OUTSIDE JEB

Birds don't mind the light – if it's dim enough

Have you have ever been on an airplane at night and looked down on the illuminated earth? Our various light sources can be seen from miles away and the brightening of the night sky above cities even has a name – urban sky glow. Obviously, light sources at night are needed in modern civilisations, but diminishing darkness can cause severe problems, such as altering wake–sleep rhythms and affecting health. Although we have found ways to live with light pollution, other animals cannot always avoid it.

Zeynep Ulgezen, from Wageningen University in The Netherlands, and an international team of colleagues wanted to know the consequences for birds of sleeping under night illumination. For their study, the researchers caught great tits (*Parus major*) from an urban and a forested area and tested whether they preferred to sleep under constant darkness or under weak green or white LED light (1.5 lx). Next, they exposed the birds to constant darkness or nightly white or green illumination for 14 days, and monitored the birds' sleep, activity and how much energy they spent per night. The researchers also took blood samples from the birds before and after the treatment to determine the animals' oxalic acid levels, a biomarker for sleep disruption, and compared the memory and learning skills of the great tits exposed to the different light conditions, by training them to differentiate between colours and select a certain colour in return for a reward.

To their surprise, Ulgezen and her colleagues found that all of the birds preferred to sleep under light instead of in constant darkness, and – when given the choice – the birds preferred green over white light sources. When the researchers looked into the consequences of sleeping under light, they found no effect of nightly illumination on the birds' memory and learning, and their blood levels did not show any indication of sleep disruption. However, both light sources caused the birds to be more active at night. The great tits that slept under white light became active almost 3 h earlier than those sleeping in constant darkness and half an hour earlier than those that slept under green light. Consequently, the birds facing nightly light pollution spent more energy than the birds that slept in complete darkness. But the effect of light also depended on the origin of the birds. The animals that were captured in a forest were most active under nocturnal white light, while urban birds showed the same amount of activity under green and white light.

This study suggests not only that urban birds can get used to the lights of the city, but also that birds actually prefer to have – at least a little – light at night. While the researchers have used light intensities that mimic realistic light pollution, the illumination was still relatively weak, and birds nesting under street lamps would experience light that was up to 13-fold more intense. But why do birds prefer light over darkness? Ulgezen and her colleagues suggest that the birds chose the illuminated areas for a simple reason: more light allows them more time to forage and enchant members of the opposite sex.

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Pigeons flap faster with friends

It is often said that birds of a feather flock together, but successfully orchestrating clustered flight has more to do with physics than poetry. Although a number of co-ordinated group flight behaviours, such as the V-formation flights observed in geese, are believed to be energy-saving mechanisms, the costs and benefits of other flocking behaviours are less well understood. Pigeons (*Columba livia*), for example, will often fly in clusters rather than go it alone, but what are the consequences of choosing quantity over quality? In a recently published study, Lucy Taylor and her team of flight biomechanists from the universities of Oxford and Royal Holloway, London, in the UK, recently set out to answer this question by investigating how the wingbeat kinematics, visual stability and navigational skills of pigeons varied between solo and paired flights.

During the first experiment, the team fitted the homing pigeons with GPS loggers and accelerometers that allowed them to track the birds' geographic locations and to record their wing movement during flight. Next, they released the birds 7 km from their home roost to fly home solo. After the birds had returned home, the team matched some of the birds with a partner of similar size or with different-sized partners and then released them in pairs, before releasing them one final time for their last solo flight. For the second experiment, the birds performed similar homing flights but the team fitted them with a tiny helmet weighing just 1 g, attached to a snuggly

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fitting backpack carrying a battery and a memory storage chip, to measure their head movements. Finally, the team used aerodynamic calculations to estimate the energy required for the birds to stay airborne.

The team discovered that while the solo pigeons flapped their wings at a frequency of around 5.5 beats s^{-1}, the wingbeat frequency of the pigeons flying in tandem was actually about 1 beat s^{-1} higher, representing an 18% increase in flaps per second – quite the opposite from the energy-saving formation flights of geese. They realised that the increase in wingbeat frequency was roughly proportional to the proximity of the birds – the closer the birds, the faster they beat their wings – and that the birds went back using a slower wingbeat if they became separated. From their aerodynamic calculations, the authors estimated that paired flight was 2% more energetically costly than solo flight, but because energy is such a precious resource, any additional expenditure is a threat to the birds' chances of survival. Finally, the second experiment revealed that the birds moved their heads 30% less when flying in a pair, which the team believes plays an important role in keeping their eyes steady and co-ordinating with their fellow flier.

Despite the additional cost of a faster wingbeat, the birds released in pairs consistently chose to fly together, suggesting that the added expense of flying together must somehow be offset by other energetic benefits. Indeed, when the team looked at the routes taken by the birds, they discovered that the paired pigeons reduced their flight distance by 7% and flight duration by 9% compared with solo pigeons, which more than compensated for the extra energy spent on additional wingbeats. When combined with their improved ability to spot predators, thanks to their pooled vigilance, increased head-steadiness and safety in numbers, it becomes much clearer why pigeons prefer to rely on the power of teamwork to avoid getting in a flap.

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Walkers take advantage of energy savings on split treadmills

Humans and other animals often walk economically so that they don't waste energy, but when learning new movement patterns, does the nervous system select movements that reduce energy use? Natalia Sánchez and Surabhi Simha, as part of a collaboration between labs at University of Southern California, USA, and Simon Fraser University, Canada, wondered how humans learn a new stepping pattern when they walk on a split-belt treadmill that has two belts, so that one leg steps at a slow speed and the other leg steps with a fast speed. The researchers focused on how humans learn to adjust the difference in the length of the left and right legs' steps. From a clever analysis of how the treadmill can transfer energy to the person walking on it, the team predicted that as steps on the fast treadmill belt became longer relative to the steps on the slow treadmill belt, the treadmill would assist the walker by providing them with additional energy, allowing the walker's muscles to decrease the work that they were doing, so that their metabolic energy consumption would decrease.

