A Pre-History of the Problem of Broca's Aphasia

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INTRODUCTION

In 1865, Armand Trousseau introduced the term "aphasia" for what Paul Broca had called "aphemia," and several years later David Ferrier (Critchley, 1964, p.240) suggested that the inferior third frontal convolution of the left hemisphere be named "Broca's area." Since then investigators have been studying, interpreting and reinterpreting both the syndrome and the cerebral region. The purpose of this paper is to present a sketch of what was known about the anatomy and physiology of the human motor system at the time Paul Broca was writing about aphasia. The material will be presented in an historical progression from ancient times to the middle of the 19th Century. In addition, I will present some historiographical evidence for tracing information to Broca. Many questions as to exactly what Broca knew, or could be reasonably expected to know, have been cleared up by Francis Schiller's recent biography of Broca (1979). Arthur Benton (1965, p.315), had pointed out that many early observations and descriptions of aphasia were not always passed one, and as a result quite similar "discoveries" were made centuries later, as if for the first time.

ANATOMY AND PHYSIOLOGY OF THE MOTOR SYSTEM TO 1800

Not surprisingly, the distinction between sensation and movement was appreciated in ancient times. Edwin Clarke and C.D. O'Malley (1968, p.11) note that Herophilus (c. 300 B.C.) in his anatomical studies differentiated motor and sensory nerves. Erasistratus (c. 260 B.C.), another Greek anatomist, described how both types of nerves of the spinal cord originated in the brain. Rufus of Ephesus (fl. 98-117 A.D.), a physician and anatomist, wrote (Clarke and O'Malley, 1968, p.113) that, "The processes springing from the brain are the sensory and the motor nerves, with the help of which we are able to feel and to move voluntarily and which are responsible for all activities of the body." Soranus of Ephesus (98-135 A.D.), whose writings are known through the work of Caelius Aurelianus (fl. 450 A.D.), distinguished between sensory and motor impairments in patients and observed the difference between flaccid and spastic paralysis (Benton and Joynt, p.207). Mondino De'Luzzi (c. 1270-1326) produced systematic anatomical findings from dissections. He studied the structure and role of the cerebellum and felt that it might be the source of the motor nerves. The proximity of the 4th ventricle (the "posterior" ventricle) to the cerebellum suggested to him that memory as well as movement could be a property of cerebellar function. For centuries, memory had been placed in the posterior ventricle. The 17th Century anatomist, Thomas Willis, also contributed much to our understanding of the structures of the motor system. In his anatomy texts of 1672 and 1681 we find detailed descriptions of the cerebellum as well as of the corpus striatum. Willis, however, did not consider the corpus striatum to be motor but rather to be the area which received all sensations (i.e. the "sensus communis").

In addition, subsequent to the Hippocratic writers, it has been known that the nervous system is crossed; many early physicians had noted that trauma to one side of the head would cause paralysis on the opposite side of the body. In 1710, Francois Pourfour Du Petit (Clarke and O'Malley, 1968, p.283-284) published his anatomical and experimental investigations where he described the decussation of the pyramids at the medulla. Pourfour Du Petit had observed human cerebral wounds on one side of the brain which caused motor paralysis on the opposite side of the body. He produced similar results with lesion experiments on dogs. Therefore, his anatomical findings of the medullar crossings lent strong support to the notion of contralateral control (Clarke and O'Malley, 1968, p.283).

Questions of form vs. function immediately arose with the study of anatomy. Clarke and O'Malley (1968, p.15) claim that Galen's (129-199 A.D.) most outstanding contributions to medicine were his experimental studies and his insistence upon the necessity of relating form to function. Cartesian doctrine, however, as far as mental function was concerned, held that form and function were separate; one could not be deduced from the other. Psychological phenomena could only be experienced and understood through subjective immediacy. Anatomists and physiologists could only manipulate the physical realm—not the mental. Consequently, reasoning about mental function (of the "soul") from physical structures was felt to be unwarranted. Karl Figlio (1975, p.179) pointed out that the French Academy of Sciences criticized the work of Gall, not for his anatomical work but rather for the functional conclusions he reached based upon anatomical structure. In addition, John and Charles Bell, in their introductory remarks to their text on anatomy (1804) wrote, "No sensible man will expect, in the most minute and unwearied investigation of the structure of the brain, to find the explanation of its function" (Figlio, 1975, p.180).

