KOPF CARRIER

April, 1994

PUBLISHED BY DAVID KOPF INSTRUMENTS • TUJUNGA, CALIFORNIA • NO 38

CLARENCE LUTHER HERRICK ON THE ORGANIZATION OF THE MOTOR CORTEX

Duane E. Haines, Ph.D.
Department of Anatomy
The University of Mississippi
Medical Center
Jackson, MS 39216-4505

Dr. Haines received his Ph.D. degree from Michigan State University and has served on the faculty at The Medical College of Virginia and West Virginia University School of Medicine. He is currently Professor and Chairman of Anatomy at The University of Mississippi Medical Center. Dr. Haines can be reached at 601-984-1640.

INTRODUCTION

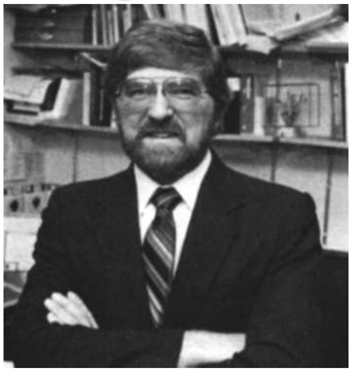
In 1889-90 the young energetic chairman of the Biology Department at the University of Cincinnati was facing a dilemma. He was already recognized nationally for his research in geology (about 24 papers in this area since 1877) and had, in 1885, established a scientific journal that was rapidly gaining an international reputation. However, his new line of scientific endeavor, that being studies on the nervous system of lower vertebrates, was creating a large amount of data for which there was no appropriate avenue for publication. To address this problem Clarence Luther Herrick, solely on his own initiative, founded *The Journal of Comparative Neurology* (JCN) in 1891 (2). Although this journal continues to be one of the most important neuroscience publications in the world, the name of Clarence Luther Herrick and most, if not all, of his rather significant scientific contributions and accomplishments are unknown to many of the present generation of neuroscientists. Yet, by establishing JCN, C, L. Herrick created a focal point for studies on the comparative morphology of the nervous system and, by this single act, established (or at the very least consolidated) the entire field of comparative neurology in the U.S.

Figure 1. Clarence Luther Herrick, ca. 1893 Courtesy, Denison University Archives.

THE MAN

The eldest of four sons, C. L. Herrick (Figure 1) was born on June 22, 1858. He received B.S. (1880), M.S. (1885), and Ph.D. (1898) degrees from the University of Minnesota. He became Professor of Geology and Natural History at Denison University in 1885 and by 1889 he had been appointed to the Chair of Biology at Cincinnati (2). His teaching success was immediate, he attracted the very best students, and he was enormously productive. Although Herrick had trans-

(Continued on page 2, Col. 2)



Editor's Column

WINTER MISSES KANSAS CITY

That might well be the headline in the local newspapers here soon. It is getting on toward March now, and all the big storms that have been hitting the rest of the nation, especially the eastern seaboard and the mid southern states with so much snow and ice, have just passed us by. Not long ago, the weather forcasters here got us all ready for a big ice storm followed by snow, and we had a bit of drizzle and about .001 inches of snow, that was gone in an hour. What a wimp of a winter!

Why am I complaining? Because I like to have some winter in winter. It just seems that if we have to have the gray and cloudy skies and the cold temperatures, we might was well have some snow to go with it. Besides, snow is pretty. I know, some of you who have had 40 inches of snow at one time will say that I can have yours. That just isn't the same. I want our own.

Oh well, I guess I could live in a place like southern California and not ever have any snow. But then, they don't expect it there (I certainly didn't when I lived there). Maybe nature is just taking it easy on us here this winter after having been so nasty to the area with the floods this past summer. In that case, I will try to contain my disgust with Kansas City winters (a sample of one isn't enough to predict from anyway) and wait for a few more to go by before I give up on winter here. In the meantime, I would like to have warm, spring weather if I can't have real winter.

