

XXV. COMMUNICATIONS BIOPHYSICS\*

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RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

The major efforts of this group continue to be directed toward an understanding of the communication senses – particularly hearing. Activity is concentrated in the four major areas of neuroelectric studies, psychophysical and behavioral studies, investigations of mathematical models, and research on problems in instrumentation and data processing. Typical examples of recent or current studies are:

1. Studies of hearing in the frog.
  - a. Single-unit responses in the green frog.
  - b. Calling behavior and variations in heart rate of bullfrogs evoked by various auditory stimuli.
2. Electrophysiological studies of discrimination behavior in the rat.
3. Investigation of the modifications in the responses of the cochlea and the auditory nerve resulting from stimulation of the olivocochlear bundle of cats.
4. Study of single-unit responses in the superior olivary complex of cats to binarual stimulation.
5. Study of membrane properties related to excitation processes and of the functional interaction of nerve cells.
6. Psychophysical investigations of sound localization, discrimination, masking, and adaptation.
7. Exploration of various mathematical models related to auditory nerve activity and auditory psychophysics.
8. Development of a compact digital correlator for on-line use.

Close cooperation continues with the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary, Boston. In particular, we are working together on activity of

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single units in the cochlear nucleus of cats and on the measurement of motion in the cat's middle ear.

W. M. Siebert, W. A. Rosenblith

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A. FURTHER OBSERVATIONS OF RESPONSE CHARACTERISTICS OF SINGLE UNITS IN THE COCHLEAR NUCLEUS TO TONE-BURST STIMULATION

A previous report<sup>1</sup> described a type of response pattern that was common to a large number of units in the cochlear nuclei of cats. Since that report many more units have

been studied and at least two more types of response patterns have been found. Systematic investigations have been restricted to the characteristic frequency, CF, of each unit (that frequency for which the threshold is lowest). From visual observations, however, it has been found that the type of response pattern of any one unit is more dependent on the stimulus intensity than on having the stimulus frequency at the CF.

Figure XXV-1 shows data for typical units representing each of the three common types. In each case, a sample from the spike-train data, and the corresponding post-stimulus time (PST) and interval (INT) histograms<sup>2</sup> are shown. The first unit, P27-7, is of the type previously reported.<sup>1</sup> An examination of the spike train shows that the interspike intervals appear relatively uniform, the INT histogram is unimodal and symmetric, and the PST histogram shows several peaks. All of these observations indicate that the firings are regular and time-locked to the onset of the stimulus. For the second unit, P25-8, an initial firing is followed by an interval of greatly diminished activity (approximately 10-12 msec in duration), which in turn is followed by one or two firings during the latter portion of the tone burst. The INT histogram for these data is bimodal — the later peak representing the interspike time intervals between the initial and second firings, and the earlier peak representing the intervals between multiple firings occurring during the latter portions of the tone bursts. The PST histogram clearly indicates the presence of the initial firing, the interval of diminished activity, and the resumption of activity. For the third representative unit, P29-5, the spike train shows that the interspike intervals are not uniform (as they were for unit P27-7), and that a fixed interval of reduced activity does not occur (as it did for unit P25-8). The INT histogram shows that the interspike time intervals range in length from approximately 1 msec to 11 msec (for this unit and this stimulus intensity) with shorter intervals occurring most frequently. The PST histogram has a relatively smooth envelope lacking the several distinct peaks, as in unit P27-7, and the region of inactivity, as in unit P25-8.

These three types of response activity are most clearly described and most easily identified by the shape of the PST histograms. Almost all of the units for which detailed tone-burst data are available have responses that are easily identified as belonging to one of these three types (80, 60, and 22 units, respectively, from a total of approximately 200). Many others have been identified by visual observations of responses as seen on an oscilloscope. Thus far, the units that do not fall into one of these categories are (i) units with low CF's, which have spikes that are phase-locked to the stimulus, (ii) units that seldom respond to the stimulus so that the number of responses is insufficient to determine to which of the three types, if any, they belong, and (iii) units that are similar to the second type described above except that they do not produce any spikes at high intensities of stimulation (only two units).

