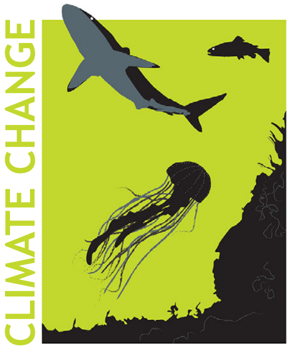
OUTSIDE JEB

Hot shark embryos freeze less to stay safe



Have you ever seen a scary movie where the murderer is stalking a potential victim, and then it cuts to a close-up of their prey frozen still, holding their breath for dear life? Believe it or not, shark embryos have a remarkably similar freeze response when predators are nearby. Small-spotted catshark (*Scyliorhinus canicula*) embryos develop for 21 weeks in egg cases called mermaid's purses. After the 10th week, these shark embryos produce secretions that open slits into the egg case, and for the remainder of their development, the tiny sharks have to move to exchange seawater to ensure enough oxygen is available to continue their development. However, these movements attract shark predators. Fortunately, the youngsters are able to detect the presence of the threat and stop moving and breathing – a behavior known as the freeze response – although they are only able to do so for a limited amount of time as they have to resume respiration and moving once again. As shark embryos are particularly vulnerable to predation, any factor that affects the freeze response is a risk for shark populations in the wild. As temperatures are expected to increase and affect the metabolic rate of marine animals, Daniel Ripley and researchers from the University of Manchester, UK, investigated the effect of increasing temperatures on the freeze response of small-spotted catshark youngsters.

First, the team transported ~3-week-old small-spotted catshark embryos from Germany to the UK and placed the developing youngsters in either 15 or 20°C water until they were 15 weeks old. Then, the researchers took the shark embryos and gently flicked them underwater, to imitate a predator inspecting an egg case, while measuring how long the youngsters froze and the amount of oxygen that they consumed at their respective temperatures. Finally, the team measured how fast the embryos fanned their gills to inhale oxygen at the different temperatures.

Despite the difference in the embryos' temperatures, the team did not find a difference in youngsters' resting metabolic rates. However, they did discover that the embryos fan their gills faster at 20°C than at 15°C. Additionally, as the resting metabolic rate or incubation temperature of embryos increased, the duration of their freezing response decreased. This means that the length of time that the embryos hold themselves still does not depend solely on their metabolic rate. Most alarmingly, the researchers also found that the warmest embryos only froze for a seventh of the time that the cooler embryos remained stock still. This decrease in the length of the freeze response has significant implications as temperatures increase as a result of climate change. The freeze response is a behavior that helps embryos avoid predators and improves their chances of survival, but small-spotted catshark embryos will likely be at increasing risk from passing predators as temperatures rise and this response declines.

For these shark embryos, the duration of this freeze response can be the difference between life and death. The research team also advises that predator avoidance behavior is another factor that needs to be taken into account when thinking about the conservation of sharks and the impact of rising temperatures owing to climate change.

doi:10.1242/jeb.236968

Ripley, D. M., De Giorgio, S., Gaffney, K., Thomas, L. and Shiels, H. A. (2021). Ocean warming impairs the predator avoidance behaviour of elasmobranch embryos. *Conserv. Physiol.* **9**, coab045. doi:10.1093/conphys/coab045

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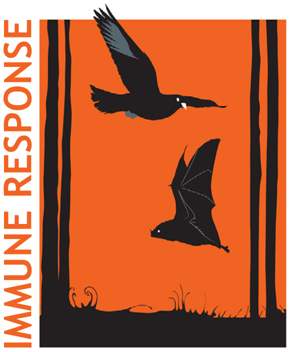
Birds of a feather shouldn't always fly together



Since the start of the Covid-19 pandemic, many of us have become more sensitive to the signs of sickness while in public. Despite my mask, I dread having to sneeze or cough while in the grocery store, for fear of the sideways glances it will inevitably elicit from people around me. While we know observing symptoms that convey sickness can cause us to change our behaviour, can it also trigger our bodies to mount protective changes in our physiology? Ashley Love and colleagues from around the USA worked to test this idea, to better understand whether visible signs of infection can lead to changes in immunity.

