Chapter 1

Historical Remarks

Interesting that just as with brain evolution, brain anatomical knowledge also took place from the bottom up, with the cerebral sulci and gyri being the last structures to be understood!
G. C. Ribas, 2017

1.1 The Cerebral Surface

Knowledge of brain anatomy in general and of its surface in particular is very recent. This is despite human interest in the brain being very old, with the making of cranial trepanations probably being the oldest systematized surgical procedure in our history (Sachs, 1952) and having been done successfully (on the basis of new bone growth after these procedures) in European Neolithic cultures about 10 000 years ago, and more frequently in South America by the pre-Inca and Inca cultures in Peru with findings that date until 2000 years ago (Finger, 1994; Graña *et al.*, 1954; Lyons and Petrucelli, 1978; Sachs, 1952).

The Egyptians were the first to provide systematic medical records with the writing of the Edwin Smith surgical papyrus (seventeenth century BC) based on the teachings of Imhotep (ca. twenty-seventh century BC), father of Egyptian medicine. The text deals particularly with traumatic lesions, but its hieroglyphics mention for the first time in history the equivalents for the words "brain" and "corrugations of the brain," and also mention a note about a patient with an opened skull wound who became "speechless" during its palpation (Breasted, 1930 apud Catani and Schotten, 2012; Catani and Schotten, 2012). The Egyptians believed that the heart, and not the brain, was responsible for intellectual, emotional, motor, and sensation

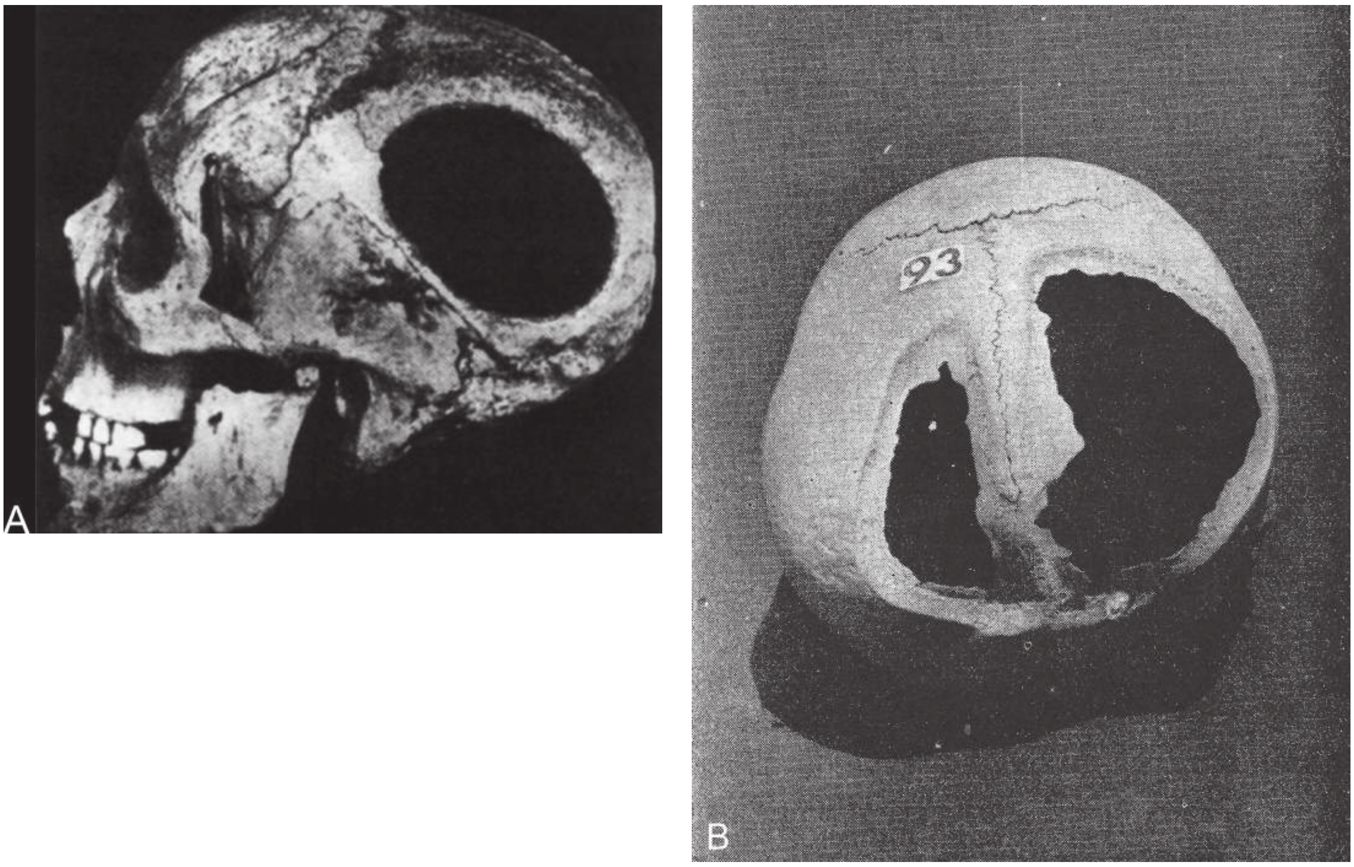


Figure 1.1 (A) Trephine skull opening from the Neolithic Period (Neolithic skull, Nogent-les-Vierges, Oise, France. Musée de l'Homme, Paris) (Sachs, 1952), and (B) trephine skull openings from the pre-Colombian Peruvian civilization, apparently with the aim of preserving bone over the superior longitudinal sinus (Graña *et al.*, 1954).

functions, and the brain was treated by them with indifference as also shown in the subsequent and much longer Ebers papyrus (Finger, 1994). Nevertheless, it is interesting to point out that, during their New Kingdom era, it was common to remove the brains of cadavers to be mummified through the nostrils and the base of the skull with the help of a small chisel and an iron hook (Finger, 1994), pioneering a trans-sphenoidal surgical route.

During antiquity, no significant contributions to neuroanatomy were made until the development of the Greek culture. Alcmaeon from Crotona (ca. fifth century BC) performed some of the earliest recorded dissections, described the optic nerves, identified that the sense organs were connected to the brain through nerves, and was the first to propose that the brain was the central organ of sensation and thought, which was also suggested by Anaxagoras (500–428 BC) at about the same time. Alcmaeon's cephalocentric concept is known to have deeply influenced later philosophers and anatomists such as Pythagoras, Plato, Herophilus, Erasistratus, and Galen (Catani and Schotten, 2012; Debernardi *et al.*, 2010).

Hippocrates (460–370 BC), the father of medicine, emphasized that the brain was responsible for mental activity and convulsions, although some important Greek philosophers of that time, like Aristotle (384–322 BC), the Stoics, and the Epicureans, still believed that the heart was the seat of intellectual, perceptual, and related functions (Finger, 1994).

Previously forbidden in Greek culture, human dissections began to be performed around 300 BC in Alexandria, Egypt, then a Greek city which was particularly culturally developed. There, Herophilus (ca. 335–280 BC), follower of Hippocrates and considered the father of anatomy, studied the brain, its ventricles, and the cerebellum, discriminated the motor from the sensitive nerves, and described the torcula of the cranial venous sinuses that bears his name (torcular Herophili). Erasistratus (ca. 310–250 BC), studying the comparative anatomy of the brain surface, already suspected a relationship between intellect and gyri complexity (Finger, 1994) and compared the arrangement of brain convolutions to the jejunum (Clarke and O'Malley, 1996).

With the decline of the Greek Empire, the Roman medicine that followed was largely a continuation of Greek ideas, particularly because many Greek physicians settled in Rome. Aurelius Cornelius Celsus (25 BC–AD 50), though not formally trained, practiced medicine and wrote the first Roman work *De Medicina*; however, it was Galen (AD 130–200) who left the best known anatomical contributions from this period (Finger, 1994; Singer, 1952; Sarton, 1954).

