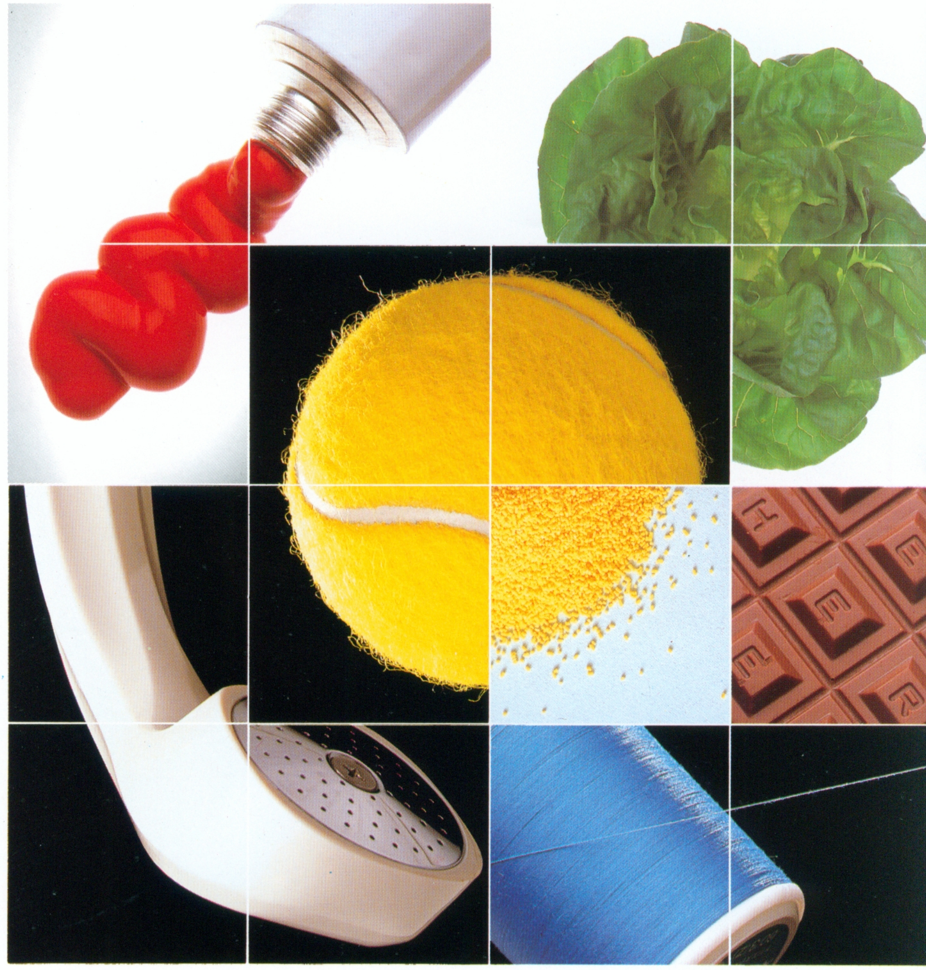
MINOLTA

PRECISE COLOR COMMUNICATION

COLOR CONTROL FROM FEELING TO INSTRUMENTATION

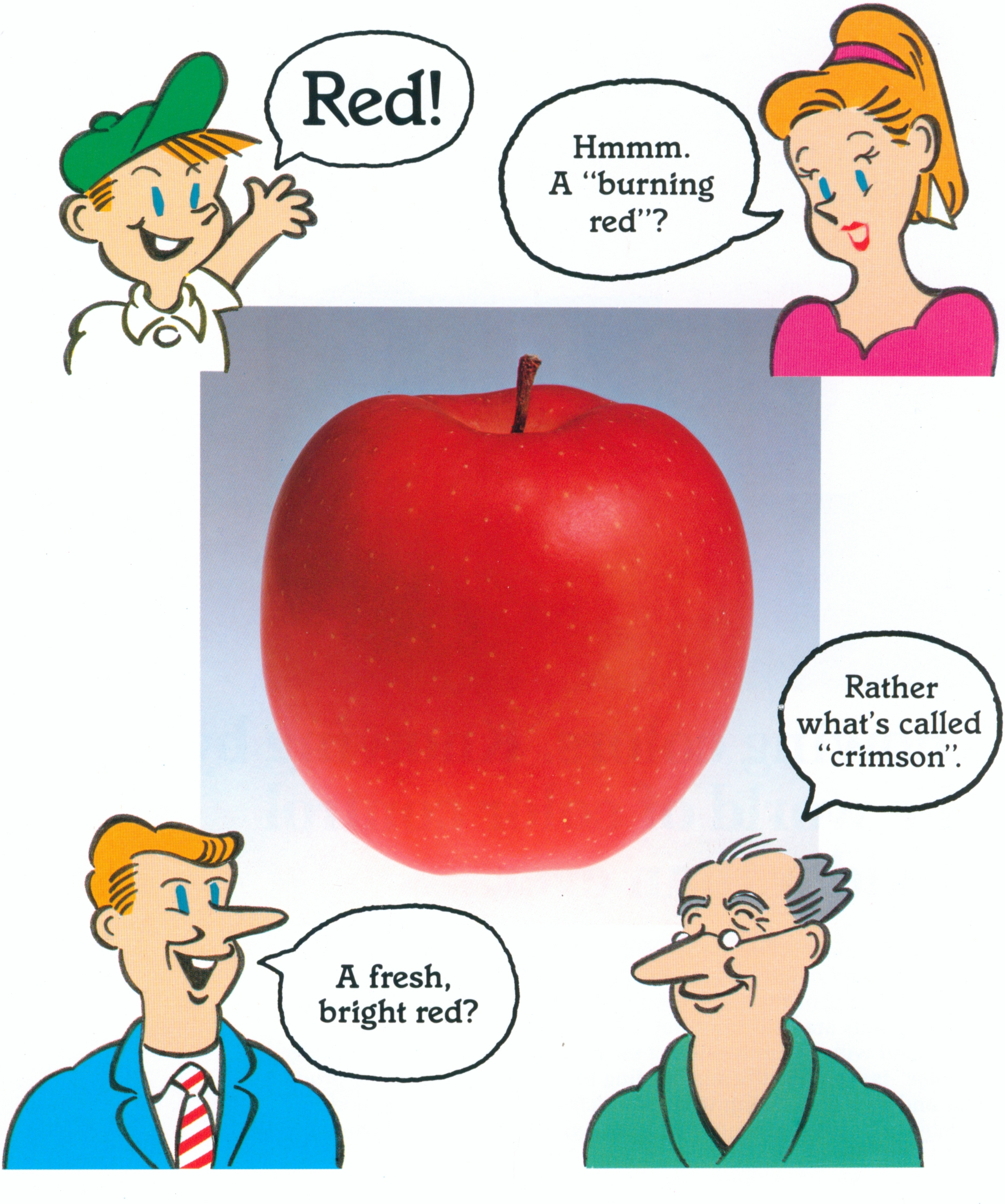


Contents

Knowing colors. Knowing by color. The world of color control is wider than ever.

An infinite number of colors surround us in our everyday lives. We all take color pretty much for granted, but its role in our daily lives ranges from influencing our tastes in food and other purchases to telling us whether plants are healthy or not. Even though colors affect us so much—and will continue to affect us more and more—our knowledge of "color" is often insufficient, leading to problems in deciding product color and even in deciding what products to stock. What methods are available to help us accurately express a given color, then relate that color to another person and have that person interpret it in the same way we perceive it? Without a doubt, a more definitive knowledge of color, its expression and communication is required in agriculture, forestry, and fishing as well as in industry, commerce medicine, academics—the whole range of human endeavor.

What color is this apple?



Color expression often means ten different colors to ten different people. "Color is" is a very difficult topic.