The article in this Carrier is especially interesting. Duane Haines has done a remarkable job of synthesizing the contributions of C.L. Herrick to our field. I hope that you enjoy this bit of history, and hope that we can publish more such work in the future. Let me know what you think.

Michael M. Patterson, Ph.D.
Science Editor
College of Osteopathic Medicine
The University of Health Sciences
2105 Independence Blvd.
Kansas City, MO 64124-2395
816-283-2308
FAX 816-283-2303

lated a small German psychology book into English and published it at his own expense in 1885, his first paper based on his own neurologic work appeared in 1889 (4). These experiments were almost certainly began in late 1886 or early 1887. In December of 1893 Herrick had a massive pulmonary hemorrhage, indicative of tuberculosis, and in early 1894 took the only cure available at that time and moved to New Mexico; he was 35 years old. Even with this dread disease Herrick was relentless in his academic pursuits. He continued to write on neurologic issues, returned to field geology, and in 1897 became the President of the University of New Mexico. His health did not improve and he died on September 15, 1904 (2).

To fully appreciate Herrick's accomplishments it must be kept in mind that he died at 46 years and 3 months of which the last 11 years were spent suffering from tuberculosis. By the time of his death Herrick had published 150 papers (74 on neurologic topics), founded several scientific journals, gained an international reputation in two unrelated scientific fields, and served as a University President.

HERRICK ON THE MOTOR CORTEX

Although Herrick made notable and important scientific contributions, perhaps some of his best, yet possibly least known, are his studies on the topography of the mammalian motor cortex (4-9). In his 1889 paper (his first research paper in neuro) Herrick briefly reviews the general state of knowledge on the histology of the cerebral cortex, and goes on to describe "a series of investigations undertaken in connection with Prof. W. G. Tight" (4). These studies centered on the groundhog while experiments on "rabbits, opossums, and raccoons served for comparison". As we will see, however, the most significant findings were actually on the raccoon. In this short paper Herrick explained that they used electrical stimulation to identify motor cortical areas that served "the fore and hind legs, the muscles of the face and neck" and, in histologic preparations, described the giant cells of the motor cortex (4).

The full blown consideration of the motor cortex appeared in 1890 (5) in a manuscript authored by C. L. Herrick and W. G. Tight. Although somewhat modestly called a "Preliminary Report" this was a detailed paper of 60 printed pages and 19 plates

(Continued on page 3, col.1)

(on 38 additional pages) containing a total of 159 carefully rendered drawings. The animals were the same as noted in the 1889 paper. Herrick and Tight (5) used a truly integrated structural-functional approach. They, 1) stimulated the cortex and recorded the motor responses of body parts, 2) extirpated selected areas based on the results of stimulation experiments and documented what somatomotor dysfunction occurred, and 3) studied the cytoarchitectural characteristics of these cortical areas in hundreds of histologic preparations (5). These authors gave a detailed description of their experimental techniques and mentioned "a method used by us for the first time" to document the exact cortical sites that were stimulated. Immediately upon removal of the electrode "a small pasteboard or wooden peg bearing a number" was inserted into the stimulation site; these were used to accurately map each site and to prepare drawings. The electrical current used to stimulate the cerebral cortex "was from one Grove cell and was just enough to operate the induction coil, producing an irritation easily endured by the tongue" (5).

In the ground hog (Arctomys) Herrick and Tight (5) described separate areas of the cerebral cortex, the stimulation of which resulted in movements of the contralateral fore leg, hind leg, and facial muscles. A lesion placed in the left fore leg area resulted in a partial loss of movement in the right leg (4,5).

