was the result of an edifice rupture, explosions caused by ground or surface water being heated by magma can also occur with little to no warning, as was the case at Mount Ontake in Japan in 2014, and at Whakaari (White Island) in New Zealand in 2019. Such explosions offer further motivation for considering the implications of hazards that give out brief and often subtle precursory signals.

Smittarello and colleagues' study, as well as those examining eruptions at Ambrym in Vanuatu[8], La Palma in Spain[9] and Bárðarbunga in Iceland[10], have provided well-documented analyses of dyke propagation in a number of contexts. In particular, these investigations have examined tectonic regimes that differ from those at well-studied volcanoes such as Kīlauea[11], Mount Etna[12] in Italy or Piton de la Fournaise in Réunion[13]. It is doubtful that these volcanoes exhibit a full range of eruptive behaviours, which makes observations of eruptions across the world all the more valuable.

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1. Smittarello, D. *et al. Nature* **609**, 83–88 (2022).
2. Barrière, J. *et al. Earth Planet. Sci. Lett.* **528**, 115821 (2019).
3. Burgi, P.-Y., Boudoire, G., Rufino, F., Karume, K. & Tedesco, D. *Geophys. Res. Lett.* **47**, e2020GL088484 (2020).
4. Barrière, J. *et al. J. Geophys. Res. Solid Earth* **127**, e2021JB023858 (2022).
5. Boudoire, G. *et al. Sci. Rep.* **12**, 7488 (2022).
6. Montgomery-Brown, E. K. & Miklius, A. *Geology* **49**, 397–401 (2021).
7. Ebinger, C. *Astron. Geophys.* **46**, 2.16–2.21 (2005).
8. Shreve, T. *et al. Sci. Rep.* **9**, 18868 (2019).
9. Carracedo, J. C. *et al. Geol. Today* **38**, 94–107 (2022).
10. Sigmundsson, F. *et al. Nature* **517**, 191–195 (2015).
11. Neal, C. A. *et al. Science* **363**, 367–374 (2018).
12. De Novellis, V. *et al. Geophys. Res. Lett.* **46**, 5817–5827 (2019).
13. Peltier, A., Bachèlery, P. & Staudacher, T. *J. Volcanol. Geotherm. Res.* **184**, 93–108 (2009).

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Condensed-matter physics

Superlattices taken to another dimension

Berit H. Goodge & D. Kwabena Bediako

A compound comprising both one- and two-dimensional components exhibits an unusual response to a magnetic field, demonstrating the potential for 'heterodimensional' materials that can host intriguing quantum behaviours. **See p.46**

Materials-by-design research aims to create synthetic compounds that have properties with potential either for technological applications or for exploring fundamental physics – ideally, both. One approach is to look for new chemical compositions, but another proven strategy stacks single- or few-atom-thick layers of two or more compounds into close-knit atomic tapestries called heterostructures. Careful engineering of such heterostructures can be used to tailor their properties by manipulating both the short- and long-range interactions between atoms and electrons in the material[1,2]. This idea has now been extended to the synthesis of 'heterodimensional' heterostructures, in which components with different dimensionalities give rise to exotic behaviour, as Zhou *et al.*[3] report on page 46.

The dimensionality of a material usually refers to its atomic connectivity. But the interactions between a material's crystal lattice, and the charge and spin (intrinsic angular momentum) of its electrons, also have a dimensionality. For example, charge-carrying electrons might be allowed to move freely throughout a crystal in all three dimensions, or they could be confined to a flat plane or a single line. Dimensionality can strongly influence a material's behaviour: the properties of pure carbon vary substantially between 3D graphite, 2D graphene and 1D carbon nanotubes. Although each of these compounds comprises carbon atoms arranged in a hexagonal lattice at the atomic scale, the constraints imposed by their dimensionalities modify their nanoscale interactions, giving rise to distinct properties.

Combining more than one dimensionality in a single material could, in principle, give rise to a compound exhibiting a mixture of 1D- and 2D-like material properties. Zhou *et al.* explored this possibility by engineering an ordered arrangement of 1D ribbons of vanadium monosulfide (VS), lined up between sheets of 2D vanadium disulfide (VS_2) (Fig. 1). In doing so, they produced a new kind of compound that shows intriguing behaviour.

