high temperatures employed in the flame-drying process in the commercial manufacture of herring meals are responsible for the low folic acid content of these meals.

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Manuscript received March 19, 1952.

Reactions of the Porpoise to Ultrasonic Frequencies[1]

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Whales and porpoises make many varieties of sounds under water (*1–6*). In the case of the bottlenose dolphin, *Tursiops truncatus* (Montagu), these can range from a low growl and groanlike sound, in the general pitch range of the bark of a seal or sea lion, to a shrill whistle which may go to several thousand cycles/sec (*4, 5*). Little is known of the way in which the porpoises themselves respond to such sounds, although they have been observed to react to artificial noises produced under water. Howell (*7*) and Fraser (*2*) report that the use of a supersonic depth finder by a vessel near a school of porpoises will immediately drive them away.

The acoustic receptor of the porpoise, moreover, is a highly developed organ especially adapted to receive sounds in a medium as dense as water (*8*), yet the olfactory or chemical sense, which is present in most fishes, is absent altogether in these cetaceans (*5, 8*). This is no less than astonishing in view of the fact that porpoises obtain all their food under water. These animals must consequently locate food by some sense or senses other than olfaction, quite likely by vision and by hearing.

Evidence from neuroanatomy supports further the view that audition is a dominant, if not the dominant, sense in the porpoise. The temporal lobes, including the cortical area for acoustic reception, are tremendously enlarged (*8, 9*). In fact, in the case of *T. truncatus,* the cerebral hemispheres are in some cases actually wider than they are long. Such a development parallels the enlargement of the frontal lobes in man, or the unusual size of the olfactory bulbs in the dog. The anatomical data point, therefore, to a kind of superacoustical area in the cerebral cortex, which in turn suggests a functional capacity, so far as hearing is concerned, which may far exceed that of other animals.

Preliminary observations on the auditory sensitivity of the porpoise were recently made at the Marine Studios at Marineland, Fla., where captive animals are available for scientific study. The subjects included 12 individuals, 10 of which were *T. truncatus,* and 2 long-snouted dolphins, *Stenella plagiodon* (Cope). These animals were kept together in a large circular tank 12 ft deep and 75 ft in diameter.[2] The sound-producing gear consisted of an oscillator with a frequency range of 20–200,000 cps, which activated a 20-w amplifier whose response characteristic was essentially linear to 100,000 cycles. Projection of these frequencies into the water was accomplished by a USRL transducer, type 1K, which was lent by the U. S. Navy on ONR contract.[3] That the equipment was capable of faithfully transmitting vibrations in water up to 200,000 cps was empirically determined by a special hydrophone and underwater sound pickup apparatus, recording through an oscilloscope. When used with porpoises, the apparatus was adjusted so as to produce a minimum underwater sound pressure of 4.03 dynes/cm^2 at a distance of 4 m from the transducer.

Since the observations were to be made in terms of the reactions or responses to auditory vibrations alone, and since porpoises are notoriously wary of strange objects in the water (*5*), it was necessary to allow a preliminary period of adaptation or adjustment to the visual appearance of the transducer before any of the actual sound tests were begun. To this end an exact wooden replica of the transducer was constructed to be used as a kind of stage "stand-in" for the real article. This model was kept intermittently in the tank at a fixed place and depth (*ca.* 5′) for a period of 2 weeks before the genuine transducer was substituted for it. In this way the porpoises learned to adjust to the sight of the new object and to accept it as a regular part of the environment.

The sound stimuli given in the tests were presented in short units or bursts of 2–3 sec. The bursts were given independently, and the porpoise reactions before and after each stimulus were compared. The time interval between stimuli was irregularly varied from 30 sec to several minutes during any single period of observation. Two to 4 observers were continuously on hand at the windows or portholes in the sides of the tank beneath the water level whenever tests were conducted. No stimulus was ever credited with producing a positive response unless all observers agreed that such a response had occurred. Since the projector or transducer focused sounds in a concentrated cone of 75°, the sound stimuli for testing were found to be most effective when the animals were swimming within this cone. The relative positions of observers, transducer, and porpoises are diagrammed in Fig. 1.

The porpoises were in continuous motion both during periods of daylight observation and during night

[1] Contribution No. 4 from the Florida State University Oceanographic Institute.

[2] The writers wish to take this opportunity to thank the management of the Marine Studios, and especially F. G. Wood, Jr., curator, for permission to make these observations, and for generous aid and cooperation.

[3] Invaluable technical and consulting assistance on the projection and propagation of underwater sound frequencies was obtained from the U. S. Navy Mines Countermeasures Station at Panama City, Fla., and from the ONR Sound Reference Laboratory at Orlando, Fla.