The localization of psychological function up to the beginning of the 19th Century was usually speculative and not based upon experimentation or clinicopathological reasoning. By the time Thomas Willis was writing, most all scientists had given up the cardiocentric localization for the cephalocentric localization of psychological functions (perception or imagination, reasoning, cogitation, judgment, and memory). Furthermore, most had shifted their attention from the ventricles (Clarke and Dewhurst, 1972, pp.10-48) to the solid portions of the brain. Willis focused upon the solid portions of the brain, and his functional localization was not atypical of late 17th and 18th Century anatomists and physiologists. For him, the corpus striatum received all sensations, the white matter fibral system was the seat of the imagination, and memories were stored in the cerebral cortex. For Willis, unlike the Greeks, the notion of imagination was more closely aligned with reasoning than with sensory perception. As I will demonstrate, Broca placed heavy importance on the role of the cortex for memory. From most accounts, Willis seems to include the whole medullary mass when using the term corpus striatum. This was not unreasonable in the 17th Century since, although the various structures had been differentiated anatomically (medulla oblongada, corpus striatum, thalamus and pons), they were viewed functionally as a continuum considered to be the "sensorium commune." Willis' concept of the sensorium commune was that it served as a "way-station," so to speak, for the sensations coming in and for movements going out. Involuntary movements were controlled by the cerebellum and voluntary movements were the domain of the cerebrum. It is from the work of Willis, then, that we are provided several crucial components, later observed in Broca's thinking: (1) the corpus striatum as a lower center involved in movement; (2) memory mediated in the cortex; and (3) volitional movements directed by the cortex, by which Willis meant that it was a "willful" direction and not a cortical motor stimulation.

The notions of voluntary vs. involuntary (reflex) movements and the relationship between the "will" and volitional movement had been discussed long before Willis. Furthermore, the concepts of the "intellect" had always been linked to willful volitional acts. All of these functions were understood to be products of the "soul." For instance, Rufus of Ephesus (fl. 98-117 A.D.) was aware that the motor nerves from the brain were involved with voluntary movement. Even before Rufus, Plato and Hippocrates claimed that willful movements stemmed from the brain. In addition, Galen (129-199 A.D.) wrote (Clarke and O'Malley, 1968, p.15), "...Therefore, we shall agree with Plato and Hippocrates...that the brain is the source of voluntary motion." Since the soul was the realm of willful phenomena as well as the mechanism of the intellect, it was natural to consider language to be expressed through willed movements of the intellect and as a direct product of the soul. As Aristotle (Critchley, 1964, p.231) put it, "...the mind is the source of speech."

EARLY OBSERVATIONS OF MOTOR APHASIA

The descriptions of what were likely to have been motor aphasias before 1800 most often lacked any indication of the site of lesion in the brain. Up to the turn of the 19th Century, clinco-pathological studies of adult aphasic syndromes were rare. Furthermore, given the accepted views of the higher functional nondivisibility of the brain, it made little sense to seek the locality of lesions. One sees primarily in these descriptions observational reports of patient behavior with no concomitant neuropathological correlation.

In Benton and Joynt (1960), Critchley (1964) and Benton (1965) we find reports of early descriptions of several types of aphasia—most of which were motor in nature. I will restrict my comments to what appear to be the nonfluent syndromes. If one goes back thirty centuries before Christ to the famous Edwin Smith papyrus, he will find a case of a speechless patient with a traumatic lesion described briefly (Critchley, 1964, p.232). Later on, the Hippocratic writers (ca. 400 B.C.) described subjects who were "anaudos" (speechless) and those who were "aphonos" (voiceless) (Benton and Joynt, 1960, p.206). However, from most of the observations and translations, we cannot always be sure when the writers were describing aphasia, dysarthria or loss of voice—such as occurs often with hysteria. In addition, the Hippocratic writers noted that patients with transient "anaudos" also presented with, "...paralysis of the tongue, or of the arm and right side of the body" (Benton and Joynt, 1960, p.206). Consequently, the Hippocratic writers should be credited with first observing that speech disorders could be accompanied by a right sided paralysis.

Johann Schmidt (1673), Peter Rommel (1683), Olof Dalin (1745), and G.B. Morgagni (1762) all described motor aphasia with right-sided paralysis (Benton and Joynt, 1960, p.209-213). The descriptions of Rommel and Schmidt are considered to be the most outstanding early studies of motor aphasia. Rommel referred to the syndrome as a "rare aphonia"; the patient could not speak fluently, nor repeat. However, the patient could comprehend written and spoken language and had retained the capacity for "serial speech"

(Lord's Prayer, Apostles' Creed, some biblical verses and other prayers) (Benton and Joynt, 1960, p.210). Dalin wrote that his patient, despite his complete loss of speech, could still sing certain hymns that he knew before the illness (Benton and Joynt, 1960, p.211). Aside from noting that patients such as these could not speak, but could comprehend, Morgagni stressed that there was most often a right sided paralysis and that subsequent autopsy frequently revealed disease or injury of the left cerebral hemisphere. However, he never correlated any of this unequivocally with the aphasia (Benton and Joynt, 1960, p.213). The writings of Willis also contain a few descriptions of motor aphasia where the patient had "a palsie ...of the whole right side," or where the patient was concurrently "paralytick in all his right side" (Critchley, 1964, p.234).

