in the germ line is not sufficient to produce a simple dominant phenotype. Rather, additional rare changes seem to be required for the oncogene to produce tumours. This has similarities to the evolving view of naturally-occurring cancers[11,15], where multiple events are most probably necessary to create the dominance that converts a normal cell into a tumour cell, and to explain the slow onset of transformation.

The production of transgenic mice harbouring new oncogenes requires that such genes do not perturb prenatal development. The work of Müller and Wagner[16] nicely suggests that not all oncogenes do affect differentiation. They have transferred the *fos* proto-oncogene into F9 embryonal carcinoma cells, where it induces characteristic terminal differentiation.

F9 cells were originally established from a teratocarcinoma and have many qualities in common with cells of the early mouse embryo, as demonstrated by their ability to form aggregation chimaeras with normal embryo cells and their representation in somatic tissues of mice that develop from the chimaera. F9 cells can be induced by the combination of retinoic acid and dibutyryl cyclic AMP to undergo a series of alterations, resulting in epithelial-like cells that cease to divide and show many characteristics of authentic endoderm tissue[17].

The c-*fos* gene, the cellular homologue of an oncogene (v-*fos*) found in several acute transforming viruses, produces a nuclear phosphoprotein[18] that is expressed at very high levels in extra-embryonic tissues, especially amnion and visceral yolk sac[19]. When F9 cells are cotransfected with c-*fos* and an unlinked neomycin gene, which confers resistance to the drug G418, two classes of drug-resistant colonies arise. One consists of proliferating cells with normal F9 morphology. The other comprises enlarged, flat cells that assume an epithelial morphology and cease to proliferate. The flat cell colonies contain high levels of c-fos DNA, mRNA and protein.

The morphologically-altered cells develop an ordered array of intermediate filaments that carry several antigens characteristic of endoderm tissue. However, these cells do not produce either laminin or $\alpha$-fetoprotein, which are found associated with parietal and visceral endoderm, respectively. Fibronectin and type IV collagen are both detected in these cells — collagen is normally present in endoderm, while fibronectin is not. In contrast, retinoic acid induces the production of the intermediate filament network and type IV collagen, as well as either laminin or $\alpha$-fetoprotein, but not fibronectin. Thus, the introduction and expression of the c-*fos* gene results in specific changes that are distinguishable from those resulting from chemical induction. The ability to induce events characteristic of differentiation through the expression of a single transferred gene provides new opportunities for studying the role of gene expression (and its regulation) in some of the specific changes that are involved in complex this differentiation pathway. □

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**Surface chemistry**

# Removing the black magic

*from J.B. Pendry*

MUCH of our chemical industry would not be economic without the presence of a catalyst, acting to short circuit energy barriers to the desired transmutation of one species of organic molecule into another and to discriminate against unwanted products. Frequently, the organic reactants are adsorbed on the surface of finely divided particles of a catalytic transition metal, the complex electronic structure of which offers a variety of possibilities for bonding, thus facilitating rearrangement of the reacting species. The key to understanding the catalyst's function lies in the configuration of the reactant molecules at the surface — that is in their crystallography. So thin and delicate is the monolayer of reactants that it is far from trivial to determine their crystallographic structure. It has only been in the last decade that surface crystallography can be said to have existed. At the International Conference on the Structure of Surfaces, 13-16 August, in Berkeley, California, Roland Koestner, Michel Van Hove and Gabor Somorjai of the university there, reported a major advance in crystallographic sophistication.

Apart from the detailed location of the hydrogen atoms, the Berkeley group was able to solve the complete crystallographic structure of hydrocarbon monolayers on platinum and rhodium surfaces formed by the adsorption of $C_nH_{2n}$, where n varies from 2 to 4. A great variety of structures form under different conditions. For example, it is possible to persuade one of the terminal carbon atoms to discard its hydrogen atoms in favour of bonding to the metal surface, settling into a three-fold hollow site available on the (III) single crystal surface used in the experiment. Some of the hydrogens are claimed by the unsaturated bonds further down the chain, forming the alkylidyne species $M_3C-(CH_2)_{n-1}-H$, which stands as close to vertical to the surface as the crooked C-C-C bond angle will allow ($M_3$ represents the three surface atoms to which the terminal carbon bonds).

For propylidyne and butylidyne species, a further wrinkle to the structure was untangled. The crooked bond angles mean that $C-CH_2-CH_3$ adopts a configuration in which the $C-CH_2$ bond is perpendicular to the surface, whilst the $CH_2-CH_3$ bond points in some direction away from the surface. At low coverages and high temperatures this arm swings around in a random manner, but at higher coverages and lower temperatures free rotation is prevented by interaction with neighbours and an ordered structure results with the arms neatly folded into an ordered structure.

How was the Berkeley group able to make such precise statements about the surface crystallography? As with most surface experiments, several techniques were employed to cross check conclusions, but the most important was low energy electron diffraction. Electrons with energies around 150 eV have a wavelength of around 1 Å, like X rays. Unlike X rays, they interact strongly with matter giving good surface sensitivity. To obtain structural information from their diffraction patterns, a sophisticated theoretical interpretation is necessitated but the Berkeley group has achieved a level of sophistication that had been thought impossible. For butylidyne on platinum, with a $(2\sqrt{3} \times 2\sqrt{3})$ R30° unit surface cell, the coordinates of about 50 atoms had to be correctly included to an accuracy of about 0.1 Å

Just as the journey from the original application of X rays to the structure of DNA was a long and difficult one, so there is a great contrast between the early determinations of coordinates for single atoms at surfaces, and the present work, although even butylidene on platinum falls short of the complexity of DNA. New possibilities for studying complex systems are opened. In particular we are brought closer to an atomistic understanding of how reactions proceed at surfaces, which help to make the evolution of new higher yielding catalysts more a matter of the science of design than the black magic of trial and error. □

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