The authors' VS_2–VS superlattice displays an unusual response to a magnetic field. In normal conductors, applying a magnetic field in a direction perpendicular to that of an electric current through the material generates a voltage along a direction that is perpendicular to both the field and the current. This is known as the Hall effect, named after US physicist Edwin Hall, who discovered the phenomenon in the late nineteenth century[4]. The effect arises from the force that is exerted on charge carriers, such as electrons, as they move through an electromagnetic field. Surprisingly, Zhou *et al.* found a strong Hall signal in their VS_2–VS superlattice even when the magnetic field was oriented along the same direction as the voltage measurement.

This intriguing response to a magnetic field can be ascribed to the heterodimensionality of the compound: the arrangement of atoms in the superlattice has certain symmetries that give rise to this effect when a magnetic field is introduced. The strong coupling between the electron spins in the material and their orbital motion also has a role – giving rise to an unusual quantum-mechanical property called the Berry curvature. This has a similar effect on electrons to that of a magnetic

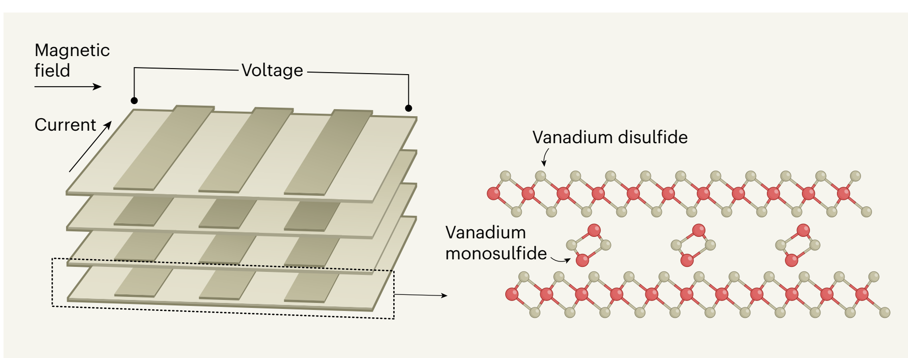

Figure 1 | A 'heterodimensional' superlattice. Zhou *et al.*[3] synthesized a material comprising 2D sheets of vanadium disulfide interspersed with 1D ribbons of vanadium monosulfide. Applying a magnetic field to the material elicited a voltage that was perpendicular to an electric current through the superlattice, but parallel to the field. This voltage, resulting from a phenomenon known as the Hall effect, usually appears in a direction perpendicular to both the field and the current. The authors attributed their unusual observation to the combination of 1D and 2D components, which could give rise to other designer-material properties.

field, resulting in a phenomenon similar to the Hall effect in magnetic materials. The authors' calculations suggest that the curious Hall effect they observed can be explained by magnetic-field-induced changes to the resistivity of VS_2–VS, which, in turn, result from the peculiar mixture of 1D and 2D components in the system.

Zhou *et al.* found that the distinctive Hall effect could be detected even at room temperature, unlike many other quantum phenomena, which occur only at much lower, cryogenic temperatures. This feature has potential in future devices. It is to be hoped that the authors' observations will launch more-detailed experimental and theoretical investigations to shed light on the origin and implications of this peculiar effect in VS_2–VS, and whether it can be reproduced in other heterodimensional structures. In a case of the whole being greater than the sum of its parts, the result indicates that such heterodimensional compounds could offer a route to maximizing the benefits of multiple classes of material. They might even be used to make materials with properties that are not possible in known 'homodimensional' structures.

Zhou and colleagues' work also offers an exciting blueprint for producing quantum materials with mixed dimensionality. Previous efforts to build heterostructures have focused largely on combining materials that have the same dimensionality. But some have succeeded in integrating 2D and 3D materials through arduous processes such as mechanical construction[5] or precise, layer-by-layer synthesis methods[6,7].

