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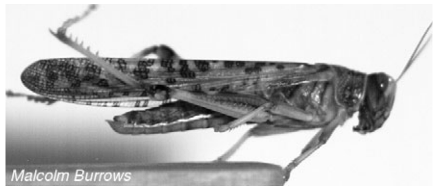
Inside JEB

BUCKLING ZONE PROTECTS LOCUST LEGS



Tiny froghoppers and planthoppers are the elite of the insect athletic world, launching themselves into the air at an impressive 5 m s^{-1}. However, hefty locusts still give them a respectable run for their money, pulling off impressive take-offs at 3 m s^{-1}. Malcolm Burrows and colleagues Tim Bayley and Greg Sutton from the University of Cambridge, UK, explain that the forces exerted on the leaping insect's hind legs come within 20% of wrecking the limbs. This puts the insects at risk of serious injury when things go wrong, either during take-off or when they misplace a kick. Filming locust take-offs, the team discovered that the leaping insects' hindlimbs buckled when they slipped and lost their footing. Explaining that William Heitler had also noticed a region of the locust hind limb just below the knee that appeared to buckle when the insects kicked (Heitler, 1977, *J. Exp. Biol.* **67**, 29-36), Burrows and his colleagues decided to find out how much the insects' legs deform and how they protect themselves from injury when a jump or kick misfires (p. 1151).

Filming leaping locusts at 1000 frames s^{-1} as they lost their footing, the team saw the slipping leg fly out before the insects took off, with the misplaced leg swinging 13 times faster than it had during a successful jump. And when they looked at the limb in closer detail, they saw that the tibia bent at angles ranging from 2 to 38 deg just below the knee joint, in the same location where Heitler had seen the tibia of kicking locusts buckle. Then the limb bounced up and down, repeatedly buckling at the same location until it had dissipated all of the misdirected energy.

Next, the scientists filmed the insects kicking and missing their targets. This time the limb swung even faster, bending in the same region by as much as 48 deg. However, when the insects aimed a successful kick, the tibia remained completely straight. Finally, the trio painted nail polish on the region of the tibia that buckled. This time, instead of bending, the tibia remained straight and bounced back and forth around the knee joint.

Having filmed the tibia's deformation, the team calculated the amount of energy absorbed as the leg buckled and it was an impressive 88% of the kick's energy. They also directly measured the amount of energy stored in the flexible region by bending the leg with a servo-motor, and found that the limb initially absorbed over 1000 μJ during the first kick, falling to 600 μJ during subsequent kicks, but recovering to the initial value after 24 h.

Intrigued by the tibia's recoverable crumple zone, the colleagues shone UV light on the limb. Explaining that the elastic protein resilin fluoresces under UV light and that the remarkable material turns up in a wide range of flexible structures, Burrows saw the material's tell-tale violet glow exactly where the tibia buckled. So the flexible zone contains elastic resilin, which allows the leg to bend without snapping.

Finally, knowing that there is a cluster of campaniform sensilla (mechanoreceptors) on the tibia, just below the buckling region, the team decided to find out whether these sensors respond when the tibia deforms. Recording nerve signals from the sensors, the trio reproduced the leg's kicking movement and found that they did fire when the leg buckled. The team explains that the mechanoreceptors' response is too slow to allow the locust to react when the leg buckles during a mistimed jump or kick. However, they suspect that the mechanoreceptors could influence the insect's subsequent behaviour or participate during the preparatory phase of a jump, when the tibia flexes and the flexible region deforms slowly.

10.1242/jeb.071555

Bayley, T. G., Sutton, G. P. and Burrows, M. (2012). A buckling region in locust hindlegs contains resilin and absorbs energy when jumping or kicking goes wrong. *J. Exp. Biol.* **215**, 1151-1161.

Kathryn Knight

MUSSEL STRATEGY FOR LONG-TERM HEAT STRESS

As the mercury rises and cold-adapted species are forced to move northward, their survival depends on their ability to adapt swiftly to changing environmental conditions. Peter Fields from Franklin & Marshall College, USA, and colleagues Marcus Zuzow and Lars Tomanek from California Polytechnic State University, USA, say, 'In order to predict which organisms will be affected most by anthropogenic temperature increases, we need to better understand the mechanisms by which temperature affects the physiology of organisms, and specifically to identify the cellular processes that are most sensitive to acute and chronic heat stress.' Explaining that cold-adapted endemic *Mytilus trossulus* (Californian) mussels are

being gradually displaced from their southernmost Pacific coast territory by their more thermally tolerant – and invasive – cousins, *Mytilus galloprovincialis*, Fields and his colleagues decided to find out how both species respond at the cellular level to long-term heat stress (p. 1106).

