original Sabin OPV1 and OPV3 counterparts.

Of note, even when a mutant arose that had lost all the attenuating mutations of nOPV1 and nOPV3, such mutants were no more virulent than were their Sabin counterparts. Furthermore, when the three nOPVs were administered to mice in a trivalent formulation, antibodies were induced against all three poliovirus serotypes. This finding indicates that there was no interference between the three viruses in terms of their ability to multiply simultaneously. Thus, the mouse model offers a proof of principle that a trivalent nOPV vaccine would work in humans.

This is impressive science, and reveals the potential for generating a safe and effective trivalent live attenuated polio vaccine. Will it lead the endgame to the finish line? That is a big question. The data from the animal studies are exciting, but the big unknown is how a trivalent version of this polio vaccine will perform in humans. The results of clinical trials will be interesting because all three polioviruses have been simultaneously 'super-engineered' for attenuation.

It has taken 42 years from the original description of the reverse-genetics[2] approach to achieve this promising move towards completing the endgame. The goal of an improved live attenuated trivalent polio vaccine is within reach.

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Condensed-matter physics

First light on orbitronics as a viable form of electronics

Tatiana G. Rappoport

An effect that transfers information using the rotational motion of electrons has been detected with light, forging a path towards technologies that are cheaper – and less harmful to the environment – than existing electronics. **See p.52**

Almost two decades ago, physicists detected a phenomenon known as the spin Hall effect[1,2], in which an electric field separates the electrons in a material on the basis of their intrinsic angular momentum, or 'spin'. This discovery stimulated the field of spintronics, which is a branch of electronics that uses spin – as well as electric charge – to transfer and store data. On page 52, Choi *et al.*[3] report the direct detection of a related phenomenon, called the orbital Hall effect, in which the field sorts electrons according to their orbital angular momentum, which is related to their rotational motion. The prospect of encoding data in orbitals has been dubbed orbitronics, and could lead to the development of environmentally friendly electronic devices.

Conventional electronics uses electric charge to process information, but computer memories built in this way are volatile. By incorporating both charge and spin, spintronics offers a more stable alternative. However, it requires the information transmitted as charge to be converted into spin currents, and vice versa. This is usually achieved by making use of a phenomenon known as spin–orbit coupling, in which an electron's spin interacts with its orbital motion. In the presence of an electric field, this interaction causes electrons to move in a direction that depends on their spin, thereby generating a flow of spins that is perpendicular to the electric current. This is the spin Hall effect.

This mechanism for converting between spin and charge works best in metals that have strong spin–orbit coupling, such as gold, platinum and tungsten. But these metals are scarce and costly, and mining them can result in considerable environmental damage. Orbitronics aims to overcome these limitations by

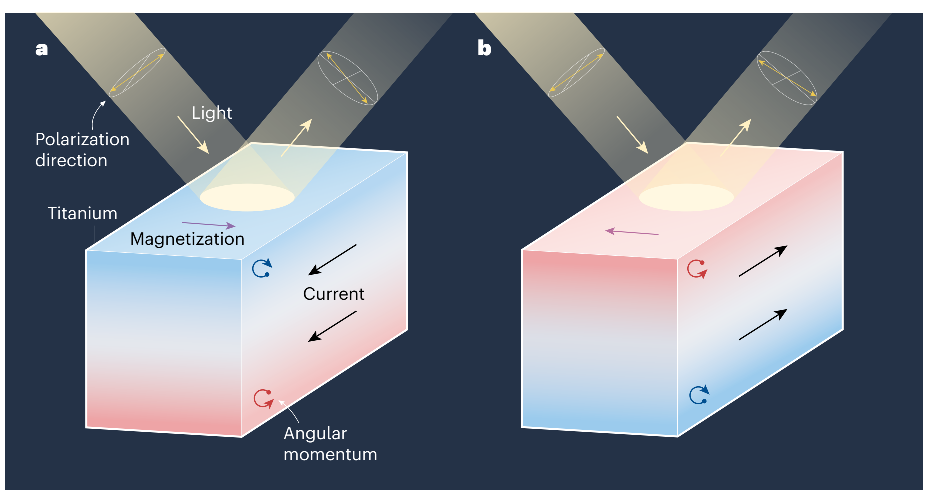

Figure 1 | Detecting the orbital Hall effect in titanium. a, The orbital Hall effect is a phenomenon in which an electric current causes electrons to separate on the basis of their orbital angular momentum, which is related to their orbital motion. This leads to the angular momentum on one surface of a material differing to that on the opposite surface, and manifests as surface magnetization in opposite directions. Choi *et al.*[3] induced this effect in titanium and then illuminated the sample with linearly polarized light, which has an electric field that oscillates in a single direction. The magnetization arising from the orbital Hall effect rotated the polarization of the reflected beam, making it detectable. **b**, When the direction of the electric field was reversed, the polarization rotated in the opposite direction, indicating that the surface magnetization had changed sign.

manipulating the magnetic moment produced by the electrons' orbital angular momentum (instead of their spin), thereby bypassing the need for materials with strong spin–orbit coupling. This approach expands the range of materials in which the magnetic moment of electrons can be controlled electrically.

