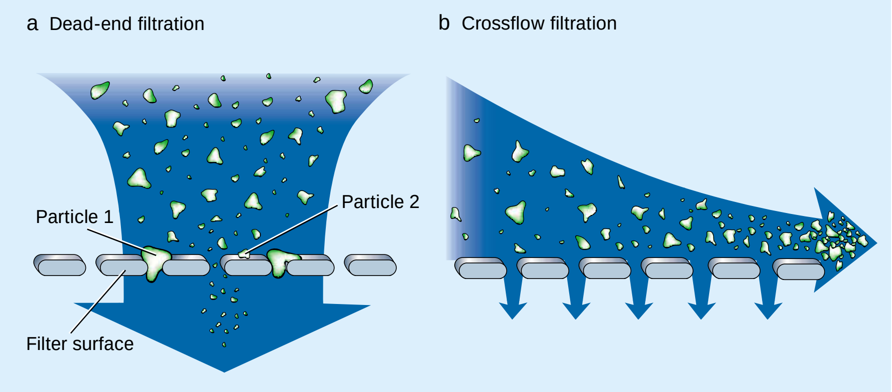

Figure 2 **Dead-end and crossflow filtration.** a, **In dead-end filtration, fluid flow is perpendicular to the filter surface and the filter rapidly becomes clogged with particles. Particles may be retained by sieving when they are larger than the filter's pore size (particle 1), or by hydrosol filtration[4] when they are smaller than the pore size (particle 2); in this case, the small particles stick to the elements of the filter.** b, **In crossflow filtration, fluid flows parallel to the filter surface and particles become more concentrated as filtrate leaves through the filter's pores.**

flow filtration in suspension-feeding fishes.

Results from studies of suspension feeding have broad implications for ecological studies of freshwater and marine ecosystems[9]. Different suspension-feeding mechanisms select differently sized particles. Only particles larger than the filter pore are retained in a dead-end sieve (Fig. 2a, particle 1), whereas particles smaller than the pore size may be retained in dead-end hydrosol filtration (Fig. 2a, particle 2) or in crossflow filtration (Fig. 2b). The filtering mechanism determines which species and life stages of planktonic organisms are consumed, and this in turn has profound effects on the structure of aquatic populations and communities. The discovery by Sanderson and colleagues[2] of a fundamentally new mechanism of suspension feeding in fishes may contribute to more realistic models of the dynamics of aquatic ecosystems. ■

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Chemistry

How green was my ester

Giorgio Strukul

Hydrogen peroxide is an ideal oxidant. It cannot yet be used widely, because viable catalysts aren't available for many industrially important processes. But there are encouraging indications of progress.

Chemistry has turned green[1,2]. The increased awareness of environmental problems has generated an overly simplistic division, however, especially in the media, between 'bad' chemistry — which first pollutes and then (sometimes) cleans up — and 'good', green chemistry. Chemists themselves are partly responsible for setting up this misleading contrast. But they are nonetheless among the leaders in trying to find less wasteful or damaging ways to handle the planet's resources. A lovely example appears on page 423 of this issue[3], as described by Corma and colleagues.

Environmental protection and economic growth are not necessarily in antithesis, but improved chemical technologies can be needed to combine them. Industrial organic chemistry often involves multistep methods in which the yield of valuable end-product is largely outweighed by the amount of waste that has to be disposed of. The synthesis of complex molecules used as pharmaceutical or agrochemical products may involve up to 10–15 steps and can generate more than 100 kg of waste for each kilogram of end-product. In this respect, the use of catalysts that can simplify stepwise synthetic procedures, or of cleaner reagents, is in principle more environmentally friendly.

