Original article

The mechanics of the brain

Half a century of research on the mind-brain dichotomy: the role of Leonardo Bianchi in the modern neuropsychological approach to the consciousness

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SUMMARY: *The contribution of the Neapolitan neuropsychiatrist Leonardo Bianchi (1848-1927) to our modern day understanding of the role of the frontal lobes in processing the higher functions of the psyche, with particular reference to consciousness, is analysed in the context of the mind-brain debate that has characterized the last five hundred years. The theory of cerebral localization of the mental functions, demonstrated experimentally in the second half of the 1800s, led Bianchi to hypothesize the importance of the frontal lobes "for the conscious fusion of the two great activities of the mind, the somatic-emotive and the intellectual", a hypothesis that he supported with animal experimentation and descriptions of the clinical presentation of several human subjects. The "frontocentric" vision of Leonardo Bianchi regarding the anatomical site of the neuropsychological functions gelled neatly with the neurophysical logic of the mechanical brain idea, and was destined to have a profound influence on modern debate on the mind-brain dichotomy.*

KEY WORDS: *Brain localization, Frontal lobe, History of medicine, Leonardo Bianchi, Neurophysiology.*

INTRODUCTION

Throughout the history of neuroscientific thought, mind-brain duality has represented a significant and puzzling conundrum, and has long provided fertile ground for debate. Over the centuries, the medical approach first tended to intersect, and then to overlap the philosophical view, a field to which the issue was initially confined[a]. However, the Renaissance saw the beginning of the end for Galen's ventricular-pneumatic conception of the brain as the site of the animal spirits and the medieval doctrine locating the mental faculties ("sensus communis", cognition and memory) in the brain ventricles[b] (Figure 1). Indeed, the centrality of man expressed by fifteenth-century humanism brought about a three-fold "discovery of the body": artistic, anatomical and motor. This discovery, in part anticipated by the dissection techniques of the Bolognese anatomist Mondino de' Liuzzi (circa

[a] Bunge M. *The mind-body problem: a psychobiological approach.* Pergamon Press, New York (USA), 1980; Sironi VA. *Il problema mente-cervello: la prospettiva storica.* In: VA Sironi (editor): *La casa dell'anima. La prospettiva delle nuove neuroscienze: oltre il problema mente-cervello?* BA Graphis, Bari (Italy), 2009: 3-10.
[b] Sironi VA. *Le teorie sul cervello.* In: VA Sironi (editor): La scoperta del cervello. Per una storia delle neuroscienze. BA Graphis, Bari (Italy), 2009: 5-19.

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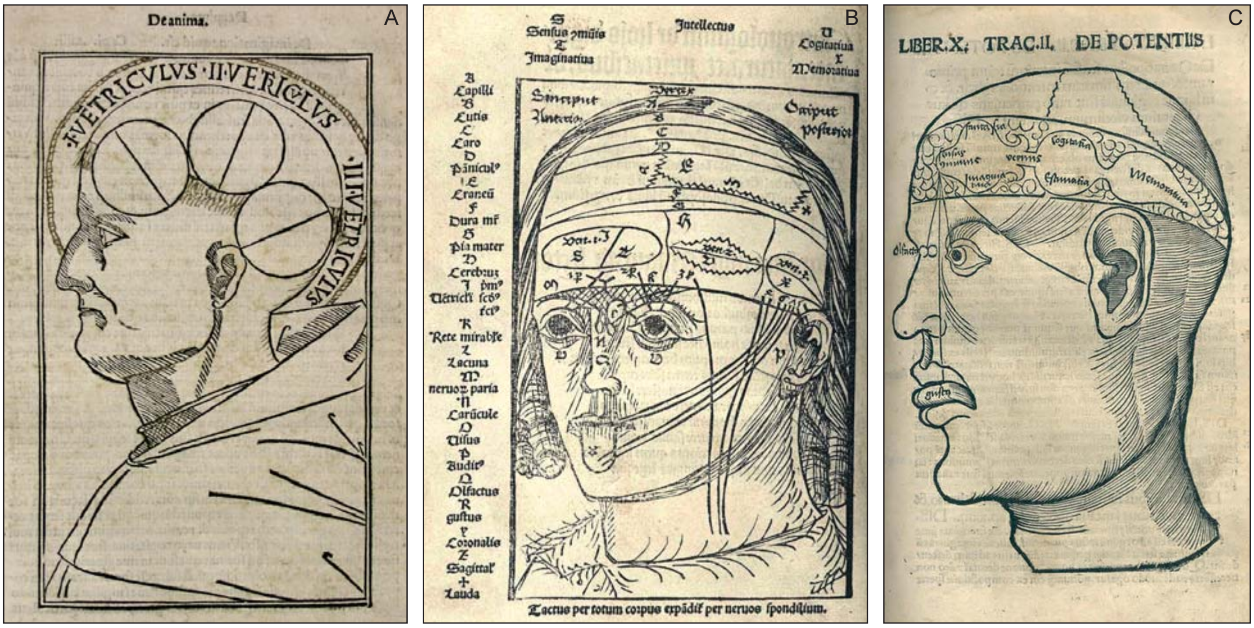