Galen was born in the Greek city of Pergamon, trained in Alexandria, and later settled in Rome where he was a surgeon for gladiators and performed dissections mainly on animals. Among all his anatomical contributions, in neuroanatomy, Galen numbered the cranial nerves and described the autonomic nervous system, but since most of his dissections and experiments were performed on cattle and on many other kinds of animal, he incorrectly considered that many of these findings were also pertinent to human anatomy (Sarton, 1954; Finger, 1994).

He followed Hippocrates in also rejecting Aristotle's ideas that the brain simply served to cool the passions of the heart and in believing that the brain was also responsible for imagination, cognition, and memory (for Hippocrates, the basic components of intellect), but he did not believe that the convolutions of the brain were associated with intelligence as previously proposed by Erasistratus.

Galen believed that a natural spirit was produced in the liver, converted in the heart to a higher form, named the vital spirit, and was then carried to the brain through the carotid and rete mirabile ("wonderful net"). This is a vascular plexus located at the base of the brain as observed by him in the dissections of some animals, particularly of oxen (Clarke and Dewhurst, 1975; Finger, 1994; Singer, 1952). It was then transformed into animal spirits within the brain ventricles as already proposed previously by Herophilus of Alexandria almost five centuries before (Dobson, 1925 apud Catani and Schotten, 2012).

The Church fathers of the fourth and fifth centuries adopted Galen's ideas associating the higher human functions mostly with the brain ventricles. One of the earliest advocates of the so-called ventricular theory of brain functions was Nemesius, Bishop of Emesa, a city in current Syria, and others that followed him in this period related the ventricular cavities with different functions (Clarke and Dewhurst, 1975; Finger, 1994), generating conceptions that lasted for many centuries.

The approximately 1000 years of the Middle Ages, roughly from the fourth to the fourteenth century, as is well known, were poor regarding scientific developments in general. Although having had the contributions of Avicenna (AD 980–1037) in the Arabic world who is credited with the first representation of the brain around the year AD 1000 by some authors (Tamraz and Comair, 2000), and the contributions of the first European human dissections by Mondino dei Luzzi (ca. 1270–1326) (Finger, 1994; Lyons and Petrucelli, 1978; Tamraz and Comair, 2000), anatomical studies were very limited, in particular because human cadaveric dissections were forbidden at that time.

The relative liberation of this practice that occurred during the Renaissance finally led to the progressive development of all anatomical knowledge, and the most preeminent figure in this field was undoubtedly Andreas Vesalius (1514–1564), professor of anatomy and surgery at Padua University, Italy.

Vesalius was a native of Brussels who studied anatomy in Paris with Jacobinus Sylvius (1478–1555), and his seminal work *De Humani Corporis Fabrica* (*On the Working of the Human Body*) (Saunders and O'Malley, 1950) was completed in Padua and Venice in 1542. It was published in Basel in 1543 (Finger, 1994; Singer, 1952) with the artwork probably done by Jan Stephan van Calcar (ca. 1499–1546) and/or by other students of the great painter Titian (ca. 1487–1586). The *Fabrica* was based on extensive human dissections, and Vesalius was particularly led to indicate Galen's anatomical errors, having counted some 200 of them. In 1544, Vesalius left Italy to become court physician to Charles V (1500–1558), which ended his career as an anatomist (Finger, 1994).

Vesalius left many contributions to neuroanatomy, with descriptions of the meninges, cerebral hemispheres distinguishing the white and gray matter, corpus callosum and septum pellucidum, ventricles, fornix, colliculi, and pineal gland, cerebellar hemispheres and vermis, infundibulum and pituitary body (Lyons and Petrucelli, 1978; Saunders and O'Malley, 1950; Singer, 1952; Tamraz and Comair, 2000). With regard to the cerebral gyri, Vesalius still illustrated them chaotically and understood their shape and folding to be responsible for anchoring the vessels that penetrate the brain through the sulci (Vesalius, 1543 apud Catani and Schotten, 2012).

Although having denied the existence of the rete mirabile in humans, Vesalius did not reject entirely the ideas defended by Galen and the ventricular localization theory itself, and this major interest in the ventricular cavities may explain the relative neglect of the brain gyri by all the anatomists throughout more than 20 centuries.

Other contemporaneous authors of this period were the great artist and also anatomist Leonardo da Vinci (1472–1519), who besides his well-known studies of the brain ventricles also made beautiful but incorrect illustrations of the cerebral surface (Cianchi and Breschi, 1997; Clayton, 1992), and Julius Casserius (ca. 1545–1616). His work represented the brain convolutions, which at that time were still understood to resemble the small bowel as described previously by Herophilus and by Erasistratus 18 centuries before (Singer, 1952).

Constanzo Varolio (1543–1575) started slicing the brain and described the pons in 1573 (Varolio, 1573 apud Clarke and O'Malley, 1996), and in 1587, Giulio Cesare Aranzi (1530–1589) described the hippocampus within the lateral ventricular cavity (Varolio, 1573 apud Clarke and O'Malley, 1996).

In 1663, Franciscus de le Boë (1614–1672), also known as Dr. Sylvius, described the lateral cerebral sulcus (Sylvius, 1663 apud Catani and Schotten, 2012), which came to be named the Sylvian fissure by Caspar Bartholin (Bartholin, 1641 apud Catani and Schotten, 2012; Catani and Schotten, 2012) in 1641. For some authors, the Sylvian fissure was primarily described by Girolamo Fabrici d'Aquapendente (ca. 1553–1619) (Collice *et al.*, 2008), who followed Andreas Vesalius (1514–1564) and Gabriel Fallopius (1523–1562) at the University of Padua (Finger, 1994).

In 1664, Thomas Willis (1621–1675) published his highly regarded *Cerebri Anatome*, which featured illustrations by the renowned architect Christopher Wren (1632–1723). In addition to describing the group of arteries surrounding the base of the brain now known as the circle of Willis, he introduced a variety of terms, including neurology, hemisphere, corpus striatum, peduncle, and pyramid, and related the cerebral gyri to memory, but still not representing the brain gyri and sulci properly. Interestingly, Willis related the striatum with movement and sensation, and the corpus callosum with imagination (Finger, 1994).

Raymond Vieussens (1644–1716) published the famous *Neurographia Universalis* in 1690 (Vieussens, 1690), describing in detail the centrum semiovale and other cerebral structures,

