Early History of Electroencephalography and Establishment of the American Clinical Neurophysiology Society

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Summary: The field of electroencephalography (EEG) had its origin with the discovery of recordable electrical potentials from activated nerves and muscles of animals and in the last quarter of the 19th century from the cerebral cortex of animals. By the 1920s, Hans Berger, a neuropsychiatrist from Germany, recorded potentials from the scalp of patients with skull defects and, a few years later, with more sensitive equipment from intact subjects. Concurrently, the introduction of electronic vacuum tube amplification and the cathode ray oscilloscope was made by American physiologists or "axonologists," interested in peripheral nerve recordings. Berger's findings were independently confirmed in early 1934 by Lord Adrian in England and by Hallowell Davis at Harvard, in the United States. In the United States, the earliest contributions to human EEG were made by Hallowell Davis, Herbert H. Jasper, Frederic A. Gibbs, William Lennox, and Alfred L. Loomis. Remarkable progress in the development of EEG as a useful clinical tool followed the 1935 report by the Harvard group on the electrographic and clinical correlations in patients with absence (petit mal) seizures and altered states of consciousness. Technical aspects of the EEG and additional clinical EEG correlations were elucidated by the above investigators and a number of others. Further study led to gatherings of the EEG pioneers at Loomis' laboratory in New York (1935–1939), Regional EEG society formation, and the American Clinical Neurophysiology Society in 1946.

Key Words: History of EEG, Evoked potentials, Hans Berger, Edgar Adrian, Hallowell Davis, Herbert Jasper.

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The discovery of electroencephalography (EEG) and evoked potentials (EPs) in animals was stimulated by European advances in cerebral cortical localization, resulting from ablation and stimulation studies. In search of a new tool for cortical localization of sensory functions, Richard Caton (1842–1926), a Liverpool physician and physiologist, deduced that, because peripheral nerve activity was accompanied by a recordable change in electrical potential, a similar phenomena might be occurring in the brain (as reviewed in Brazier, 1988; Schoenberg, 1974). Perhaps, he was influenced by recent verification of the light evoked electroretinogram in animals (referenced in Granit, 1947). In 1875, Caton reported visual evoked electrical current variations and spontaneous current variations (EEG) from the exposed cortical surface of rabbits and monkeys, using a Thomson reflecting galvanometer image projected on a wall (cited in Grass, 1984). Two years later, he reported that a feebler current could be recorded from the scalp as well (as reviewed in Brazier, 1984, 1988; Caton, 1875, 1877). In 1890, Caton's findings were confirmed and extended in rabbits and dogs by the Polish physiologists, Beck and Cybulski, who used a modified galvanometer observed through a telescope (Brazier, 1988). They also noted desynchronization or blocking of spontaneous activity by stimulation of the animal (as reviewed in Brazier, 1988; cited in Collura, 1993). In 1912, the first photographic picture of the EEG and EP appeared in the literature (Goldensohn et al., 1997), from Pravdich-Neminsky, a Ukrainian who used an Einthoven string galvanometer in the dog (Brazier, 1961). Cybulski, 2 years later, published a photograph of a cortical EEG tracing depicting an epileptic seizure in a dog produced by electrical stimulation (as reviewed in Brazier, 1961; cited in Collura, 1993; cited in Goldensohn et al., 1997).

In 1931 Oskar Vogt (1870–1959), a well-known neuroanatomist and neuropathologist, with support of the Rockefeller Foundation, organized and opened a large multidisciplinary, clinical and research facility known as the Kaiser-Wilhelm Institute of Brain Research in the Berlin suburb of Buch (Berlin-Buch) (as reviewed in Haymaker, 1970; as reviewed in Jung, 1975; cited in Klatzo, 2002). A neurophysiology section was established that included the exceptionally talented physicist and electrical engineer–Jan F. Tonnies (1902–1970). Tonnies had worked for the instrument maker, Siemens, and independently developed a differential amplifier and the first ink-writing electroencephalograph in 1932, followed by a five-channel ink-writing unit in 1935 (as reviewed in Jung, 1975; as reviewed in Niedermeyer, 2005; as reviewed in O'Leary and Goldring, 1976). This equipment was used by A. S. Kornmuller (1932, 1933) in animals and later in man to investigate the scalp and cortical surface [electrocorticogram (ECoG)] EEG correlates of Vogt's cortical architectonic zones (cited in Davis and Davis, 1936) and by MH Fischer (1932) in animals to study the spontaneous ECoG and effect of visual EPs upon the occipital striate ECoG. By 1933, the Berlin-Buch neurophysiologists had recorded ECoG seizure discharges in animals after the administration of convulsive substances (Fischer, 1933; Fischer and Lowenbach, 1934; Kornmuller, 1935; as reviewed in Niedermeyer, 2005; cited in Swartz and Goldensohn, 1998). Fischer made mention of the work of Hans Berger in the human and added that his "findings were of considerable interest" (cited in Adrian, 1971; Fischer, 1932).

Hans Berger (1873-1941) (Figs. 1A and 1B), a neuropsychiatrist interested in cerebral metabolism worked in relative isolation at the University of Jena near Berlin, Germany. At the age of 18 years on maneuvers with the German army, Berger had a near fatal accident and, at the same time, hundreds of miles away, his sister told their father that Hans was in grave danger and the father sent him a telegram. Berger then became a firm believer in psychic phenomena or telepathy, providing his great motivation to record from the human brain. Using a capillary electrometer in 1902, he detected the EEG from the cortical

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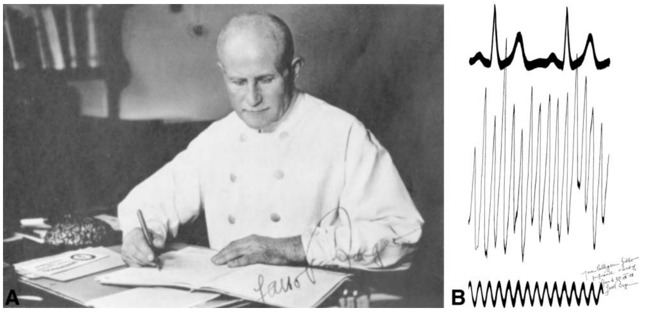

FIG. 1. **A**, Hans Berger. **B**, EEG tracing presented "To my colleagues the Gibbses with warm regards, Hans Berger, 8/25/1938." Simultaneous EKG tracing at top, EEG middle, and 0.10-second marker at bottom. (Courtesy of Frederic A. Gibbs to John R. Hughes.)

surface of the dog, as had others before him. Several years later, using a string galvanometer and a photographic method, he had only very limited success. Berger persevered because he believed that psychic function in the human would be expected to release metabolic energy in the form of localized heat and electrical currents, leading to an increased understanding of normal and disturbed mental processes. He performed elaborate brain surface temperature and pulsatility studies from animals and man with inconclusive results (as reviewed in Gloor, 1969a; as reviewed in Millett, 2001).

In 1924, Berger began to record from human subjects with skull defects and obtained positive but inconsistent results with a larger Edelmann string galvanometer (sensitivity 1 mV/cm). In 1926, he procured a more sensitive Siemens double-coil galvanometer (sensitivity of 130 μV/cm), which allowed the use of low impedance surface electrodes (cited in Grass, 1984). Berger (1929) experimented with many different surface and epidural needle electrodes in skull defect patients. His results in patients and subjects without skull defects consistently improved, especially in bald males. He published the first report of the human EEG in 1929 and described the term "alpha waves" and "beta waves" and the abolishment of alpha with the eyes open (as reviewed in Gloor, 1969a; as reviewed in Brazier, 1968). The following year, Berger performed the first human ECoG recordings and recordings from the adjacent white matter, in a patient undergoing surgery for a brain tumor (as reviewed in Gloor, 1969a, 1969b; as reviewed in Jung, 1975). He also noted that the EEG of infants and young children differed from that of adults. His preferred montage for scalp recording was the bipolar linkage of forehead to midoccipital, and he never had access to an ink-writing machine. He had at most the above two separate channel galvanometers, and in 1931, the Edelman string instrument was fitted with a Siemens amplifier. Only in his later years did he elicit the help of an electrical engineer. Many of Berger's reports included extensive controls, proving that the recorded EEG was not artifact, such as EKG or muscle, and truly represented cerebral cortical activity. Nevertheless, his numerous contributions to both technical and experimental aspects of EEG were very substantial (referenced in Collura, 1993; as reviewed in Gloor, 1969a).

The nearby Berlin-Buch neurophysiology group, who likely possessed the finest recording instrumentation in the world, considered Berger a misguided, nonphysiologist with limited technical knowledge and support. Kornmuller, in particular, believed Berger's nonlocalized recording of the cerebral cortex as a whole was futile and the alpha rhythm did not exist (as reviewed in Jung, 1975; cited in Hughes and Stone, 1990; reviewed in O'Leary and Goldring, 1976). Others believed the blocking of a prominent rhythm with stimulation was contrary to existing theories of brain function (cited in Schwab, 1951). Berger worked in relative seclusion in a room in his clinic, perhaps in fear that his work would be stolen by the aggressive Berlin-Buch group. Several family members, loyal clinic employees, and later neuropsychiatry residents were used as volunteers or assistants (referenced in Ginzberg, 1949; reviewed in Gloor, 1969a; cited in Lemke, 1956; as reviewed in Jung, 1975).

Berger's articles were written in a difficult style and published in a psychiatric and not a physiological journal, likely accounting for the 5-year period before his work was confirmed. Berger published over 20 reports on the electroencephalogram, a term he introduced in 1929. Berger never obtained a satisfactory recording of a generalized tonic-clonic seizure with loss of consciousness but noted flattening of the record following the episode. However, a focal motor seizure was captured, and by 1930, he observed that "absence attacks" were associated with high voltage regular 3/s waves but did not record a spike component (as reviewed in O'Leary and Goldring, 1976; as reviewed in Gloor, 1969a). Berger was also the first to describe interictal, paroxysmal sharp waves and believed they indicated a predisposition to seizures. However, he was uncertain if they were epileptic potentials or artifact in that myoclonic face twitching was observed during the seizures (as reviewed in Gloor, 1969a, 1969b). Berger published these findings in 1933 when his questions about artifacts was lessened after the Berlin-Buch group described similar convulsive potentials in strychnine- and picrotoxin-treated animals (as reviewed in Jung, 1975). Forced by the Nazi regime to discontinue his EEG research in 1935, he continued to publish from his notes and earlier recordings (cited in Hughes and Stone, 1990; cited in Schwab, 1951). Fortunately, Berger lived to see his EEG work confirmed and internationally acclaimed in the later 1930s but he became despondent, resulting in suicide in 1941 (cited in Gibbs, 1970; as reviewed in Gloor, 1969a; cited in Hughes and Sundaram, 1987; cited in Lemke, 1956).

The noted neurophysiologist E. D. Adrian (1889–1977), who had shared the 1932 Nobel Prize in Medicine or Physiology with fellow Englishman, Charles Sherrington (1857–1952) (Fig. 2),

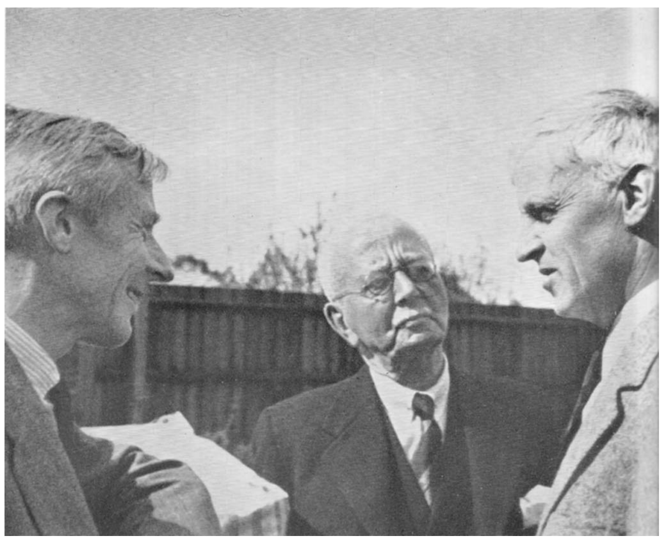

FIG. 2. E. D. Adrian, C. S. Sherrington, and A. Forbes (left to right), 1938.

became aware of Berger's EEG work in late 1933 after finding several Berlin-Buch references in German (cited in Adrian, 1971). Adrian's engineer, Brian Matthews, had earlier developed an electromagnetic ink-writing electrocardiograph (about 1926), which made use of a three-stage capacity-coupled amplifier (cited in Grass, 1984). By this time, Matthews had independently designed the differential input amplifier (referenced in Collura, 1993; cited in Grass, 1984). Consequently, in early 1934, they were able to record the EEG and confirm Berger's observations, including the alpha rhythm and the blocking effect because of eye opening. (Adrian, 1934; cited in Adrian, 1971). More volunteers were studied, and the majority showed some sign of the alpha rhythm and blocking by eye opening. After initial skepticism, the Cambridge group came to believe in its cortical origin. Adrian and Matthews (1934) also performed ECoG recordings from the cortical surface during neurosurgical procedures.

