

## OUTSIDE JEB

### Fish want to see the light at the end of the tunnel



Picture a poorly designed city with enormous city blocks and few roads. It would probably be difficult to get around, so you might try to avoid going across town if you could. Now, if alleyways were created throughout this city as shortcuts, you might be more likely to walk across town. But what if those alleys were dark, sketchy and had a guy in a trench coat sharpening a knife? Even though you technically can use these alleys as shortcuts, you would almost certainly be too afraid to walk through them. Craig Franklin and colleagues from the University of Queensland in Brisbane, Australia, wondered whether riverine fish are also afraid of using dark alleys. Except the alleyways used by fish are called culverts and they allow rivers and streams to pass underground beneath streets. Culverts can vary in structure, from corrugated plastic tubes to rectangular channels, and function to redirect waterways, reduce erosion near infrastructure and physically connect upstream and downstream environments, but do they also alter the way fish move up and down rivers?

The team wanted to know if the abrupt transition between a sunny stream and a dim culvert would act as a barrier to fish movement, so they made an experimental culvert: a 12 m long fish tank with water flowing through it and a light over one side while the other half was blacked out to simulate a natural culvert. In addition, the team included a viewing window in the middle to watch fish travel between the two sides. They then placed several native Australian fish species – one

species at a time – in the experimental culvert at different locations to see if the light levels affected their movements.

Overall, the team found that the experimental culvert affected fish behaviour. Australian smelt and fly-specked hardyhead strongly preferred the light half, rarely venturing to the dark half. These small species are most active during the day and rely heavily on sunlight to navigate their environment. Meanwhile, the Australian bass joined the dark side of the culvert, rarely visiting the light side. These fish are crepuscular, which means that they are mainly active at dawn and dusk, using their large eyes to see in low light conditions when ambushing unsuspecting prey.

While there probably are no cane toads in trench coats sharpening knives in Australian culverts, fish that are active during the day might be afraid of predators – such as Australian bass – lurking in the shadows, reducing their ability to migrate through streams. This means that while culverts may be created with the best intention of connecting fish habitats, they may effectively perform as barriers if they are too dark. So, how much light do day-active fishes need to encourage them to pass through culverts?

After testing various light levels, the team found that the light threshold for the daylight-loving species was very low. They do not need much light to find their way around in culverts. However, the researchers measured the light levels in various Australian culverts and found them to be dimmer than the minimum that the fish require, suggesting they may be hindering fish migrations. Fortunately, there is a simple solution to the problem: lights. The scientists suggest that dim lighting could be installed in culverts to help shy fish complete their journeys. Just like everyone in the world right now, daytime fishes also want to see the light at the end of the tunnel.

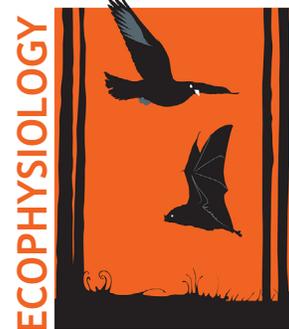
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### Stress in the egg makes gull chicks fitter



Biologists have known for years that conditions experienced during early development can dramatically influence health and longevity through to adulthood. When the environment becomes persistently challenging or too unpredictable, mothers pass on the stress hormones produced in response to difficult conditions to their offspring developing in the womb or egg. It is commonly believed that these increases in stress exposure have detrimental consequences for developing creatures long into their futures, such as the increased risk of illness and reduced survival. However, the stress communicated to a developing embryo by its mother could also be an advanced warning, which helps the youngster to develop in ways that might improve its chances of survival later in life. In new research led by Jose Noguera and his team at the University of Vigo, Spain, they provide evidence suggesting that this might be the case.

Noguera and colleagues headed out to Sálvora Island, off the Atlantic coast of northern Spain to study a wild breeding colony of yellow-legged gulls. The team stealthily monitored the birds as they laid their eggs and selected the first egg from

46 nests – the first laid egg is often the only one that hatches successfully – before injecting some with a stress hormone, corticosterone. Soon after the chicks hatched the researchers took a small blood sample to investigate how the hormone boost had affected the developing chicks by looking at the DNA packaged in the birds' red blood cells. Knowing that the ends of each DNA chromosome are tipped with specialised structures, telomeres, which protect them from wearing down and generally shorten with age, the team decided to find out how the stress hormone in the chick's eggs affected the length of the telomeres. In addition, the team checked the enzyme, telomerase, which is responsible for building and maintaining telomeres, to find out how well prepared the youngsters were for the rigours of life after hatching.

The researchers found that the chicks that were exposed to stress hormones as eggs had more active telomerase and longer telomeres compared to the chicks that had not received a corticosterone boost. These results suggest that increased exposure to stress during embryonic life leads to changes that might improve the chicks' survival prospects. Interestingly, using data collected previously from the same population of gulls, they also showed that starting life after hatching with longer telomeres increases the chances of chicks surviving for at least up to 8 days. This time window corresponds to the period of highest mortality in this species as gull chicks face constant danger, competing with their siblings for food while predators lurk in the colony.

Noguera's study suggests that maternally derived stress hormones may be a key mechanism through which mothers transmit valuable signals to their offspring that could help them to program their biology in preparation for life on the outside. More broadly, the team challenge the common view that increased levels of stress hormones in the egg inevitably incur costs for the developing chick as a consequence of poor maternal conditions. It seems, instead, that the mother's stressful gift to her offspring may provide an opportunity to make them fitter, at least during the earliest and most challenging stages of life.