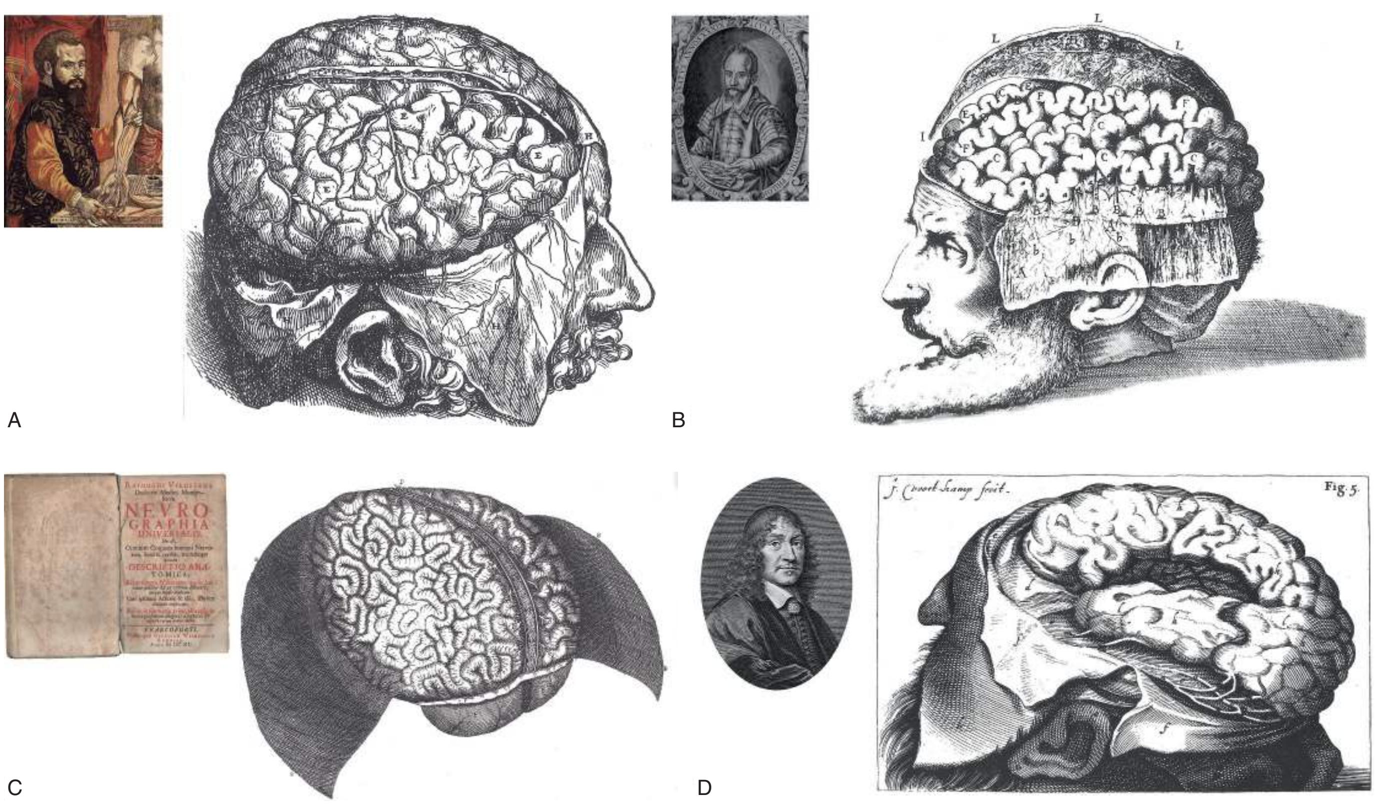


Figure 1.2 Illustrations of the cerebral surface from the Renaissance: (A) by Andreas Vesalius (1514–1564), (B) by Giulio Casserio (ca. 1545–1616), (C) by Raymond Vieussen (1641–1716), and (D) by Franciscus de le Boë, known as Dr. Sylvius (1614–1672) already depicting the lateral fissure that bears his name. (Illustrations from Clarke and Dewhurst (1975) and from Saunders and O'Malley (1950).)

but still illustrating the brain surface similarly to the small bowel (Finger, 1994; Tamraz and Comair, 2000). Godefroid Bidloo clearly displayed the central sulcus in his atlas and textbook published in 1685 (Tamraz and Comair, 2000), and subsequently Félix Vicq d'Azyr (1748–1794), famous for describing the mammillothalamic tract, also described the precentral and postcentral convolutions separated by the central sulcus, and coined the term uncus (Tamraz and Comair, 2000). In 1809, Johann Christian Reil (1759–1813) provided a comprehensive description of the insula (Lockard, 1977), which had already been identified by Bartholin in 1641 (Finger, 1994; Tamraz and Comair, 2000). In 1827, Herbert Mayo, student of the renowned anatomist and surgeon Charles Bell (1774–1842), published illustrations of the corona radiata and internal capsule, as well as other important tracts (Türe *et al.*, 2000). In 1829, the Italian anatomist Luigi Rolando (1773–1831) published his text *Della Struttura degli Emisferi Cerebrali* (Rolando, 1829 apud Türe *et al.*, 2000), becoming the first author to accurately portray the central sulcus, which is still also referred to as the fissure of Rolando (Finger, 1994; Tamraz and Comair, 2000).

In the early nineteenth century, Frans Joseph Gall (1758–1828) related the different brain convolutions to different mental faculties and "propensity," adopting the concept of organology where each brain convolution corresponded to a specific organ. For Gall, each gyrus would cause an impression on the skull, generating an external protrusion that would express each individual character (Clarke and Dewhurst, 1975; Gall and Spurzheim, 1810–1819 apud Catani and Schotten, 2012). Although not justified at all, Gall's concepts, altogether known as phrenology, encouraged the investigation of cortical localizations and hence the clinico-anatomical correlation method (Catani and Schotten, 2012).

Achille Loius Foville (1799–1891) was the first author in the history of neuroanatomy to illustrate perfectly the sulci and gyri of the brain surface, in his atlas of brain anatomy edited in 1844, but did not describe their organization within the text (Brogna *et al.*, 2012).

It was the German physiologist Friedrich Arnold (1803–1890) who first used the terms frontal, parietal, and occipital to describe the cranial bones. In a text published in 1851 (Broca, 1876b), Arnold recognized only the Sylvian fissure and the parieto-occipital sulcus (then known as the internal perpendicular fissure) (Déjérine, 1895) as anatomically constant sulci, and he described the temporal region as an anterior extension of the occipital region.

It is notable that, despite the intense interest that humankind has always had in relation to the brain, it was only in the middle of the nineteenth century that the general anatomical organization of the cerebral sulci and gyri was perceived and described by the French anatomist Louis Pierre Gratiolet (1815–1865) who succeeded his professor Francois Leuret (1797–1851) (Leuret and Gratiolet, 1857–1959 apud Türe *et al.*, 2000; Gratiolet, 1854 apud Pearce, 2006; Pearce, 2006). In addition to his well-known description of optic radiation, Gratiolet together with Leuret also distinguished between primary and secondary sulci based on their phylogenetic appearance, adopted the terms initially proposed by Arnold to divide each cerebral hemisphere into lobes, and coined the elegant term "plis de passage" to describe the connections between adjacent gyri. Gratiolet was the first anatomist to understand and describe the fact that, despite individual variations, the cerebral sulci and gyri are organized in accordance with a general arrangement (Gratiolet, 1854 apud Pearce, 2006; Pearce, 2006).

In relation to his original concept of brain lobes, it is interesting to point out that regarding the precentral and postcentral gyri, Gratiolet initially considered the former one, then called the "first anterior ascending gyrus" (Déjérine, 1895), as belonging to the parietal lobe (Gratiolet, 1854 apud Pearce, 2006), and only a few years later decided to consider it part of the frontal

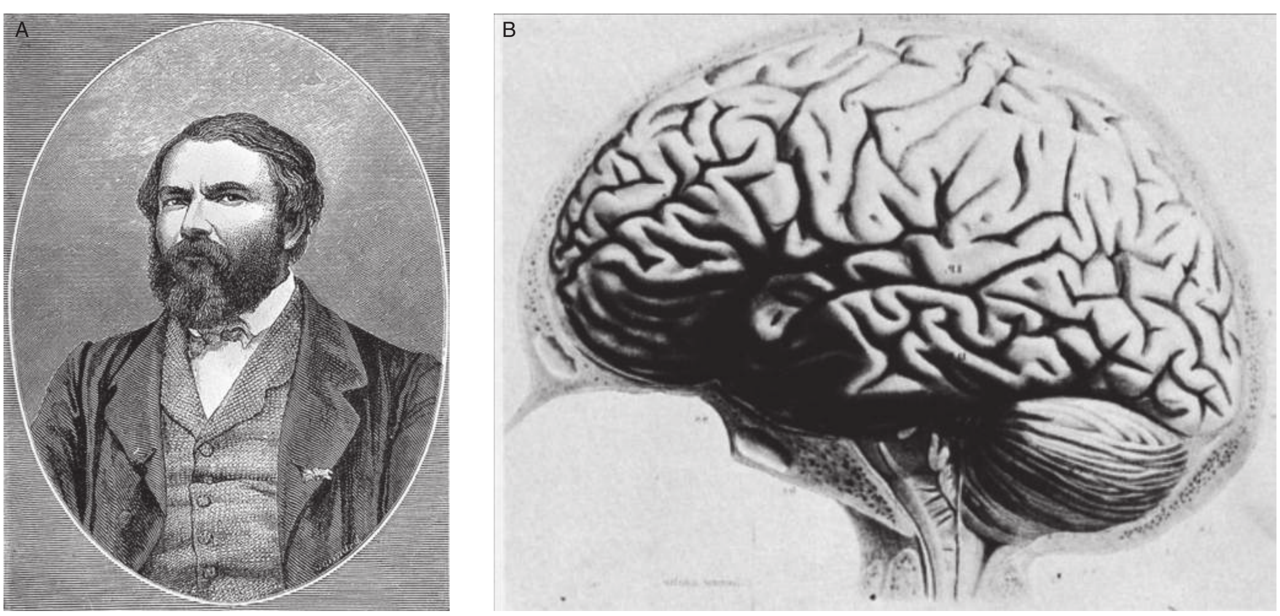


Figure 1.3 The cerebral surface as depicted by (A) Louis Pierre Gratiolet (1815–1865), who described (B) the basic organization of the cerebral gyri. (Illustrations from Clarke and Dewhurst (1975).)

lobe, leaving the latter, then called the "second anterior ascending gyrus" (Déjérine, 1895), part of the parietal lobe (Leuret and Gratiolet, 1857–1959 apud Türe *et al.*, 2000).