On May 12, 1934, Adrian and Matthews demonstrated their EEG findings at a meeting of the Physiological Society in Cambridge, England, and gave full credit to Hans Berger for this discovery (Adrian, 1934; cited in Adrian, 1971). In contrast to Berger's belief, Adrian was initially convinced that the alpha rhythm and EEG was largely an occipital phenomena, secondary to visually related neurons with a tendency to rhythmical beating (Adrian, 1934). However, a few years later, by the use of multiple, differential recording channels, Adrian would add to the early understanding of the spatial and temporal relationships and neuronal physiology responsible for the EEG (referenced in Collura, 1993). W. Grey Walter (1910–1977), an English psychologist who had worked with Adrian and Matthews, is usually considered the founder of clinical EEG in England. Walter (1936, 1937), stimulated by the London-trained neuropsychiatrist Frederick L. Golla (1878–1968), described delta slow waves in 1936 and their utility in localizing brain tumors and also described EEG findings in epilepsy (Golla et al., 1937; cited in Cobb, 1971; cited in Walter, 1953). In addition to Berger, Kornmuller, and Adrian, pioneering European ECoG recordings during human surgical procedures were also performed in early 1934 by Tonnies and Jung (cited in Jung, 1975) and reported thereafter by others (Foerster and Altenburger, 1935; Walter, 1936). However, in England, clinical neurology was particularly slow to accept EEG as a useful clinical tool and relegated its usage to Ph.D. psychologists (as reviewed in Niedermeyer, 2005).

Over the next several years, other European countries followed Adrian in confirming Berger's work, such as Italy, France, Belgium, and Romania, and developed further interest in EEG (Durup and Fessard, 1936; cited in Cobb, 1971; referenced in Fessard, 1959; Gozzano, 1935). Because of rising unrest and instability in much of Europe after the mid-1930s, several investigators, such as W. T. Liberson and H. Lowenbach, emigrated to the United States to continue their contributions to the field of EEG (Liberson, 1936; Fischer and Lowenbach, 1934; as reviewed in Niedermeyer, 2005).

AMERICAN DEVELOPMENTS

In the first and second decades of the 20th century, nearly a dozen American investigators designed and constructed their own amplifying and recording equipment to study muscle and nerve physiology. Most of these World War I era researchers were physician-physiologists who visited and were strongly influenced by the British "schools of neurophysiology." The major British school was that of Sir Charles Sherrington at Liverpool and later at Oxford, who emphasized cortical localization studies in primates, motor function control and feedback, and the hierarchical nature of central integrative brain and spinal cord reflexes (Sherrington, 1906). The other major school was at Cambridge where Keith Lucas (1879–1916) and his prodigious student Edgar D. Adrian advanced electrically oriented nerve, muscle, and later sensory organ and cortical electrophysiology (as cited in Adrian, 1972; as reviewed in Clarke and O'Malley, 1996; cited in Hearnshaw, 1964; cited in Shepherd, 2010).

The American investigators who initially worked with electrical studies in peripheral nerve called themselves "axonologists" and frequently met informally as guests at the home of a local colleague during yearly meetings of the American Physiological Society (APS) between 1929 and 1942. They were also labeled the "Needlework Society" in that they often used fine sewing needles for electrical nerve stimulation or recording. Their gatherings prompted honest, cooperative, and lively discussion, important for open dissemination of experiences and information among American neurophysiologists with common interests. Patterned after the Physiological Society in London, significant developments in neurophysiology were typically presented at APS meetings and published in the American Journal of Physiology (cited in Fenn, 1963; as reviewed in Marshall, 1983; as cited in Marshall and Magoun, 1998; as reviewed in O'Leary and Goldring, 1976).

Those axonologists who would later contribute significantly to American developments in EEG included Alexander Forbes (1882–1965) and Hallowell Davis (1896–1992) of the Harvard Medical School (HMS) in Boston; Joseph Erlanger (1874–1965), Herbert S. Gasser (1888–1963), George H. Bishop (1889–1973), and James L. O'Leary (1904–1985) of Washington University in St. Louis; Ralph W. Gerard (1900–1974) at the University of Chicago and University of Illinois; and Detlev W. Bronk (1897–1975), a biophysicist at the University of Pennsylvania and Johns Hopkins in Baltimore. The group of American EEG pioneers includes Lee E. Travis (1896–1987), an experimental psychologist at the University of Iowa, and Alfred L. Loomis (1887–1975), an independent physicist who worked near New York city (cited in Fenn, 1963; as reviewed in Marshall, 1983; as reviewed in O'Leary and Goldring, 1976).

The most well-known American neurophysiologist from this era was Alexander Forbes (Fig. 2) who was responsible for the development of modern neurophysiology at the HMS in Boston. Following his M.D. degree in 1910, he spent nearly 2 years with Sherrington at Liverpool, studying central nervous system reflex excitation and reciprocal inhibition. He next studied muscle and nerve excitability from a visit to Cambridge where he was introduced to the string galvanometer by Lucas. Forbes brought a string galvanometer back to Boston and was likely the first to skillfully use such an instrument in America to perform electrical recordings of peripheral nerve, muscle, and central reflex phenomena (as reviewed in Eccles, 1970). Forbes was strongly influenced by many additional visits to Adrian and Sherrington over the next 3–4 decades. In 1918, with neuropsychiatrist Donald J. MacPherson (1889–1977), Forbes' laboratory obtained the first photographic recordings of 10/s spontaneous electrical activity (EEG) in America from the exposed cerebral cortex of the cat, although, at that time, Forbes believed it was artifact secondary to tremors from a nearby construction site (cited in Davis, 1965; cited in Fenn, 1969; cited in Goldensohn, 1998; cited in Schwab, 1951). We have been unable to locate a published report of the experiment.

When working with the radio compass in World War I, Forbes came to understand that the vacuum tube could be used to amplify radio signals. Forbes and Thatcher (1920) established a new "electronic era" in electrophysiology by using electronic (vacuum tube) condenser-coupled equipment to amplify the nerve impulse. This impulse was displayed by a string galvanometer from which permanent records could be made, and Forbes was the first to use this tool in a physiological experiment. Next, Forbes extensively worked with Adrian, establishing electronic amplification methodologies at the Cambridge laboratory (Adrian and Forbes, 1922; as reviewed in Bradley and Tansey, 1996).

Over the following decades, Forbes went on to describe the effects of anesthetic agents on spontaneous and evoked brain electrical activity (Forbes et al., 1935) and embrace the then controversial theory of combined electrochemical synaptic transmission. Later, he studied spinal cord neurophysiology with his brilliant graduate student, Birdsey Renshaw (1911–1948), who with their microelecrode recordings on single brain cells helped to establish the synaptic origin of the EEG (cited in Davis, 1965; cited in Fenn, 1969; referenced in Fessard, 1959; Forbes et al., 1937; Forbes and Grass, 1937; cited in Goldensohn, 1998; Renshaw et al., 1938, 1940). Forbes had a complete understanding of both Sherrington and Cambridge schools, producing a unique neurophysiological insight and clarity. He reasoned that the central nervous system was composed of elements that likely had the same general properties as the peripheral nervous system and the differences rested in our ignorance of the facts at that time (reviewed in Eccles, 1970). His insights on brain function hinted at the theoretical and philosophical–cybernetic and computational modeling, movements that would be taken up by future experimental neurophysiologists (as reviewed in Cobb, 1965; as reviewed in Eccles, 1970; as reviewed in Fenn, 1969).

During the era when a string galvanometer was used as the recorder of amplified electrical signals from peripheral nerve, a particularly vexing problem existed. The delicate silver- or gold-coated quartz strings of the instrument often broke because of the force of the signal it received. In addition, because of damping secondary to the string's mass, the galvanometer had difficulty capturing the very minute and brief changes in electrical potential and, also, the faster oscillations or frequencies. Consequently, the accurate study of recorded electrical potentials from nerves was significantly limited (cited in Collura, 1993; cited in Grass, 1984; as reviewed in O'Leary and Goldring, 1976).

This latter problem was solved in 1921 by the ingenious use of Braun's cathode ray oscilloscope (CRO) by Joseph Erlanger and Herbert S. Gasser at Washington University in St. Louis. By use of the Braun vacuum tube, the moving part in such a tube is the inertialess electron beam, which is deflected by the action of the amplified potential derived from nerves and would appear on the fluorescent screen as an illuminated spot of light that could be photographed as well. Because the mass of the electron beam was negligible, the CRO gave the first accurate measurements of nerve action potential duration and refractory periods (Gasser and Erlanger, 1921). The output of the signal could also be fed into a loudspeaker. These investigators were also then able to accurately demonstrate that a peripheral nerve is made up of different kinds of fibers with various conduction velocities (Erlanger and Gasser, 1924). For their accomplishments, Erlanger and Gasser were awarded the Nobel Prize in 1944 (as reviewed in Clarke and O'Malley, 1996). The earlier CRO units had a lower sensitivity and were unsuitable for EEG, largely because of poor visibility of the spot usually requiring repetitive phenomena like EPs with superimposed traces to obtain a reasonable photographic record (cited in Davis, 1991). The CRO replaced the earlier galvanometers of mercury electrometer or string type but were not commercially available until the early 1930s.

MIDWESTERN ANIMAL RESEARCH

S. Howard Bartley (1901–1988), a graduate psychology student at the University of Kansas in 1930, used electronic amplification and a string galvanometer to record the slower frequency brain waves from the exposed cortex of the dog (Bartley, 1932; Bartley and Newman, 1930, 1931). Bartley had obtained critical advice from the experimental psychologist Lee Travis at Iowa, who since 1927 had been studying electromyographic reflex times in humans and animals with transformer-coupled input and output amplifiers and a high-frequency Westinghouse oscillograph recorder (cited in Lindsley, 1969). Bartley moved to St. Louis to work with George H. Bishop, where they used a newly modified CRO (as reviewed in Niedermeyer, 2005; as reviewed in O'Leary and Goldring, 1976). Studies on the rabbit and cat were concerned with interaction of visual EPs with the spontaneous intrinsic cortical rhythm, and later work with O'Leary was concerned with the geniculate relay pathways and included cellular recordings from specific striate cortical layers (Bartley and Bishop, 1933; Bishop and O'Leary, 1936; O'Leary and Bishop, 1936).

In 1930, Travis reported cortical potentials from the dog and rat using the higher frequency transformer-coupled amplifier and mirror galvanometer, which showed variation of the high frequency background with sensory and reflex excitation, but the slower activity was not well recorded (cited in Lindsley, 1969; Travis and Herren 1930, 1931; Travis and Dorsey, 1931). Travis was initially interested in electrical brain wave activity as he believed it might relate to higher level reflex activity and the problem of stuttering (cited in Lindsley, 1969; as reviewed in O'Leary and Goldring, 1976). Travis was one of the earliest Americans to obtain EEG equipment for human recordings (Travis and Knott, 1936) and provided graduate training to four prominent American electroencephalographers: Herbert Jasper, Donald Lindsley, John Knott, and Charles Henry (see below).

Ralph Gerard of Chicago, a noted axonologist, who had studied nerve and muscle metabolism with European Nobel laureates A. V. Hill and O. Myerhoff, was one of the most talented and perhaps most diversified of the American neurophysiologists. By 1930–1931, Gerard had a CRO and three stage resistance-capacity-coupled amplifier designed and built by Wade H. Marshall (1907–1972). They began some of the earliest unicellar or unit brain recording studies in animals, using fine Adrian-Bronk concentric needle electrodes manipulated by a Horsley-Clark stereotactic instrument. The signal was fed to the CRO and a loud speaker. The group explored the entire cat brain, distinguishing spontaneous activity from EPs (visual, auditory, and tactile), terms they introduced to neuroscience (Gerard, 1936; Gerard et al., 1933, 1936; cited in Magoun, 2003; as reviewed in O'Leary and Goldring, 1976). They also described evoked responses detected in unexpected places, such as the cerebellum and hippocampus (cited in Gerard, 1975). Gerard was joined by the innovative engineer, Franklin Offner (1911–1999), who developed the high-speed piezoelectric ink-writer (Offner and Gerard, 1936). Gerard's group also used the technique to identify the anoxic susceptibility of certain brain areas, such as the hippocampus (Sugar and Gerard, 1938).

THE NEW ENGLAND GROUP: DAVIS, JASPER, GIBBS, AND LINDSLEY

Hallowell Davis (1896-–1992) (Fig. 3) obtained his M.D. degree from the HMS in 1922 and, after 1 year of neurophysiological study in Cambridge under Adrian, joined Forbes back at Harvard in studies on muscle and nerve physiology. By the middle to late 1920s, Hallowell Davis had become an active member of the APS, and his advice was frequently sought by younger neurophysiologists who visited his Boston laboratory and university teaching sessions and informally gathered at his home in the "axonology" tradition

FIG. 3. Hallowell Davis circa early 1930s. (Courtesy of Hallowell Davis to John R. Hughes.)

(cited in Davis, 1975). In 1929, Davis was appointed by the Chairman of Harvard's Physiology Department, Walter B. Cannon (1871–1945), to organize the highly successful scientific sessions for the 1929 International Physiological Sciences Congress in Boston (cited in Fulton, 1946).