Love and colleagues exposed domestic canaries (*Serinus canaria domestica*) to the bacterial pathogen *Mycoplasma gallisepticum*, which causes the birds to reduce their activity levels, become skinnier and develop severe eye inflammation known as conjunctivitis. After being infected with the bacteria, each bird gained a buddy in the form of an otherwise healthy canary. The two birds saw each other during the 14 h of daylight each day over the course of a month, but stayed just far enough apart to prevent the buddy from picking up the infection. The scientists figured if the healthy birds could detect the infection building in their bacteria-exposed pal, this visual information about disease risk could create a proactive change in their immune system in preparation for a potential bacterial attack, especially at the peak of the infection's transmissibility.

The researchers first observed how the infection impacted the birds, recording that the animals became lethargic around 5–10 days after exposure, while their conjunctivitis also took hold, providing the most obvious warning signals that the birds were harbouring an infection. At the same time, Love and colleagues collected blood from the buddies, to search for any clues of changing immunity as the signs of infection changed through time.

Amazingly, the team detected some profound changes in the immune systems of the otherwise healthy buddies. In particular, a group of proteins that stimulate a protective inflammatory response (known as complement activity) and heterophil white blood cells (known to 'eat', or phagocytose, invading pathogens) spiked at 6–12 days after their visibly sick pals picked up the infection. This time point also coincides with when their own infection risk would be highest, based on when the disease symptoms peaked. Collectively, these physiological changes – triggered simply by observing another bird carrying the infection – conspire to make the birds more resilient to infection.

Surprisingly, however, Love and colleagues measured no concurrent changes in the immune systems' 'communicators', known as cytokines, which spread the word around your body of damage or infection. As immune responses are super energetically costly to mobilise, these mixed changes to the birds' immune response could indicate a tempered reaction that could prepare the body for a potential infection, but delays mounting a complete defensive attack until an actual challenge is detected, to avoid wasting energy unnecessarily.

These results suggest that simply seeing signs of infection can lead to immune responses in otherwise healthy individuals, suggesting that the buddies recognized the presence of an infection risk and mounted a proactive response in preparation for a potential immune challenge. Thus, these pre-warning social signals about infection risk can create protective changes in the physiology of animals that potentially reduce their susceptibility to disease. The next step in this research will be to understand if these physiological changes actually increase protection from infection, lower disease severity, and/or reduce the time to recover, information that could inform our own human response to outbreaks of disease.

doi:10.1242/jeb.236976

Love, A. C., Grisham, K., Krall, J. B., Goodchild, C. G. and DuRant, S. E. (2021). Perception of infection: disease-related social cues influence immunity in songbirds. *Biol. Lett.* **17**, 20210125. doi:10.1098/rsbl.2021.0125

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Elephants hoover up their dinner

If I were to pick one modification to make to my own human form, I would choose to swap my nose for an elephant's trunk. The trunk really is an anatomical Swiss Army penknife: one appendage, many functions. Elephants use their trunks to grab heavy objects, deftly manipulate light items, feed themselves, shower and even breathe underwater. Some of these behaviours share an elusive quality that is hard to observe unless you try really hard to look for it – suction force.

David Hu, Andrew Schultz and Jia Ning Wu from the Georgia Institute of Technology (Georgia Tech), USA, wanted to find out how elephants use suction to manipulate the world around them. Along with their colleagues – both human and proboscidean – from Georgia Tech, the University of Alabama, the Icahn School of Medicine at Mount Sinai and Zoo Atlanta, USA, they devised experiments to showcase how elephants use their trunks to lift material off the ground and store it in their trunk.

The trio, accompanied by Sung Yeon Sara Ha, Greena Kim (also from Georgia Tech) and Stephanie Braccini Slade from the University of Alabama, worked with the elephant keepers at Zoo Atlanta and an adult female African elephant, weighing in at 3360 kg. The scientists gave the elephant a series of foodstuffs to pick up with her trunk, varying the size, number and type of food items. They wanted to find out whether the elephant would use suction to draw the foodstuff to her trunk, or whether she would simply pick it up with the top of her proboscis.

First, the team tried to tempt the elephant with cubes of swede cut into different sizes. Regardless of size, the elephant preferred to suction the food into the tip of her trunk whenever there were 10 or more pieces. Fewer than 10, and she was content with picking up each cube individually. Suction feeding seems to be a convenient way of gathering lots of small objects at once. Next, the researchers tried out the elephant's tactile proboscis on large, fragile, tortilla chips. This time the elephant carefully used suction to levitate the crispy snack off the ground, before transporting it to her mouth – without even breaking it. Schultz, Wu and Hu were delighted to see how the trunk, a thick muscular tube weighing 100 kg alone, could be used in such a precise manner.