Still another significant aspect of motor aphasia had been appreciated well before the turn of the 19th Century. This was the observation that faulty articulation of speech did not necessarily imply lingual paralysis. Soranus of Ephesus in the 2nd Century A.D. distinguished speech output problems due to paralysis of the tongue from cases of loss of speech resulting from some other disease (Benton and Joynt, 1960, p.207) where, "the tongue does not change color or the condition of its surface, or lose sensation or mobility, or change position" (Benton and Joynt, 1960, p.207). The famous Renaissance physician, Paracelsus, also observed that defects of speech could occur in the absence of paralysis (Benton and Joynt, 1960, p.208). The 16th Century medical scholar Johann Schenck von Grafenberg wrote (Benton, 1965, p.317) the following, "I have observed in many cases of apoplexy, lethargy and similar major diseases of the brain that, although the tongue was not paralyzed, the patient could not speak because the faculty of memory being abolished, the words were not produced." Johann Gesner (1770) described a case where the "...expressive aphasia could not be interpreted as merely a paralysis of the tongue or any other organ" (Benton and Joynt, 1960, p.214).

In sum, a good deal concerning motor speech disorders had been described before 1800: (1) speech output difficulty with paralysis of tongue; (2) without paralysis of the tongue; (3) concomitant right sided paralysis; (4) relatively intact comprehension; (5) left hemisphere lesions; and (6) retention of automatic speech, serial speech and singing. I would, however, concur with Benton (1965, p.321) that prior to the turn of the 19th Century, "Beyond the recognition that aphasia was a manifestation of disease of the brain, there was little interest or knowledge in the neuropathological basis of the disorder."

IMMEDIATE PRECURSORS OF BROCA

In reality, it was not the prior descriptions of motor aphasia that provided the impetus for Broca's efforts, but rather the new theories of localization of function in the cerebral cortex. These theories were the product of early 19th Century phrenology. In addition to the phrenological influence, the late 18th and early 19th Century saw the rise of experimental physiology as well as the development of clinico-pathological methodology.

Broca's contributions must be understood within the context of the so-called "Bell-Magendie" motor-sensory dichotomy. In order to understand fully how the Bell-Magendie principle progressed, one must be aware of how the "sensorium commune" came to be physically explorable and knowable. Figlio's (1975) thesis is that the 18th Century bore witness to the emergence of the hitherto purely phenomenological "sensorium commune" as a "natural object." Both Albrecht von Haller and Samuel Thomas Sömmering experimented on the lower nervous structures in the latter half of the 18th Century, searching for areas whose stimulation provoked convulsions. Even by the late 18th Century, the "medullary mass" (medulla, corpus striatum, thalamus and pons) was considered to be continuous. Sömmering (publishing his ideas in the period 1791-1796) conceived of the medullary mass as interacting in some fashion with the sensorium, which he felt was located in ventricular fluid; he could find no effect from cortical stimulation. Up to this period, the sensorium was a useful concept referring to that point at which all sensory nerves converged. It was the seat of the "unity of consciousness," and it was there that the "will" was located. Nevertheless, movement was not emphasized to the extent that sensation was until the dawn of the 19th Century. Consequently, most descriptions of the sensorium considered it to be a nervous endstage for all perceptual modalities. Sensation had been highlighted over movement because epistomological theories tended to focus upon how we learn and attain knowledge through perceiving the world and then how we interrelate the various perceptions by association. Early association psychologists stressed sensations almost to the exclusion of movement, (except for David Hartley) and they invoked the concept of the sensorium as the seat of all sensation. Walther Riese and E.C. Hoff (1950, p.56) point to the various localizations given for the sensorium: cerebral ventricles, corpus callosum, corpus striatum, pons, corpora quadrigemina, thalamus, and others. As I mentioned above, many took the sensorium to be the whole of the medullary mass. By the last quarter or so of the 18th Century, the stage was set for the experiments of the Scottsman, Charles Bell, of the Frenchman, François Magendie, and for the motor-sensory principle which followed from their work.