In spite of the claim (4,5) that the raccoon (Procyori) studies were supplemental to those of the ground hog, the best documented set of experiments were those conducted on this animal. A large expanse of cortex was exposed and explored with a stimulating electrode (Figure 2). The cruciate sulcus, although not named by Herrick and Tight, is clear on their drawing and essentially identical to that shown in contemporary illustrations (3,10). Those sites at which no motor responses were elicited are indicated by unnumbered ellipsoids (5). The seven sites from which motor responses were elicited are marked by numbered ellipsoids (#l-#7) (5). With the single exception of #2, which is located at the lateral terminus of the cruciate sulcus, all sites from which movements could be elicited were located in the strip of cortex (the posterior cruciate gyr-us) found immediately caudal to the cruciate sulcus.

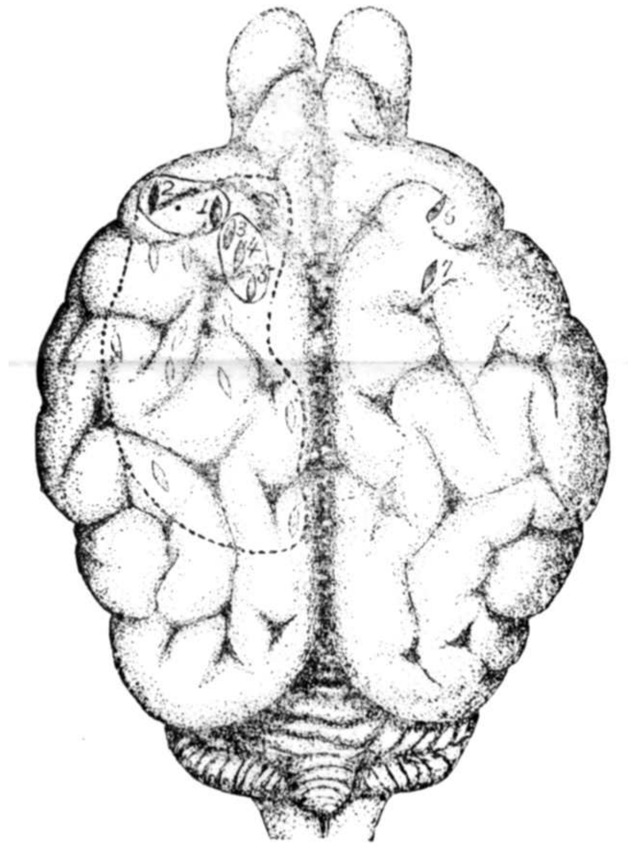


Figure 2. A dorsal view of raccoon brain. The area exposed for stimulation is outlined by the dashed lines. Stimulation of points represented by the unnumbered ellipsoids resulted in no movements. Movements of the extremities were seen when the points indicated by the numbered ellipsoids were stimulated. See text for details. From Herrick and Tight, 1890, courtesy of Denison University Archives

Stimulation at points #1, #2 and #6 (Figure 2) resulted in movements of only the contralateral fore leg; these being a "forward and inward motion" (at #1), an "undefined movement" (at #2), and an elevation and flexion (at #6). Cortical stimulation at points #3, #4, #5 and #7 (Figure 2) resulted in movements of the opposite hind leg. These included "flexion of pes...elevation of right hind leg" (at #3), same as #3 plus slight inward rotation of fore leg (at #4), and extension and fanning of the digits (at #5 and #7). It is especially significant to note

Continued on page 4, col.1

that some of the cortical sites in Herrick and Tights' (5) study, the stimulation of which elicited specific movements, are markedly similar to sites from which essentially the same movement was elicited in contemporary studies (see ref. 3). These include an inward "motion" (rotation) of the fore leg (at#1), movements of the fore leg from the cortex immediately around the lateral end of the cruciate sulcus (at #2), flexion of the fore leg (at#6), and a "divarication" (spreading) of the digits on the hind leg (at #5 and #7).

