How to Ride a Wave

by Graham Berry

With a streamlined piece of metal in a water tunnel, Caltech engineers have resolved a problem that has puzzled scientists for years – a problem in physics that any reasonably bright young dolphin solves without so much as cracking a textbook.

These streamlined mammals are able to ride the bow waves of ships, apparently indefinitely, without having to wiggle a flipper. Nearly or completely submerged, they move along at the speed of the ship, not having to exert any energy themselves. Mere people can't do it. What laws of physics do the dolphins use?

For years only the dolphins knew the answer, while physicists and naturalists debated the issue with equations, diagrams, experiments and articles in scientific journals. There have been some lively disagreements over the relationships of the forces involved: weight versus buoyancy, and drag versus thrust.

A group of Caltech engineers decided to try and resolve these differences, once and for all. They spent a few hours one Saturday in the Hydrodynamics Laboratory setting up and observing a small metal simulation of a dolphin. The model, which actually was the model of a torpedo used in earlier Navy experiments, was attached to a force balance, which sensitively measures the lift, drag, and tendency of the test model to upset.

The investigating team consisted of Allan J. Acosta, associate professor of mechanical engineering; Taras Kiceniuk, group leader in the Hydrodynamics Laboratory, and Byrne Perry, associate professor of civil engineering from Stanford University.

The streamlined metal "dolphin," about one foot long and two inches in diameter, was suspended in the water at depths ranging from a little more than one inch to nearly six inches. In nature the dolphin moves through the water. In the test the model remained stationary and the water moved past it. The purpose of the experiment was to determine whether the drag force acting on the model would be reduced when the model was located in the forward part of the wave. If the force was reduced, it would demonstrate that the dolphin also might obtain similar assistance from a wave.

A level stream of water flowing past the "dolphin" produced some lift and considerable drag. The water flow was accelerated to about five miles an hour, at which speed it produced a standing wave in the water tunnel. The "dolphin" produced much more drag and also more lift when riding in the trough of the wave.

The model was moved into the forward slope of the wave and tilted at an angle corresponding with the wave's slope. In this position and at depths ranging from nearly two inches to four inches – while the model was entirely submerged – forward thrust was detected! This thrust was sufficient to be effective only with a very streamlined and slick body, like that of the dolphin.