Elephants also use their trunk to suck up, store and transport water, sometimes to drink, and other times to shower themselves with. How much water can an elephant's trunk hold? The team and Sam Rivera from Zoo Atlanta measured the volume of water that the elephant preferred to suction into her trunk, while using an ultrasound probe to show how the muscles of the trunk worked to accommodate the water.

The ultrasound images revealed that the muscles, radiating from the centre to the edges of the trunk, are capable of dilating the volume of the nasal passages by, in some cases, up to 64%. Using this extra reservoir, the elephant was able to accommodate and rapidly expel 5.5 l of water at a time. The trunk isn't just a static drinking straw; instead, it's a distensible organ under fine muscular control. By combining their experiments with mathematical modelling, Schultz, Wu and Hu found that the trunk is capable of shifting air at a speed of 150 m s^{-1} – on a par with bullet trains in Japan.

How does this compare with our ability to suction food from the floor? A person can just about lift a piece of paper from the ground using suction, but next to an elephant it would be a far less dignified manoeuvre. Rather than teaching human beings new tricks, Hu and colleagues hope that the elephant's trunk will inspire a new generation of robots based on their extraordinary capacity to manipulate objects by hoover power.

doi:10.1242/jeb.236935

Schulz, A. K., Wu, J. N., Ha, S. Y. S., Kim, G., Braccini Slade, S., Rivera, S., Reidenberg, J. S. and Hu, D. L. (2021). Suction feeding by elephants. *J. R. Soc. Interface* **18**, 20210215. doi:10.1098/rsif.2021.0215

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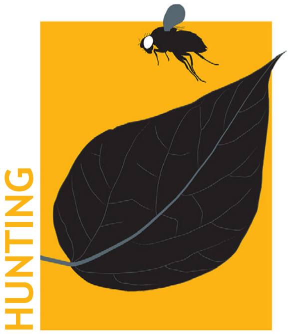
How diving flies navigate in for the kill



Snatching their next meal often requires insects to attack upwards, as their prey is more easily visible towards a clear sky background. But this is not the case for killer flies (*Coenosia attenuata*), which take the risk of performing swift aerial dives to grab their prey from above. Intrigued by this behaviour, Paloma Gonzalez-Bellido from the University of Minnesota, USA, with Sergio Rossoni from the University of Cambridge, UK, and collaborators from Cambridge and the University of Lincoln, UK, set off to understand how these dives compare with upwards or sideways attacks more commonly found in insects in the wild to learn about the flies' unorthodox hunting strategy.

The team released pairs of killer flies in a transparent rectangular arena, dangled a moving black bead in front of them to give them a target to attack, and filmed their hunting manoeuvres in 3D using high-speed cameras. The researchers then used the recordings to extract the flies' velocity and acceleration during each dive and found that the flies that were taking off from the ceiling reached significantly higher accelerations than those taking off from the walls or the floor of the arena. The dive accelerations were also higher than those measured in free-falling unconscious killer flies, suggesting that they work together with gravity to propel themselves downwards even faster. The researchers also found that the aeronauts could use the angle of their line of sight – the imaginary line between the fly and its prey – to time their take-off to target and influence their dive angle.

Aiming to understand how these flight characteristics affect the flies' hunting strategy, the researchers looked into the factors that determine how the killers navigate in for a kill. Do the flies head directly toward their target, or do the killers observe how their meal changes direction to predict where their victim is going to arrive and aim to intercept it at some point in the future? The researchers converted these strategies into mathematical models, used the data for the position and velocity of real flies and the position of the bead target, and simulated potential flight paths that could have resulted from each strategy. They then compared those paths with the real-life trajectories of the killers and were able to show that the second strategy, where the attackers aim to intercept their quarry at some point in the future, best predicted the killer flies' paths, no matter where they took off from. However, they also noted that the flies that took off from the ceiling and further ahead of their target were particularly vulnerable to missing their meal. The researchers then adapted their model of the flies' navigation strategy to include the acceleration needed for the killers to turn a corner and attempt a follow-up attack – a measure of the steering effort required – and showed an even higher compatibility of this adapted model to real-life flight trajectories.

