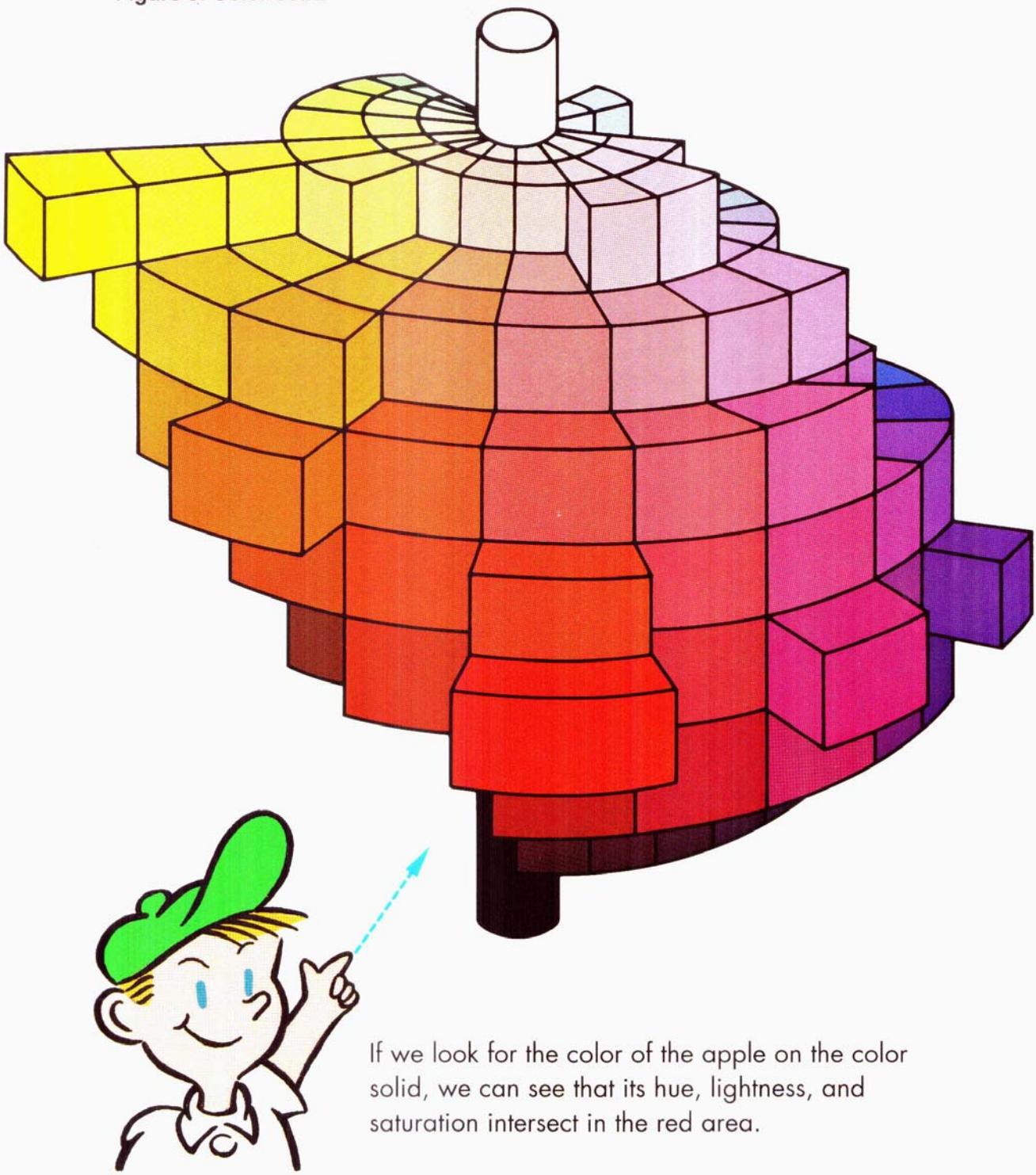
Figure 5: Color solid



If we look for the color of the apple on the color solid, we can see that its hue, lightness, and saturation intersect in the red area.

Let's look at some color spaces.

XYZ tristimulus values and the Yxy color space

XYZ tristimulus values and the associated Yxy color space form the foundation of the present CIE color space. The concept for the XYZ tristimulus values is based on the three-component theory of color vision, which states that the eye possesses receptors for three primary colors (red, green, and blue) and that all colors are seen as mixtures of these three primary colors. The CIE in 1931 defined the Standard Observer to have the color-matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ shown in Figure 6 below. The XYZ tristimulus values are calculated using these Standard Observer color-matching functions.