To illustrate the dependence of this activity on stimulus intensity, three typical

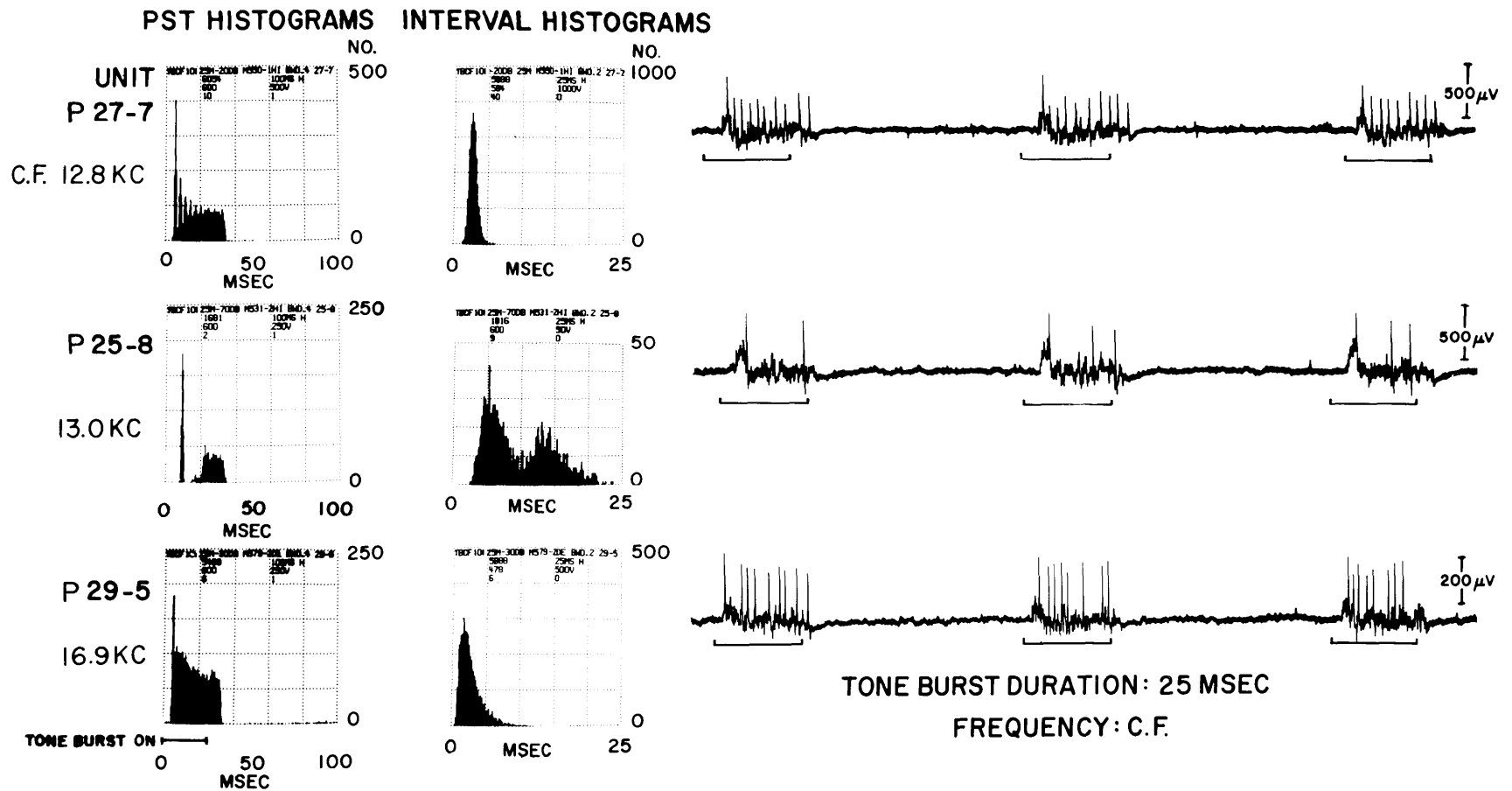


Fig. XXV-1. Poststimulus time and interval histograms of responses to tone-burst stimuli for 3 different units. Individual responses to 3 tone bursts are shown on the right for each unit. All tone bursts had 2.5-msec rise and fall times, 25-msec durations, and 10/sec repetition rates. The stimulus intensity with respect to threshold for visual detection of synchronized responses on an oscilloscope (UVDL - unit visual detection level) was 73, 28, and 55 db from top to bottom. Each PST histogram represents responses to 600 stimuli. The INT histograms represent 584, 600, and 478 stimuli. Locations of the units were posterior ventral cochlear nucleus, dorsal cochlear nucleus, and ventral cochlear nucleus, respectively.

examples of variations in the PST histograms with changes in stimulus intensity are shown in Figs. XXV-2, XXV-3, and XXV-4.

Figure XXV-2 shows an intensity series for unit P28-9, another representative of the first type of unit discussed. The top PST histogram is obtained from the spontaneous activity of this unit. As expected, there is no locking in time of the spikes and the artificial stimulus marker. The second histogram (-65 db) shows the presence of responses to the stimulus. At -60 db, the responses are seen clearly, but the histogram does not have several distinct peaks. The peaks for this unit emerge at higher intensities (between -60 and -50 db). Most often, for these units, the peaks emerge at threshold, but always within 10 db of threshold.

Figure XXV-3 shows an intensity series for a unit of the second type. Responses are seen to be present at -80 db. At -70 db three distinct, regularly spaced peaks are present. At higher intensities, however, the region of greatly diminished activity, characteristic of the second type of unit, appears. Thus far in this study, all of the units of this type required signal intensities between 20 db and 25 db above their thresholds to produce this zone of reduced activity.