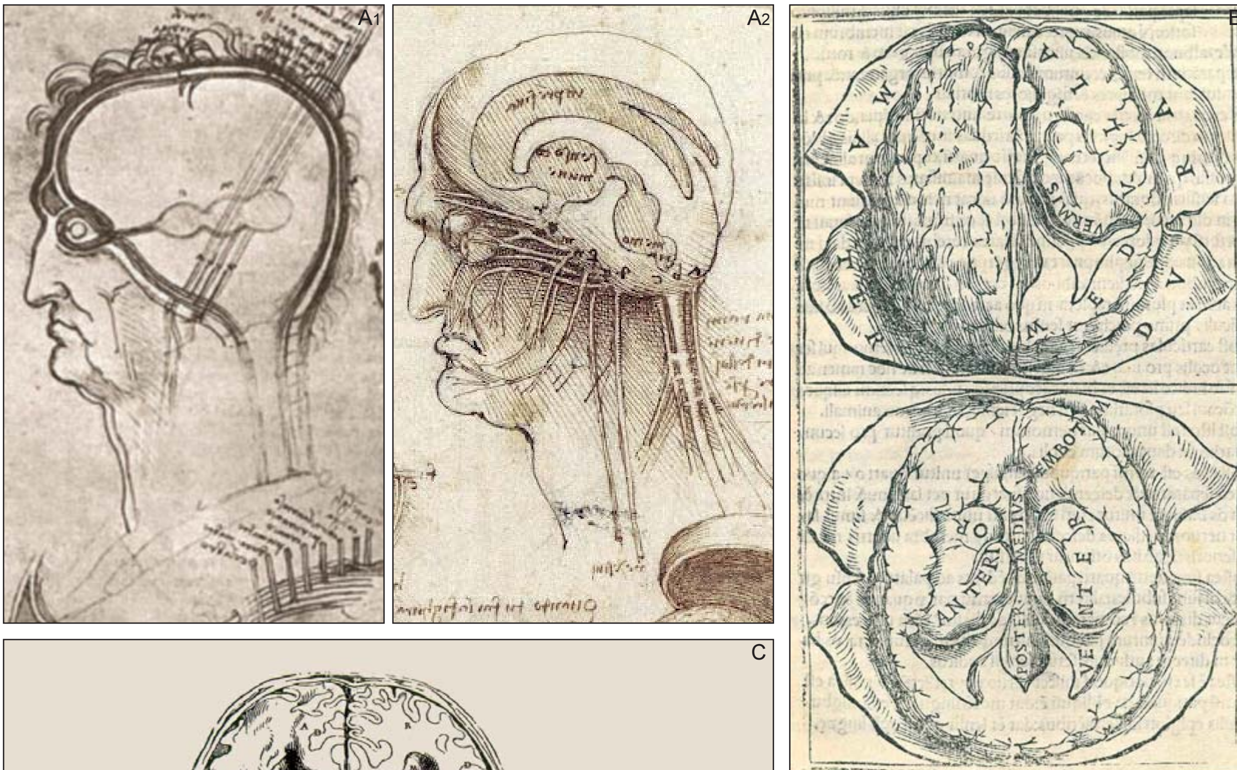
Figure 1. Illustrations of the medieval "cell" doctrine of brain functions: from Albertus Magnus in *Philosophia pauperum* of Albertus Orlamünde (1496) (A), Magnus Hundt in *Anthropologium* (1501) (B) and Gregor Reisch in *Margarita philosophica* (2nd edition, 1504) (C). The mental faculties are located in the cerebral ventricles: the two lateral (anterior), which were considered as one cavity, the first cell, are the seat of "sensus communis" (perception), imagination and fantasy, whereas cognition is located in the middle cell (our third ventricle) and memory in the posterior third cell (our fourth ventricle).

1270-1326) and the operating practices of surgeons such as Ruggero Frugardi, Rolando da Parma, Guglielmo da Saliceto and Guido Lanfranchi, reached its artistic zenith in the aesthetic and scientific works of artists such as Leonardo da Vinci (1452-1519) and Michelangelo Buonarroti (1474-1564), and its anatomical heights with the publication in Basel in 1543 of the seven printed books comprising the work *De humani corporis fabrica* (*On the Structure of the Human Body*) by Andreas Vesalius (1514-1564), chair of Surgery and Anatomy at Padua (Figure 2). This, the first "modern" anatomy textbook, was enriched by accurate illustrations, fruit of the observation of human dissection, ably executed by a student of the Titian school[c].

□ THE PREMISE BEHIND LEONARDO BIANCHI'S "MECHANICS OF THE BRAIN": THE STUDY OF THE BRAIN FROM THE RENAISSANCE TO POSITIVISM

The anatomical revolution introduced by Andreas Vesalius led to the critical debunking of theories held since antiquity. Already Leonardo da Vinci, at the end of the fifteenth century, had demonstrated the anatomical inexactitude at the foundations of the three "cell" doctrine, in his studies of the cerebral ventricles of an ox, obtained by injecting them with wax to make a cast (even though his drawings - unknown for several centuries - would have no influence on anatomical theory). Furthermore, the distinguished Berengario da Carpi (1460-1530) had included in his work *Isagogae breves* (*A Short Introduction to Anatomy*) (1522) two woodcuts that illustrated the two cerebral hemispheres and their respective ventricles with a fair amount of precision. Nevertheless, only the morphological and experimental data yielded by the accurate study of anatomy performed by Vesalius enabled him to confute with certainty the doctrine of localization of the mental faculties in the cerebral ventricles. How was it possible to localize the faculty of the rational soul in the cerebral ventricles of man if these were structurally similar to those in mere

[c] Sironi VA. *La rivoluzione anatomica e lo spettacolo del corpo: il ruolo di Leonardo da Vinci.* In the collected works: *I segreti del corpo. La prima edizione dei disegni anatomici di Leonardo da Vinci e il lungo viaggio alla scoperta della "meravigliosa macchina" umana*. Anthelios, Milan (Italy), 2008: XXIV-XXXV.



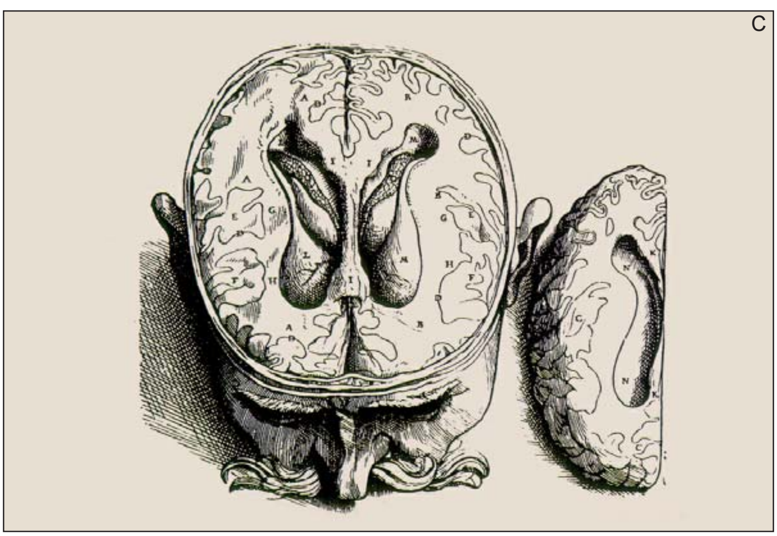


Figure 2. In the Renaissance, anatomical drawings of dissected corpses showed that the ventricles were not in fact three globes, but instead possess a far more complex structure, first demonstrated by Leonardo da Vinci (it is interesting to compare his initial sketches of sagittal sections featuring 3 cells, like *The Layers of the Scalp Compared with an Onion* (1490) (A1), with his later works, drawn after injecting wax into the ventricles of cattle, like: *Study of Brain Physiology* (1508) (A2)), then Berengario da Carpi (*Isagogae breves*, 1522) (B) and, in particular, Vesalius (*De humani corporis fabrica*, 1543) (C).

animals, which lacked this rational soul? Despite having perfected a precise understanding of the anatomical structure (form) of the brain, however, the way in which it operated (function) still lay outside his grasp. With humility and prudence he stated: "I am unable to understand how the brain can perform its office of imagining, meditating, thinking, and remembering"[d].

