

Broca, prisoner of his time

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ABSTRACT

On April 18, 1861, French physician Paul Broca addressed the Anthropological Society of Paris to present the case of a patient who had suffered speech loss associated with a lesion in the third convolution of the left frontal lobe. This finding would be the first evidence of the relationship between language and the brain's functional organisation. Broca's assertion was revolutionary in light of the prevailing belief that the brain was a symmetrical organ. His contemporaries opposed the idea that two halves of the same organ, having the same location, the same organisation, and apparently the same detailed structure, had not been assigned identical functions by nature. Despite the evidence, Broca was not ready to challenge the 'law' of organic duality; he maintained an intense inner struggle, in which his clinical observations clashed with the available body of knowledge. Like his contemporaries, Broca was a prisoner of his time.

KEYWORDS

Frontal lobe, brain injury, cerebral localisation, aphasia, 19th century history, neurosciences

Introduction

On 18 April 1861, Paul Broca (1824-1880) presented a brief case report before the Anthropological Society of Paris that would revolutionise the study of neurosciences.¹ The case report described a patient aged 51 years, recently deceased, who had lost the ability to speak. The autopsy revealed a lesion in the third frontal gyrus of the left hemisphere that could explain the patient's language impairment.^a Broca presented a second case with similar characteristics that same year, featuring another lesion in localisation described above.³ Subsequently, Broca would have the opportunity of studying multiple patients with similar disorders; these cases confirmed the relationship between the ability to produce articulate speech and the third frontal gyrus of the left hemisphere.^{4,5} Two years later, in 1865, Broca concluded, "*nous parlons avec l'hémisphère gauche*" (we speak with the left hemisphere).⁶ This is the general outline that most textbooks provide on the subject of Broca's findings. However, this view omits information that is highly relevant to our understanding of the scientific climate in which Paul Broca and his contemporaries worked.

Nobody questions the phenomenon of hemispheric specialisation today, but in mid-19th century France, the

scientific community unanimously held that the brain's two hemispheres were identical duplicates. One of the main proponents of this principle was the father of modern histology, François Xavier Bichat (1771-1802). In his text *Recherches physiologiques sur la vie et la mort* (1800), Bichat divides life into two categories: organic life (*vie végétative*) and animal life (*vie de relation*).⁷ According to Bichat, organic life is regulated by organs that are asymmetrical, such as the heart and intestines. Organic life is associated with the passions and the body's metabolic functions. Animal life, which is related to memory and intellect, is located on a higher plane, and its organs are characterised by their symmetry and harmony (e.g. eyes and ears). Organic and animal life then interact through the cooperation of three organs: the heart, lungs, and brain. The brain, which is necessary for animal life, is a symmetrical organ; any change in its symmetry would create chaos within the body. Bichat hypothesised that symmetry in an organ's

^a Paul Broca inspected a patient's brain visually and observed a superficial lesion in the left frontal lobe. In 2007, Dronkers et al.² examined the same brain using high-resolution magnetic resonance imaging. Their examination revealed lesions in the left inferior frontal gyrus, inferior parietal lobe, and the anterior region of the superior temporal lobe. They also detected lesions in the putamen, globus pallidus, head of the caudate nucleus, and the external and internal capsules; the insular cortex was completely destroyed. The right hemisphere contained no lesions.

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structure was indicative of the symmetry or harmony of its function. This idea would give rise to the so-called law of symmetry: the notion that two parts with essentially identical structures could not function in different ways. One of the first intellectuals to consider the law of symmetry as an irrefutable truth was a man who would come to revolutionise knowledge about the functional organisation of the brain: Franz Joseph Gall.



Figure 1. François Xavier Bichat (1771-1802)

In the late 18th century, Franz Joseph Gall (1758-1828) stated that just as the body contains organs associated with certain physiological functions, the brain is also made up of 'mental organs', each of which manages a specific task.⁸ Gall identified 27 such mental organs, which were located symmetrically in both hemispheres of the brain. In his writings, Gall supports the idea of functional organisation being present in the cerebral cortex, but he mentions no functional differences between the two hemispheres. More precisely, he states the opposite. In consonance with the law of symmetry proposed by Bichat, Gall believed that each of the hemispheres was an exact copy of the other, meaning that either one would constitute a complete version of the mind. If both hemispheres are structurally symmetrical, they must also be functionally identical. In this way, if one hemisphere suffers an injury, the other hemisphere will be able to assume its functions. In cases in which unilateral lesions resulted in loss of function, Gall posited that the function must depend on balance or symmetry

between the two hemispheres, and that the lesion had therefore altered the brain's bilateral harmony.

