that hunter-gatherers lived in harmony with nature, and in some circles it is thought to be the job of anthropologists and archaeologists to protect this empirically incorrect idea. What evidence do these researchers rely on to support this idea? Normally, it is the absence of an association between extinct animals and humans, as well as the lack of evidence for human occupation at times early enough to be consistent with humans causing the extinctions.

Yet for reasons of basic probability, it is unlikely that we will ever find the 'first' settlers of a land, or even direct evidence for the hunting of extinct megafauna[7]. So our estimates of the 'earliest' occupation might underestimate its actual timing. A paper[8] published in 2016 showed that early Australians had penetrated the harsh arid interior of Australia by around 49,000 years ago, and those researchers found the earliest definitive evidence for megafaunal fossils in association with tool-like artefacts in Australia. Taking this work together with the findings of Clarkson and colleagues now provides compelling evidence that humans were in Australia early enough to cause many of the megafaunal extinctions.

My PhD adviser, J. Desmond Clark, who studied African archaeology, regularly exhorted his students to get out of the office and "go put holes in the ground". Fieldwork is hard and challenges one's life in myriad ways. Yet we need not only discover sites, but also return to the old ones with new methods with which to refine what we know. The latest work in Australia shows us the pay-off, and provides a reminder that this massive continent could reveal many other secrets during future fieldwork. Such studies might also further increase our understanding of the pace and character of human colonization, and its impact on the fauna and flora of that time.

We now know that modern humans, after they left Africa around 70,000 years ago, dispersed rapidly to a coastal area that became the departure gate for their journey to Australia. From that launch pad, perhaps some of them envisaged other lands across the water that they could not see. They decided to take a chance and built boats, loading them with both new and tested technologies. Then, with their families, they boarded to embark on a journey of discovery. Sounds familiar — sounds like humans reaching for the stars. ■

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MATERIALS SCIENCE

Chemistry and physics happily wed

A major advance in the quantum theory of solids allows materials to be identified whose electronic states have a non-trivial topology. Such materials could have many computing and electronics applications. SEE ARTICLE P.298

GREGORY A. FIETE

Many computing, communication and sensing technologies require knowledge of how electrical charge moves through a material. All fields of science, large sectors of the economy and crucial government functions rely heavily on these technologies for day-to-day work. But despite more than 80 years of research on the quantum theory of electronic motion in solids and the impressive capabilities of devices such as the modern smart phone, there remain gaps in our knowledge. In a conceptual breakthrough, Bradlyn *et al.*[1] report on page 298 a theory that combines aspects of both chemistry and physics. The theory improves our understanding of known materials and can be used to search for materials that have previously undiscovered electronic properties.

When developing a theory for any phenomenon, physicists rely on conservation laws as powerful constraints on the theory's mathematical structure. Two of the best-known laws are the conservation of energy and the conservation of momentum. Less widely appreciated is the origin of conservation laws: symmetry. For example, the conservation of momentum is a direct consequence of a system that looks the same when moved along a line — a property called translational symmetry.

In a crystal containing a regular, periodic arrangement of atoms on a lattice, the environment looks the same only if the crystal is moved by an amount equal to an integer multiple of the lattice spacing. As a result of this 'imperfect' translational symmetry, there is an imperfect conservation of momentum. The conserved component is known as quasi-momentum and is the natural quantity to characterize an electron's quantum state.

The relationship between the energy of an electron and its quasi-momentum is known as the electronic band structure (Fig. 1a). Since the 1940s, many powerful theoretical tools have been developed to compute the band structures of materials. This information can be used to determine, for a given material, whether it is a metal or an insulator, how it would function in a transistor (the nanoscale electrical switches that are ubiquitous in modern electronics) and how it responds to light — a crucial consideration for optical applications such as solar cells.

For many decades, the concept of electronic band structure reigned supreme. But in the mid-2000s, it was discovered[2–4] that two insulating materials that have very similar band structures could be entirely different from the point of view of the quantum wavefunctions that describe the spatial distribution of electrons. These differences could have dramatic consequences for the surfaces of the insulating materials, and are intimately related to — in fact, determined by — topological properties of the electronic states in the bulk of the materials. The field of topological insulators was born[5–8]. Pioneering work in the 1970s and 1980s that led to the current explosive growth in our understanding of topological materials (those that have a non-trivial topology) was awarded the 2016 Nobel Prize in Physics.

Most known topological materials have surfaces that exhibit a high degree of immunity to imperfections and defects. Moreover, an electric field can be used to control the flow of a magnetic property of electrons, called spin, through such materials. The combination of these features has inspired many proposals for applications. Finding topological materials is therefore of great interest to the scientific community. The standard search procedure involves computing the band structure of a particular material, finding the electronic states, and feeding this information into a formula that will reveal whether the material is topological.