In the following century, the French philosopher René Descartes (1596-1650) attempted to provide an explanation for this puzzle: he conceived the brain as a material automaton driven by a nonmaterial soul. What was the point of conjunction between these two entities? He localized the action of the soul to a single, solid part of the brain, the pineal gland, located at a crossroads in the ventricular system situated in a median position at the centre of the brain (Figure 3). This conception permitted him to easily replace the localization of the various mental faculties in the ventricles with a theory in which these derived from the action of the unitary soul on a single organ (i.e. the pineal gland), able to receive and transmit by mechanical means the flow of the animal spirits, which were then passed on by the mechanical arrangement of the vari-

[d] Descartes R. *La passion et l'âme*, cited in RG Manzolini: *Schemi e modelli della macchina pensante* (1662-1762), in: *La fabbrica del pensiero.* Electa, Milan (Italy), 1994: 70.

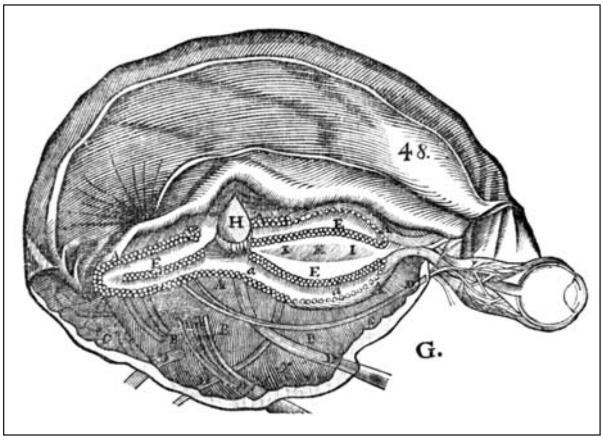


Figure 3. Drawing from the 1686 edition of Descartes *Tractatus de homine et de formatione foetus*. In the 17th century, Descartes abandoned the idea of a tripartite soul, and instead replaced this with a single version (where mind and soul are equated) located in the pineal gland, situated in the middle of the anterior ventricles, because this structure is unpaired, and its destruction resulted in death. He also proposes an essentially mechanical description of reflexive behaviour, suggesting that stimuli reach the pineal gland, which serves to orientate the "spiritus animus" in the right direction to induce an appropriate reaction, without the intervention of will, for example blinking in response to the sudden appearance of an object before the eyes or movement of a limb subjected to a painful heat stimulus.

ous contraptions making up the human machine. Regarding the seat and indivisibility of the soul, in 1649 he wrote: "The reason which persuades me that the soul cannot have any other seat in the body than this gland wherein to exercise its functions immediately, is that I reflect that the other parts of our brain are all of them double, just as we have two eyes, two hands, two ears, and finally all the organs of our outside senses are double [...] it must necessarily be the case that there must be somewhere a place where the two images by the two eyes [...] can unite before arriving at the soul"[e].

Alongside the soul localization theory, Descartes' other important contribution concerned the mechanical view of the brain. He maintained that the human mental faculties and passions could be easily interpreted, provided that the brain (like the rest of the organism) was considered as a machine. In *De homine* (*Man*), he conclude: "I desire that you consider that all the functions that I have attributed to this machine [the body], [...] follow in this machine simply from the disposition of the organs as wholly naturally as the movements of a clock or other automatons follow from the disposition of its counterweights and wheels. To explain these functions, then, it is not necessary to conceive of any vegetative or sensitive soul, or any other principle of movement or life, other than its blood or its spirits"[f].

It was the particular sensibility of the brain that enabled the human organism to perform a reflex action "mechanically". He wrote in 1649: "If someone quickly thrusts his hands against our eyes as if to strike us [...] we [...] have trouble preventing ourselves from closing them. And this shows that it is not by the intervention of the soul that our eyes close, seeing that it happens against our will [...]. Rather it is because the machine or body is so formed that the motion of a hand towards our eyes excites another motion in our brain, which conducts the animal spirits into the muscles, causing the eyelids to close"[g].

Like Descartes, who tried to go beyond the static description of cerebral anatomy, investigating cerebral function through the mechanical method, so too did Thomas Willis (1621-1675), via his dynamic investigations of the brain, emulating those of William Harvey (1578-1657) on the heart. This latter luminary had discovered and described the circulation of the blood, attributing a new physical (mechanical) function to the heart. Willis, on the other hand, intended to provide a theory for the circulation of the animal spirits, attributing a chemical (dynamic) function to the brain in both their processing and transmission. In his theory, the blood that bathes the base of the brain (flowing through arteries that form a roughly pentagonal anastomotic loop and described so well by him that it is still today known as the "Circle of Willis") undergoes a process of distillation and spiritualization in the grey matter of the cerebrum and cerebellum, both of which he compared to alembics, thereby becoming animal spirit, which then flowed along the nerves from the brain to the periphery and back again. He too abandoned the ventricles as the seat of the mental faculties, assigning the performance of specific functions not to one but to several structures. He associated consciousness and voluntary movement to the corpus striatum, imagination to the corpus callosum, memory to the cerebral cortex, instinctive behaviour to the central part of the brain (mesencephalon), and involuntary movement (regulation of the vital functions) to the

[e] Ivi, p. 71.
[f] Descartes R. *De homine.* Petrus Leffen & Franciscus Moyardus, Leiden (Netherlands),1662.
[g] Descartes R. *La passion et l'âme*, cited in P Girard: *Storia della neurologia*. In the collected works: *Storia della medicina, della farmacia, dell'odontoiatria e della veterinaria* (volume 3). Walk Over, Bergamo (Italy), 1982: 337.

cerebellum and intercostal nerve (sympathetic chain). To Franz de le Boë (1614-1672), commonly known as Franciscus Sylvius, is attributed the description of the channel uniting the third and fourth ventricles, now universally known as the aqueduct of Sylvius, while the first descriptions of the pyramids and olivary bodies of the medulla oblongata, the semioval centre (or centrum semiovale) and the semilunar ganglia were the merit of Raymond Vieussens (1644-1716). In the century that followed, Antonio Pacchioni (1665-1726) described the dura mater, Alexander Monro (1697-1767) the interventricular foramina (or foramina of Monro), which connect the lateral ventricles with the third, and Félix Vicq d'Azyr (1748-1794) began the arduous task of identifying the various cerebral circumvolutions, also describing the mammillo-thalamic tract, the eponymous bundle of Vicq d'Azyr.