In 1929–1930, Forbes and Davis became attracted to the electrophysiological study of the auditory system, and in 1931, Davis took charge of an expanded neurophysiology laboratory, as Forbes devoted more time to outside interests. Davis assembled an up-to-date electroacoustic installation with amplifiers, sound-generating equipment, and a sound insulated animal room. The HMS Physiology Department engineer, E. Lovett Garceau (1906–1966), installed the amplifiers and their first CRO (Garceau and Davis, 1934; cited in Lindsley, 1969). Subsequently, several graduate students assisted Davis in the invasive recording of auditory evoked cochlear, brainstem, and cerebral potentials in cats (Davis and Saul, 1931; Saul and Davis, 1932, 1933). Localized unit recordings were performed with a straight silver wire, insulated except at the tip or the recently introduced Adrian-Bronk electrode (Adrian and Bronk, 1929). Central nervous system visual and somatosensory EPs were also recorded, in addition to spontaneous activity from subcortical nuclei in the cat (Saul and Davis, 1933). With the cooperation of neurosurgeons Harvey Cushing and Tracy Putnam in 1932–1933, they also recorded auditory, visual, and somatosensory EPs in human beings (Saul and Davis, 1933). Similiarly, Gerard et al. (1934, 1936) in Chicago, working with neurosurgeon Percival Bailey and neurologist Theodore Case, had recorded cortical EPs from neurosurgical patients operated under local anesthesia, but, as typical for that period, electrical interference in the operating room prevented adequate study.

In addition to auditory evoked cochlear and auditory nerve EPs, Davis' team observed the electrical activity of the cat cortex beginning in 1932 (as reviewed in Davis, 1976). In July 1933, the team observed a spontaneous 10/s cortical rhythm that was not affected by such auditory stimuli (cited in Davis and Davis, 1940). Davis recognized the shortcomings of the CRO, without memory capability and with photographic problems, which did not easily give "on-line" information, especially for spontaneous, nonrepetitive activity. Thus, Davis decided that an ink-written trace was essential to better determine the nature of these biologic potentials. By the Fall of 1933, plans were made for Garceau to construct an ink-writing ocillograph for use in the laboratory (cited in Davis, 1975; cited in Davis and Davis, 1940; Garceau and Davis, 1935; cited in Grass, 1984; as reviewed in Zottoli, 2001). Lindsley (1969) stated that "so fixed was the idea that the only electrical activities that could occur in nervous tissue were spike potentials," the first American article that clearly described central nervous system slow potentials was that of Gasser and Graham (1933) who recorded slow waves from the spinal cord. Gasser and Graham (1933) stated: "all … are in agreement … that the waves in question are long potential changes rather than a summation of shorter ones." This was also the first publication outside of Europe to mention the work of Berger (cited in Lindsley, 1969).

In late 1933, before the Harvard CRO ink-writing apparatus was built, Davis became aware of Hans Berger's first article on the human EEG (Berger, 1929; cited in Davis, 1975, 1991). He believed that the article may have been brought to his attention by Arthur J. (Bill) Derbyshire, his first Ph.D. graduate student, or Howard N. Simpson, a medical student in the laboratory with Derbyshire, although both later claimed Davis had told them about it (cited in Davis, 1991; as reviewed in O'Leary and Goldring, 1976). Both Davis and Forbes with their knowledge of peripheral nerve and auditory pathway potentials thought that Berger's alpha rhythm was "undoubtedly artifact." They considered it unlikely that enough axons in the brain could be synchronized to yield such a slow, regular 10/s rhythm and also to be recorded without a skull trephination (cited in Davis, 1975). However, Davis agreed that their recording equipment was sensitive enough, could pass a frequency of 10/s with only moderate attenuation, and allowed them to try (cited in Davis, 1975). Davis and Davis (1940) stated: "In January 1934 … Derbyshire and Simpson failed in their attempt to record the Berger rhythm using needle electrodes in the scalp….." As Davis later related: "About three weeks later Bill and Howard (who had been working on this in their evenings) came to my office again, looking a bit sheepish. 'You are right, chief', said Bill. 'We have stuck needles in each other's scalps (vertex and occipital). The base line is unsteady, but we can't see anything like the 10/sec rhythm on the scope. But come and see if we are doing it right before we say anything about it'. I went with them to the lab and Bill stuck needles into Howard's scalp. Howard sat in the shielded room and closed his eyes. The spot wobbled unsteadily across the scope. That's what I thought, I said, but three heads are better than two. Put the electrodes on my head. They did, and I sat in the room and closed my eyes. Immediately there were shouts outside: There it is! There it is! It was indeed the Berger rhythm. It seems that I have very strong alpha waves. Bill's and Howard's are weaker, and they were excited, anxious, and perhaps more uncomfortable than I was. Other members of our staff volunteered and they were divided about evenly into 'Bergers' (Davis, Cannon, Lindsley), and 'non-Bergers' (Derbyshire, Simpson, Forbes, Pauline Davis). We were convinced Berger was right. It was some time later that we learned that Adrian had already confirmed him; but at least my alpha rhythm was the first to be recognized as such in the Western Hemisphere. I also soon realized that we were probably watching a new slow potential of neural origin." (cited in Davis, 1975). Davis' group went on to verify a number of Berger's EEG observations such as blocking of the alpha rhythm with eye opening or mental activity such as performing calculations, etc. One of the authors (J. R. H.) had the opportunity to discuss the details of this history with Bill Derbyshire in the home of J. R. H. in 1964.

In early June 1934, Adrian came to the United States to address the American Neurological Association in Atlantic City, NJ (Adrian, 1934). He described recent cortical recordings in animals and the disruption of the animal's spontaneous cortical rhythms by sensory stimulation. Adrian next disclosed that he and Matthews had confirmed the 10/s brain waves (Berger rhythm) on humans, as reported by Berger in 1929. They also noted the occipital rhythm's ability to increase its rate to that of a flickering visual beam (photic driving), up to rates of 25/s (Adrian, 1934). In the published discussion that followed the article, Donald MacPherson of Boston, who years earlier photographed the animal EEG, asked: "Has Dr. Adrian tried making visual images, and if so, could the images derived from an imaginary source have an effect like that produced by allowing images to come in through the eye? Answer: No. We have tried to abolish the rhythm by visual imagery, but neither Matthews nor I can do so. The mind's eye, so to speak, is not concerned with the effect. The phenomenon seems to be very much on the material side." J. D. Dusser de Barenne, a Dutch neurophysiolgist working at Yale, commented that recent work on the monkey showed the presence of slow waves after the superficial cortical layers were eradicated by thermocoagulation (Dusser de Barenne and McCulloch, 1936). In addition present was Ernst Spiegel of Philadelphia, a German émigré who several months earlier had published reference to the work of Berger and the Berlin-Buch group (Spiegel, 1934). It was the same Dr. Spiegel whose thalamotomy operation was attended by one of the authors (J. R. H.) in 1948.

Back in Boston, Garceau took about 6 months to develop America's first ink-writing oscillograph–one pen and a 5/8-in. wide tape. Garceau had obtained a single-channel Western Union Morse code "undulator," designed to graphically record the very slow telegraphic signals from transatlantic cables. He substituted stronger magnets and stiffer springs and "forced its natural period to be above 20/sec. Damping was provided by the friction of the pen on the tape. Crude and nonlinear, but effective, it was the ancestor of the (clinical) EEG inkwriters later developed by Albert Grass, Franklin Offner, and many others…" (cited in Davis, 1975). By June 1934, the ink-recorder was at work in the animal laboratory at the HMS (Fig. 4A), and on July 12, 1934, the first record of a human EEG in the United States made on an ink-writer came from the head of Hallowell Davis (cited in Davis, 1975; cited in Davis and Davis, 1940). Previous to the ink-writer, the HMS group had used photographic capture from the CRO (Fig. 4A) (cited in Lindsley, 1969). The HMS group was also known to have an optical instrument as well (cited in Hughes and Stone, 1990).

Herbert H. Jasper (1906–1999) (Fig. 5A), who obtained his Ph.D. in 1931 with Travis at Iowa, had met Davis at APS meetings and, also, had contact with Bartley, Bishop, Gasser, and Erlanger in St. Louis. Jasper subsequently obtained a fellowship to study neurophysiology in Paris under A. Monnier on the crustacean neuromuscular system. During his time in Europe, Jasper met Adrian and a number of other neurophysiologists. While in Paris in 1932, Jasper recalled that Berger's work was skeptically discussed (cited in Jasper, 1969). In the fall of 1933, Jasper returned from research with L. Lapique in Paris to Providence, RI, to work with psychologist Leonard Carmichael at Brown University. He established a neurophysiological laboratory at Bradley Hospital, supported by the Rockefeller Foundation (cited in Jasper, 1969).

About this time, Jasper sought information from a German psychiatrist, William Malamud, from the University of Iowa, who was in Boston where Jasper visited him to discuss Berger's work and also to obtain English translations (cited in Jasper, 1996). Jasper also consulted with Hallowell Davis in Boston in the fall of 1933 over technical issues related to cortical recordings (cited in Davis and Davis, 1940). Davis shared his observations and opinions with Jasper regarding their laboratory results in obtaining slow spontaneous activity directly from the cerebral cortex of the cat. Jasper then asked Davis if it was possible that such activity could be recorded from humans, but Davis was skeptical. In his endeavor, Jasper chose to use photographic recordings from an optical galvanometer whereas Davis, then involved in animal work, sought to develop a continuous ink-writing machine that he believed essential for effective investigation (see above) (cited in Davis and Davis, 1940).

Jasper subsequently learned (late 1933 or early 1934, see above) that Adrian was beginning to take Hans Berger's work seriously (cited in Jasper, 1969, 1975). By July 1934, Howard Andrews, their engineer at Brown, had built direct current amplifiers with a frequency response from 1 to over 2 kHz and good amplitude linearity. He also assembled a Westinghouse galvanometer mirror oscillograph for Jasper and Carmichael to photographically record the EEG on July 9, 1934 (Fig. 5B) (cited in Cobb, 1971; cited in Grass, 1984; cited in Jasper, 1996). In 1935, they were the first to publish an EEG article in America and to confirm several of the normal findings, noted by Berger and Adrian (Jasper and Carmichael, 1935; cited in Magoun, 2003). Jasper's earliest contributions to EEG concerned the many technical issues and localization in humans by "triangulation" (bipolar) methods (Jasper, 1936, 1937; Jasper and Andrews, 1936).

By 1935, Jasper was joined at Brown by Margaret B. Rheinberger, a postdoctoral psychologist and neurophysiologist trained by John Fulton at Yale. In the unanesthetized cat, Rheinberger's major investigation studied the critical concept of EEG desynchronization after sensory stimulation (Rheinberger and Jasper, 1937), which would be elaborated a decade later by Moruzzi, Magoun, Lindsley, Jasper, and others in the study of the brainstem reticular activating system (as reviewed in Berlucchi, 2010; as reviewed in Clarke and O'Malley, 1996; as reviewed in Marshall and Magoun, 1998). One of the present authors (J. R. H.) was given many documents dealing with the early EEG history by Dr Rheinberger in 1963.

At Brown, Jasper's group also studied the human EEG in epilepsy (Jasper and Hawke, 1938) and began work on behavior disorders in children (Jasper et al., 1938). In 1938, Jasper, with the support of Frederic Gibbs (see below), departed Brown University for the Montreal Neurological Institute where he joined Wilder Penfield (1891–1976) in developing a major clinical and basic research epilepsy center (as reviewed in Feindel, 1992) (Fig. 8). Jasper's work during this period would become crucial in the elucidation of both focal and generalized epilepsies and the great advancement of EEG and clinical neurophysiology both nationally and internationally (as reviewed in Andermann, 2000; Jasper, 1941; Jasper and Kerschman, 1941; Penfield and Jasper, 1940, 1954).

