plug and then repair the wound. By contrast, dermal collagen remained immobile.

The authors then tested whether EPFs from the fascia drive the movement of the prefabricated plug. They inserted non-adhesive membranes in mice to separate the fascia from the dermis, which resulted in delayed repair and non-healing wounds that remained open. Animals in which these membranes were not inserted did not show these effects. The removal of fascial EPFs by a genetic approach also resulted in the plug not entering wounds and in poor healing. These findings indicate that fascial EPFs do indeed steer the plug that seals deep wounds.

Although this study has potential relevance for human disease, most of the work was carried out in an artificial mouse model. Moreover, mice have a type of muscle called the panniculus carnosus, which lies between the fascia and the skin and is used to twitch the skin[6]. However, humans lack this twitching ability and have only a small remnant of this muscle. Therefore, the authors needed to determine whether scar formation occurs in a similar manner in humans and mice despite such differences.

The team analysed fascial fibroblasts in human skin and investigated a type of human raised scar called a keloid, which grows bigger than the original injury and can be profoundly itchy, inflamed and painful[7]. Many of the proteins that characterize the mouse fascia were also highly expressed in human fascia and keloid scars. This similarity suggests that the same processes are involved in wound healing and scar formation in both species. However, it is not yet clear whether these findings in mice reveal general principles that are relevant to human skin disease.

The authors' findings provide satisfying potential explanations for some unsolved clinical conundrums. Nerves, blood vessels and macrophages in the prefabricated plug are dragged into the mouse wound; if the same phenomenon occurs in humans, this could explain why keloids itch and are painful. Keloid formation is more common at sites of thicker fasciae (such as the chest, back and thighs) than at sites where the fascia is thinner (for example, the feet), which is consistent with a model in which the fascia drives keloid formation.

Could these discoveries about the skin shed light on other clinically relevant fibrotic diseases (conditions associated with the accumulation of extracellular matrix) that affect organs in which the fascia is not present, such as the lungs and liver? Perhaps the mechanisms uncovered in mice might have relevance for the processes underlying skin damage in the leg ulcers that can develop in people who have diabetes. In any case, it is clear that advances made in understanding the biology of the fascia might reveal new targets for treating scarring diseases of the skin.

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Condensed-matter physics

Heat transferred in a previously unknown way

Karthik Sasihithlu

Experiments show that quantum fluctuations can allow heat to be transported between two objects separated by a vacuum gap. This effect could be harnessed to exploit and control heat transfer in nanoscale devices. **See p.243**

Acoustic waves and electromagnetic waves can transport heat between objects through their respective energy carriers: phonons and photons. At or near room temperature, the heat transfer between objects separated by a material medium occurs at a much higher rate when facilitated by phonons than by photons. However, phonons are generally thought to be ineffective at transporting heat between objects separated by a vacuum gap, because these energy carriers are vibrations in an atomic lattice and thus would require a

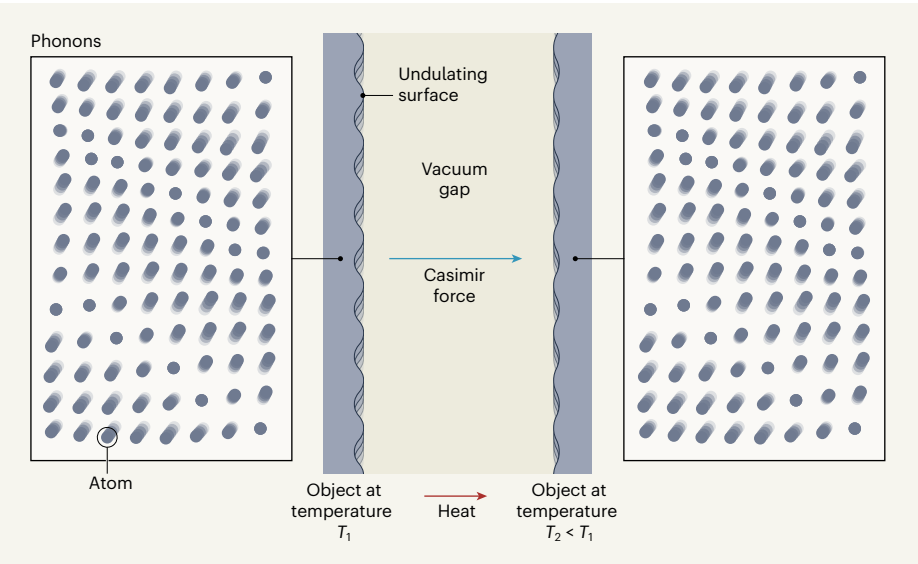

Figure 1 | Phonon transmission across a vacuum. Fong *et al.*[1] show that phonons — vibrations in an atomic lattice — can be transported between objects that are separated by a vacuum gap. To understand how this process occurs, consider an object at a fixed temperature T_1. Thermal agitation of the object's atoms produces phonons that propagate as acoustic waves and cause the object's surface to exhibit time-varying undulations (the amplitudes of the undulations shown are exaggerated for clarity). A second object, at a fixed temperature $T_2 < T_1$, is brought close to the first object, with a vacuum gap between the objects. The undulations of the first object's surface exert a time-varying 'Casimir' force (caused by quantum fluctuations) on the second object's surface, which gives rise to phonons in the second object. Because phonons are heat carriers, heat is transferred from the first object to the second one.

material medium to propagate. On page 243, Fong *et al.*[1] report experimental evidence that phonons can travel across a vacuum gap and therefore induce heat transfer between vacuum-separated objects because of the effect of quantum fluctuations.