It was around this time, halfway through the eighteenth century, that a schism concerning the doctrine regarding the localization of the soul occurred: some authors extended its action to cover the entire nervous system, while others maintained that it was impossible to localize to any specific part of the brain.

The first of these schools of thought, the animist perspective, was authoritatively represented by Robert Whytt (1714-1766), who stated that humans contained an immaterial sentient and intelligent principle (the anima, or sentient soul), which was at the origin of life, movement and the senses. Studying automatism (involuntary responses to stimuli) in decapitated frogs, he observed that stimulation of the spinal cord (even small residual portions) caused contraction of the lower limbs, while its complete destruction prevented further movement. He therefore deduced that the "soul" was present even in the small pieces remaining.

The second school of thought, the vitalist perspective, was upheld by Albrecht von Haller (1708-1777), who managed to demonstrate experimentally a diversified reaction to stimulation in the human body. According to him, irritable (those that reacted to stimulation by contracting) and sensible (those that transmitted the impression of touch to the soul causing pain) parts could be identified. Irritability was a specific property of all muscular tissue and sensibility of nervous tissue. He refuted the idea that the soul resided in the pineal gland (as maintained by Descartes) or the spinal cord (as concluded by Whytt). He declared that the localization problem was difficult if not impossible to solve, as too few cerebral lesions could be accurately and purposefully provoked, but hypothesized that the soul was likely to reside in the encephalic white matter, in particular at the origins of the nerves, which together made up the *sensorium commune*.

The process of understanding the intrinsic characteristics of the brain and nerves, in the search for that *ens vitae* that could explain the "life force" and the "essence of the soul", led Luigi Galvani (1737-1798) to repeat the experiments performed by Stephen Hales (1677-1761) on decapitated frogs. In these, and experiments of his own design, he saw that even the leg of the same animal, suspended on an iron bar by a copper hook, was able to contract. According to Galvani, animal electricity was the reason for this contraction, and this new "energy", this "new force" intrinsic to living things, excluded the necessity of resorting to the pneuma, animal spirits or imponderable essences to explain the functioning of the body and brain.

The cerebral dissection techniques pioneered by scholars in the sixteen and seventeen hundreds had revealed themselves to be inadequate for the purposes of precisely elucidating the structure and functions of the brain. In the nervous system, in which, unlike others, anatomy (structure) and physiology (function) are inseparable, only more accurate and systematic neuroanatomical research would lead to a better understanding of neurophysiology[h]. The initiator of this new approach was Luigi Rolando (1773-1831), who, in his treatise on the structure of the brain, *Saggio sopra la vera struttura del cervello e sopra le funzioni del sistema nervoso* (*Essay on the Real Structure of the Brain and on the Functions of the Nervous System*) (1809), demonstrated how, from an anatomical perspective, the cerebral circumvolutions and sulci (among which the eponymous fissure of Ronaldo) are repeated systematically in the brain of man, and also follow a similar ordered pattern in various animal species. The study of sulci and gyri - classified by him into frontal, parietal, temporal and occipital - was later researched in greater detail by Louis Pierre Gratiolet (1815-1865). We have, however, Franz Joseph Gall (1758-1828) and his pupil Johann Gaspar Spurzheim (1776-1832) to thank for the development of a tendency towards exasperation of the anatomical study of the brain, which led to the elaboration of a particular doctrine termed "phrenology" (Figure 4). In brief, this theory was based on

[h] Sironi VA. *Nascita ed evoluzione delle neuroscienze*. In: VA Sironi (editor): *La scoperta del cervello*, cit., pp. 47-69.

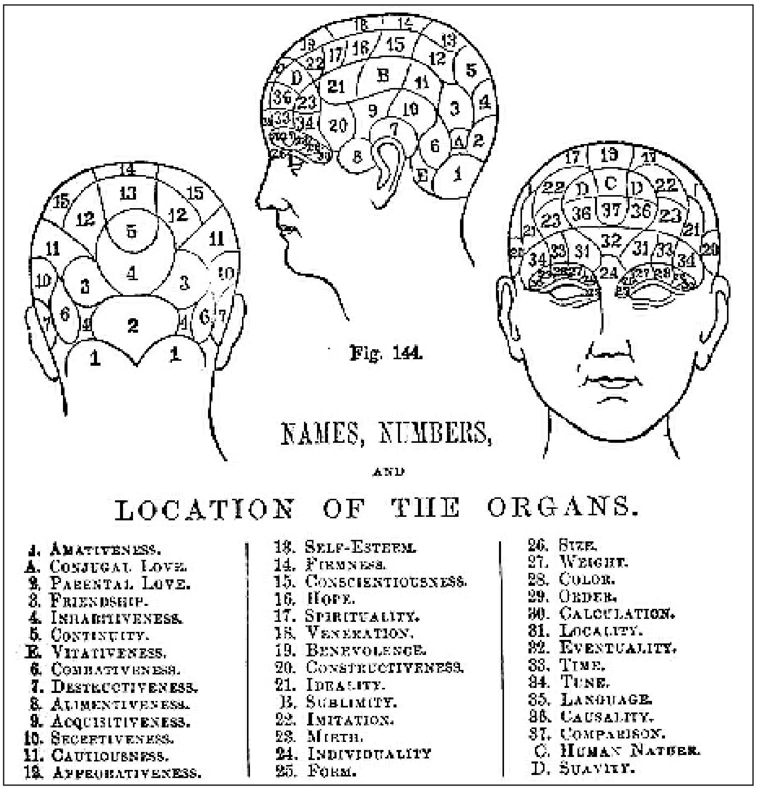


Figure 4. At the end of the 18th century, Franz Joseph Gall postulated that the brain was the organ of the mind, and that mental faculties were located in specific areas on its surface. Specific mental faculties were sited in 27 circumscribed areas (organs) of the cerebral cortex, 19 of which were shared with other animal species; their use conditioned their size, and in turn determined the formation of protuberances on the cranial surface corresponding to the particular cortical centre. In the picture, a phrenology chart shows details of these areas and their correspondence (from: Ackerknecht EH, Vallois HV. *Franz Joseph Gall, Inventory of Phrenology and his Collection*. University of Wisconsin Medical School, Madison (USA), 1956).

four suppositions, i.e. a) that moral and intellectual faculties are innate; b) that their exercise or manifestation depends on cerebral morphology, which is in turn measurable by analysis of the conformation of the skull; c) that the brain is the organ of all the propensities and faculties; and d) that it is composed of as many organs as there are different faculties. Despite the mistaken assumptions inherent in the phrenological idea of the brain, this tendency to identify parts of the brain as the seats of particular functions later led Gustav Theodor Fritsch (1838-1927) and Eduard Hitzig (1838-1907) to perform experiments on the brains of dogs that were fundamental for the development of the theory of cerebral localizations that we hold true today (Figure 5). This idea was lent weight by the observations of David Ferrier (1843-1928) relative to the identification of points on the cerebral cortex of the monkey where stimulation triggered specific peripheral movements.