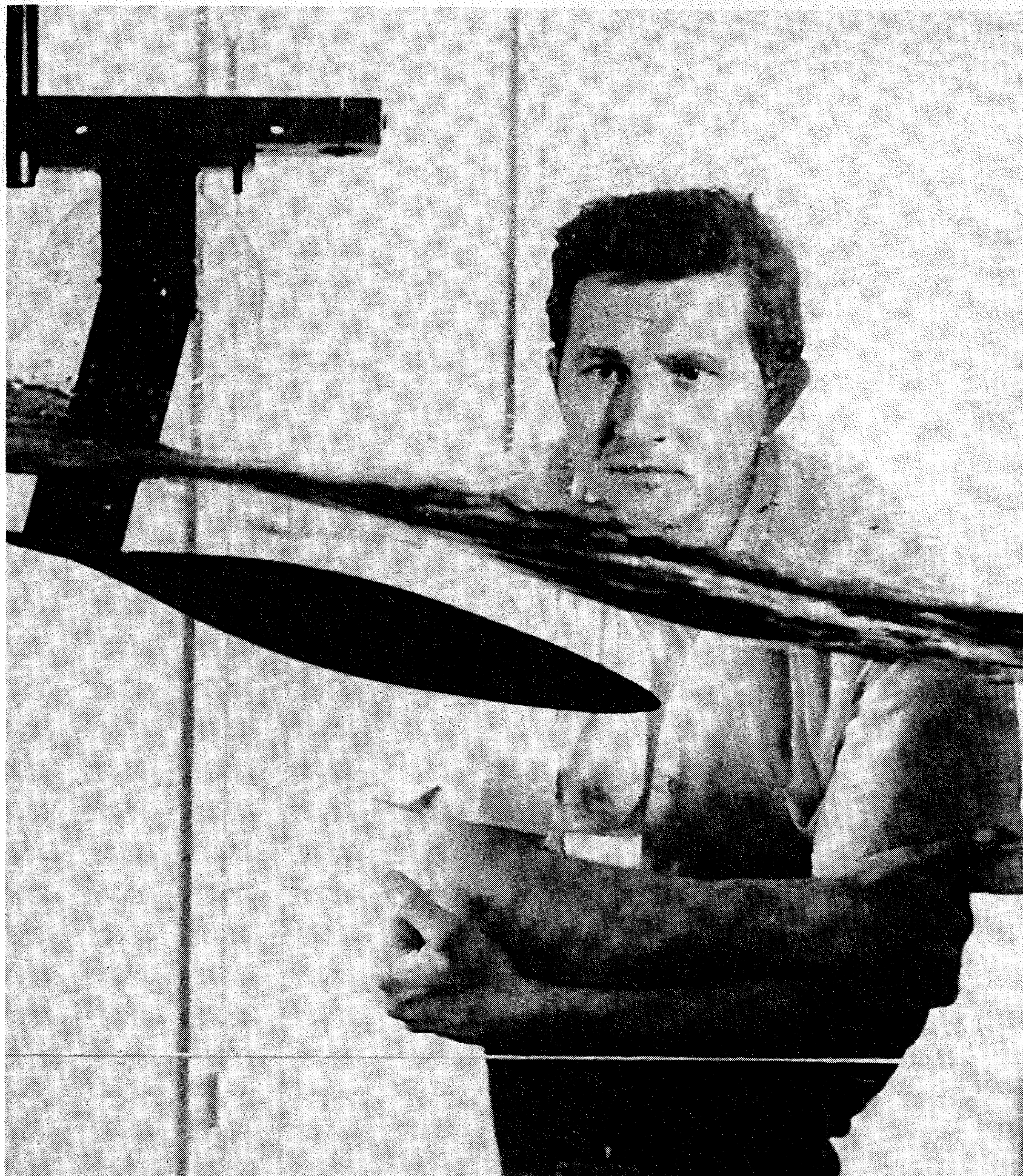
This, then, appeared to be the secret of the dolphin's ability to free-load rides on the bow waves of vessels. His propulsion may be likened to that of a surf rider who is constantly "falling" down the slope of an advancing wave and who will move forward as long as he holds his planing position on the wave's slope.

According to Kiceniuk, the dolphin's forward thrust is produced by the fact that the buoyant force is not directly upward, as it would be if there were no waves, but is tilted forward, being at right angles to the forward slope of the wave. "The mere existence of the measured forward-acting thrust on the test body in a wave demonstrates that a rigid body with turbulent flow can perform the wave-riding trick," he says.

The Caltech experiment appears to substantiate a mathematical analysis of the problem which was developed some time ago by a Caltech alumnus, Wallace D. Hayes (BS '41, AE '43, PhD '47), now professor of aeronautical engineering at Princeton University.

Wave-riding may be a skill that must be learned, says Kiceniuk. Young dolphins probably do it by watching their elders, and follow up the observations by practice. They learn to do it by "feel," just as a child learns how to ride the breakers at the beach or to ride a bicycle. They use their kinesthetic senses instead of mathematical equations.

Free-riding in this manner is believed to be a common practice in nature.



With a metal model, Taras Kiceniuk, group leader in Caltech's Hydrodynamics Laboratory, tries to find out what laws of physics dolphins use when they take free rides on the bow waves of ships.

"It has been suggested that dolphins and porpoises migrate long distances by riding the ocean waves that are created by the winds," Kiceniuk says. "Whales should be capable of learning this art, too, but they probably haven't ever done it because they are too large for most natural waves."

The bow waves of ships are evidences of pressure fields created in the water by large moving objects. In the same way that dolphins ride the waves, they also may ride the pressure fields. Pressure fields may be created by another dolphin, or even, conceivably, by a submerged submarine. A pilot fish may be free-riding a shark's pressure field when he precedes the shark on its forays.

Other creatures are known to free-ride by taking advantage of flow disturbances which are created for them in the air. It is why geese fly in a "V." All but the lead bird take advantage of the air spilled off the end of the wing of the bird ahead. This spilled air approaches following birds with a slight upward velocity, enabling them to fly with less effort. Birds have been observed taking turns flying in the lead position, where the most effort is required to maintain flight.