In 1869, Johann Alexander Ecker (1816–1887) also accurately described all of the cerebral sulci and gyri, introducing the designations orbital, precentral, parieto-occipital, and transverse occipital to describe these various sulci (Tamraz and Comair, 2000).

William Turner (1832–1916), who also studied the brain sulci in detail, with his name becoming an eponym of the intraparietal sulcus (Lockard, 1977), emphasized in 1866 that the central sulcus should be considered the posterior limit of the frontal lobe (Broca, 1876b; Tamraz and Comair, 2000; Turner, 1866 apud Catani and Schotten, 2012; Yasargil, 1994). On the other hand, regarding particularly a proposed concept of a central lobe of the brain, it is interesting to mention that, in 1868, the German anatomist T. L. W. Bischoff referred to the pre- and postcentral gyri, respectively, as "anterior and posterior central convolutions of the brain" (Broca, 1876b), as did Edward H. Taylor in 1900 (Taylor and Haughton, 1900 apud Uematsu *et al.*, 1992), already clearly suggesting to group these two gyri together and separate from the adjacent gyri.

The knowledge of the correlations between the nervous structures and their respective neurophysiological functions, in turn, only came to be developed from the second half of the nineteenth century, and the pioneers of the location of cerebral cortical functions were undoubtedly Pierre Paul Broca (1824–1880) in France, and John Hughlings Jackson (1835–1911) in England (Finger, 1994; Lockard, 1977; Schiller, 1992).

An anthropologist, anatomist, neurologist, and surgeon, Broca evidently relied initially on anatomical knowledge available at the time, and was particularly motivated and influenced by the aforementioned descriptions by Gratiolet (Broca, 1876b; Türe *et al.*, 2000). He introduced the concept of brain location (Lockard, 1977).

Following the previous observations of Bouillaud in 1825 (Schiller, 1992; Bouillaud, 1825 apud Catani and Schotten, 2012), and of Auburtin in 1861 (Schiller, 1992; Auburtin, 1861 apud Catani and Schotten, 2012) who described a transient aphasia secondary to the compression of an opened left fronto-opercular wound in a patient who had sustained a gunshot suicidal lesion, in 1861, Broca also outlined the cortical motor speech area based on the clinical-anatomical study of two patients who died after left fronto-opercular strokes (Broca, 1861 apud Finger, 1994), locating it in the "posterior portion of the third frontal gyrus, adjacent to the Sylvius fissure." It is interesting to note that only after two years did Broca note that this type of involvement was particularly related to the left side of the brain, and that he came to deal more clearly with this issue in 1865 (Finger, 1994).

Around the same time, in England, Hughlings Jackson suggested the existence of a somatotopical cortical motor area based on clinical observations of epileptic patients. In Germany in 1870, Gustav Fritsch and Edward Hitzig confirmed experimentally Jackson's conceptions in dogs, demonstrating that both motor and sensory functions are related to the cerebral cortex. In 1886 in England, David Ferrier mapped in detail the sensorimotor cortex of the monkey, as did other authors such as Sidney Grunbaum (1861–1921) and Charles Sherrington (1857–1952) in apes.

In 1874, the human cortical area responsible for language understanding was described by Carl Wernicke (1848–1904) as located within the left temporoparietal region (Wernicke, 1874 apud Catani and Schotten, 2012; Finger, 1994), and in 1892, Joseph Jules Déjérine (1849–1917) described the cortical area responsible for reading as located in the left angular gyrus based on clinical-anatomical findings (Déjérine, 1892 apud Catani and Schotten, 2012).

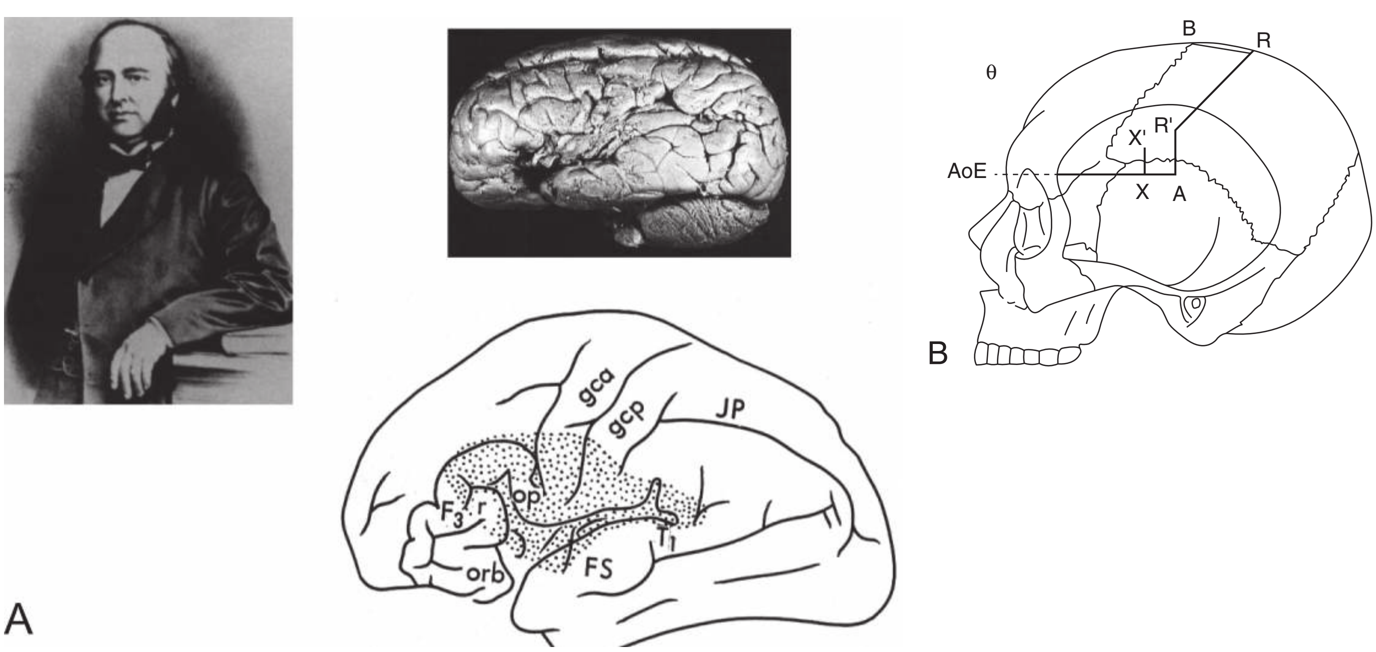


Figure 1.4 (A) Pierre Paul Broca (1824–1880), with the sketch of his description of the language motor cortical area in 1861, together with a picture of the brain of his patient Mr. Leborgne; (B) Broca's sketch of the cranial-cerebral relationships of the speech area, based on the Broca-Championnière Method, for the drainage of brain abscess causing a motor aphasia, in 1876 (from Stone (1991)).

CAMBRIDGE
Cambridge University Press & Assessment
978-1-107-15678-4 — Applied Cranial-Cerebral Anatomy
Brain Architecture and Anatomically Oriented Microneurosurgery
Guilherme C. Ribas
Excerpt
More Information

Victor Horsley (1857–1916), considered the father of neurosurgery, was one of the pioneers of human trans-operatory cortical stimulation and, in 1885, observed that "the main motor cortical representation is anterior to the central sulcus" (Finger, 1994; Lyons and Petrucelli, 1978). After him, Harvey Cushing (1869–1939), who briefly trained with Horsley and became the most prominent surgeon in the establishment of neurosurgery as a specialty in the United States, repeated these procedures with patients under local anesthesia and was also able to reproduce such auras and seizures in epileptic patients (Finger, 1994; Lyons and Petrucelli, 1978).