Alongside this approach regarding macroscopic neuroanatomy, the parallel field of microscopic scrutiny of the brain began to develop. Research into cerebral histology and architecture, pioneered in the study of the fine anatomy of the brain performed by Marcello Malpighi (1628-1694), benefited from invaluable contributions by Johannes Evangelist Purkinje (1787-1869) and Theodor Schwann (1810-1882). It was, however, thanks to the use of the silver nitrate black stain developed by Camillo Golgi (1843-1926) that Santiago Ramon y Cajal (1852-1934) was able to identify the basic cells comprising the brain, the neurons, intuiting correctly, in opposition to the reticular theory upheld by Golgi, that only the neuron theory could explain the micro-functioning of the brain correctly.

The understanding of the cerebral (macroscopic) and neuronal (microscopic) mechanisms which took shape at the end of the 19th century and the beginning of the 20th represented the end point of a process of research and interpretative hypothesizing that considered it was possible to investigate and explain central nervous system phenomena via a “neurophysiological model”, in which scientific knowledge of physics (mechanics, hydraulics and electricity) and chemistry took precedence over the growing body of biological information.

These interpretations were lent weight by the studies of the Scottish surgeon Charles Bell (1774-1842), who in 1811 demonstrated that the motor nerves exit from the anterior roots of the spinal cord and the sensory nerves from the dorsal roots. This discovery was confirmed in 1822 by François Magendie (1783-1855), and what later became the “Bell-Magendie law” was explained by Bell in his 1826 paper *On the Nervous Circle* “Now it appears that the muscle has a nerve in addition to the motor nerve, which [...] has no direct power over the muscle, but circuitously

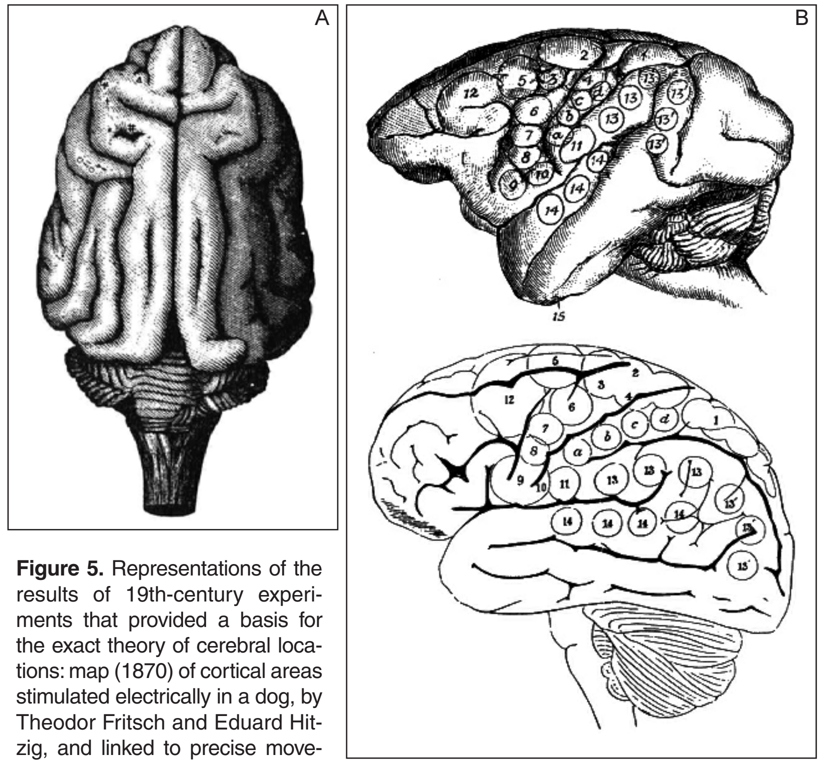


Figure 5. Representations of the results of 19th-century experiments that provided a basis for the exact theory of cerebral locations: map (1870) of cortical areas stimulated electrically in a dog, by Theodor Fritsch and Eduard Hitzig, and linked to precise movements (A), and map (1876) of cortical areas stimulated electrically, by David Ferrier, to obtain specific responses in a macaque, and transposition of results onto the human brain (B).

through the brain, and by exciting sensation it must become a cause of action”[(i)]. The reflex action described by Bell would later enable another scientist with an Edinburgh connection, Marshall Hall (1790-1857), to fully expound upon the concept of the reflex arc in his 1833 paper *On the Reflex Function of the Medulla Oblongata and Medulla Spinalis* and in his 1837 memoir *On the Reflex Function* because “the medulla spinalis” - as he states - “is the middle arc of the reflex function” along the afferent sensory nerves of the dorsal roots and the efferent motor fibres of the anterior roots. Several types of animal movement can therefore be performed: reflex movement, possible even after cerebral ablation because it is mediated by the spinal cord; respiratory movements, dependent on the medulla oblongata; voluntary movement, reliant on the brain; and involuntary movements, triggered by the irritability of the muscle fibres. This conception reinforced the idea that the functioning of the entire central nervous system, comprising both spinal cord and brain, could be explained via recourse to mechanical models. It is this school of thought that the original research work of Leonardo Bianchi served to consolidate.

☐ THE “NERVOUS MACHINE”, THE MECHANISM OF THE BRAIN AND THE FUNCTION OF THE FRONTAL LOBES ACCORDING TO LEONARDO BIANCHI

Leonardo Bianchi was born in 1848 in San Bartolomeo in Galdo (Benevento) (Figure 6). Upon his graduation in Medicine from the University of Naples in 1871, he was appointed physician at the Bourbon Hospice for the Poor, where he developed an interest in pathological anatomy and began to practice neuropsychiatry. In 1881 he became assistant to Giuseppe Buonuomo, director of the province of Naples lunatic asylum, and started teaching psychiatry at the University of Naples. In the following year he founded both the Psychiatric Institute of Naples and the Italian journal *Annali di Neurologia* (*Annals of Neurology*), and in 1883 launched the periodical *La Psichiatria, la Neuropatologia e le Scienze affini* (*Psychiatry, Neuropathology and Related Sciences*). In 1890, upon the death of Buonuomo, Bianchi took over his mentor’s teaching post at the university, effectively uniting the chairs of Neuropathology (the term used to designate nervous system diseases) and Psychiatry.

