[37] von Euler, C., and U. Soederberg, *J. Physiol.*, **118**, 555 (1952).
[38] Akert, K., and F. Kesselring, *Helv. Physiol. et Pharmacol. Acta*, **9**, 290 (1951).
[39] Andersson, B., *Acta Physiol. Scand.*, **41**, 90 (1957).
[40] Iberall, A. S., *Trans. Am. Soc. Mech. Engrs.*, Sect. D: Basic Eng. **82**, 513 (1960).

COCHLEAR POTENTIALS IN THE MARMOSET*

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From a comparative standpoint the primate ear claims a special interest, for this order is the one to which man belongs. It is more than a little surprising, therefore, that our knowledge about the hearing of members of this group is severely limited. Apart from man himself, only the chimpanzee and Old World monkeys (the rhesus monkey and its close relatives) have been tested for auditory acuity.

These considerations led Seiden,[1] working in our laboratory, to carry out auditory measurements in the marmoset, one of the New World primates that is considered more primitive than the species mentioned above. He used five animals of the species *Hapale jacchus* and trained them to respond to sounds by a shock avoidance method. The animal was placed in a tipping cage and was required to cross over its center line when a tone was sounded, being given a mild electric shock if it failed to do so within 0.5 to 3 seconds after the tone began. Observations of threshold sensitivity were attempted over a frequency range from 100–80,000 cycles, but all the animals reached their limit between 25,000 and 37,000 cycles.

After these measurements had been completed, the same animals were used for cochlear potential studies, and the results of these studies are the subject of the present report.

The animals were anesthetized with diallylbarbituric acid and ethyl carbamate (Dial), in a dosage of 1 cc/kg of body weight. The recording electrode was a platinum foil on the round window membrane, with an indifferent electrode in inactive tissue nearby. In all the animals the observations were made on the right ear. The stimulating and recording equipment described earlier in our experiments on the cat[2] was used to obtain measurements over the range of 100–100,000 cycles.

Some of the results are given by the dashed-line curves of Figures 1 and 2, together with Seiden's curves of threshold acuity shown by solid lines. Figure 1 shows a representative ear, and the data for three other animals were closely similar to these. As will be seen, the potentials were obtained over the full range of 100–100,000 cycles. As the frequency was raised above 100 cycles, the sensitivity in terms of these potentials improved slowly, except for an irregularity around 700 cycles, until 1,500 cycles was reached, after which the level remained fairly uniform up to 20,000 cycles. Beyond this point the sensitivity was poorer, and the course of the curve was somewhat more irregular than elsewhere.

A comparison with the behavioral threshold curve shows a number of differences. The gain in sensitivity as the frequency is raised above 100 cycles is noticeably

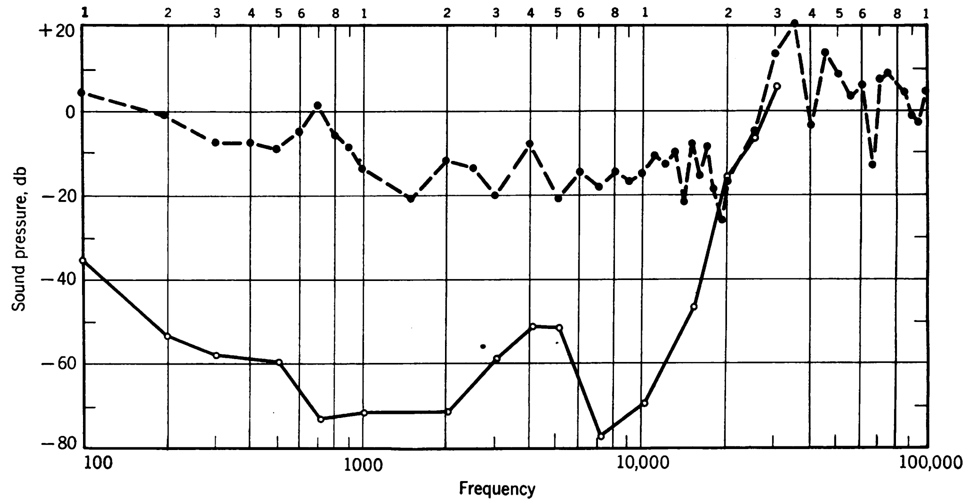

FIG. 1.—Auditory sensitivity in a marmoset as determined by behavioral and cochlear response methods. The ordinate shows the sound pressure in decibels relative to 1 dyne/sq cm at the threshold of hearing for the two ears (solid line) and that necessary to produce a potential of 1 microvolt in the right ear (dashed line).

