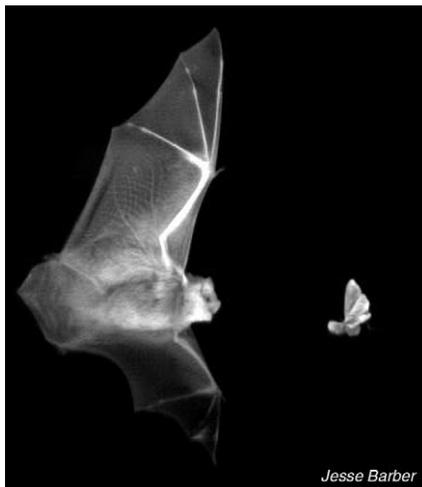


Inside JEB highlights the key developments in *The Journal of Experimental Biology*. Written by science journalists, the short reports give the inside view of the science in JEB.

# Inside JEB

## BATS SPOT DIFFERENCE BETWEEN GOOD AND BAD TASTING MOTH MIMICS



No matter how stealthy, a bat can't hide its approach from sharp-eared moth victims. As soon as a target hears an inbound attacker, it takes immediate evasive action. But that isn't the moth's only line of defence. Jesse Barber from Wake Forest University explains that some moths taste bad to deter predators. Some of these species also emit ultrasonic clicks to warn attackers off. While bats quickly learn to avoid the warning clicks of unpleasantly flavoured moths, it wasn't clear whether the predators would extrapolate and avoid all clicking moths, regardless of whether they tasted good or bad. Curious to find out more about bats' responses to warning clicks, Barber and his supervisor, William Conner, set about filming naïve bats' reactions to clicking prey with 3D high speed video to find out how they responded to clicking mimics and whether they could discriminate between the clicks of good and bad tasting species (p.2141).

According to Barber there are two ways in which moths mimic bad tasting moths for protection. Some tasty moths disguise themselves to look as if they taste bad by making ultrasonic warning clicks; they are known as Batesian mimics. However, bad tasting species also mimic the warning clicks of other unpleasantly flavoured moths in the hope that they will be attacked less frequently; these are known as Müllerian mimics. But before Barber could begin analysing naïve bats' responses to bad tasting tiger moths and their mimics, he had to find baby bats that had not learned to recognise tiger moths' warning clicks.

Having contacted surrogate bat-mum Barbara Schmidt-French at Bat Conservation International in Austin, Texas, Barber learned to rear tiny red bat and big brown bat pups and trained them to catch

moths in a confined space in the lab. Barber then switched to offering the animals two species of foul tasting clicking tiger moths as he filmed the bats' super fast reactions. After five nights, Barber switched the moths, replacing the original tiger moth species either with a pleasant tasting Batesian mimic or a vile flavoured Müllerian mimic and filmed the young bats' reactions to the new species' click patterns.

Working with Nick Garrett to digitise the 3D highspeed movies of the bats' antics and Brad Chadwell to analyse the bats' manoeuvres, Barber found that the young bats soon learned not to approach bad tasting moths when they heard the insect's warning clicks. And after five nights of encounters with the unpleasant tiger moths the young bats were steering well clear. However, when Barber introduced the clicking mimics, the bats' behaviours changed. Most of the bats began moving closer than they had done the night before, but still called the attack off at the last moment. The bats were still interpreting the clicks as warnings to stay away, but they had realised that there was a new species in the enclosure and decided to take a closer look. And some of the bats that were presented with a pleasant tasting mimic eventually saw through the subterfuge. After 5 nights they began ignoring the warning clicks and started feasting on the tasty mimics. Barber explains that he could only get this highly detailed information about the bat's manoeuvres with the video system. 'This could only have been done with 3D high speed video,' says Barber.

So the bats take heed of the warning clicks that different tiger moth species emit, giving all tiger moths a wide berth once they are wise to the warning. But their hearing is subtle enough to pick up minor differences between species' clicks, allowing them to take a closer look at unfamiliar moths before being absolutely sure that they want to avoid the bad taste that some moth mimics may leave behind.

