OUTSIDE JEB

Kicking kangaroo rats deter rattlesnakes

Rattlesnakes represent the quintessential ambush predator. They can withstand months of starvation whilst they patiently await the arrival of prey within striking distance. Only then can a snake launch an attack to envenomate, subdue and consume its meal. Whilst studying this dramatic act, it is no wonder that most researchers have directed their attention to the traits of the impressive reptilian predators. But a pair of studies, recently published by Rulon Clark's group at the San Diego State University, USA, focused instead on the adaptations that their prey, specifically kangaroo rats, use to evade death.

Like the Australian marsupials from which their name is derived, kangaroo rats have huge, powerful legs to propel them across the sandy terrain. In the first study, led by Grace Freymiller, the team investigated how the legs of the kangaroo rats can be used to escape or for self-defence (doi:10.1093/biolinnean/blz027). To study the event, the team tracked snakes, which they had rigged earlier with small radio transmitters, in an Arizona desert. When they found a rattlesnake lying in ambush, the group set up high-speed video cameras and infrared lighting so that they could film after nightfall, when the kangaroo rats become active. To lure the kangaroo rats to the arena, the research team sprinkled a few sunflower seeds – a tempting treat – in the vicinity of the snakes.

Freymiller and colleagues filmed a breath-taking series of interactions, in which the agile rodents displayed a plethora of kicks, flips and twists to deter and escape a rattlesnake strike. The kangaroo rats made near-vertical leaps 40 cm into the air (an impressive feat corresponding to 6 times the animal's body length). Unlike the case with most other rodents, the jumps were skilfully controlled to direct their path away from the snake. Most strikingly of all, some of the kangaroo rats targeted powerful kicks at the attacking rattlesnakes. The authors therefore believe that the huge hindlimbs may have evolved first as a tool to evade predators.

The prevailing, predator-centric dogma has assumed that the success of an attack primarily depends on the performance of the hunter, in this example the velocity or accuracy of a snake's strike. However, the team now realised that the prey may also be capable of life-saving self-defence mechanisms. In their second paper, led by Malachi Whitford, the group sought to quantify how effective the kangaroo rats' acrobatics were (doi:10.1111/1365-2435.13318).

The team noted how often the snakes hit their target and how often the kangaroo rats survived the encounter. Furthermore, they recorded whether or not the snake released the rodent from its bite of its own volition, or whether the kangaroo rats actively removed the fangs. Of the 32 strikes that Whitford and colleagues analysed, in just over half (17) the snake missed the kangaroo rat. Usually, this was because the rat dodged the strike, although in one case a snake comically collided with a branch. Of the 15 hits, seven strikes resulted in fatalities, whereas eight kangaroo rats survived the encounter. In only three cases did the snake voluntarily release its fangs, all of which resulted in the rodent's death. However, when the kangaroo rat was able to prematurely dislodge the viper's fangs, it increased its chances of survival to 67% (8/12).

These harmonious companion studies show us that the adaptations of prey animals can be just as extraordinary as those of their predators. After all, they are fighting for their lives, whilst the predator is merely hoping for its next meal. Kangaroo rats are able to effectively defend themselves and, to some extent, hold their fate in their own hands (or feet).

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Freymiller, G. A., Whitford, M. D., Higham, T. E. and Clark, R. W. (2019). Escape dynamics of free-ranging desert kangaroo rats (Rodentia: Heteromyidae) evading rattlesnake strikes. *Biol. J. Linn. Soc.* **127**, 164-172. doi:10.1093/biolinnean/blz027

Whitford, M. D., Freymiller, G. A., Higham, T. E. and Clark, R. W. (2019). Determinants of predation success: how to survive an attack from a rattlesnake. *Funct. Ecol.* doi:10.1111/1365-2435.13318

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Snakes diffract like a light ray to put them on the right track

Snakes travel in the form of an undulating S-shape produced by a wave of muscle contractions propagating from their head to their tail. How do snakes preserve their motion when they encounter unexpected obstacles on their way? Perrin Schiebel and her colleagues at the Georgia Institute of Technology in Atlanta, USA, wanted to find out whether the snakes' strategy to deal with unforeseen hurdles relies on sensory information to carefully guide their path or whether they exploit the unguided natural motion that is intrinsic to their undulating bodies to set them on the right course.