He initially called his doctrine *Schädellehre* (doctrine of the skull) before changing it to *Organologie*, and last of all, *physiologie de cerveau*. The term 'phrenology', habitually used to refer to the knowledge system that Gall proposed, was adopted by Gall's research assistant and student Johann Kaspar Spurzheim (1776-1832) after reading Thomas Foster's article 'Sketch of the phrenology of Gall and Spurzheim'.¹¹

In the early 19th century, phrenology was a popular and visible practice in France among both doctors and laymen.⁹ Some of its most famous practitioners included Giovanni Antonio Lorenzo Fossati (1786-1874), a doctor of Italian origin who founded the Société Phrénologique in 1831; and François Joseph Victor Broussais (1772-1838), head of the department of general and therapeutic pathology at the Faculty of Medicine in Paris and personal physician to Casimir Pierre Périer (the prime minister under Louis Philippe I). Jean-Baptiste Bouillaud (1796-1881) also contributed significantly to the field of phrenology by demonstrating that anatomical pathology studies were important for gaining knowledge about the functional organisation of the brain.¹⁰ On 21 February 1825, Bouillaud presented a paper to the Académie Royale de Médecine in Paris, which stated, based on clinical evidence, that the capacity for articulate speech resides in the frontal lobes. According to Bouillaud, this confirmed Gall's hypothesis regarding the localisation of language and speech. Despite the support phrenology received, it was also criticised by certain figures among France's academic elite, especially George Cuvier (1769-1832) and Marie-Jean-Pierre Flourens (1794-1867). Political pressure, resistant attitudes based on ultraconservative ideology, and repeated instances in which phrenology was denied recognition by the academic world all led to the decline of this practice and the discrediting of the contributions made by Gall and his followers.¹¹

Material and methods

In the 1860s, a large majority within the French scientific community *a)* clearly opposed all studies having to do with phrenology, and *b)* completely accepted the notion that both the structure and the function of the brain were symmetrical. Broca himself was part of this scientific community, and he actively participated in numerous medical societies and wrote more than 500 articles on an array of medical and anthropological topics. While Broca

was an extraordinary observer and scientist, he was also bound to the moment in history in which he lived. As is only natural, he was shaped by the concepts and theories that made up the knowledge base of his time. The purpose of this article is to examine Broca's studies of the neuroanatomical localisation of language and the papers on that topic which he published between 1861 and 1865 in order to describe the changes in his ideas about this area of neuroscience.

Broca and the localisation of language (1861-1865)

At the meeting of the Anthropological Society of Paris held on 18 April 1861, Broca presented the case of a 51-year-old man examined in the surgical department of Hôpital Bicêtre in Paris. The patient had lost the ability to speak 21 years previously.¹ The Anthropological Society of Paris, co-founded by Broca in 1859, was dedicated to the study of the origin and biological diversity of the human species. It was the first society of its kind in the world. Broca's article provides a concise description of the clinical case and the main findings from the autopsy of the patient described above. The autopsy revealed softening of most of the left frontal gyri; the orbitofrontal region was relatively unaffected. Broca concluded his presentation by stating that all evidence suggested that the lesion to the left frontal lobe is what caused the patient's inability to speak. In August of the same year, he presented the case once again before the Société Anatomique de Paris. That scientific society was founded in December 1803 by Laennec and Dupuytren at the Paris School of Medicine. The eminent anatomist Jean Cruveilhier (1791-1874), a staunch opponent of localisationism, presided over the society for more than 40 years in order to continue the anatomical and clinical work begun by François Xavier Bichat. Cruveilhier insisted that the ability to produce articulate speech does not correspond to a set location in the brain; rather, the ability is lost whenever a large volume of brain tissue is destroyed at any location.¹²

In his presentation to the members of the Société Anatomique, Broca insisted that it would be difficult to determine whether the ability to produce articulate speech depended on the frontal lobe as a single unit, or, more specifically, on one of its gyri. He highlighted that in the case in question, the lesion was located in either the second or third frontal gyrus, most probably in the latter. On this basis, Broca indicated that the capacity for language could reside in either of those two gyri. He

closed the presentation by stating that comparison of his observations with those made by earlier scholars would be sufficient to refute the idea that the capacity for articulate speech was limited to a specific location situated in the most anterior part of the frontal lobe. This argument contradicted Gall's hypothesis regarding the localisation of the capacities for language and speech.¹³