Sir Charles Bell (1774-1842) is usually credited with first proposing the motor-sensory division at the level of the spinal cord in 1807 (Carmichael, 1926, p.193). Bell was actually an outspoken critic of animal physiological experimentation (Young, 1970, p.46-47). He drew his conclusions largely from the study of anatomy and natural motions (Young, 1970, p.48). Magendie was considered the father of experimental physiology in France. Joseph Schiller (1968, p.79) has written that all the history of scientific physiology in the first decades of the 19th Century revolves around Magendie. It has been said that what Bell described in 1807 anatomically, Magendie verified physiologically 14 years later in 1821. Young (1970, ftn 8, p.78) goes a step further and writes that, "The thesis was not generally considered to be proved until after Johannes Mueller's experiments in 1831." Two immediate consequences of the Bell-Magendie "law" were forthcoming. First, there was now clear experimental evidence that the medullary mass was not simply a wholistic functional continuum but had discrete motor-sensory characteristics—discoverable through experimentation. The second result was that ultimately the "will," "memory," and the "intellect" were placed above the medullary mass in the cerebral cortex. For our purposes, then, the cortical "will" directed the medullary motor centers for volitional movement. Magendie, in a later publication of 1843 wrote (Young, 1970, p.87) that, "...the will and the action of the brain, which produces directly the contraction of the muscles, are two distinct phenomena." He placed the "will" in the cerebral hemispheres and the "direct" motor center in the "medulla spinalis." We can appreciate which functions were actually ascribed to the volitional system by Magendie when he described motions from the lower centers after those centers had been separated from the cortex: "When, we prevent the will from determining and directing these motions...they are nevertheless executed; however,...they become irregular in extent, rapidity, duration, and direction" (Young, 1970, p.87). Thus, for Magendie, the will was a type of "cerebral action" which caused, but did not directly execute, volitional movements. The actual production of the muscular contraction was associated with the spinal nerve roots, spinal cord, corpora quadrigemina, cerebral penduncles, thalamus, corpora striata and cerebellum. Once the posterior spinal roots were shown to be sensory and the anterior roots to be motor, the remainder of experimental sensory-motor physiology was, "...primarily concerned with tracing the progressive application of this functional division to successively higher parts of the central nervous system..." (Young, 1970, p.79). We can locate the decade (1860-1870) of Broca's principle contributions to the study of aphasia within this progressive movement up the neuraxis at a point just short of the cerebral cortex. At the time Broca was writing and presenting material to the Anthropological Society of Paris, the highest direct motor center was thought to be the corpus striatum, while the highest discretely localizable sensory center was felt to be the thalamus. Robert Young (1970, pp.111-112) gives credit to Robert Todd and William Bowman, who in 1845 ultimately carried the Bell-Magendie principle to these structures. Young (1970, p.112) quotes from their text on anatomy and physiology: "The corpora striata and optic thalamus bear to each other a relation analogous to that of the anterior to the posterior horn of the spinal gray matter. The corpora striata and the anterior horns are centres of motion; the optic thalami and posterior horns are centres of sensation." Before 1845, Flourens and Mueller had moved the dichotomy up to the medulla oblongada. Interestingly enough, as early as 1809, Luigi Rolando had evoked contractions from electrically stimulating the cerebral hemispheres of a pig. Although Rolando concluded from this that the cortex contained actual fibers for volitional movement, his observations fell on deaf ears because the scientific paradigm of the time accepted the view of a non-motoric cortex. This was coupled with the criticism that in electrical excitation studies, the movements produced were actually due to the direct spread of an intense current through the unstimulatable cortex to the lower structures.

Before turning to the influence of the phrenologists, some discussion of the development of theories of movement and of the concept of "muscle sense" is in order. This essentially dichotomous concept of muscle sense combined motor and sensory (movement and sensation) phenomena. Through the work of David Hartley, Johannes Mueller and Alexander Bain, association psychology developed into a general psychological theory, which increasingly included motion—both voluntary and involuntary. The basic idea was that moving a limb, for instance, would give rise to a sensational impression of that movement recorded within the nervous system. Repeated instances of the movement would further entrench the sensory impression; an association was accordingly built up between the two. Subsequently, the sensory impression would acquire the power of "calling up" the movement. By 1842, Mueller had developed this "motor theory," which Young (1970, p.116, 119) sees as a synthesis of the Bell-Magendie sensory-motor physiology and association psychology. Its influence was soon evident in Bastian's (1869) insistence upon a kinaesthetic component in motor aphasia. Nevertheless, in the early 19th Century there was still a distinction between sensory-motor function (thalamus—corpora striata) on the one hand and "intellect" and "will" on the other. In addition, Flourens' influence was extensive, and most researchers believed the cortex to be unresponsive to irritation and hence better conceived of as the seat of the will and intellect—not of raw sensory-motor function. The phrenologists, on the other hand, were not at all hesitant in assigning discrete functional roles to cerebral zones.