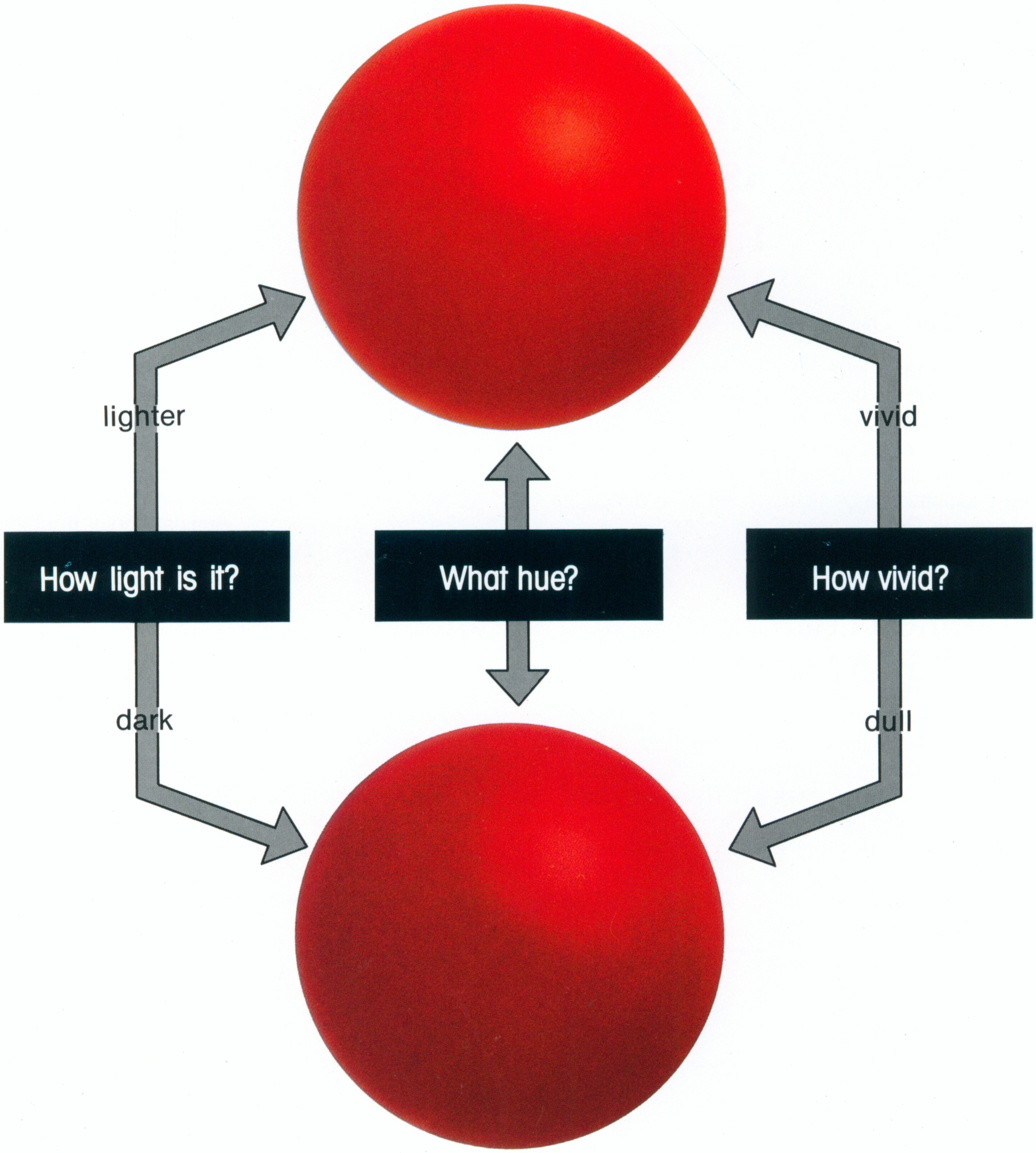
If you show the same apple to four different people, you are bound to get four different answers.

Color is a matter of perception, of subjective interpretation. To express the same color, different people will draw upon different references and express the exact same color in different words. It is because there are such varied expressions that communicating a particular color is so difficult—and vague. Can we tell someone "the apple was a burning red" and then expect them to be able to exactly duplicate that color? Verbal expression of color is simply too complicated and difficult. But... if there were a standard method by which colors could be accurately expressed, color communication would become much simpler and more straightforward. Precise color communication would, in a word, simply eliminate color troubles. And what a simple world that would be.

Common color names and general color names: To what extent can words express color?

Words that express colors have always changed with the times. If we consider, for instance, the red we've been talking about, there's "vermillion", "cinnabar", "crimson", "scarlet". These are called "common color names".
Today a somewhat more precise expression is obtained by using such adjectives as "bright", "dull", and "deep". Terms such as "bright red" used by the man in the picture are called "general color names".
Although there are many such devices used for a slightly better definition, different people will still interpret "crimson" or "bright red" in different ways. This is obviously still not clear.
Well then, how should colors be verbalized without misunderstanding one another?

Two red balls.
Now tell someone the difference between them.



To better understand accurate color expression, let's take a look at color.

The color of the color red. Extremely similar, exactly how are they different?

Two red balls. At first glance they look the same, but upon closer examination you know they are different. But in how many ways? The COLOR of both is red, but the upper ball is somewhat BRIGHTER than the lower ball—and of course the lower one is darker. At the same time, the upper appears VIVID—which the bottom ball certainly isn't. When colors are classified, they can be broken down into the three primary elements of their "hue (color)", "lightness (brightness)", and "saturation (vividness)".

Hue. Value. Chroma. The world of color is a combination of these three elements.

Fig. 1: Color wheel

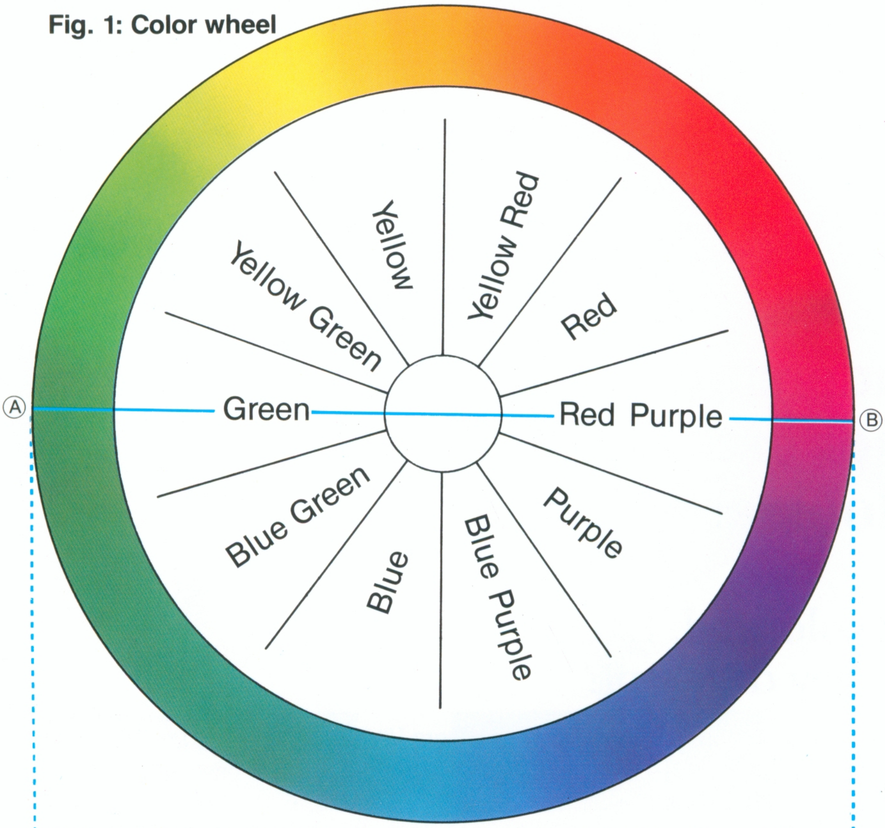


Fig. 2: Changes in value and chroma of reddish Purple and Green

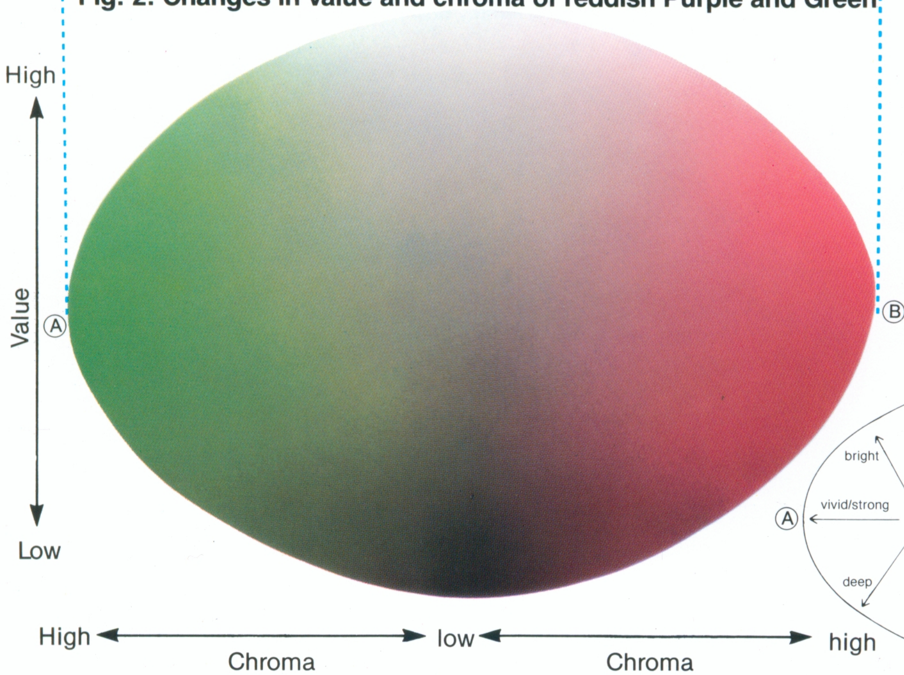
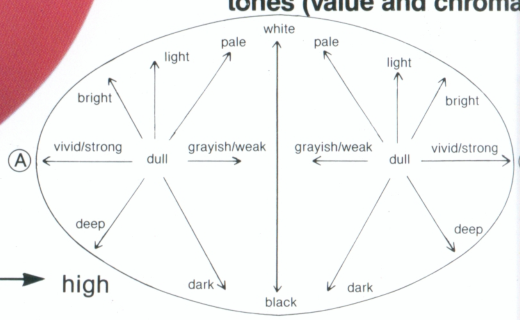


Fig. 3: Modifiers related to colo tones (value and chroma



Color is "hue", lightness is "value", saturation is "chroma": this is the world of color.

Hue "Red", "yellow", "green", "blue"... "Color" forms the color wheel.