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## The mechanical puzzle of crush-resistant beetles



The dangers of becoming someone's lunch can weigh heavily on a tiny insect, but the diabolical ironclad beetle (*Phloeodes diabolicus*) handles the pressure with ease. This flightless beetle is able to withstand crushing blows that would pulverize other species. Jesus Rivera from the University of California, Riverside, USA, and colleagues from universities in the USA and Japan used mechanical testing, advanced microscopy and spectroscopy to explore how this remarkable species is able to join together pieces of its exoskeleton to form an impenetrable armour.

First, Rivera and his team compressed the beetles between steel plates to see how tough they were and found that they can resist crushing forces twice as great as those endured by other beetles. Most beetles have exoskeletal structures, called elytra, which cover the wings at rest, but move out of the way to allow flight. However, the researchers found that the elytra of the diabolical ironclad beetle are fused together along the back and at the sides of the body, creating an air-filled space beneath that can cushion impacts. Other terrestrial beetles also have this built-in airbag, so the team wondered whether the impressive crush resistance in this diabolical insect comes from the seams that bond the elytra together.

One way of connecting materials is through interdigitation, where a protruding 'blade' on one side of a seam fits into a space on the other side; in cross-section, this looks similar to how

jigsaw puzzle pieces fit together. Examining the connections between the elytra and the exoskeleton along the sides of the body, Rivera and his colleagues found interlocking puzzle piece-like structures toward the front of the ironclad beetle's body, but the connecting structures transition toward the back of the body, becoming looser. This arrangement allows the elytra to compress and absorb impacts in the air-filled cavity without bursting at the seams.

Focusing on the seam connecting the two elytra down the beetles' backs, the researchers found additional interdigitation, but unlike the less resilient seams in other flightless species, this connection included multiple puzzle piece-like blades. Using computer simulations to explore the effects of blade number on the strength of the seam, they found that connections with fewer blades tend to pull apart and fail, but connections with more blades fall apart when the necks of the narrow blades snap. So how is the diabolical ironclad beetle able to form interdigitated connections with multiple slender blades without suffering damage?

The team found that the blade structures are made of multiple layers of material that pull apart under tension, dissipating energy without breaking completely. This microstructure allows the diabolical ironclad beetle to have a strong interdigitated seam between the two elytra without the risk of catastrophic damage to the blades that hold the wing casings together. And, when the researchers created a physical prototype of the connector with a similar shape and layered material, the design outperformed current fastening systems used in extremely demanding applications, like aerospace engineering.

In this study, Rivera and colleagues found that the remarkable crush-resistance of the diabolical ironclad beetle comes from a unique set of structural and material features of the exoskeleton. By fusing together their elytra using interdigitation to provide a uniquely strong connection, these beetles create an airbag that cushions impacts and prevents irreparable damage. Ironically, the authors suggest that the high-performance mechanical fastening which has robbed the beetles of flight has the potential to inspire new advances in aviation design.

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## Ogre-faced spiders listen with their legs



The giant eyes on *Deinopis spinosa* spiders have earned them the apt if insensitive moniker ‘ogre-faced’ and are responsible for their remarkable ability to catch insects using nets spun between their forelegs. Sometimes, however, these spiders snag out-of-sight meals by quickly lunging backwards and capturing whoever was trying to sneak behind them unnoticed. A team of scientists from Cornell University, USA, looked past the mesmerizing eyes of these ogre-faced hunters to determine how they catch flying insects that they can’t see. The researchers found that

despite a lack of ears, the spiders hear sound through their legs and certain sounds prompt a hunting spider to strike behind itself.

To determine that the spiders detect sound, the researchers measured brain activity in response to tones with frequencies ranging from 100 to 1000 Hz. The spiders’ brains responded more to tones from 150–200 Hz, 400–450 Hz and 700–750 Hz, indicating that they can hear over those ranges. Notably, those tones also overlap with the wingbeat frequencies of tasty insects like flies and mosquitoes. Next, the team set out to test if sound alone triggers predatory acrobatics in *D. spinosa* spiders by playing the same tones to spiders that had already spun nets and were ready to hunt. Whether in the lab or in the wild, half of the spiders that heard the researchers’ tones lunged backwards, if they moved at all. Further, spiders in the wild as well as in the lab only responded to certain frequencies – 150 Hz, 400 Hz, and occasionally 750 Hz – the same frequencies at which they observed brain responses, which also match the wingbeat frequencies of potential prey. The spiders seemed to be responding to some sounds with backward strikes, so the researchers wanted to figure out how they are able to hear these sounds without ears.

Fortunately, insects have evolved some impressive strategies to tune in to the audible world. Spider legs have groups of tiny sensors that detect forces like air pressure changes and, therefore, may be sensitive to sound. To determine

whether the sensors on the legs detect noises, the team recorded nerve activity in the leg while playing the same tones that had triggered brain signals. Although they found more nerve activity, they still weren’t sure whether the tiny sensors were involved in detecting the pressure differences caused by sound waves or if the sound was detected by other means, such as the hairs on the leg. This time, the team gently held the leg so that the sensors wouldn’t be able to detect any more pressure from sound but the hairs could still vibrate. They recorded much less nerve activity, indicating that the tiny sensors allow the spiders to ‘listen’ to the pressure of sound waves bouncing into their legs. Whereas the brain was more active at wingbeat frequencies, the leg nerves responded to higher frequencies of 1000–10,000 Hz, possibly to detect sounds emitted by predators.

Like the mythical monsters these spiders resemble, their outward appearance doesn’t tell the whole story. They use more than big eyes to find food: they also use their legs to keep an ‘ear’ to the air behind them to create a panoramic hunting ground.

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