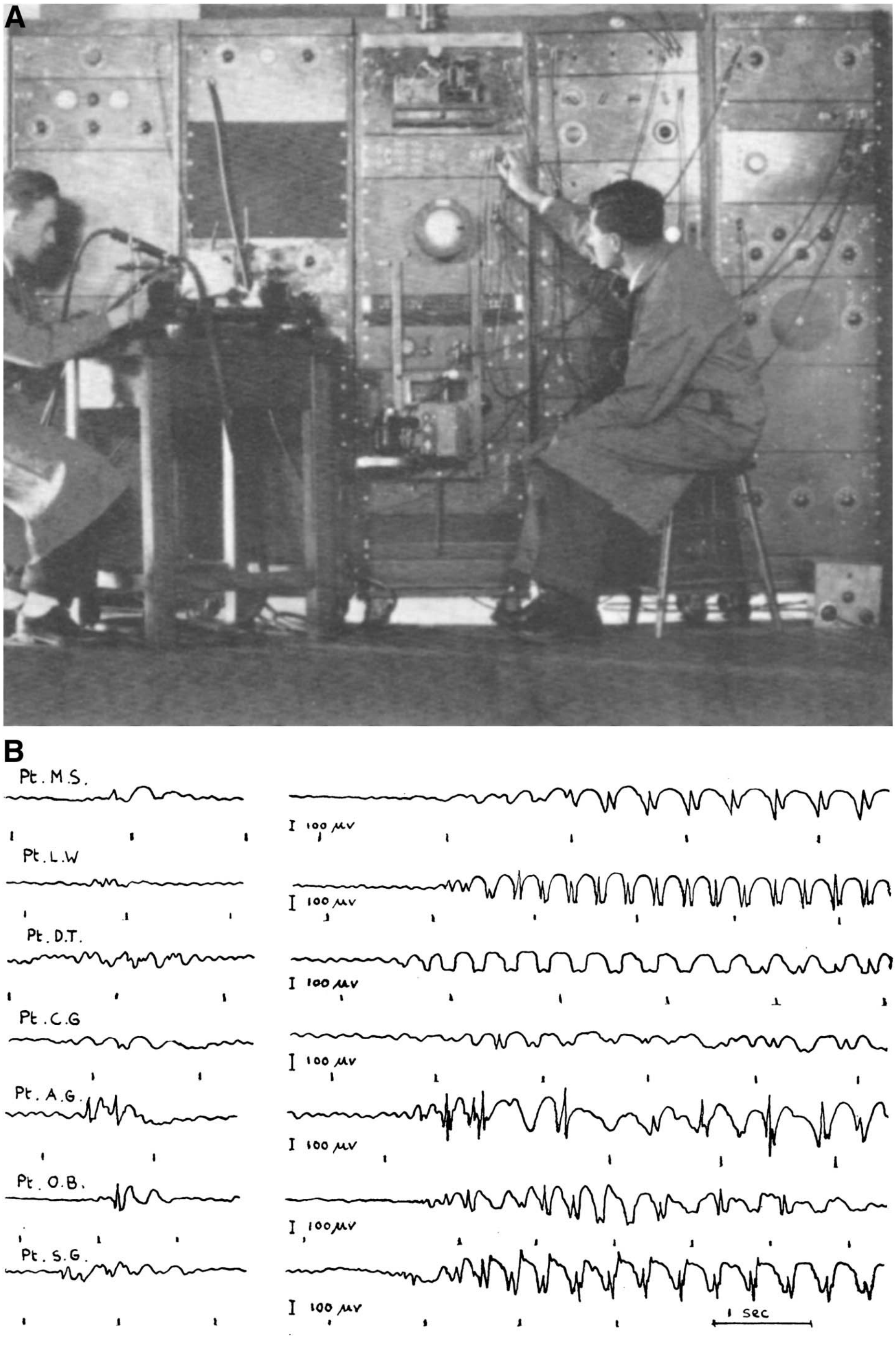

FIG. 4. **A**, EEG equipment used in Hallowell Davis' HMS laboratory, December 1934. Davis is seated on the right adjusting the cathode ray oscilloscope (CRO). Note the single-channel Western Union undulator ink-writing electroencephalograph above the CRO and below the camera for still or moving film, which could be swung up in front of the CRO. To the left is A. J. (Bill) Derbyshire working on an animal preparation (from Davis, 1984). **B**, Several examples of EEGs recorded with the undulator ink-writer from petit mal (absence) seizure patients, 1934–1935 (from Gibbs et al., 1935).

Frederic A. Gibbs (1903–1992) (Fig. 6) was initially drawn to neuroscience because his father had died of a brain tumor. After his M.D. degree from Johns Hopkins (1929), Gibbs joined the HMS-Rockefellar Foundation supported Boston City Hospital Neurological Unit then under the creative leadership of neuropsychiatrist Stanley Cobb (1887–1968) (referenced in Adams, 1975). An associate, William G. Lennox (1884–1960) (Fig. 6), shared Cobb's interest in epilepsy (Cobb, 1924; Lennox and Cobb, 1928). Gibbs' title was neuropathology research assistant, but he was assigned to blood chemistry studies in epilepsy and related changes in cerebral blood flow by Cobb and Lennox (referenced in Adams, 1975; as reviewed in Aird, 1994; as reviewed in White, 1984). In 1930, Gibbs married Lennox's research assistant, Erna Leonhardt (1906–1987), and they continued joint research for many decades. For the next 2 to 3 years, Gibbs worked under a Macy Foundation grant in Detlev Bronk's physiology laboratory in Philadelphia. Bronk, a creative biophysicist and future leader of American science, had earlier worked with Adrian on pioneering single cell recording with high-resistance electrodes (Adrian and Bronk, 1929). Gibbs' project involved the creation of a micropipette thermoelectric blood flow probe in the form of

FIG. 5. **A**, Herbert H. Jasper. **B**, EEG photographically recorded at the Bradley Hospital, Providence, RI, by Jasper and Carmichael on July 9, 1934. Time line, 25 Hz (from Grass, 1984).

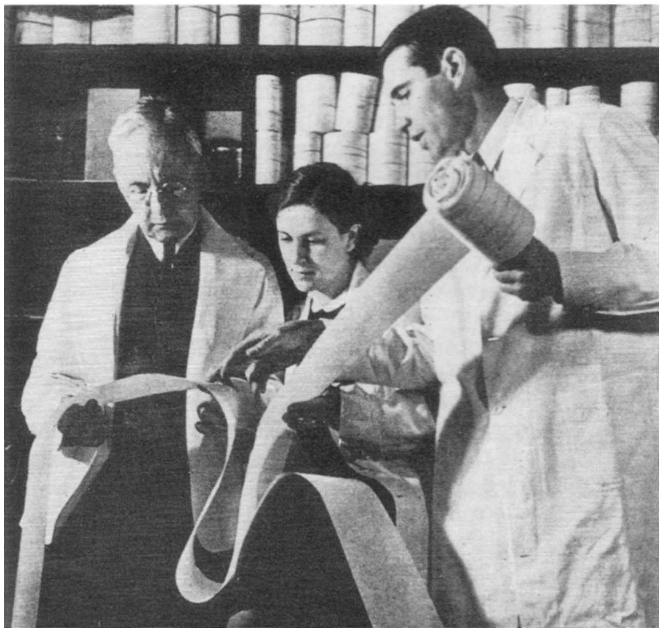

FIG. 6. William Lennox, Erna Gibbs, and Frederic Gibbs examining EEGs on paper rolls in 1937.

a needle. Back at Harvard, Gibbs used this device to prove in animals and man that a seizure was accompanied by greatly increased cerebral blood flow, disproving the prevalent anoxic theory of seizure onset (as reviewed in Aird, 1994; Gibbs, 1933; referenced in Stone, 1994). Gibbs' work in this regard came to the attention of Wilder Penfield, a close friend of Cobb and Bronk (cited in Hughes and Stone, 1990; as reviewed in White, 1984).

In the spring of 1934, Gibbs and Lennox observed an early demonstration of the EEG in Davis' HMS laboratory and immediately realized a possible use in epilepsy patients. Only after full support and encouragement from Cobb, the director of the Boston City Hospital unit until early summer of 1934 when he relocated to the Massachusetts General Hospital (as reviewed in White, 1984; as reviewed in Zottoli, 2001), did Gibbs approach Davis regarding collaborative study using the EEG. Gibbs showed Davis a recent publication from Berlin-Buch physiologist M. H. Fischer who had given dogs convulsive substances and recorded "grand mal discharges" from the cerebral cortex (as reviewed in Brazier, 1959/60; Fischer, 1933; referenced in Gibbs and Gibbs, 1941, 1951; as reviewed in Niedermeyer, 2005). Gibbs asked: "Do you think we could find something like this in epileptics? He (Davis) said there was a good chance and that we would have to try." (cited in Hughes and Stone, 1990). Davis and his graduate students then showed Gibbs the equipment and basic techniques in recording the EEG (Fig. 4). The Gibbs thus became members of the group that included Hallowell Davis and his wife Pauline (1896–1942), performing human studies with the single-channel undulator EEG ink-recorder (Gibbs et al., 1935; as reviewed in White, 1984). By October 1934, Gibbs was formally appointed Physiology Research Fellow in the HMS.

The monumental breakthrough that most believe went far to establish clinical EEG came one evening in December 1934 when two of Lennox's patients with petit mal (absence) epilepsy were studied with the EEG at Davis' HMS physiology laboratory. Lennox chose patients with petit mal in that they could be motionless during their seizures and therefore would not disturb the EEG with movement artifact. Hallowell and Pauline Davis assisted, along with Frederic and Erna Gibbs and also William Lennox. The group was astonished by the immediate finding of clear, 3/s spike and wave complexes in these patients (cited in Davis, 1975; cited in Hughes and Stone, 1990). In April 1935, an abstract on the changes in the human EEG associated with loss of consciousness by sleep, nitrogen breathing, hyperventilation, and epileptic seizures was presented at the APS meeting and constituted the second American publication on EEG (Gibbs and Davis, 1935). Twelve children with absence epilepsy were included in their groundbreaking article published in December 1935 (Fig. 4B) (Gibbs et al., 1935).

Over the next several years, the Gibbs and Lennox team additionally studied the EEG patterns of grand mal and psychomotor (partial complex) seizures, in addition to interictal epileptiform discharges (Gibbs et al., 1936, 1937). This article spurred international interest in the role of EEG in clinical epilepsy and linked the term "psychomotor epilepsy" to a specific EEG pattern, although the Gibbses' use of ear references initially led to false localization (cited in Engel, 1993; referenced in Feindel et al., 2009). These EEG descriptions with clinical correlations revolutionized neurology and epileptology (Gibbs, 1937, 1942; Lennox et al., 1936, 1938; as reviewed in Brazier, 1959/60; as reviewed in Niedermeyer, 2005; as reviewed in O'Leary and Goldring, 1976; referenced in Stone, 1994; cited in Swartz and Goldensohn, 1998). The group envisioned epilepsy as a form of "cerebral dysrhythmia" and considered surgical approaches to intractable patients. In 1935, Gibbs performed subcortical recordings in one such patient through a neurosurgically placed burr hole, perhaps the first to do so since Berger in 1930 (cited in Lennox, 1960; referenced in Stone, 1994). In 1936, Gibbs and Lennox were the first to advise an operation on a medically intractable epileptic patient, solely based upon focal pathologic ECoG activity leading to a portion of brain removed (Gibbs et al., 1937, 1938; cited in Lennox, 1960; referenced in Stone, 1994).

In the summer of 1935, after attending the International Physiological Congress in Leningrad and Moscow, Davis and the Gibbses visited Hans Berger in Germany and other neurophysiology laboratories in Europe, bringing home ideas for future EEG instrumentation and development (cited in Davis, 1975; cited in Grass, 1984; cited in Hughes and Stone, 1990). Erna Gibbs, of German upbringing and fluent in the language, was likely the first American to extensively communicate with Berger (cited in Hughes and Stone, 1990). Several months earlier, Frederic Gibbs had been instrumental in recruiting the electrical engineer, Albert Grass, from the Massachusetts Institute of Technology to the HMS Physiology Department with plans to construct a three-channel ink-writing EEG machine by the fall of 1935. This instrumentation was constructed by Grass (Grass Model 1), greatly aided by technical advise gathered by Gibbs during the summer visit to Tonnies at the Berlin-Buch Institute and to Matthews at Cambridge University (cited in Davis, 1975, 1991; cited in Hughes and Stone, 1990; cited in Grass, 1984; cited in Zottoli, 2001). Unfortunately, by then, the German regime had taken the recording instruments from Berger (cited in Schwab, 1951) who was stunned and saddened by these events. However, he was excited to see the Gibbses' 3/s spike and wave recordings, which were still unpublished, and gratified the young couple expanded upon his EEG work (cited in Hughes and Stone, 1990). Jasper and Walter also visited Berger in the summer of 1935 (cited in Jasper, 1975; cited in Walter, 1953). These helpful visits would occur several additional times until the beginnings of World War II. The Gibbses and Lennox were predominately concerned with epilepsy, sleep, and pathologic entities in which the EEG could be very useful (as reviewed in Niedermeyer, 2005).

Back in Boston from 1935 onward, the Davises actively collected a great number of EEGs on healthy adults to better define the normal limits, also studying the EEG of many psychotic patients (Davis, 1937; Davis and Davis 1937). Several years later, they introduced Grass to the idea of folded paper as a way to preserve EEG over time (cited in Davis, 1975; Davis and Davis, 1939). Davis and the Gibbses in December 1936 informally published and distributed the "Christmas Index" of English translations of Hans Berger's articles as a gift to those Americans working in the field (cited in Hughes and Stone, 1990; cited in Lindsley, 1969). A comprehensive review by Jasper (1937) was also important in disseminating the EEG work of Berger and others. Frederic Gibbs became aware of Wilder Penfield's skepticism as to the value of EEG and informed him that it was in his best interest to use this technique. Therefore, he suggested that he consider Herbert Jasper to assist him (cited in Hughes and Stone, 1990). In 1944, the Gibbses moved to the University of Illinois in Chicago, where Warren McCulloch and engineer Craig Goodwin had come from Yale to establish neurophysiology research with Dorothea de Barenne in clinical EEG. The Gibbses concentrated on complex partial (psychomotor) seizures and the activation of discharges in EEGs performed during sleep. They next collaborated with the neurosurgeon, Percival Bailey, to establish a multidisciplinary epilepsy surgery program, which significantly contributed to the refinement of anterior temporal lobectomy in nonlesional patients (reviewed in Hermann and Stone, 1989; reviewed in Hughes, 1993; reviewed in Hughes et al., 1994; referenced in Stone, 1994).

