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## 50 YEARS AGO

The resemblance between the X-ray photographs of *B8* and those of tobacco mosaic virus may perhaps appear rather slender. However, the strong similarity between *B8* and tobacco mosaic virus protein in other respects (immunochemical cross-reactions, size of the basic chemical unit, and diameter of the rod-shaped particles) makes it very probable that a close structural relationship exists...

If we are right in thinking that the structure of *B8* is closely related to that of tobacco mosaic virus protein, then considerable importance must be attached to the reversal of the sign of birefringence in *B8*. We must conclude that the ribonucleic acid makes a positive contribution to the birefringence of tobacco mosaic virus, and hence that the purine and pyrimidine rings are aligned approximately parallel to the axis of the particle. If the ribonucleic acid in tobacco mosaic virus forms a central core... it follows that its structure must differ considerably from the structure of deoxyribonucleic acid described by Crick and Watson. **Rosalind E. Franklin**

From *Nature* 18 June 1955.

## 100 YEARS AGO

"The Inheritance of Acquired Characters." Is the following an instance of such inheritance? Lately I heard a missionary at a May meeting tell of the marvellous facility with which Chinese children memorise whole books of the Bible; the four Gospels, and sometimes the Acts also, being an easy feat for children of ten or twelve years. Having carefully sought information from other authorities, I find these facts confirmed, and that the same applies to Mohammedan children. We are aware that for ages their ancestors have been compelled to memorise long portions of their sacred books, and although occasionally we meet with a child of any nation with a gigantic memory, that differs widely from the case of a people where it has become a general characteristic.

From *Nature* 15 June 1905.

50 & 100 YEARS AGO

atomic dimensions — the sort of ideal characteristics for which the theory was intended.

Unfortunately, most bodies and surfaces are far from ideal, and both elastic (especially viscoelastic or plastic) properties and surface roughness can affect adhesion and friction. In the case of polymer surfaces, the adhesion force can be many orders of magnitude higher than the JKR value; for hard, rough surfaces, it can be many orders of magnitude lower. Hence the need for more refined theories. In addition, there is growing interest in contacts with nearly atomic dimensions, for example in microelectromechanical systems that often fail because of undesired adhesion.

Luan and Robbins[1] used molecular simulations to compare the atomic-scale behaviour of deformations, local stresses, adhesion and friction with that predicted by continuum theories. They considered three types of curved surface: a bent crystal lattice, or atomically smooth surface; an amorphous, randomly rough material with a curved, randomly rough surface; and a stepped surface whose steps are cut from a crystal lattice to produce a macroscopically curved surface (see Fig. 1 on page 929). All had the same average radius of curvature with root-mean-square deviations of less than an atomic diameter, yet the small differences in surface structure led to dramatic changes in behaviour.

A particularly important implication of this work is that the commonly used term 'surface roughness' can hide a multitude of effects. Surface bumps (asperities) can be regular (periodic, such as a sine wave) or irregular (random), and both can have a range of horizontal and vertical length scales. A perfect lattice is periodic, but so is a surface that has been nano- or micromachined to have a regular array of holes or channels. Two such periodic surfaces may be commensurate (when the hills and valleys on opposite surfaces match) or incommensurate (when they don't match). All of these effects, the authors found, can produce very different deformations and forces, even when the 'roughness', as defined in the conventional way in terms of the root-mean-square amplitude (Fig. 1), is the same.

Luan and Robbins observed that, for atomically smooth surfaces, the Hertz and JKR theories work well when describing the macroscopic contact area as a function of load, and the stress distribution within that contact. But both the rough and stepped surfaces showed large fluctuations in the local pressures or stresses and greatly reduced adhesion forces $F$ compared with the JKR prediction. The stepped surface had the largest deviations from continuum behaviour, showing sharp discontinuities in the contact area with load. The friction forces were even more sensitive to surface structure, as previously found experimentally[5], with rough and incommensurate surfaces having very low friction.

These results[1] have both fundamental and practical implications. On the fundamental side, they show that mean field theories, in which properties such as surface roughness or texture are averaged or smeared out, are doomed to grossly oversimplify the real situation. On the practical side, they show how surfaces might be tailored to interact in desirable ways, but only if the atomic-scale details are taken into consideration. In this regard, the results bear out what has long been known in biology: fine details often determine macroscopic behaviour. For example, the precise primary sequence of amino acids determines protein folding and so a protein's properties.

There is much still to do before the physical interactions between 'real' surfaces are fully understood. First, the asperities on most surfaces have a complex hierarchy of length scales from the atomic to the macroscopic; Luan and Robbins considered only a narrow class of these, namely atomic-scale asperities. The relative roles of stiffness and adhesion are believed to depend on the detailed shapes of surface bumps. Second, they considered only the limit at which stiffness dominates over adhesion, so that deformations remained relatively small, as for hard crystalline surfaces such as metals and ceramics. In contrast, soft polymeric and biological surfaces often deform into full contact by adhesive forces. And finally, non-equilibrium and rate-dependent effects often determine how real surfaces interact in 'real time'. These interactions include rate-dependent friction and lubrication forces. The results of Luan and Robbins are illuminating — they have just skimmed the surface of this complex class of phenomena, but indicate just how rich the behaviour can be. ■

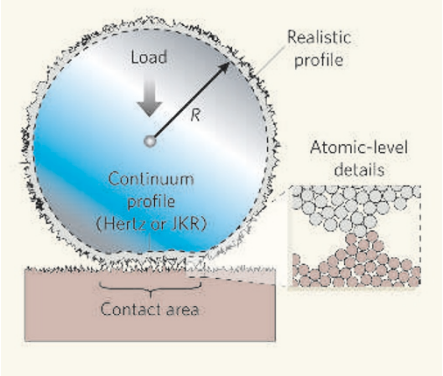


**Figure 1 | Forms of mechanical contact.** Continuum theories (dashed black circle of radius $R$) predict the average macroscopic profiles of adhesive (JKR) or non-adhesive (hertzian) contacts when two surfaces are pressed together by a load. In their study, Luan and Robbins[1] also use a realistic profile that preserves the underlying atomic-scale surface structure of the material. This inherent roughness (represented by a root-mean-square roughness) determines the macroscopic adhesion and friction forces.

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