undesirable hexagonal structure. The authors find that the pseudocubic structure remains stable for at least a year at room temperature.

A compressive strain is imposed on the α-FAPbI$_3$ film because the dimensions of the cubic array of the substrate are different from those of the natural atomic array of α-FAPbI$_3$. Chen and colleagues were therefore able to control the strain of α-FAPbI$_3$ from 0 to 2.4% compressive deformation by growing FAPbI$_3$ on substrates that have different lattice dimensions. The authors found that this squeezing of the α-FAPbI$_3$ crystal increases the mobility of positively charged quasiparticles called holes, which correspond to the absence of electrons in the crystal. The authors attribute this increased mobility to the modification of the electronic structure of the crystal under compressive strain: compression leads to faster oscillations of the holes' wavefunctions, speeding up the movement of charge wavepackets (superpositions of wavefunctions) and thus producing higher charge mobility.

Previous work on the strain engineering of halide perovskite films lacked strain control[7] or involved straining methods that are harder to use[8,9]. By contrast, Chen and colleagues' study provides an extremely accessible and practical avenue through which to explore and use the physical properties of strained halide perovskites.

Questions remain about how the authors' findings could be used in solar cells. Currently available halide perovskite photovoltaic devices do not contain a genuinely epitaxial substrate, and so new cell designs will be needed to make use of the reported discovery. But a range of halide perovskite compounds are available that have similar atomic arrays to α-FAPbI$_3$, and which exhibit many different technologically important electronic properties. Chen and co-workers' study therefore suggests that there is plenty of scope for designing and developing epitaxial quantum-well devices using these materials, by mimicking the way in which quantum-well devices were developed using semiconductors from the III–V family of materials. This might bring down the cost of manufacturing these devices.

Finally, it will be interesting to see whether crystals of halide perovskites can be grown with sufficient atomic precision to make superlattices — periodic structures that contain multiple layers of two or more materials. The use of halide perovskites in superlattices could open up otherwise inaccessible electronic band structures, thereby allowing a rich array of physics to be explored, and emerging quantum-well devices to be further developed.

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Population biology

Predator–prey cycles achieved at last

Alan Hastings

A combination of laboratory experiments and mathematical and statistical analysis provides an affirmative answer to a decades-old question — can a predator and its prey coexist indefinitely? **See p.226**

A key question in ecology is what allows species to persist over time — particularly when there are pairs of species in which one is an exploiter and the other its victim. A long-standing theory attempts to answer this question by explaining how relative numbers of predators and their prey can cycle continuously[1]. First, prey numbers would increase, giving the predator more food. The subsequent increase in predators would lead to a decline in prey. Predator numbers would then decline owing to a lack of food, restarting the cycle. However, it has proved unexpectedly challenging to demonstrate this type of persistent predator–prey cycle in simple controlled systems in the laboratory. On page 226, Blasius *et al.*[2] report just such a demonstration, succeeding where almost 90 years of experimental work has failed.

Ecological theories of persistent predator–prey cycles are supported by the apparent existence of such cycles in nature, for instance between the lynx and hare in Canada[3]. However, it is hard to prove that these cycles endure in the wild, because observations over many decades would be needed. But if the theories provide a complete explanation of natural cycles, then it should be possible to demonstrate persistent cyclic behaviour in the laboratory, using species that have much shorter cycle times.

The challenge posed by such a demonstration was exemplified in 1934 by the ecologist Georgii Gause[4], who studied the dynamics of two unicellular organisms — the predator *Didinium nasutum* and its prey, *Paramecium caudatum*. Gause found that, on the one hand, if the predator was efficient, it ate up all the prey and then starved. On the other hand, if part of the environment helped to conceal the prey, the predator was less efficient — and so starved (Fig. 1a). Coexistence and long-term cycles could be achieved only through artificial means — namely, by adding prey at regular intervals.

In 1974, work with the same system showed that, by making the predator less efficient and by providing the prey with less food, the two populations could persist for longer[5]. Even so, coexistence could be maintained for just a few predator–prey cycles. Since then, some models that allow long-term cycle persistence have focused on space, for instance incorporating metapopulation dynamics[6]. In this phenomenon, subpopulations of a species migrate around a larger region. Although a subpopulation might become extinct in one area, the species persists across the region as a whole and can migrate back into that area. However, a better understanding of whether exploiter–victim cycles can persist locally without external input is still sorely needed.

Blasius and colleagues studied the aquatic invertebrate *Brachionus calyciflorus* and its prey, the green algal species *Monoraphidium minutum*. They found that, under simple and constant environmental conditions, the two species could coexist for more than a year — that is, over 50 predator–prey cycles. This result finally demonstrates that the long-standing theory of persistent cycles can be consistent with the reality of simple ecological systems.

Next, the researchers carried out a rigorous statistical analysis of the cycle dynamics in their system. Specifically, they used wavelet analysis, which focuses on dynamics over short periods; the technique has become a standard way to study the presence of periodic behaviour in ecological time series[7]. The analysis revealed interesting dynamic phenomena. The oscillations in the relative numbers of each species showed a characteristic lag in phase, with predator numbers mostly changing in the wake of altered prey numbers.