The approach reported by Corma and colleagues[3] fits the bill nicely. The authors have produced a new class of catalysts for the Baeyer–Villiger oxidation of ketones. This reaction, shown in Fig. 1a, was first described in 1899 by German chemists Adolf Baeyer and Victor Villiger[4]. It involves the transformation of a ketone into an ester (an organic molecule containing an extra oxygen atom with respect to the parent ketone), using an organic oxidant. Organic chemists have used the reaction for over a century. It is applied in the synthesis of a wide variety of chemicals, ranging from simple monomers used in the plastics industry to the more complex molecules that constitute pharmaceutical or agrochemical products[5]. However, as shown in Fig. 1a, the oxidant (generally an organic peroxy acid) produces waste — and often in larger amounts than the desired esters. So there has long been an interest in finding more environmentally friendly oxidants for this and similar reactions, hydrogen peroxide being the ideal choice.

Hydrogen peroxide, H_2O_2, is familiar because just about every household has a bottle of it, in dilute solution, for use as a disinfectant. Its main industrial applications are in the bleaching of paper, cellulose or textiles, or in making detergents; its applications in the manufacture of organic chemicals are minimal. The great advantage of hydrogen peroxide as a reagent is that it produces water as the waste product, and in small amounts only (Fig. 1b). The problem is that hydrogen peroxide does not react directly with substrates, but needs a catalyst to mediate the reaction. Over the years the search for such catalysts has progressed slowly[6,7], especially so in the case of the Baeyer–Villiger oxidation of ketones, for which the use of catalysts is relatively recent[8]. Unfortunately, the few catalysts capable of promoting hydrogen peroxide oxidation are almost exclusively metal complexes that are soluble in the reaction medium (homogeneous catalysts). These are not desirable for industrial purposes because they require several costly operations to separate the catalyst from the end-products.

Corma *et al.*[3] open a new avenue for exploiting the Baeyer–Villiger process, based on insoluble (heterogeneous) catalysts that can be easily separated from the reaction medium by filtration. These catalysts are derivatives of a particular class of synthetic zeolite to which a metal — tin — has been added (Fig. 2). Zeolites are crystalline materials, many of which can be found in nature, that have a regular array of internal channels. They are composed of oxides of silicon and aluminium, and are similar to clays but with a different structure.

Incorporating tin atoms into the zeolite framework requires a special synthetic

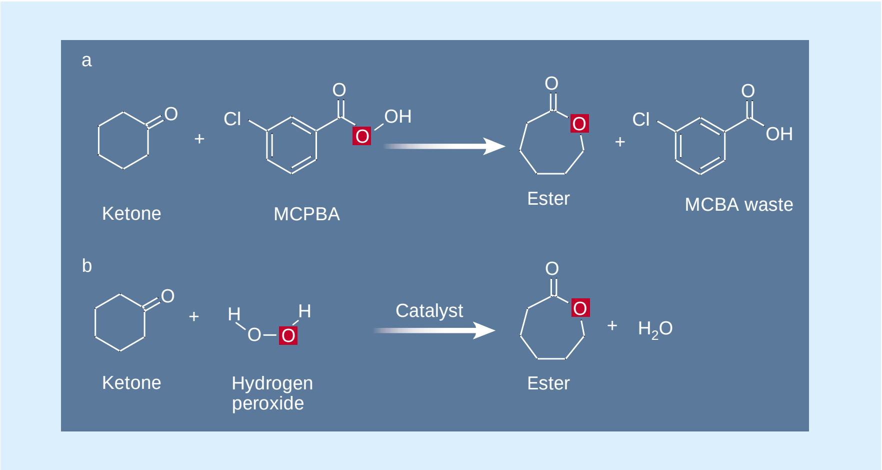

Figure 1 **The Baeyer–Villiger oxidation of ketones.** a, **The conventional oxidation using a common organic oxidant (MCPBA, an organic peroxy acid). The reduced form of the oxidant (MCBA, an organic acid), is the waste product of this reaction.** b, **The same reaction, but using the zeolite catalyst of Corma *et al.*[3] and hydrogen peroxide as the oxidant. Only a small amount of water is produced as waste.**

procedure[3]. The tin centre is responsible for the activation of the ketone substrate and increases its reactivity in being oxidized by hydrogen peroxide. The new catalysts have exceptional selectivity. In the oxidation of complex ketones containing other, potentially oxidizable, functional groups, they oxidize only the ketone group — that is, they perform Baeyer–Villiger oxidation. The catalysts are insoluble in water and in all organic solvents, and the reaction occurs at the interface between the solid catalyst and the liquid solution. At the end of the reaction, the catalyst can be removed and reused.