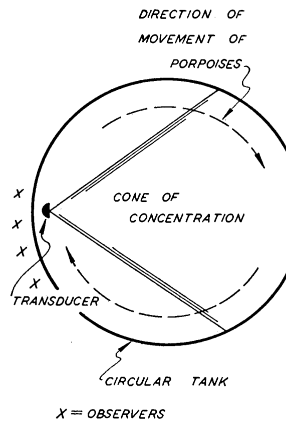

FIG. 1. General arrangement for studying the reactions of captive porpoises to underwater sound frequencies at the Marine Studios, Marineland, Fla., showing the location of observers and transducer, together with the direction of movement of the animals observed.

observations, which were made up until 10:00 P. M. They circled the tank at an approximately constant "cruising speed," in groups of 2–6—almost always moving in a clockwise direction against the current in the tank. The reactions made to the projected underwater sounds were alterations in, or modifications of, the regular circling behavior, which was always present. The direction of swimming was generally not changed (except in special cases described below), so that the total response was neither an approaching nor an avoiding reaction. It was instead an immediate speed-up in the rate of locomotion. There was an abrupt increase in the vertical movement of the horizontal tail flukes, accompanied by a lunge forward, or sudden increase in swimming speed. This increase in speed would last for several seconds after the termination of the stimulus. An analogous response in man would be described as going from a walk to a run, or in a horse as going from a trot to a gallop. Reactions of this sort were elicited by the sound stimuli when the porpoises were on the side of the tank nearest the transducer, as well as when they were on the opposite side of the tank, 50′ or 60′ from the source of the sound.

The range of hearing as measured by this method extended from 100 to 50,000 cps. Particular attention was paid to the higher frequencies because of the special and unusual nature of this result.[4] Responses could also be obtained to porpoise sounds played back to the animals from tape recordings of their own noises, as well as to the sound of the human voice and recorded music. In the case of the lower frequencies, however, a considerable increase in gain or volume was necessary in order to get results. The high level of background water noise in the tank, which probably masked the lower sounds at ordinary intensity levels, was no doubt responsible for this fact.

The reactions produced by oscillator frequencies between 100 and 400 cps were, it should be noted, peculiarly different from those occurring within the range of 500–50,000 c. The lower tones appeared to disturb the animals a great deal more. Instead of simply swimming faster to a particular sound burst, they would break up their swimming formations, and sometimes dive out of the water, swerving thereby from the customary circular pathway around the tank. At times they seemed to charge or "attack" the transducer as a result of these low-frequency vibrations. It is possible in such cases that they were "feeling" the vibrations as tactile stimuli through the skin.

At least three significant inferences may be drawn from these data:

1) If the underwater frequencies which were presented affected the acoustic receptors of the porpoises, this means that these animals must possess an exceptionally high upper limit of hearing, extending approximately 30,000 cps beyond that of man. In this respect the porpoise may resemble the bat, although within a somewhat lower range, since the bat can probably hear sounds up to 120,000 cps (*10*).

2) If the vibratory stimuli did not affect the ear, then the porpoise must possess some as yet unknown mechanism for reacting to high-frequency vibrations in water. Tests made with the present apparatus have indicated that human subjects are unable to sense water vibrations on the skin even when the frequency is as low as 2500 cps.

3) If the first interpretation is correct, it follows as a unique possibility that porpoises may not only hear frequencies as high as 50,000 cps, but that they may also produce or emit ultrasonic vibrations. The inference seems inescapable that the porpoise, like the bat, may orient itself with respect to objects in its environment by echolocation—that is, by the reflection of its own sound waves. Porpoises are exceptionally fast swimmers, and many varieties visit shallow bays and estuaries that are often murky and turbid. They also navigate at night. In instances where light penetration is low because of sediment in the water, or because of darkness, the visual receptor would be of little value in locating submerged piling, boats or ships, the ocean bottom, or possibly schools of fish for food.

The particular advantage of ultrasonic frequencies in this connection is that such frequencies would be less subject to masking by the ordinary background noise that exists in water—such as the sound of waves, the rush of water which occurs during rapid swimming, the sound of propellers, or the underwater noises of other organisms known to be generally in the lower frequency range (*11*).