In Leonardo Bianchi, exponent of “politicized medicine”, which was fairly widespread in Italy in the last decades of the 19th century, and protagonist of a “positive idea” that was typical of the scientific mentality of the time; political commitment, among the ranks of the democratic left, was a constant companion to his medical activity, and he was particularly involved in social issues (reform of the penitentiary system and the laws governing prostitution, as well as

[(i)] Sironi VA. *Nascita ed evoluzione delle neuroscienze*. In: VA Sironi (editor): *La scoperta del cervello*, cit., p. 62.

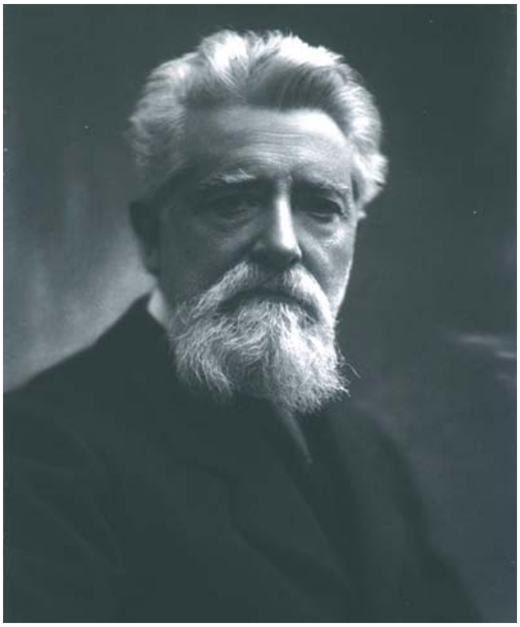


Figure 6. Leonardo Bianchi was born in San Bartolomeo in Galdo, in the province of Benevento, on 5th April 1848; he graduated in Medicine and Surgery from the University of Naples in January 1871, and died on 13th February 1927 after a sudden attack of angina pectoris during a conference in Naples, where he had spent the vast majority of his life, with the exception of a few brief interludes in other Italian cities.

the fight against malaria and tuberculosis). In 1904, as a parliamentarian, he drafted the first national legislation on asylums and the mentally alienated, while as Minister for Public Instruction (from 28th March to 24th December 1905) he established the first Italian chair of experimental Psychology at the Universities of Rome, Naples and Turin. He was elected senator in 1919 and died in Naples in 1927.

The principal focus of his medical research was the cerebral localization of neuropsychological processes, and the war provided him with many brain-damaged subjects to observe. Based on the resulting case reports and experimental evidence, he formulated various theoretical hypotheses according to which the frontal lobes were to be considered the seat of the intellect, emotions and higher mental functions. He expounded his theories in various publications, including the particularly significant *Sulle localizzazioni cerebrali* (*On Cerebral Localization*) (Naples 1893), *The function of frontal lobes* (in "Brain", 1895), *Trattato di psichiatria ad uso dei medici e degli studenti* (*Text-book of Psychiatry for Physicians and Students*) (Naples 1905) and *La meccanica del cervello e la funzione dei lobi frontali* (Turin 1920). This latter work, which took on international resonance thanks to its translation into French in 1921 and into English the following year, represented the sum of more than twenty years of work on the subject, a distillation of his thoughts and analyses on the functions attributed to the frontal lobes[l].

The hypothesis that the frontal lobes could be the site of the higher mental functions had already been considered in the past. "From ancient times" - Bianchi reminds us - "anatomists, physiologists and poets have spoken of the frontal lobes as the organ of intelligence"[m]. Already the Italian anatomist and physiologist Giovanni Maria Lancisi (1654-1720) had indicated the frontal lobes as the "factory of thought", while the German anatomist and physiologist Karl Friedrich Burdach (1776-1847) believed that they played a role in neuropsychological function and objective consciousness. The French anatomist Louis Pierre Gratiolet (1815-1865), although against the localization theory, subscribing instead to the doctrine of Jean Pierre Flourens (1794-1867) on the equivalence of the cerebral areas, recognized in the frontal lobe the "majesty of the human brain."

To Eduard Hitzig (1843-1928) "must be given the credit" - writes Bianchi - "of having placed the question upon an experimental basis [...] in his controversy with the German physiologists". As far back as 1874, Hitzig had contradicted Friedrich Goltz (1834-1902) and Immanuel Munk (1852-1903), providing experimental proof that demonstrated the "loss of recent acquisitions" resulting from ablation of the frontal lobes in monkeys.

In contrast to the reductive hypothesis of David Ferrier (1843-1928), who considered frontal lobe lesions only in terms of the movement disturbances

[l] For a biography of Leonardo Bianchi, see Saporito F. *Leonardo Bianchi.* L'Ospedale Psichiatrico 1948-1949; XVI-XVII: 229-252, and websites: www.accademiaxl.it/Biblioteca/Virtuale/Ipertesti/neuroscienzeXL/bianchi.htm e www.archiviopsychologica.org/index.php?id=1012 [cited 2010, 2 December]. On the works of Leonardo Bianchi in particular: Lambiase M, Salomone G, Bianchi VD. *La dottrina sui lobi frontali di Leonardo Bianchi.* In: G Zanchin, L Premuda (editors): *Lo sviluppo storico della neurologia italiana: lo studio delle fonti.* La Garangola, Padova (Italy), 1990: 99-102, and Lambiase M, Salomone G, Bianchi VD. *Leonardo Bianchi: "La meccanica del cervello"*, ivi, pp. 207-210.

[m] Bianchi L. *La meccanica del cervello e la funzione dei lobi frontali.* Bocca, Turin (Italy), 1920: 85. All of the subsequent Bianchi quotations are taken from the authorized translation of this work: *The Mechanism of the Brain and the Function of the Frontal Lobes*, by James H. MacDonald. E&S Livingstone, Edinburgh (United Kingdom), 1922.

Figure 7. The first edition of Leonardo Bianchi's book *La meccanica del cervello* (1920) (A), which were translated into English: *The Mechanism of the Brain and the Function of the Frontal Lobes* (1922). From the English translation frontispiece (B), author's preface (C) and figures of his experimental studies on the monkey brain, showing the extent of mutilation or decortication and also the parts of the frontal lobe that were spared. In particular, figure 53 (D) shows frontal lobes separated from the motor area with the exception of the operculum, and left *in situ*; figure 54 (E) a cerebral section in a case of frontal lobe decortication, left *in situ*; and figure 55 (F) a section through the posterior limit of the experimental lesion in front of the motor area, the orbital surface and, on one side, the operculum are spared.

A

Prof. LEONARDO BIANCHI

LA MECCANICA

DEL

CERVELLO

E LA FUNZIONE DEI LOBI FRONTALI

Con 61 figure e 4 diagrammi intercalati nel testo.