The catalysts devised by Corma *et al.* have been shown to work under laboratory conditions only, and moving from the production of just a few milligrams of ester to an industrial scale will not necessarily be straightforward. The catalysts will have to be synthesized in large quantities, their activity and lifetime will have to be improved, and their capacity to withstand industrial reaction conditions assessed. But they have genuine potential to be of great benefit in 'real world' applications.

Zeolitic materials have already successfully catalysed other oxidation reactions involving hydrogen peroxide as the oxidant. For instance, the Italian company EniChem is using titanium silicalites[9] to produce bulk chemicals such as propylene oxide, caprolactam and phenols. Titanium silicalites are a different class of zeolite, and are perhaps the most innovative oxidation catalysts to have emerged over the past 20 years. Given that background, one can be relatively optimistic about the prospects for the process developed by Corma *et al.* — it may prove to be a powerful tool in matching economic interests with sensible use of the environment. ■

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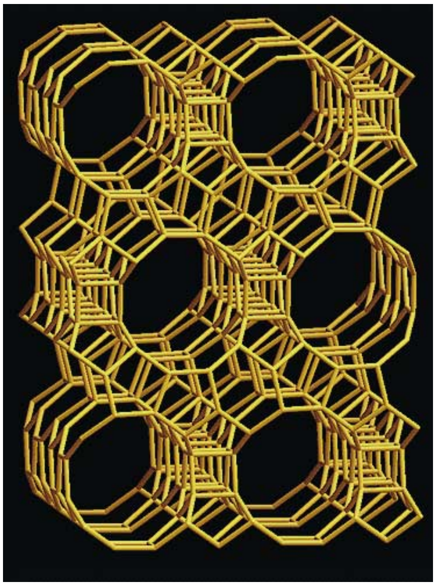

Figure 2 **A β-type zeolite of the form used by Corma *et al.*[3]. This view of the silicon- and aluminium-oxide framework shows the array of internal channels in which catalysis takes place. In synthesizing the new catalysts, tin is substituted for some of the silicon or aluminium atoms facing the channel, and so is incorporated into the framework. Tin centres are responsible for the catalytic activity of these materials. (Reproduced from ref. 10.)**

Neurobiology

Feeling bumps and holes

J. Randall Flanagan and Susan J. Lederman

We use our hands as well as our eyes to perceive physical objects. New insight into how our hands feel a surface may have implications for developing virtual-reality tools such as training devices for surgeons.

We can use our hands not only to manipulate the physical world, but also to perceive it. Using our hands to perceive the shape of an object often involves running the fingertips over the object's surface. During such 'active touch', we obtain both geometric and force cues about the object's shape: geometric cues are related to the path taken by the fingertips, and force cues to the contact forces exerted by the object on the fingertips. These cues are highly correlated, and it is difficult to determine the contribution of each to perception. On page 445 of this issue[1], however, Robles-De-La-Torre and Hayward describe an ingenious experiment in which they used a robotic device to uncouple force from geometric information. In a task involving the detection of bumps and holes, they show that force cues — not geometric cues — determine perceived shape. The result has implications for virtual-reality applications, and may lead to new insights into how our perceptions of shape are built up from sensory signals obtained during active touch.

The use of one's hands to perceive the physical world is known as 'haptic perception'. As a perceptual organ, the hand has several advantages over the eye: the hand can effectively 'see' around corners and can directly detect object properties such as hardness, temperature and weight. During active touch, the perceptual and motor functions of the hand are tightly linked, and people tailor their hand movements to the information they wish to extract[2]. Whereas 'local' information about the object, at the fingertip's point of contact, can be extracted simply by touching the surface[3,4], more global features can be determined either by