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.

SIMULATED FISH RACES SUGGEST THAT WATER SHAPED FISH

Catch a glimpse of a fish's body shape, and you can often guess which is the speediest. Tuna and mackerel look as if they should outpace frilly reef fish and eels. But how have all of these diverse body shapes evolved? Have fish bodies been shaped by the hydrodynamics of their environment or did they evolve for other reasons? However, answering this question with real fish is almost impossible. 'It is very difficult to control real fish, you can't tell them what to do and a mackerel will always swim like a mackerel,' explains engineer Fotis Sotiropoulos. So he turned to computational fish: they are much more cooperative and adaptable. 'They allow you to explore scenarios that real fish could not,' says Sotiropoulos: such as how would an eel-shaped fish that swam like a mackerel perform in a race with a mackerel swimming like a mackerel? Curious to find out how much of an influence hydrodynamics has had on fish shape and swimming styles, Sotiropoulos and colleague Iman Borazjani from the University of Minnesota decided to race hybrid and realistic fish in a massive parallel computer cluster to find out what influence the aquatic environment has had on fish shapes and swimming techniques (p. 89).

But building the computational fish was far from straight forward. 'We started this work over 5 years ago,' says Sotiropoulos, and adds 'it was a challenge because we had never simulated anything living before'. Having developed the algorithm, the duo was able to control the computational fish's tail beat frequencies and the viscosity of the fluid around the fish to see how they performed under different conditions.

But why vary the viscosity of the fluids in the computational ponds? Borazjani explains that the hydrodynamic forces exerted on swimmers vary enormously depending on their size and speed. Slow tiny swimmers (like sperm and bacteria) are held back by viscosity, while medium fast swimmers (eels) experience viscous forces and their own inertia. However, the fastest swimmers (mackerel) are hardly affected by fluid viscosity: the main force that affects them is inertia. Knowing that mackerel and eels swimming in water experience different hydrodynamic environments, the duo simulated these different environments by varying the computational fluid's viscosity.

Building two computational mackerels (one that beat its tail like a mackerel and a second that wiggled like an eel) and two eels (one that wiggled and another that beat its tail like a mackerel), the engineers set the fish racing from standing starts and waited to see how they performed.

Analysing the race results from medium speed hydrodynamic conditions, it was clear that no matter whether the fish was shaped like an eel or a mackerel, the winner always used the eel-type wiggle. However, for races swum under high-speed hydrodynamic conditions the winner always used the mackerel tail beat, even if it was shaped like an eel. So the real mackerel and eel's swimming styles are perfectly adapted to the hydrodynamic environments that they inhabit.

The duo also measured the fishes' efficiencies. The mackerel body shape was the most efficient in the high-speed hydrodynamic conditions while the eel shaped swimmers were most efficient in the medium fast environment. Finally the duo calculated the wake structure generated by the computational fish and realised that many of the features that they found in the wakes of the mathematical fish are produced by real fish when they swim. 'Even though we have stripped down the fish to their basic shapes and removed some degrees of freedom, we still had enough of the physics there to reproduce these experimental findings,' says Borazjani.

But what do the duo's calculations tell us about the influence that the aquatic environment has had on fish forms and swimming styles? 'We can deduce that each particular shape and swimming mode is consistent with the hydrodynamics of the regime they swim in. It is significant evidence that there is a link,' says Sotiropoulos.

10.1242/jeb.041020

Borazjani, I. and Sotiropoulos, F. (2010). On the role of form and kinematics on the hydrodynamics of self-propelled body/caudal fin swimming. *J. Exp. Biol.* **213**, 89-107.

