of rapamycin complex 1 (TORC1). Mutations that would usually cause hyperactivation of TORC1 signalling instead restored normal growth and food intake in Hodor mutant flies. Taking this evidence together, Redhai and colleagues propose a model whereby Zn^{2+}-dependent Hodor activity in the mid-gut drives TORC1-dependent metabolic programs that enable larval feeding and growth.

That Hodor acts through TORC1 signalling is not surprising, although it is difficult to draw conclusions about the exact nature of the link between the two. In a similar way to insulin in mammals, ILPs are potent activators of TORC1 in flies[6]. In turn, TORC1 is a prime driver of metabolic processes and growth in all animals. At the cellular level, TORC1 activation occurs on the lysosomal membrane and requires lysosomal acidification[7]. Thus, loss of Hodor might impair TORC1-driven growth through loss of insulin signalling, loss of lysosomal acidity, or both (Fig. 1).

The link between Hodor and TORC1 is not the only avenue for further research opened up by the current study. Another question concerns the relationship between feeding behaviour and TORC1 signalling, which is currently only partially characterized. ILPs are secreted from the brain in response to feeding and stimulate TORC1, placing TORC1 signalling downstream of feeding[5]. However, Redhai and co-workers' observation that increasing TORC1 activity restores growth and feeding behaviour in Hodor mutants, in which ILP secretion seems to be impaired, suggests that the picture is more complex. TORC1 might act both upstream of feeding (in the brain) and downstream of it (in the gut and other tissues).

How exactly does activation of Hodor by Zn^{2+} stimulate feeding and ILP release? It seems reasonable to suppose that a factor secreted from the gut in response to Hodor activation might affect the neuronal circuits that control feeding in the brain[8]. But identification of such a factor will require more work.

Finally, Hodor belongs to the family of Cys-loop channels, which have been a target of efforts to develop insecticides[9]. Redhai *et al.* provide evidence that Hodor is expressed only in insects, and show that mosquitoes engineered to lack the *hodor* gene die at larval stages. Given the protein's gut-specific expression, the authors suggest that ingestible substances could be laced with drugs that block Hodor activity, and these substances could be placed at known larval breeding sites. Thus, Redhai and colleagues' study could have broader implications than might have been anticipated in the hunt for a micronutrient sensor.

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Materials science

Nanowires light the way to silicon photonics

Anna Fontcuberta i Morral

Silicon used for electronics has a cubic crystal lattice, which makes the material unsuitable for photonics applications. A method for producing germanium and silicon–germanium alloys that have hexagonal lattices offers a solution. **See p.205**

Silicon is a prodigious material for electronics. Its useful electronic properties, high abundance, low cost and excellent processability helped to stimulate a revolution in silicon technology: the development of mass-produced silicon chips, which allow computing capabilities to be integrated into almost any device. But, alas, silicon is an inefficient absorber and emitter of light, preventing it from being used in many photonics applications. Writing on page 205, Fadaly *et al.*[1] report the development of silicon–germanium alloys that have excellent optoelectronic properties, and could thus aid the development of photonics technologies that are compatible with currently available silicon electronic devices.

Silicon's lack of useful optoelectronic capabilities is due to its electronic properties — it is said to be an indirect-bandgap semiconductor. As an example of the problem, solar cells based on silicon must be at least 100 times thicker than those based on gallium arsenide (a direct-bandgap semiconductor, which absorbs and emits light efficiently) to collect the same amount of light, but they still convert the light into electricity much less efficiently[2]. And silicon-based lasers remain an unrealized dream, even after decades of intense research efforts. Instead, lasers are typically made using 'compound' semiconductors, which incorporate costly elements such as indium or gallium. The components used to absorb or emit light in currently available silicon photonics schemes are also mostly made from compound semiconductors, and are usually bonded to the silicon or used off-chip[3].

Several generations of scientists have tried to convert silicon and silicon-containing alloys

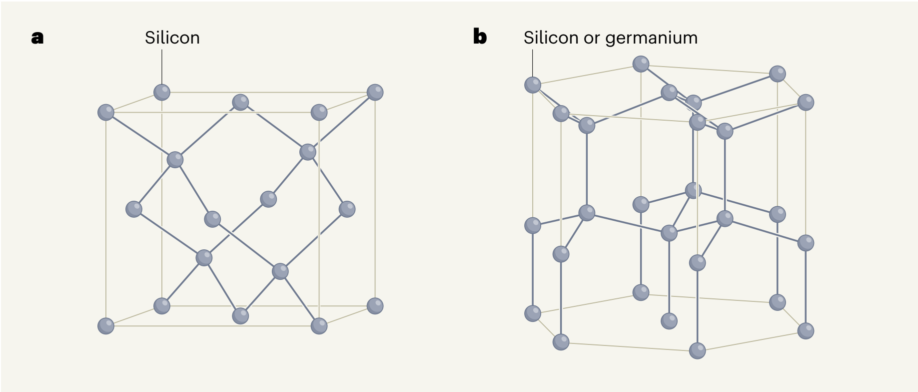

Figure 1 | Cubic and hexagonal crystal lattices. a, The silicon used for electronics has a cubic crystal lattice, which causes the material to be a poor absorber and emitter of light — limiting its use in optoelectronics. **b**, Fadaly *et al.*[1] report a way of producing germanium and silicon–germanium alloys that have a hexagonal lattice. The resulting materials are good light absorbers and emitters, and would be compatible with existing silicon electronics technology, potentially opening the way to the development of new optoelectronic devices.