The first human cortical map was developed by Fedor Krause (1857–1937) in 1911, but it was Wilder Penfield (1891–1976) who described in detail the motor, sensitive, and other functional cortical areas based on his trans-operatory studies of cortical stimulation of epileptic patients operated on by him under local anesthesia in the Montreal Neurological Institute (Penfield and Boldrey apud Brodal, 1981).

1.2 Cerebral Cortical Cytoarchitecture

The advent of the microscope invented by Marcello Malpighi (1628–1694) and Antony Van Leeuwenhoek (1632–1723) (Finger, 1994) allowed the study of the brain cortex, and in 1840, Jules Baillarger (1809–1890) described the six cortical layers and the two white lines or bands pertinent to layers IV and V of the cerebral cortex which are known as the Baillarger striae (Baillarger, 1840 apud Clarke and O'Malley, 1996; Lockard, 1977), and which correspond to the line of Gennari within the calcarine cortex previously described by Francesco Gennari (1750–1796) in 1782 (Lockard, 1977).

Preceded by Camillo Golgi (1843–1926) who developed the silver stain, Santiago Ramón y Cajal (1862–1934) utilized the same techniques and, concomitantly with Charles Sherington (1857–1952) who established the concept of the synapse, delineated the basics of the cortical cell connections. While Golgi proposed the syncytium theory with the notion that a network connected all neurons, Ramón y Cajal described the neuron theory with the proper concept that each neuron acts as a single cell (Squire *et al.*, 2003; Finger, 1994).

Following these pioneers of neurohistology, Alfred Walker Campbell (1868–1937), Korbinian Brodmann (1868–1981), and Constantin von Economo (1876–1931) studied and described the whole cerebral cortical cytoarchitecture and further brain sulci and gyri details.

Although less detailed than the von Economo map (von Economo, 2009), Brodmann's cytoarchitectonic map (Brodmann, 1909 apud Penfield and Baldwin, 1952) became much more popular. Oscar Vogt (1870–1959) and Cecile Vogt (1875–1962) partially based their myeloarchitectonic studies (Vogt, C. and Vogt, O., 1926 apud Catani and Schotten, 2012) on Brodmann's areas (Catani and Schotten, 2012).

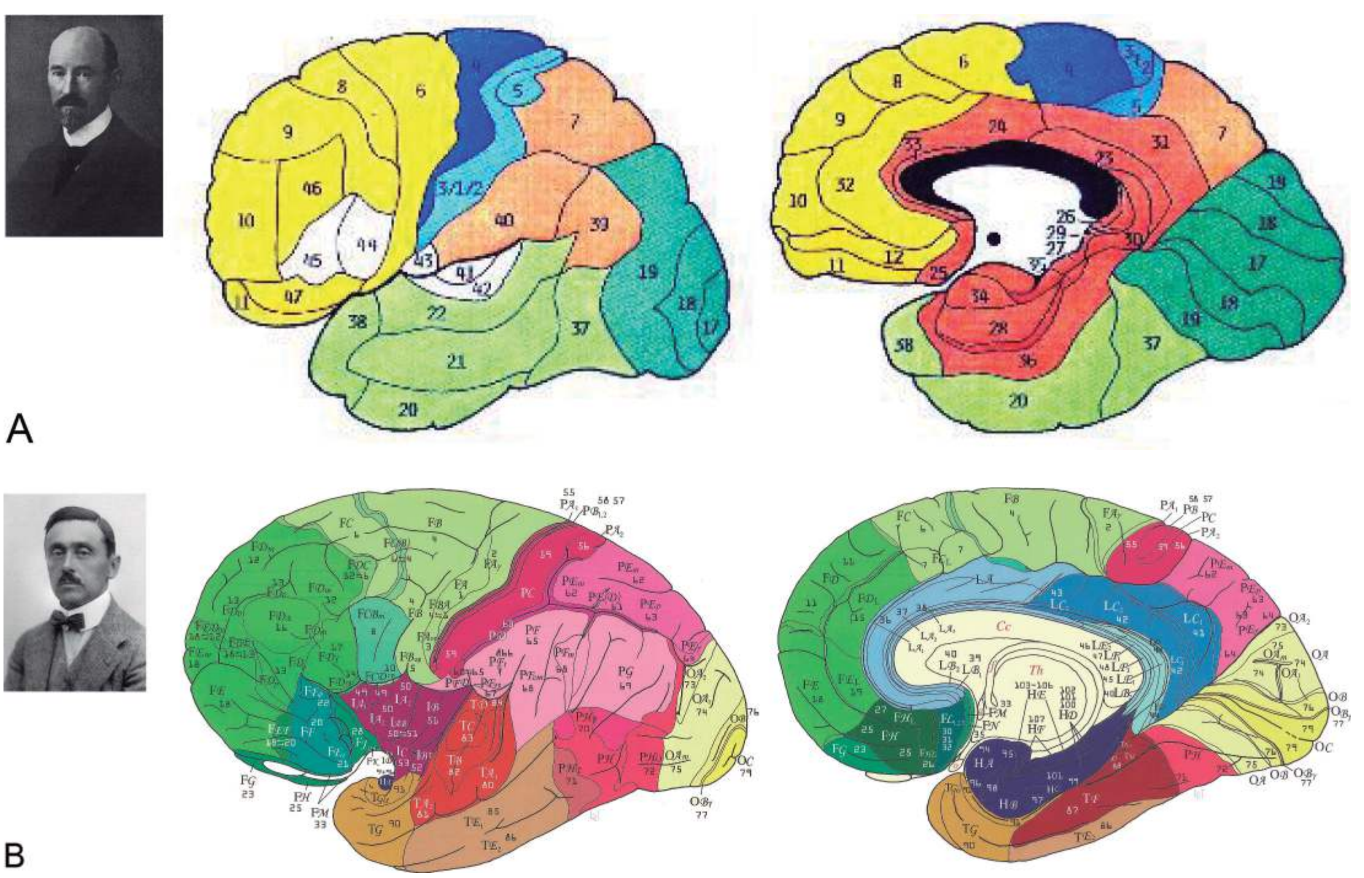


Figure 1.5 Human cortical cytoarchitecture maps: (A) of Korbinian Brodmann (1868–1918) as described in 1909, and (B) of Constantin von Economo (1876–1931) as described in 1925.

1.3 White Matter Fibers

Another major contribution of the microscope was to provide a clear differentiation between the gray and white matter, which had already been observed by Malpighi himself, and which encouraged further studies of the white matter bulk that until then was understood as having only a mechanical support function (Catani and Schotten, 2012).

Nicolaus Steno (1638–1686) was the first to suggest its study through fiber dissections (Steno, 1669 apud Clarke and O'Malley, 1996), which became possible with the aid of new methods to harden the soft brain tissue. Raymond Vieussens (1641–1716) boiled the brain in oil and was able to demonstrate the brain continuity of the corona radiata fibers with the internal capsule and within the brainstem, and to differentiate ascending and descending fibers from callosal fibers (Vieussens, 1690; Catani and Schotten, 2012); however, it was Félix Vicq d'Azyr (1748–1794) who further differentiated the inter-hemispheric from the intra-hemispheric association fibers (Vicq d'Azyr, 1786 apud Clarke and O'Malley, 1996; Catani and Schotten, 2012), which later supported Theodor Meynert's (1833–1891) classical classification of projection, commissural, and association fibers (Meynert, 1867–1868 apud Catani and Schotten, 2012; Meynert, 1885 apud Catani and Schotten, 2012; Meynert, 1872 apud Türe *et al.*, 2000). Meynert was a very important anatomist, neurologist and psychiatrist who had among his students Carl Wernicke, Sergei Korsakoff, August-Henri Forel, Paul Flechsig, and Sigmund Freud (Catani and Schotten, 2012). Among other contributions, he also described the fasciculus retroflexus and the substantia innominata with the basal nucleus that currently bears his name (Lockard, 1977).