The tristimulus values XYZ are useful for defining a color, but the results are not easily visualized. Because of this, the CIE also defined a color space in 1931 for graphing color in two dimensions independent of lightness; this is the Yxy color space, in which Y is the lightness (and is identical to tristimulus value Y) and x and y are the chromaticity coordinates calculated from the tristimulus values XYZ (for details, refer to p. 47). The CIE x, y chromaticity diagram for this color space is shown in Figure 7. In this diagram, achromatic colors are toward the center of the diagram, and the chromaticity increases toward the edges. If we measure the apple using the Yxy color space, we obtain the values x=0.4832, y=0.3045 as the chromaticity coordinates, which correspond to point Ⓐ on the diagram in Figure 7; the Y value of 13.37 indicates that the apple has a reflectance of 13.37% (compared to an ideal reflecting diffuser with a reflectance of 100%).

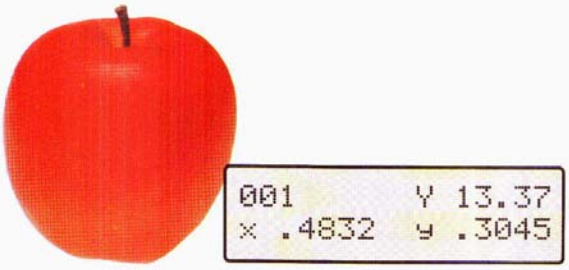


Figure 6:
Spectral sensitivity corresponding to the human eye
(Color-matching functions of the 1931 Standard Observer)

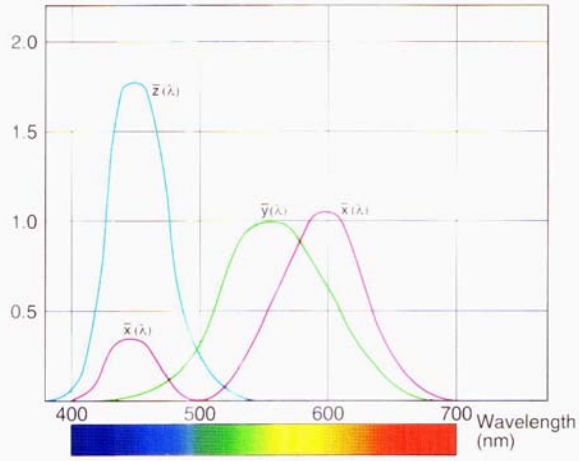
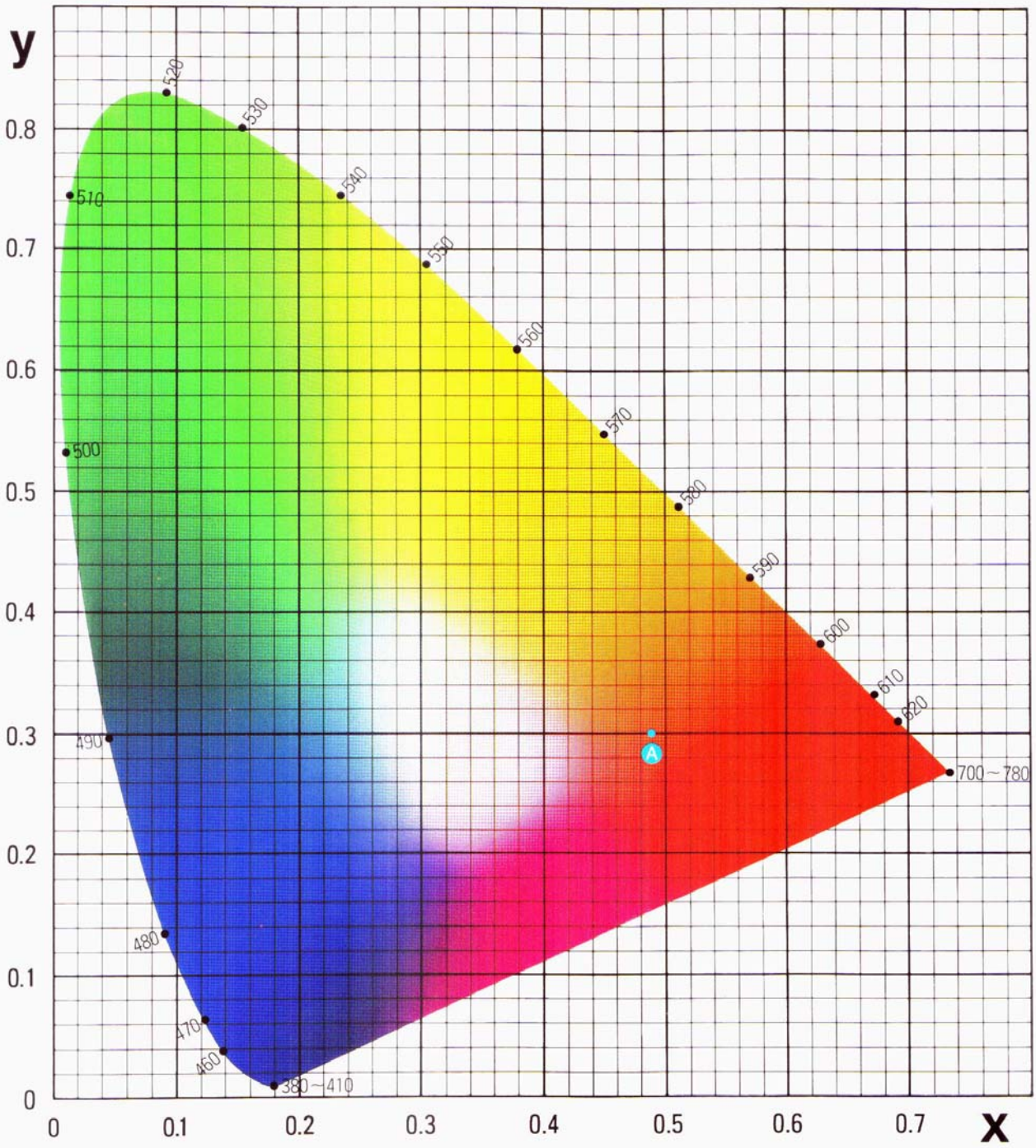