The cetaceans may consequently have used sonar long before it was ever thought of by man. At the present writing, this possibility is of course no more

[4] Subsequent tests, completed too late to be included in this article, were made on 2 young captive females (*T. truncatus*) at the Lerner Marine Laboratory at Bimini, B. W. I. Water noise was almost nonexistent, and conditions on the whole were more favorable for making accurate measurements of auditory sensitivity. The upper threshold under these circumstances was found to be closer to 80,000 cps than to 50,000 cps. A more detailed report covering these new findings will be published later.

than an interesting speculation, to be investigated in the future.

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Manuscript received March 17, 1952.

The Function of Vitamin C in the Adrenal Cortex[1]

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Under usual conditions the adrenal cortex produces two types of compounds. One type, which includes cortisone (17-hydroxy-11-dehydrocorticosterone), is more highly oxidized than the other type, which includes desoxycorticosterone. These compounds seem to have the opposite effect on the development of arthritic lesions in the scorbutic guinea pig (*1, 2*). The injection of cortisone tends to inhibit the development of these arthritic lesions, whereas the injection of desoxycorticosterone promotes such lesions.

Since cortisone prevents the development of severe arthritic lesions in the scorbutic guinea pig, it may be concluded that for some reason the adrenal cortex does not produce an adequate amount of this type of hormone when the guinea pig receives a diet deficient in vitamin C. On such a diet the adrenal cortex contains very little vitamin C (*3*).

One explanation for the failure of the adrenal cortex to function normally under scorbutic conditions could be that vitamin C is a necessary component of the oxidation-reduction system which produces the oxy-type of adrenal hormones. Such an explanation seems reasonable since it has been shown that vitamin C can serve as a coenzyme in a biological oxidation system (*4*) and also that desoxycorticosterone can be oxidized *in vitro* to cortisone by the adrenal cortex in the presence of vitamin C (*5*).

The adrenal cortex of scorbutic guinea pigs is capable of responding to injections of adrenalcorticotropic hormone (ACTH), since it has been shown to reduce the cholesterol content of the adrenal cortex (*6*). From earlier work (*3, 7*) it is suggested that the adrenal cortex of guinea pigs affected with scurvy is capable of producing some adrenal-cortical hormones when activated by ACTH. If this hypothesis is true, then injections of ACTH should prevent arthritic lesions in a manner similar to the results produced by the injection of cortisone (*1*).

TABLE 1

THE EFFECT OF DAILY INJECTIONS OF ACTH, CORTISONE, AND DESOXYCORTICOSTERONE INTO SCORBUTIC GUINEA PIGS ON THE DEVELOPMENT OF ARTHRITIC LESIONS

Group	No. of pigs	Daily injections	Severity of arthritis	Days for scorbutic symptoms to occur
I	7	None	Very severe	13
II	6	5 mg cortisone acetate*	Very slight	13
III	6	5 units ACTH†	Severe	11
IV	5	5 mg desoxycorticosterone acetate‡	Very severe	8
V	6	4.3 mg vitamin C	None	

* Cortone acetate (11-dehydro-17-hydroxycorticosterone-21-acetate), Merck & Co.
† Corticotropin, Wilson.
‡ Cortate, Schering Corp.

The following experiment was conducted to determine whether ACTH has an action similar to that of cortisone in preventing arthritic lesions in scorbutic guinea pigs. Five groups of female guinea pigs weighing 300–450 g were fed a basal ration deficient in vitamin C and injected subcutaneously, as shown in Table 1. The group receiving vitamin C was given 4.3 mg each day, as this meets the requirements reported by Kuether (*8*).

With the exception of the group receiving ascorbic acid, all groups showed varied degrees of scorbutic symptoms. On the eighth day the group receiving desoxycorticosterone showed the first evidence of scurvy, and by the thirteenth day their joints were swollen and they exhibited signs of pain. After 11 days the guinea pigs receiving ACTH were less active than they had been previously, and on the thirteenth day symptoms appeared that were similar to those present in Group IV, but not as severe. One guinea pig receiving ACTH was afflicted with swollen joints, and all the animals of this group showed signs of pain. The negative control (Group I) also developed severe scorbutic symptoms by the thirteenth day, whereas the animals in Group II evidenced only slight pain and no articular enlargement during the same period.

Administration of desoxycorticosterone and ACTH apparently aggravated the arthritic condition, and, conversely, cortisone suppressed these clinical manifestations, which is in agreement with previous work (*1*). From this experiment it is evident that the injections of ACTH did not stimulate the cortex of the

[1] Contribution No. 124, Department of Veterinary Medicine, and Contribution No. 469, Department of Chemistry, Agricultural Experiment Station, Kansas State College.

[2] Portion of a thesis presented as partial fulfillment of the requirements for the M.S. degree in physiology at Kansas State College.