The orbital Hall effect was first proposed[4] in 2005, but making use of it has proved challenging. Part of the problem is that it is difficult to distinguish the magnetic moments arising from orbital angular momentum from those associated with spin. To circumvent this issue, Choi and colleagues used titanium, a lightweight metal with weak spin–orbit coupling and a negligible spin Hall effect. Titanium itself does not have substantial benefits over metals with strong spin–orbit coupling, apart from the fact that it is much more abundant in Earth's crust than are these metals. But the authors' proof of principle shows the feasibility of orbitronics, which could be used to manipulate orbitals in any type of material — thus showcasing the potential for environmentally friendly electronics.

One of the reasons that measuring the orbital Hall effect presents a challenge is that the orbital currents generated do not affect the magnetization of a material directly, so these currents can be detected only indirectly in magnetic materials, through spin–orbit coupling. A possible solution to this problem involves using the light reflected off the surface of a material to measure orbital magnetization through a phenomenon called the magneto-optical Kerr effect. To detect spin accumulation, this experimental technique requires spin–orbit coupling, but if this coupling is weak enough, the measurements are more sensitive to orbital angular momentum than they are to spin.

Choi *et al.* generated accumulations of magnetic moments with different orientations at opposite surfaces of a titanium sample by passing an electric current through it (Fig. 1). They then illuminated the sample with light that was linearly polarized; this means that the light's electric field is confined to a single plane and oscillates along a fixed direction. By analysing the polarization of the beam that was reflected off the surface, they could detect the magnetic moments because the magneto-optical Kerr effect rotates the polarization of light — and the degree of rotation is proportional to the magnetization of the surface. Having confirmed an orbital accumulation resulting from the orbital Hall effect, the authors used complementary measurements to rule out other possible explanations.

Although the data suggest a direct detection of the orbital Hall effect, the measured magnetic-moment accumulation was much smaller than theoretical calculations had predicted[3]. This discrepancy shows that the behaviour of orbital angular momentum in solids is still not fully understood. Estimating magnetic-moment accumulation requires an understanding of how orbital angular momentum diffuses through a material and the different ways in which orbitals can lose their magnetic moment, a process known as relaxation. Although several of these processes are known for spin, little is known about the mechanisms for orbital angular momentum and the interplay between spin and orbital-relaxation processes[5].

Furthermore, other scattering processes that electrons undergo in titanium could potentially lead to orbital relaxation, as well as to other forms of the orbital Hall effect. The presence of impurities in a material with strong spin–orbit coupling can cause electrons to scatter, resulting in a type of spin Hall effect that differs from the one in pure metals. It is unclear whether such scattering processes can also generate an orbital Hall effect.

Choi and colleagues' work and other studies[6] shed light on directions for exploring the potential of orbitronics. One of the most pressing challenges in this field is to understand how orbital dynamics interacts with spins, light and phonons (collective atomic vibrations) — and how these interactions can be used in new technologies. Exploring other orbitronic effects, such as the connection between orbital magnetic moments and electric polarization in solids, could also have far-reaching implications for the future of electronics. But in detecting the orbital Hall effect, Choi *et al.* have taken a key step towards developing methods for manipulating magnetic materials using electric fields alone, eliminating the need for spin–orbit coupling.

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Infection

Viruses trick bystander cells into lowering defences

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The microenvironment of virus-infected cells and uninfected adjacent cells influences infection. Human cytomegalovirus dampens the immune response of neighbouring uninfected cells, but distant cells can mount an antiviral defence.

The microenvironment around cells is neither simple nor silent. There is a constant chattering of cellular communications that involves membrane-bound proteins, chemical signals such as peptides and even the proteins, lipids and RNAs associated with extracellular vesicles. Cells can therefore talk to themselves, to neighbouring cells and to distant cells. During a viral infection, the conversations between cells take on a warning tone. Writing in *Science Advances*, Song *et al.*[1] shed light on this process.

Signalling molecules called cytokines and interferons, which carry messages through the microenvironment, are released from an infected cell and thereby alert nearby cells to an impending viral threat, enabling them to mount a pre-emptive antiviral defence and limit the spread of infection. These immune signalling pathways are well studied and described for many disease-causing agents. However, viral infection also triggers other less-well-appreciated messages that aid viral objectives. Just as viruses hijack cellular machinery for their own replication, they also disrupt and co-opt communications between cells to thwart antiviral defences in their cellular microenvironment.

Song and colleagues reveal the profound effects of viral infection on neighbouring uninfected cells using human cytomegalovirus (HCMV) as a model system. HCMV belongs to the herpesvirus family and commonly infects humans. Similar to all herpesviruses, it establishes a life-long dormant (latent) infection in an infected individual[2]. Although an HCMV infection does not typically cause overt disease, reactivation of the latent virus