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On the Definition of Hydrophobicity, Conditions for Porosity and the Attachment of Hydrophobic Particles to the Surface of Water

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Teflon® is usually regarded as the classic example of what is meant by a hydrophobic surface. However, it has recently been argued on the basis of experimental data that hydrophobic solids can have a significant attraction to the surface of water and, in that sense, could be regarded as relatively hydrophilic. The meaning of the terms "hydrophobic" and "hydrophilic" differ between subject fields, but in surface science they are related to concepts of wetting. Understanding why a solid surface commonly described as "hydrophobic" (i.e. water-fearing) can behave in a "hydrophilic" (i.e. water-liking) manner is important in understanding the conditions under which water will penetrate a granular material, such as a sandy soil, or will collect and transport away the grains of the material thus eroding the surface. In this work, we clarify what is meant by hydrophobic and hydrophilic and show why these terms often do not simply indicate surface chemistry, but can include assumptions about the relative orientation of surfaces, and surface rigidity and topography. We will show why a contact angle below 90 degrees, commonly referred to as hydrophilic, does not necessarily result in water penetration into a fixed bed of solid grains. We will also describe a key experiment showing that when smooth solid films of Teflon® are contacted by a droplet of water, the solid quasi-instantaneously wraps around the droplet. This effect can be understood as a direct consequence of the attempt of the solid-water-air interfaces to minimize surface free energy, but with the usual restriction of a rigid solid substrate relaxed; this wrapping is energetically favored for all solids which have a Young's law contact angle less than 180 degrees. In this sense, we argue, all solids can be regarded as absolutely hydrophilic (to some extent) and that a contact angle of 90 degrees does not provide a simple classification of the transition from hydrophilic to hydrophobic tendencies unless roughness is taken into account in a Wenzel manner. When the energy stored in bending the solid is infinite, so that the substrate is completely rigid, droplet wrapping cannot occur. This is the usual situation under which a surface free energy derivation of Young's law is performed and represents the extreme case that a droplet placed on a solid spreads to a partial or full wetting shape whilst the solid retains its shape without distortion. Thus, Young's law does not simply represent the effect of the surface chemistry, but also includes an implicit assumption about the rigidity of the solid. Hydrophobic soil often appears loose and fluffy with grains that are not fixed. Thus, hydrophobic soil provides a surface which can respond and rearrange on contact by a droplet of water. We show that this situation is an extreme case of droplet wrapping and that contacting such a surface with a droplet of water leads to grains attaching themselves to the droplet. The extreme case is that a droplet can becomes encased in a layer of grains (i.e. a liquid marble) and can become highly mobile with consequences for both water penetration and erosion.