DUCKLINGS STRESSED BY CHILLY INCUBATION

Most mums are determined to give their young the best start in life, and mother ducks are no exception. Settling down to incubate her eggs, an expectant mum will only move if it is absolutely necessary. However, even in the best case, this often means abandoning her eggs to feed for two brief periods a day. And stressed mothers may have to leave even more. According to William Hopkins, from Virginia Polytechnic Institute and State University, ducklings incubated by mums that take longer or more frequent breaks from the nest pay a price; they hatch with high levels of stress hormones. But without a direct


William Hopkins

route of communication between the mothers and their young, it wasn't clear why the ducklings were stressed and what affect it may have on their development. Then Hopkins' student, Sarah DuRant, had an idea: maybe the mother's brief absences were lowering the eggs' incubation temperatures and that was causing the ducklings stress. The duo decided to find out what effect low temperatures had on duckling stress and their development (p. 45).

Hopkins and DuRant teamed up with duck expert Gary Hepp from Auburn University to collect freshly laid individual eggs from wild birds' nests before returning to Virginia Tech where they could be incubated. 'Gary had published a study that demonstrated that very small changes in incubation temperature could affect the body size and composition of the hatchlings,' explains Hopkins, so the team opted to incubate the eggs at 35, 35.9 and 37°C, all within the normal temperature range, and waited for them to hatch.

The first thing that the team noticed was that the coolest eggs took longer to develop. 'At low temperatures they take 37 days and at higher temperatures they take 31 days,' says Hopkins, also the hatchlings looked perfectly normal, regardless of their incubation temperature, so the team moved the ducklings together into a room and monitored their development and stress hormone (corticosterone) levels.

But within a few days, things started to go wrong for the cold incubated ducklings. Hopkins and DuRant carefully collected blood samples from the ducklings, analysed their corticosterone levels with Ignacio Moore and found that the resting cold incubated ducklings had higher stress hormone levels then the ducklings incubated at warmer temperatures. And when they tested the ducklings' reactions to stress they found that the cold incubated ducklings' hormone levels rocketed compared with those of the ducklings incubated at warmer temperatures. Incubation at a cooler temperature had increased the ducklings' stress hormone levels, but had this also affected other aspects of their biology?

Monitoring the youngsters' growth, the team realised that the cold incubated ducklings failed to thrive. They grew slower than ducklings incubated at warmer temperatures and, even more surprisingly, the cold incubated ducklings began to die 4 or 5 days after hatching. 'Normally most mortality occurs in the first couple of days after hatching,' explains Hopkins, 'but in the cold incubated chicks 75% of their mortality is after days 4 and 5, which suggests that there is a latent effect. Something is not right physiologically and causes the birds to fail to thrive'.

Hopkins speculates that lower incubation temperatures delay the ducklings' development and this could prevent them from thriving. He also adds that this discovery could have an impact on avian ecologists. 'What is interesting to me is that avian ecologists in the field look at hatching and fledging success, but that does not necessarily mean that you have a good understanding of the quality of the offspring. For that you need to monitor the young birds longer,' says Hopkins.

10.1242/jeb.041038

DuRant, S. E., Hepp, G. R., Moore, I. T., Hopkins, B. C. and Hopkins, W. A. (2010). Slight differences in incubation temperature affect early growth and stress endocrinology of wood duck (*Aix sponsa*) ducklings. *J. Exp. Biol.* **213**, 45-51.

PENGUIN COUPLES ADAPT TO BREEDING CONSTRAINTS

Antarctica is possibly the most inhospitable place on earth to rear young, yet millions of penguin parents succeed every year. However, some years the environmental conditions are tougher than others, making raising chicks even more challenging. According to Michaël Beaulieu, from the Institut Pluridisciplinaire Hubert Curien in France, varying sea ice conditions can make rearing chicks harder some years than others. Curious to find out how penguins adapt to fluctuating Antarctic conditions, Beaulieu and his colleagues, André Ancel, Yan Ropert-Coudert and Yvon le Maho, decided to find out how penguin couples cope when foraging is difficult. But instead of manipulating the sea ice and tampering with the birds' food supply, the team decided to subtly alter the manoeuvrability of one partner to see how the animals adapt to difficult foraging conditions (p. 33).

