The simple display screens of watches and calculators use ambient light as the source (you can't see the display in the dark), and a mirror behind the LCD to reflect the light back. There are only a few pixels, corresponding to the elongated segments needed to form the numbers from 0 to 9 (and letters in some displays), as seen in Fig. 24–52. Any pixels to which a voltage is applied appear dark and form part of a number. With no voltage, pixels pass light through the polarizers to the mirror and back out, which forms a bright background to the dark numbers on the display.

Color television and computer LCDs are more sophisticated. A color pixel consists of three cells, or subpixels, each covered with a red, green, or blue filter. Varying brightnesses of these three primary colors can yield almost any natural color. A good-quality screen consists of a million or more pixels, much like the surface of a color CRT monitor (Fig. 17–20). Behind this array of pixels is a light source, often thin fluorescent tubes the diameter of a straw. The light passes through the pixels, or not, depending on the voltage applied to each subpixel, as in Fig. 24–51a and b. See Fig. 24–53.

FIGURE 24–52 Calculator LCD display. The black segments or pixels have a voltage applied to them. Note that the 8 uses all seven segments (pixels), whereas other numbers use fewer.

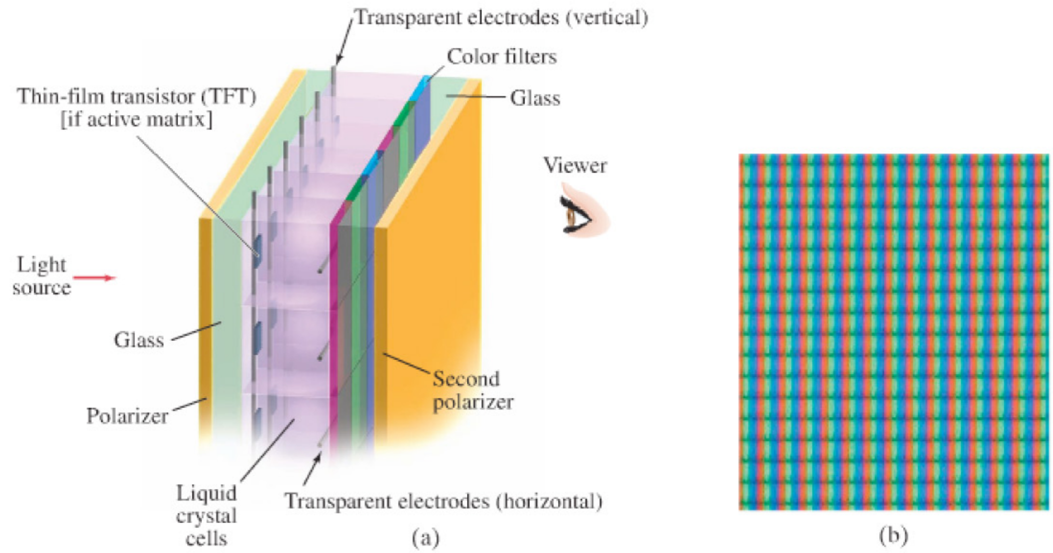

FIGURE 24–53 Basic layer construction for an LCD computer or television screen. Every pixel contains three cells (subpixels), each with a red, green, or blue filter. An active matrix display has thin-film transistors and is more complex.

In a *passive matrix* LCD, a set of vertical and a set of horizontal electrodes carry electric signals to the pixels: two wires, one from each set, "intersect" at each subpixel, and careful electronic timing (called "addressing") turns the voltage there on or off. The signals can affect nearby subpixels, reducing the contrast and quality of the picture. Better pictures are obtained with an *active matrix* LCD which has a *thin-film transistor* (TFT) at each subpixel to accurately control its brightness.

To obtain a range of gray scale or range of color brightness, each subpixel cannot simply go on or off as in Fig. 24–51. Several techniques can be used depending on the construction of the LCD. If the voltage applied in Fig. 24–51b is small enough, the disorientation of the molecules may be small, allowing some rotation of the polarization vector and thus some light can pass through, the actual amount depending on the voltage. Alternatively, each subpixel can be pulsed—the length of time it is *on* affects the perceived brightness. The effect of stronger or weaker brightness can instead be provided by the number of nearby subpixels of the same color that are turned on or off; this type lets the eye "average" over many pixels, but reduces the sharpness or resolution of the picture.