Figure XXV-4 shows an intensity series for a unit of the third type. The presence of a response is just noticeable at -80 db. As the intensity increases, the histograms show neither several distinct peaks nor a region of inactivity within the response portion.

Thus it can be seen that these three types of activity are distinct over a wide range of intensity, although it is difficult in some cases to make judgments of type near threshold. Whereas no discrimination can be made between the first two types for intensities within 25 db of unit thresholds, unambiguous determinations for all three types are always possible at intensities above the 25-db level.

All three types of activity are usually observed in the same animal, for example, units P27-6, P27-7, and P27-13 are different types, but are all from cat 27. Furthermore, these types do not appear to depend on depth of anesthesia because they all can be found both at the beginning and at the end of an experiment (usually approximately 12-18 hours in duration). These types of activity, however, do seem to depend on the location of the electrode tip. The gross anatomical location of the electrode tip can be determined on the basis of results obtained by Rose et al.<sup>3</sup> and Rose<sup>4</sup> which pertain to the "tonotopic" organization of the single units in the cochlear nucleus. Their results showed that successive units encountered in a given electrode pass exhibited CF's that changed in an orderly sequence except for distinct discontinuities correlated with the boundaries of gross anatomical structures. On the basis of the location of a unit with respect to the distinct discontinuities in the sequences of the CF's one is thus able to determine if a unit is in the dorsal cochlear nucleus (DCN), ventral cochlear nucleus (VCN), or one of the latter's subdivisions — the posterior ventral or anterior ventral