Donald B. Lindsley (1907–2003) in 1932 obtained his Ph.D. in psychology from Travis in Iowa 1 year after Jasper was there, and spent 2 years of graduate work in physiology under the direction of Forbes and Davis at the HMS from 1933–1935 (as reviewed in Lindsley, 1995; as reviewed in Zottoli, 2001). Lindsley's major project was the recording of motor unit responses from muscle, and he pioneered the study of clinical electromyography in Cobb's patients with neuromuscular disorders at Boston City Hospital and the Massachusetts General Hospital (referenced in Lindsley, 1944; as reviewed in Lindsley, 1995). In the HMS Physiology laboratory, Lindsley worked in a room adjacent to Davis' room and was found to possess one of the better alpha rhythms among the HMS physiologists. He was thus used as a subject in several of Hallowell Davis' early EEG demonstrations (cited in Davis, 1975, 1991; as reviewed in Lindsley, 1995; as reviewed in O'Leary and Goldring, 1976). By fall of 1935, Lindsley had relocated to Case Western University in Cleveland where he began his EEG career, moving to Brown University after Jasper's departure. Lindsley, a psychologist interested in child development intensively studied maturation of the EEG in children (Lindsley, 1936, 1939, 1944), recorded the first in utero EEG (Lindsley, 1942), and had a long, fruitful research and teaching career (as reviewed in Lindsley, 1995).

Another New Englander, Hudson Hoagland (1899–1982), (Hoagland, 1936; Hoagland et al., 1936; cited in Magoun, 2003) who after a Ph.D. in Biology at the HMS and completion of training with Adrian in 1930, became a biochemist-physiologist at Clark University who performed pioneering EEG studies at the Worcester State Hospital on patients with schizophrenia and metabolic encephalopathy (Hoagland et al., 1936; cited in Magoun, 2003).

In these early years of EEG, the New England group of electroencephalographers attended meetings of the Boston Society of Psychiatry and Neurology for fruitful exchanges and discussion on technical EEG issues, such as polarity, recording procedures, and instrumentation. These often spirited meetings helped disseminate the knowledge and value of EEG during this formative period (Jasper, 1936). In the summer of 1936, the Cold Spring Harbor Biological Laboratory on Long Island, NY, hosted a 5-week symposium on neurophysiology, including EEG and EPs. The nearly 60 participants included those most active in the United States and a number of European countries. These very thoughtful published presentations and discussions reflect clear documentation of the knowledge at the time. As to the cortical origin of the EEG, the articles by Davis (1936) and Gerard (1936) suggested that the EEG was a summation of excitatory and inhibitory neuronal activity. Forbes in the discussion that followed Davis' article described recent work by Renshaw who detected cortical waves with a 100 msec duration using intracellular recordings in the chicken. The general consensus was that the EEG was characterized as 10/s activity that could not be satisfactorily explained by a conglomeration of axonal action potentials whose duration was known to be about 1 msec (Gerard, 1936; Davis, 1936). During this period, Tracy Putnam (1894–1975) and Houston Merritt (1902–1979), working at the Boston City Hospital neurological laboratory, surveyed many possible anticonvulsant compounds (as reviewed in Aird, 1994). They were stimulated by the EEG findings of Gibbs, Davis, and Lennox and used an electroconvulsive threshold model and research equipment built by Albert Grass. In 1937, their work led directly to the discovery and subsequent clinical usefulness of diphenylhydantoin (phenytoin) (as reviewed in O'Leary and Goldring, 1976; Putnam and Merritt, 1937).

In 1937, the neurologist Robert S. Schwab (1903–1972), who had trained under Adrian, Davis, and Gibbs and was a collaborator of Cobb, introduced a two-channel EEG machine at Massachusetts General Hospital, Boston (Schwab, 1939; Schwab and Cobb, 1939; cited in Young, 1972). Because operating funds were not available, they initiated charging the patient, as was done for other diagnostic tests. Thus, the first hospital-based clinical EEG laboratory was established (cited in Denny-Brown, 1975; cited in Schwab, 1951). Over the next several years, EEG laboratories for clinical investigation, diagnosis, or neurophysiological studies began to appear in all the large neuropsychiatric centers in the United States and the rest of the world.

ADDITIONAL EARLY HUMAN EEG CENTERS IN AMERICA

At Iowa city, Lee Travis initiated EEG studies in 1936 with his trainees John R. Knott (1911–1993) and Charles Henry (1915–2010). In 1934–1935, Travis obtained specifications from Andrews and Jasper and, with his engineers P. E. Griffith and T. A. Hunter, built a two-channel amplifier with a Westinghouse galvanometer as the recorder. They also modified several Western Union undulators as recorders (as reviewed in O'Leary and Goldring, 1976). Travis thought that the EEG pattern of a subject remained steady and constant and each subject's tracing was part of his identification like a fingerprint (Travis and Gottlober, 1937). They studied consciousness, personality, and mental and the conditioning effects on the EEG (Henry, 1941; Henry and Knott, 1941; Knott, 1939; Knott and Travis, 1937; Travis, 1937). Travis had an additional interest in stuttering–from which Knott suffered (Travis and Knott, 1936; Travis and Malamud, 1937).

At the University of Chicago, an EEG laboratory under direction of T. Case performed some of the early studies in brain tumor localization (Case and Bucy, 1938). Similar work was done in Boston by Williams and Gibbs (1938) and Yeager (1938) at the Mayo Clinic. American ECoG recording from this period included the work of Sachs et al. (1939) from St. Louis and the studies of Scarff and Rahm (1941) from New York city.

THE LOOMIS LABORATORY IN NEW YORK: A COOPERATIVE GATHERING OF ELECTROENCEPHALOGRAPHERS, 1935–1939

In 1935, another important early American EEG group was under the direction and inspiration of physicist, Alfred L. Loomis (1887–1975), who quite independently began to record and investigate the EEG. Loomis was born and raised in New York city to a well-known family of physicians, educated at Yale (1909), and graduated Harvard Law School (1912) at the top of his class. He practiced corporate law and investment banking, amassing a fortune in electrical utilities and on Wall Street, despite the great depression. His perused generous philanthropy to major East Coast academic institutions and to promising young individuals. To advance his personal investigative interests, Loomis built a private laboratory near his mansion in the village of Tuxedo Park, NY, 45 miles north of New York City. Here, he assembled a group of engineers and investigators to obtain or build the finest instrumentation to study various areas, such as an accurate study of time or chronology (as reviewed in Alvarez, 1980; as reviewed in Conant, 2002; cited in Hughes and Stone, 1990). By using fine amplifiers, he also developed a sensitive electrocardiograph and, by placing electrodes on the head, recorded fluctuating potentials, which Loomis believed reflected brain electrical activity. He was directed to Hallowell Davis at the HMS for further information, and the Davises began work with Loomis and his team (as reviewed in Conant, 2002; cited in Davis, 1975). About this time, Loomis also consulted the Berlin-Buch engineer and Physiologist, Jan Tonnies (see above), who was then in New York City working with Gasser at the Rockefellar Institute (cited in Jung, 1975; as reviewed in O'Leary and Goldring, 1976). Several years later, Tonnies developed the cathode ray follower, which facilitated single nerve cell recordings from high impedance electrodes (cited in Jung, 1975; as reviewed in Niedermeyer, 2005; cited in Magoun, 2003).

The Loomis laboratory's major emphasis was the performance of EEGs during sleep with an associated interest in hypnosis, and in 1935, they published the third and fourth reports from the United States on the human EEG (Loomis et al., 1935a, 1935b, 1936a, 1936b). The intellectual, charming, charismatic, and highly capable Loomis attracted and performed EEGs upon many prominent scientific figures, such as Albert Einstein, Niels Bohr, and Enrico Fermi (cited in Brazier, 1984; reviewed in Conant, 2002; cited in Jasper, 1996). Their sleep studies were facilitated by adequate sleeping space, infrared photography, microphones, and a large drum–three-channel ink-writting oscillograph for prolonged recordings (Davis et al., 1937). Loomis described various "interference patterns" arising in sleep, such as the K complex, 14/s sleep spindles, and the first grading system of sleep. During these collaborative studies, Pauline Davis observed and published the first human auditory cortical EPs captured during sleep with the EEG (Davis, 1939; referenced in Davis, 1976), and possibly, she was the first to observe human cortical EPs on the awake EEG in response to auditory, visual, and somatosensory stimuli (cited in Brazier, 1984; referenced in Davis, 1976, 1984, 1991).

On November 10, 1935, Loomis hosted a conference on "The Electrical Potentials of the Brain" and invited 50 American workers in EEG or related fields (Fig. 7, Appendix 1). It is believed that Hallowell Davis presented introductory remarks and a history of EEG, but no further information is available on this conference. Similarly, it was a lavish event as were other scientific conferences hosted by Loomis at Tuxedo Park. The four invited women were

CONFERENCE
on
The Electrical Potentials of the Brain
to be held at
The Loomis Laboratory
at
Tuxedo Park, New York
November 10, 1935.

FIG. 7. Announcement of 1935 EEG Conference at Loomis' Laboratory (see Appendix 1).

Pauline A. Davis, Erna L. Gibbs, Margaret B. Rheinberger, and Myrtle B. McGraw, a New York City pediatrician who had assisted Loomis' with infant EEG recordings (Loomis et al., 1936b). This was likely the first major gathering of electroencephalographers in the world. Many active American EEG pioneers would be invited to Tuxedo Park from time to time, especially during the summers of 1937 to 1939 (cited in Davis, 1976; cited in Hughes and Stone, 1990; cited in Jasper, 1996).

In 1939, with unrest and war looming in Europe, Loomis donated his EEG equipment to the HMS and turned his scientific interest to experimental waveform physics. By using his extensive scientific and political connections, Loomis would be pivotal in the accelerated research and development of radar (as reviewed in Alvarez, 1980). He was also involved with development of the atomic bomb, modern long-range radio navigation, and ground-controlled approach technology (as reviewed in Conant, 2002; cited in Wikipedia, 2011). President Franklin Roosevelt is said to have credited Loomis as second to Winston Churchill in turning the tide of World War II in the Allies favor (cited in Wikipedia, 2011). Loomis, who always shunned attention and sought anonymity, retired to his estate on Long Island and refused interviews (as reviewed in Alvarez, 1980; cited in Wikipedia, 2011).

WORLD WAR II

By the beginning of World War II, EEG laboratories were in all the large neuropsychiatric centers in the world. The medical divisions of the major powers at war used the EEG in the selection of aviators, evaluation of physically and mentally injured soldiers, and various neurophysiological experiments (Forbes and Davis, 1943; as reviewed in O'Leary and Goldring, 1976; cited in Schwab, 1951). The comprehensive Gibbs' Atlas of EEG in 1941 was then the standard publication used by most electroencephalographers worldwide and for a number of years to come (Gibbs and Gibbs, 1941; referenced in Lindsley, 1944; cited in Magoun, 2003). The development of the four-channel Model II EEG by Albert Grass, and the emergency wartime usage of many machines, was a testament to the value and progress of EEG in epilepsy identification and lesion localization (as reviewed in O'Leary and Goldring, 1976; cited in Schwab, 1951). Hallowell Davis, who was then acting Chair of Physiology at the HMS (1942–1943), would become a founder of the Eastern and American EEG Societies (see below). Davis returned to auditory work after the war but later in St. Louis intensively studied averaged auditory evoked responses and pioneered their use in audiometry (as reviewed in Davis, 1976, 1984).

After the war Albert Grass and his wife, Ellen R. Grass (1914–2001), developed an innovative commercial EEG instrument company and became unwavering supporters of the EEG community and associated research for the next 60 years (cited in Grass, 1984; cited in Zottoli, 2001). Franklin Offner, a Chicago engineer who worked with Gerard, by 1935, had constructed an EEG and ink-writer and also formed a commercial EEG instrument company to serve the needs of the EEG community. In the 1950s, Offner was the first to introduce electronic components into EEG, which aided the machine's safety and portability (cited in Collura, 1993; cited in Grass, 1984).

FORMATION OF THE AMERICAN CLINICAL NEUROPHYSIOLOGY SOCIETY (AMERICAN EEG SOCIETY).

By late 1934 or early 1935, the New England EEG group consisted of 8 to 10 individuals who met as an informal club every month or two, to exchange experiences and ideas. Hallowell Davis acted as host and discussion leader (cited in Davis, 1991). As the number of interested individuals especially on the East Coast and in Montreal (Fig. 8) increased, the need for organizational plans became evident, and the Eastern EEG association or society was formed in 1939 with Robert Schwab, one of the early organizers (cited in Schwab, 1951). Yearly annual meetings typically were held in early December in New York City, but in February, a ski meeting was held in the Laurentian Mountains north of Montreal, where a 50th anniversary ski meeting was celebrated in 1991 (cited in Henry, 1992). The Central EEG Society was formed in 1943 or 1944 after the arrival of the Gibbses to Chicago and alternated meetings between Chicago,

FIG. 8. EEG conference inaugurating the opening of the Electrophysiological Laboratories at the Montreal Neurological Institute, February 24–26, 1939. Participants and invited guests: First row (left to right): Robert S. Schwab, S. Humphreys, Herbert Jasper, A. Cipriani, Garret Hobart, N. Frazer, and W. V. Cone. Second row: Leslie F. Nims, David Lloyd, Joseph G. Hughes, Stanley Cobb, E. Newton Harvey, Wilder Penfield, Alfred L. Loomis, Alexander Forbes, and Hallowell Davis. Third row: Colin Russel, (unidentified), Margaret Rheinberger, E. J. Baldes, G. E. Hall, Theodore C. Erickson, John E. Goodwin, Theodore J. Case, Molly R. Harrower-Erickson, Mrs. Robert S. Schwab, and Arthur Elvidge. Fourth row: Howard L. Andrews, Joseph Evans, Donald Y. Solandt, (unidentified), John Kershman, J. Roy Smith, Donald B. Lindsley, Choh-Luh Li, and Simon Dworkin.

