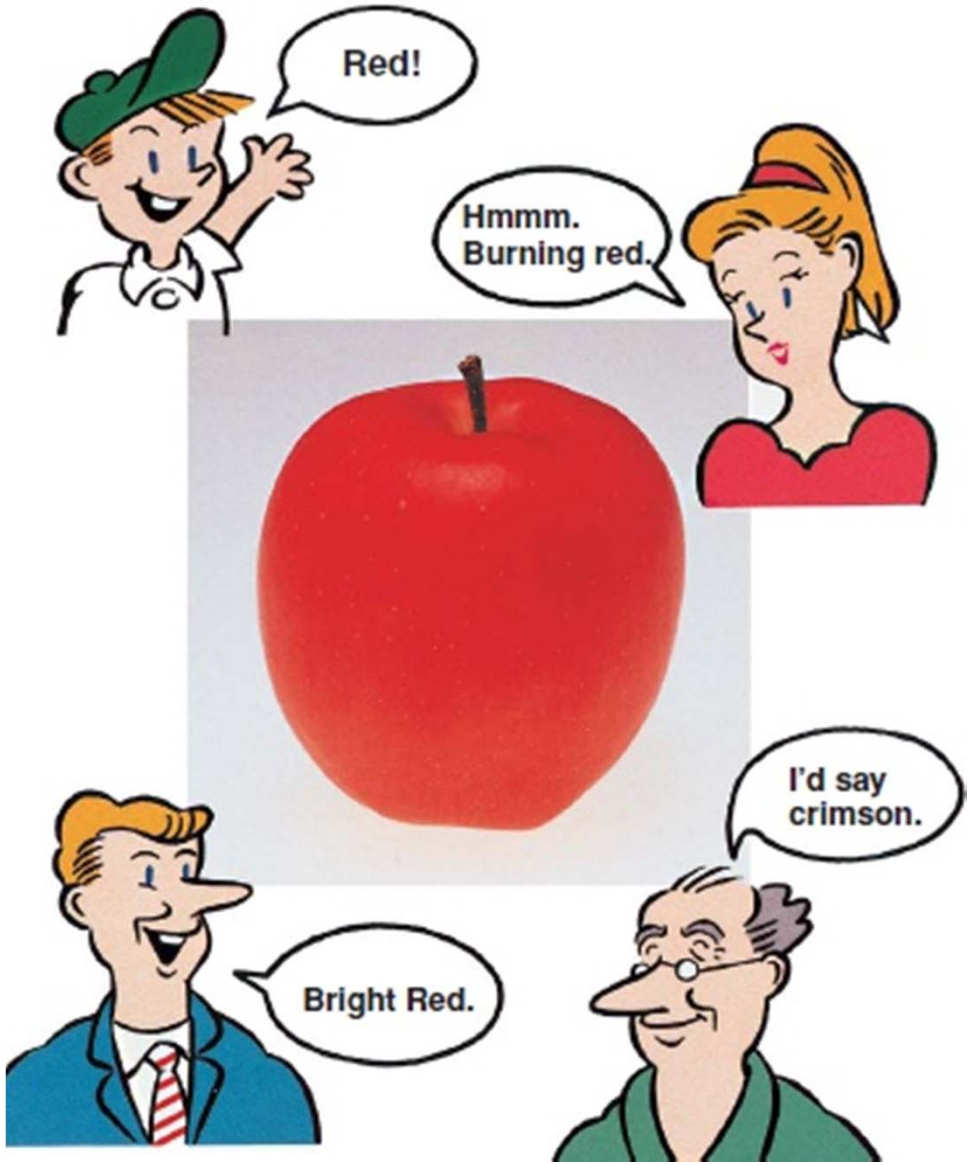
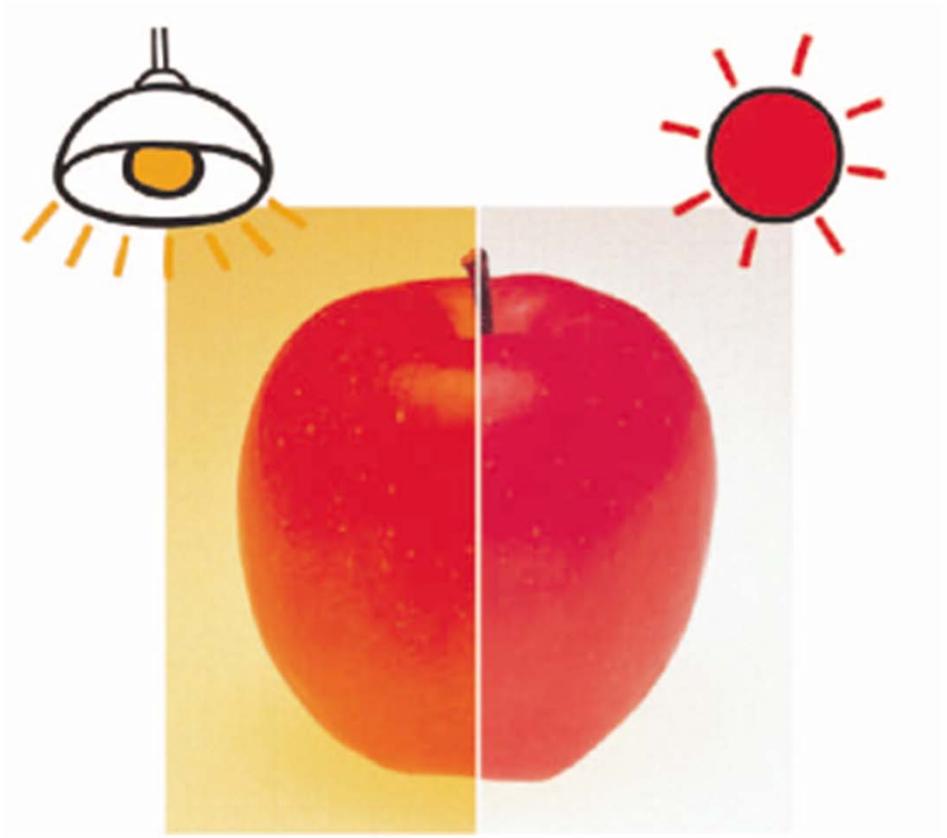
What color is this apple ?



