Motor Field in Cerebral Cortex of the Bottlenose Dolphin*

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The largest animals that have ever lived belong to the order Cetacea. Man in general and biologists in particular have been intrigued by the size of these mammals and by their adaptation to a completely aquatic life. They have been regarded popularly since antiquity as creatures of insight with a special relation to man. Scientific curiosity has been heightened by recent knowledge about their respiration, circulation, sonar, communication, behavior, and trainability.

Neurological scientists have a particular reason for interest in the Cetacea. The brains of whales are the largest that exist. Aside from great size, the cerebrum may be anticipated to show an unusual organization. The plan of the nervous system must reflect the remarkable specialization of bodily form and function in this ancient group, which arose, as did man, from non-specialized land mammals.

We studied a representative cetacean, the bottlenose dolphin (*Tursiops truncatus*), or porpoise as it is commonly called along the eastern U.S. coast. The bottlenose, which has a brain slightly larger on the average than that of man, has in common with other cetaceans a cortex of good histological quality which is extensively fissured. This impressive mass of cerebral tissue and the vocal capacity of the species has led to a serious attempt by Lilly to communicate with the dolphin through a “complex language.”

Little is known of the functional anatomy of the massive cerebral mantle of the cetaceans. No map of cortical cytoarchitectonics in the style of Brodmann is presently available and anatomists point out that parcellation in this particular cortex is difficult unless functional correlates are available. As a start in understanding this or any other cerebrum, the cortical sensory and motor areas should be defined and compared with known patterns of organization.

An attempt to stimulate the motor cortex was made by Langworthy in 1928 on “an open beach in February with a strong wind blowing from the sea.” The difficulties of his nonproductive efforts were increased when the entire population of the island came to witness the experiment. A group of eminent neurophysiologists attempted a serious study of cortical mapping at Marineland, Florida, in 1953 but were thwarted by difficulties with anesthesia.

The significant problems of anesthetization were later essentially solved by Nagel, et al., thus opening the way for a variety of in vivo studies. Basically, they modified the methods developed over the years for human anesthesia to fit the unusual requirements of the porpoise. They used endotracheal intubation, inhalation anesthesia, and respiratory control with a modified Bird respirator. The application of clinical methods to future cetacean research will involve the neurosurgeon, as well as the anesthesiologist, because of his experience with large, complicated craniotomies.

In the present study we aimed to establish the location and nature of the cetacean motor fields by stimulation of the surgically exposed cortex in the anesthetized animal.

**Materials and Methods**

This study was done at Marineland, Florida, in September, 1965, on 11 bottlenose dolphins (*Tursiops truncatus*) of both sexes caught off that coast. Individual weights estimated by experienced observers varied from 175 to 500 lbs, averaging 353 lbs. Measured lengths ranged from 194 to 252 cm, averag-
The pressure.

A craniectomy was performed over the right hemisphere with the techniques used in human neurosurgery. Electrocautery was used to outline and excise a large square of skin and underlying blubber which extended up to the sagittal midline. It was necessary to remove much of the melon, a massive but relatively avascular eminence of blubber in front of the skull. The cutaneous blowhole was closely undercut, and much of the complex of air sacs beneath it was excised. Musculature overlying the cranium was reflected with a periostal elevator and excised. A rather extensive removal of soft tissues with a large venous supply was required to expose the rostral portion of the skull. Entry into the skull was made with a perforator and burr.

A craniectomy was then performed with rongeurs. In most animals the dura mater was closely adherent to the undersurface of the skull and was torn to some degree during the craniectomy despite attempts to free it with a dissector. It was necessary to remove much of the right bony blowhole (naris) to expose the medial aspect of the frontal pole. The skull became increasingly thick toward the midline where it formed a crest approaching 2 inches in depth. It proved necessary to remove much of this to expose the excitable cortex. The dura mater was reflected back from the cortex, which often appeared initially to be under slightly increased pressure. Most of the frontal half of the cerebral convexity was exposed.

The cortex was stimulated by direct application of a unipolar electrode held by hand, which used 60-cycle current calibrated in milliamperes. Ordinarily, at least 1 minute was allowed between successive stimuli. We attempted to establish threshold responses. The region of exposure was widely stimulated before focusing attention on an area found to be excitable. Attempts to record evoked potentials were unsuccessful. The weights of five unselected brains sectioned at the lower medulla and fixed in formalin varied from 1432 to 1567 gm, averaging 1494 gm.

In general, the extensive craniotomies and deep anesthetic levels were poorly tolerated. Eleven animals were successfully anesthetized in acute experiments, but positive results on stimulation were obtained in only three of these. Animals were sacrificed at the conclusion of each experiment by an overdose of anesthetic agent. Failures were generally due to premature deaths, which were difficult to analyze at the time. Anesthetic problems and deaths are being considered by one of us (S.A.) in another report.

Results

We found an excitable area marked by a constant pattern of sulci on the frontal pole near the sagittal sinus in a region that lay roughly beneath the ipsilateral blowhole (naris) in the intact animal (Figs. 1 and 2). This motor area was seen to occupy a gyrus medial to (in front of) the rostral termination of an exceedingly long and deep sulcus, which we have termed “alpha.” This sulcus, which consistently bordered the motor area, always ended frontally in an inverted T-shape (Fig. 2). From this T the sulcus traversed the frontal pole obliquely to the midline where it crossed over to the medial wall and there pursued a lengthy course. Two other vertical sulci, which roughly paralleled alpha and delimited the gyri on either side of it (Fig. 2), were also found to be constant.

The excitable gyrus medial to the T of alpha was most clearly shown in two of the three animals in which results were obtained. In each of these, widespread stimulation of the exposed cortex produced negative results except in that gyrus. In the third animal, we obtained movements on stimulation of the gyrus lateral to the T of alpha, but in that case the gyrus medial to the T was not exposed or stimulated.