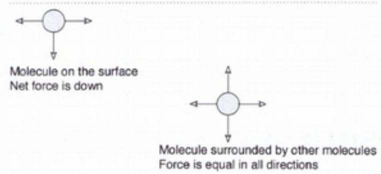

FIGURE 4.1 Surface tension.

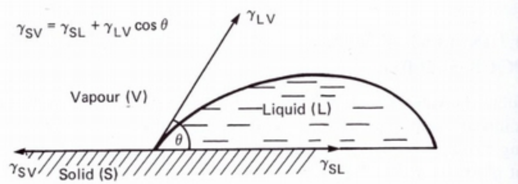

FIGURE 4.2 The forces in a stable drop of liquid on a surface. γ_{SV} is the surface tension of the solid in the presence of the liquid vapour. γ_{SL} is the surface attraction between the solid and the liquid. γ_{LV} is the surface tension of the liquid in the presence of its own vapour.

The molecules in a drop of liquid at the junction with the surface of a solid will be subjected to three forces along the interface (Figure 4.2):

1. The attractive forces acting from within the liquid itself
2. The attractive forces acting from the surface of the solid with the vapour above it
3. The attractive force between the liquid and the solid.

If the liquid molecules are much more attracted to each other than they are to the solid – such as water on polyethene – they will ball up to form droplets sitting on the surface. This preference can be measured by the angle, $\theta > 90°$. If the liquid molecules are much more attracted to the solid than they are to each other, the liquid will spread out completely and wet the surface spontaneously, e.g. acetone on clean glass, and θ is 0°. At intermediate values of θ, i.e. between 90° and 0°, the liquid will spread and wet the surface if force is used to expand the drops. It takes energy to stretch the skin and make more surface.

This description of a spreading drop applies only when the surface is absolutely smooth. However, most surfaces contain pores and crevices into which the liquid must flow if complete wetting is to be achieved (Figures 4.3 and 4.4). Air trapped in a pore will oppose the penetration of the liquid. If the air has time to diffuse out of the hole before the adhesive sets, the penetration will be deeper. This is one cause for the increasing adhesion of self-adhesive tapes with time, since the adhesives used remain liquid. A consolidant or adhesive used in conservation should be given time to penetrate before it hardens. A low-viscosity liquid is obviously more likely to flow readily into the pores.

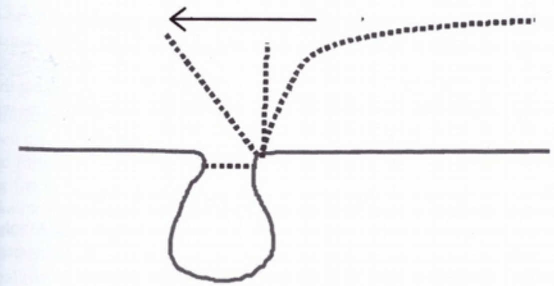

FIGURE 4.3 The flow of a liquid over a surface impeded by a hole. When the liquid (flowing from right to left) reaches the hole, the contact angle with the surface increases rapidly. In order for the liquid to flow and wet the surface, it has to accommodate the increased contact angle, which takes time and energy. The liquid may not flow into the crevice but bridge to the other side, so creating an area of no adhesion – a weak point. The trapped air can also prevent the liquid flowing into the crevice.

FIGURE 4.4 Time, choice of a suitable viscosity and curing time enable the flow of a liquid adhesive into the interstices of a substrate and the flow of air away from the pores in the interface. This increases mechanical interlocking of the adhesive with the adherend, the difficulty of reversing the joint and removing the adhesive. *Adapted from Pocius (2002).*

The liquid adhesives used in conservation have low surface energies, below 10^{-5} N/m. Hard solids such as dry glass or metals have much higher energies, 5×10^{-5} to 10^{-3} N/m, and are termed high-energy surfaces (Zisman, 1977). A low-energy liquid will spread and wet a high-energy solid. Therefore, initial wetting and adhesion is rarely a problem with these materials, provided the surface is free of contaminants. It is likely that the adhesive force in the majority of instances is derived from the physical attractive forces of dispersion, dipolar and hydrogen bonding described in Section 3.2.

The wetting description above implies that a polymer in solution should spread easily over a flat surface, although it may need mechanical assistance and/or time to achieve good coverage over a real object surface. There are two types of situation where this does not occur. The first is when the object surface has been contaminated by a layer of detergent, fatty acid or alcohol. The polar part of the molecules stick to the polar surface, leaving the hydrocarbon ends of the molecules sticking up. These act like a layer of wax on the surface and so repel most solvents. This is the reason that strong alkalis are used to clean glass milk bottles, in order to strip these organic molecules off the surface.