MILANO TORINO ROMA

FRATELLI BOCCA, EDITORI

Depositario per la Sicilia: Orazio Fiorenza - Palermo.

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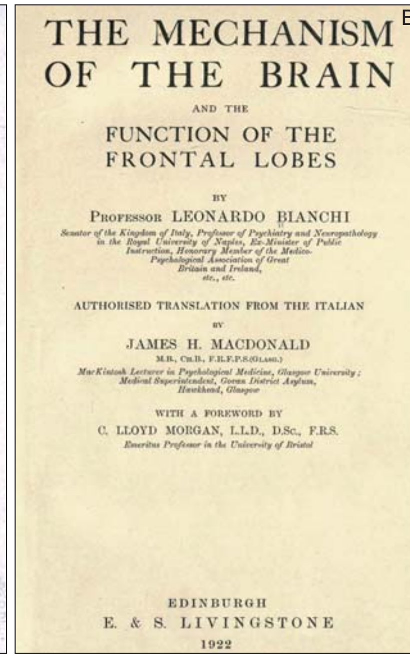

B

THE MECHANISM OF THE BRAIN

AND THE

FUNCTION OF THE FRONTAL LOBES

BY

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AUTHORISED TRANSLATION FROM THE ITALIAN

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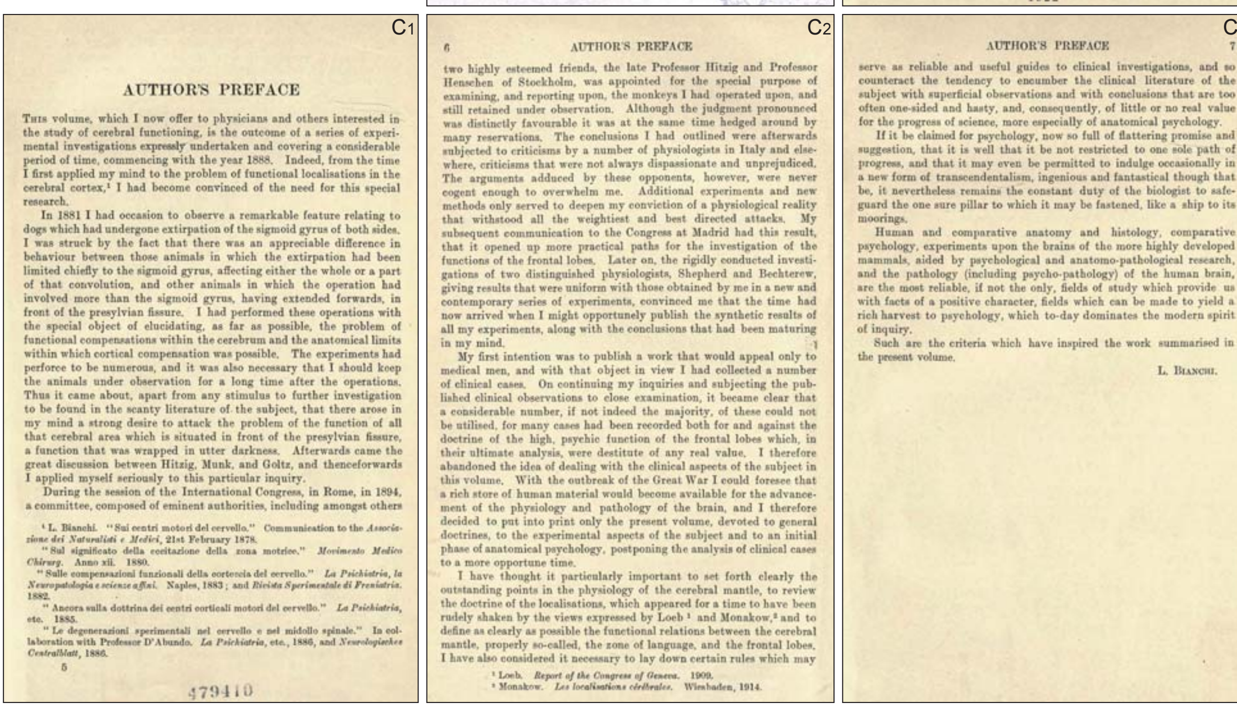

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AUTHOR'S PREFACE

THIS volume, which I now offer to physicians and others interested in the study of cerebral functioning, is the outcome of a series of experimental investigations expressly undertaken and covering a considerable period of time, commencing with the year 1888. Indeed, from the time I first applied my mind to the problem of functional localisations in the cerebral cortex,[1] I had become convinced of the need for this special research.

In 1881 I had occasion to observe a remarkable feature relating to dogs which had undergone extirpation of the sigmoid gyrus of both sides. I was struck by the fact that there was an appreciable difference in behaviour between those animals in which the extirpation had been limited chiefly to the sigmoid gyrus, affecting either the whole or a part of that convolution, and other animals in which the operation had involved more than the sigmoid gyrus, having extended forwards, in front of the presylvian fissure. I had performed these operations with the special object of elucidating, as far as possible, the problem of functional compensations within the cerebrum and the anatomical limits within which cortical compensation was possible. The experiments had perforce to be numerous, and it was also necessary that I should keep the animals under observation for a long time after the operations. Thus it came about, apart from any stimulus to further investigation to be found in the scanty literature of the subject, that there arose in my mind a strong desire to attack the problem of the function of all that cerebral area which is situated in front of the presylvian fissure, a function that was wrapped in utter darkness. Afterwards came the great discussion between Hitzig, Munk, and Goltz, and thenceforwards I applied myself seriously to this particular inquiry.

During the session of the International Congress, in Rome, in 1894, a committee, composed of eminent authorities, including amongst others

[1] L. Bianchi. "Sui centri motori del cervello." Communication to the *Associazione dei Naturalisti e Medici*, 21st February 1878.

"Sul significato della eccitazione della zona motrice." *Movimento Medico Chirurg.* Anno xii. 1880.

"Sulle compensazioni funzionali della corteccia del cervello." *La Psichiatria, la Neuropatologia e scienze affini.* Naples, 1883; and *Rivista Sperimentale di Freniatria.* 1882.

"Ancora sulla dottrina dei centri corticali motori del cervello." *La Psichiatria,* etc. 1885.

"Le degenerazioni sperimentali nel cervello e nel midollo spinale." In collaboration with Professor D'Abundo. *La Psichiatria*, etc., 1886, and *Neurologisches Centralblatt*, 1886.

