the absorption discontinuity of any comparatively heavy element present in relative abundance. The fact that the wave-lengths for the elements concerned lie in the range 3-6 Angström units probably explains why no such effect has been discovered to date. Conversely, if a sufficiently sensitive criterion of biological effect could be found, perhaps some genetic change, it would serve as a test for the presence of specific heavy elements in the hereditary material.

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A Quantitative Study of the Cochlear Response.*

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Quantitative measurements of the cochlear response in animals have been part of a program concerned with investigations on hearing problems during the past year and one-half in these laboratories. The methods and apparatus used for the detection of the responses was similar to that described by Garceau and Davis.[1] An accurate system for the measurement and generation of pure stimulation tones was essential. An audio-frequency oscillator generated electrical voltages for the production of these tones. The voltages were amplified, measured, attenuated to the desired level and finally transformed into sound by a Western Electric 555 speaker unit. The harmonic content of the sound wave as measured by means of a Brush crystal microphone, amplifier and General Radio Distortion Factor meter was never more than one per cent for tones below 4000 cycles per second. The total power of the harmonics was therefore 40 decibels below that of the fundamental in this range. A fabric reinforced rubber tube 6 feet in length conveyed the sound to the animal's ear.

The stimulus was calibrated in terms of microwatts of acoustical energy. This was accomplished by measuring the power level to the speaker necessary to produce threshold stimuli for each ear of 6 humans. The mean value of these thresholds was considered

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[1] Garceau, E. L., and Davis, H., *Am. J. Physiol.*, 1934, **107**, 305.

identical to the "minimum audible pressure" threshold values as determined by Sivian and White.[2]

The electrical voltages generated in the cochlea of the animal's ear were amplified and recorded with an electrode placed on the round window and an indifferent electrode buried in the muscles of the neck. The low level amplifier consisted of 4 stages which were resistance capacity coupled. A set of electrical filters made it possible to measure any frequency component to the exclusion of all others. These filters were necessary in the "masking" studies and their use also extends the limit of the smallest measurable input voltage.

For oscillographic purposes any one of 3 oscillographs were available, the choice depended upon the particular test.

The response for each frequency reaches a definite maximum value (Davis[3]). Over a considerable range of intensities the response in microvolts is practically proportional to the sound pressure. This linear relation holds from very low values of stimulation, presumably threshold values, to intensities within approximately 20 decibels of the intensity that gives the maximum cochlear response. Over this range of intensities the wave form of the stimulus is faithfully reproduced in the response and the harmonic content is less than 5%. The sensitivity of the response at 1000 cycles is 65 microvolts per dyne per sq. cm. The departure from this linear relation at high intensities of stimulation resembles the departure noted when any mechanical device is overloaded.

The rate of increase of response with increase of stimulus is greater for tones below one thousand cycles per second than for those above. This characteristic is probably associated with the greater change of loudness for a given change of intensity for low tones (Fletcher[4]).

The curve obtained by plotting the stimulus necessary to produce the maximum response as a function of the tone frequency resembles approximately the threshold of feeling curve (Wegel[5]). The maximum response at 1000 cycles is reached for a stimulus 18 decibels below the human threshold of feeling. This was checked by having several observers place the same tube used in testing the

[2] Sivian, L. J., and White, S. D., *J. Acoust. Soc. Am.*, 1933, **4**, 288.

[3] **Davis, H., A handbook of general experimental psychology. C. Murchison,** Clark Univ. Press, Worcester, Mass. 1934, pp. 962-986.

[4] **Fletcher, H., Speech and Hearing. D. Van Nostrand Co., Inc., New York,** 1929. p. 226.

[5] Wegel, R. L., *Ann. otol., rhinol. and laryngol.*, 1932, **41**, 740.

cats in their own external canals and increasing the stimulus until discomfort was experienced. The results suggest that the threshold of feeling occurs at a lower stimulus for a cat than for a human.

Contours of equal output, obtained by plotting the stimulus necessary to give various values of response as a function of the tone frequency resemble the familiar human equal loudness curves of Kingsbury (Fletcher[4]). Although the one microvolt (effective value) curve is about 20 decibels above the human threshold of audibility, the response can be detected for intensities of stimulation very close to the human threshold of hearing.

The presence of any tone decreases the cochlear response to any other tone. The percentage decrease of the response to any tone increases with the intensity of the interfering tone. It was thought that perhaps a detailed study of the relative decrease caused by various interfering frequencies would reveal information concerning subjective masking. The results, however, revealed that the percentage decrease of the response to any tone was the same for a high frequency interfering tone as for a low frequency interfering tone. There was no correspondence to subjective masking of high frequencies by low frequencies. The maximum total response to 2 tones (250 to 3000 cycles) does not proportionally exceed the maximum response due to either tone alone.