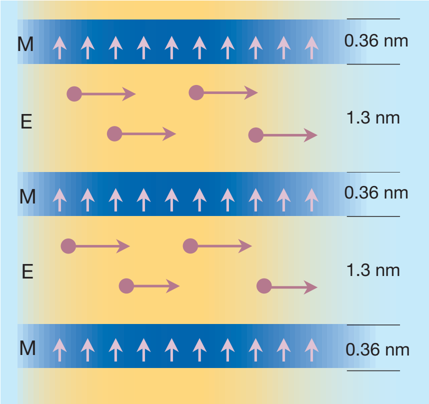

Figure 2 **The molecule-based multilayer structure created by Coronado *et al.*[1], in which ferromagnetic layers (M) alternate with metal-like conducting ones (E).**

polymers — essentially plastic conductors — for which Alan MacDiarmid, Alan Heeger and Hideki Shirakawa received this year's Nobel Prize for Chemistry. In addition to conducting polymers, other charge-transfer salts were discovered and studied. Of these, the molecule [TTF][TCNQ], which led to the first examples of organic superconductors, is probably the best known. Several organic superconductors[3] and organic metals were made from a related molecule called BEDT-TTF (Fig. 1a). Coronado *et al.* make use of the conducting properties of this molecule in their new material.

Ferromagnetism is the parallel alignment of all the magnetic moments in a material, whether atomic or molecular, induced by applying a weak external magnetic field. This leads to a spontaneous magnetization, which may remain once the external field is removed, as is found in the magnets used on doors, or it may disappear, as in modern current-transformers. Molecule-based ferromagnetism was first reported in 1972 for an iron chloride coordination compound[4,5]. Then in 1986 ferromagnetism was discovered in an organic-based material[6]. These materials became ferromagnets at extremely low temperatures (below 5 K) and were soluble in conventional organic solvents. In 1992 Okawa and co-workers surprised researchers when they reported a layered bimetallic compound that behaved as a two-dimensional ferromagnet[7]. Although insoluble, these magnets are crystalline and their molecular components self-assemble into a layered structure in aqueous solutions.

Coronado *et al.*[1] created their material using controlled self-assembly of alternating single layers of a bimetallic ferromagnet (Fig. 1b) and BEDT-TTF molecules. Precise control of the assembly is possible because the BEDT-TTF layers are positively charged and the magnetic layers are negatively charged. The alternating monolayers of BEDT-TTF and the ferromagnet are just 1.3 and 0.36 nm thick, respectively (Fig. 2). So the magnetic layers develop bulk ferromagnetic ordering, but this remains independent of the current flowing in the organic layers. The authors find no evidence that the ferromagnetic and conducting subsystems interact with each other, except when an external magnetic field is applied perpendicular to the layers.

The synthesis of molecular materials that can deliver technologically important physical or chemical properties, or a combination of these properties, is now a major goal for chemists. Coronado *et al.*'s results[1] show that self-assembly allows multifunctional materials to be made while keeping precise control over their composition and structure at the nanoscale. In the past few years we have witnessed the birth of 'spintronics' — electronic devices that are based on interactions between the 'spins' of electrons rather than their charge. A popular example is a so-called spin valve. This consists of two ferromagnetic layers separated by a weaker diamagnetic layer, which can be either an insulator or a metallic conductor only a few atomic layers thick. The ferromagnetic layers communicate with each other through electron-tunnelling effects or through the mobile electrons in the metallic layer. The material reported by Coronado's group suggests that molecule-based materials with these properties are on the horizon. This could make these devices easier to process and lead to a substantial reduction in production costs.

In conventional metallic ferromagnets, the mobile electrons play a crucial role in both the magnetic interactions and the conductivity. But in Coronado *et al.*'s system, the conducting electrons in the organic layer do not appear to interact with the magnetic moments of the ferromagnetic layer. This unique feature, which is only possible because of the molecular nature of the system, may yet yield unforeseen physical behaviour. It will also be desirable to develop hybrid molecular materials in which the conducting and magnetic subsystems do interact with each other — these could then be used to develop new electronic devices that operate at the nanoscale. It is easy to imagine other hybrid materials that combine magnetism with nonlinear optical properties, or ferromagnetism with superconductivity. The latter will be useful for exploring the interplay between superconductivity and magnetism, which, like oil and water, usually do not mix. ■

Fernando Palacio is at the Instituto de Ciencia de Materiales de Aragón, CSIC, Universidad de Zaragoza, 50009 Zaragoza, Spain.
e-mail: palacio@posta.unizar.es
Joel S. Miller is in the Department of Chemistry, University of Utah, Salt Lake City, Utah 84112-0850, USA.
e-mail: jsmiller@chemistry.utah.edu

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Daedalus

David Jones

David Jones, author of the Daedalus column, is indisposed.

Anthropology

Lovely grub

Western gourmets are happy to tuck into a bowl of mussels or get to grips with a lobster, but a plate of earthworms or ants would probably be politely declined. The example of Amazonian Amerindians shows that these fusspots are passing up a nutritious and ecologically friendly food source.

From fieldwork and surveys of the literature, Maurizio Paoletti and colleagues found that invertebrates form an important part of the diets of 32 Amazonian ethnic groups (*Proc. R. Soc. Lond. B* **267,** 2247–2252; 2000). The most widely consumed species are those that feed on leaves or leaf litter, including leaf-cutter ants, termites, caterpillars (including the cassava hornworm, pictured) and large earthworms. The last, when smoked, are a delicacy to the Ye'Kuana people of Venezuela — who even 'farm' the worms by introducing them into worm-poor patches of ground and reharvesting them.

Leaves are the most abundant source of plant matter in the Amazon. So the animals that feed on them are a highly efficient and sustainable source of nutrients. This is a good example, say Paoletti *et al.*, of how indigenous peoples support themselves from natural resources without causing ecological damage. **John Whitfield**