Figure 7: 1931 x, y chromaticity diagram



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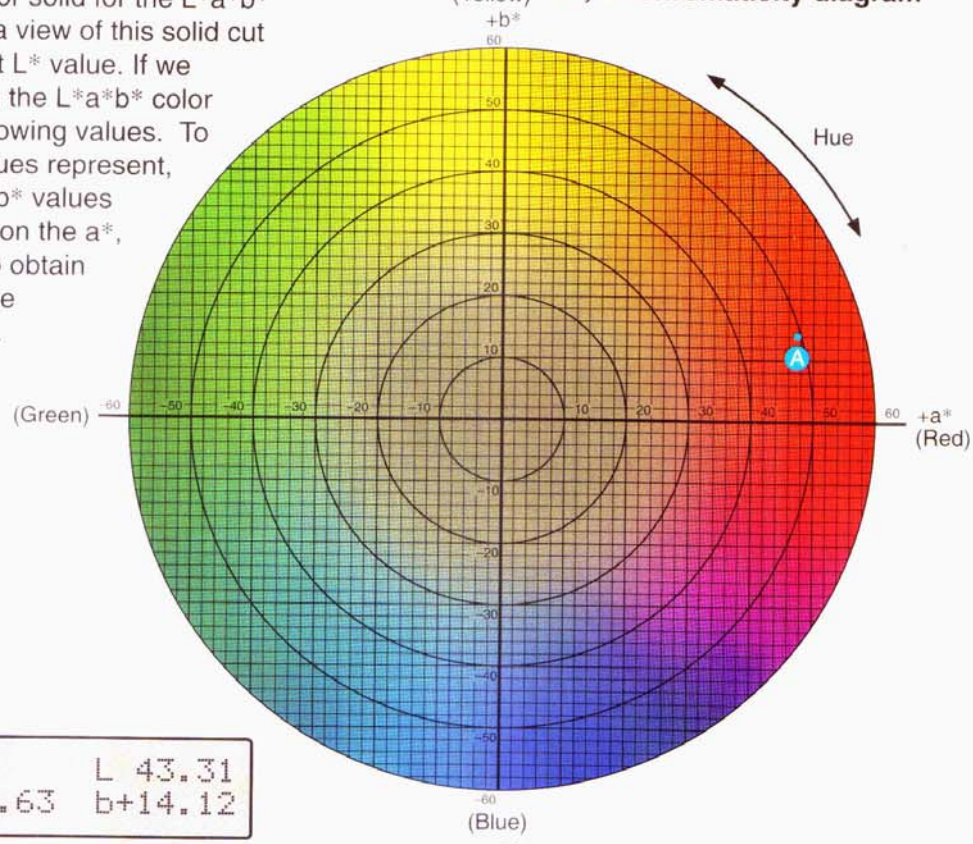
L*a*b* color space

The L*a*b* color space (also referred to as CIELAB) is presently one of the most popular color space for measuring object color and is widely used in virtually all fields. It is one of the uniform color spaces defined by CIE in 1976 in order to reduce one of the major problems of the original Yxy color space: that equal distances on the x, y chromaticity diagram did not correspond to equal perceived color differences. In this color space, L* indicates lightness and a* and b* are the chromaticity coordinates. Figure 8 shows the a*, b* chromaticity diagram. In this diagram, the a* and b* indicate color directions: +a* is the red direction, -a* is the green direction, +b* is the yellow direction, and -b* is the blue direction. The center is 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*=+14.12) on the a*, b* diagram in Figure 8 to obtain point A, which shows the chromaticity of the apple.

Figure 8:
a*, b* chromaticity diagram



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

Figure 9:
Chromaticity and lightness