But why perform aerial dives given the additional steering effort required, compared with a direct attack from below? Well, for starters, Gonzalez-Bellido and her colleagues discovered that dives provide the fastest route for a first encounter with a victim and that plummeting from above produces a greater impact than attacks mounted from the walls or the floor of the arena. If, in addition, we include that killer flies in the wild are not limited by the size of a laboratory flight arena and would certainly attack again after the first near-miss, there is only one conclusion to make: dives are a powerful attack strategy, but a head start isn't helpful if you are a hungry fly.

doi:10.1242/jeb.236950

Rossoni, S., Fabian, S. T., Sutton, G. P. and Gonzalez-Bellido, P. T. (2021) Gravity and active acceleration limit the ability of killer flies (*Coenosia attenuata*) to steer towards prey when attacking from above. *J. R. Soc. Interface* **18**, 20210058. doi:10.1098/rsif.2021.0058

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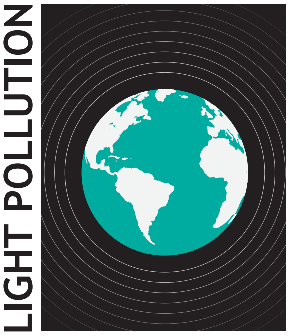
Colored night lights impact phytoplankton communities



Artificial light helps people drive, walk and see safely at night, but manmade light can be hazardous for nocturnal creatures, affecting their ability to find food, reproduce, migrate and survive. Though certain hues can minimize these negative effects on coastal land animals, colored light pollution might threaten aquatic organisms such as phytoplankton, which rely on light to create food. Recent work by Christina Diamantopoulou and colleagues at the University of Ioannina, Greece, and the University of Glasgow, UK, suggests that red and green light alternatives can increase the growth of the tiny organisms and have a detrimental effect on the diversity and composition of phytoplankton communities.

To test how different colors of artificial light affect phytoplankton, Diamantopoulou and colleagues grew the tiny organisms under either white, red or green light inside laboratory flasks of water with nutrients. The team first looked at how colored light affects the growth of the green algae *Tetraselmis suecica*. The researchers counted the number of individual algal cells every 2 days as the colony grew and measured the amount of chlorophyll, which converts sunlight into energy, after 18 days. The team suspected that the algae grown under artificial white light would have (produced the most chlorophyll and grown produced the most cells) the most, because white light is more readily absorbed by the pigment.

However, the flasks of algae exposed to green light contained the most cells and chlorophyll and grew the fastest, while the algae grown under red light were less prolific, although they still produced more chlorophyll than the algae in flasks left under white light. This suggests that green glows spur both the growth and productivity of green algae, while red light just increases phytoplankton's energy production, possibly because the light receptors that guide the phytoplankton toward green tones affect their movement.

The team then nurtured flasks containing multiple species of algae to examine how different colored lights affect the growth and energy production of entire phytoplankton communities. They found that containers exposed to red, green and white light contained more phytoplankton cells after 12 days than those left in the dark. However, the number of cells in each flask was similar, suggesting that artificial light boosts growth in phytoplankton communities, regardless of the color. However, algae grown in red light had much more chlorophyll, suggesting that red hues increase the tiny organism's energy production, possibly because chlorophyll readily absorbs red light during photosynthesis.

To investigate whether artificial light color affects the structure of phytoplankton communities, Diamantopoulou and colleagues examined the liquid communities under a microscope to determine the number of different algal species present. The team also calculated how many cells there were of each species and found that although light color did not affect the number of different algal species, it did affect which species were most abundant. The most dominant species, which tend to vary in proportion from community to community in the dark, were present in almost equal numbers when grown under red or green light. In other words, red and green light affect the demographics of phytoplankton communities.

Though green and red artificial light pollution might be less damaging than white light for some land-based animals, excessive phytoplankton growth owing to colored glows could cause algal blooms along coastlines, stripping oxygen from the water and killing other aquatic organisms, such as fish. To redress the damaging effects of light pollution, researchers and policymakers must balance the benefits of alternative hues for land animals against the potential harm to aquatic organisms.

doi:10.1242/jeb.236943

Diamantopoulou, C., Christoforou, E., Dominoni, D. M., Kaiserli, E., Czyzewski, J., Mirzai, N. and Spatharis, S. (2021). Wavelength-dependent effects of artificial light at night on phytoplankton growth and community structure. *Proc. R. Soc. B* **288**, 20210525. doi:10.1098/rspb.2021.0525

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