Outside JEB reports on the most exciting developments in experimental biology. The articles are written by a team of active research scientists highlighting the papers that JEB readers can't afford to miss.

To answer their question, the team observed the desert-dwelling, shovel-nosed snake as it made its way across a 165 cm-long sandbox covered in carpet that the researchers had built. The snakes often travel at about 30–80 cm s^{-1} and usually encounter obstacles such as small plants and twigs in their natural environment, so the researchers mimicked these obstructions by placing six posts spanning the width of the box, mid-way along, spaced about 2 cm apart, which the snakes had to pass to get to the other end. Schiebel and her colleagues observed the angle of the path that the snakes took when they slid past or collided with the posts: 0 deg if the snake maintained its movement straight forward, negative angles if the snake veered to the left and positive angles if it veered to the right. To make sure that the snakes didn't pre-plan their encounters with the posts, the team temporarily blindfolded the animals by using face paint to cover the scales over their eyes.

When the team looked at the path deflections as the snakes passed between the posts, they found that they ranged from −57.2 to 56.1 deg, with three distinct peaks representing the angles that the snakes were most likely to take. The team noted that the pattern of deflections looked similar to the way that rays of light bend – diffract – when passing through a narrow slit. This remarkable similarity between the physical wave-motion of the snakes' bodies and how light rays behave led the researchers to realise that the snakes were not responding to sensory signals that they had gathered about their surroundings. Were their movements being guided by a passive process instead?

To understand how the intrinsic springiness and structure of the snakes' body might passively result in the deflection pattern, the team developed a series of equations that they used to calculate the snakes' manoeuvres. By using the wave of muscle-activating nerve signals that pass along the length of the snake's body, the team determined the points where the animal would buckle, which could subsequently determine the direction in which it moved. Impressively, the deflection angles calculated by the equations replicated Schiebel's observations, which suggests that the deflections may arise purely from the intrinsic mechanical properties of the animal's body without any need for sensory inputs.

Schiebel and her colleagues have discovered a remarkable similarity between a snake's route through an obstacle-strewn path and the way that rays of light diffract. Their results suggest that snakes use a simple strategy when they encounter obstacles that depends on the passive dynamics of their bodies without the need for sensory information to guide them. And they are optimistic that the snake's passive approach could inspire new strategies for helping snake-like robots overcome unexpected bumps in their way.

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Schiebel, P. E., Rieser, J. M., Hubbard, A. M., Chen, L., Rocklin, D. Z. and Goldman, D. I. (2019). Mechanical diffraction reveals the role of passive dynamics in a slithering snake. *Proc. Natl. Acad. Sci. USA* **116**, 4798-4803 doi:10.1073/pnas.1808675116

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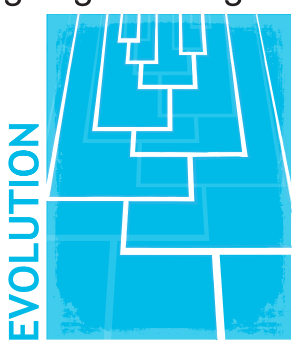
Lice dodge death by going to the light



Feather lice take a heavy toll on their bird hosts by reducing survival and mating success. But to do their damage, and to survive themselves, these parasites need to evade detection by the continued efforts of their grooming hosts. As shown in a remarkable new paper from Sarah Bush and her colleagues at the University of Utah, USA, one of the most effective ways that lice can save their skin is by blending in.

Bush and her team focused on the much-maligned rock pigeon, a feral species whose plumage ranges from black to white. Looking more closely, they observed a close correspondence between feather colour and lice colour: white birds have light lice and dark birds have darker lice. But what drives this association? One possibility was that lice are phenotypically plastic and can change colour by increasing or decreasing pigmentation if they find themselves on a mismatched host. This isn't apparently the case. When the team bred lice on a middle-of-the-road grey bird, they determined that baby lice are the same colour as their parents; colour is highly heritable. The second option for colour matching was natural selection imposed by the vigilance of preening pigeons.

The preening idea makes good sense. Our eyes, and those of pigeons, are very good at resolving colour contrasts – black stands out on a white background and vice versa. To test whether pigeons selectively preened mismatched lice, the team used a series of manipulations that were perfect for their simplicity and clarity. They painted lice: some white and some black. Then they loaded these lice onto black and white pigeons, half of which were fitted with little mouthguards that prevented them from fully closing their beaks, thus rendering their preening useless. As expected, preening works as a means of removing lice; birds with mouthguards had 10 times more lice than those without. More importantly, after only 48 h, birds that could preen normally were almost twice as likely as their impaired counterparts to have removed conspicuously mismatched lice. In other words, preening was highly selective.