Immersing mussels at 7, 13 and 19°C for 4 weeks, the team analysed the protein expression patterns in the mussels' gills to identify differences in the two species' physiological responses. They found that both species changed their cytoskeletal composition and energy metabolism protein expression in response to higher temperatures, and showed signs of stress at lower temperatures. However, the Californian mussels showed more signs of stress than their heat-tolerant cousins. The invasive *M. galloprovincialis* mussels also responded more strongly to cold acclimation than the Californian native, with *M. galloprovincialis* changing their protein expression patterns at 7 and 13°C while the *M. trossulus* expression patterns were almost the same at the two temperatures.

Comparing these new data with the results from experiments where the mussels were acutely stressed – simulating the experience of exposed mussels at low tide – the team says, 'The combination of cold acclimation (or acclimatisation) followed by acute heat exposure could represent a particularly severe level of stress and be a major limiting factor in setting distribution ranges.'

10.1242/jeb.071563

Fields, P. A., Zuzow, M. J. and Tomanek, L. (2012). Proteomic responses of blue mussel (*Mytilus*) congeners to temperature acclimation. *J. Exp. Biol.* **215**, 1106-1116.

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TARANTULAS DO NOT SHOOT SILK FROM FEET

When Rainer Foelix read a 2006 *Nature* paper from Stanislav Gorb's lab (Gorb et al., 2006, *Nature* **443**, 407) and Claire Rind's 2010 *JEB* paper (Rind et al., 2011, *J. Exp. Biol.* **214**, 1874-1879) reporting that tarantulas secrete silk from their feet to steady themselves during falls, Foelix was sceptical. In 1968, he had discovered chemosensitive (taste) hairs on the legs of spiders, and when he saw the electron microscopy images of the hair structures that were proposed to produce the tarantula's stabilising foot silk, Foelix was perplexed. They looked very similar to the taste hairs that he had identified 40 years before, but the hairs produced some kind of secretion when the animals slipped, which could be silk. Intrigued by the puzzle, Foelix decided to take a closer look at the hairs to find out whether they are silk-producing spigots or chemosensors (p. 1084).

As he was familiar with the structure of arachnid chemosensory hairs, Foelix knew that he would have to look inside the hair structures to find out whether they had any of the telltale features that he would expect to find. Collecting specimens from five species of tarantula, Foelix scrutinised their shed skins with light microscopy and scanning electron microscopy. He found the long ridged hair shafts that the other researchers had described protruding above the spider's brush-like adhesive hairs. The ridged hairs were also sparsely distributed amongst the adhesive hairs. Zooming in on the hairs, Foelix found a narrow pore at the tip of each hair, which was often covered by a blob of fluid. Foelix says, 'A distal pore opening is a must for any contact chemoreceptor. This is where the nerve endings (dendrites) are exposed to the environment. They also have to be bathed in a fluid (receptor lymph), otherwise they would dry out quickly.' And when Foelix looked through the hair shaft using light microscopy, the pore continued into a central canal. Also, instead of extending to a silk canal at the base of the hairs, the canal terminated much earlier; just like the fluid-filled canal in other arachnid chemosensors.

Having convinced himself that the hairs had all of the characteristics of chemoreceptors and not silk spigots, Foelix was still left with the puzzle about the secretions produced by the hairs. Were they silk or some other substance? Teaming up with Bastian Rast and Anne Peattie, Foelix compared the tarantula foot hairs with the spigots on the spiders' spinnerets. Pressing the spiders' feet and spinnerets against clean glass slides, the team found that the spinnerets produced masses of silk thread. However, the footprints appeared to produce only a few silk threads, which Foelix suspects had been picked up previously from the tarantula's spinnerets.

Next, Peattie caused the feet of a Chilean rose tarantula to slip on a glass slide. This time they successfully produced the same silk-like trails from the hairs that other researchers had found. However, instead of continuing to pay out after losing contact with the glass, the threads always snapped. And when Foelix took a closer look at the secretions, he realised that the trails could not be threads, as some of them were composed of droplets rather than a continuous strand. Foelix suspects that instead of exuding silk, the hairs ooze lymph as they are dragged along a surface during a slip.