No discussion of direct precursors of Broca would be complete without consideration of the contributions of Franz Gall (1758-1828). Arthur Benton (1965), MacDonald Critchley (1964), Robert Joynt (1964), Francis Schiller (1979), Robert Young (1970) and Walther Riese (1977) have all alluded to the continuity from Gall to Broca. Haymaker and Schiller (1970, p.31) reflect the opinion of most historians of neuropsychology when they write, "Franz Joseph Gall, the scholar and neuroanatomist, is buried under Gall, the showman and phrenologist..." Hecaen and Albert (1978, p.13) write that, "Gall, by introducing the concept of phrenology, was the first to propose a systematic relationship between specific psychological components of human behavior and specific cerebral regions." Temkin (1953), Ackernknecht (1958), Young (1970), Bynum (1975) and others have stressed the excellence of Gall's anatomical contributions. Through his anatomical studies he clearly established the basic division between white and grey matter. He recognized the grey matter as "the matrix of the nerves" and noted the "conductor" function of the white matter, which he observed to be fibrous in nature. He is usually credited with contributing to our modern understanding of the CNS pathways: U-shape fibers, association fibers, projection fibers and commissural fibers. He provided further description of the pyramidal decussation and added evidence that many cranial nerves originate in the medulla as well as in the pons.

Although considered by most to be a materialist, Gall always considered function primary, anatomical localization secondary; he repeatedly claimed that direct study of the brain could never be a substitute for psychology (Young, 1970, p.27). Gall's reasoning with respect to the nervous system and its relationships to behavior are of considerable importance in the history of neuropsychology. In establishing clear guidelines for isolating and discovering behavioral faculty categories, Gall arrived at the concept of separate disruptability of function, which, as a way of arguing about functional autonomy, is still used today. In fact, Galen, in the 2nd Century, reasoned that each mental faculty could be separated from the others on the basis of their separate disruptability (Clarke and O'Malley, 1968, p.462). Gall isolated functions by observing their pathological manifestations and their changes independent of other functions. Furthermore, he reasoned that if two functions had different developmental patterns and time tables, they were separable. Gall claimed that functional separability implied distinct mechanisms, which in turn had to have different anatomical locations.

Gall, as well as Spurzheim, made substantial contributions on different aspects of language and its disturbances. To begin with, Gall and Spurzheim (1935, vol. 2, p.166-167) thought that mental faculties were doubly represented in both hemispheres and consequently that a faculty might not be destroyed if only one hemisphere were damaged. No one in the first quarter of the 19th Century was aware of lateralized hemispheric function, and few if any were cognizant of Marc Dax's alleged pronouncements on unilateral left hemisphere function for language and its correlation with right-handedness. Furthermore, clinico-pathological evidence for exact localization of the faculty of speech within the anterior lobe was so imprecise that even by 4 April 1861, Auburtin (Clarke and O'Malley, 1968, p.493) had to admit that, "...the anterior lobes are of considerable size and the precise point where the faculty of speech resides has not yet been determined."