The team recruited 16 healthy young volunteers to walk on the split-belt treadmill while the left belt ran at 0.5 m s^{-1} and the right belt ran at 1.5 m s^{-1} over a range of step lengths across values where the step on the slow belt was longest to where the step on the fast belt was longest. In order to test how treadmill work, muscle work and metabolic energy changed with step lengths, the team placed a screen in front of the treadmill that showed the position of the volunteers' feet as they walked and instructed the volunteers to step at specific locations, thereby enforcing different values of step lengths. Following the guided stepping trials, the volunteers then freely adapted their step lengths so that the team could determine their self-selected step lengths. From the forces that the volunteers exerted on the treadmill belts, the researchers calculated the mechanical work that the treadmill performed on the person and the mechanical work that the person's muscles produced. Last, the team calculated the volunteers' metabolic energy use from the amount of oxygen that the volunteers inhaled through a mask.

Consistent with the team's predictions, the amount of work that the treadmill performed on the person increased by 28% as the step on the fast belt became longer than the step on the slow belt, while the amount of work that the person's muscles produced decreased by 13%. This suggests that the person walking on the treadmill used the additional energy provided by the treadmill to reduce the work that their own muscles must do. To understand whether the flow of energy from treadmill to person resulted in reductions in metabolic energy consumption, the team compared the amount of muscle work with the volunteers' metabolic energy and found that metabolic energy decreased with decreases in muscle work. This suggest that the treadmill's work conferred an energetic benefit to the volunteers.

When the team looked at how metabolic energy changed with differences in the step lengths and how the volunteers adjusted their step lengths throughout the learning period, they found that the step length adjustments reduced the energy cost by 14%. This suggests that humans can learn to take advantage of the assisting work that a split-belt treadmill can provide by learning a new movement pattern to capitalise on the energy savings. Although the adapted step lengths that the volunteers learned were not necessarily energetically optimal, they can learn to adapt their step length to reduce energy costs. These results could help patients that are recovering from neurological damage by using the split-belt treadmill to improve their walking symmetry and energy economy.

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Fungused frogs fail to fix fast fluid flux

Amphibian populations are facing a crisis – the chytrid fungus *Batrachochytrium dendrobatidis* is responsible for the decline of more than 500 species around the world. This fungal infection targets the skin of amphibians, making it leaky and susceptible to water loss. To fight back, amphibians shed their outer layer of skin – called sloughing – hopefully removing the fungus in the process. However, skin sloughing itself can also interfere with water balance, as water moves easily through the highly permeable fresh skin. In healthy amphibians, a compensatory mechanism seems to exist, but chytrid-infected amphibians are not so lucky, and perhaps skin sloughing is to blame.

A new study, led by Nicholas Wu at the University of Queensland, Australia, aimed to discover the molecular mechanisms used to regulate water balance during amphibian skin sloughing and asked whether chytrid interfered with this process. First, the authors compared how fast thirsty green tree frogs absorbed water through their skin, and found that the rate depended on the degree of chytrid infection. The more infected the frog, the slower the rate of water absorption, suggesting that the skin was impaired in some way.

Next, the authors collected samples of frog skin and used radioactive water to measure the flow rate across the skin in each direction. Chytrid infection had no effect on inward water flow, but almost doubled the flow of water out of the frogs. To understand why outward water flow in infected frogs was so much faster, Wu and colleagues zeroed in on a group of protein water channels known as aquaporins. Salts constantly leak out of frogs across the skin into the environment, and this movement of salt tends to pull water along with it; aquaporins are thought to fight back against this process to help maintain water balance in the frogs. The team used mercury chloride to disrupt the aquaporin proteins in the skins of infected frogs and found that the rate of water loss across the skin increased, consistent with the idea that aquaporins are key to reducing outward water flow. Intrigued, the authors next measured the expression levels of genes that encode aquaporin proteins in healthy and infected frogs before and immediately after skin sloughing. In healthy frogs, the aquaporin gene expression levels increased as much as 45-fold after sloughing, suggesting that this is a key mechanism that maintains water balance during the sensitive period. However, the increase in aquaporin gene expression was completely absent in the infected frogs, which may explain why they lose water so much faster.

The team also knew that water can move through the tiny gaps between skin cells and animals can slow this movement by tightening those inter-cellular gaps using junction proteins. To examine whether frogs use this tightening to conserve water after skin sloughing, the authors again measured gene expression levels. In healthy frogs, the junction protein gene expression levels increased after sloughing, suggesting that it usually works alongside increased aquaporin levels to protect the animals' water balance. However, the junction protein gene expression levels were even higher in chytrid-infected frogs, even when they were not sloughing their skin. This is likely an attempt to compensate for the high rates of water loss after infection, but, unfortunately for the frogs, it is only a partial solution.

This is the first evidence of chytrid infection directly interfering with the molecular machinery responsible for water balance in amphibian skin, but we need to examine more species to be certain. However, it appears that in green tree frogs at least, infection poses a 'damned-if-you-do, damned-if-you-don't' scenario. If frogs try to clear the fungus by sloughing their skins, impaired water uptake across the aquaporin-deficient fresh skin makes water balance problematic, but without sloughing, the frogs succumb to direct damage from the fungus.

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