This study by Herrick and Tight (5) clearly showed that the motor cortex, governing the legs and paws in raccoon, 1) was located immediately caudal to what we now call the cruciate sulcus, 2) was made up of a medial area concerned with the hind leg and an adjacent lateral area related to the fore leg, and 3) when stimulated gave rise to a specific movement of the appropriate extremity. Further evidence of a hind leg area was seen in a "pup" with a lesion in the general area of cortex, the stimulation of which in raccoon had resulted in contralateral leg movement (Figure 3). The authors noted that, in this animal, there was a "slight motor disturbance of the hind leg of the opposite side". Herrick and Tight went on to illustrate large "typical" motor neurons, from numerous histologic preparations, including those "from the area governing [the] sphincters of [the] eye-lids". This latter comment indicates that they had knowledge of a face region of the motor cortex. They also confirmed that all movements and deficits occurred contralateral to the stimulation or lesion.

This 1890 paper was the high point of Her-rick's work on the motor cortex. He later describes, albeit very briefly, the motor area in opossum and illustrates the point with a drawing of the large pyramidal cells of the motor area (6). In another study aimed primarily at elucidating sensory cortical areas, Herrick noted that a large lesion of the cortex in cat resulted in a "decided disturbance of the motor and sensory functions for both limbs" (7).

Herrick revisited his earlier studies in 1898 (9), mainly in response to a paper by Cunning-ham (1). Here he reiterated his earlier comments on raccoon motor cortex and offered some new observations, although they were of little consequence. He did however, give new data regarding the motor area of a kitten by noting medial points that, when stimulated, were "devoted to the hind leg" and lateral sites that related to movements of the fore leg (9).

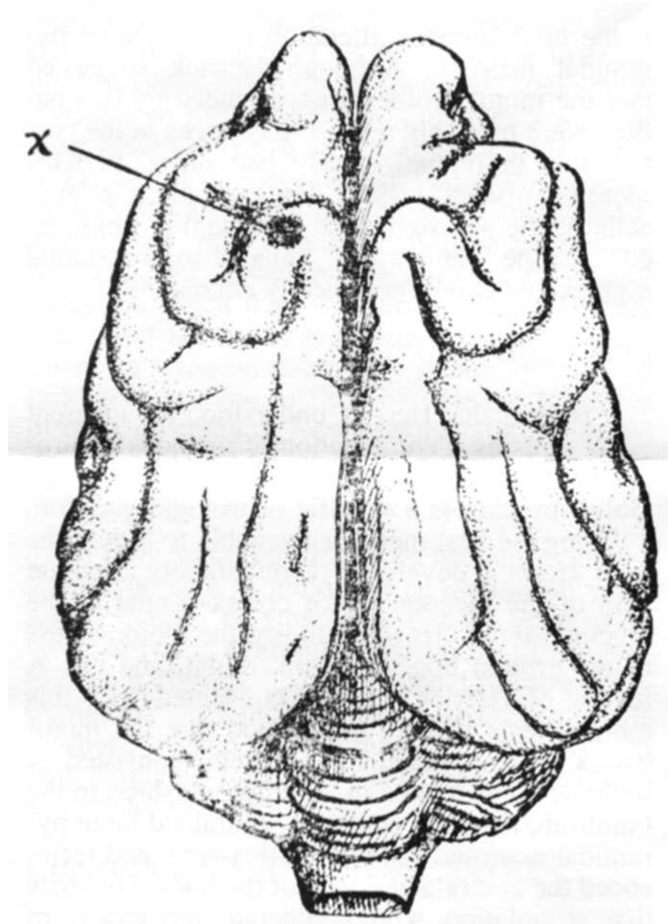


Figure 3. Dorsal view of the brain of "a quarter grown pup." A lesion at "X" (compare with #3, #4 or #5 in Figure 2) resulted in motor deficits in the contralateral hind leg. From Herrick and Tight, 1890, courtesy of Denison University Archives.