Apples are red, lemons are yellow, the sky is blue—and that's how we all perceive color in everyday language. The term used to distinguish these red, yellow, and blue colors is called "hue". Of course, what we call "red" and "yellow" are completely different colors, but if you take paints and mix red and yellow you get yellow red, with yellow and green, yellow green; blue and green, blue green, and so forth. The continuum of these color hues creates the color wheel shown in Fig. 1.

Value Light colors, dark colors. The "lightness" of colors changes vertically.

Colors can be separated into "light" and "dark" colors when their values are compared. Take for instance the yellow of a lemon and that of a grapefruit. Without a doubt, the lemon yellow is much lighter, wouldn't you say? If so, what about lemon yellow and the red of a sweet cherry? Again, the lemon yellow is lighter, right? This lightness, which can be measured independently of color hue, is "value". Now take a look at Fig. 2. This figure corresponds to a cross-section of Fig. 1 when cut between Ⓐ (green) and Ⓑ (red purple). As the figure indicates, value increase toward the top, and decreases toward the bottom.

Chroma Vivid colors, dull colors. "Saturation" varies horizontally.

Going back to the example of yellow, how do you compare the colors in a lemon and a banana? You might say the lemon is "light", as we did above, but more to the point in this case, it is "vivid" while that of the banana is "dull"—another big difference, but this time one of color intensity, or clarity. This third property of color that is distinguishable from both value and hue is called "chroma". Just as value changed vertically in Fig. 2, chroma varies horizontally. Colors in the center are dull (gray). Fig. 3 shows color tones that indicate the value and chroma of a specific color. For a more exact expression of a color with words, refer to both Fig. 2 and 3.

Viewing colors three dimensionally in terms of hue, value, and chroma

If you combine the color wheel with a vertical axis of value and a horizontal axis of chroma from the center...

Hue, value, and chroma. These three elements are the three color characteristics, and can be visualized in three dimensions as shown in Fig. 4. Color hues are on the outside around the center axis, with value forming the vertical axis and chroma the horizontal axis from the center.
If the three attributes shown in Fig. 4 were actually combined into a three-dimensional system, they would appear as a color solid shown in Fig. 5. Because the chroma steps on the horizontal axis vary with each hue and value, the final solid assumes a fairly complicated configuration. When expressed in a figure like this, the relationship between hue, value, and chroma becomes much clearer.

Fig. 4: 3D color system

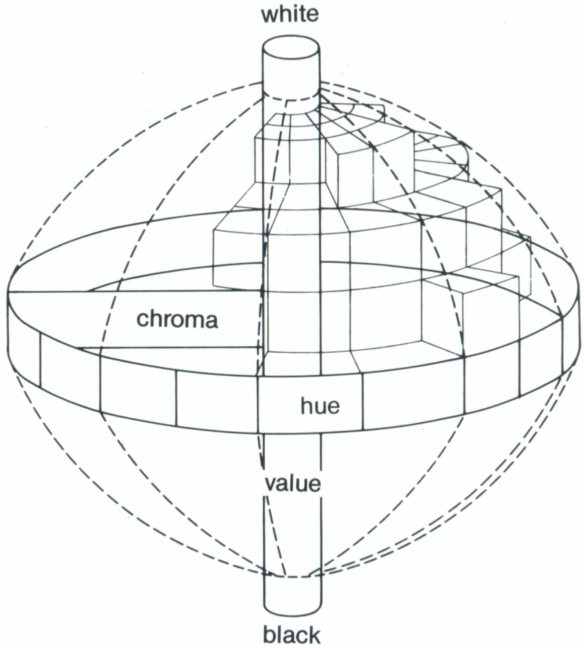
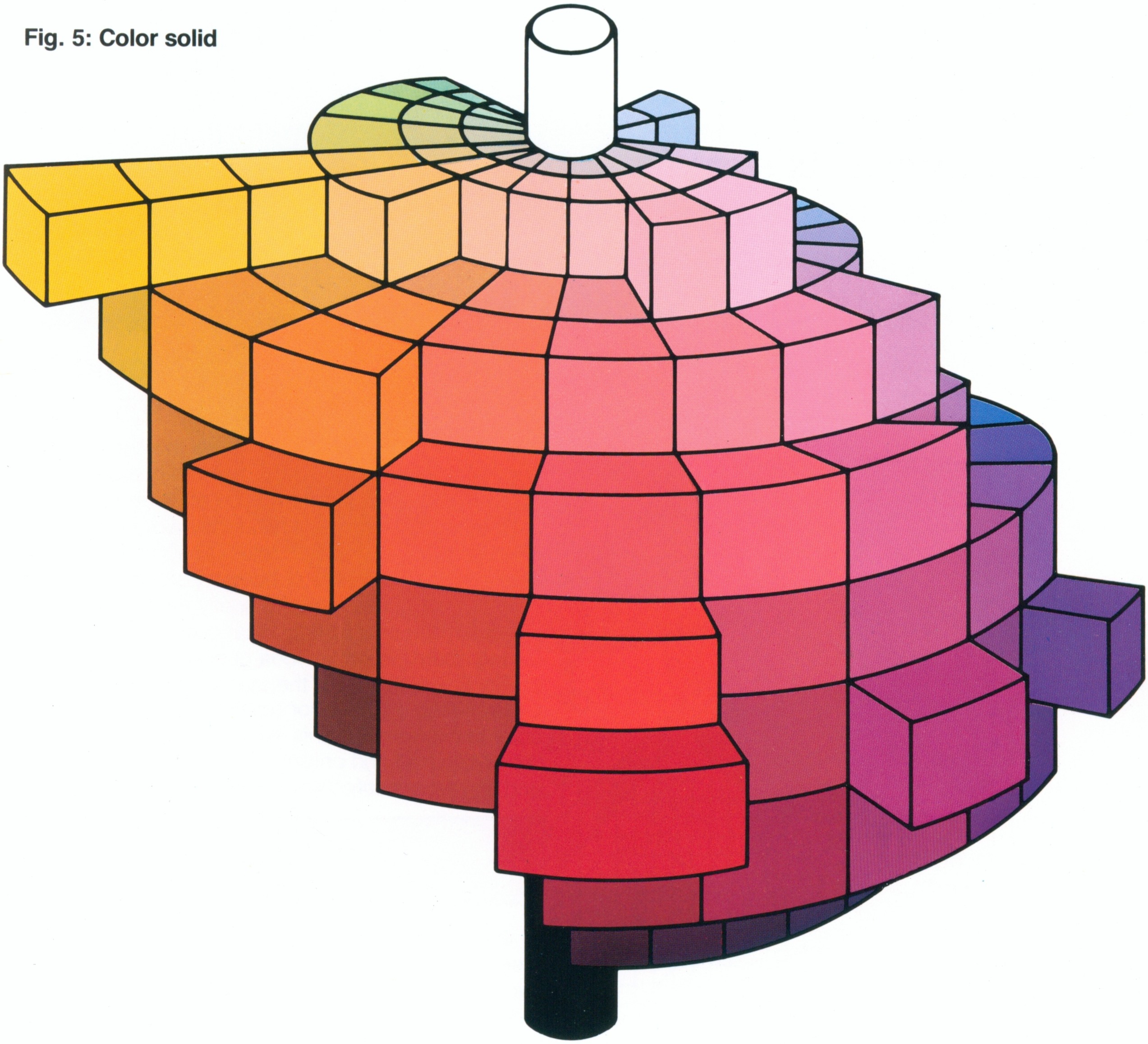


Fig. 5: Color solid

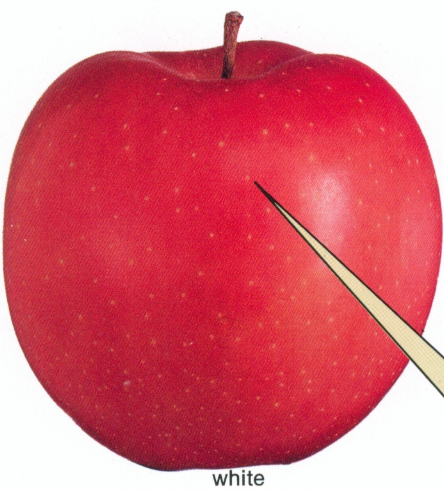


If the limitlessly expanding world of color could be numerically encoded...

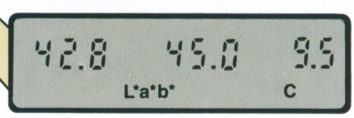
Expressing colors more precisely than with words: Numerical color communication

If the color of this apple was expressed numerically, it would be:

$L^*=42.8$ $a^*=45.0$ $b^*=9.5$

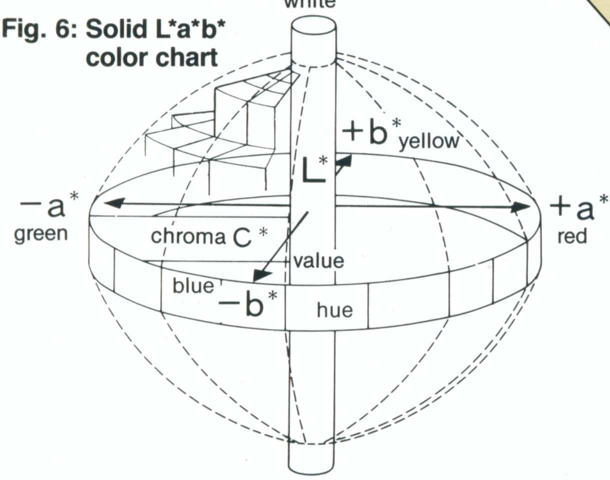


Some people may quickly come to the conclusion that if color can be broken down into hue, value, and chroma, then there must be an even more precise way to express it. And they would be correct. Minolta Chroma Meter CR-100 convert all colors within the range of human perception into a common numerical code to finally enable anyone to tell anyone else exactly what color they are talking about. To get an idea of how it works, look at Fig. 6, which shows the L*a*b* (pronounced L-star, a-star, b-star) color notation system. When a color is expressed in this system, value becomes "L*", while hue and chroma are expressed as a* and b*, respectively.