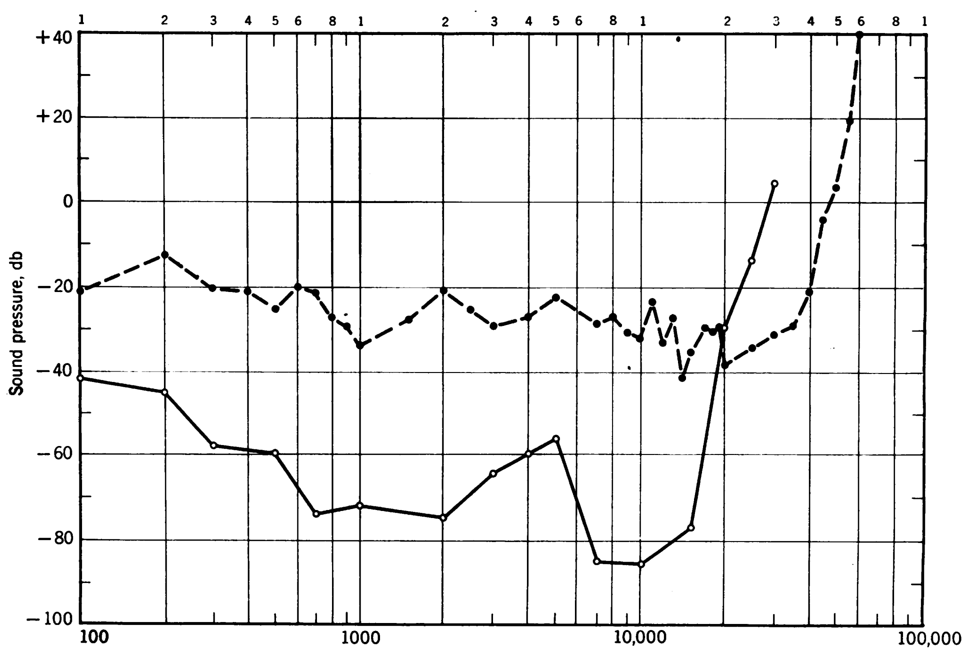

FIG. 2.—Results as in the preceding figure for a second animal with relatively poor cochlear potential sensitivity for the highest tones.

more rapid for the behavioral function. There is also a striking variation in the curve between 2,000 and 7,000 cycles, which consists of a fall in sensitivity to 5,000 cycles, then a rapid rise, and finally a rapid fall. The curve continues to show this fall in sensitivity to its end at 30,000 cycles, which represents the upper limit of hearing under the conditions of the experiment.

Every one of Seiden's animals exhibited the variation between 2,000 and 7,000 cycles and in exactly this same region of frequency. It is notable that this feature has no counterpart in the cochlear potentials. It evidently has its origin in the auditory nervous system.

Figure 2 represents an ear that does not conform exactly to the others of the group. This animal was a female, and from her general appearance she was judged to be older than the others. A few days before the cochlear potential measurements were made she gave birth to two young. The threshold acuity was much the same as for the first animal, but a difference appeared in the cochlear potential curve in the high frequencies. Beyond 30,000 cycles the response required increasingly intense sounds, and could no longer be obtained beyond 60,000 cycles.

An explanation has already been offered[3] for the attainment of an upper limit by the acuity function while the cochlear potentials are still maintained. It is supposed that certain mechanical and neural factors operate so as to enhance the acuity to high tones, thereby accounting for the greater slope of this function and the remarkable degree of sensitivity exhibited in the region of 6,000–15,000 cycles. However, these factors ultimately reach a limit of effectiveness and then decline. The most likely factors that operate in this fashion are the following. The pattern of response on the basilar membrane becomes narrower as the frequency rises, and at the same time there is a shift of the region of most vigorous activity toward the basal end of the cochlea. The basal shift finally moves the main response area to a region of the cochlea where the density of innervation falls off precipitously. Further, the excitability of nerve fibers by the cochlear potentials increases with frequency over a considerable range, but at last attains a limit. Finally, at low and intermediate frequencies there is a synchronous relation between sound waves and auditory nerve impulses, and therefore the rate of impulses rises with the frequency. In the upper frequencies, however, the synchronous relation is disturbed and finally fails, and the average rate of impulses suffers a decline. For all these reasons, we believe, the acuity and cochlear potential curves vary in their courses in the high frequencies and have different limits.

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[1] Seiden, Herbert R., "Auditory Acuity of the Marmoset Monkey, *Hapale jacchus*," Thesis, Princeton University, 1957.

[2] Wever, E. G., J. A. Vernon, W. E. Rahm, and W. F. Strother, "Cochlear Potentials in the Cat in Response to High-Frequency Sounds," these PROCEEDINGS, **44**, 1087–1090 (1958).

[3] Wever, E. G., "The Cochlear Potentials and Their Relation to Hearing," *Ann. Otol. Rhinol. & Laryngol.*, **68**, 975–989 (1959).