were specifying the permissible dosages for manned space flight.

There are three errors in the second section of Table 2. Item *b* should read: "Electrons, $E > 200$ kev: omnidirectional intensity: $\leqq 1 \times 10^8$ cm^{-2} sec^{-1}." Item *c* should read: "Protons, $E > 60$ Mev: omnidirectional intensity: $\leqq 10^2$ cm^{-2} sec^{-1}" (*1*).

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Note

1. The symbol $\lesssim$ here means "less than or approximately."

Sustained Swimming in Dolphins

Johannessen and Harder, authors of the report "Sustained swimming speeds of dolphins" [*Science* **132**, 550 (1960)], imply that the "length of time at observed speed" (in their Table 1) necessarily represents in each case a time during which the animals swam continuously and unaided at the indicated speeds. It is this implication on which I wish to comment.

Establishing the sustained work capacity of dolphins by the observational methods used by these authors requires identification of the individual animals during the indicated timing periods. The valdity of using groups of dolphins for this purpose is questionable. How can the authors be sure that a group, seen from a quarter of a mile to several miles away, is necessarily made up of the same individuals, or is even the same group, as one seen a few minutes earlier or later?

Part of the problem of proving the marine animal's capacity for sustained swimming at high speed seems to be that of showing that a portion or all of the required energy is not derived from waves. Observations have shown that in some cases no apparent swimming effort is required for dolphins in a bow wave to move through the water at 10 knots (*1*). They have also been seen riding natural waves near shore (*2*).

The numerous observations of "wave-riding" dolphins have been variously explained as resulting from gravity (*3*), buoyancy (*4*), and pressure (*5*)—forces associated with the waves. The question of the origin of the force or forces actually producing the "wave riding" seems at present unresolved.

The work referred to above suggests strongly that observational programs designed to demonstrate the work capacity of marine animals swimming near the surface should give particular attention to waves. The sizes and directions of motion of local wind waves and of swell may be important, especially as they are related to the directions and speeds of motion of the observing ship and of the animals observed.

If dolphins and other marine animals can indeed utilize the energy of waves on the open sea, as well as bow and coastal waves, then the virtual absence of wave data in the observations reported by Johannessen and Harder makes it seem doubtful that these observations can be regarded as clear evidence of the sustained-work capacity of the animals concerned.

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3. A. H. Woodcock and A. F. McBride, *J. Exptl. Biol.* **28**, 215 (1951).
4. W. D. Hayes, *Nature* **172**, 1060 (1953).
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In answer to Woodcock's comments we suggest that the questions raised are not applicable to our report to the extent that Woodcock infers. He wonders at our using groups of dolphins instead of individuals. Anyone experienced in shepherding even a well-disciplined group of children will testify that group velocity is equal to and usually less than the velocity of the individual. This indicates that the group velocity is a conservative indicator of the maximum capability of sustained swimming speed in dolphins. The infrequency with which large groups were observed is a reasonable guarantee that the observer, Andrews, did not see two disparate groups, at the beginning and end of each observation. A group of 200 individuals swimming at 14 to 18 knots is well delineated by a zone of splashing water.

Although it is well known that dolphins can and do ride bow waves of ships, there is not even unofficial report, to our knowledge, that they can ride the random waves of the open sea. Of course one should not confuse the "lift" a pelagic mammal might obtain from an ocean current with the riding of random waves. The sightings reported by us were made during times of general calm, and during the sighting of the fourth group (200 to 300 individuals) the observer reported an exceptionally smooth, or "glassy," sea.

Finally, it should be pointed out that we are not reporting on the "sustained-work capacity" of dolphins but on their sustained swimming speeds.

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Woodcock gives a number of references in support of his conclusion that the origin of forces producing the "wave riding" is unresolved. This conclusion requires examination. He and McBride (*1*) asserted that only the underwater weight of the dolphin could be effective in providing a wave-induced propulsive force, and they reported on their killing a *Tursiops* to find this weight. Subsequently W. D. Hayes (*2*) showed that, from hydrodynamic theory, the forces on the dolphin would be equal to the component of its *total* weight acting parallel to the water surface. More exactly, the component acting is parallel to the surface of constant pressure passing through the animal (the free surface is one surface of obvious constant pressure), for there is no corresponding pressure gradient in this direction.

Woodcock is not alone in believing the hydraulic explanation of questionable validity. Scholander (*3*) proposed yet another mechanism for wave riding and reported on an experiment designed to test the "Hayes effect." He concluded that there was none. When challenged by Hayes to produce data (*4*), he published a figure showing his measurements of the drag on a small fishlike object towed in various parts of a ship's bow wave (*5*). The expected value of the "Hayes effect" force, based on a reasonable 10- to 15-degree inclination of the equal-pressure surface, was from 110 to 170 grams in this case, in which the object weighed only 650 grams. Although his results were admittedly crude (the scatter in many of the experimental runs exceeded the magnitude of the expected "Hayes effect" itself) and were certainly not conclusive, Scholander in effect invited Hayes to abandon hydrodynamics and to compete with him in the experimental verification of the balance-of-force principle of mechanics. Hayes's explanation is based on such fundamental principles that to deny it is to deny Newtonian mechanics; thus, I cannot agree that the question is "unresolved."

It is curious that whereas Woodcock's original analysis of the forces required for wave riding was in error, his conclusion, that dolphins experience less friction than an equivalent solid body, seems to be true. Quite apart from the evidence of low friction inferred from the unusually high swimming speed of dolphins, mechanical models of dolphin skin made of rubber have been shown to exhibit only about 40 percent of the surface drag coefficient of otherwise equivalent rigid skins (*6*). The present question seems to be, not whether dolphins have an anomalously low friction drag, but rather how low this drag is. Our report of the sustained swimming speeds of dolphins was intended to provide some of the data needed to answer that question.

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Comets

In Thornton Page's report on the Fourth Berkeley Symposium on Mathematical Statistics and Probability [*Science* **132**, 1870 (1960)] there are several points on which I would like to comment.

First, in the legend of Fig. 4, Page states that the semimajor axis of an orbit is one-half the maximum distance from the sun. Instead, the semimajor axis is one-half the *sum* of the maximum and the minimum distances from the sun. Only in the case of the "sungrazing" comets can the closest approach distance be ignored, because it is small in comparison with the maximum distance. In fact, in most parabolic or near-parabolic orbits it is quite impossible to give a good value for the semimajor axis.