Nevertheless, Gall distinguished between a general faculty of language, which for him was the faculty of attending to and distinguishing words. Of utmost importance for this faculty was the recollection of words or "verbal memory." This was faculty (#33) located at the orbits. In Gall's words (Clarke and O'Malley, 1968, p.479), "I regard as the organ of memory of words that part of the brain which rests on the posterior half of the orbital roof..." When this cortical area was large, the result was that "...the eyeball must be pushed forward" (Clarke and O'Malley, 1968, p.479). This faculty was primarily for comprehension and verbal memory. By "memory," Gall meant rote memory of verbal material—often memorizing poems, lines in plays, sylloquies, etc. For Gall, verbal memory involved the sense of words, not necessarily their articulation. Admittedly, there is some ambiguity in Gall's use of the term "memory" here, since at times he appears to be talking about the ability to simply memorize verbal material and at other times he seems to be describing what we now understand as long-term lexical memory. Nevertheless, Gall conceived of separate faculties for verbal memory and verbal articulation. Recall his reasoning for separating these: one could be damaged, while the other remained intact. In Gall and Spurzheim (1835, vol. 5, p.17) there is a description of a patient who, although suffering a right sided paralysis, appeared to have word- (and proper name) finding difficulties with well-articulated indefinite pro-forms as "Mr. Such-a-One." In addition, there were cases described by Gall and Spurzheim (1835, vol. 5, p.23) where the patient was "...unable to express his sentiments and ideas by spoken language." They noted that the patient had not lost his intellectual powers, could comprehend and could demonstrate that he had not lost his verbal memory in terms of the sense of words, since, although incapable of articulating "arm chair" when asked about it, the patient, "...answered me by sitting down in the chair." It becomes clear that Gall divided language into distinct aspects of memory—memory for the sense of words, memory for the articulation of words, and even (Head, 1926, p.11) a memory for grammatical patterns. These faculties were all considered to be intellectual, since at that time all memory systems in general were viewed as products of the intellect. Of course, the point was that patients could lose one type of memory and not another; as a consequence, "memory" was gradually parcelled into separable entities. Gall and Spurzheim believed (Gall and Spurzheim, 1835, vol. 2, p.115) that, "...the intellectual faculties of the soul are seated in the anterior and upper part of the head." In general, then, for Gall and the phrenologists, the cerebral organs mediating these "intellectual faculties" of language and speech were located in those anterior frontal convolutions which border the orbits. In reality, however, all one needed to do in the early 19th Century in order to corroborate this was to show some language deficit secondary to frontal lobe damage; i.e. roughly anterior localization. Further, it could be in either the left, right, or both hemispheres.

Memory for articulate language is the crucial notion to focus upon with respect to the continuity from Gall to Broca, since aphemia was essentially understood to be an articulatory disorder. Gall felt (Head, 1926, p.7) that, "The human nervous system does not differ fundamentally in structure from that of the beasts; its functions are identical in quality but more highly developed." Thus, for Gall, animals have a faculty of language as well— but theirs is primarily communicated and received via gestural signs. Gall and Spurzheim (1835, vol. 5, p.34) wrote that, "...all possible signs, the language of gesture as well as verbal language, are the product of the activity of the faculties, inclinations, affections, and passions of men and animals." Gall and Spurzheim are clearly claiming that language is not species-specific. This issue has recently been revived by William Orr Dingwall (1975, 1979) and by Philip Lieberman (1975). Articulatory exteriorization of language is obviously superior to limb gestures; it is species-specific in humans and has significant evolutionary advantages, which were clearly appreciated by Gall and Spurzheim. The memory of articulate speech in Man is then quite important, and the faculty for that memory accordingly takes on á special role for human language. There is a very significant passage from Gall and Spurzheim (1835, vol. 5, p.36) concerning the efficiency of verbal articulatory communication of language in Man:

> Verbal language, it is true, is of all languages and of all possible artificial signs, the most convenient to employ; it needs neither instruments nor preparations as for traced figures; it requires neither space nor freedom of limbs as for gestures; in whatever position one is, maimed, sick, acting, he can produce this language. It is heard as well by night as by day, at a distance as well as near, without disturbing one's self, without turning toward the speaker, without being earnestly attentive, without even wishing it. These properties, which sounds possess, of being the most natural and the most convenient of signs, cause them to become by custom the most habitual of all, and within us they are the most intimately connected with the ideas which they represent.

Unfortunately, as we mentioned above, the phrenological contributions concerning the faculty of articulate speech did not include any unequivocally clear-cut anterior lobe localization. This, of course, was left to Broca.

Aside from Jean Baptiste Bouillaud and Ernest Auburtin, there are several other intermediaries connecting phrenological findings with Broca. Combining the information in Ackerknecht (1958), on the contributions of Gall, with Schiller's (1979) recent biography of Broca, we can see that Broca came into contact with Gall's work at several points. For instance, Ackerknecht (1958, p.149) writes that Soury studied with Gall, while Schiller (1979, pp.254-257) notes that Soury, a well known historian of the nervous system, was admired by Broca. Ackerknecht (1958, p.152) says of Foville, the famed anatomist, that he was indebted to Gall; in Schiller (1979, p.256) we see that Broca studied with Foville. Foville envisaged the cerebral cortex as being in its entirety an organ of the intellect—but, of course, so did Pierre Flourens, who was an ardent anti-phrenologist in most respects. At least Gall considered all faculties in the anterior lobes to be intellectual. It is well known that in his August, 1861 (trans. von Bonin, 1960) paper, Broca accepted that it was an open question (Young, 1970, p.143) whether aphemia and speech in general involved intellectual or motor functions. It is also well-known that he opted for the intellect—calling it the intellectual faculty for the memory of articulated sounds. He was thus in agreement with all three: Gall, Flourens and Foville. The disagreement between Flourens and the phrenologists was not over whether the cortex was the mediator of intelligence, but rather it involved the discrete parcelling out by the phrenologists of distinct intellectual functions, faculties or memories in different cerebral areas. This was anathema to those who, like Flourens, believed that the cortex was an unanalyzable functional whole, which served the intellect and the will equipotentially. This, of course, was the widely accepted conception of the "sensorium," as pointed out earlier. In addition, Schiller (1979, p.17) documents the fact that Broca's early medical school schedule included a course in "Therapeutics" with Andral, who, according to Ackerknecht (1958, p.152), was once president of the Société de Phrenologie and was indebted to Gall for many of his ideas. In addition to Soury, Foville and Andral as presumed sources for phrenological influence upon Broca, the most well-known connections from phrenological theory to Broca were provided by Jean-Baptiste Bouillaud and Ernest Auburtin (Head, 1926, Pt. I, pp.13-29; Clarke and O'Malley, 1968, pp.489-494; Stookey, 1963; Young, 1970, pp.134-149), especially concerning language and speech localization in the cortex.