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into materials suitable for optoelectronics (optoelectronic-grade materials) by modifying the electronic band structure of silicon in different ways. Fadaly *et al.* make use of a strategy known as zone folding, which was originally outlined[4] in the 1970s. The idea is that the presence of a periodic electric potential in an indirect-bandgap semiconductor could transform it into a direct-bandgap semiconductor.

Until now, the best example of this approach was the production of a pseudodirect-bandgap semiconductor (which absorbs and emits light more efficiently than do indirect-bandgap semiconductors, but less efficiently than do direct-bandgap ones), in a special type of silicon–germanium alloy known as a superlattice, reported[5] in 1992. This was achieved by alternating atomic layers that have different compositions of atoms, but the resulting material still couldn't absorb or emit light efficiently enough for potential applications.

Nearly three decades later, Fadaly and colleagues have taken a different approach. Instead of modifying the atomic potential by alternating layers of different composition, they alternate two types of atomic stacking in germanium and in silicon–germanium alloys. This changes the symmetry of the materials' crystal lattices from a cubic form to a hexagonal one (Fig. 1).

The unit cell (the smallest repeating unit) of the hexagonal lattice contains twice as many atoms as the unit cell of the cubic form. This halves the size of the Brillouin zone — a unit cell of the abstract 'momentum space' that is used to describe the properties of electrons in semiconductors. This size reduction, in turn, results in the folding of the materials' electronic bands in momentum space, moving the position at which the energy value of the conduction band is at a minimum to the centre of the Brillouin zone, and thus generating a direct bandgap. Fadaly *et al.* use quantum-mechanical calculations to determine the exact band structure of germanium and silicon–germanium alloys in the hexagonal crystal structure, thereby confirming that these materials have a direct bandgap.

Most importantly, the authors demonstrate that hexagonal germanium behaves as an optoelectronic-grade direct-bandgap semiconductor. Moreover, by alloying hexagonal germanium with different amounts of silicon, they find that they can tune the energy of photons emitted from the resulting materials from 0.3 to 0.67 electronvolts. These emission energies are extremely relevant for chemical sensing and optical-communication technologies[3,6].

All of this work was made possible by producing the materials in the form of nanowires, filamentary crystals that have a tailored diameter of between a few and a few hundred nanometres. In simple terms, the high surface-to-volume ratio of nanowires enables the formation of metastable crystalline phases such as hexagonal silicon or germanium[7,8]. Fadaly *et al.* are the first to report that defect-free hexagonal germanium and silicon–germanium alloys can be made in a scalable manner using this approach.

The nanowire structure also offers another advantage: it causes light to interact with the nanowire material in a way that is ideal for photonic applications[9,10]. For example, nanowire shape can be engineered to ensure efficient light absorption and to prevent light from being trapped in the nanostructure by internal reflection. Nanowires could potentially also be used in light detectors for the ultra-rapid collection of the charge carriers produced from incoming photons, an effect that might be extremely useful for high-speed telecommunications.

Fadaly and colleagues' findings could potentially lead to the development of the first silicon-based laser, or be used to make mid-infrared light detectors, both of which would be compatible with the complementary metal-oxide semiconductor (CMOS) silicon technology that underpins much of the circuitry in computers. Such mid-IR detectors could be used in a scalable and economic lidar platform — a laser-based surveying technology that could be used by self-driving vehicles to detect objects. Mid-IR light does not damage the human eye, which means that mid-IR lasers could be used at high power in lidar systems; this enables object detection at long distances, thus allowing self-driving vehicles to travel safely at high speeds[11]. More broadly, the development of silicon-based alloys that have optoelectronic functionality could spark a second revolution in silicon technology, this time in silicon photonics.

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Neuroscience

A heated response to danger

Dayu Lin

Psychological stress can trigger physiological responses, including an increase in body temperature. A neural circuit that underlies this stress-induced heat response has been identified.

You are about to take the stage to speak in front of a large audience. As you wait, your heart starts to pound, your breathing quickens, your blood pressure rises and your palms sweat. These physiological responses are evolutionarily conserved mechanisms to prepare your body to fight against imminent dangers, or to run away quickly. Another key response is an increase in body temperature. Emotional stress can cause this psychogenic fever in many mammalian species, from rodents to humans[1,2]. What is the neural mechanism that underlies this phenomenon? Writing in *Science*, Kataoka *et al.*[3] describe a key neural circuit in psychologically induced hyperthermia.

The current work builds on a long legacy of research by the same group, who began their quest for a neuronal circuit that triggers heat production in 2004, using brown fat tissue as an entry point[4]. Brown fat is a type of 'good' fat that can generate heat when needed. Blocking the activity of β_3-adrenergic receptor proteins, which are abundant in brown fat and enable the tissue to respond to signals from neurons, attenuates stress-induced hyperthermia[5].

In the 2004 study, the researchers injected viral 'retrograde tracers' into brown fat in rats; the tracers move through connected neurons, allowing the authors to identify brain regions from which neurons project to the fat[4]. This revealed that neurons in a brainstem area

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