Book Reviews

Discoverer of the Brain Wave

Hans Berger on the Electroencephalogram of Man. The Fourteen Original Reports on the Human Electroencephalogram. Translated from the German and edited by PIERRE GLOOR. Elsevier, New York, 1969. xii + 350 pp., illus. $31.50. Electroencephalography and Clinical Neurophysiology, supplement 28.

Hans Berger, in 1929, was the first to describe the human electroencephalogram, and the volume here reviewed is a translation of the 14 reports he wrote between 1929 and 1938 of his studies of the EEG. Actually Berger's consuming interest in the electrical expressions of brain activity had a much earlier origin, for in 1902 he was already attempting to record from the dog's brain and to measure temperature changes in cerebral cortex in response to a variety of stimuli. Even then Berger appeared to be able to detect the spontaneous rhythms reported earlier by Caton, Beck and Cybulski, and others; but he failed to evoke a specific change in potential through stimulation. Perhaps this failure, together with his keen interest in the psychic manifestations of brain functioning, led him eventually to the realization that the recording of the human EEG might present a more fruitful line of attack. He turned to that approach in 1920 and by 1924 had made a successful recording from a youth with a cranial defect. He soon repeated this success through scalp recordings on other subjects.

Besides these 14 reports of such recordings, together with their bibliographies and illustrations and a detailed index, the volume contains a foreword by Herbert Jasper and an introduction by the translator. The latter includes a brief biography that contributes much to our understanding of this unusual man. Gloor calls attention to the difficulties in translation arising from Berger's use of oblique and often tortuous phraseology, but he has succeeded remarkably well in preserving Berger's style and at the same time avoiding a too cumbersome rendition of the German text. It therefore becomes this reviewer's pleasant task to forego criticism and turn to summarizing for the casual reader the historical significance of Berger's contributions to both bench electroencephalography and behavioral science.

Trained in medicine and neuropsychiatry after a period spent in German military service, Berger became a junior staff member in psychiatry in the University of Jena in 1897. There he remained, except for another military interlude, until his retirement. In the era following the first World War he was appointed head of the department of psychiatry and director of the clinic, positions he continued to hold until 1938. His retirement in that year, though legally correct, was motivated by his unadaptability to the Nazi regime. Thus, shortly after reaching the pinnacle of his productivity and acclaim, Berger was forced into an obscurity which largely deprived him of both the fruits of his past research and the opportunity to continue to develop the rich lode his persistence had opened up. In a state of depression he took his own life in 1941.

We are told that Berger was a shy and reticent man who hid a sensitive and humane personality behind a facade of sternness and self-discipline. His clinic was run with quasi-military discipline, and his colleagues there appraised him as unimaginative and would hardly have classed him as an innovator. During clinic hours he spoke not at all of what interested him most—the human electroencephalogram. That study was conducted during the early evening hours in the seclusion of his research quarters, after the completion of a full day's work. In the after-dinner hours he often dictated his correspondence.

Throughout his life at Jena Berger's contacts with electrophysiology, defined as the study of nerve processes associated with excitation, were tenuous. In 1910 he did receive some assistance from a Dr. Stübel who worked under Professor Biedermann, head of the department of physiology, but he evidently had no contacts with Biedermann himself, who was a foremost electrophysiologist and author of one of the all-time classics concerning excitation processes in nerve.

The EEG studies Berger undertook about 1920 were conducted with a minimum of technical aid. His first subjects were patients with skull defects; later he undertook scalp tracings from subjects with intact crania. He used needle electrodes inserted to the periosteum and alternatively electrodes placed upon the skin. A favorite arrangement connected points high on the forehead and on the back of the head above the inion (Jasper and Carmichael, *Science* **81,** 51 [1935]). In 1924 he used an Edelmann string galvanometer, but changed in 1926 to a Siemens coil galvanometer. Later he used an amplifier-oscillograph.

Although primarily a psychiatrist, Berger was evidently an excellent neurologist and an ardent student of cerebral localization. Knowledge of the latter subject facilitated his EEG studies greatly; and particularly when he identified the site of origin of an epileptic discharge in a case of Jacksonian epilepsy (report 7) as referable to the opposite motor cortical area, he was using that kind of knowledge. He showed for the first time that the large potential oscillations which appeared in his EEG traces represented discharges from the very region from which the records were taken, and preceded in origin the clonic jerks of the opposite extremity. His attention to the exact origin of the potentials he was recording would be commendable even in modern electroencephalography, where sufficient attention is infrequently paid to volume conductor considerations. He also worked systematically to eliminate every biological as well as mechanical source of contamination of his brain potentials, and in the course of his studies assured himself that he could record his rhythms directly from the surface of the human brain as well as through the dura and the thin tissue overlying skull defects. Measured by today's standards, the recording equipment he used to produce his often excellent tracings was appallingly crude, and that he succeeded at all is evidence of his remarkable tenacity. Finally, in the light of today's electroencephalography we can see that he was successful early in recording the 3-per-second domes of the petit mal absences, but without the accompanying spikes.

In estimating the significance of Ber-

ger's work as presented in these reports it is important to consider the related activities of the electrophysiological school, which was by no means idle during the 1930's. No question of priority is involved here, but we would indicate the scientific basis of the healthy skepticism with which his 1929 report was first met, and the change to nearly universal approval as the 1930's progressed.