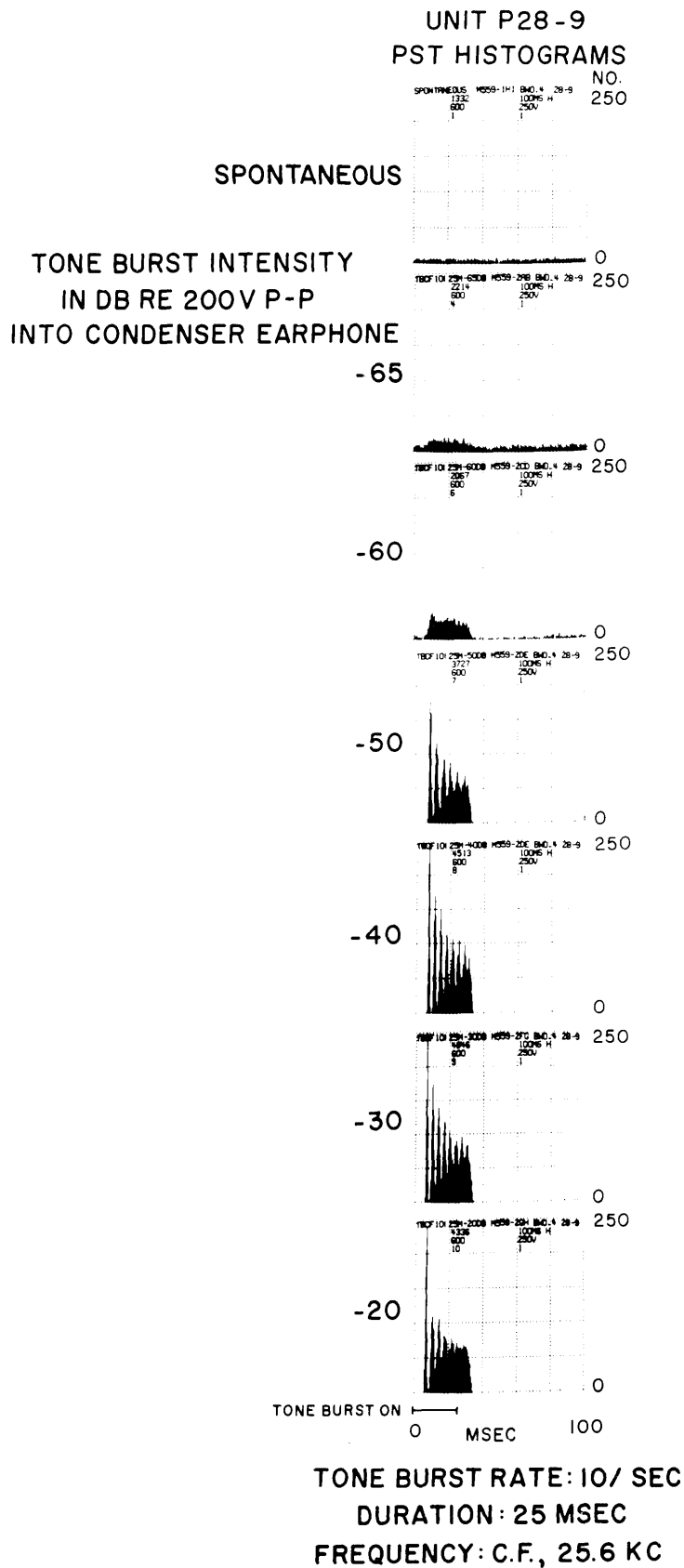


Fig. XXV-2  
Poststimulus time histograms of responses to repeated tone bursts as a function of stimulus intensity. The first PST histogram is of 1 minute of spontaneous activity of this unit. Intensity increases from top to bottom. Each histogram represents responses to 600 stimuli (1 minute of data). The UVDL of this unit was -63 db. Stimulus-locked responses can be seen at intensities below UVDL, that is, below -65 db. This unit was located in the posterior ventral cochlear nucleus. The abscissa scale has a 0.4-msec quantization interval. All tone bursts had 2.5-msec rise and fall times.