A

AMERICAN SOCIETY
OF
ELECTROENCEPHALOGRAPHY

First Annual Meeting

June 13, 14, and 15, 1947

MARLBOROUGH-BLENHEIM HOTEL
ATLANTIC CITY, N. J.

B

PANEL DISCUSSIONS

AFTERNOON SESSION, FRIDAY, JUNE 13, 1947

ELECTRODES 2:00 P.M.

Basic Principles . . . . L. F. NIMS
Experiments and Practice . . . . . D. B. LINDSLEY
Recommendations . . . . A. FORBES (CHAIRMAN)
Discussion

ELECTRODE POSITIONS AND METHODS OF ATTACHMENT 3:00 P.M.

Pros and Cons of Positions in Use . . . J. KERSHMAN
Methods of Attachment . . . . . . J. A. ABBOTT
Recommendations . . . . R. S. DOW (CHAIRMAN)
Discussion

RECORDING APPARATUS 4:00 P.M.

Characteristics of Existing Equipment . . H. DAVIS
Ideal Characteristics . . . . J. L. O'LEARY
Scope and Limitations of Various Types of Amplifiers for Neurophysiological Investigation . . . . PROF. K. S. LION (by invitation)
Recommendations . . . . E. J. BALDES (CHAIRMAN)
Discussion

C

EVENING SESSION, FRIDAY, JUNE 13, 1947

TRAINING AND QUALIFICATIONS 8:30 P.M.

Existing Training Programs . . . . . F. A. GIBBS
Ideal Training Programs and Qualifying Examinations . . . . R. B. AIRD
Recommendations . . . . R. S. SCHWAB (CHAIRMAN)
Discussion

RESOLUTIONS 9:30 P.M.

SCIENTIFIC SESSION

MORNING SESSION, SATURDAY, JUNE 14, 1947

CALIBRATIONS OF E. E. G. AND ASSOCIATED EQUIPMENT 9:30 A.M.
L. A. GEDDES (by invitation)

THE ELECTROENCEPHALOGRAM FOLLOWING OCCIPITAL LOBOTOMY 10:00 A.M.
RICHARD L. MASLAND, FRANCIS C. GRANT and GEORGE M. AUSTIN

VALUE OF SIMULTANEOUS UNIPOLAR, BIPOLAR AND AUTONOMIC RECORDS (TWELVE CHANNELS WITH POLYGRAPH) 10:30 A.M.
CHESTER W. DARROW and CHARLES E. HENRY

D

EVENING SESSION, SATURDAY, JUNE 14, 1947

ROUND TABLE

HISTORICAL INTERLUDE 8:30 P.M.
ALEXANDER FORBES and
DONALD J. MACPHERSON

THE GREY WALTER ANALYZER IN ACTION 9:00 P.M.
MARY A. B. BRAZIER

OPEN DISCUSSION

SUNDAY, JUNE 15, 1947

BUSINESS MEETING 10:00 A.M.

All members of the American Neurological Association and physicians and scientific workers interested in electroencephalography and neurophysiology are invited to attend the meetings on June 13 and 14.

On June 15, the business meeting is open only to members.

FIG. 9. **A–D**, Brochure from the first meeting of the "American Society of EEG" held in Atlantic City, NJ, June 13–15, 1947.

St. Louis, and Iowa. Over the next several years, Southern and Western EEG Societies were also formed in the United States.

EEG had become so firmly established in American Neurology after World War II that, in March 1946, the Eastern Association of Electroencephalographers (EAE) was formally organized by 27 members for the purpose of promoting research in the field with plans to pool scientific information concerning the neurophysiology and clinical applications of EEG (Anonymous, 1946). Hallowell Davis was appointed Chairman of a committee to approach the American Neurological (ANA), Psychiatric (APA), and Medical Association (AMA), and the American Physiological Society (APS) regarding minimal standards for approved EEG laboratories (Anonymous, 1946). In June 1946, the EAE Council determined the need for a National EEG society with the goals of raising the standards and quality of the work and establish uniformity in recording (cited in Knott et al., 1992). A multidisciplinary group of seven electroencephalographers met in Boston in December 1946. Robert B. Aird and Robert Aring represented the ANA, and Robert Schwab and Charles Stephenson represented the APA, E. J. Baldes represented the AMA and Jasper and Gibbs represented the APS. Alexander Forbes and Stanley Cobb acted as ex officio advisors (cited in Knott et al., 1992). A Council was chosen with Jasper as President, Gibbs Vice President, Schwab Secretary, and Mary A. B. Brazier as Treasurer. The Council initially nominated 44 Charter Members, but some declined and more were added before the first meeting to bring the total to roughly 50 (Appendix 2). Of Charter Members, 58% were neurologists; 16% basic scientists: physiology, biochemistry, biophysics; 14% psychololgists; and 10% psychiatrists (cited in Knott et al., 1992).

The first Society meeting was held in Atlantic city, NJ, June 13–15, 1947 (Figs. 9A–9D) several days before the annual meeting of the ANA. Original articles were presented and group discussions concerned minimal standards for EEG equipment, basic training, EEG examinations for electroencephalographers, and the future establishment of minimal competence in EEG. The second Society President was Gibbs (1947–1948), followed by Davis (1949–1950), and Schwab (1950–1951). Interestingly, and without any known reason, in the correspondence from December 1947, we find that the Society name was changed from the "American Society of EEG" to the "American EEG Society." Following the First International EEG Congress in London (1947), plans were made for an international quarterly EEG journal (cited in Schwab, 1951). Subsequently, in 1948–1949, members of the Society gave extensive financial and editorial support to the International Federation of Societies for EEG (Fig. 10) for the "Journal of EEG and Clinical Neurophysiology," which began publication in 1949.

In the early years of the American EEG Society, the problems were those of an emerging medical subspecialty with a new technique. Relationships with the ANA, AMA, and nonmedical groups, such as the Air Force and Veterans Administration, were important (cited in Davis, 1991). Davis believed his most noteworthy action as Society President was to direct the Society Council to appoint the first Board of Qualification in EEG (thus establishing standards for training of electroencephalographers and their technicians). The original Board consisted of Robert Aird–Chairman, A. Earl Walker–Secretary, and members Frederic Gibbs, John Knott, and Richard Masland. The first oral examination was given in New York city in 1950 (cited in Erwin, 1985). Robert Schwab, an appointee to the Board several years later, encouraged more emphasis on clinical EEG and less instrumentation emphasis. By the late 1950s, after much discussion, Board testing for certification only became open to physicians (cited in Erwin, 1985). In 1969, the Board of Qualification of the Society was replaced by the American Board of Qualification in EEG, Inc (ABQEEG), renamed the American Board of Clinical Neurophysiology (ABCN) in 1986. Eligibility is now limited to physicians with at least 3 years postdoctoral training in neurology, neurosurgery, or psychiatry (cited in Erwin, 1985). In 1970, Guidelines in EEG were published by the Society, and in 1984, the *Journal of Clinical Neurophysiology* was established as the Society's official journal.

In 1995, the Society's name changed to The American Clinical Neurophysiology Society (ACNS), and the following year, a 50th anniversary banquet was held at the annual meeting in Boston. With membership over 1200, the Society continues to flourish and maintain standards of professional excellence in the clinical applications of neurophysiology. The Society, with its semiannual- and annual-focused courses and scientific meetings, addresses the full field of clinical neurophysiology, and also practice parameters and position statements, including representation and advocacy at

FIG. 10. Photograph of a committee meeting at the Third International Congress of Electroencephalography in Cambridge, MA, 1953. Front row: M. Kennard, M. A. B. Brazier, H. Gastaut, E. D. Adrian, A. Forbes (President), W. G. Walter, H. Jasper, R. S. Schwab, and F. Buchthal. Back Row: K. A. Melin, R. Aird, C. E. Henry, E. A. Walker, M. R. Hess, J. R. Knott, J. O'Leary, B. Kaada, R. Jung, E. J. Baldes, O. Magnus, R. W. Meyer-Mickeleit, G. Moruzzi, and J. A. Abbott (from Cobb, 1971).

the federal and American Medical Association level. The mission statement of the ACNS remains "dedicated to fostering excellence in clinical neurophysiology and furthering the understanding of central nervous system function in health and disease through education, research, and the provision of a forum for discussion and interaction." (American Clinical Neurophysiology Society History: 1947 to Present).

DISCUSSION

The history of EEG began in Europe in the last quarter of the 19th century and culminated in the work of Hans Berger and other Germans in the early to mid-1930s. Before and after World War I, the British Schools of neurophysiology under Sherrington and Adrian stimulated and nurtured perhaps a dozen American neurophysiologists, most notably Alexander Forbes and Hallowell Davis at Harvard. In Great Britain and America, Berger's EEG findings were verified, perhaps simultaneously in early 1934, although over the next several years, America led in establishing the clinical usefulness of EEG. Adrian and a number of American neurophysiologists pursued investigative work in the following decades, which elucidated the cortical synaptic or dendritic origin of the EEG.

It is evident that America has been a worldwide leader in the development and applications of clinical neurophysiology as an essential and life-saving medical specialty. As a developed country of wealth, American philanthropic foundations supported most of the worldwide neurological investigators and institutions of the 1920s and 1930s, who produced our leading clinical neurophysiologists. American developments in the EEG field initially slowed with our involvement in World War II, while European advancements were largely halted for a decade. American involvement in World War II saw acceleration of useful applications for EEG and improvements in the instrumentation followed. The founders and members of the ACNS, such as Jasper and others, unselfishly supported international clinical neurophysiology development as Europe rebuilt. We believe that the history of American EEG and clinical neurophysiology has a particularly noteworthy heritage in the on-going advancement of neuroscience and one we can be most proud of.

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REFERENCES

Adams RD. Stanley Cobb 1887–1968. In: Denny-Brown D, ed. *Centennial anniversary volume of the American Neurological Association*. New York: Springer, 1975:253–259.
Adrian ED. Electrical activity of the nervous system. *Arch Neurol Psychiatry* 1934;32:1125–1136.
Adrian ED. The discovery of Berger. In: Remond A, ed. *Handbook of Electroencephalogr and Clinical Neurophysiology*. Amsterdam: Elsevier, Vol. 1A. 1971:5–10.
Adrian ED. Forty years' progress in neurophysiology. *Electrencephalogr Clin Neurophysiol* 1972;(suppl 31):3–7.
Adrian ED, Bronk DW. The frequency of discharge in reflex and voluntary contractions. *J Physiol* 1929;67:119–151.
Adrian ED, Forbes A. The all-or-nothing response of sensory nerve fibres. *J Physiol* 1922;56:301–330.
Adrian ED, Matthews BHC. The Berger rhythm: potential changes from the occipital lobes of man. *Brain* 1934;57:355–385.
Aird RB. *Foundations of modern neurology: a century of progress*. New York: Raven Press, 1994.
Alvarez LW. Alfred Lee Loomis 1887-1975. *Biog Mem Nat Acad Sci* 1980; 51:308–341.
American Clinical Neurophysiology Society. Web site and history: 1947 to Present.
Andermann F. Herbert Henri Jasper 1906–1999. *Epilepsia* 2000;41:113–120.
Anonymous. Organization of Eastern Association of Electroencephalographers. *Arch Neurol Psychiatry* 1946;55:535–536.
Bartley SH. Analysis of cortical response to stimulation of the optic nerve. *Am J Physiol* 1932;101:4P.
Bartley SH, Bishop GH. The cortical response to stimulation of the optic nerve of the rabbit. *Am J Physiol* 1933;103:159–172.
Bartley SH, Newman EB. Recording cerebral action currents. *Science* 1930;71:587.
Bartley SH, Newman EB. Studies on the dog's cortex. I: the sensori-motor areas. *Am J Physiol* 1931;99:1–8.
Berger H. Uber das Elektrenkephalogramm des Menschen. *Archiv Psychiat Nervenkr* 1929;87:527–570.
Berlucchi G. The contributions of neurophysiology to clinical neurology: an exercise in contemporary history. In: Finger S, Boller F, Tyler KL eds. *Handbook of Clinical Neurology*, Vol 95 (3rd series), *History of Neurology 2010*. Holland: Elsevier, 2010;169–188.
Bishop GH, O'Leary J. Components of the electrical response of the optic cortex of the rabbit. *Am J Physiol* 1936;117:292–308.
Bradley JK, Tansey EM. The coming of the electronic age to the Cambridge physiological laboratory. *Notes Rec R Soc Lond* 1996;50:217–228.
Brazier MAB. The EEG in epilepsy. A historical note. *Epilepsia* 1959/60;1:328–336.
Brazier MAB. *A history of the electrical activity of the brain*. New York: Macmillan, 1961.
Brazier MAB. *The electrical activity of the nervous system*. 3rd ed. London: Pitman, 1968.
Brazier MAB. Pioneers in the discovery of evoked potentials. *Electroenceph Clin Neurophysiol* 1984;59:2–8.
Brazier MAB. *A history of neurophysiology in the 19th century*. New York: Raven Press, 1988.
Case TJ, Bucy PC. The localization of cerebral lesions by electroencephalography. *J Neurophysiol* 1938;1:245–261.
Caton R. The electric currents of the brain. *Br Med J* 1875;2:278.
Caton R. Interim report on investigation of the electric currents of the brain. *Br Med J* 1877;(suppl 1):62–65.
Clarke E, O'Malley CD. *The human brain and spinal cord. A historical study illustrated by writings from antiquity to the twentieth century*. 2nd ed. San Francisco: Norman, 1996;228–234, 238–240.
Cobb S. Electromyographic studies of experimental convulsions. *Brain* 1924;47:70–75.
Cobb S. Alexander Forbes. *J Nerv Ment Dis* 1965;141:609–614.
Cobb W. The past forty years of EEG. In: Remond A ed. *Handbook of electroencephalography and clinical neurophysiology*. Amsterdam: Elsevier, Vol 1A. 1971:25–38.
Collura TF. History and evolution of electroencephalographic instruments and techniques. *J Clin Neurophysiol* 1993;10:476–504.
Conant J. *Tuxedo Park*. New York:Simon & Schuster, 2002.
Davis H. Some aspects of the electrical activity of the cerebral cortex. *Cold Spring Harbor Symp Quant Biol* 1936;4:285–291.
Davis H. The electrical activity of the human brain. *New Eng J Med* 1937;216:97–98.
Davis H. Electrical phenomena of the brain and spinal cord. *Ann Rev Physiol* 1939;1:345–362.
Davis P. The electrical response of the human brain to auditory stimuli. *Am J Physiol* 1939;126:455–476.
Davis H. Alexander Forbes 1882–1965. *J Neurophysiol* 1965;28:986–988.
Davis H. Crossroads on the pathways to discovery. In: Worden FG, Swazey JP, Adelman G, eds. *The neurosciences: paths of discovery*. Cambridge: MIT Press, 1975;311–321.
Davis H. Principles of electric response audiometry. *Ann Otol Rhinol Laryngol* 1976;85(Suppl 28):5–93.
Davis H. The development of auditory neurpphysiology. In: Dawson WW, Enoch JM, eds. *Foundations of sensory science*. Berlin: Springer-Verlag, 1984;25–64.