Of course, natural lice aren't painted and lice live and reproduce on pigeons, which creates the potential for them to evolve increased camouflage through time. The team examined this possibility by infecting birds with a mixture of greyish lice. They then left them to do their thing (when two lice love each other very much…) for 4 years, representing about 60 lice generations, while periodically measuring lice coloration. Their results were unambiguous. Lice on dark birds evolved to become darker and lice on white birds evolved to become much lighter – indeed, as light as lice that have been living on another species of white pigeon for millions of years.

The most amazing thing about this study is the pace of the response. It reveals an incredible capacity for evolutionary change in these lice, and clarifies how effectively host defenses can drive and reinforce rapid adaptive changes in parasites. In addition, the work argues forcefully for the power of experimental evolution to measure adaptation in real time. Seeing, or not seeing in this case, is definitely believing.

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Bush, S. E., Villa, S. M., Altuna, J. C., Johnson, K. P., Shapiro, M. D. and Clayton, D. (2019). Host defense triggers rapid adaptive radiation in experimentally evolving parasites. *Evol. Lett.* **3**, 120-128. doi:10.1002/evl3.104

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Egg temperature affects chicks' clumsiness

The temperature of reptile eggs affects offspring sex, size and running speed. Warmer temperatures usually make for faster reptiles. However, reptiles are ectotherms and cannot produce heat on their own: if it's cold when their running speed is tested, they might just be slower. Birds, in contrast, are endotherms like us. While the temperature of bird eggs affects how long it takes for chicks to hatch, there is little information on how egg temperature affects motor skills in birds. Starlie Belnap and colleagues at Florida International University, USA, recently used bobwhite quail eggs to test whether incubation temperatures influence the way chicks walk.
First, the researchers kept bobwhite quail eggs in three different incubators: one at the optimal temperature (37.5°C) for hatching, a high-temperature incubator at the maximum temperature that the eggs can tolerate (38.1°C) and a low-temperature incubator at the coolest temperature (36.9°C) that the eggs can endure. They then collected chicks that hatched on the same day and found that baby bobwhite quails incubated in cooler temperatures weighed less and had larger leg joint angles than their counterparts. The differences in weight are not surprising, as temperature is known to affect an animal's metabolism; when endotherms are cold, they burn more energy to keep warm which, over time, can result in weight loss. Additionally, the differences in leg joint angle might mean that the legs are stiffer, decreasing the chicks' range of motion after they have hatched.

Intriguingly, Belnap and colleagues found that the baby birds from the higher temperature incubator had shorter lower legs than those from the optimal and lower temperature incubators. This is in contrast to their original prediction that warmer temperatures would be beneficial to the chicks, optimizing their bodies for movement and enhancing their coordination. However, bobwhite quails with shorter lower legs have a smaller base of support and might be less stable than bobwhite quails with longer lower legs. And when the scientists checked the coordination of the bobwhite quail chicks from the warmer incubator, they were astonished by the youngsters' clumsiness. The team enticed the chicks to walk on a runway towards a speaker playing calls from a mother bobwhite quail and found that chicks incubated at the hot and cold temperatures fell more than 3 times as often as chicks incubated at the optimal temperature. This suggests that egg incubation temperature affects the coordination of hatchlings. The scientists' suspicions were backed up when they noticed that the stride length of the chicks from the cold incubator were very variable, which suggests poor motor control and increases the risk of them tripping and falling over.

However, many features of the chicks' walks were not affected by their different starts in life. For example, the speed and average size of their steps did not differ significantly between hatchlings from the optimal- temperature incubator and those from the high- or low-temperature incubators. This study provides evidence that incubation temperature affects bobwhite quail chick motor coordination after hatching. If mama birds do not keep their eggs at the optimal hatching temperature, they might end up with some seriously clumsy chicks.

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Belnap, S. C., Currea, J. P. and Lickliter, R. (2019). Prenatal incubation temperature affects neonatal precocial bird's locomotor behavior. *Physiol. Behav.* **206**, 51-58. doi:10.1016/j.physbeh.2019.03.002

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