Even though it's actually the same color,
it looks different. Why?



A variety of conditions affect how a color looks.

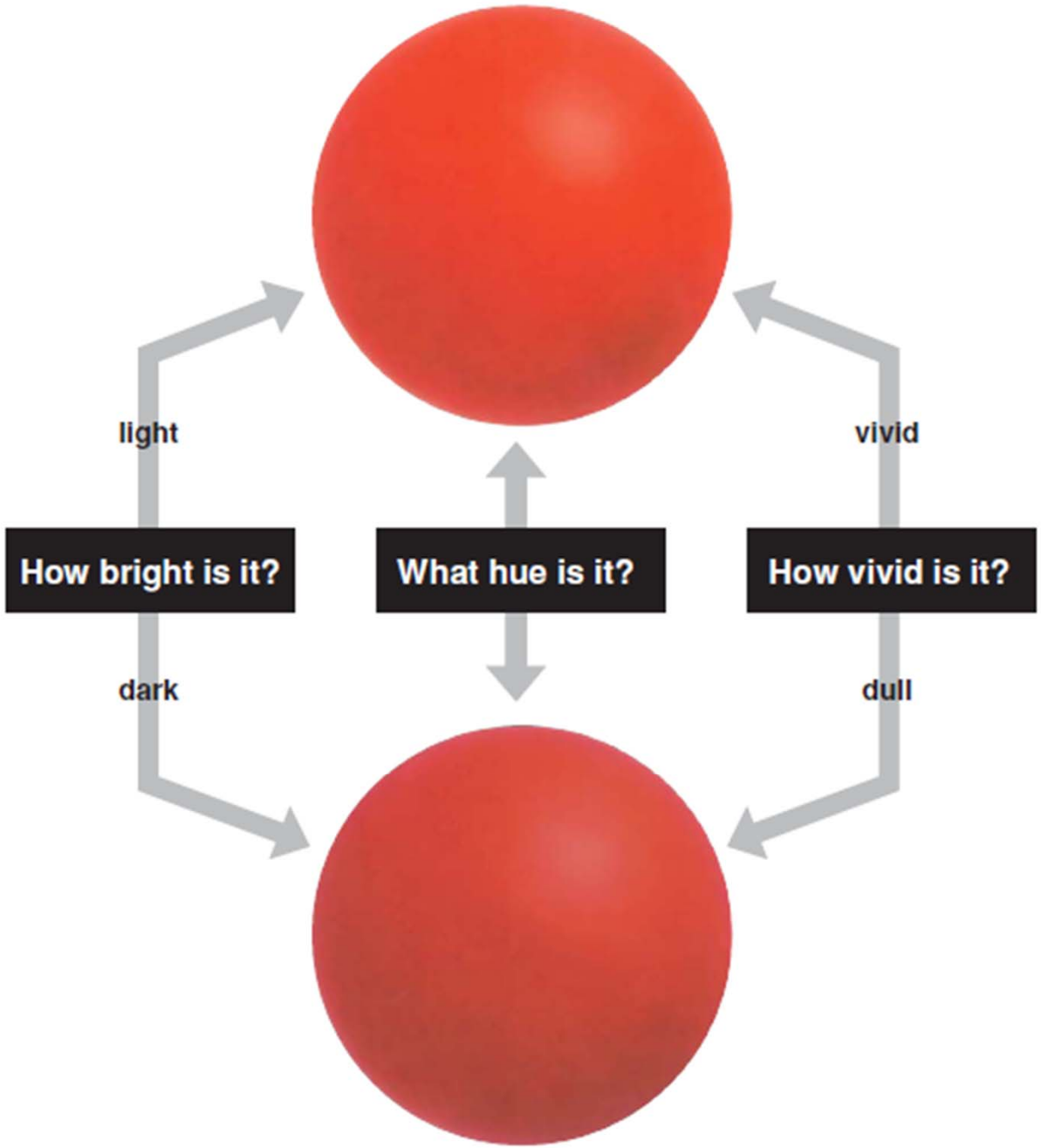
Light-source differences

Background differences

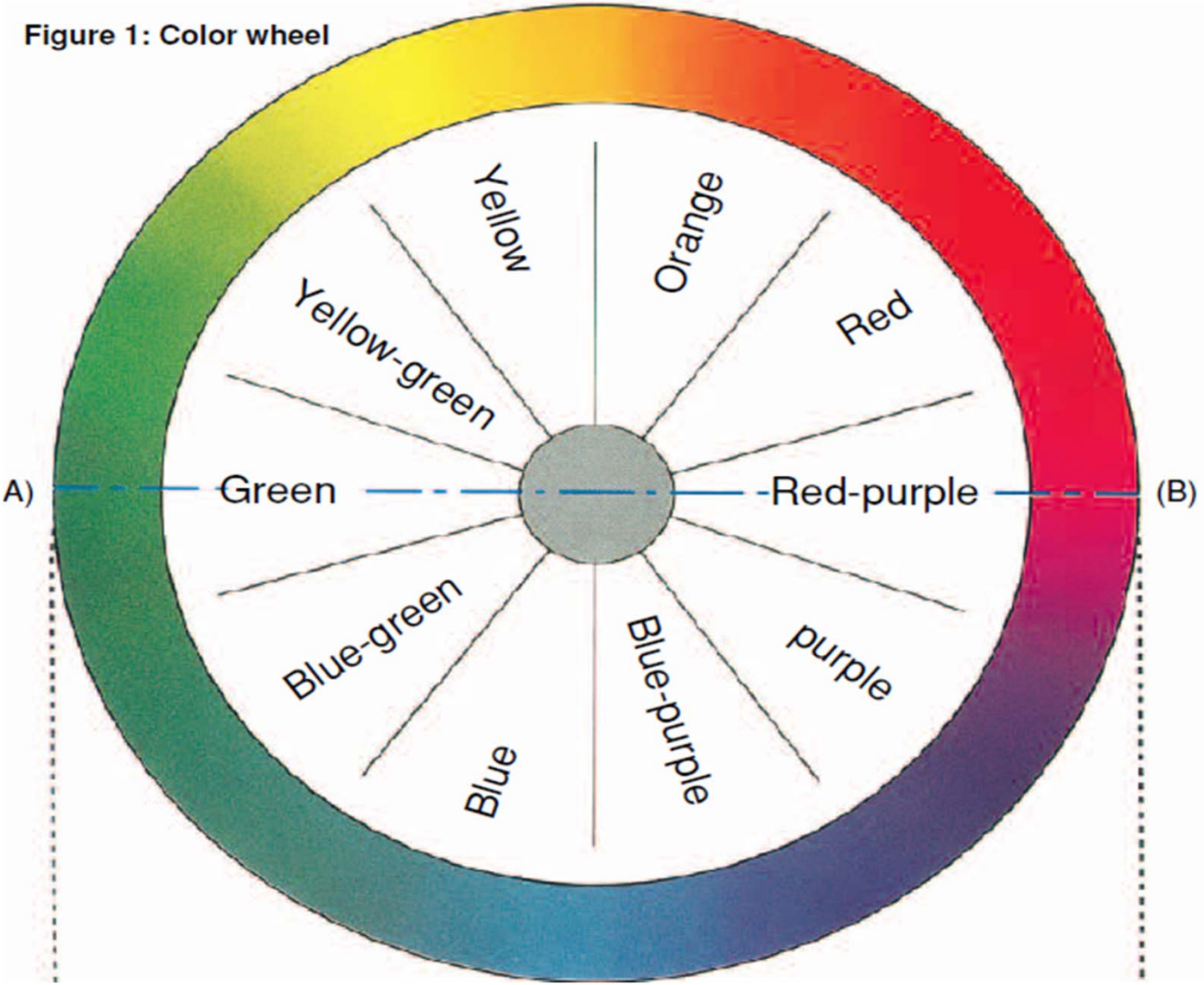
Observer differences

Size differences

Directional differences


light
vivid
How bright is it?
What hue is it?
How vivid is it?
dark
dull

Hue. Lightness. Saturation. The world of color is a mixture of these three attributes.



Hue. Lightness. Saturation. The world of color is a mixture of these three attributes.