UNIT P27-13  
PST HISTOGRAMS

NO. 500  
SPONTANEOUS: H253-100, B44, 0, 27-13, 15 H, 500V, 1  
2772, 500, 1

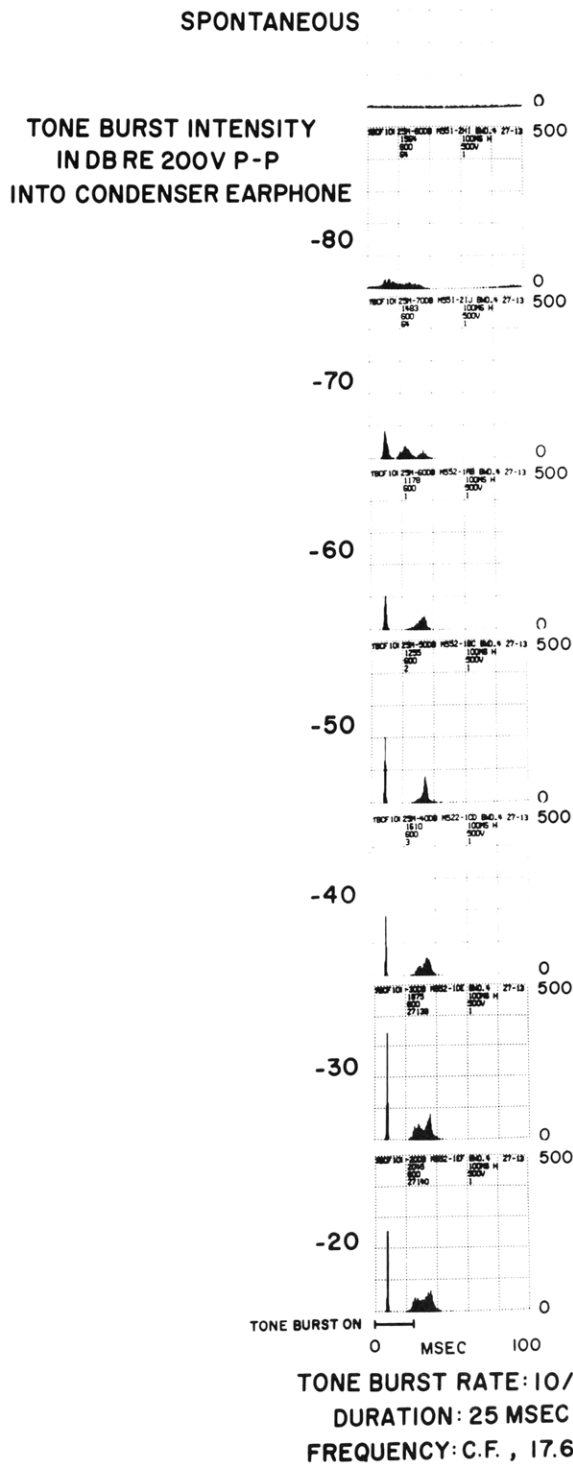


Fig. XXV-3.

Poststimulus time histograms of responses to repeated tone bursts as a function of stimulus intensity. The first PST histogram is of 1 minute of spontaneous activity of this unit. Intensity increases from top to bottom. Each histogram represents responses to 600 stimuli (1 minute of data). The UVDL of this unit was -85 db. This unit was located in the dorsal cochlear nucleus. The abscissa scale has a 0.4-msec quantization interval. All tone bursts had 2.5-msec rise and fall times.