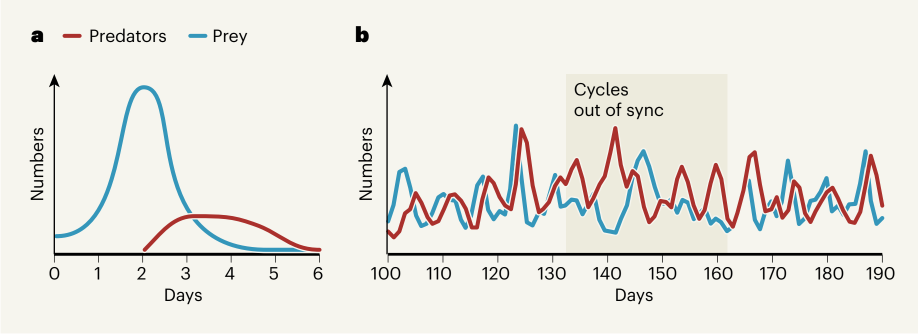

Figure 1 | A difficult balance to strike. Ecological theory predicts that the relative numbers of a predator and its prey should oscillate in persistent cycles, but demonstrating this in the laboratory has been hard. **a**, Classic experiments[4] from the 1930s failed to achieve cycles, because predators were either too inefficient at eating prey (not shown) or too efficient, and ate them all. Either way, predator numbers dwindled. **b**, Blasius *et al.*[2] have succeeded in achieving persistent predator–prey cycles in the laboratory. They found that cycles were mostly in phase, with predator cycles slightly lagging behind prey cycles. However, there were transient periods in which the two — for unknown reasons — fell out of sync. (Adapted from Fig. 2b of the paper.)

However, these oscillations would undergo sudden shifts, without any external driver. During these transient periods, both populations would oscillate out of sync with one another, before the in-phase cyclic dynamic resumed (Fig. 1b).

The authors also performed experiments in which they introduced pulses of nutrients to the species' environment. This mimics seasonal environmental changes experienced in many natural systems. The overall dynamics of the predator–prey cycle remained the same in these conditions, indicating that predator–prey interactions can govern cycle dynamics, even in a seasonally varying environment.

Although Blasius and colleagues' work answers one question, it raises others. First and foremost, why are the results so different from those of earlier experiments? It is not just a quirk of the species used, because the authors repeated the experiment using a different prey species and achieved the same result. One contributing factor could be that the researchers used a predator that has a complex life history involving transitions through several stages, from egg to adulthood. Another could be that persistence depends on the specific amplitude of oscillation in the cycle.

In support of these ideas, previous work involving a predator with a simpler life cycle demonstrated that populations of predators, prey or both went extinct if cycles reached an amplitude at which population numbers become low[4]. In addition, analysis of a different marine predator–prey combination[8] showed that cyclic dynamics eventually gave way either to extinction or to persistence of the two populations in equilibrium. And mathematical theory[1] suggests that the small-amplitude cycles observed by Blasius and colleagues would occur only under very specific conditions. Demonstrating persistent cycles in other systems is therefore a key challenge for the future. The life-history characteristics of the predator used by Blasius and colleagues could be a starting point in the search for systems that show similar behaviour.

Another intriguing avenue for future study is to determine the relationship between transient dynamics and switches in system behaviour. Does a sudden change in the dynamics of a cycling system reflect changing environmental conditions, or is it an intrinsic phenomenon? The existence of unexpected, transient shifts in predator–prey dynamics limits the predictability of ecological systems[9]. In the real world, sudden shifts of this nature could spur an erroneous quest to identify drivers of the change, whereas the current study indicates that there may be none. The possibility of transient dynamics could also make it more difficult to predict the effect of ecological-management strategies.

Blasius *et al.* have provided one of the clearest demonstrations so far of transient dynamics in the laboratory, where it is absolutely certain that no external influences caused the change. It will be important to bring together this work (and another convincing experimental demonstration[10]) with theoretical models that are currently being developed[9]. Doing so should provide more insights into the role of transient dynamics in natural systems.

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Materials science

The physics of ice skating

Daniel Bonn

The slipperiness of ice is poorly understood at a microscopic level. Experiments that probe how the surface of ice melts and flows in response to wear help to explain the exceptionally low friction that underpins winter sports.

It is widely thought that ice skating is enabled by the formation of a layer of water on the surface of ice, which lubricates the skate. Writing in *Physical Review X*, Canale *et al.*[1] report that, although there is indeed a layer of something, it is not simply water — the lubricating layer has surprising flow properties that are very different from those of bulk water, and are intermediate between those of liquid water and ice.

The idea that a thin film of meltwater wets the surface of ice has been accepted since the nineteenth century[2]. This layer should be present beneath skates or other objects sliding on ice. Most of the debate about this topic, therefore, deals with the origin of the layer — is it the result of surface melting, heating associated with friction generated by the skate, or pressure-induced melting? Pressure melting has largely been discounted, because this process is impossible for ice below about −20 °C, whereas skating is possible at such low temperatures. Surface melting and frictional heating also seem unlikely explanations because these phenomena are not specific to solid water ice, yet ice is almost the only