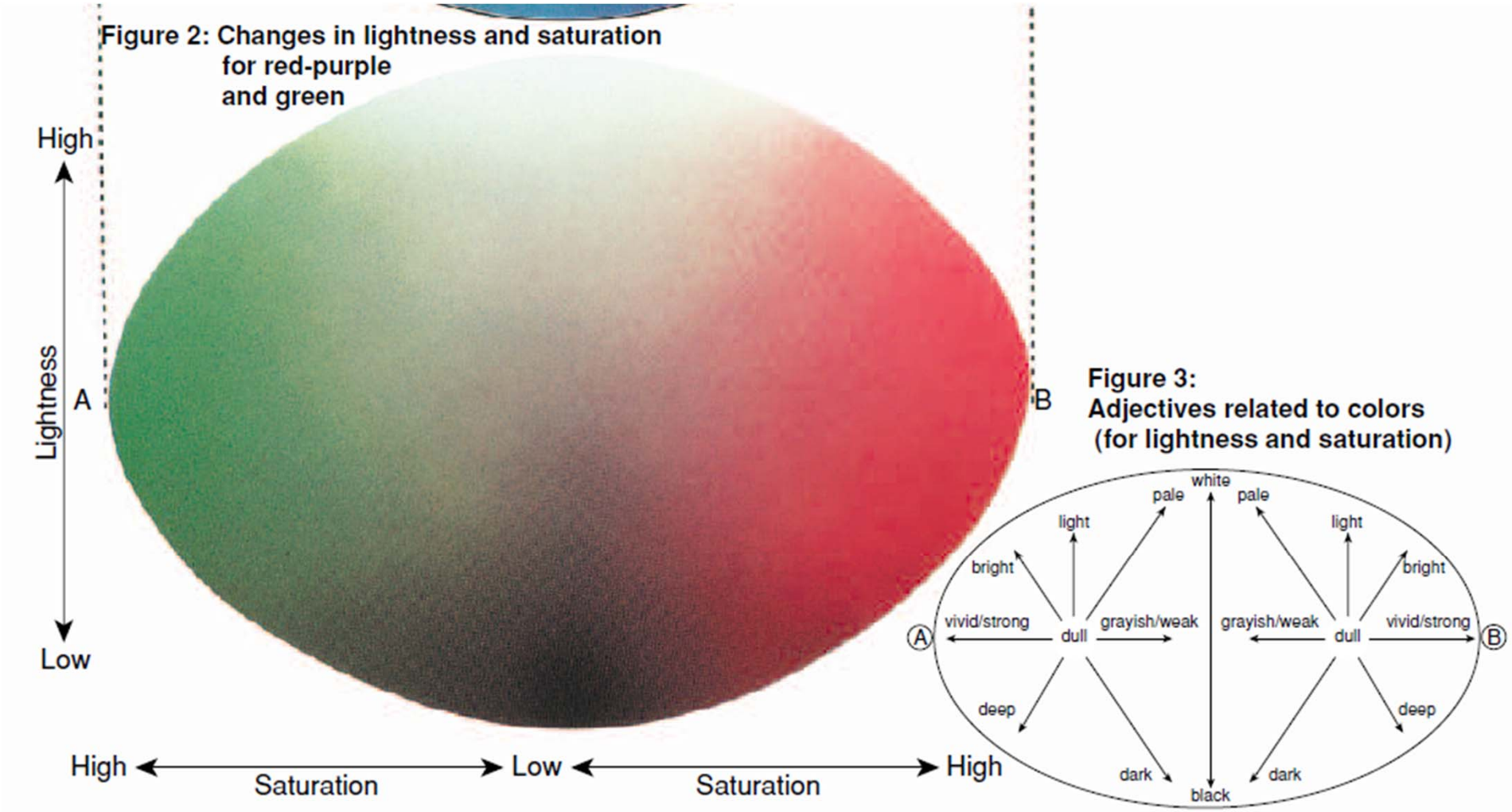


Figure 2: Changes in lightness and saturation for red-purple and green

Figure 3: Adjectives related to colors (for lightness and saturation)

Let's create a color solid.