Davis H. *The professional memoirs of Hallowell Davis*. St. Louis: Central Institute for the Deaf, 1991;112 pp.

Davis H, Davis P. Action potentials of the brain in normal states of cerebral activity. *Arch Neurol Psychiatry* 1936;36:1214–1224.

Davis H, Davis P. The human electroencephalogram in health and in certain mental disorders. *Arch Neurol Psychiatry* 1937;37:1461–1462.

Davis P, Davis H. The electroencephalograms of psychotic patients. *Am J Psychiatry* 1939;95:1007–1025.

Davis P, Davis H. Development of electroencephalography: retrospect and outlook. *Am J Orthopsychiarty* 1940;10:710–718.

Davis H, Saul LV. Action currents in the auditory tracts of the midbrain of the cat. *Science* 1931;86:448–450.

Davis H, Davis P, Loomis AL, et al. Changes in human brain potentials during the onset of sleep. *Science* 1937;86:448–450.

Denny-Brown D. *Centennial anniversary volume of the American Neurological Association*. Denny-Brown D, ed. New York: Springer, 1975;417–419.

Durup G, Fessard A. L'electrencephalogramme de l'homme. Observations psychophysiologiques relatives a l'action des stimuli visuels et auditifs. *Annee Psychol* 1936;36:1–32.

Dusser de Barenne JG, McCulloch WS. Some effects of laminar thermocoagulation upon the local action potentials of the cerebral cortex of the monkey. *Am J Physiol* 1936;114:692–694.

Eccles JC. Alexander Forbes and his achievement in electrophysiology. *Perspect Biol Med* 1970;13:388–404.

Engel J Jr. Historical perspectives. In: Engel J Jr, ed. *Surgical treatment of the epilepsies*. 2nd ed. New York: Raven Press, 1993;695–705.

Erlanger J, Gasser HS. The compound nature of the action current of nerve as disclosed by the cathode ray oscilloscope. *Am J Physiol* 1924;70:624–666.

Erwin CW. American Board of Qualification in Electroencephalography. *J Clin Neurophysiol* 1985;2:305–307.

Feindel W. Brain physiology at the Montreal Neurological Institute: some historical highlights. *J Clin Neurophysiol* 1992;9:176–194.

Feindel W, Leblanc R, de Almeida AN. Epilepsy surgery: historical highlights 1909-2009. *Epilepsia* 2009;50(suppl 3):131–151.

Fenn WO. *History of the American Physiological Society: the third quarter century, 1937-1962*. Washington: American Physiological Society, 1963;23–26, 44–46, 92–92, 143.

Fenn WO. Alexander Forbes. *Biog Mem Nat Acad Sci* 1969;40:113–141.

Fessard A. Brain potentials and rhythms—introduction. In: Field J, Magoun HW, Hall VE, eds. *Handbook of physiology. Section 1: neurophysiology*, Vol I. Wahsington: American Physiological Society, 1959;255–259.

Fischer MH. Elektrobiologische erscheinungen an der hirnrinde. *Pflug Arch ges Physiol* 1932;230:161–178.

Fischer MH. Elektrobiologische auswirkungen von krampfgiften am zentralnervensystem. *Med Klin* 1933;29:15–19.

Fischer MH, Lowenbach H. Aktionsstrome des zentralnervensystems unter der einwikung von krampfgiften. I. Miteilung strychnine und pickrotoxin. *Arch Exp Pathol Pharmakol* 1934;174:357–382.

Foerster O, Altenburger H. Elektrobiologische vorgange an der menschlichen hirnrinde. *Dtsch Z Nervenheilk* 1935;135:277–286.

Forbes A, Davis H. *Electroencephalography of naval aviators. Report # 13*. Washington: Division of Research, Civil Aeronautics Admin, April 1943.

Forbes A, Grass AM. Simple direct-coupled amplifier for action potentials. *J Physiol* 1937;91:31–35.

Forbes A, Thacher C. Amplification of action currents with the electron tube in recording with the string galvanometer. *Am J Physiol* 1920;52:409–471.

Forbes A, Derbyshire AJ, Rempel B, Lambert EF. The effects of ether, Nembutal and avertin on the potential patterns of the motor cortex. *Am J Physiol* 1935;113:43–44.

Forbes A, Renshaw B, Rempel B. Units of electrical activity in the cerebral cortex. *Am J Physiol* 1937;119:309–310.

Fulton JF. *Harvey Cushing—a biography.* Springfield: Charles C. Thomas, 1946;577pp.

Garceau EL, Davis H. An amplifier, recording system and stimulation devices for the study of cerebral action currents. *Am J Physiol* 1934;107:305–310.

Garceau EL, Davis H. An ink-writing electroencephalograph. *Arch Neurol Psychiatry* 1935;34:1292–1294.

Gasser HS, Erlanger J. The cathode ray oscilloscope as a means of recording nerve action currents and induction shocks. *Am J Physiol* 1921;59:473–474.

Gasser HS, Graham HT. Potentials produced in the spinal cord by stimulation of dorsal roots. *Am J Physiol* 1933;103:303–320.

Gerard RW. Factors controlling brain potentials. *Cold Spring Harbor Symp Quant Biol* 1936;4:292–304.

Gerard RW. The minute experiment and the large picture. In: Worden FG, Swazey JP.Adelman G, eds. *The neurosciences: paths of discovery*. Cambridge: MIT Press, 1975;456–474.

Gerard RW, Marshall WH, Saul LJ. Cerebral action potentials. *Proc Soc Exper Biol Med* 1933;30:1123–1125.

Gerard RW, Marshall WH, Saul LJ. Brain action potentials. *Am J Physiol* 1934;109:38–39.

Gerard RW, Marshall WH, Saul LJ. Electrical activity of the cat's brain. *Arch Neurol Psychiatry* 1936;36:675–735.

Gibbs FA. Hans Berger (1873-1941). In: Haymaker W, Schiller F, eds. *The founders of neurology*. 2nd ed. Springfield: Thomas, 1970;171–175.

Gibbs FA. A thermoelectric blood flow recorder in the form of a needle. *Proc Soc Exp Biol* 1933;31:141–146.

Gibbs FA, Gibbs EL. *Atlas of Electroencephalography*. Cambridge, MA: Cummings, 1941:2–8.

Gibbs FA, Gibbs EL. *Atlas of Electroencephalography*. Volume One, 2nd ed. Reading, MA: Addison-Wesley, 1951:1–4.

Gibbs FA. Interpretation of the electro-encephalogram. *J Psychol* 1937;4:365–382.

Gibbs FA. Diagnostic and prognostic value of the electroencephalogram. *JAMA* 1942;118:216–218.

Gibbs FA, Davis H. Changes in the human electroencephalogram associated with loss of consciousness. *Am J Physiol* 1935;113:49–50.

Gibbs FA, Davis H, Lennox WG. The electro-encephalogram in epilepsy and in conditions of impaired consciousness. *Arch Neurol Psychiatry* 1935;34:1133–1148.

Gibbs FA, Lennox WG, Gibbs EL. The electro-encephalogram in diagnosis and in localization of epileptic seizures. *Arch Neurol Psychiatry* 1936;36:1225–1235.

Gibbs FA, Gibbs EL, Lennox WG. Epilepsy: paroxysmal cerebral dysrhythmia. *Brain* 1937;60:377–388.

Gibbs FA, Gibbs EL, Lennox WG. Cerebral dysrhythmias of epilepsy: measures for their control *Arch Neurol Pychiatry* 1938;39:298–314.

Ginzberg R. Three years with Hans Berger. A contribution to his biography. *J Hist Med* 1949;4:361–371.

Gloor P. Hans Berger and the discovery of the electroencephalogram. [Introduction]*Electroencephalogr Clin Neurophysiol* 1969a;28(suppl):1–36.

Gloor P. Hans Berger on the electroencephalogram of man.*Electroencephalogr Clin Neurophysiol* 1969b;28(suppl):1–350.

Goldensohn ES. Animal electricity from Bologna to Boston. *Electroencephalogr Clin Neurophysiol* 1998;106:94–100.

Goldensohn ES, Porter RJ, Schwartzkroin PA. The American Epilepsy Society: an historic perspective on 50 years of advances in research. *Epilepsia* 1997;38:124–150.

Golla F, Graham S, Walter WG. The electro-encephalogram in epilepsy. *J Ment Sci* 1937;83:137–155.

Gozzano M. Ricerche sui fenomeni elettrici della corteccis cerebrale. *Riv Neurol* 1935;3:212–261.

Granit R. *Sensory mechanisms of the retina.* London: Oxford University Press, 1947.

Grass AM. *The electroencephalographic heritage*. Quincy: Grass Instrument, Co, 1984.

Grass AM, Gibbs FA. A Fourier transform of the electroencephalogram. *J Neurophysiol* 1938;1:521–526.

Haymaker W. Cecile Mugnier Vogt (1875-1962) and Oskar Vogt (1870-1959). In: Haymaker W, Schiller F. *The founders of neurology*. 2nd ed. Springfield: Thomas, 1970;384–388.

Hearnshaw LS. *A short history of British Psychology 1840–1940*. London: Methuen, 1964;69–81, 231, 303–304.

Henry CE. Electroencephalographic individual differences and their constancy. I. During sleep. *J Exp Psychol* 1941;29:117–132.

Henry MH. Albert Melvin Grass 1910-1992. *J Clin Neurophysiol* 1992;9:419–421.

Henry CE, Knott JR. A note on the relationship between personality and the alpha rhythm of the electroencephalogram. *J Exp Psychol* 1941;28:362–366.

Hermann BP, Stone JL. A historical review of the epilepsy surgery program at the University of Illinois Medical Center: the contributions of Bailey, Gibbs, and collaborators to the refinement of anterior temporal lobectomy. *J Epilepsy* 1989;2:155–163.

Hoagland H. Pacemakers of human brain waves in normals and in general paretics. *Am J Physiol* 1936;116:604–615.

Hoagland H, Rubin MA, Cameron DE. Electrical brain waves in schizophrenia during insulin treatment. *J Psychol* 1936;3:513–519.

Hughes JR. In memorium. Frederic A. Gibbs, MD. *Am J EEG Technol* 1993;33:90–92.

Hughes J, Stone JL. An interview with Frederic A. Gibbs, MD and Erna L. Gibbs. *Clin Electroencephalogr* 1990;21:175–187.

Hughes MG, Sundaram M. Hans Berger: other discoveries. *J Clin Neurophysiol* 1987;4:285–286.

Hughes JR, Penney DW, Stone JL. History of Neuropsychiatric Institute of the University of Illinois Medical Center, Chicago, Illinois. *Clin Electroencephalogr* 1994;25:99–103.

Jasper HH, Localized analyses of human brain function by the electroencephalogram. *J Nerv Ment Dis* 1936;84:679–683.

Jasper HH. Electrical signs of cortical activity. *Psychol Bull* 1937;34:411–481.

Jasper HH. Electroencephalography. In: Penfield W, Erickson TC, eds. *Epilepsy and cerebral localization*. Springfield: Thomas, 1941;380–454.