10.1242/jeb.034405

Barber, J. R., Chadwell, B. A., Garrett, N., Schmidt-French, B. and Conner, W. E. (2009). Naïve bats discriminate arctiid moth warning sounds but generalize their aposematic meaning. *J. Exp. Biol.* 212, 2141-2148.

## SMELL OF FEAR IMPROVES SNAILS' MEMORIES

Fear can do all sorts of things to memory. A traumatic experience can disrupt memory formation, while a brush with a predator can make a memory stick for days, weeks and even years for others. Ken Lukowiak



from the University of Calgary is fascinated by the mechanics of memory formation, but rather than untangle the complex networks that hold our own memories, Lukowiak has focused on the circuit that regulates how *Lymnaea stagnalis* pond snails remember to breathe. Lukowiak explains that Dutch pond snails' memories improve significantly after a fearful encounter: a sniff of their predator, the crayfish, makes a trained snail remember not to breathe air for days rather than just hours. But how would the snails' memories respond to a predator that they had never experienced before? Would their memories improve after smelling a predator from another part of the world, such as the tiger salamander that preys on Canadian pond snails? Lukowiak and his student Michael Orr decided to test Canadian and Dutch snails' abilities to form memories after a sniff of their own, and each others', predators (p. 2237).

So how do snails' memories work? Lukowiak explains that the snails usually breathe through their skins. However, when oxygen levels are low they supplement their oxygen supply by breathing air through their breathing tubes (pneumostomes); 'It's like they are yawning,' he says. Lukowiak uses this simple behaviour to test the snails' memories. He explains that the snails can learn to keep their pneumostomes closed when the water's oxygen is low (hypoxic). By gently tapping the molluscs whenever they open their pneumostomes, Lukowiak trains the snails to keep their pneumostomes closed, even when they are out of breath. Returning the snail to hypoxic water several hours later, Lukowiak tests whether the snail remembers to keep its pneumostome closed, or whether the mollusc has lost the memory and pops its pneumostome up for a gulp of air.

Collecting wild Dutch snails from their native polders and wild Canadian snails from an isolated pond on his neighbour's farm, Lukowiak teamed up with Karla Hittel to test the snails' memories. They gave the snails a half hour long sniff of their own predator's 'scent' (Dutch snails were placed in water taken from a crayfish's tank, while the Canadian snails were placed in water from a salamander's tank) before training the molluscs to keep their pneumostomes closed in hypoxic water. After training, the duo tested the snail's memories, transferring them to

hypoxic water 3, 24 and 72 h later to see if the molluscs remembered to keep their pneumostomes closed and find out whether the smell of their own predator had improved the length of their memories.

It had. Both snails remembered to keep their pneumostomes closed 24 h after training, while snails that had not sniffed predator water only retained the memory for 3 h. And when Michael Orr tested neural activity in the key nerve cell that stores the memory, known as RPeD1, there was no activity. The memory had inactivated the neuron, just as he expected.

So what happened when the team switched the smell of fear to a predator that neither snail had previously encountered? Resting Dutch snails in salamander water and Canadian snails in crayfish water before training, the team tested the snails' memories 3, 24 and 72 h later. This time the snails had completely forgotten to keep their pneumostomes closed by 24 h, and the RPeD1 memory cell had recovered its activity, firing whenever the snail opened its pneumostome. The snails' memories were only improved by the scent of their own predator.

10.1242/jeb.034397

**Orr, M. V., Hittel, K. and Lukowiak, K. (2009).** 'Different strokes for different folks': geographically isolated strains of *Lymnaea stagnalis* only respond to sympatric predators and have different memory forming capabilities. *J. Exp. Biol.* **212**, 2237-2247.

JEB Classics is an occasional column, featuring historic publications from *The Journal of Experimental Biology*. These articles, written by modern experts in the field, discuss each classic paper's impact on the field of biology and their own work. A PDF of the original paper is available from the JEB Archive (<http://jeb.biologists.org>).

## JEB Classics

*J. Exp. Biol.* (1968), **49**, 347-355  
 With 20 text-figures  
 Printed in Great Britain

377

### POWER REQUIREMENTS FOR HORIZONTAL FLIGHT IN THE PIGEON *COLUMBA LIVIA*

By C. J. PENNYCUICK  
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(Received 24 April 1968)

#### INTRODUCTION

The primary aim of this paper is to estimate the mechanical power required for a pigeon to fly at various speeds. Although this is only one aspect of 'performance' in powered flight, it is perhaps the most informative, and sheds much light on more general performance limitations in flying animals.