Figure 4:
Three-dimension
(hue, lightness, saturation) solid

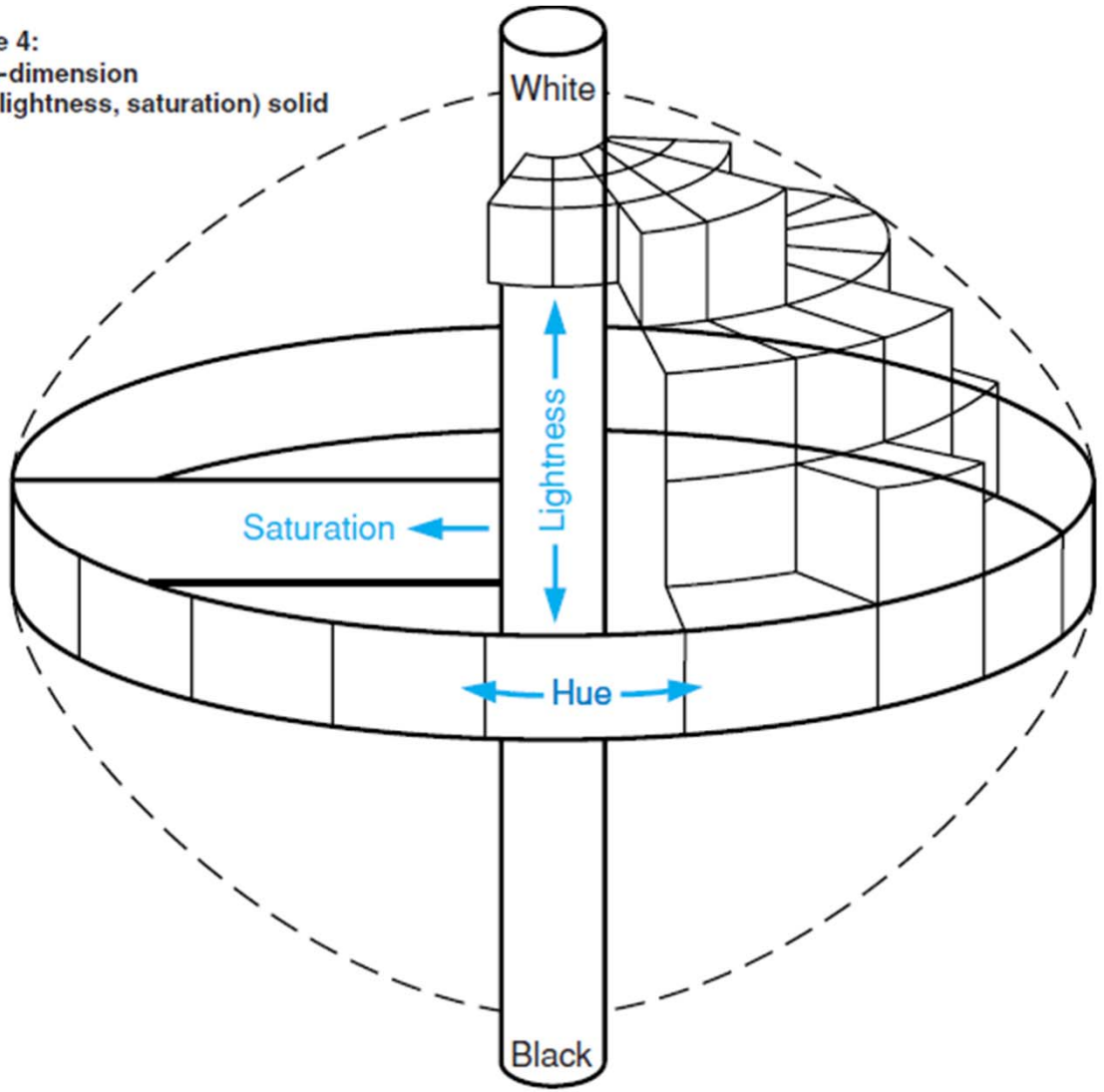
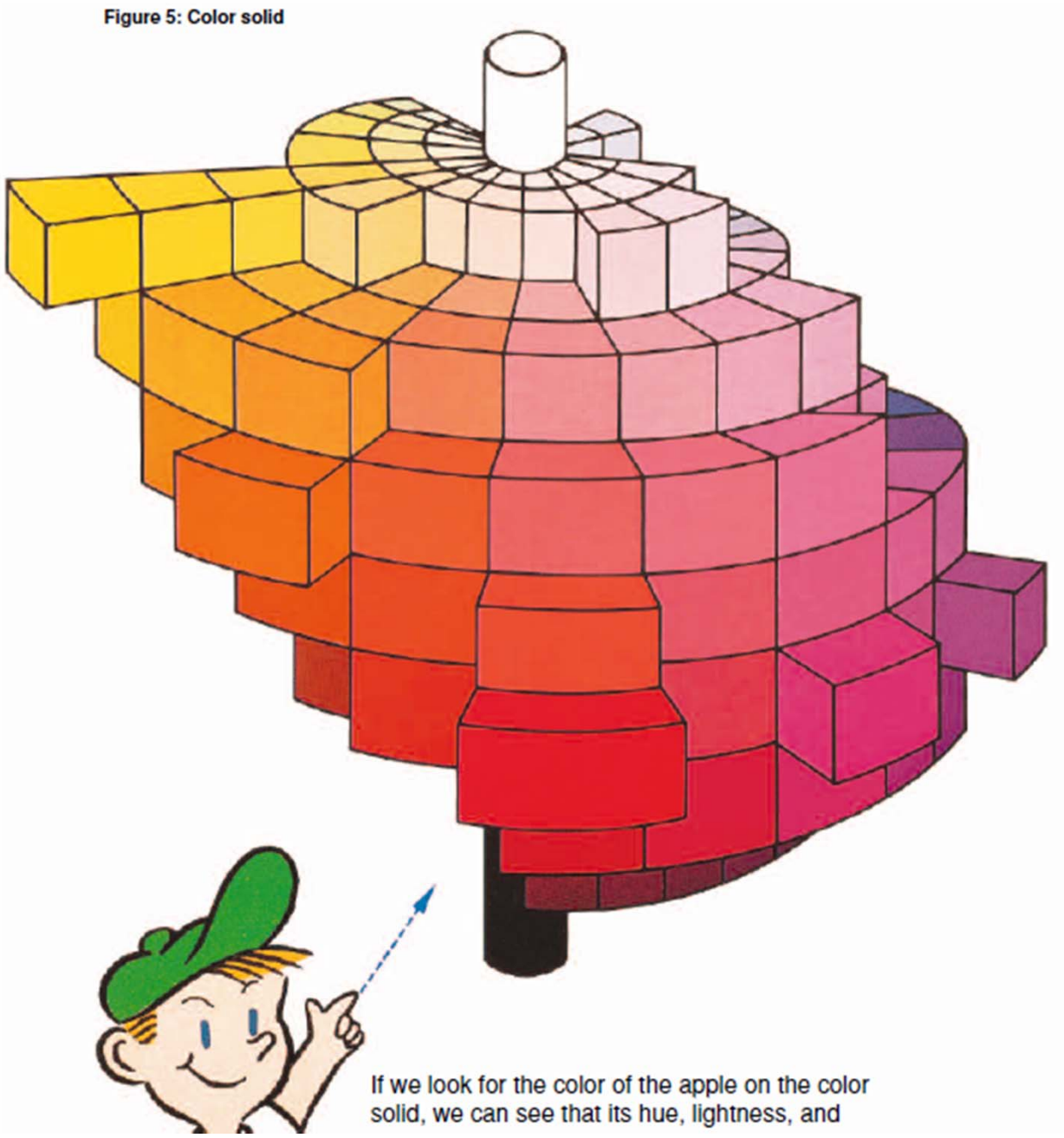


Figure 5: Color solid



If we look for the color of the apple on the color solid, we can see that its hue, lightness, and

By creating scales for hue, lightness, and saturation, we can measure color numerically.

achromatic; as the a* and b* values increase and the point moves out from the center, the saturation of the color increases. Figure 10 is a representation of the color solid for the L*a*b* color space; Figure 8 is a view of this solid cut horizontally at a constant L* value. If we measure the apple using the L*a*b* color space, we obtain the following values. To see what color these values represent, let's first plot the a* and b* values (a*=+47.63, b*=+l4.l2) on the a*, b* diagram in Figure 8 to obtain point Ⓐ, which shows the chromaticity of the apple.