$L^*=42.8$
$a^*=45.0$
$b^*=9.5$

Fig. 6: Solid L*a*b* color chart



a* and b* indicate two color axes, with a* the red-green axis and b* the yellow-blue. If we go back to our apple at the beginning of this discussion, its red would be quantified as: [$L^*=42.8$ $a^*=45.0$ $b^*=9.5$] And just what do these numbers mean? Look at Fig. 7: the point Ⓐ at which $a^*=45.0$ and $b^*=9.5$ intersect is the color of this apple. At the same time, chroma C*[1] is added so that when chroma and value axes are compared as in Fig. 8, the final color tone is obtained. If this were expressed in general terminology, it would become "vivid red purple".

[1]Chroma C* is decribed by the equation $C^*=\sqrt{a^{*2}+b^{*2}}$

Fig. 7: L*a*b* color chart (hue and chroma)

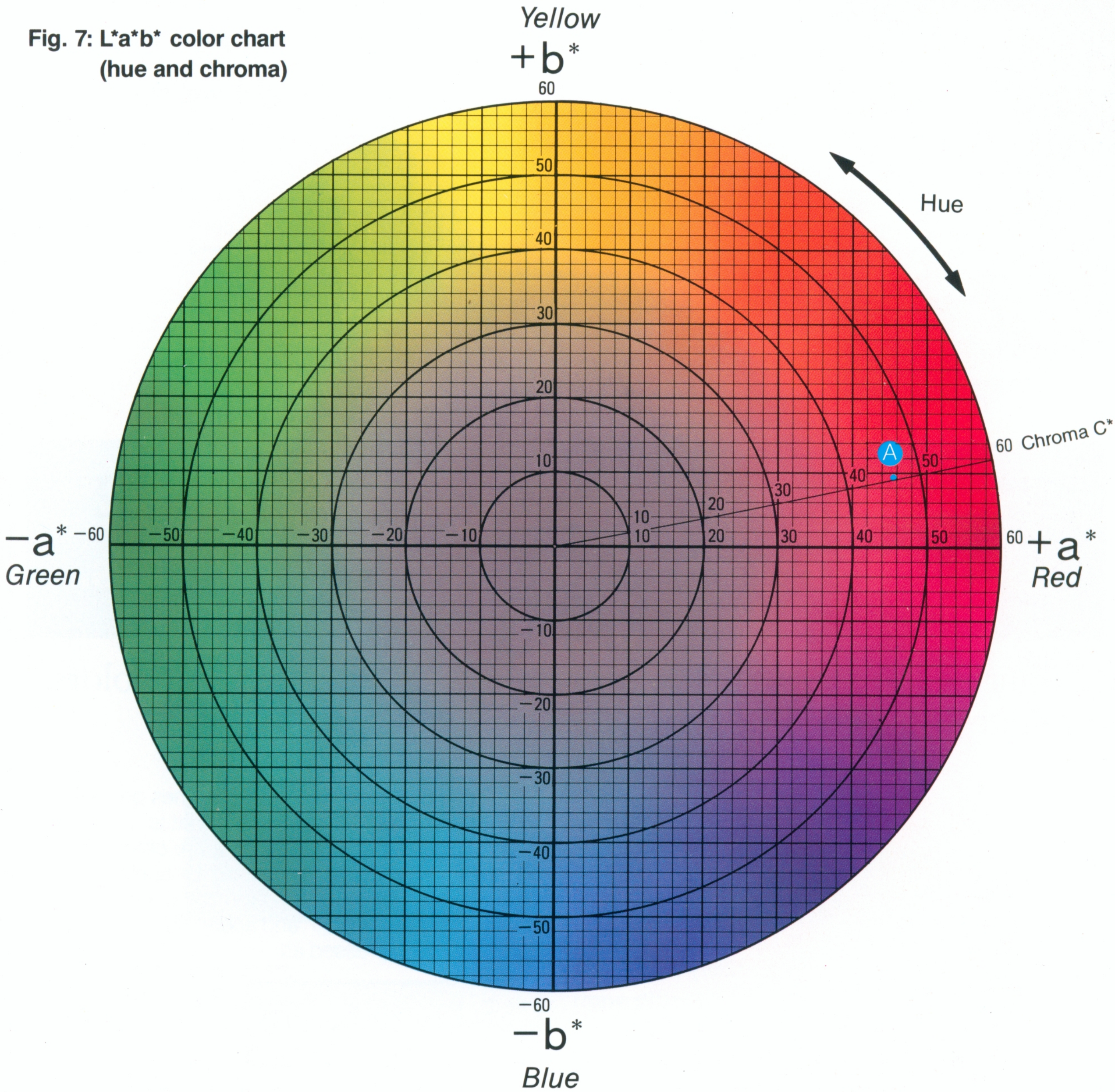
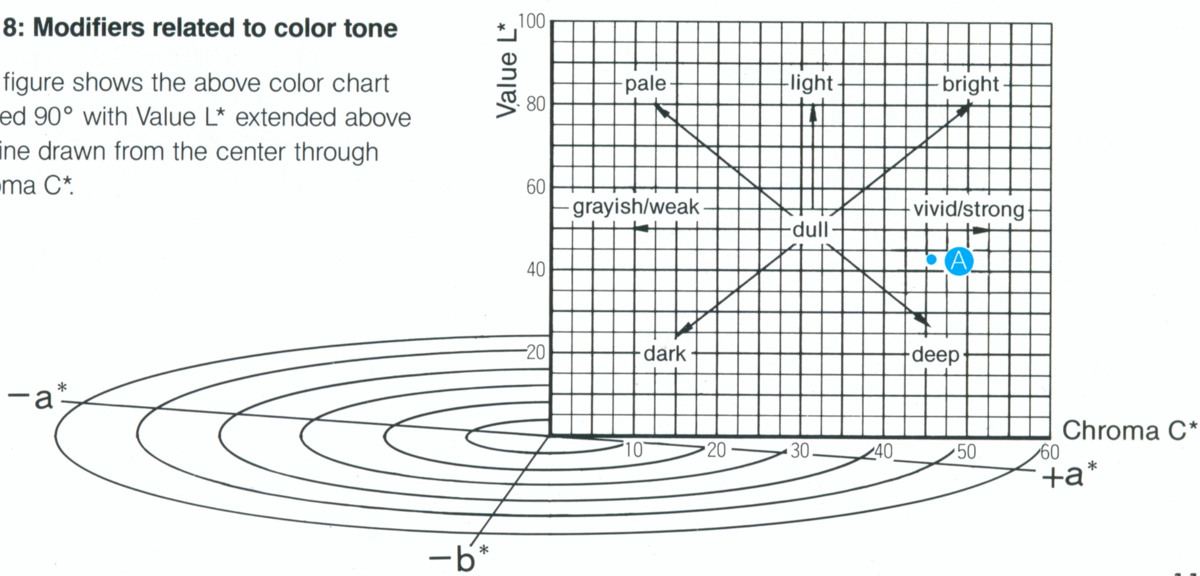


Fig. 8: Modifiers related to color tone

This figure shows the above color chart rotated 90° with Value L* extended above the line drawn from the center through Chroma C*.

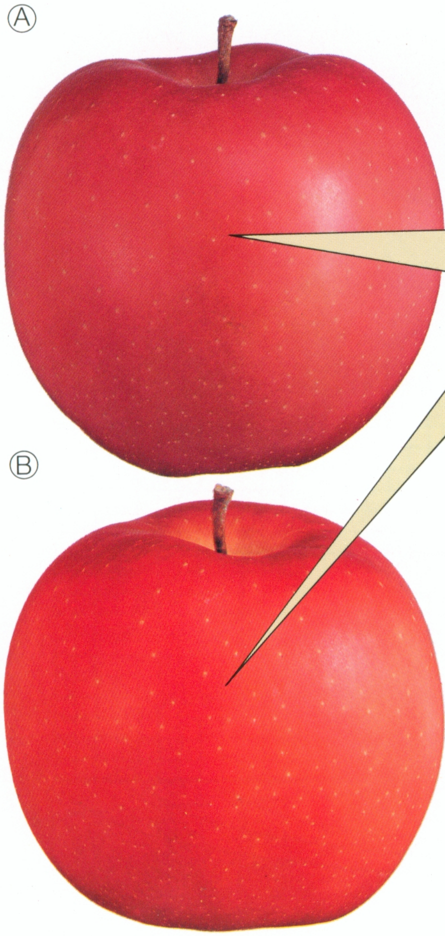


Numerical expression of minute color differences: These are color differences.