Most small and medium-sized flying animals are able to hover, at least for short periods, and they thus share with helicopters the ability to fly horizontally at any speed from zero up to some maximum. Like helicopters, they use the whole lifting surface for propulsion as well as for balancing the weight, instead of using a physically separate source of thrust as in a fixed-wing aeroplane. The more general principles of helicopter theory also apply to flying animals, and are adapted here to investigate the power requirements of the pigeon. Among several excellent textbooks on helicopter engineering, that of Shapiro (1955) has been found especially useful.

The conclusions of the present study are in general agreement with those of Tucker (1958), who made respiratory and other measurements on budgerigars (*Malpinetus undulatus*) flying in a wind-tunnel. The present power calculation is based entirely on mechanical observations, and provides indirect estimates of such quantities as oxygen consumption, range and endurance, and may thus be regarded as a complementary approach to the same general problem.

#### MATERIALS AND METHOD

The same pigeons (*Columba livia*) were used as those on which the previous paper (PennyCUICK, 1968) was based. Some of the data required in the calculation were derived from the gliding measurements described in that paper, others from further experiments described below, in which the same wind-tunnel and training technique were used. In all the experiments described in this paper the wind-tunnel was set with its axis horizontal, and observations were made with a Bell and Howell 70 DA 16 mm. cine camera running at 48 frames/sec. (Determined by timing a clock at the end of each film). Three camera positions were used (Fig. 1): (1) 9 m. downstream of the bird, level with the bird and looking upstream; (2) 6 m. above the bird, and 1.9 m. downstream; (3) 1.0 m. to one side, looking at right angles to the airstream.

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## COMING SOON TO JEB CLASSICS

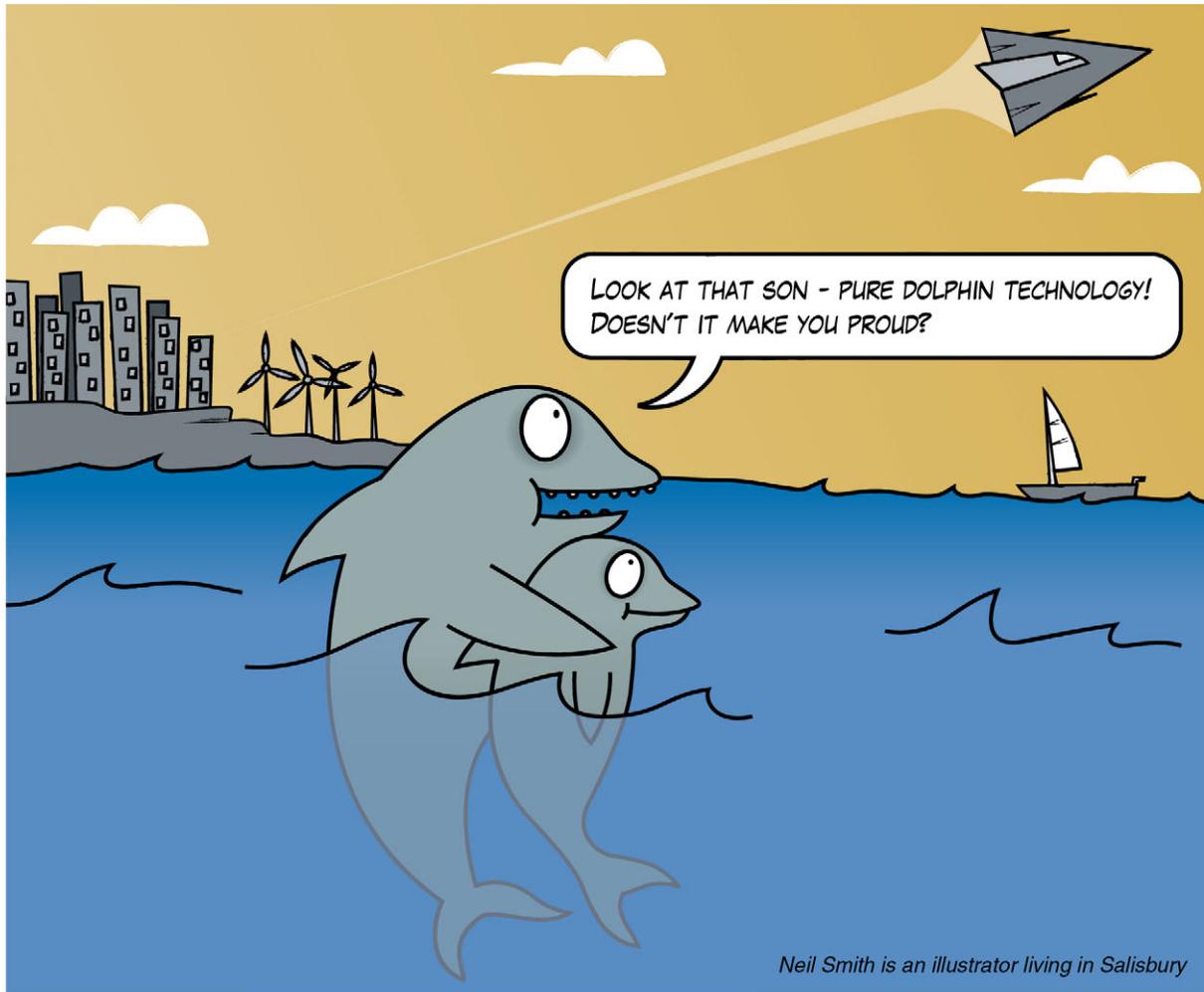
In issue 18 Malcolm Burrows writes about Henry Bennet-Clark and Eric Lucey's classic 1967 JEB paper on flea jumping.