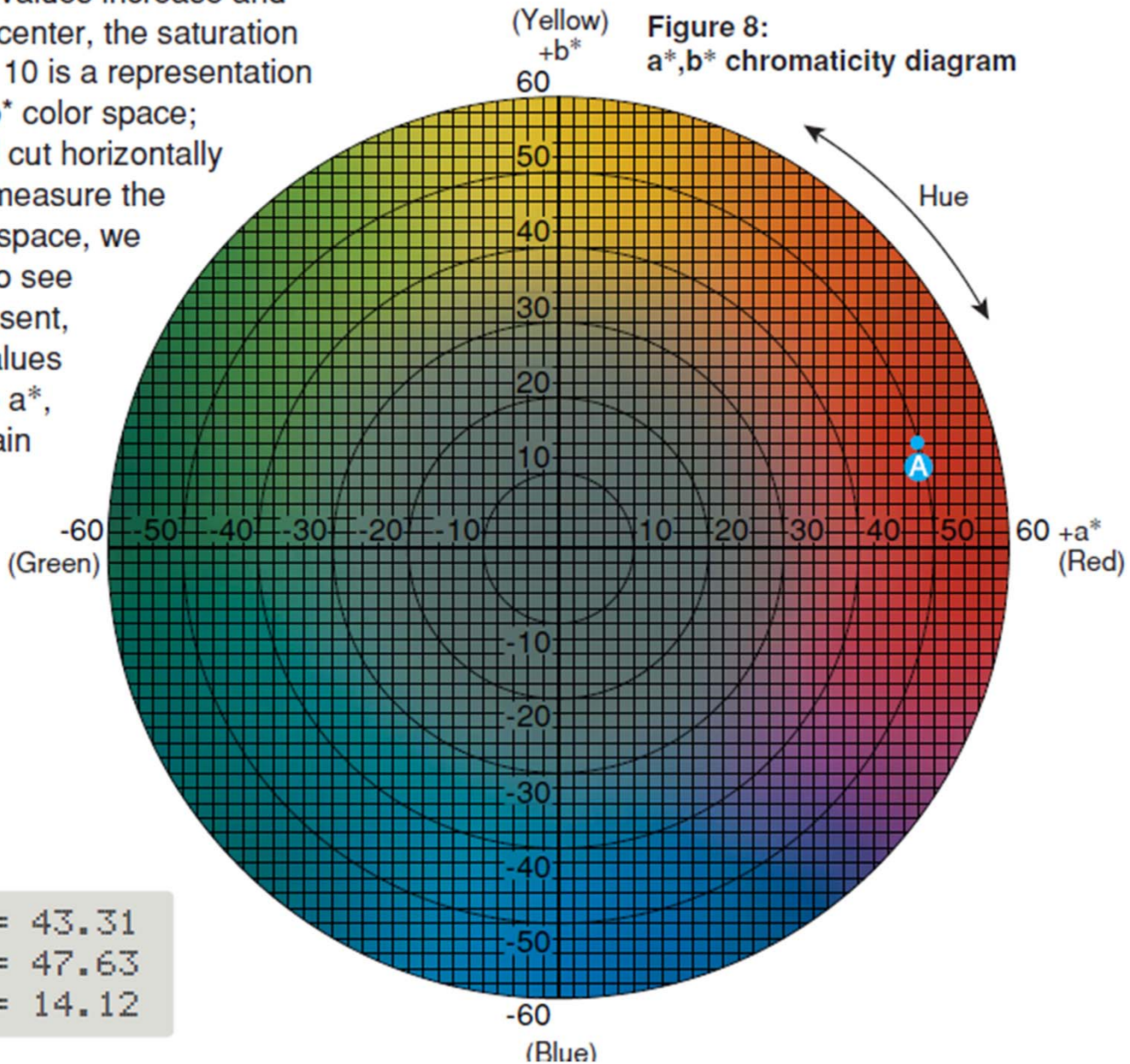
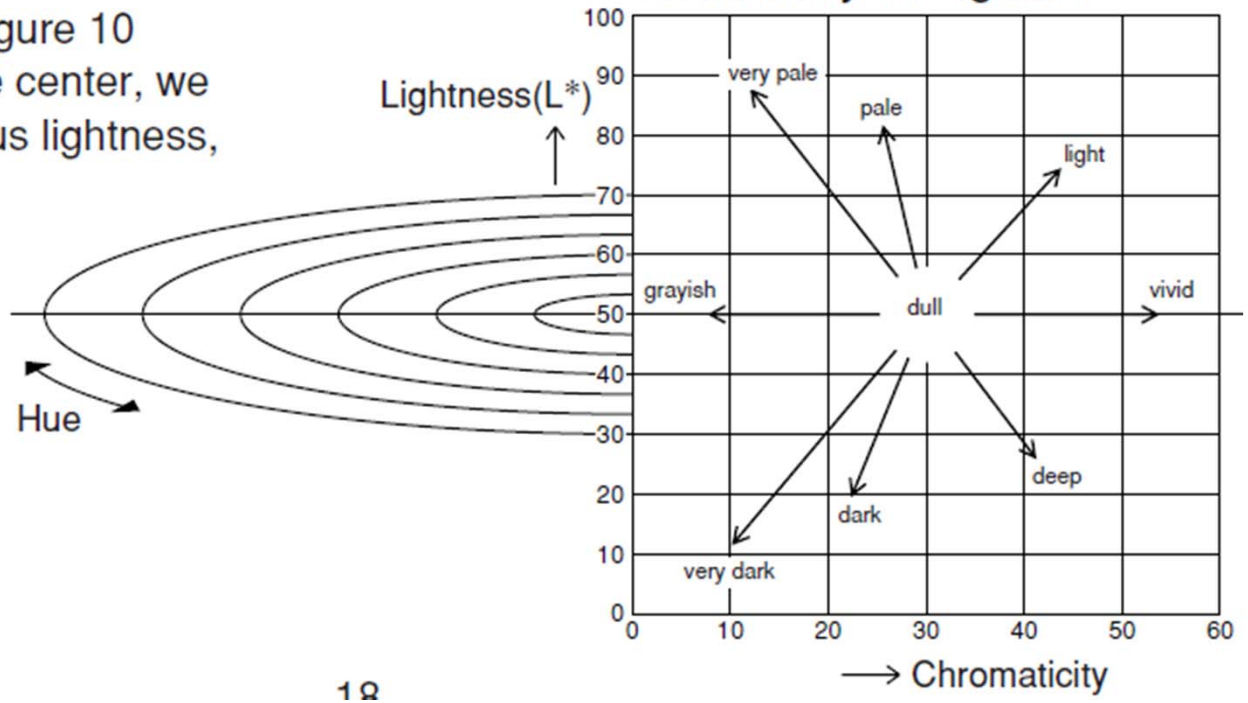