In simple terms, quantum fluctuations can be understood as being the source of an electromagnetic signal that a perfectly sensitive detector would detect in a vacuum, even when this vacuum is shielded from all possible internal and external sources of electromagnetic waves, such as charges and currents[2]. The fluctuations are a consequence of a law in quantum mechanics known as Heisenberg's uncertainty principle[3], which states that certain pairs of physical quantities cannot be determined at the same time with absolute precision. The presence of quantum fluctuations subtly influences surrounding matter, leading to several observable effects.

One of these effects, relevant to Fong and colleagues' work, is the Casimir force[4] — the force that two neutral atoms separated by a vacuum gap exert on each other. The Casimir force results when quantum fluctuations induce fluctuating charge densities in these atoms; the charge densities then interact through their electric fields. The force that sticks a gecko's foot to a wall is an example of a macroscopic manifestation of the Casimir force. It arises from the combined interactions between fluctuating charge densities in all the atomic constituents of the two objects.

To understand how the Casimir force can induce phonon transfer between vacuum-separated objects, consider an object that is maintained at a particular temperature by being kept in contact with a heat source (Fig. 1). Thermal agitation of the object's atoms, which can be thought of as being interconnected by elastic springs, gives rise to phonons. In the presence of these phonons, the surface of the object undulates over time. When a second object is brought close to the first one, it is subjected to a time-varying Casimir force owing to its interaction with the undulations of the first object's surface. The second object's surface is thus subjected to tugging that then gives rise to phonons in the object's interior. Phonons are therefore transmitted from the first object to the second one.

Because phonons are heat carriers, when they are transported from one object to another across a vacuum gap, as a result of the Casimir force, they induce heat transfer if the second object is maintained at a lower temperature than that of the first one. This phenomenon of heat transport facilitated by the Casimir force has been predicted previously using theoretical models[5–7]. Fong *et al.* have now measured such a heat-transfer mode experimentally.

The authors used a technique called optical interferometry to observe the thermal agitation of atoms (Brownian motion) at the surface of a membrane. This membrane was kept in contact with a heat source held at a constant temperature. Measurements of thermal agitation can be related to, and therefore used as a gauge for, the temperature of the atoms at the membrane's surface. Moreover, the difference in this temperature with and without Casimir interaction with another, closely juxtaposed membrane is directly proportional to the resulting heat transfer between the two interacting membranes. The authors used these features to estimate the amount of heat transmitted between the membranes for vacuum gaps of different sizes. They found that their measurements accurately conform to theoretical estimates of such heat transport.

"Fong and colleagues' work provides conclusive evidence that the Casimir force can induce heat transfer."

Fong and colleagues' work provides conclusive evidence that the Casimir force can induce heat transfer. However, the use of this method to transport heat between two objects is limited, because the Casimir force decreases rapidly in strength as the space between the objects is increased. It is only when the gap between two objects is of the order of a few nanometres that the Casimir force is strong enough for this heat-transfer mode to dominate over competing modes, such as photon tunnelling[8].

The authors discovered a way to amplify the Casimir mode of heat transfer so that it remains dominant even when the gap between the membranes is in the range of hundreds of nanometres. The membranes were carefully designed in such a way that their dimensions and the temperatures at which they were maintained allowed them to vibrate with their maximum possible displacements — in other words, at their natural frequencies. Thus, applications that are devised to exploit this heat-transfer mode to dissipate heat (such as in a hard-disk drive, where the distance between the writing head and the storage disk is a few nanometres) would require such careful design to ensure that the mode is amplified. Achieving this would be a challenge for the future.

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Structural biology

Malaria parasites fine-tune mutations to resist drugs

Leann Tilley & Philip J. Rosenthal

Drug resistance in malaria parasites is mediated by mutations in a transporter protein. The transporter's structure reveals the molecular basis of how key mutations bring about resistance to different drugs. **See p.315**

About half a million people, most of them children living in Africa, are killed each year by malaria[1]. Management of malaria, particularly that caused by the highly virulent protozoan parasite *Plasmodium falciparum*, is challenged by the emergence of resistance to antimalarial drugs[2]. On page 315, Kim *et al.*[3] report the structure and molecular properties of a key protein that facilitates resistance, the *P. falciparum* chloroquine-resistance transporter (PfCRT). The structure reveals the consequences of finely tuned mutations of the amino-acid residues that line a crucial central cavity in PfCRT. These mutated residues allow resistant parasites to transport certain antimalarial drugs away from their site of action — and the effect of the mutations is different for closely related drugs.

Malaria parasites spend part of their life cycle inside human red blood cells. There, they use a specialized membrane-bound compartment known as the digestive vacuole to degrade the protein haemoglobin, thereby generating amino-acid building blocks for growth[4]. Haemoglobin digestion also produces a toxic side product called haem,