trometer, now ready for a new balloon flight, for $\bar{p}$ measurements to a lower energy range than they used previously; they have also made significant improvements in their trajectory measuring apparatus. New $\bar{p}$ instruments are also being planned by Goret[12] and by groups at Berkeley and Goddard[13,14]. Although no high-energy ^{3}He/^{4}He experiments seem to be planned, the stimulating and exciting new results underscore their need. □

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Marine reptiles

Lifestyle of plesiosaurs

from Michael A. Taylor

THE plesiosaurs, large extinct carnivorous marine reptiles of the Mesozoic period, have always excited dispute over how they swam[1] and reproduced. Did they swim like marine turtles, 'flying' with winglike, hydrofoil limbs, or did they row by moving their limbs back and forth (Fig. 1*a*, *b*)? And did they come on shore to lay eggs, or give birth in the water to live young? Recent research provides a new animal model that might answer these questions.

In 1975, Jane Ann Robinson argued that the plesiosaurs must have flown underwater, like turtles and penguins, because this movement was the most efficient use of their long hydrofoil-like limbs[2]. If the plesiosaurs had rowed, they should have had webbed folding feet like those of ducks. She suggested that they swam by flapping both pairs of limbs up and down, producing lift force that propelled the animal forwards.

Seven years later Samuel Tarsitano and Jürgen Riess suggested a modification to Robinson's analysis[3]. Although agreeing that plesiosaurs must have used their limbs to fly underwater, they noted that the simplest — and apparently most effective — up-and-down action was anatomically impossible because the bones of the shoulder joints would block the appropriate operation of the forelimbs above the horizontal. Moreover, plesiosaurs do not seem to have had the large dorsal muscles needed to lift the wings powerfully upwards. Dino Frey and Jürgen Riess[4] then suggested that the 'wings' had an active downstroke, and a comparatively passive upstroke as they were returned to the starting point. They suggested that the two pairs of limbs beat out of phase: one pair propelling the animal during its downstroke while the other was being brought back to the start of its own active stroke. This limb action would still be relatively inefficient compared with that of modern animals such as penguins, whose wings produce propulsive force throughout virtually the whole of the upstroke and downstroke.

Stephen Godfrey has now suggested a different living model for comparison[5]. The sealion swims by beating its forelimbs forcefully downwards and then relatively passively upwards, while always moving

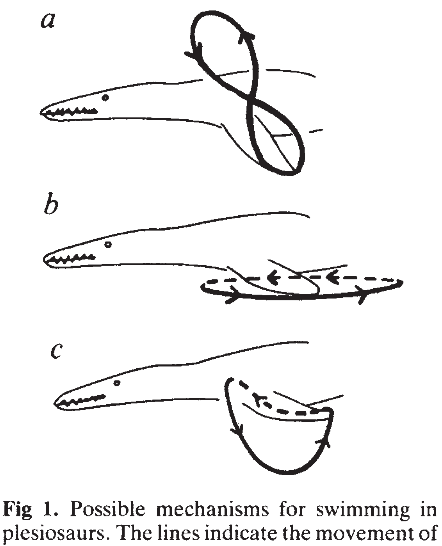

Fig 1. Possible mechanisms for swimming in plesiosaurs. The lines indicate the movement of the wingtip. *a*, Flying underwater like a penguin, with an up-and-down beat of the limbs; this movement would have been ideal for the limb shape but only the downstroke could have been really powerful. *b*, Rowing underwater like a duck, with an active power stroke backwards (bold line) then a recovery stroke forwards (dotted line). The plesiosaur's limb shape is particularly unsuited to such a movement. *c*, Swimming like a sealion, with a backwards power stroke and forwards recovery stroke, a movement combining elements of *a* and *b*.

them backwards. Once fully backwards, the limbs can then be feathered and brought forwards during the recovery stroke. Evidence points to the plesiosaurian shoulder and hip girdles having the massive muscles needed for such limb action (Fig. 1*c*). Ironically, sealion swimming combines elements of underwater flight — up-and-down action — with rowing — backwards movement. The new model thus combines both the old theories.

If the plesiosaur had a swimming movement similar to that of the sealion, with a powerful downwards and backwards thrust, it is slightly easier to imagine how it pushed itself along a beach. However, the plesiosaurs with their rigid bodies could not have humped themselves along as sealions do but must have dragged themselves along, belly to sand, much as sea turtles now do. Whether they also laid eggs in the sand like turtles, or gave birth to live young in the water, as sea snakes do and ichthyosaurs are known to have done, is still unresolved.

The discovery of a pregnant female plesiosaur would settle the question, but none has yet been found. Perhaps we have not looked inside the bodies of enough plesiosaurs or perhaps the embryos decomposed before they could become fossilized. Two early reports of relevant fossils have recently been discounted. In the 1880s H. G. Seeley described an intriguing clutch of diminutive plesiosaur embryos from Whitby, Yorkshire, a discovery forgotten until R. A. Thulborn re-examined it[6]. The find turned out to be a forgery, an unusually shaped nodule (originally, he suggests, shrimp burrows) which had been 'improved' to strengthen resemblance to a clump of plesiosaur embryos, each several inches long. And a reported 'plesiosaur egg'[7] is now thought to be an inorganic concretion[8]; even if it was an egg, it would probably be crocodilian, because crocodiles were much more common than plesiosaurs in the Upper Lias of Whitby[8].

Tantalizingly, one clutch of eggs — but no young reptiles — was long ago reported from marine beach (or close inshore) deposits from the Middle Jurassic near Cirencester, England[9]. Again these were described as crocodilian rather than belonging to the much rarer plesiosaurs. What is needed, of course, is a clutch of eggs *in situ*, complete with tiny plesiosaurs; but such finds are exceedingly rare even for land animals such as dinosaurs[10] and are even more unlikely to have been preserved on a wave-washed beach. □

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