

## OPENING KEYNOTE LECTURE DOLPHIN HYDRODYNAMICS: GRAY'S PARADOX REVISITED

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### ABSTRACT

Belief that some dolphin species possess an extraordinary laminar-flow capability dates back at least as far as Gray (1936). In his analysis of dolphin energetics and hydrodynamics, Gray followed the usual practice of marine engineers to estimate the hydrodynamic drag experienced by the dolphin at the commonly observed swimming speed of 10 /s. According to this approach, if conventional hydrodynamics were involved, the flow over the dolphin would be mostly turbulent and a large drag would be experienced. So large, in fact, that at 10 /s its muscles would have to deliver about seven times more power per unit mass than any other mammalian muscle. This mismatch between the required and expected muscle output has become known as *Gray's Paradox*. It led Gray and others since to argue that the dolphin must be capable of maintaining laminar flow by some extraordinary means.

Resolving Gray's paradox may, at first, seem straightforward. Nevertheless, more than 65 years later, complete resolution still eludes us. A full appraisal requires a multifaceted and multidisciplinary approach. In this lecture the main aspects will be reviewed. The focus will be on the structure of dolphin skin (see Figure) and the features with a potential laminar-flow function. The artificial analogue dolphin skins (compliant walls), designed by Kramer (1957,1960) and others, will also be described. There is ample evidence that such compliant walls can maintain laminar flow. This will be reviewed and used to provide evidence of the laminar-flow capability of the real dolphin skin.

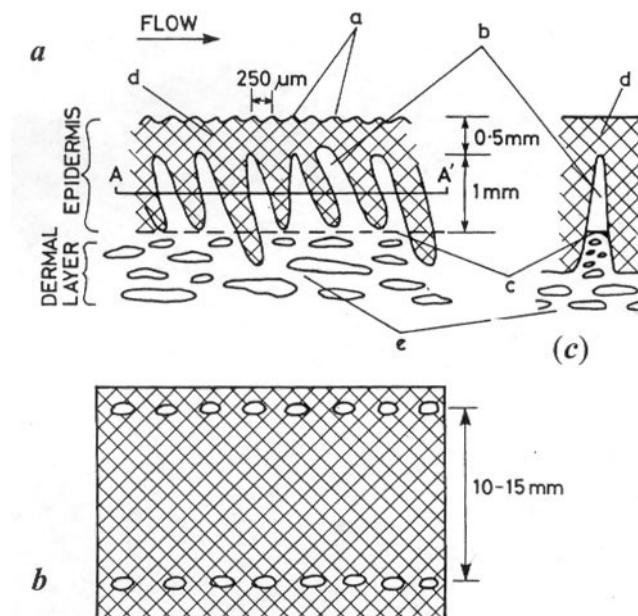


Figure: Structure of dolphin skin. (a) Cross-section; (b) Cut through dermal papillae at AA'; (c) Front view. Key: a, cutaneous ridges or microscales; b, dermal papillae; c, dermal ridge; d, upper epidermal layer; e, fatty tissue.