Beaulieu, Thierry Raclot and David Lazin headed south to the French Antarctic research station, Dumont d'Urville in Adélie Land, and attached light Plexiglas backpacks to one half of a penguin duo to impede the penguin's manoeuvrability and foraging. The trio also electronically tagged, weighed and took blood samples from both birds before they laid their eggs and 45 days after egg laying, so that the team could see how both partners responded to the impediment.

Returning to France with the penguin blood samples, Beaulieu teamed up with Marion Spée to measure the levels of a hormone (corticosterone) in the birds' blood to see if the impediment had stressed the birds. He also measured the ratios of stable carbon (^{13}C) and nitrogen (^{15}N) in the birds' blood to see if the birds changed their foraging strategy. Then Beaulieu began looking to see how the hampered penguin couples had coped compared with unimpeded couples.

Not surprisingly, the hindered partner in a foraging pair had spent 70% more time foraging when chick rearing than their unimpeded partners. But had the unhampered partner adjusted the length of his or her foraging foray to compensate for their partner's delayed return? No. And when Beaulieu compared the hampered and unhampered penguins' stress hormone levels, the birds in hampered couples were no more stressed than couples that were unhindered.

So the only birds that had changed the length of time spent foraging were the impeded penguins and the Plexiglas backpacks had not increased the birds' stress levels. But had the impediment changed the range over which the birds foraged?

Analysing the ratios of ^{13}C and ^{15}N in the penguins' blood, it was clear that instead of heading out to sea to catch fish, the hampered partner had taken to foraging on krill close to the sea ice and, amazingly, so had the unhampered half of the partnership. Both members of the couple had changed their foraging behaviour, even though only one of them had supported the backpack.

Beaulieu suspects that both members of a handicapped couple adjust their foraging behaviour to compensate for the hindered partners' inefficiency. 'This change in foraging decision may optimize feeding time by decreasing travelling time,' explains Beaulieu. So penguin partnerships are adaptable and are able to adjust their foraging strategies to cope with the constraints they face when breeding.

10.1242/jeb.041046

Beaulieu, M., Spée, M., Lazin, D., Ropert-Coudert, Y., le Maho, Y., Ancel, A. and Raclot, T. (2010). Ecophysiological response of Adélie penguins facing an experimental increase in breeding constraints. *J. Exp. Biol.* **213**, 33-39.

FASTING PENGUINS USE MORE ENERGY THAN THOUGHT

Neil Smith is an illustrator in Salisbury, UK

Becoming a parent can be the most rewarding yet arduous experience. Incubating king penguins have to tough it out on sub-Antarctic beaches, taking it in turns to venture off in search of food while waiting for the egg to hatch. But at what cost? How much energy do the stay-at-home parents consume? René Groscolas and his colleagues from the Institut Pluridisciplinaire Hubert Curien, France, and the Université Laval, Canada, explain that scientists usually estimate energy expenditure by simply measuring a bird's heart rate. However, the team suspect that the act of measuring birds' oxygen consumption as a function of their heart rate could have flustered the animals and sent their heart rates rocketing, causing scientists to underestimate energy consumption rates (p. 153).

The team decided to remeasure incubating king penguins' energy consumption rates without agitating the birds. Knowing that king penguins lose weight while incubating their individual eggs, the team recorded the incubating birds' heart rates, measured their weight loss and converted the weight loss into energy consumed. Plotting the birds heart rates against their energy consumption, Groscolas and his colleagues found that the birds were using as much as 26% more energy than had been estimated previously.

'This result suggests that stress induces a disproportionate increase of heart rate *versus* oxygen consumption and that the use of energy expenditure/heart rate relationships obtained in stressed birds could lead to underestimated energy consumption values,' say Groscolas and his colleagues.

10.1242/jeb.041053

Groscolas, R., Viera, V., Guerin, N., Handrich, Y. and Côté, S. D. (2010). Heart rate as a predictor of energy expenditure in undisturbed fasting and incubating penguins. *J. Exp. Biol.* **213**, 153-160.

Kathryn Knight
kathryn@biologists.com