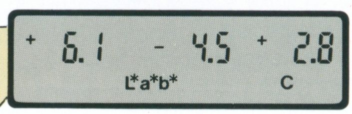
Numerically reading the difference between two similar colors, another apple becomes: $L^*=48.9$ $a^*=40.5$ $b^*=12.3$

Ⓐ

Ⓑ



When colors are digitalized, it becomes possible to express minute differences in what is essentially the same color. These are called color differentials. If we take the values for apple Ⓐ measured on the previous page, the color difference between Ⓐ and apple Ⓑ on this page can be expressed as:



$\Delta L^*=+6.1$
$\Delta a^*=-4.5$
$\Delta b^*=+2.8$

Now look at Fig. 9, an exploded section of Fig. 7 from the previous page. If the value for apple Ⓑ is plotted as point Ⓑ and compared with point Ⓐ of apple Ⓐ, it can be seen that Ⓑ is slightly more red than Ⓐ. If chroma C* and ΔC*① are compared, point Ⓑ is somewhat lower. Similarly, it is plain from Fig. 10 that the value of Ⓑ is fractionally higher than Ⓐ, and if color Ⓑ was verbalized, it would be a "pale color". If the color of Ⓑ was expressed in general terms, it would be "slightly pale red".

① Δ (delta) is used to indicate deviation.

Fig. 9: L*a*b* color chart (enlargement of Fig. 7)

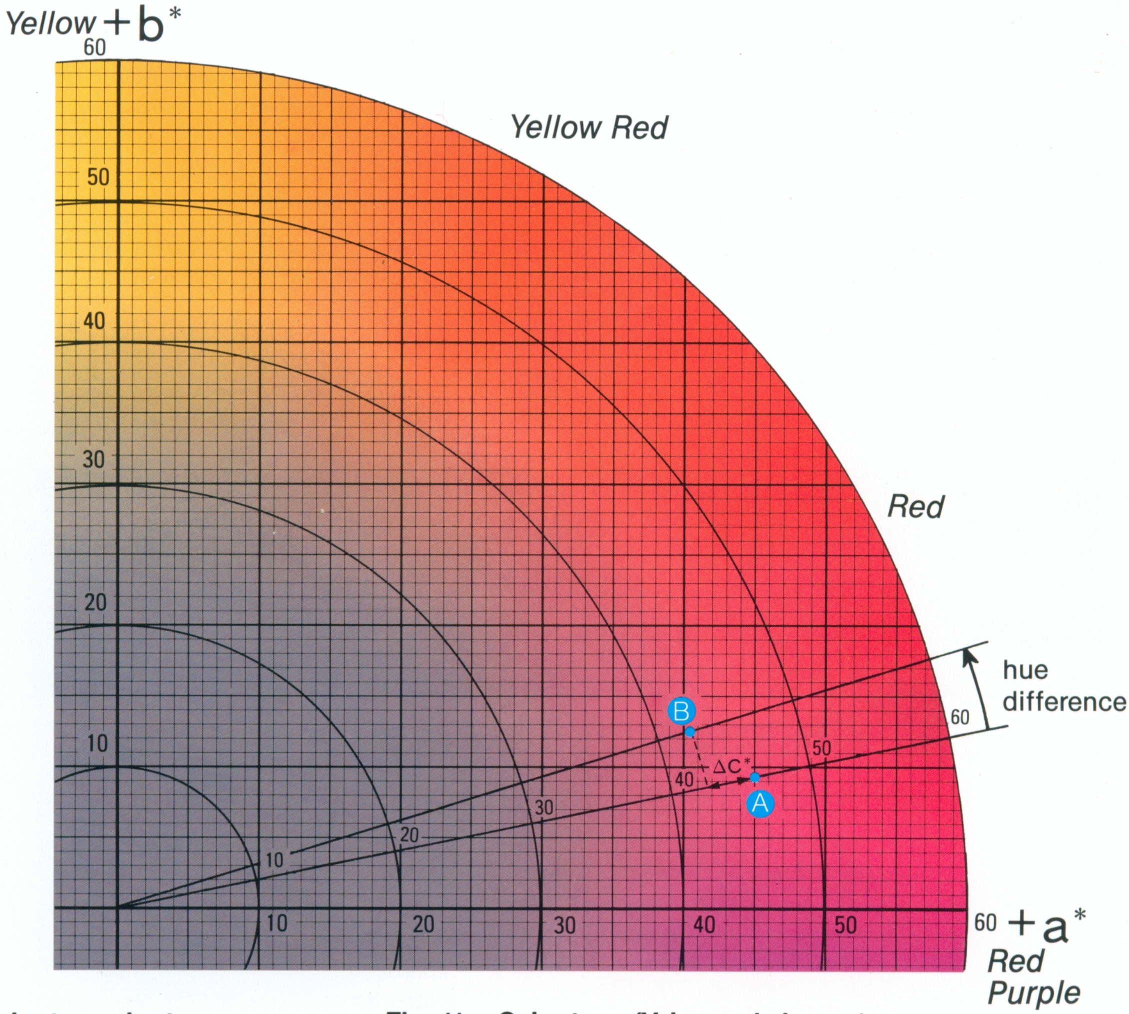


Fig. 10: Color tone chart (Value and chroma)

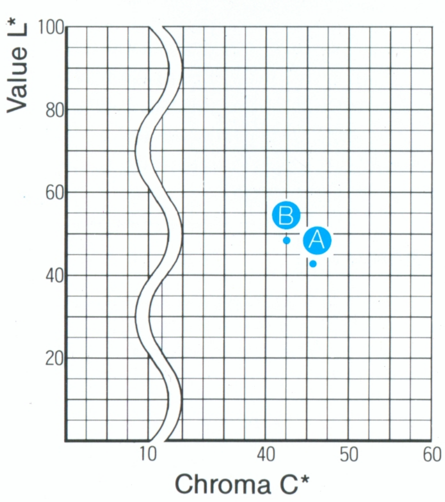
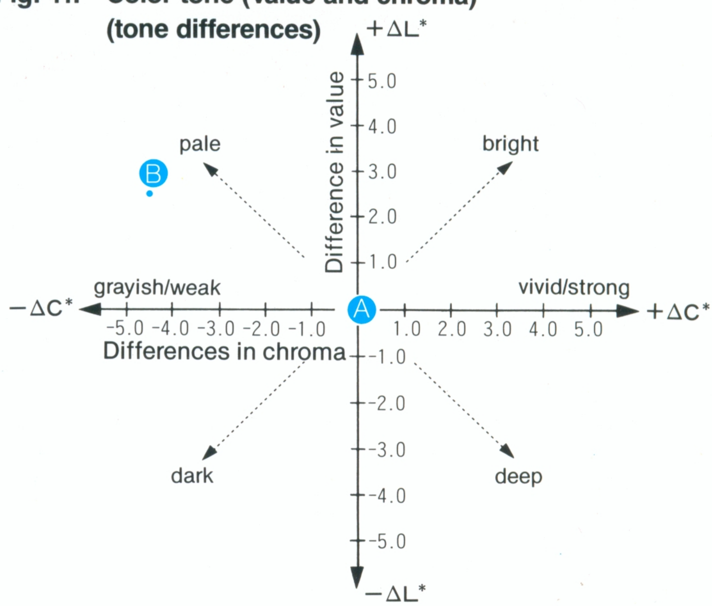


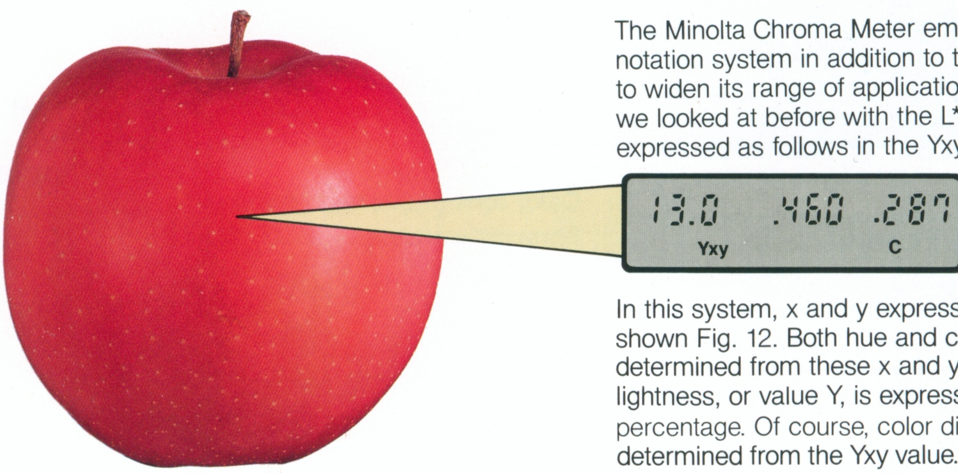
Fig. 11: Color tone (Value and chroma) (tone differences)



Numerical color expression: fundamental psychophysical color order system called the Yxy color system

Remember that Y is lightness and xy is tone (hue and saturation when displayed on the Chroma Meter CR-100

The Minolta Chroma Meter employs the Yxy color notation system in addition to the L*a*b* system to widen its range of applications. The red apple we looked at before with the L*a*b* system is expressed as follows in the Yxy system:



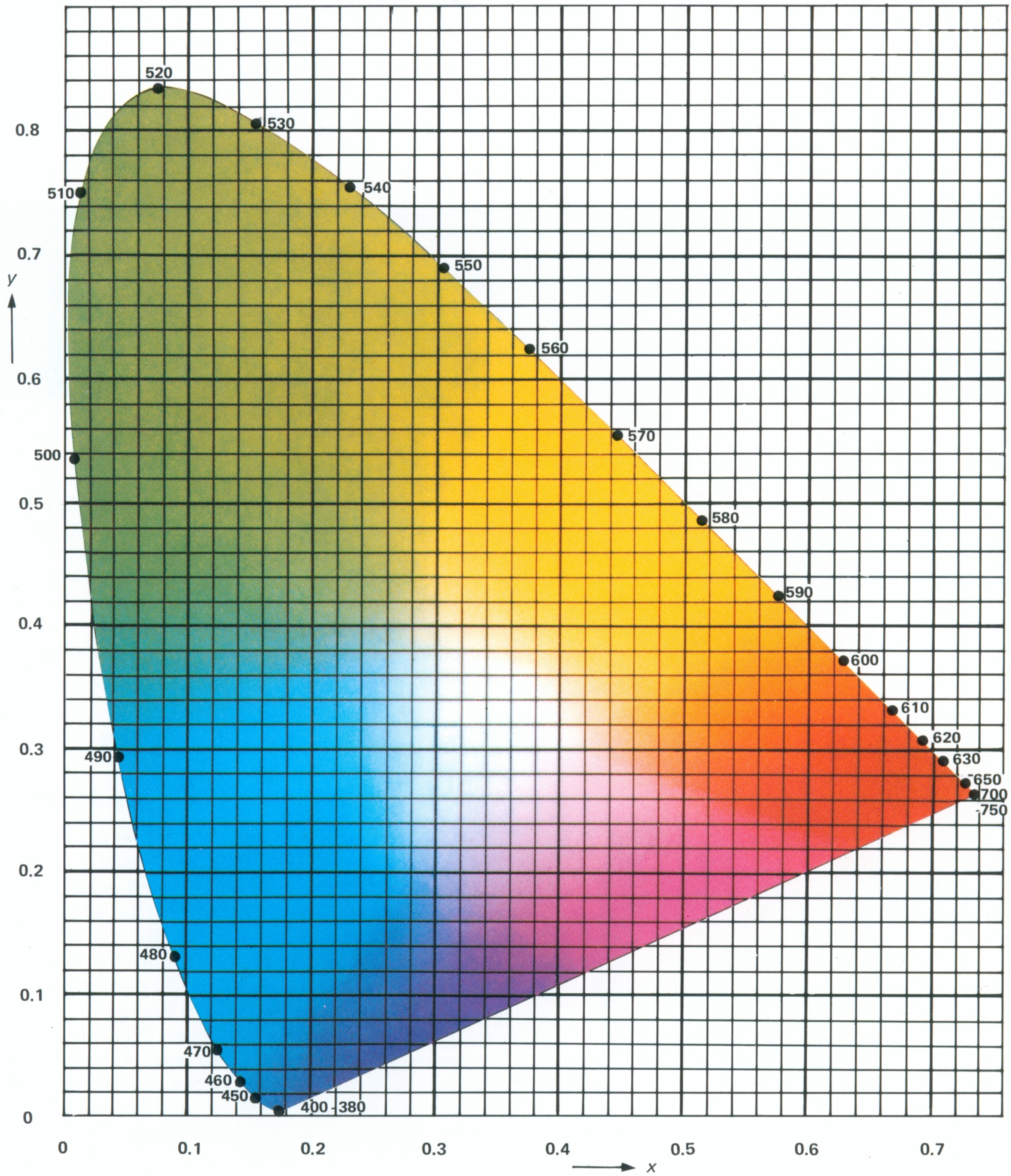
Y= 13.0
x= 0.460
y= 0.287

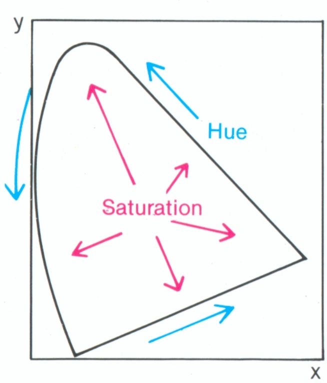
In this system, x and y express color tone as shown Fig. 12. Both hue and chroma can be determined from these x and y values, while lightness, or value Y, is expressed as a percentage. Of course, color differences can be determined from the Yxy value.

Please note:

- Yxy system has a limitation caused by its non-uniform visual spacing; this is corrected by the simple transformation equations that result in the L*a*b* system.

Fig. 12: CIE 1931 (x,y)-Chromaticity Diagram





Neither all words nor all numbers The Munsell color system uses abbreviations to differentiate colors.

What is Munsell notation?

Colors can also be identified by assigning letters and numbers to the various steps in a three-dimensional color chart. Originally developed by the American artist A.H. Munsell, this chart is appropriately called the Munsell color chart.

Now take a look at Fig. 13, and observe the "5R" (for Red) hue abbreviation on the outside (also 10R for Red, 5YR for Yellow Red, etc.). Value and chroma numbers are assigned according to Fig. 14 with value running vertically and chroma running horizontally. Munsell notations are assigned by combining these two charts, and are widely used in design work.

The color of this cup is "5G 5/10"

How would the color of the green cup in the photograph at left be described in Munsell notation? Well, first closely examine the color. Next, locate the color closest to it on the wheel in Fig. 13, and observe the given notation, 5G in this example. Next, refer to Fig. 14 to obtain the value and chroma for the color—5 and 10 respectively for this cup. Now simply combine the two notations, and this green becomes "5G 5/10". This is the simplest and most widely used of the three systems discussed in these pages, and many people reading this booklet are probably already familiar with these Munsell color notations.

Please note:

- Check that the object to be measured has not faded or changed colors, and is not dirty.
- Check that the light source is appropriate for measurement.
- Note also that any color will vary greatly depending upon the angle from which it is measured. Improper measurement angle will result in inaccurate measurements. Unlike the human eye, chroma meters are precise measuring devices that will provide accurate chroma values when measurements are taken correctly.

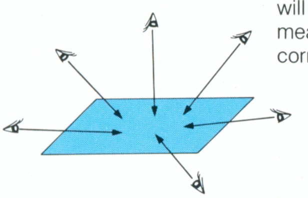


Fig. 13: Munsell color wheel

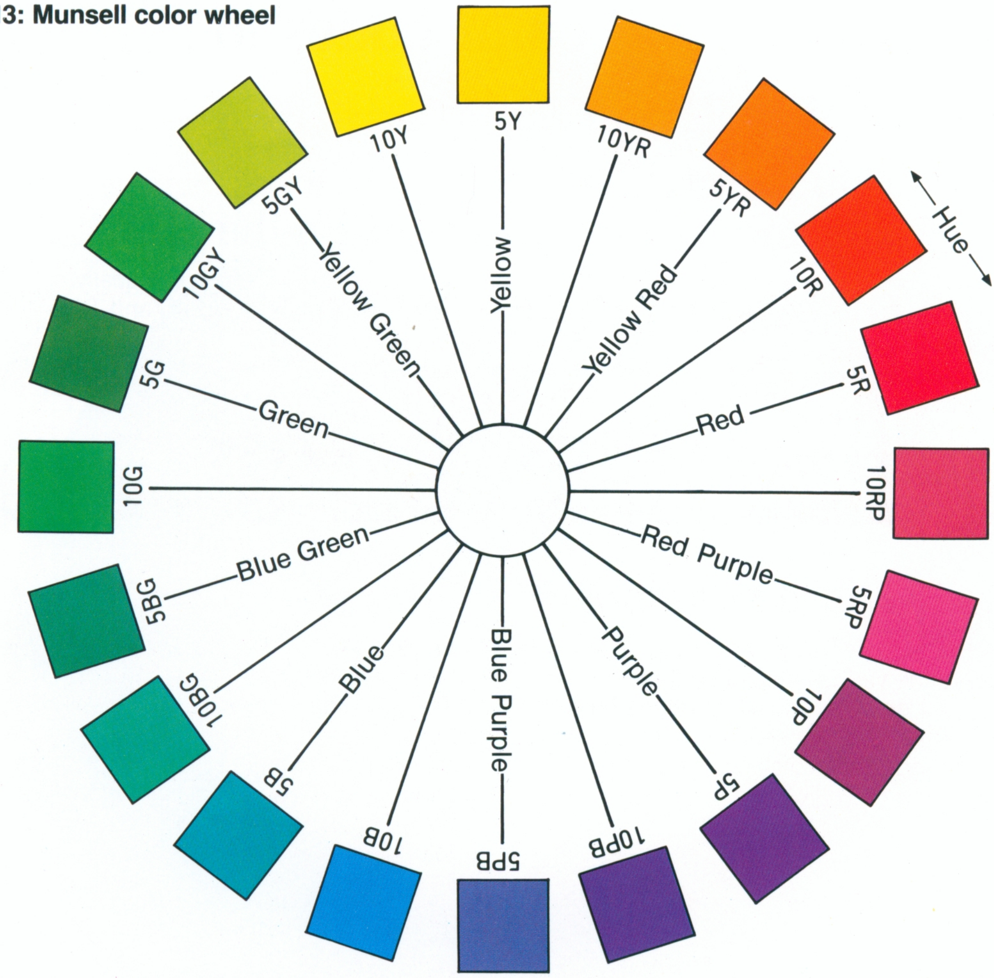
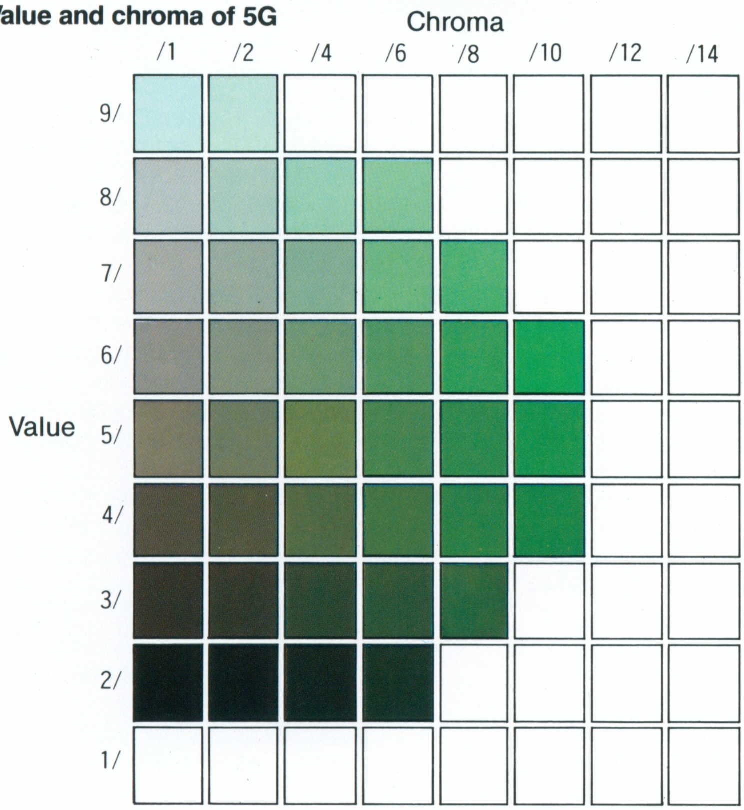