In issue 22, Matt Bundle writes about Vance Tucker's classic 1968 JEB paper on respiration during flight.

## COMING UP IN 2010

Discussions of J. W. Truman's 1972 paper 'Physiology of insect rhythms: I. Circadian organization of the endocrine events underlying the moulting cycle of larval tobacco hornworms' and Roger Payne's 1971 paper 'Acoustic location of prey by barn owls (*Tyto alba*)'.

DOLPHINS' FLIPPERS ACT LIKE AEROFOILS



Neil Smith is an illustrator living in Salisbury

We can only marvel at the way that dolphins, whales and porpoises scythe through water. Their finlike flippers seem perfectly adapted for maximum aquatic agility. However, no one had ever analysed how the animals' flippers interact with water; the hydrodynamic lift that they generate, the drag that they experience or their hydrodynamic efficiency. Laurens Howle and Paul Weber from Duke University teamed up with Mark Murray from the United States Naval Academy and Frank Fish from West Chester University, to find out more about the hydrodynamics of cetacean flippers (p.2149).

Using computer tomography scanning of the fins of seven different species ranging from the slow swimming Amazon River dolphin and pygmy sperm whale to the super-fast striped dolphin, the team made

scaled models of the flippers of each species. Then they measured the lift and drag experienced by the flipper at inclinations ranging from  $-45$  deg. to  $+45$  deg. in a flow tunnel running at a speed that would have been the equivalent of  $2 \text{ m s}^{-1}$  for the full scale fin.

Comparing the lift and drag coefficients that the team calculated for each flipper at different inclination angles, they found that the flippers behave like modern engineered aerofoils. Defining the flippers' shapes as triangular, swept pointed or swept rounded, the team used computer simulations of the fluid flows around the flippers and found that sweptback flippers generate lift like modern delta wing aircraft. Calculating the flippers' efficiencies, the team found that the bottle nose dolphin's triangular flippers are the

most efficient while the harbour porpoise and Atlantic white-sided dolphin's fins were the least efficient.

Commenting that environmental and performance factors probably play a significant role in the evolution of cetacean flipper shapes and their hydrodynamics, Howle and his colleagues are keen to find out more about the link between the flippers' performances and the environment that cetaceans negotiate on a daily basis.

10.1242/jeb.034413

Weber, P. W., Howle, L. E., Murray, M. M. and Fish, F. E. (2009). Lift and drag performance of odontocete cetacean flippers. *J. Exp. Biol.* **212**, 2149-2158.

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