MICHAEL C. SINGER & CAMILLE PARMESAN

ECOLOGY

Precarious preferences

In 1993, three ecologists reported[1] that an isolated population of the butterfly *Euphydryas editha* that inhabited a meadow in Nevada was starting to evolve a preference for laying its eggs on *Plantago lanceolata* — a non-native plant introduced to the region by cattle ranchers. On page 238, two of these researchers now show[2] that the butterflies became completely dependent on the exotic plant, with adverse consequences.

Originally, *E. editha* laid its eggs on the native plant *Collinsia parviflora*, but the longer life span of *Plantago* enabled larvae to feed on it for longer, increasing larval survival. In the current study, Singer and Parmesan report that all the female butterflies they examined in 2005 preferred to lay their eggs on *Plantago* (pictured, *E. editha* resting on *Plantago*). And by 2007, all the larvae they found in the field were feeding on this non-native plant.

But cattle ranching ceased in 2005, leading to a rapid build-up of grassy vegetation and a decline in the dominance of *Plantago*. This, in turn, led to the extinction of the isolated *E. editha* population between 2007 and 2008, probably because the long grasses blocked out sunlight, cooling the warmth-loving larvae. The growth of the grasses quickly abated, but the butterfly population remained extinct until between 2013 and 2014, when *E. editha* recolonized the field, laying its eggs on *Collinsia*, and so setting the stage for the process to begin again.

These findings demonstrate how the adaptation of insect populations to human-induced environmental change can render those populations dependent on the continuation of specific human practices — a potentially precarious position, given the rapidity with which such things can change. **Anna Armstrong**

1. Singer, M. C., Thomas, C. D. & Parmesan, C. *Nature* **366**, 681–683 (1993).
2. Singer, M. C. & Parmesan, C. *Nature* **557**, 238–241 (2018).

PARTICLE PHYSICS

Weak charge of the proton measured

The proton's weak charge defines the strength of certain interactions between protons and other particles. A precise determination of this quantity provides a stringent test of the standard model of particle physics. SEE LETTER P.207

XIAOCHAO ZHENG

Subatomic particles interact through four fundamental forces. However, only two of these forces have effects on macroscopic scales: gravity keeps us grounded on Earth, and electromagnetism causes lightning on stormy days. We are not directly influenced by the other two forces — the weak and strong forces. Similarly, it is generally known that mass is at the root of gravitational interactions and that electric charges and magnetic moments are central to electromagnetism. But the physical properties that describe the strength of weak and strong interactions, known as weak and colour charges, respectively, are less familiar. On page 207, the Jefferson Lab Q_{weak} Collaboration[1] reports the first high-precision measurement of the weak charge of the proton, which sets tight constraints on physics that cannot be described by current theories.

The strong force is so overwhelming that the particles that interact through it, known as quarks and gluons, are tightly bound to one other and exist only as composite objects, such as protons and neutrons. By contrast, the weak force is so feeble that its interactions are almost completely masked by those of electromagnetism. One might therefore wonder how the weak charge of a particle can be measured if it is as small as the name implies. Fortunately, nature provides a convenient yardstick that is associated with a principle known as parity symmetry.

A process conserves parity symmetry if it occurs with the same probability as its exact mirror image. It is straightforward to see that parity symmetry is broken in the macroscopic world, particularly in biological systems. For example, most humans are right-handed. If parity symmetry were conserved for the handedness of humans, half of the population would be right-handed and half would be left-handed.

Particles also have a handedness. A right-handed particle spins in the direction defined by the curl of your four fingers when you point your right thumb along the direction of the particle's velocity. Conversely, a particle is left-handed if you must use your left hand to relate its spinning and velocity directions. Remarkably, all subatomic particles violate parity symmetry when they interact with one another through the weak force. Weak charges can therefore be determined by comparing the behaviour of left- and right-handed versions of particles.

To extract the proton's weak charge, the Q_{weak} Collaboration fired beams of electrons that had a particular handedness at a proton target. They measured an asymmetry that describes the difference in the probability that right- and left-handed electrons are scattered from the proton (Fig. 1). The authors found an asymmetry of −226.5 ± 9.3 parts per billion, where the minus sign indicates that left-handed electrons are more likely to be scattered than their right-handed counterparts. To put the magnitude of this asymmetry in perspective: if parity symmetry were violated for the height of mountains, Mount Everest and its mirror-image twin would differ in height by a mere 2 millimetres, and this difference would have been measured to a precision of ± 80 μm.

The authors' result has a much higher precision than all previous experiments that studied parity violation by scattering electrons from a nuclear target. The E158 experiment at the SLAC National Accelerator Laboratory in Menlo Park, California, had a comparable precision, but measured the weak charge of the electron rather than that of the proton[2]. The Q_{weak} Collaboration used its measured asymmetry to determine that the proton's weak charge is 0.0719 ± 0.0045, which is in excellent agreement with the value predicted by the standard model of particle physics[3]. For comparison, in the convention used by the authors, the proton's electric charge is +1.

