

Letters to the Editor

(Letters may be shortened due to lack of space)

Dear Sir,

Dolphins swimming performance—Videler and Kamermans (Aquatic Mammals, Vol. 11, No. 2)

The authors state that 'Purves view that the upstroke is essentially the power stroke still remains to be proved'. This hypothesis has been proven by direct observation by Dudok van Heel. He told me that when *Tursiops* is required to stand upright with only its caudal peduncle and flukes in the water, the extensor, or upstroke takes the entire weight of the body. During the flexor, or downstroke, the animal tends to sink. Thus, when maintaining the upright position, there is a vertical, oscillating movement of the body which is synchronous with the tail movements. Moreover, when required to move backwards in this position, the upward thrust is reduced during each alternate stroke of the tail and the centre of gravity of the body is such that the animal tends to fall backwards. This tendency is corrected by augmentation of alternate power strokes. The result is that the whole animal progresses backwards. I consider these observations to be ample proof of the hypothesis. The authors also state that 'there is no unanimous opinion in the literature regarding the division of epaxial and hypaxial masses of locomotor muscles'. This I agree with because most of the authors cited were simply not competent to do so. . . In *Mesoplodon* and *Hyperoodon* the epaxial muscle mass is approximately three times the weight of the hypaxial muscle mass, and the entire epaxial muscle mass from occiput to tail is involved in locomotion.

Turning now to the mathematics of the subject. The authors have used the classical mathematical formulae which are applied to flat, aerofoil plates to calculate the forward thrust of the dolphins tail. These formulae cannot be applied to the downstroke of the tail because of the upward curvature of the flukes during the downstroke. This phenomenon was first described and figured by William J. L. Felts in a paper called *Some Functional and Structural and Characteristics of Cetacean Flippers and Flukes*, published in *Whales, Dolphins and Porpoises*, edit K. S. Norris, California University Press, 1966. The detailed anatomical reason for this, using phase-contrast and electron microscopy of the collagen fibres of the flukes, was published by me in the *Zeitschrift für Säugetierkunde* 34 1969. The mathematics of curved surfaces moving underwater, are exceedingly complex and there were no computers

in those days. Moreover the cross section of the flukes is the reverse of an aerofoil and tends to pull the tail downwards when moving through water. . . I have seen many. . . films of whales and dolphins on television, and they all show the same phenomenon. . . Since I first referred to Slijper's cine-frames of *Tursiops* giving birth, I have realised by reference to the position of stones on the bottom of the tank, that this animal was not swimming at all but was being held stationary by some person.

I do not understand Fig. 1 of the paper under comment. Why does the profile of the fluke gradually disappear during the downward stroke unless it is due to upward curvature, but surely the camera would have to be moved vertically during the downstroke to obtain the true 'angle of attack'? if any. I have not read the paper by Strickler on *Pontoporia*. . . It has long been classified amongst the *Platanistoidea* or *River Dolphin*. . .

I think I have dealt with most of the comments that I wish to make on this paper.

Yours sincerely,
P. E. Purves

Dear Sir,

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To approach the problem of locomotion in cetaceans cinematographically is, of course sound, but the results in this case are inconclusive. Inconclusive, because of the underlying lack of being at home with the way dolphins propel themselves under various circumstances bearing in mind their anatomy and some relevant research.

Purves and myself have—either together or apart—weighed between us the hypaxial and epaxial muscles of a considerable number of dolphin species. . . Invariably, the weight relations were in the 1:2 range of magnitude. It is even more pronounced in *Mesoplodon bidens*, a juvenile of which, Purves and myself were able to examine in particular. In this animal, the relation between hypaxial and epaxial muscles was 1:3. No wonder cetaceans have to make active swimming movements to stay upright and, when dead, turn on their sides or upside down. Their centre of gravity is above the horizontal centreline, in particular in *Mesoplodon*.

Although cetaceans usually cruise along at a very

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moderate speed, a number of them among delphinids, ziphiids and rorquals are built to swim extremely fast. . . Lang, 1966, stated that the tip of the fluke curl upwards during the downstroke because of the large power of the hypaxial muscles. Purves, however, showed that the anatomical structures of the upper and lower surfaces of the fluke are different. These structures allow the tips of the fluke to curl upwards during the downstroke, but to remain rigid during the upstroke with the same or a higher pressure load. This seems logical in the light of hypaxial/epaxial muscle relations of 1:2 or 1:3. When bearing in mind this relation, a cetacean reaches the speed which is commensurate with the peak performance of the relatively weak hypaxial muscles, the fluke would start to act as a brake during the latter part of the downstroke, were it not for the curling up of the tips of the fluke. The surface of the fluke, becoming decreasingly smaller by the increasing pressures on the fluke of the accelerating animal, enables the hypaxial muscles to remain functional in bringing the fluke downwards of the horizontal and into position for a next and complete upstroke. At the same time, the epaxial muscles are able to exert their maximal possible output commensurate with the total surface of the fluke. A cetacean has a changeable pitch propellor of sorts. . . Therefore, it might very well be possible

that at low speeds, the cetacean is not performing adequately, but just forces its way, so to speak, through the lower end of its speed range and giving us a distorted view of its ultimate way of locomotion. The smaller surface of the fluke during the downstroke may be the cause of the lower drag on the body during the downstroke at the low speeds in the present experiment. The ultimate way of locomotion probably establishes itself only above a certain speed. The experiment of Purves (1975) may give an indication in this respect. . .

The *Introduction* to the present paper and the *References* indicate that the above considerations and the relevant literature which was given, c.q. referred to, have not been taken into consideration. The experiment should have been carried out not only at low speed—of just as little value as the present authors attribute to the papers of Parry and Slijper—but also at a higher speed. Knowing the situation at Antwerp, an adaptation of the experiment would have been perfectly possible. A great chance has been missed to clarify some major questions concerning locomotion in cetaceans. The experiment should be repeated with all considerations brought to bear.

Yours sincerely,
W. H. Dudok van Heel