The visual fibers were initially demonstrated by Bartholomeo Panizza (1785–1867), and the optic radiation was later completely described from the lateral geniculate body to the occipital cortex by Louis Pierre Gratiolet (1815–1865) (Párraga *et al.*, 2012).

Other important contributions in this field were made by Johann Christian Reil (1759–1813) who soaked the brain in alcohol and described the cingulum, the ansa peduncularis, the tapetum fibers underneath the optic radiation and also the substantia innominata (Reil, 1812 apud Catani and Schotten, 2012; Lockard, 1977), and by Karl Burdach (1776–1847) who, among many tracts, described the arcuate fasciculus and occipital-temporal connections (Burdach, 1819–1822–1826 apud Catani and Schotten, 2012) which were later identified as the inferior fronto-occipital fasciculus by Curran in 1909 (Curran, 1909 apud Catani and Schotten, 2012).

Regarding particularly the basal forebrain region previously known as the "Substantia Innominata (unnamed substance) of Reichert" and that currently corresponds to the ventral-striato-pallidal region, it received its original name of "Ungenannte Maksubstans" given by Johann Christian Reil in 1809, had its name later apparently erroneously attributed to the neuroanatomist Karl Bogislau Reichert due to its mention within his atlas of 1859, and was finally better described and popularized by Theodor Meynert (Heimer *et al.*, 1997; Lockard, 1977; Meynert, 1867–1868 apud Catani and Schotten, 2012; Meynert, 1885 apud Catani and Schotten, 2012).

More recently, the method of freezing the brain before its dissection proposed by Josef Klinger in 1935 (Klinger, 1935 apud Türe *et al.*, 2000; Ludwig and Klinger, 1956) reactivated the practice of fiber dissections, currently widely used for studying brain anatomy. The process of freezing the brain after its fixation causes the formalin to crystallize, which separates the fibers, easing their dissection.

1.4 Cranial-Cerebral Relationships

Knowledge of the locations of the main functions of the cortical surface led to anatomical-clinical correlations, but the absence of imaging technology that could demonstrate the precise location of potentially surgical intracranial lesions in relation to the cranial surface generated studies in the second half of the nineteenth century correlating the location of cortical areas and their recently discovered functions with repair points on the cranial surface.

Broca was also the pioneer of these studies, having reported to the Anatomical Society of Paris in 1861 the results of his first study on cranial-cerebral topographical correlations. The study was performed on 11 cadavers of adult males and was published in the same year (Broca, 1861 apud Finger, 1994). In his study, Broca introduced wooden pins through strategically located cranial perforations and then examined in detail their positions in the respective brains removed at their autopsies. In this first work, we note the observations that "the occipital cleft coincides with or is directly before the lambdoid suture," and that "the upper end of the Rolandic sulcus is between 40 and 52 millimeters behind the Bregma," contradicting and correcting Gratiolet's earlier findings which placed it under the Bregma (quoted from Broca (1876b)).

In 1876, Broca published the work "Sur la topographie crânio-cérébrale" (on cranial-cerebral topography) (Broca, 1876b), which constituted a true monograph on the subject where he described his findings and compared them with those of other authors of the time. In this text, Broca already distinguishes the sulci from the fissures, classifies the sulci as primary or secondary according to their major or minor anatomical findings, and recognizes as fissures only the fissure of Rolando that corresponds to the central sulcus, the lateral fissure of Sylvius, and the external occipital fissure which corresponds to the emergence of the occipital sulcus in the convexity. Besides the topographical correlations of these fissures, Broca also studied the cerebral correlations of the craniometric points he had previously described in anthropological studies (Broca, 1875; Gusmão *et al.*, 2000).

The methods of cranial-cerebral topographic correlations that were studied and proposed during the transition period between the nineteenth and twentieth centuries were mainly

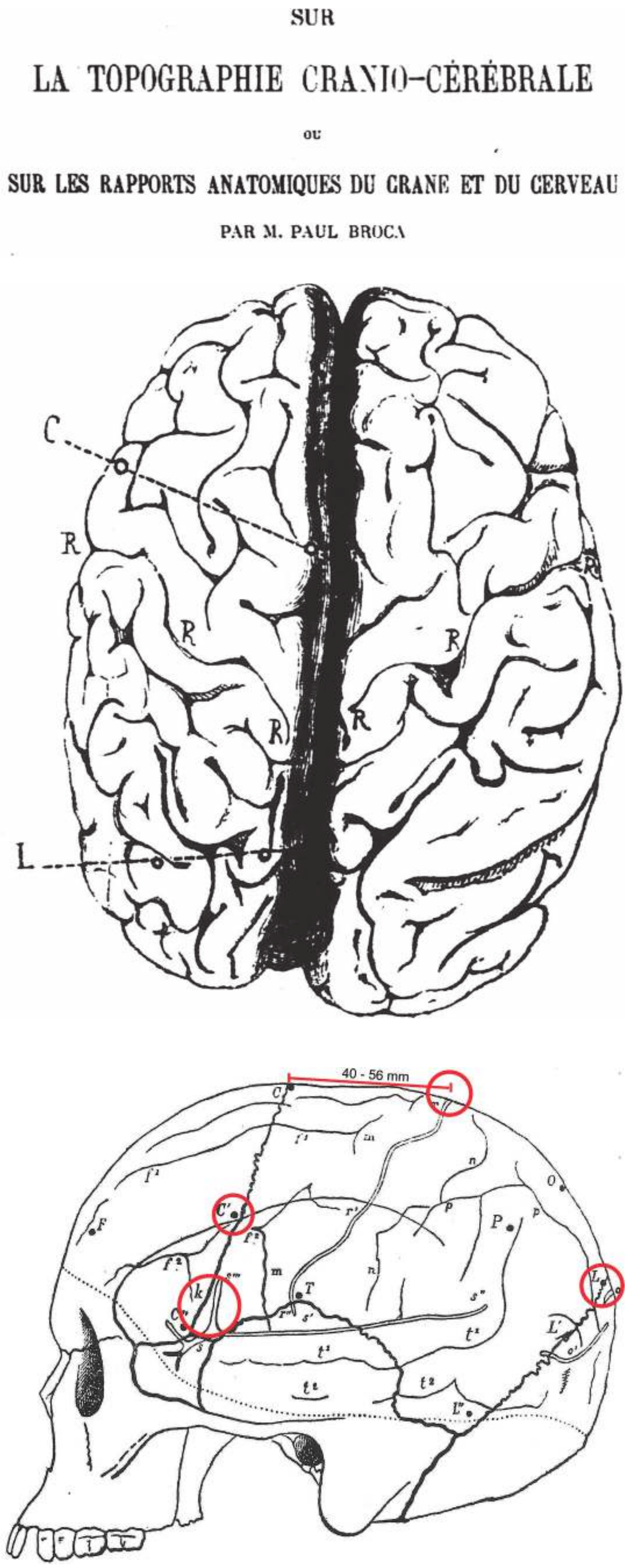


Figure 1.6 Illustrations from Broca's monograph "Sur la topographie crânio-cérébrale" of 1876, which pioneered the study of cranial-cerebral relationships (Broca (1876b)).

based on the establishment of measurements along lines drawn from easily identified cranial points.