The human cerebral cortex was briefly considered by Herrick (8) as part of a detailed histologic study of the brain of a 40 year old male who had died of a myriad of problems. This patient was demented, had a variety of motor and mental problems, and a "speech disturbance". About 1.5 years before his death "he had a sudden epilepti-form seizure with hemiplegia on the right side, -which...lasted for about three weeks". Herrick notes that the sulci were more prominent than one would expect based on the "age of the subject". He also describes, and illustrates, motor cells of the precentral gyrus and notes that an accumulation of a "fatty pigmentary degeneration"

Continued on page 5, col 1

is the most obvious alteration in these large pyramidal neurons. Although Herrick suggested that the motor problems experienced by this patient were probably related to changes in the cortex, this individual clearly had other, perhaps more significant, lesions. For example, the large cells of the striatum were "thoroughly implicated" and the "remarkable" cells of the substantia nigra were "almost completely altered" (8).

EPILOGUE

It is clear that Herrick understood the inherent value of using a combination of methods (neuro-physiologic, extirpation, histologic - Nissl and Golgi) to address a specific neurologic question.

Using the best methods available to him at the time Herrick developed a remarkably accurate map of the raccoon motor cortex caudal to the cruciate sulcus. He also studied the motor cortex of the ground hog, opossum, rabbit, and cat. A review of Herrick's papers concerned with this topic reveals that he understood that the motor cortex was restricted in its extent, consisted of separate areas related in an orderly fashion to the hindlimb, forelimb, and face, contained large pyramidal neurons "typical" of this area, and influenced the contralateral side of the body. He knew that stimulation would generate movement of specific parts of the contralateral extremity and that lesion of the same cortical area would result in comparable deficits of the same extremity. Even though Herrick's studies on the cerebral cortex have rarely been acknowledged or cited, this American neuroscientist conducted innovative experiments and offered new data on the functional organization of the nervous system. His work on the motor cortex was comparable to, or superior to, the best of his scientific peers.

ACKNOWLEDGMENTS:

The author is deeply indebted to Ms. Florence W. Hoffman (Denison University), to Drs. J. I. Johnson (Michigan State) and W. Welker (Wisconsin) and to Ms. Sally Brown (West Virginia University). Ms. Rainer did the typing.

REFERENCES

1. **Cunningham, R. H.** (1898) The cortical motor centers of the opossum, *Didelphys virginiana. J. Physiol*, *22:*264-269.

2. **Haines, D. E.** (1991) The contributors to volume 1 (1891) of *The Journal of Comparative Neurology:* C. L. Herrick, C. H. Turner, H. R. Pemberton, B. G. Wilder, F. W. Langdon, C. J. Herrick, C. von Kupffer, O. S. Strong, T. B. Stowell. *J. Comp. Neurol, 314:*9-33.

3. **Hardin, W. B., Arumugasamy, N.** and **Jameson, H. D.** (1968) Patterns of localization in 'pre-central1 motor cortex of raccoon. *Brain Research, 11:*611-627.

4. **Herrick, C. L.** (1889) A contribution to the histology of the cerebrum. *Cinn. Lancet-Clinic N.S., 23:*325-327.

5. **Herrick, C. L.** and **Tight, W. G.** (1890) The central nervous system of rodents. Preliminary report. *Bull. Sci. Lab. Denison Univ., 5:*35-95 + plates.

6. **Herrick, C. L.** (1892) The cerebrum and olfactories of the opossum, *Didelphys virginica. J. Comp. Neurol, 2:*1-20.

7 **Herrick, C. L.** (1892) Localization in the cat. *J. Comp. Neurol, 2:*190-191.

8. **Herrick, C. L.** (1893) Report upon the pathology of a case of general paralysis. *J. Comp. Neurol, 3:*141-162.

9. **Herrick, C. L.** (1898) The cortical motor centres in lower mammals. *J. Comp. Neurol, 8:*92-98.

10. **Sakai, S. T.** (1982) The thalamic connectivity of the primary motor cortex (MI) in the raccoon. *J. Comp. Neurol, 204:*238-252.