As Broca was aware that the case he had described could receive criticism (the specimen showed chronic, progressive syphilitic lesions making it difficult to delimit the anatomical origin of the aphemia^b), he presented another case before the Société Anatomique de Paris in November 1861. On that occasion, his 84-year-old patient had lost the ability to speak following a stroke.³ Unlike the lesions in the first autopsy, the lesions found in the autopsy of the second case were perfectly delimited, and they affected the second and third gyri of the left frontal lobe. In both the first and the second cases, the second left frontal gyrus had sustained less damage than the third. This finding led Broca to conclude that the third gyrus was very likely to be the origin of the primary lesion. While his declarations were cautious, and he was well aware that the two cases he described were insufficient to clarify the neuroanatomical location of language, Broca did state that the third gyrus would necessarily be intact in order for a subject to produce articulate speech. Furthermore, as Bouillaud did, he contemplated the possibility of loss of language being caused by lesions of either the left or the right hemisphere. Broca was only interested in the localisation, and not the lateralisation, of the capacity for articulate speech.

On 2 April 1863, Broca presented results from the analysis of eight cases of aphemia before the Anthropological Society of Paris. Broca highlighted that all of those cases presented lesions in the posterior third of the left third frontal gyrus. In the same presentation, he recognised his surprise at learning about two cases of patients with aphemia due to parietal lesions. One of these cases had been described by Charcot and the other, by Duchenne. Broca requested permission to examine the brains of these patients himself, and in both cases he discovered lesions in the third frontal gyrus. Also in April

^b In his writings, Broca uses the term 'aphemia' (*aphémie*) to refer isolated changes in articulate speech, with comprehension, reading, memory, and intelligence remaining intact. In 1864, Armando Trousseau (1801-1867) suggested using the term 'aphemia' rather than 'aphasia'.¹⁴ Despite Broca's objections, 'aphasia' quickly became accepted by many authors, who used it frequently in medical literature.

1863, before the Société Anatomique, Broca presented the case of a patient who showed no signs of aphemia in life, but whose post-mortem study revealed significant atrophy of the right third frontal gyrus. The same gyrus on the left side was healthy and perfectly intact.⁴ And yet, despite the mounting evidence, Broca never ventured so far as to conclude that the capacity for articulate speech was localised in the left third frontal gyrus. Instead, he remained watchful for new data that might confirm this unsettling coincidence.

Three months later, on 17 July 1863, Jean-Martin Charcot (1825-1893) sent a letter to the editor of *Gazette Hebdomadaire de Médecine et de Chirurgie* in which he described an aphemic patient with no visible changes in the left third frontal gyrus. While Broca was puzzled by this report, he recognised its importance. He did, however, point out that one negative finding would not invalidate a series of positive pathological findings, especially in the area of brain pathology.¹⁵ On 31 July, a few days after the letter described above was published, Jules Parrot (1829-1883) published a case in which there was massive injury to the right third frontal gyrus with no aphemia, also in the *Gazette Hebdomadaire*. This new case study added to the evidence supporting Broca's hypotheses. Broca stated that if an increasing number of observations were to show that some left-hemisphere lesions were accompanied by aphemia, while similar lesions located in the right hemisphere were not, then the left hemisphere would have to be recognised as the seat of language.¹⁶ Many scholars who disagreed with his hypothesis voiced their support for Bichat's law of symmetry. Jean Baptiste Vincent Laborde (1831-1903) was disgusted by the mere idea that the two halves of an organ having identical and symmetrical structures would not serve exactly the same purpose.¹⁰ Laborde insisted that situating language in the left hemisphere would constitute a serious exception to the law of organic duality, and therefore violate the concept of functional unity. According to Luis Francisque Lélut (1804-1877), the left hemisphere in cases with speech disorders was no more or less damaged than the right hemisphere. Lélut believed that the two hemispheres of the brain had to fulfil identical functions, just as other duplicate organs of the body serve the same purpose. Furthermore, he stated that establishing links between specific parts of the nervous system and mental capacities would constitute a new form of phrenology, which would be both unacceptable and reprehensible.¹⁷ British neurologist Henry Charlton Bastian (1837-1915) wrote that the sensory

organs are all bilaterally symmetrical. On this basis, he concluded that the two hemispheres of the brain, which are the final recipients of the impressions captured by these hemispheres, must also exhibit bilateral symmetry.¹⁶