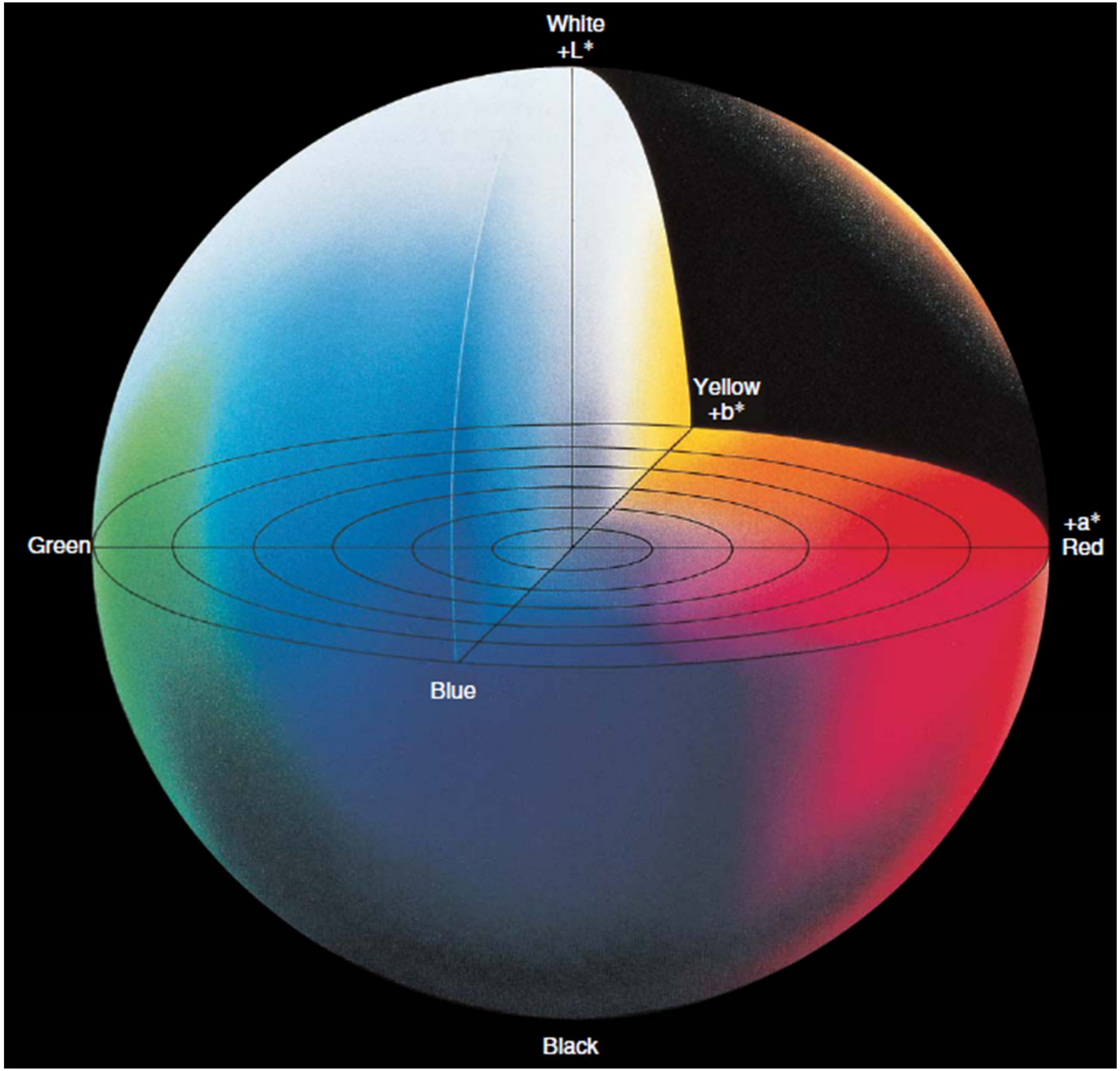
Figure 8:
a*,b* chromaticity diagram

L*= 43.31
a*= 47.63
b*= 14.12

Now, if we cut the color solid of Figure 10 vertically through pointt Ⓐ and the center, we obtain a view of chromaticity versus lightness, part of which is shown in Figure 9.

Figure 9:
Chromaticity and lightness




White
+L*
Yellow
+b*
Green
+a*
Red
Blue
Black

coordinates instead of rectangular coordinates. In this color space, L* indicates lightness and is the same as the L* of the L*a*b* color space, C* is chroma, and h is the hue angle. The value of chroma C* is 0 at the center and increases according to the distance from the center. Hue angle h is defined as starting at the +a* axis and is expressed in degrees; 0° would be +a* (red), 90° would be +b* (yellow), 180° would be -a* (green), and 270° would b* (blue). If we measure the apple using the L*C*h color space, we get the results shown below. If we plot these values on Figure 11, we obtain point Ⓐ.

