such anastomoses carry blood into the pulmonary vessels is a real one and that in some cardiopulmonary diseases the Fick more nearly measures the pulmonary arterial flow.

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COCHLEAR POTENTIALS IN THE CAT IN RESPONSE TO HIGH-FREQUENCY SOUNDS*

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Partly because of its availability and partly because of its particular anatomy, the cat has been a favorite subject in auditory experiments for many years. Probably its hearing is better known to us than that of any other animal except man. In the present experiments the study of cochlear potentials in the cat is extended to the ultrasonic frequencies, up to 100,000 cycles. A few earlier observations have indicated that these potentials are elicited by tones well above man's upper limit of hearing, but no systematic studies have been made.

As is well known, the ultrasonic frequencies present particular difficulties of a technical nature. Because of their short wave lengths, their acoustic behavior differs from that of ordinary sounds in many respects, and their production, control, and measurement require special methods. For the generation of tones in the range up to 100,000 cycles we have made use of a solid dielectric condenser receiver. For the measurement of sound pressures in this range we have extended the calibration of one of our condenser microphones (Western Electric Type 640A) by the use of an electrostatic actuator.

The measurement of cochlear potentials in this range also presents a problem, because the magnitude of these potentials is small in relation to the usual background of physiologic noise. To solve this problem, a high-frequency wave
analyzer was designed and constructed and used as a selective voltmeter. This instrument was valuable also in the measurement of the output of the condenser microphone in the high-frequency range where this microphone presents an unfavorable signal-to-noise ratio.

The experiments were carried out mainly in young cats, though a few older ones were included for comparison. The anesthetic was 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 the masseter muscle.

Some of the results are given in Figure 1, represented as the sound pressure required to produce a response of 1 microvolt. The solid curve represents the responses of a fairly old cat (4½ years), whereas the dashed curve represents those of a young one (about 1 year). There is little difference in sensitivity in the lower range, up to 15,000 cycles, but a significant variation beyond. The older cat showed a decline in sensitivity that became marked above 30,000 cycles and ceased to give any detectable responses above 70,000 cycles. The younger one, on the other hand, continued to show fairly uniform sensitivity up to 50,000 cycles, and only thereafter suffered a decline to a final value at 95,000 cycles, which was the highest frequency used. Most of the young animals gave curves like the dashed one shown here and usually extended to 100,000 cycles, which was the limit of the apparatus.

The maximum amount of cochlear potential at the uppermost frequencies was small, often no more than 1 microvolt and sometimes less. Yet, within the range within which measurements could be made, the intensity functions for the high frequencies show the same form as for the low frequencies: the functions are linear over their main course and then bend as overloading enters for intense sounds.

These relations may be seen in Figure 2. Here a special sort of plotting has been used to facilitate a comparison of the forms of the curves for the different frequencies. The abscissa represents sound pressure in decibels relative to 1 dyne/sq cm for a tone of 1,000 cycles, and the curves for the other frequencies have been shifted

![Figure 1](image-url)
along the abscissa until their straight portions coincide with the 1,000-cycle curve. This procedure neglects variations in sensitivity and brings out especially the difference in level at which overloading occurs.

There is a systematic decline in the maximums as the frequency is raised. Thus the observations extend those already obtained for the ordinary range of tones, which have been interpreted as revealing the forms of displacement of the basilar membrane as a function of frequency and specifically as indicating that the displacement curves grow continually narrower and their peaks shift basalward as the frequency is raised. The present results are not sufficient to determine whether the displacement curves for these uppermost tones have a true maximum that shifts with frequency or whether merely the tail of the usual response curve exists at the extreme basal end and declines in magnitude as the frequency rises.

These results show that tones as high as 100,000 cycles enter the cat’s ear and are carried by its conductive mechanism to the sensory cells of the cochlea, where they produce electrical potentials. There is still a question whether these cochlear processes are able to affect the auditory nerve fibers and bring about a perception of the sounds. Of particular relevance to this question are the results of Neff and Hind, who used a training method and measured auditory thresholds in cats for tones over a wide range. They found a maximum of sensitivity around 8,000 cycles, good sensitivity as far as 50,000 cycles and an upper limit at 60,000 cycles. The correspondence with the cochlear potential curves shown here is of interest, with only a difference in the upper limit attained.

This difference can be explained in either of two ways. It may be that in the highest frequencies, those above 60,000 cycles, the level of cochlear activity is suf-
icient to give measurable potentials but is not capable of exciting the auditory nerve endings. It is well known that the nerve fibers have excitatory thresholds, whereas none has been found for the cochlear potentials.

A second possibility is that the cats studied by Neff and Hind would have responded to tones above 60,000 cycles if these tones had been available at higher intensities. The limit of their oscillator was 70,000 cycles, and so the higher tones were not tried. Also their sound source, which was a Western Electric 633A dynamic microphone, was probably less efficient in the high frequencies than the speaker that we employed in the present experiments.

We are inclined to accept the second of these two explanations. Our reason is that the amount of cochlear potential observed at the highest frequencies, including 100,000 cycles, seems fully adequate to excite the auditory nerve fibers. Thus in one of our sensitive animals a response of 1 microvolt was obtained at 100,000 cycles at a sound pressure of 0.24 dynes/sq cm. Certainly, for lower frequencies this amount of potential far exceeds that produced by a tone at the behavioral threshold. McGill made a comparison between behavioral thresholds in cats and the magnitude of cochlear potentials recorded from the round window. These potentials are below the level of practical measurement when the tones are presented at threshold intensities, but, by extrapolation, it appears that they have a fairly uniform value of about 0.006 microvolt for tones over the range of 500–10,000 cycles.

An extrapolation of the Neff and Hind curves to 100,000 cycles gives a value of about 0.5 dyne. From the above considerations we should expect that a 100,000 cycle tone of this intensity, or somewhat less, would be audible to the cat. It is obvious, however, that further study is needed to decide this question.

Summary.—Measurements of cochlear potentials in the cat have been extended to 100,000 cycles. For the uppermost frequencies the intensity functions have the same form as for ordinary tones, and the maximum values continue to decline, from 1,000 cycles onward, as the frequency is raised. Consideration is given to the question whether these uppermost frequencies affect the neural elements of the auditory system.

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4 The details of construction will appear in an article by W. E. Rahm, Jr., and W. F. Strother.