In a series of publications from 1825 to 1848, Bouillaud presented clinico-pathological data purporting to support and confirm Gall's location for the organ of articulate language. However, it must be stressed again at this point that Gall had delineated several different language-related faculties for the anterior lobes. Moreover, as I said earlier, all one had to do, or so it seemed, was to demonstrate some form of "pert (loss) de la parole (speech)" together with some frontal lobe involvement in order to "confirm" Gall's theory. Recall that even by 1861, Auburtin admitted that there was little if any real specificity <u>within</u> the frontal regions for the localization.

Nevertheless, Bouillaud's ideas were very important, and in many aspects clearly antedate Broca. For one thing, Bouillaud distinguished carefully between: (1) the lower (subcortical) nerves and peripheral vocal tract musculature for speech; (2) a faculty (an intellectual one involving the "memory" for the movement procedures) for the articulation of words; and (3) another faculty for memory of the "senses" of words. Quite obviously, he was drawing from Gall. Like Mueller and Bain (Young, 1970, Chapt. 3), Bouillaud hypothesized that most all complex movement patterns—especially those of speech—were directed by intelligence and volition. Intelligence and the will were cortical phenomena and "played upon" the lower motor centers, which gave rise to the "raw" or "direct" nervous innervation. For speech, the cerebral center was in the anterior lobes, but again we search in vain for a specific zone. For instance, Bouillaud's third conclusion in his 1825 paper (Clarke and O'Malley, 1968, p.491) states that, "This cerebral center occupies the anterior lobes." In addition, there is some interesting evidence that Bouillaud was at least somewhat ambivalent on the exact contribution of the cortex for speech innervation. In the Clarke and O'Malley (1968, p.491) translation of Bouillaud's 1825 article we see the quandary: "...the nerves which animate the muscles which cooperate in the production of speech, for example, have their origin in the anterior lobes, <u>or at least have essential communications with them</u>." (underlining - HWB) Obviously, Bouillaud, as well as Broca thirty-six years later, was forced into this vacillation due to the constraints set forth by the limited progress of the Bell-Magendie principle. We recall the succinct remarks of Broca in his August, 1861 paper (trans. von Bonin, 1960, p.70): "Everyone knows that the cerebral convolutions are not motor organs." Not until the demonstrations of cortical excitability by Fritsch and Hitzig (1870) could any center higher than the corpus striatum be considered motor in the sense of "raw" innervation. Therefore, Bouillaud's caveat was well motivated at the time. Nerves which innervate muscles for voluntary movement might not have their origin in the anterior lobes, but they must at least "communicate" somehow with the anterior lobes. Of course, Bouillaud did not enter into a discussion of just what kind of "communication" he conceived of. I would claim that what we have here is an early 19th Century "mind-brain" barrier, or perhaps "soul-brain."

Bouillaud's notion of the special "memory" for articulation was practically borrowed in toto by Broca. The nature of the faculty of articulated speech involved a particular kind of memory of the procedure one has to follow in order to articulate words. Furthermore, this type of memory could be isolated from other memories. The loss of memory for speech, although this was an intellectual faculty, did not mean the loss of the whole of intelligence. Bouillaud realized that these patients with "pert de la parole" had not necessarily lost other intellectual capacities. Furthermore, many could comprehend both spoken and written language. In 1839, Bouillaud made special note of the fact that some of the cases of loss of speech were not accompanied by writing problems. For him, this separability provided even more crucial support for isolating an autonomous faculty for speech output alone.