Fig. 14: Value and chroma of 5G

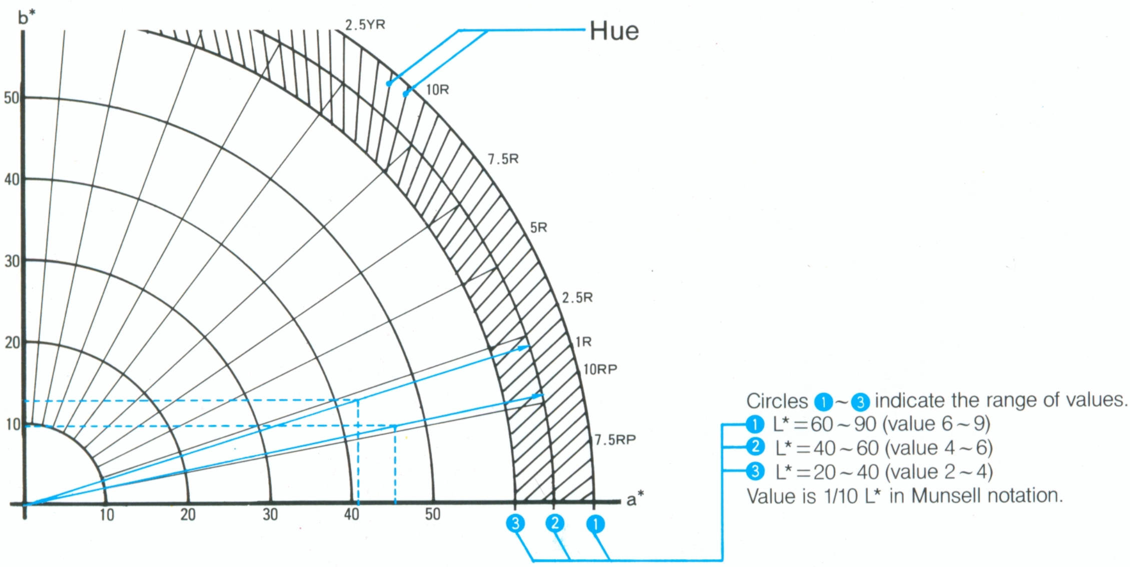


Convert numerical color codes to Munsell notation

From L*a*b* to Munsell notation
Read the value and let your eyes confirm the color.

When numerical color codes are used in the printing and design industries, they must usually be converted to the most commonly used color system, Munsell notation. To do this, refer to Fig. 15 and Table 1 for quick, easy conversion.
In the following discussion, we will consider the conversion between the L*a*b* code and Munsell notation as it relates to apple Ⓐ measured on page 10.

Fig. 15 is a combination of Fig. 7 on page 11 and the Munsell notations from page 17 used for easy conversion of measured values (numerical) to Munsell notation.



Based on the above, we will now convert the measured values of apple Ⓐ to Munsell notation. Apple Ⓐ was measured as:
L*=42.8; a*=45.0; b*=9.5; C*=46.

1. Locate the intersection of a*=45.0 and b*=9.5 on Fig. 15.
2. Since L*=42.8 is value circle ❷, draw a line from the center through the intersection of a* and b* to the value circle ❷.
3. If you look at the point where this drawn line intersects value circle ❷, you will see that the hue line indicates a Munsell notation of 10RP. (If the drawn lines intersects value circle ❷ in-between two hue lines, take the closest hue line.)
4. Next, since chroma C*=46, refer to the RP hue column in Table 1 and locate the number closest to the chroma. In this case, it would be 44, so read across the table to obtain the Munsell chroma notation of 10.

With the above values determined as: hue=10RP; value=4; and chroma=10 the Munsell notation can now be written: 10RP 4/10.

Now run through the same procedure to determine the Munsell notation for apple Ⓑ, which was measured to be:
L*=48.9; a*=40.5; b*=12.3; C*=42.

1. Locate the intersection of a*=40.5 and b*=12.3 in Fig. 15.
2. Since L*=48.9 (approx. 50) is value circle ❷, draw a line from the center through the intersection of a* and b* to the value circle ❷.
3. If you look at the point where of this drawn line intersects value circle ❷, you will see that the hue line indicates a Munsell notation of approx. 2.5R.
4. Since chroma C*=42, refer to the R column in Table 1 and locate the figure nearest to the chroma. In this case, it would be between 37 and 46 in the left column, so read chroma in Munsell notation as 9.

With the values determined as: hue=2.5R; value=5; and chroma=9; Munsell notation becomes 2.5R 5/9.

By following the above steps with Fig. 15 and Table 1, L*a*b* values can be easily converted to Munsell notation.

Fig. 15: L*a*b* and Munsell notations (hue, value)