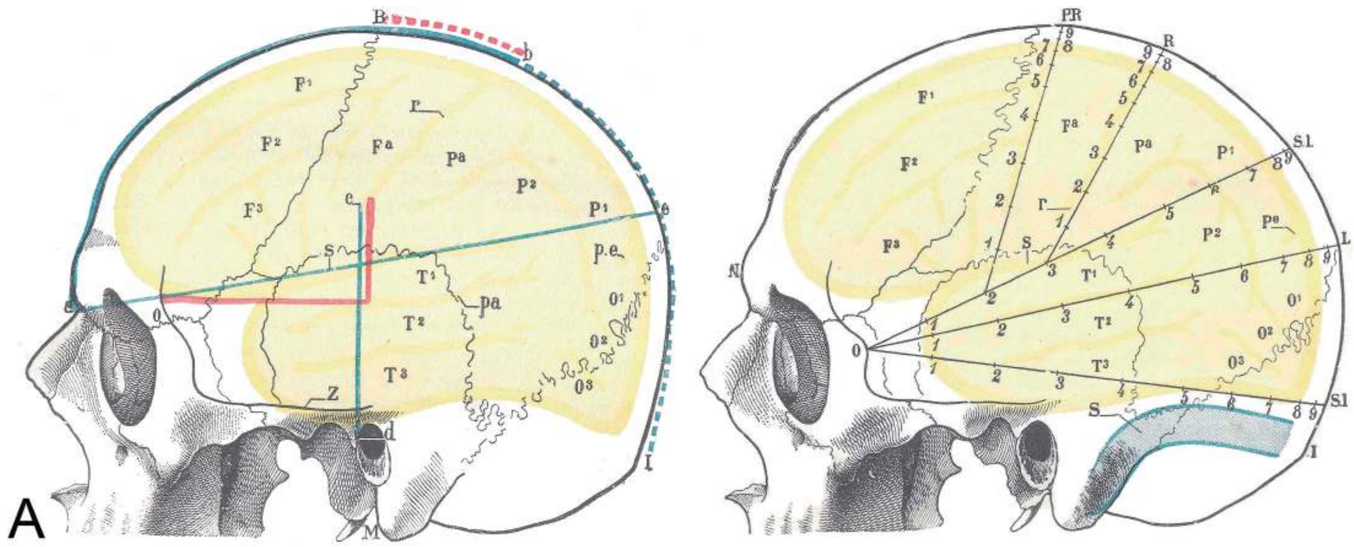
Among those methods stand out those proposed by Championnière, Poirier, Le Fort and Chipault (Testut and Jacob, 1932) in the 1990s also in France; of Turner (Turner, 1873 apud Greenblatt, 1997) in 1873, Horsley (Horsley apud Ebeling *et al.*, 1987) in 1892, Thane and Godlee (Krause, 1912) in 1896, and Taylor and Haughton (Taylor and Haughton, 1900 apud Uematsu *et al.*, 1992) in 1900, in England; of McClellan (McClellan, 1896) in 1896 in the United States; and of Bischoff (Bischoff, 1868 apud Broca, 1876b) in 1868, of Krönlein (Krause, 1912) in 1898, and Kocher in 1907 (apud Krause, 1912; Krause, 1912) in Germany. It is interesting to mention that Emil Thiodor Kocher (1841–1917) and Rudolf Ulrich Krönlein (1847–1910) were both eminent Swiss surgeons, with Kocher being awarded the Nobel Prize in Medicine and Physiology in 1909 in the light of his studies in physiology and surgery of the thyroid gland, and with Krönlein being particularly known for his work on abdominal wall hernias (Anderson, 1999).

In relation to the actual surgical application of these cranial-cerebral relationships, Broca was a pioneer again in 1876 with the report of the surgical treatment of a patient with a cerebral abscess in the language area, drained by "a trepanation done 1.5 centimeters posterior to the coronal suture and 2 centimeters above the Sylvius fissure." With this operation, Broca established modern neurosurgery by making these procedures more scientifically oriented and hence less exploratory (Broca, 1876a apud Stone, 1991; Gusmão *et al.*, 2000).

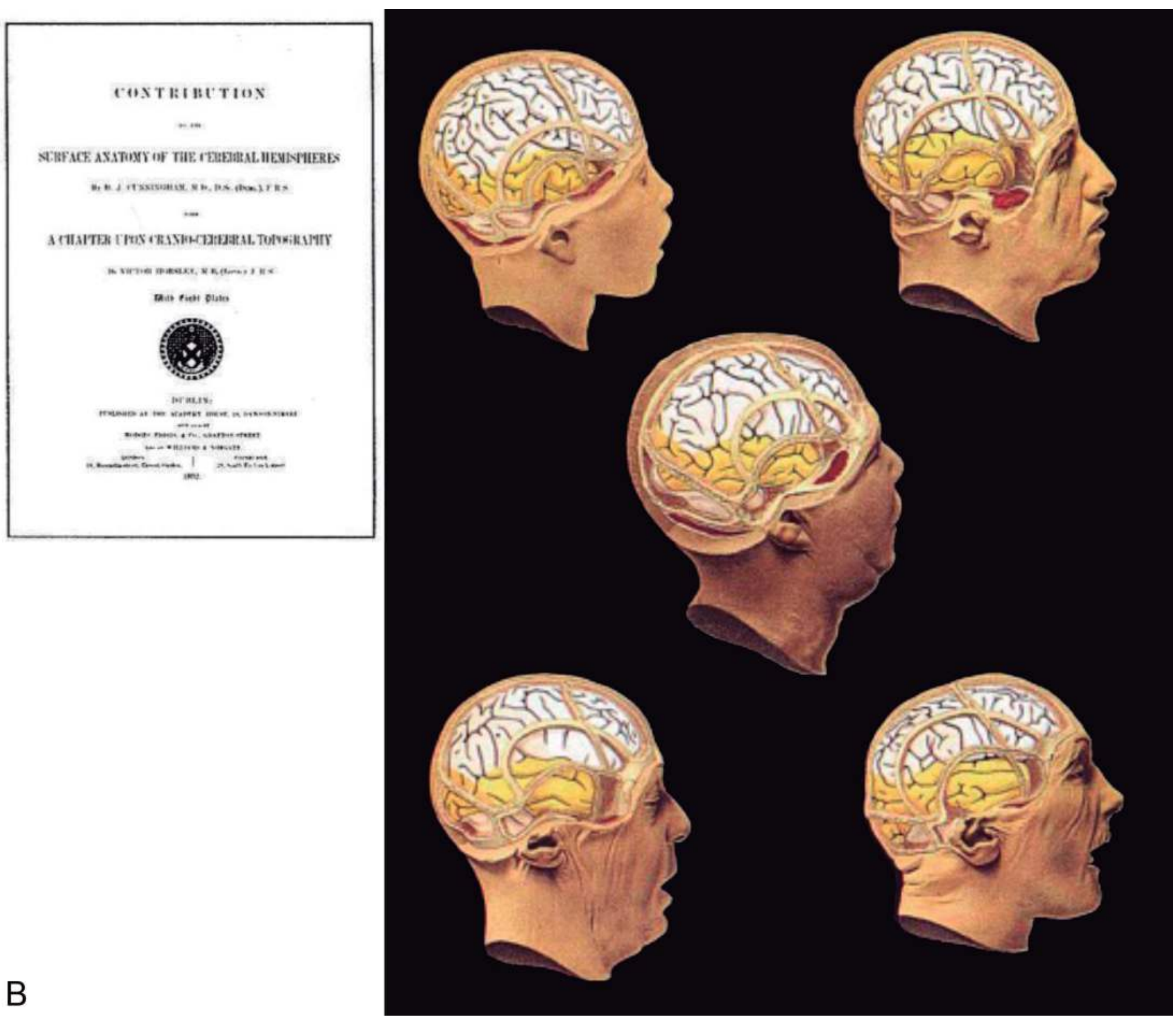
In 1884, Rickman Godlee performed the first glioma surgery based on neurological findings (seizure and hemiparesis) in the patient and directed by the knowledge of cranial-cerebral relationships described by B. D. Thane and himself, in the Hospital for Epilepsy and Paralysis, in London, in the presence of Hughlings Jackson, David Ferrier, Victor Horsley, and Joseph Lister (Kaye and Laws, 2001).

With regard to the relationships of the cranial sutures with the brain sulci and gyri, it is interesting to note that the more classic textbooks present illustrations pertinent to these relationships, but barely mention them in their texts. Among these treatises and atlases that contain beautiful illustrations of the relationships between the cranial sutures and the brain surface, standouts are the *Treatise on Topographic Anatomy* by Testut and Jacob (1932) with its first edition dating back to the beginning of the twentieth century, the textbook *Surgery of the Brain and Spinal Cord* by Krause (1912), and the more recent *Atlas of Topographical and Applied Human Anatomy* by Pernkoff (1980), with its first edition dating back to 1968.