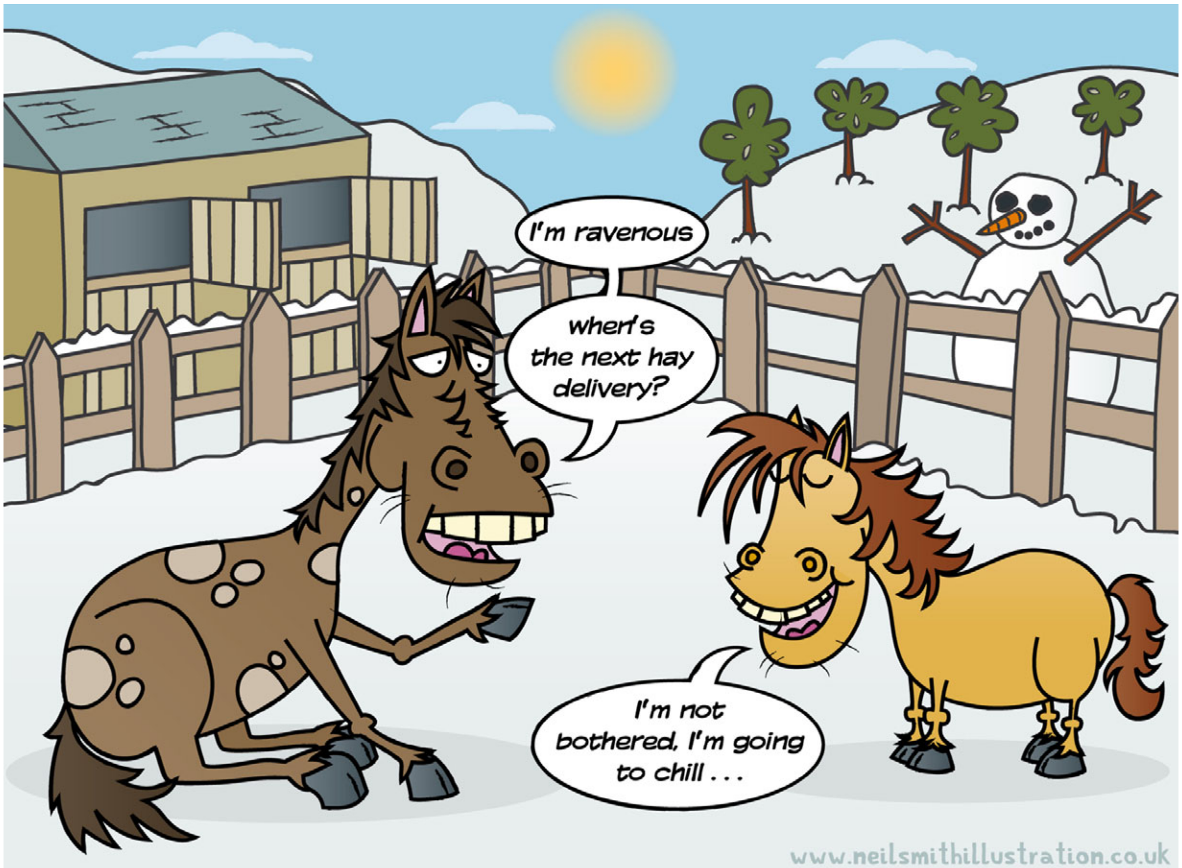
So Foelix and his colleagues are convinced that the hairs are chemosensors instead of spigots and that tarantulas do not exude silk from their feet to break a fall, and he keenly anticipates the next instalment in this heated debate.

10.1242/jeb.071597

Foelix, R. F., Rast, B. and Peattie, A. M. (2012). Silk secretion from tarantula feet revisited: alleged spigots are probably chemoreceptors. *J. Exp. Biol.* **215**, 1084-1089.

Kathryn Knight

SHETLAND PONIES CHILL WHEN FOOD IS SCARCE



Maintaining a constant warm body temperature has major advantages: it's easier to get going in the morning and your activity levels aren't prey to the vagaries of the climate. However, there is one colossal down side: it costs a metabolic fortune, so some small creatures drop their body temperature when resources are scarce to conserve energy. Lea Brinkmann and colleagues from the University of Göttingen, Germany, explain that some ungulates also take advantage of the energy savings incurred by low body temperatures, yet most were thought to have lost this ability when they became domesticated. However, recent studies show that the ancient wild predecessor of modern horses, the Przewalski horse, appears to have retained this ability. Curious to find out whether domesticated horses were also capable of regulating their body temperature, Brinkmann and colleagues decided to find out whether Shetland ponies, one of the earliest domesticated horse breeds, drop their body temperature when food is scarce (p. 1061).

Monitoring the activity levels, subcutaneous and rectal temperatures, heart rate and general body condition of a group of ponies over a year, the team noticed that the animals' subcutaneous temperatures dropped over night and rose again during the day in the summer. 'This is consistent with a daily shallow hypometabolism,' the team says. Then, as the winter set in, the team fed half of the group full rations while simulating food shortages by cutting the other half's diet by 30%. This time, the ponies experiencing the harsher winter conditions lowered their body temperature and were as much as 1.1°C cooler than the well-fed animals. In addition, they had much slower heart rates, suggesting that they also had a lower metabolic rate. 'Domesticated Shetland ponies showed similar seasonal adjustment mechanisms described for the wild counterpart, the Przewalski horse,' say Brinkman and colleagues.

So, the domesticated animals have retained their wild ancestors' ability to conserve energy when resources are scarce, while improving their metabolic efficiency to lay down fat during times of plenty.

10.1242/jeb.071571

Brinkmann, L., Gerken, M. and Riek, A. (2012). Adaptation strategies to seasonal changes in environmental conditions of a domesticated horse breed, the Shetland pony (*Equus ferus caballus*). *J. Exp. Biol.* **215**, 1061-1068.

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