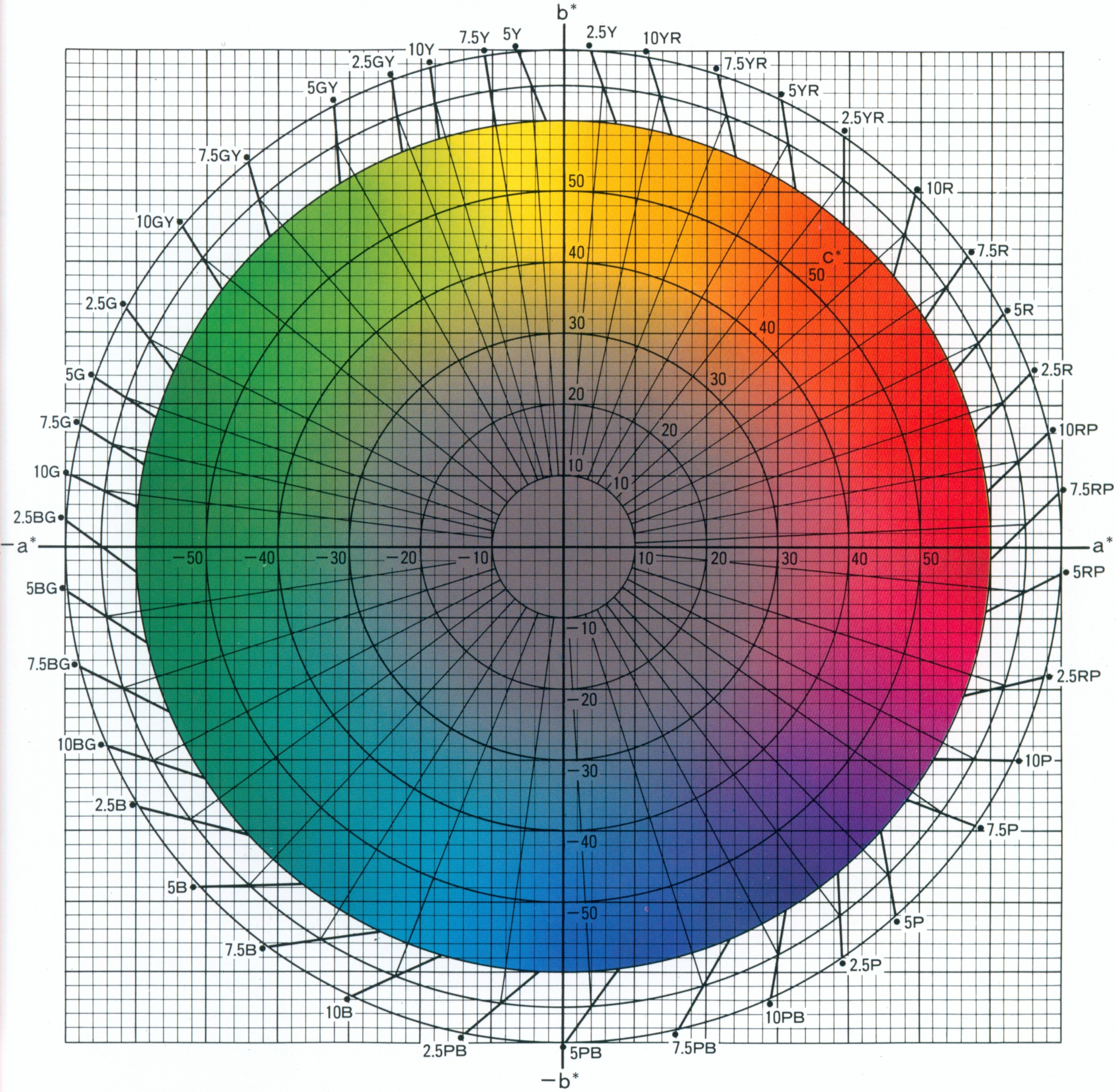


Table 1: Munsell (chroma C) and L*a*b* (chroma C*) notations

Munsell hue notation / L*a*b* chroma / Munsell chroma	R	YR	Y	GY	G	BG	B	PB	P	RP
1	5	7	8	7	6	5	4	4	4	4
2	9	12	15	13	11	10	9	9	9	9
3	15	17	22	22 19	16	15	13	13	13	13
4	19	22 25	29	29 25	22	20	17	17	18	18
6	27 30	34 38	42 45	43 39	34 31	28	26	26	27	26
8	37 41	46 50	56 59	58 51	45 42	38	34	34	36	35
10	46 51	57 63	70 74	73 65	56 53	51 47	44 40	41 44	45	44
12	55 62	68 76	84 88	87 77				48 55	53	51
14	64 73	79 90	98					66	62	60
16	84	94 101	109					75		

In columns with two digits, left figures are for hues 1 ~ 5; right figures for hues 6 ~ 10.

Please note:

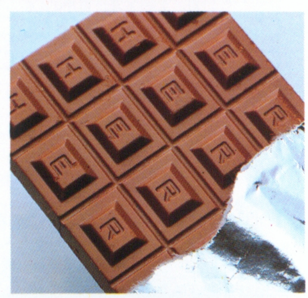
- For extremely small or large a*b* values, multiply or divide them by an appropriate amount before plotting and reading the hue values.

* Colors of figures and photographs in this manual may vary from the actual ones due to printing.

The Minolta Chroma Meters are applicable to all industrial and scientific fields.

APPLICATIONS

	CR-100	CR-110	CR-121	CR-131	CT-100
• Applied Coatings					
paints	√		√	√	
metallic powders	√	√	√	√	
metal plating	√		√	√	
printing inks	√		√	√	
powdered pigments	√		√	√	
• Processed Materials					
paper	√		√	√	
plastic	√	√	√	√	
rubber	√				
glass	√				
sheet metal	√		√	√	
metal cable	√		√		
• Clothing/Textiles					
natural fibers		√			
carpeting		√			
thread	√				
leather	√				
dyed fabric	√	√	√	√	
• Chemicals					
liquids					√
• Building Materials					
concrete	√	√			
drywall		√			
wood		√			
• Processed Foods					
powders	√	√			
granules	√	√			
pastes	√	√			
liquids or syrups					√
• Agriculture					
soil	√	√			
fruit	√				
vegetables	√				
leaves	√	√			
grass		√			
• Medicine/Cosmetics					
powders	√	√			
granules	√	√			
ointments	√	√			
human skin	√				
liquids					√
• Petroleum					√



SPECIFICATIONS
FOR CHROMA METERS CR-SERIES AND CT-100

	CR-100	CR-110	CR-121	CR-131	CT-100
Type	Hand-held dual-function reflected subject-color colorimeter with pulsed xenon light source				Hand-held dual-function transparent-color colorimeter with pulsed xenon light souce
Receptors	6 silicon photocells (for double-beam feedback system) filtered to detect primary stimulus values for red, green, and blue light				
Spectral response	Within 2% of CIE Standard Observer curves ($\bar{x}_2\lambda$, $\bar{y}\lambda$, and $\bar{z}\lambda$)				
Measuring modes and chromatic system	Yxy (CIE 1931) and L*a*b* (CIE 1976) for chromaticity; $\pm\Delta$ (Yxy), $\pm\Delta$ (L*a*b*), and ΔE for color deviation				
Color deviation mode	One channel for memory of reference color (measured or input); deviation from reference color determined and displayed				
Calibration standard	WHITE: Minolta standard-white reflector plate VARI: User-selected calibration standard				WHITE: Calibrated by distilled water VARI: User-selected calibration standard
Lighting	Pulsed xenon arc lamp built into measuring head with double-beam feedback system for accuracy control				
	d/0 illuminating system		45/0 illuminating system		Measuring distance: 20mm
Illuminant conditions	CIE Illuminant C (6774K) or D_{65} (6504K)				
Display	11 digit LCD type; desired readout selectable by pressing appropriate key before/after reading made; "E9" displayed when measured value is out of display range				
Measuring area	ϕ8mm	ϕ50mm	ϕ3mm	ϕ25mm	ϕ4mm (minimum depth of object liquid: 45mm
Measuring range	1.0—100% reflectance ratio; display blinks when measured value is under range				1.5—100% transmittance; display blinks when measured value is under range
Short-term repeatability	Chromaticity (x, y): $\pm$0.0005; color deviation (ΔE): 0.4				
Terminals	Remote-control socket, data-output terminal				
Data output	1-bit serial, open-collector; remote-control operable				
Power source	Meter body: one 9v battery (Eveready 216 or equivalent) Measuring head: built-in nickel-cadmium battery with Ni-Cd charger or four 1.5v AA-size batteries in external battery pack				
Dimensions	Meter body: 195 × 72 × 33mm ($7^{11}/_{16} \times 2^{13}/_{16} \times 1^{5}/_{16}$ in.)				
	Measuring head: ϕ60 × 138mm ($\phi 2^{3}/_{8} \times 5^{7}/_{16}$ in.)	Measuring head: ϕ56 × 155.5mm ($\phi 2^{3}/_{16} \times 6^{1}/_{8}$ in.)	Measuring head: ϕ60 × 138mm ($\phi 2^{3}/_{8} \times 5^{7}/_{16}$ in.)	Measuring head: ϕ117 × 176mm ($\phi 4^{5}/_{8} \times 6^{15}/_{16}$ in.)	Lighting head: ϕ65 × 166mm ($\phi 2^{9}/_{16} \times 6^{9}/_{16}$ in.) Measuring probe: 18 × 28 × 88mm ($^{11}/_{16} \times 1^{1}/_{8} \times 3^{7}/_{16}$ in.) Fiber pipe: 85mm ($3^{5}/_{16}$ in.)
	Optical fiber cable for measuring head: ϕ14.5 × 1000mm ($\phi ^{9}/_{16} \times 39^{3}/_{8}$ in.)				
Weight (without battery)	910g ($32^{1}/_{8}$ oz.)			1400g ($49^{3}/_{8}$ oz.)	1300g ($45^{7}/_{8}$ oz.)
Other					Material (Measuring probe and fiber pipe): SUS316, compound glass, epoxy resin, silicone resin

Chroma Meter CT-210 (Sampling type transparent color colorimeter) Available in mid 1986.

Specifications subject to change without notice

MINOLTA

Minolta Camera Co., Ltd.	**30, 2-Chome, Azuchi-Machi, Higashi-Ku, Osaka 541, Japan**
Minolta Corporation Head Office (Meter Div.)	101 Williams Drive, Ramsey, New Jersey 07446, U.S.A, Phone: 201-825-4000
Minolta Camera Handelsgesellschaft m.b.H.	Kurt-Fischer-Strasse 50, D-2070 Ahrensburg, West Germany, Phone: 04102-70-1
Minolta France S.A.	357 bis, rue d'Estienne d'Orves, 92700 Colombes, France
Minolta (UK) Limited	1-3 Tanners Drive, Blakelands North, Milton Keynes, MK14 5BU, England
Minolta Austria Gesellschaft m.b.H.	Amalienstraße 59-61, 1131 Wien, Austria
Minolta Camera Benelux B.V.	Zonnebaan 39, 3606 CH Maarssenbroek, P.B. 264, 3600 AG Maarssen, The Netherlands
Minolta (Schweiz) GmbH	Riedhof V, Riedstrasse 6, 8953 Dietikon-Zürich, Switzerland
Minolta Svenska AB	Brännkyrkagatan 64, Box 17074, S-10462-Stockholm 17, Sweden
Minolta Hong Kong Limited	Room 208, 2/F, Eastern Center, 1065 King's Road, Hong Kong, Phone: 3-676051-6
Minolta Singapore (Pte) Ltd.	10, Teban Gardens Crescent, Singapore 2260, Phone: 563-5533

PCC 601E-C1 9242-4802-01 Printed in Japan