One might question why physicists want to measure the proton's weak charge to such high precision. The short answer: to test the limits of our knowledge. At a basic level, physicists seek to discover if, and at what length scale, current theories fail to explain observational data. Such a failure could imply the existence of a fifth fundamental force — a previously undiscovered type of interaction that has a role at energies higher than have been explored so far.

The measurement reported by the Q_{weak} Collaboration shows that such interactions, if they exist, would reveal themselves at particle energies beyond several TeV (1 TeV is 10^{12} electronvolts). For comparison, the energies released in nuclear-fission reactors, in which nuclei split into two or more fragments, are at the level of 10^6 eV per particle. The authors' lower limit for the energy scale of new physics is comparable to, and complements, that set by experiments at the Large Hadron Collider at CERN, Europe's particle-physics laboratory near Geneva, Switzerland[4,5]. This is remarkable, given that the energy of the authors' electron beams is thousands of times lower than that of the Large Hadron Collider's proton beams.

More than a century ago it was demonstrated that electric charge comes in discrete chunks[6], which provided a bridge between classical electromagnetism and modern quantum mechanics. By measuring quantities — from physical constants to particle properties such as the proton's weak charge — at increasingly higher precision, new interactions and particles could be discovered that require current theories to be revised. Such lofty pursuits can be maintained only if research is carried out by multiple groups across generations, as opposed to single groups in isolated instances. One day, the knowledge acquired might lead to a breakthrough. In the meantime, it will make our world a better one by providing a deeper understanding of the physical laws of nature. ■

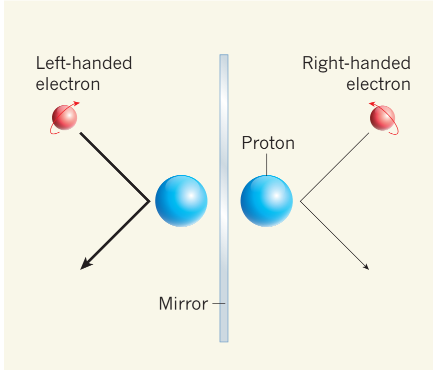

Figure 1 | Parity violation in electron–proton scattering. Electrons can be either left- or right-handed, depending on the direction in which they spin (red arrows) relative to their motion (black arrows). The Jefferson Lab Q_{weak} Collaboration[1] reports that left-handed electrons are slightly more likely to be scattered from a proton target than are their right-handed counterparts. This result violates a principle known as parity symmetry because the two scattering processes are mirror images of each other. The authors used the measured asymmetry to determine the value of a fundamental physical quantity known as the weak charge of the proton to an unprecedented precision.

Xiaochao Zheng *is in the Department of Physics, University of Virginia, Charlottesville, Virginia 22904, USA.*
e-mail: xz5y@virginia.edu

1. The Jefferson Lab Q_{weak} Collaboration. *Nature* **557**, 207–211 (2018).
2. SLAC E158 Collaboration. *Phys. Rev. Lett.* **95**, 081601 (2005).
3. Patrignani, C. *et al.* (Particle Data Group). *Chin. Phys. C* **40**, 100001 (2016).
4. ATLAS Collaboration. *Eur. Phys. J. C* **74**, 3134 (2014).
5. CMS Collaboration. *Phys. Lett. B* **746**, 79–99 (2015).
6. Millikan, R. A. *Phys. Rev.* **2**, 109–143 (1913).

NEUROSCIENCE

Connections that control defence strategy

When presented with a threat, most mice freeze or hide, but a few respond more aggressively. The brain circuits underlying this behavioural choice have now been unpicked. SEE ARTICLE P.183

DAYU LIN

My nine-year-old daughter got a pair of mice for Christmas. To acclimatize her new pets to her presence, she put her hands into their cage. One of the mice ran straight to its shelter and hid; the other stayed in a corner, held its tail up against the glass wall and rattled it rapidly. Tail rattling is a common response to stress across species (most famously in snakes[1]), and is considered a warning to intruders[1,2]. But why do some mice hide, and others threaten? What brain mechanisms determine which defensive strategy to deploy in the face of potential danger? On page 183, Salay *et al.*[3] reveal a brain region that could be responsible for this decision in mice.

Salay *et al.* first surveyed the brain regions that are activated by threatening cues. They placed mice in a test arena, then presented them with an overhead looming stimulus — an expanding dark-coloured circle, to mimic an approaching predator. When the mice detected the looming cues, they either froze or quickly ran towards a shelter under which they could hide from the stimulus. Occasionally, mice rattled their tails once they had reached the safety of the shelter.

To identify the neurons that determine these behavioural responses, the researchers analysed the protein c-Fos, which is expressed rapidly in neurons after they have been highly active. Many brain regions show consistently high levels of c-Fos in response to looming, and one caught the authors' attention — the ventral midline thalamus (vMT). The vMT is interesting in that it is not a part of the eye-to-brain visual pathway or a motor pathway, as might be expected for neurons involved in processing visual stimuli such as the looming cues in this study. Instead, it receives diffuse inputs from limbic areas and the midbrain (regions that support emotion, motivational behaviours and bodily responses), and projects heavily to higher cognitive areas, such as the prefrontal cortex[4]. Thus, this region is well suited to signalling the internal state of the animal and guiding its defence strategies.