Whereas physicists focus on the motion of electrons, chemists often think in terms of atomic orbitals that describe the position

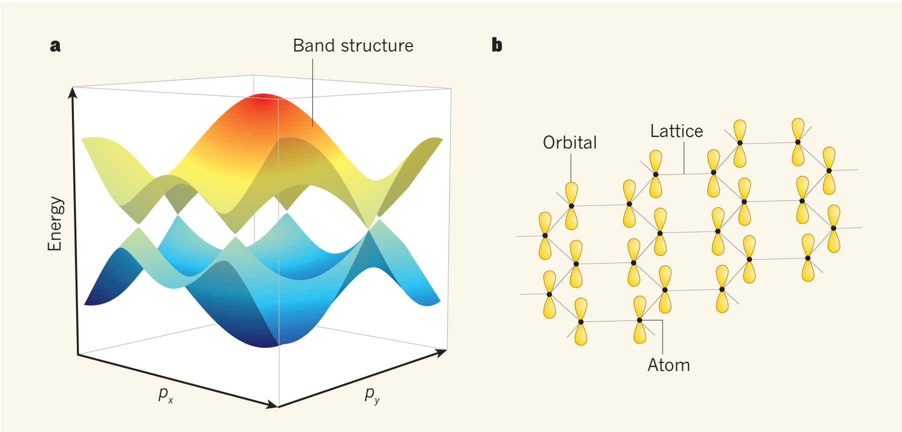

Figure 1 | Two descriptions of electrons in a crystal. Bradlyn *et al.*[1] report a theory that reconciles two fundamentally different perspectives on materials advocated by physicists and chemists. Shown here is an example of these perspectives for graphene, a crystalline material comprising a 2D hexagonal lattice of carbon atoms. **a**, Physicists describe materials using the motion of electrons and in particular, the electronic band structure — the relationship between the energy of an electron and its 'quasi-momentum'. The components of quasi-momentum in the *x*- and *y*-directions are denoted by p_x and p_y, respectively. The top and bottom surfaces correspond to electrons in two different bands (the conduction and valence bands, respectively). **b**, By contrast, chemists describe materials using the position of electrons around atoms. The physical region of space where an electron can be present is known as an atomic orbital.

of electrons around a given nucleus (Fig. 1b). This is because chemists usually deal with systems that have fewer atoms and lower symmetry than those studied by physicists. Furthermore, chemical bonding is naturally described in the language of orbitals.

One of the most celebrated ideas in quantum mechanics, the Heisenberg uncertainty principle, states that the more one knows about the position of an object, the less one knows about its motion, and vice versa. Formulating a theory that relies on both the chemists' perspective of electronic position and the physicists' perspective of electronic motion therefore requires a certain amount of mental and mathematical gymnastics, but that is what Bradlyn *et al.* have accomplished.

The authors' theory provides a way to predict and experimentally discover topological materials. Their work exploits existing materials databases and enables large-scale automated searches that have already turned up hundreds of topological-material candidates that could not have been easily anticipated by other theories. For example, the authors show that lead suboxide (Pb_2O), the topological properties of which had not previously been explored, will be a topological insulator when subjected to strain. The authors are also able to predict semi-metals — materials whose properties are intermediate between those of metals and non-metals.

In addition to its predictive power, Bradlyn and colleagues' theory also provides a new perspective on topological states, both complementing and extending previous theories. However, despite these successes, the authors' theory cannot address the complexities of strong electronic correlations in topological states, which are often beyond both the band-structure picture and the single-particle orbitals that underlie the theory. Strongly correlated systems are of great interest because they can exhibit 'emergent' excitations that are useful for quantum computing, and can give rise to many exotic forms of magnetism and superconductivity.

Owing to limitations in the theoretical and computational tools currently available to theoretical physicists, electronic correlations will continue to pose a challenge in the foreseeable future[9,10]. Strong correlations in quantum systems are at the heart of a frontier in modern physics research — independent of the question of whether or not topology is relevant — and touch on topics far beyond materials science, including nuclear physics and neutron stars. A leap forward in our understanding of these correlated systems could therefore uncover new details about the Universe itself. ■

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IMMUNOLOGY

Nervous crosstalk to make antibodies

Immune cells called T cells help immune-system B cells mature to produce antibodies. This entails signalling between cells using the molecule dopamine — a surprising immunological role for this neurotransmitter. SEE ARTICLE P.318

HAI QI

The production of antibodies by the B cells of the immune system is essential for an animal's defence against infection. The process involves close communication and collaboration between B cells and immune cells called T cells. On page 318, Papa *et al.*[1] present a study investigating this step, and report that a molecule better known for its function in nerve-cell signalling also has a role in the interactions between immune cells that underlie antibody generation.

For the immune system to efficiently fight infection, B cells must mature into antibody-producing cells known as plasma cells. To do this, B cells need help from a type of T cell that expresses the protein CD4 and is known as a follicular helper T cell (T_{FH} cell)[2,3]. When a B cell and a T_{FH} cell recognize a pathogen, they become activated, proliferate and migrate to structures called germinal centres, which are mainly found in lymph nodes and in the spleen[4].

In germinal centres, highly mobile T cells and B cells specific for the same pathogen can directly interact with each other through the formation of dynamic specialized surface structures called T–B immunological synapses[5]. Through these structures, T_{FH} cells deliver signals to promote B-cell maturation, while also receiving signals from B cells