To a large extent, the doctrine of cerebral localization of function from the turn of the 19th Century on was promulgated by the clinico-pathological method, and forms of reasoning and argumentation took shape accordingly. The whole enterprise assumed a largely inductive view of things; it essentially reflected the clinical thinking of physicians. Based on prior correlated observations of some localized lesion X and some syndrome Y, in a future case, if we witness Y (the syndrome) then we predict X (a lesion in a certain part of nervous system). Byron Stookey (1963) documents two famous inductive wagers—one by Bouillaud, the other by Auburtin. Both presumably laid their localization theories on the line. Bouillaud, in January of 1848, offered 500 Francs to anyone who could produce a patient with a profound deep lesion of the anterior lobes but with no speech problem. Bouillaud was predicting the syndrome from the lesion. Later, on April 4th 1861, Auburtin predicted a loss of speech and claimed he would renounce his ideas if at autopsy the anterior lobes were found to be normal. As it turns out, Bouillaud eventually lost his wager to Alfred Velpeau in 1865 (Schiller, 1979, p.199), who did observe a patient with destroyed frontal lobes but with no speech problem. Schiller (1979, p.199) writes that, "After a long and heated discussion, Bouillaud had to pay." But, did this "negative" case disprove anything? The answer is no. What it did do, and in fact what all ensuing negative cases did, was to force further examination in order to explain the lack of confirmation of what, by inductive reasoning, had been likely to occur. Non-confirmatory findings do not and cannot in fact "disprove" an inductive theory. Bertrand Russell (1912, pp.62, 68) observes that things which in the past have been observed to occur together (syndrome and lesion in certain cerebral zones, in our case) may not be found together in some future case, but to the extent that they have been found together in a great many cases, the probabilistic statement that they will co-occur in some future instance is quite valid. An occasional negative case certainly did not appear to worry Broca. For instance, regarding an earlier negative case of Charcot—a patient with aphemia from a supramarginal gyrus lesion—Broca (Schiller, 1979, p.190) wrote, "One negative fact does not destroy this series of positive ones; in pathology and especially in cerebral pathology, there is no rule without some exception." A great deal of knowledge in science actually accrues through attempts to explain negative cases, but valid inductive inference is never "disproven." In any event, the localization position still holds today, and even more strongly in its weaker form, which simply claims that damage to certain cerebral zones typically leads to certain predictable syndromes. This weak version of the localization doctrine can be put another way: There are certain types of functions which are predictably vulnerable to disruption secondary to damage of specific cortical regions. The strong claims, of course, resulted from phrenological reasoning and were made by Broca as well as by Gall, Spurzheim, Bouillaud and Auburtin. Those claims were that the seat (siege) of the faculty of articulate speech was located in the anterior lobes. Broca's principal contribution was to more precisely sharpen that localization upon the inferior foot of the third frontal convolution within the anterior lobe, and several years later to single out the left hemisphere as the dominant one.

CONCLUDING REMARKS

In this paper I have attempted to provide an outline of what was generally known about the anatomy and physiology of motor systems up to the time Broca presented his first cases of aphemia. By 1860, the motor-sensory dichotomy had reached the basla ganglia and the thalamus, respectively. The cerebral cortex was still not considered to mediate in any direct way motor or sensory stimuli; this took place in the lower centers. Most everyone felt that the cortex was the seat of the will and the intellect. One hundred years before, the whole medullary mass had been viewed more or less as the cortex was in 1860 (i.e. as a "sensorium commune"—wholistic, continuous and indivisible), but the growth of experimental motor-sensory physiology parcelled out motor-sensory functions on the way up the neuraxis, and at the cortex, the phrenologists were boldly localizing functions of a higher sort. By 1860, the only remaining structures for the "soul" were the cerebral hemispheres, but again, the "soul" itself was being threatened by phrenologists.

Descriptions of aphasia between 1800 and 1860 had shown that speaking and comprehending language could be separately disrupted by brain damage. Words could be "forgotten" as a consequence of a stroke (apoplexy) in patients who could nevertheless articulate well, and there had been many descriptions of articulatory disorders without loss of the "sense" of words. Since language was considered "intellectual," however, each separable aspect of language had to have a distinct cortical seat. Thus, the intellectual faculty for memory of the procedures for articulating words was assigned an autonomous role, since that faculty alone could be disturbed. It unwittingly fell to Broca to suggest an exact localization for this faculty. He did just that, and the ensuing course of the history of Broca's aphasia can be characterized as a series of efforts to either confirm or deny this specific localization, or to refine the description of the phenomenological aspects of the symptom.

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