man at birth.[7] Some investigators have obtained results comparable with our determinations in cord blood and others have found higher values similar to ours in blood drawn from the infant after delivery. The exact source and time of collection of newborn blood have not always been stated. The difference which we have found between cord (venous) blood at the moment of birth and capillary blood from the infant less than an hour later is truly surprising but may be more apparent than real. A similar difference between venous and capillary blood has been reported in pernicious anemia but not in normal adults.[8] It is possible that macrocytes in the blood of infants as well as of P.A. patients block some of the capillaries and thus effect a concentration of corpuscles.

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Cerebellar Action Potentials in Response to Stimulation of Cerebral Cortex.

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The problem of functional localization in the cerebellum is one which has received considerable attention. Recent comparative anatomical studies[1] and ablation experiments[2] have supported a division of the cerebellum based on afferent fiber connections. Recently Dow[3] has recorded action potentials in the cerebellum as a result of stimulating various afferent fiber tracts, and his results are in accord with Larsell's anatomical findings. The present work is an attempt to explore by the oscillographic method the projections of the cerebral cortex to the cerebellar cortex.

Methods and Results. Twelve cats, under barbiturate anesthesia, were used in this work. The method of stimulating and recording is described elsewhere.[4] Single electrical shocks were

7 Waugh, T. R., Merchang, F. T., and Maughan, G. B., *Am. J. Med. Sc.*, 1939, **198**, 646.

8 Duke, W. W., and Stoffer, D. D., *Arch. Int. Med.*, 1922, **30**, 94.

1 Larsell, O., *Arch. Neurol. Psychiat.*, 1937, **38**, 580.

2 Fulton, J. F., and Dow, R. S., *Yale J. Biol. Med.*, 1937, **10**, 89.

3 Dow, R. S., *J. Neurophysiol.*, 1939, **2**, 543.

4 Curtis, H. J., 1940, in preparation.

applied to the cerebral cortex by means of bipolar electrodes about 1 mm apart resting lightly on the pia. Monopolar recording was employed, the active electrode being a chlorided silver wire in light contact with the pia of the cerebellar cortex. Fig. 1 is a record of a cerebellar action potential obtained in this way. Following the shock artefact there is a surface positive wave having a latency of about 25 msec to the crest of the wave, and a second positive wave having a latency as long as 200 msec. The second wave by no means always accompanies the first, but the factors causing this wave have not been determined.

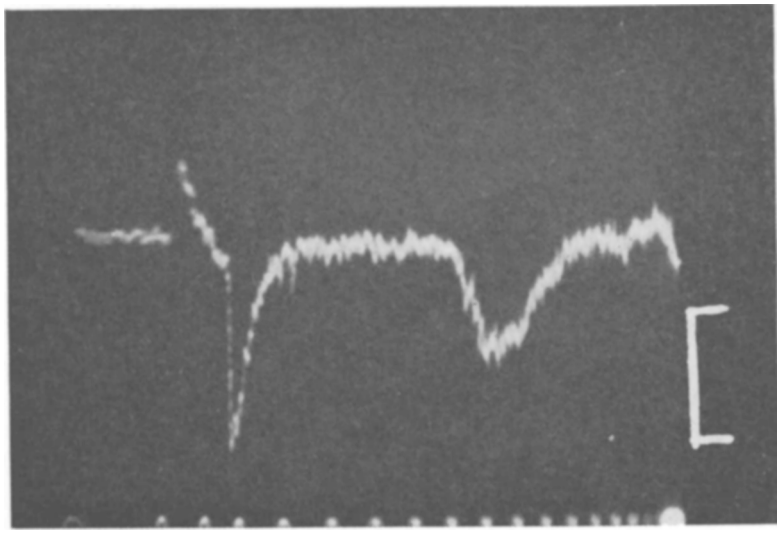

FIG. 1.
Cerebellar action potential recorded from Crus I, Lobulus ansiformus, as a result of a single electrical shock applied to the middle suprasylvian gyrus. The initial upward deflection is the shock artefact. Downward deflection indicates a surface positive potential. Time marks, 60 cycle; calibration mark, 200 μV.

Stimulation of one cerebral cortical point may produce simultaneous potentials in as many as 14 distinct points on the cerebellar cortex. Considering the extensive foliation of this structure, it must be true that only a small fraction of the total surface was explored; the total number of points which yield potentials must be far greater than this. The most easily detected potentials are on the contralateral side, and in general for each of these potentials there is a smaller potential on the ipsilateral side at a point roughly symmetrical to it.

If the stimulus is well localized the cerebellar potentials may be very sharply localized; a point exhibiting a large potential may be

only 1 mm away from a point which shows no measurable potential. On the other hand, when the stimulating electrodes are moved the pattern of the potentials on the cerebellar cortex is changed, but the potential at any single point may remain almost unchanged while the stimulating electrodes are moved by as much as 2 cm. This phenomenon is not due to a spread of the stimulating current, since a displacement of the stimulating electrodes by only 1 mm will often very markedly change the pattern of the cerebellar response.