UNIT P27-6  
PST HISTOGRAMS

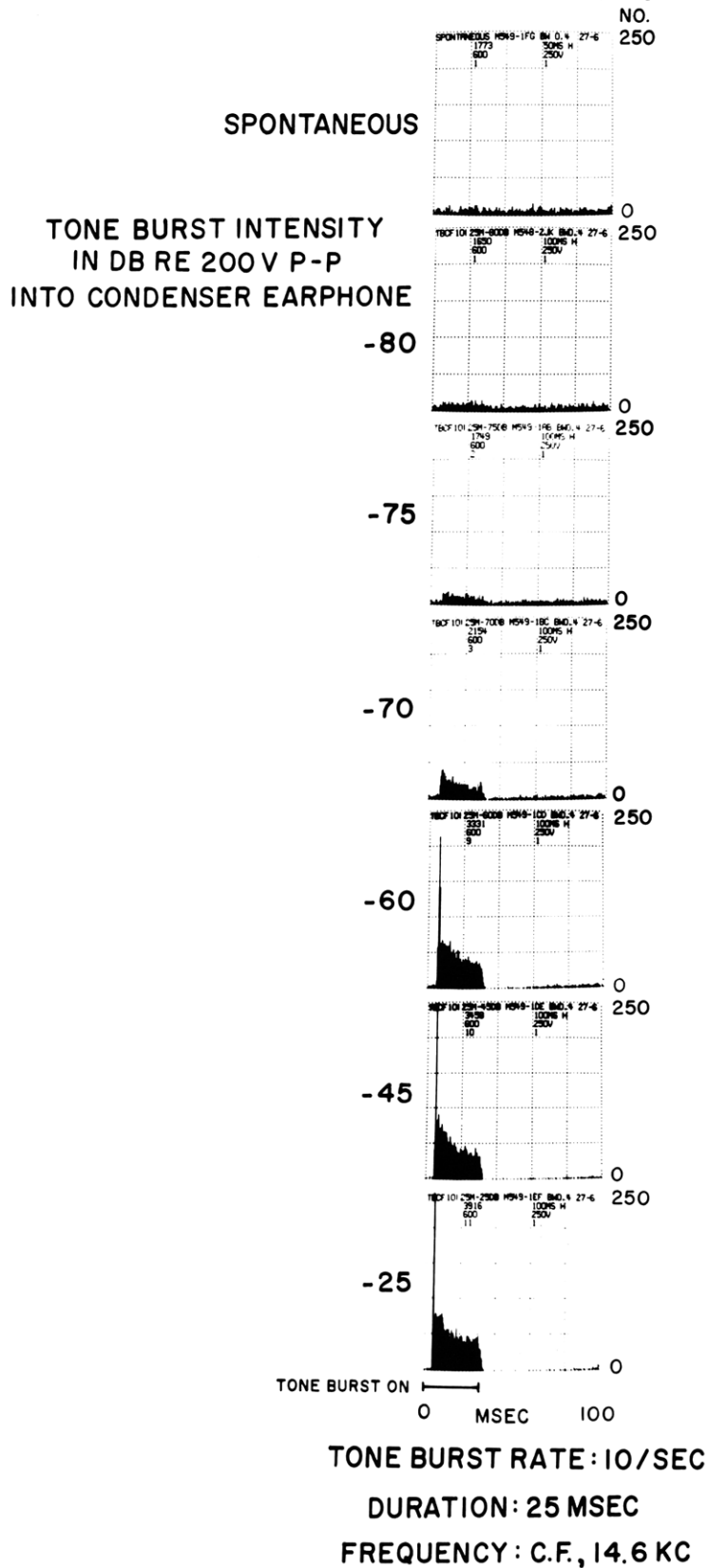


Fig. XXV-4.

Poststimulus time histograms of responses to repeated tone bursts as a function of stimulus intensity. The first PST histogram is of 1 minute of spontaneous activity for this unit. Intensity increases from top to bottom. Each histogram represents responses to 600 stimuli (1 minute of data). The UVDL of this unit was -75 db. Stimulus-locked responses can be seen at intensities below the UVDL, that is, below -80 db. This unit was located in the posterior ventral cochlear nucleus. The abscissa scale has a 0.4-msec quantization interval. All tone bursts had 2.5-msec rise and fall times.



cochlear nucleus, PVCN and AVCN, respectively. By using this method, units of the first type described, for example, P27-7 and P28-9, have been found almost exclusively in the VCN, with a few (6) in the DCN. The second type, for example, P25-8 and P27-13, has only been found in the DCN (or extremely close to the DCN-PVCN border on the PVCN side). The last type described above, for example, P29-5 and P27-6, has only been found in the VCN, and, when finer location was possible, it has always been found in the PVCN.

We also found,<sup>5</sup> and will report elsewhere, that correlations exist between these types of response activity and other properties of the units, such as their spontaneous activity and their response patterns to other types of stimuli.

R. R. Pfeiffer

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