(a)

Artery wall
thickening

Blockage

(b)

FIGURE 10–33 A cross section of a human artery that (a) is healthy, (b) is partly blocked as a result of arteriosclerosis.

different parts of the body. Another aspect is that the radius of arteries is reduced as a result of arteriosclerosis (thickening and hardening of artery walls, Fig. 10–33) and by cholesterol buildup. When this happens, the pressure gradient must be increased to maintain the same flow rate. If the radius is reduced by half, the heart would have to increase the pressure by a factor of about $2^4 = 16$ in order to maintain the same blood-flow rate. The heart must work much harder under these conditions, but usually cannot maintain the original flow rate. Thus, high blood pressure is an indication both that the heart is working harder and that the blood-flow rate is reduced.
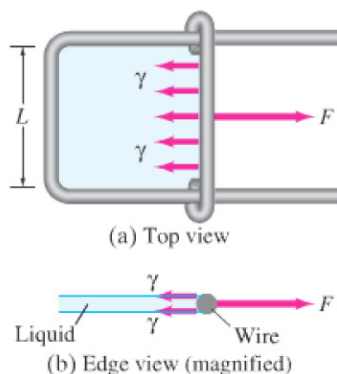
*10–13 Surface Tension and Capillarity
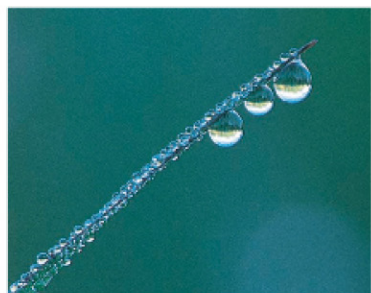
FIGURE 10–34 Spherical water droplets, dew on a blade of grass.

Surface tension

FIGURE 10–35 U-shaped wire apparatus holding a film of liquid to measure surface tension ($\gamma = F/2L$).

(a) Top view

(b) Edge view (magnified)

The *surface* of a liquid at rest behaves in an interesting way, almost as if it were a stretched membrane under tension. For example, a drop of water on the end of a dripping faucet, or hanging from a thin branch in the early morning dew (Fig. 10–34), forms into a nearly spherical shape as if it were a tiny balloon filled with water. A steel needle can be made to float on the surface of water even though it is denser than the water. The surface of a liquid acts like it is under tension, and this tension, acting along the surface, arises from the attractive forces between the molecules. This effect is called **surface tension**. More specifically, a quantity called the *surface tension*, γ (the Greek letter gamma), is defined as the force F per unit length L that acts perpendicular to any line or cut in a liquid surface, tending to pull the surface closed:

$$\gamma = \frac{F}{L}. \qquad \qquad \textbf{(10–10)}$$

To understand this, consider the U-shaped apparatus shown in Fig. 10–35 which encloses a thin film of liquid. Because of surface tension, a force F is required to pull the movable wire and thus increase the surface area of the liquid. The liquid contained by the wire apparatus is a thin film having both a top and a bottom surface. Hence the length of the surface being increased is $2L$, and the surface tension is $\gamma = F/2L$. A delicate apparatus of this type can be used to measure the surface tension of various liquids. The surface tension of water is 0.072 N/m at 20°C. Table 10–4 gives the values for several substances. Note that temperature has a considerable effect on the surface tension.

Because of surface tension, some insects (Fig. 10–36) can walk on water, and objects more dense than water, such as a steel needle, can float on the

FIGURE 10–36 A water strider.