None of the areas in the cerebral cortex which have been explored has failed to produce at least one potential in the cerebellum, and these areas include the sigmoid gyrus, marginal gyrus, middle suprasylvian gyrus, and middle ectosylvian gyrus. It was found that with the exception of the declive and tuber vermis all of these areas project to the neocerebellum[1] and to the posterior part of the anterior lobe. Fig. 2 shows a dorsal view of the cerebellum; the cross hatching indicates regions from which potentials have been recorded, shading indicates regions explored without finding potentials, and the unshaded regions were not explored. There seem to be no anatomically distinct regions which can be said to be associated with particular areas of the cortex. In other words, any given region in the cross-hatched areas of Fig. 2 may receive im-

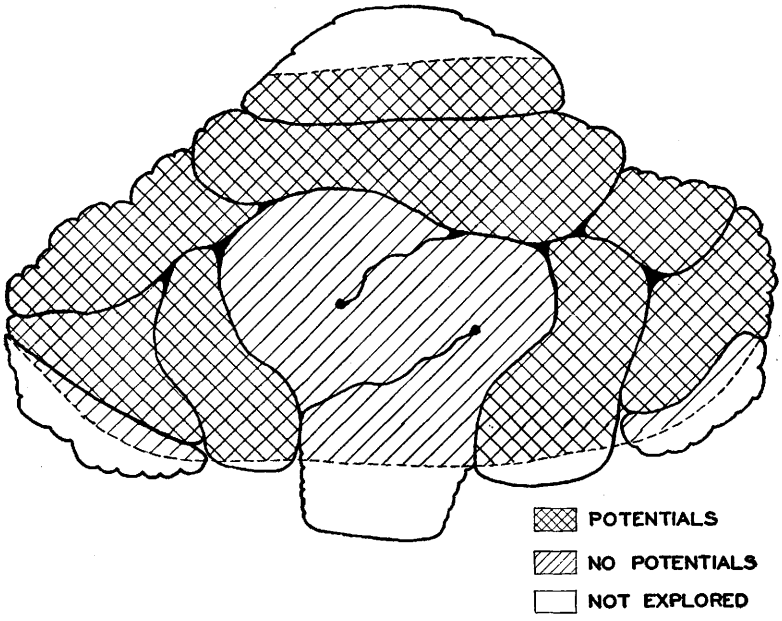

FIG. 2.
Diagram of dorsal view of cat's cerebellum showing regions from which potentials have been obtained as a result of stimulating the cerebral cortex.

pulses from any or all of the areas of the cerebral cortex which were explored.

The application of a small quantity of 0.3% picrotoxin solution to the surface of the pia over a small region exhibiting one of these potentials, radically changed the size and shape of the recorded potential. The initial surface positive wave was immediately followed by a large surface negative wave, giving the response a diphasic appearance. The effect seems to be quite similar to that observed in the cerebral cortex[4] except that it is necessary to use more concentrated solutions in the case of the cerebellum to evoke the response, a fact which may explain why Dow[5] failed to observe "strychnine spikes" in the cerebellum.

Discussion and Conclusions. These results appear to support and extend the ideas of functional localization in the cerebellum[6] as opposed to those of anatomical localization.[7] They indicate that there is no region in the neocerebellar cortex which can be said to be particularly related to any region of the cerebral cortex. Since the cerebellum has come to be known as an organ of synthesis and coordination, it would hardly seem strange (a) that many different functional areas in the cerebral cortex are connected with a single point in the cerebellum, and (b) that a single cerebral cortical point projects to a number of cerebellar foci. This is in good agreement with Dow's work[3] in which he found that stimulation of spinal nerves produced a pattern of potentials in the anterior lobe of the cerebellum which changed very little when nerves from different parts of the body were stimulated.

The fact that most of the individual cerebellar potentials obtained in the present study are very sharply localized perhaps throws some doubt on the concept of mass function of the cerebellum, at least as far as the afferent connections are concerned. The results indicate that a relatively small number of cerebral cortical efferents are capable of exciting a large number of small isolated cerebellar units. Thus it appears probable that a single cortical efferent makes synaptic connections with several cerebellar afferents in the pontine nucleii. The occurrence of multiple potentials over the surface of the cerebellar cortex cannot be due to spread of excitation there, since there is no very appreciable difference in latency between the potentials recorded from the different points which form any one pattern.

The distribution of potentials shown in the map of Fig. 2 is, in

[5] Dow, R. S., *J. Physiol.*, 1938, **94**, 67.

[6] Sherington, C. S., in Schäfer, *Textbook of Physiology*, 1900, **2**, 884.

[7] Bolk, L., *Das Cerebellum der Saugetiere*, 1906, Harlem, Bohn.

general, what one would expect from the known cerebellar afferent connections assuming that all cerebro-cerebellar connections are effected by synapses in the pontine nucleii. Dow,[3] by directly stimulating the pons, obtained potentials not only in all areas from which potentials were recorded in the present work, but also in the declive and tuber vermis, pyramis, and paraflocculus. The fact that no potentials have been obtained from the declive and tuber vermis on cerebral cortical stimulation is interesting in view of the fact that Larsell[1] includes this part of the organ in the neocerebellum. It should be emphasized, however, that one must interpret the absence of potentials with extreme caution.