JULIETTE HALSEY FOR NATURE

academia, industry and schools — the largest such study worldwide in the physical sciences (see 'LGBT+ experiences'). Most respondents self-identified as LGBT+, although the survey also included a minority of people who were both heterosexual and cisgender — identifying with the gender they were assigned at birth.

Language — such as derogatory use of the word gay — harmful humour and people using the wrong pronouns were some of the factors that created an unwelcoming climate. It's "all the tiny things that, over time, build up to create a culture that isn't particularly welcoming", says Jennifer Dyer, head of diversity at the London-based Institute of Physics, which conducted the survey with the Royal Astronomical Society and the Royal Society of Chemistry.

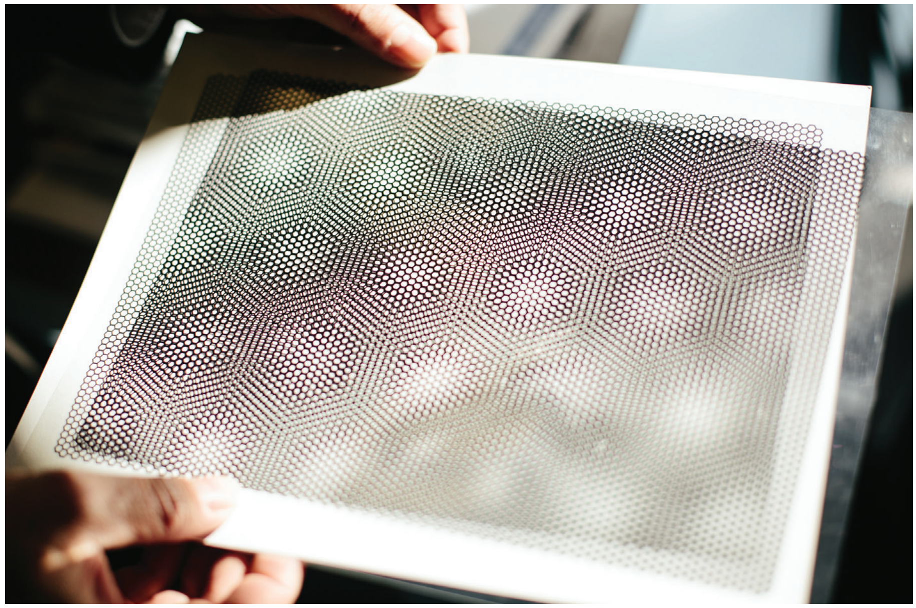
Overall, three-quarters of LGBT+ respondents reported feeling comfortable at work and almost 70% said they thought the situation was improving. But this masks "an underlying picture", in which almost half agreed there was a lack of awareness of LGBT+ issues at work, says Dyer.

REPRESENTATION MATTERS

The results echo those of a survey published by the American Physical Society in 2016, and come as the academic community grapples with endemic discrimination against and exclusion of minority communities. The latest survey is crucial as a benchmark against which to monitor progress, says astrophysicist Alfredo Carpineti, who co-founded the UK campaign organization Pride in STEM (science, technology, engineering and mathematics) in 2016.

The report says that despite a wealth of evidence that diversity benefits science, workplaces still have much to do to cultivate inclusive environments. The societies make specific recommendations for individuals and institutions, including championing LGBT+ scientists and networks, and implementing science-specific training that effectively supports LGBT+ staff. It also suggests that people put their pronouns in e-mail signatures and on name badges at events. This normalizes the idea that not everybody is a he or a she, says Dyer.

One reason that scientists might face more challenges than people in other sectors is the international nature of research — a successful career often means interacting with people in cultures that are less inclusive of LGBT+ people. Scientists reported feeling less safe being open about their gender or sexual identity when working in these cultures, and in some cases felt they might be expected to "return to the closet" for the sake of a smooth collaboration. It is essential that institutions reflect the international nature of science in their LGBT+ policies, says the report. ■ SEE EDITORIAL P.5



Misaligned layers of graphene seem to exhibit a phenomenon known as fragile topology.

TOPOLOGY

Strange materials excite physicists

'Fragile topology' is the latest addition to a set of quantum phenomena that give materials exotic properties.

BY DAVIDE CASTELVECCHI

The mathematics hidden in materials keeps getting more exotic. Topological states of matter — which derive exotic properties from their electrons' 'knotty' quantum states — have shot from rare curiosity to one of the hottest fields in physics. Now, theorists are finding that topology is ubiquitous — and are recognizing it as one of the most significant ways in which solid matter can behave.