Jasper HH. Preface to P. Gloor - Hans Berger on the electroencephalogram of man. *Electroencephalogr Clin Neurophysiol* 1969;28(suppl):v-vii.
Jasper HH. Philosophy or physics—mind or molecules. In: Worden FG, Swazey JP, Adelman G, eds. *The neurosciences: paths of discovery*. Cambridge: MIT Press, 1975;401–422.
Jasper HH. Some highlights of 70 years in neuroscience research. In: Squire LR, ed. *The history of neuroscience in autobiography*. Vol 1. Washington: Society for Neuroscience, 1996;320–346.
Jasper HH, Andrews HL. Human brain rhythms: I. Recording techniques and preliminary results. *J Gen Psychol* 1936;14:98–126.
Jasper HH, Carmichael L. Electrical potentials from the intact human brain. *Science* 1935;81:51–53.
Jasper HH, Hawke WA. Electro-encepahlography. IV. Localization of seizure wave in epilepsy. *Arch Neurol Psychiatry* 1938;39:885–901.
Jasper HH, Kerschman J. Electroencephalographic classification of the epilepsies. *Arch Neurol Psychiatry* 1941;45:903–943.
Jasper HH, Solomon P, Bradley C. Electroencephalographic analyses of behavior problem children. *Am J Psychiatry* 1938;95:641–658.
Jung R. Some European neuroscientists: a personal tribute. In: Worden FG, Swazey JP, Adelman G, eds. *The neurosciences: paths of discovery*. Cambridge: MIT Press, 1975;477–511.
Klatzo I. Cecile and Oskar Vogt: the visionaries of modern neuroscience. *Acta Neurochir Suppl* 2002;80:1–129.
Knott JR. Some effects of mental set upon the electrophysiological processes of the human cerebral cortex. *J Exp Psychol* 1939;24:384–405.
Knott JR, Travis LE. A note on the relationship between duration and amplitude of cortical potentials. *J Psychol* 1937;3:169–172.
Knott JR, Lindsley DB, Henry CE. The American Electroencephalographic Society: the original list of characters. *J Clin Neurophysiol* 1992;9:422–423.
Kornmuller AE. Architektonische lokalization bioelektrischer erscheinungen auf der grosshirnrinde. *J Psychol Neurol* 1932;44:447–459.
Kornmuller AE. Die ableitung bioelektischer effekte architektonischer rindenfelder vom uneroffneten schadel. *J Psychol Neurol* 1933;45:172–184.
Kornmuller AE. Der mechanismus des epileptischen anfalles auf grund bioelektrischer untersuchungen am zentralnervensystem. *Fortschr Neurol Psych* 1935;7:391–400, 414–432.
Lemke R. Personal reminiscences of Hans Berger. *Electroencephalogr Clin Neurophysiol* 1956;8:708.
Lennox WG. *Epilepsy and related disorders*. Vol 2. Boston: Little Brown, 1960.
Lennox WG, Cobb S. *Epilepsy*. Baltimore: Williams & Wilkins, 1928.
Lennox WG, Gibbs FA, Gibbs EL. Effect on the electro-encephalogram of drugs and conditions which influence seizures. *Arch Neurol Psychiatry* 1936; 36:1236–1245.
Lennox WG, Gibbs FA, Gibbs EL. The relationship in man of cerebral activity to blood flow and to blood constituents. *J Neurol Psychiatry* 1938;1:211–225.
Liberson WT. Electroencepahlographie transcranienne chez l'homme. *Le Travail Humain* 1936;4:303–320.
Lindsley DB. Brain potentials in children and adults. *Science* 1936;84:354.
Lindsley DB. A longitudinal study of the occipital alpha rhythm in normal children: frequency and amplitude standards. *J Genet Psychol* 1939;55: 197–213.
Lindsley DB. Heart and brain potentials of human fetuses in utero. *Am J Psychol* 1942;55:412–416.
Lindsley DB. Electroencephalography. In: McV Hunt J, ed. *Personality and behavior disorders*. New York: Ronald Press, 1944;1033–1103.
Lindsley DB. Average evoked potentials—achievements, failures and prospects. In: Donchin E, Lindsley DB, eds. *Average evoked potentials. Methods, results and evaluations*. Washington: Office of Technology Utilization, National Aeronautics and Space Administration, 1969;1–43.
Lindsley DB. Life and reflections of a psychologist-psychophysiologist from a personal and historical perspective. *Int J Psychophysiol* 1995;20:83–141.
Loomis AL, Harvey EN, Hobart G. Potential rhythms of the cerebral cortex during sleep. *Science* 1935a;81:597–598.
Loomis AL, Harvey EN, Hobart G. Further observations on the potential rhythms of the cerebral cortex during sleep. *Science* 1935b;82:198–200.
Loomis AL, Harvey EN, Hobart G. Brain potentials during hypnosis. *Science* 1936a;83:239–241.
Loomis AL, Harvey EN, Hobart G. Electrical potentials of the human brain. *J Exp Psychol* 1936b;19:249–279.
Loomis AL, Harvey EN, Hobart G. Distribution of the disturbance-patterns in the human electroencephalogram, with special reference to sleep. *J Neurophysiol* 1938;1:413–430.
Magoun HW. Marshall LH, ed.*American neuroscience in the twentieth century. Confluence of the neural, behavioral, and communicative streams*. Lisse: Swets & Zeitlinger, 2003.
Marshall LH. The fecundity of aggregates: the axonologists at Washington University, 1922-1942. *Perspect Biol Med* 1983;26;613–636.
Marshall LH, Magoun HW. *Discoveries in the human brain. Neuroscience prehistory, brain structure, and function*. Totowa: Humana Press, 1998.
Millett D. Hans Berger-from psychic energy to the EEG. *Perspect Biol Med* 2001;44:522–542.
Niedermeyer E. Historical aspects. In: Niedermeyer E, Lopes da Silva F, eds. *Electroencephalography. Basic principles, clinical applications, and related fields*. 5th Ed. Philadelphia: Lippincott Williams & Wilkins, 2005;1–15.
O'Leary JL, Bishop GH. The source of cortical potentials. *Am J Physiol* 1936;116:115.
Offner F, Gerard RW. A high speed crystal ink writer. *Science* 1936;84:209–210.
O'Leary JL, Goldring S. *Science and epilepsy. Neuroscience gains in epilepsy research*. New York: Raven Press, 1976;119–152.
Penfield W, Jasper HH. Electroencephalography in focal epilepsy. *Trends Am Neurol Assoc* 1940;66:26–30.
Penfield W, Jasper HH. *Epilepsy and the functional anatomy of the human brain.* Boston: Little, Brown & Co, 1954.
Putnam TJ, Merritt HH. Experimental determination of the anticonvulsant properties of some phenyl derivatives. *Science* 85:525–526.
Renshaw B, Forbes A, Drury C. Electrical activity recorded with microelectrodes from the hippocampus. *Am J Physiol* 1938;123:169–170.
Renshaw B, Forbes A, Morison BR. Activity of the isocortex and hippocampus: electrical studies with microelectrodes. *J Neurophysiol* 1940;3:74–105.
Rheinberger MB, Jasper HH. Electrical activity of the cerebral cortex in the unanesthetized cat. *Am J Physiol* 1937;119:186–196.
Sachs E, Schwartz HG, Kerr AS. Electrical activity of the exposed human brain. *Tr Am Neurol Assoc* 1939;65:14–17.
Saul LJ, Davis H. Action currents in the central nervous system. I. Action currents of the auditory tracts. *Arch Neurol Psychiatry* 1932;28:1104–1116.
Saul LJ, Davis H. Action currents in the central nervous system. *Arch Neurol Psychiatry* 1933;29:255–259.
Scarff JE, Rahm WE Jr. The human electro-corticogram: a report of spontaneous electrical potentials obtained from the exposed human brain. *J Neurophysiol* 1941;4:418–426.
Schoenberg BS. Richard Caton and the electrical activity of the brain. *Mayo Clin Proc* 1974;49:474–481.
Schwab RS. Method of measuring consciousness in attacks of petit mal epilepsy. *Arch Neurol Psychiatry* 1939;41:215–217.
Schwab RS. *Electroencephalography in clinical practice*. Philadelphia: Saunders, 1951;1–7, 39–79.
Schwab RS, Cobb S. Simultaneous electromyograms and electroencephalograms in paralysis agitans. *J Neurophysiol* 1939;2:36–41.
Shepherd GM. *Creating modern neuroscience. The revolutionary 1950s*. New York: Oxford University Press, 2010;71–73.
Sherrington CS. *Integrative action of the nervous system.* New Haven: Yale University Press, 1906.
Spiegel EA. Labyrinth and cortex: electrencephalogram of cortex in stimulation of the labyrinth. *Arch Neurol Psychiatry* 1934;31:469–482.
Stone JL. Biography —Frederic A. Gibbs, MD. *Surg Neurol* 1994;41:168–171.
Sugar O, Gerard RW. Anoxia and brain potentials. *J Neurophysiol* 1938;1: 558–572.
Swartz BE, Goldensohn ES. Timeline of the history of EEG and associated fields. *Electroencephalogr Clin Neurophysiol* 1998;106:173–176.
Travis LE. Brain potentials and the temporal course of consciousness. *J Exp Psychol* 1937;21:302–309.
Travis LE, Dorsey JM. Mass responsiveness in the centra nervous system. *Arch Neurol Psychiatry* 1931;26:141–145.
Travis LE, Gottlober A. How consistent are an individual's brain potentials from day to day? *Science* 1937;85:223–224.
Travis LE, Herren RY. Action currents in the cerebral cortex of the dog and rat during reflex activity. *Am J Phsysiol* 1930;93:693.
Travis LE, Herren RY. The relation of electrical changes in the brain to reflex activity. *J Comp Psychol* 1931;12:23–39.
Travis LE, Knott JR. Brain potentials from normal speakers and stutterers. *J Psychol* 1936;2:137–150.
Travis LE, Malamud W. Brain potentials from normal subjects, stutterers and schizophrenic patients. *Am J Psychiatry* 1937;93:929–932.
Walter WG. The location of cerebral tumours by electro-encephalography. *Lancet* 1936;2:305–308.
Walter WG. The electro-encephalogram in cases of cerebral tumours. *Proc R Soc Med* 1937;30:579–598.
Walter WG. Electro-encephalography in cases of mental disorder. *J Ment Sci* 1942;88:110–121.
White BV. *Stanley Cobb: a builder of the modern neurosciences*. Boston: FA Countway Library, 1984.
Wikipedia. Alfred Lee Loomis (1887-1975). Wikipedia Foundation, Inc. Accessed November 25, 2011.
Williams D, Gibbs FA. The localization of intracranial lesions by electroencephalography. *New Eng J Med* 1938;218:998–1002.
Yeager CL. Electro-encephalography as an aid in localizing organic lesions. *Proc Mayo Clin* 1938;13:422–426.
Young RR. Robert S. Schwab, MD 1903-1972. *Arch Neurol* 1972;27;271–272.
Zottoli SJ. The origins of the Grass Foundation. *Biol Bull* 2001;201:218–226.

APPENDIX 1

List of the 50 Invitees Whose Acceptances Were Received for the Loomis Laboratory EEG Conference at Tuxedo Park, New York, November 10, 1935. Howard L. Andrews, S. Howard Bartley, Charles W. Bray, Detlev W. Bronk, Stanley Cobb, Kenneth S. Cole, Karl T. Compton, Hallowell Davis, Mrs. Hallowell Davis, A. J. Derbyshire, H. Flanders Dunbar, Joseph Erlanger, Gerald Evans, Jacob Finesinger, Alexander Forbes, T. W. Forbes, John F. Fulton, George Gammon, E. Lovett Garceau, Herbert S Gasser, Ralph W. Gerard, Frederic A. Gibbs, Mrs. Frederic A. Gibbs, H. Keffer Hartline, E. Newton Harvey, John P. Hervey, Samuel E. Hill, Hudson Hoagland, Garret A. Hobart, Herbert Jasper, George Kreezer, William G. Lennox, Erich Lindemann, William F. Loomis, Max Mason, Louis Wm Max, Myrtle B. McGraw, J. H. Means, John T. Menke, Floyd B. Odlum, Dudley Roberts, Margaret Rheinberger, David Slight, J. Roy Smith, Frederick Tilney, Warren Weaver, E. G. Wever, Horatio B. Williams, Theodore P. Wolfe, and Robert W. Wood.

APPENDIX 2

Charter ACNS Members: John A. Abbott, Robert B. Aird, Russell A. Anthony, Charles D. Aring, B. K. Bagchi, E. J. Baldes, Nicholas A. Bercel, Mary A. B. Brazier, Theodore J. Case, Paul T. Cash+, Robert Cohn, Chester W. Darrow, Hallowell Davis, A. J. Derbyshire, Robert S. Dow, George L. Engel, Knox H. Finley, Frederic A. Gibbs, John E. Goodwin, Milton Greenblatt, William Hawke+, Charles E. Henry, Hudson Hoagland, Paul F. A. Hoefer, Joseph Hughes, Herbert H. Jasper, Margaret A. Kennard, John Kershman+, John R. Knott, Margaret Lennox, William G. Lennox, W. T. Liberson, Donald B. Lindsley, Hans Lowenbach*, Theodore Lyman+, Clemson Marsh,.Richard L. Masland, Leslie F. Nims, James L. O'Leary, Mortimer Ostow+, Bernard L. Pacella, Margaret B. Rheinberger, E. Roseman, Robert S. Schwab, Donald Scott, Jr, H. M. Serota, Charles W. Stephenson, Hans Strauss, A. Earl Walker, and Charles L. Yeager*. *Charter Members Accepted at 4th Central Council Meeting of the Society, Shawbridge, Quebec, February 23, 1947, per Minutes of Robert S. Schwab, Secretary. +Charter Members included by Knott et al., 1992.