June 1865. In a meeting of the Anthropological Society of Paris, Broca theorised that aphemia –loss of articulate speech– was 'almost always' related to the destruction of the left third frontal gyrus.⁶ These conclusions would lead him to consider the possibility of the two halves of the brain exhibiting functional differences. This approach called the law of symmetry into question and changed the way physiology was understood at the time. Although Broca never mentioned Bichat's name, he cited a 'physiological law' stating that two equal or symmetrical organs must have the same properties or attributes. The brain's two hemispheres would present a very rare exception to this law. Broca stated that it was common knowledge that minor differences in brain fold patterns were observed between different individuals, but that no such differences could be detected between the hemispheres of the same brain. Broca went on to stress that in any case, observations are more reliable than theories, and that scholars must bow to the facts even when they may seem paradoxical and inexplicable. Aware of the need for an answer to this controversial question, Broca drew on ontogenic arguments based on the research on brain development completed by anatomist Louis Pierre Gratiolet (1815-1865).¹⁶ According to Gratiolet's observations, the left frontal lobe develops before the right one in a process that might explain why articulate speech would naturally tend to be linked to the left hemisphere. Broca believed that there were no innate functional differences between the brain's two hemispheres, and that both frontal lobes would therefore have the same potential initially. The asymmetrical localisation of language would therefore result from the different maturity rates which Gratiolet observed. Nevertheless, he does stress that this tendency would not designate the left hemisphere as the exclusive seat of language, i.e., the ability to establish relationships between concepts and signs. Lesions to the anterior part of the left hemisphere would only remove the ability to reproduce the sounds in articulate speech. They would not affect a subject's ability to understand speech and link concepts to words. Broca would go on to state that capacity for understanding speech belongs to both hemispheres, and that in cases of illness, one hemisphere may substitute the other. Likewise, he recognised that a few individuals were able to talk using the right



Figure 2. Paul Broca (1824-1880)

hemisphere, and that such exceptions would explain the rare cases in which aphemia is caused by a right-sided lesion.⁶

Closing remarks

Broca's presentation before the Anthropological Society of Paris on 18 April 1861 constituted the starting point for scientific research into the localisation of different mental abilities. Although nearly all clinical types of aphasia had been described prior to Broca's study, reports of such cases were almost always limited to a description of symptoms. Doctors had never attempted to find a link between language disorders and the neuroanatomical localisation of the lesion. Broca provided the first empirical evidence pointing to a connection between neuroanatomy and distinct mental activities, as well as the earliest scientific proof that brain function was asymmetrical.

Broca's observations on brain function were viewed as a direct challenge to both the principle of cortical equipotentiality, proposed by the eminent physiologist Flourens in the 1820s, and to Bichat's law of symmetry. In any case, Broca's most radical and ground-breaking proposal was not the discovery of a concrete cerebral localisation for language, but rather, the idea that its localisation was asymmetrical and limited to the third left frontal gyrus. Nevertheless, despite issuing reports that were clearly opposed to the dominant theories, as described in the preceding section, Broca found himself embroiled in an intense internal struggle. His data and clinical observa-

tions were at odds with the body of knowledge which he had studied. This being the case, he was unable to completely discard the notion that brain structure and function were both symmetrical, as demonstrated by his ideas regarding the role of the right hemisphere in language comprehension. Broca had probably heard of cases in which subjects experienced diminished ability to understand language as a result of left brain injury. It was not until May 1874 that *Der Aphasische Symptomenkomplex* by Carl Wernicke (1848-1905) was published; this monograph contained the first systematic, in-depth description of verbal comprehension disorders, together with a model of the relationship between specific aphasic syndromes and focal neuroanatomical lesions. In his book, Wernicke hypothesised that the left superior temporal gyrus was the centre for "the auditory images of words", a fundamental part of verbal comprehension.¹⁸ Unfortunately, we do not know how Broca responded to Wernicke's hypotheses, as Broca published his last paper on the brain and language in 1869.¹⁹

Paul Broca collected new data on processes taking place in the brain, providing a better understanding of that organ's mysteries. Likewise, his valuable contributions would give rise to a paradigm shift in the scientific community's understanding of the biological basis of behaviour. But this transformation, like all changes, did not come about easily; Broca was forced to question the body of knowledge of his time, and contradict the 'incontestable truths' which his mentors had taught him. Broca's presentation to the Paris Society of Anthropology on 18 April 1861 marked the start of a new chapter in the study of cerebral processes and created the methodological basis which would later be employed by numerous scholars of the central nervous system.

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