In the past few years, physicists have identified a 'fragile' version of topology that might occur in almost all crystalline solids, according to a preprint published in May[1]. Another study[2], published last month, describes hints of a fragile state in the electrons of a carbon-based device — which could be the first experimental evidence for fragile topology.

It is too early to say whether these discoveries will have a major impact on practical materials. But researchers suggest it might help to explain certain kinds of superconductivity, and could be important in photonics — technologies that carry information in light pulses rather than electrons.

The latest studies show that fragile topology "is not just a radical, academic rabbit hole that people are going down", says Ashvin Vishwanath, a theoretical physicist specializing in condensed matter at Harvard University in Cambridge, Massachusetts. "I am having a hard time keeping up with the field, even though it's just a year old."

Topology is the branch of mathematics that deals with deformations that reshape objects continuously — as opposed to those that cut or break objects, in the way that cutting two linked loops unlinks them. In some materials, electrons can exist in 'knotty' quantum states, and these can keep an electron moving in a particular direction, because altering course would require an abrupt change of its state, akin to cutting a knot. As a result, the physical qualities are protected, allowing some materials called topological insulators to be, despite their names, perfect conductors on their outer edges while the bulk of the material is insulating.

'Strongly topological' materials that harbour these robust effects might provide the basis of future topological quantum computers, which could solve certain problems exponentially faster than classical computers.

Strong topological properties come from quirks in the quantum states of electrons: rather than crowding around individual ▶

atoms as they do in a typical insulator, some electrons in a topological material are 'delocalized' and share collective quantum states that stretch over the bulk of a material.

But theorists have calculated that there are some materials that have delocalized electrons, yet don't have strongly topological properties. In other words, strongly topological materials make up only one category in a vast taxonomy of delocalized states. Among them are electron states that are protected from small perturbations, but aren't quite as robust as strongly topological states. They can be made normal, by, for example, slightly changing the impurities mixed into the crystal. In 2018, Vishwanath's team dubbed the phenomenon fragile topology.

"We had thought this had no application. Then there was this huge deal."

TWISTED DISCOVERY

At first, physicists weren't sure whether fragile topology was important, but that changed after a surprising discovery in 2018. Physicists revealed[3,4] that two stacked layers of graphene, the single-atom-thick form of carbon, become superconducting when they are misaligned at particular 'magic' angles, carrying electricity with zero resistance. Vishwanath and others soon calculated that certain electron states in this twisted graphene display fragile topology. "We had thought this had no application. Then there was this huge deal," says Vishwanath. At present, it is unclear whether fragile states actually play a part in making twisted graphene superconducting. Whereas strong topology manifests in known, measurable ways, fragile topology might be subtler.

Still, fragile topology is bound to affect materials' behaviour, some physicists say, because it is more ubiquitous than strong topology. Studies have suggested that about one-quarter of materials are strongly topological. But physicists reported in May[1] that almost all materials have some electrons in fragile topological states.

Now, the first experimental hints of fragile topology are emerging. A June study in *Nature*[2] found evidence of fragile topology in a non-twisted double layer of graphene. The researchers were trying to make a topological insulator by sandwiching graphene between layers of another 2D material, and applying an electric field. As the field varied, they recorded electrons moving at the edge of the device, as expected in topological insulators. But other measurements showed that it could not be a conventional topological insulator. So the researchers turned to a theorist colleague who realized that this was a first experimental hint of a fragile state.

Although it remains to be seen whether fragile topology will have many applications, to a theorist it is interesting, says Barry Bradlyn, a theoretical physicist at the University of Illinois at Urbana–Champaign. It "defies the conventional lore" of how electron states in materials are supposed to work, he says. ■

1. Song, Z., Elcoro, L., Regnault, N. & Bernevig, B. A. Preprint at https://arxiv.org/abs/1905.03262 (2019).
2. Island, J. O. *et al. Nature* https://doi.org/10.1038/s41586-019-1304-2 (2019).
3. Cao, Y. *et al. Nature* **556**, 43–50 (2018).
4. Cao, Y. *et al. Nature* **556**, 80–84 (2018).

CORRECTIONS

The World View 'Unintended consequences of gender-equality plans' (*Nature* **570**, 277; 2019) mischaracterized the Chatham House rules. They allow information to be disclosed, but not participants' identities or affiliations.

The News Feature 'CRISPR babies: when will the world be ready?' (*Nature* **570**, 293–296; 2019) gave the wrong name for the gene associated with lower cholesterol levels and cited an inappropriate reference for the finding. It also gave the wrong reference for the study based on UK Biobank data: the correct reference is X. Wei and R. Nielsen *Nature Med.* **25**, 909–910 (2019).