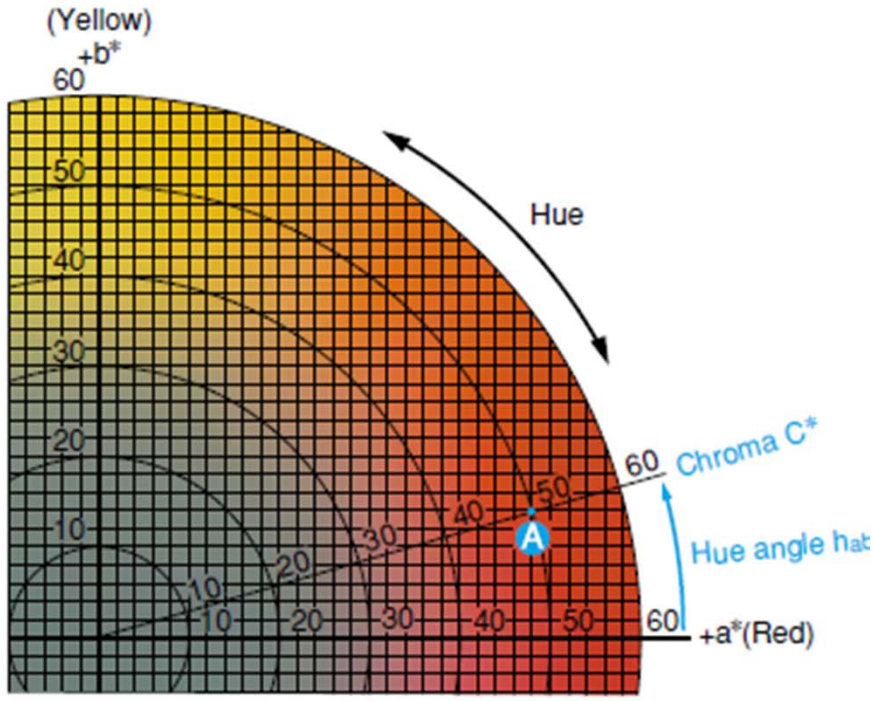
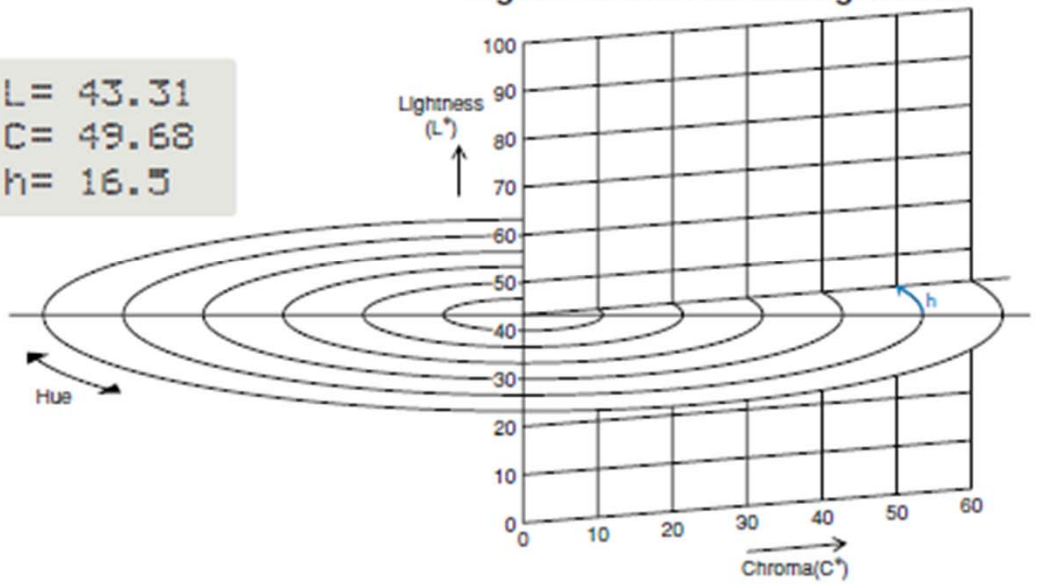


Figure 12: Chroma and lightness

$$\text{Chroma } C^* = \sqrt{(a^*)^2 + (b^*)^2}$$

$$\text{Hue angle } h_{ab} = \tan^{-1}\left\{\frac{a^*}{b^*}\right\}$$

L= 43.31
C= 49.68
h= 16.5



Colorimeters excel at reporting even minute color differences.

Apple❶

Apple❷

anywhere that color is used. But with a colorimeter, even minute color differences can be expressed numerically and easily understood. Let's use the L*a*b* and L*C*h color spaces to look at the color difference between two apples. Using apple ❶'s color (L*=43.31, a*=+47.63, b*=+14.12) as the standard, if we measure the difference of apple ❷'s color (L*=47.34, a*=+44.58, b*=+15.16) from apple ❶'s color, we get the results shown in display A below. The difference is also shown on the graph in Figure 14.

A:L*a*b* color difference

```
ΔL*= +4.03
Δa*= -3.05
Δb*= +1.04
ΔE*=  5.16
```

B:L*C*h* color difference

```
ΔL*= +4.03
ΔC*= -2.59
ΔH*= +1.92
ΔE*=  5.16
```

The diagram of Figure 13 should make color difference in the L*a*b* color spaces easier to understand. In the L*a*b* color space, color difference can be expressed as a single numerical value, ΔE^*_{ab}, which indicates the size of the color difference but not in what way the colors are different. ΔE^*_{ab} is defined by the following equation

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

If we put the values ΔL^*=+4.03, Δa^*=-3.05, and Δb^*=+1.04