In America the preceding decade had witnessed a rapid advance in the physiology of nerve resulting from the development of vacuum tube amplifiers and the use of the inertia-less cathode ray oscillograph for recording purposes (Erlanger, Gasser, Bishop). Before 1930 the principal components from which such an amplifier-oscillograph could be constructed had become available commercially and there was a sprinkling of engineers who could design the equipment. In 1929 the last of three kinds of conducted axon spikes of peripheral nerve (the nonmyelinated) was identified, characterized by high threshold, very slow conduction, and long spike duration (Heinbecker, *Proc. Soc. Exp. Biol. Med.* **26**, 350). In the early 1930's attention turned to recording from central tracts leading from the periphery (the dorsal root–dorsal column system and the optic nerve tract). These studies employed the stimulus response techniques of nerve physiology to follow components of the conducted nerve axon potential to the first cell station in the neuraxis and beyond. In time it became relatively easy to identify in animals the slower spontaneous potential components (among them alpha rhythm) and to trace evoked potentials through the maze of spontaneous activity in accord with the expectancy from anatomical knowledge. Synapse time could be estimated by measuring the interval between pre- and post-synaptic conducted spikes. The insurmountable difficulty for the electrophysiologist lay in thinking customarily along the lines of fast axon spikes of peripheral nerve. How could forebrain activity of which they were the sole expression summate to produce spontaneous rhythms with the duration of alpha waves or slower? Only the very slow C fibers of peripheral nerve came even close to satisfying the needs of such summation, but that possibility was considered seriously because it was known from Ramón y Cajal that nonmyelinated axons constituted a large proportion of the forebrain neuropil. Slow cellular and dendritic potentials were still below the horizon; only Forbes, Gerard, and Heinbecker considered them seriously.

Hallowell Davis, recalling the EEG developments at Harvard, the difficulties that presented themselves originally, and how (early in 1933) a conclusion supporting Berger's thesis was reached there, says, "It seemed unthinkable that a slow, regular, 10-per-second rhythm could originate in the brain." Nevertheless Derbyshire, who had uncovered Berger's 1929 report, set to work with a fourth-year medical student, each recording from the other. After two weeks' work they reported that they had found nothing. Davis then suggested that they try him as the subject. Needle electrodes were placed at vertex and occiput, and Davis, sitting in a shielded room, closed his eyes. Clear, rhythmic, 10-per-second activity appeared on the oscilloscope, and Davis believes that this was the first recognition of alpha rhythm as such on this side of the Atlantic. The English workers Adrian and Matthews were able to confirm Berger's studies on lower mammals, monkey, and man, and their publication in 1934 upon confirmation in man materially strengthened Berger's position.

Your reviewer recalls two symposia of this period which indicate the generally high level of work undertaken by American investigators related to Berger's thesis, and they may also be taken as indicative of the extent to which electrophysiological knowledge had also developed in England, France, Germany, and elsewhere. One, the 1936 Cold Spring Harbor Symposium (proceedings, vol. 4), contained articles by Bishop, Davis, Gerard, Hoagland, and Jasper covering aspects of forebrain cortical activity. Davis's continues to have pertinence today, for it states the guiding principles that underlie EEG interpretation more succinctly than does any modern breviary. By 1939 central nervous system recording in experimental animals had progressed markedly, and that progress is reflected in the 1939 symposium of the American Physiological Society, undertaken to honor C. S. Sherrington and published in the *Journal of Neurophysiology* in that year. It includes articles by Bronk, Erlanger, Forbes, Gasser, and Lorente de Nó and had its principal focus upon synaptic conduction, including data on synapse time, electrical versus chemical synaptic transmission, and the detonator concept of synaptic action.

From its inauspicious beginnings in the seclusion of Berger's laboratory, the applications of EEG recording have diversified widely. Particularly after the second World War, with the release of technical developments in electronics, reliable multichannel EEG equipment became widely available, as did the cathode ray recorders, cameras, and other appurtenances fulfilling the many requirements of both the animal and the human laboratory. In fact, engineers played a leading role from the very inception of electroencephalography in the United States, as is exemplified in developments at the Davis laboratory in Boston, which included the evolution of the old Western Electric undulator into the modern multichannel inkwriter.

The parent disciplines from which early students of brain wave recording were drawn included chiefly neurology, psychiatry, physiology, psychology, and engineering. Once opened up by Berger and his immediate followers, knowledge expanded rapidly in technique, instrumentation, and interpretation. Among subjects of special interest have been sleep, Fourier analysis, cross- and autocorrelation leading into more complex aspects of computer programming, and unit and field potentials in freely moving animals recorded under a variety of conditions. In man scalp recording has been used to display the principal sensory evoked potentials by means of averaging techniques, and depth recording to search out epileptogenic foci situated far beneath the cortical surface. In short, besides being utilized in clinical diagnosis of paroxysmal and organic brain disorder, Berger's EEG has become a dependable asset to data analysis in many branches of behavioral science, both human and experimental.

Finally, it is a matter of profound satisfaction that this reticent and unpretentious man, whose work was technically so unprepossessing by comparison with that of his contemporaries in the same field and whose reward in life was so tragically curtailed, has remained posthumously a prestigious figure—the Father of Electroencephalography—to many men of intelligence, virtue, and scientific prowess. Gloor is to be commended for adding to his luster.

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Aid acknowledged from Hallowell Davis and George H. Bishop.