By comparison, the authors' method produces mesoscale crystals through a relatively rapid process called chemical-vapour deposition, which involves reacting vaporized precursor materials. This technique is a staple of the semiconductor industry, meaning that materials grown in this way might one day be scaled up for industrial applications with relative ease. If the approach (or methods like it) can be extended to other chemical compounds, it could provide a fruitful playground for enhancing the properties of a wide new family of materials.

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1. Novoselov, K. S., Mishchenko, A., Carvalho, A. & Castro Neto, A. H. *Science* **353**, aac9439 (2016).
2. Ramesh, R. & Schlom, D. G. *Nature Rev. Mater.* **4**, 257–268 (2019).
3. Zhou, J. *et al. Nature* **609**, 46–51 (2022).
4. Hall, E. H. *Am. J. Math.* **2**, 287–292 (1879).
5. Geim, A. K. & Grigorieva, I. V. *Nature* **499**, 419–425 (2013).
6. Ohtomo, A., Muller, D. A., Grazul, J. L. & Hwang, H. Y. *Nature* **419**, 378–380 (2002).
7. Lee, C.-H. *et al. Nature* **502**, 532–536 (2013).

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Immunology

Immune cells use hunger hormones to aid healing

Vishwa Deep Dixit

Immune cells called monocytes have long been implicated in the killing of invading bacteria. However, a closer look reveals a surprising role for them: monocytes partner with a hormone to improve skin healing after bacterial infection. **See p.166**

Production of the hormone ghrelin from stomach cells stimulates hunger[1], whereas the hormone leptin, which is released from fat cells called adipocytes, acts on the hypothalamus in the brain to inhibit food intake[2]. A loss of appetite is the most common symptom associated with the fever and inflammation that are induced by infection[3]. To coordinate a successful response to infection and to ultimately restore normal function, the body's immune, metabolic and nervous systems need to communicate by means of receptors, signalling molecules called cytokines, and hormones[4]. What are the specific restorative signals that dictate tissue healing and repair after infection? Kratofil *et al.*[5] report on page 166 a previously unsuspected connection between hormones and immune cells during healing.

"This study chimes with current ideas that immune and metabolic systems are not completely independent."

The eradication of bacterial infection by immune cells requires a strong inflammatory response. This is followed by the production of factors that promote healing and the repair of tissue damage. Research in this area has long focused on the production of pro- or anti-inflammatory cytokines, which can govern the action of infection-fighting immune cells and induce wound healing by activating stromal cells. A new research trend is to investigate how the ending (resolution) of inflammation is influenced by a variety of other molecules such as metabolites, hormones and neurotransmitters[6]. The identification of such tissue-reparative factors might enable better management of infection and repair responses in at-risk individuals, such as older people or those with obesity-associated metabolic diseases.

A major hurdle for endeavours to identify factors needed for healing is the scarcity of suitable experimental systems to mimic disease and recovery. What is needed is a clinically relevant animal model of infectious disease, in which the immune cells in question can be tracked and investigated during repair processes. To try to overcome this problem, Kratofil and colleagues developed a model system in which beads were coated with *Staphylococcus aureus* bacteria to mimic bacterial entry on a foreign body such as a splinter. These beads were inserted into the skin of mice to imitate the typical entry route of skin-penetrating bacteria during infection. This method revealed that neutrophils, immune-cell first responders to infection, infiltrated the skin and ingested (engulfed) the bacteria, whereas immune cells of another type, called monocytes, moved in from blood vessels to envelop the infection site.

The authors used live-cell imaging and determined that monocytes surround this bacterial invasion zone (Fig. 1) to orchestrate healing and tissue repair, but do not directly kill the bacteria inside the wound. This result was unexpected because, in several previous studies of models of infection, monocytes were implicated in killing the harmful bacteria[3]. By studying mice that lack the gene *Ccr2*, which is crucial for recruitment of monocytes into the skin after infection, the authors found that there was delayed wound healing in the absence of monocytes, and that overgrowth and leakage of newly formed blood vessels increased swelling in the area — a characteristic reminiscent of non-resolving persistent inflammation.