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special feature

technology : Natural mimics

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Many useful materials and structures in technology feature regular patterns. A computer monitor screen, for example, contains a regular grid of tiny phosphor dots that glow when struck by a beam of electrons. Behind the dots is a mesh that shields each dot from the electrons intended for its neighbours. And deep within the computer's circuitry are electronic components arranged regularly on a chip, which serve as the 'working memory' of the machine.

Each individual element of these patterned arrays has been painstakingly put in place one by one: every hole in the mesh was punched out separately. But as technological devices and structures get smaller -- for example, as chip circuitry is miniaturized -- making patterns in this way becomes fiddly and difficult, and therefore expensive.

Nature too has regular grids of holes and dots: the mesh of a diatom shell, for example (see first article) and the light-sensitive blobs of an insect's compound eye. Some of the scales tiling a butterfly's wings are lined with microscopic ridges, which scatter light and give the wing a coloured, iridescent appearance. These patterns are not made by laborious machining: they assemble themselves. Technologists are eager to learn some of nature's tricks to develop cheap and easy microscopic patterning methods.

The benefits of a regular pattern are well known in the petrochemicals industry. Natural minerals called zeolites have atomic-scale frameworks in which atoms of aluminium, silicon and oxygen are arranged into scaffolds, laced with tunnels and pitted with cavities. These openings form regular grids with holes that are just the right size to admit individual hydrocarbon molecules into the warren. Once inside, the molecules react with the mineral walls, which break the molecules apart or rearrange their atoms. So zeolites are used as 'molecular sieves': if the hydrocarbons fit into the channels, they are converted, whereas if they are too big they are left intact. This kind of selective conversion is used to boost the octane rating of petroleum fuels.

Since the 1930s, chemical engineers have devised ways of extending the range of tunnel patterns -- their shapes, sizes and how they are interconnected -- in synthetic zeolites. In the 1960s they discovered that

small organic molecules called 'surfactants' act as templates, around which the patterned mineral can crystallize. A templated synthetic zeolite called ZSM-5 is now one of the most important zeolite catalysts in the petrochemicals business.

The pores of conventional zeolites match the sizes of small molecules. In the 1990s a team at the Mobil Research Laboratories in New Jersey discovered a way to scale up the templating process to make patterned porous solids with larger (but still regular) pores. They use surfactants that assemble themselves into aggregates, and these aggregates (rather than the individual molecules) then act as templates. The surfactant aggregates pack into an orderly array, rather like a raft of bubbles, and the researchers deposit silica in the spaces in between, creating a honeycomb structure.

This procedure has clear similarities to the way that marine organisms like radiolarians make their patterned shells (see first article) by templating them on bubble-like structures. The pores in the Mobil material are about ten times wider than those in normal zeolites, and they are being investigated as selective catalysts to convert large molecules. These materials could also serve as straightforward sieves, separating molecules of different sizes.

But some researchers want a regular array of even larger pores. A thin film of a material peppered with pores about one micrometre (millionth of a metre) in size could act as a filter to separate cells (such as bacteria) from water. It could also find a more exotic use: as a material that will capture and confine light.

During the past decade, physicists realized that materials perforated with regularly spaced holes can act as 'photonic crystals', through which light cannot penetrate. If the holes have roughly the same size and separation as the wavelength of light, then they scatter light just as a pinball (but not a football or a speck of dust) is scattered by the bars and flippers of a pinball table. This scattering prevents the light from passing even the first rank of holes. A 'light insulator' of this sort could be useful in telecommunications, for example to provide optical fibres with a leak-proof coat. Most long-distance telecommunication sends infrared light pulses down such fibres; but their leakiness means that the signal has to be continually re-amplified along the way.

Photonic crystals could also be used to guide light around on a chip, enabling electronic engineers to make circuits that operate using light rather than electricity. And they could give rise to new lasers with very low power consumption. But the catch is that the pattern -- the mesh -- must be microscopically small. It is very hard to drill holes at this scale.

In the past few years, materials scientists have learnt how to exploit nature's trick of templating to make photonic crystals. One approach is to allow tiny spheres of silica or polystyrene to settle out of a suspension, like

mud settling out of river water. If all the spheres are the same size, they will stack into an orderly array like fruit on a greengrocer's stall. This is called a colloidal crystal. A solid material can then be crystallized in the gaps between the spheres, and the spheres can be dissolved chemically or burnt out to leave behind the regular, templated mesh. In this week's *Nature* [25 May 2000], a team of researchers from Canada and Spain, led by Sajeev John of the University of Toronto, describe a templated photonic crystal made in this way from silicon. The porous material appears to be impenetrable to infrared light at a wavelength close to that used in telecommunications.

A different patterning process is used to lay down arrays of tiny dots or stripes of semiconducting material, just a few nanometres (billionths of a metre) in size, on a surface. These 'quantum dots' are so small that their properties (such as how they react to light) are governed by the rules of quantum mechanics. Quantum dots could provide the 'neurons' of a memory device capable of storing data at much higher density than existing computers. Quantum dots can be regularly arranged on a surface by depositing the semiconductor from a gas. If the spacing between atoms in the semiconductor crystals differs from that of the atoms on the surface, then the mismatch squeezes the quantum dot, or expands the region of the surface it sits on. This can create circular regions of stress, making the dots repel one another and guiding them into a regularly spaced array. The process has some parallels with the chemical 'inhibition' that is thought to arrange the leopard's spots (see first article).

Research on materials patterned by 'self-organization', rather than by hand, is still in its infancy. But perhaps one day these processes will allow us to make microscopic designs as beautiful as those that nature has produced for millions of years.

See also **technology** : [Pattern of life](#)

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