Neurosurgical texts published more recently rarely mention cranial-cerebral relationships, and when they do, the mentions are brief and only pertinent to the classic nineteenth century descriptions (Rhoton, 1999; Seeger, 1978; Hansebout, 1982).

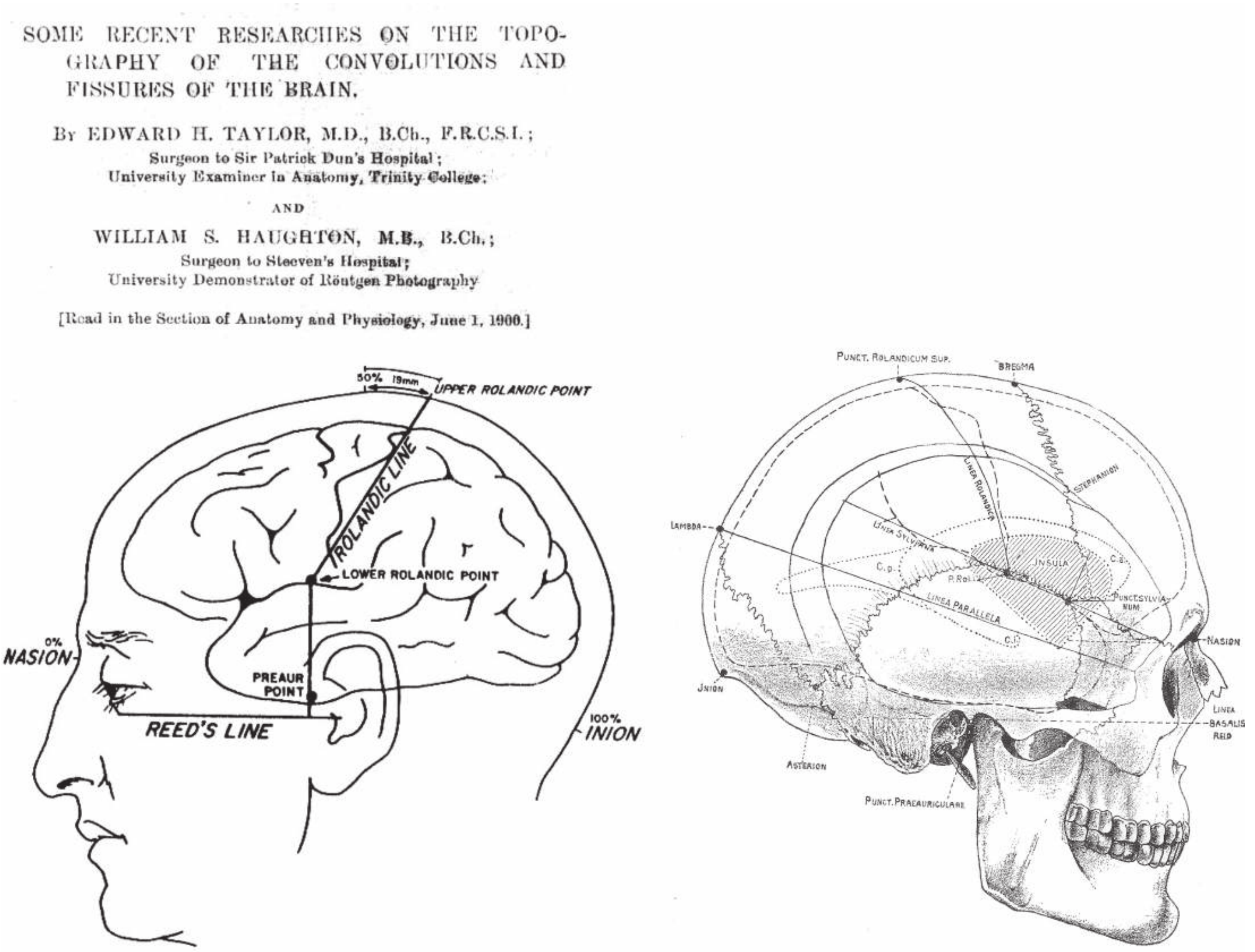


A



B

Figure 1.7 Other pioneering methods to establish the cranial-cerebral relationships:
(A) of Poirier-Chapionnière (1980), and of Chipault (1984) (see Testut and Jacob (1932)), in France;
(B) of Horsley (1892), in England;
(C) of Taylor and Haughton (1900), and of Thane and Godlee, 1896 (In Krause (1912)), in England;
(D) of Ferrier (1876), in England;
(E) of Krönlein (1898), and of Kocher (1907), in Germany;
(F) of McClellan (1896), in the United States.



SOME RECENT RESEARCHES ON THE TOPOGRAPHY OF THE CONVOLUTIONS AND FISSURES OF THE BRAIN.

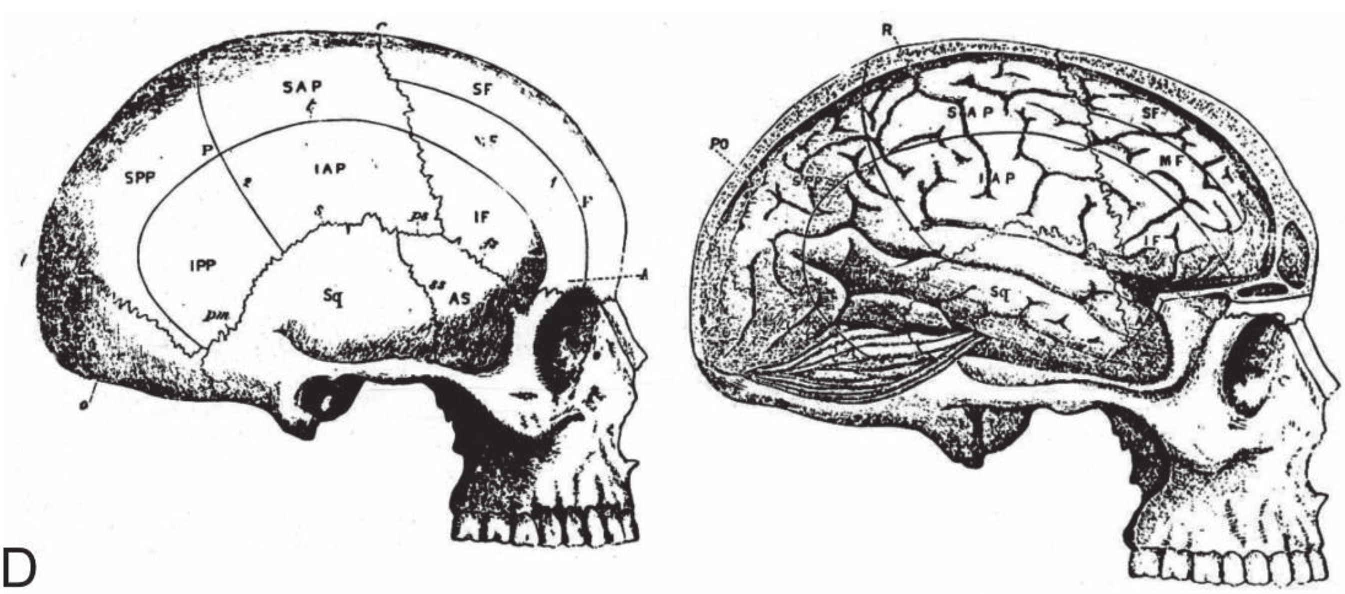
By EDWARD H. TAYLOR, M.D., B.Ch., F.R.C.S.I.;
Surgeon to Sir Patrick Dun's Hospital;
University Examiner in Anatomy, Trinity College;

AND

WILLIAM S. HAUGHTON, M.B., B.Ch.;
Surgeon to Steeven's Hospital;
University Demonstrator of Röntgen Photography

[Read in the Section of Anatomy and Physiology, June 1, 1900.]

C



D

Figure 1.7 (cont.)