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two highly esteemed friends, the late Professor Hitzig and Professor Henschen of Stockholm, was appointed for the special purpose of examining, and reporting upon, the monkeys I had operated upon, and still retained under observation. Although the judgment pronounced was distinctly favourable it was at the same time hedged around by many reservations. The conclusions I had outlined were afterwards subjected to criticisms by a number of physiologists in Italy and elsewhere, criticisms that were not always dispassionate and unprejudiced. The arguments adduced by these opponents, however, were never cogent enough to overwhelm me. Additional experiments and new methods only served to deepen my conviction of a physiological reality that withstood all the weightiest and best directed attacks. My subsequent communication to the Congress at Madrid had this result, that it opened up more practical paths for the investigation of the functions of the frontal lobes. Later on, the rigidly conducted investigations of two distinguished physiologists, Shepherd and Bechterew, giving results that were uniform with those obtained by me in a new and contemporary series of experiments, convinced me that the time had now arrived when I might opportunely publish the synthetic results of all my experiments, along with the conclusions that had been maturing in my mind.

My first intention was to publish a work that would appeal only to medical men, and with that object in view I had collected a number of clinical cases. On continuing my inquiries and subjecting the published clinical observations to close examination, it became clear that a considerable number, if not indeed the majority, of these could not be utilised, for many cases had been recorded both for and against the doctrine of the high, psychic function of the frontal lobes which, in their ultimate analysis, were destitute of any real value. I therefore abandoned the idea of dealing with the clinical aspects of the subject in this volume. With the outbreak of the Great War I could foresee that a rich store of human material would become available for the advancement of the physiology and pathology of the brain, and I therefore decided to put into print only the present volume, devoted to general doctrines, to the experimental aspects of the subject and to an initial phase of anatomical psychology, postponing the analysis of clinical cases to a more opportune time.

I have thought it particularly important to set forth clearly the outstanding points in the physiology of the cerebral mantle, to review the doctrine of the localisations, which appeared for a time to have been rudely shaken by the views expressed by Loeb [1] and Monakow,[2] and to define as clearly as possible the functional relations between the cerebral mantle, properly so-called, the zone of language, and the frontal lobes. I have also considered it necessary to lay down certain rules which may

[1] Loeb. *Report of the Congress of Geneva.* 1909.

[2] Monakow. *Les localisations cérébrales.* Wiesbaden, 1914.

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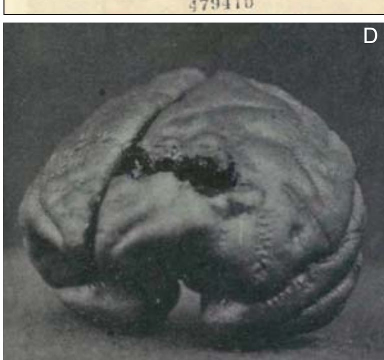
serve as reliable and useful guides to clinical investigations, and so counteract the tendency to encumber the clinical literature of the subject with superficial observations and with conclusions that are too often one-sided and hasty, and, consequently, of little or no real value for the progress of science, more especially of anatomical psychology.

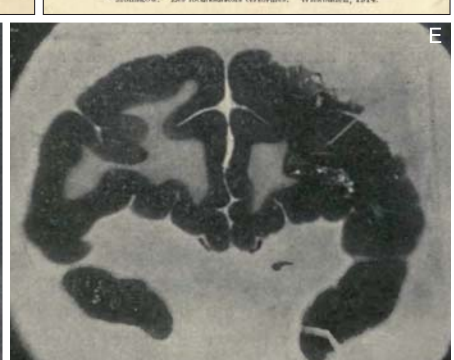
If it be claimed for psychology, now so full of flattering promise and suggestion, that it is well that it be not restricted to one sole path of progress, and that it may even be permitted to indulge occasionally in a new form of transcendentalism, ingenious and fantastical though that be, it nevertheless remains the constant duty of the biologist to safeguard the one sure pillar to which it may be fastened, like a ship to its moorings.

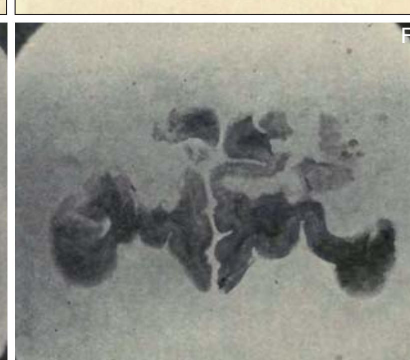
Human and comparative anatomy and histology, comparative psychology, experiments upon the brains of the more highly developed mammals, aided by psychological and anatomo-pathological research, and the pathology (including psycho-pathology) of the human brain, are the most reliable, if not the only, fields of study which provide us with facts of a positive character, fields which can be made to yield a rich harvest to psychology, which to-day dominates the modern spirit of inquiry.

Such are the criteria which have inspired the work summarised in the present volume.

L. BIANCHI.







they produced in the head and eyes, and the negativist assumption of Luigi Luciani (1840-1919), who excluded that the frontal lobes played any part in neuropsychological processes, the clinical and experimental observations of Leonardo Bianchi bolstered the postulated role of these cerebral lobes in the genesis of the higher brain functions.

His research *Sul substrato anatomico della mente* (*On the Anatomical Substratum of the Mind*) (1896) had been preceded by the summary of the results of a series of animal experiments begun in 1888 regarding *The function of frontal lobes* (1895), and was later further developed in the considerations *Sulla geografia psicologica del mantello cerebrale e la dottrina di Flechsig* (*On the Psychological Geography of the Cerebral Mantle and Flechsig's Doctrine*) (1900). Bianchi would go on to discuss his ideas on the topic in even more detail several years later, when he explained the dynamic functioning of the 'brain machine,' in *The Mechanics of the Brain*, which would definitively clarify *the function of the frontal lobes*. "I think" - he wrote in 1920 - "that the entire brain contributes to the formation and extrinsication of intelligence, not in the sense of Flourens, but in the sense of a division of labour between the various cortical areas, and of a coordination and association of the various products on the part of a particular cerebral organ. [...] I never asserted that the frontal lobe is the organ of the intellect, rather that it is *an organ of intellect* and that the work of the entire brain contributes to this, its highest manifestation. Does there exist a cerebral organ which has the faculty of utilising the mental products of the sensory areas of the cortex for the construction of mental syntheses more suited for the spiritualization [...]?". He went on to remark. "My hypothesis is that the frontal lobes are the seat of *co-ordination and fusion of the incoming and outgoing products of the several sensory and motor areas of the cortex*."

Thus the frontal lobes are seen as the anatomical substratum indispensable for the extrinsication of the mind, and as "capital" in the geography of the psyche, the fundamental cog, necessary for the function of the cerebral mechanisms of the 'mechanical brain'. He re-iterates: "My idea is that the frontal lobe is the organ of the physiological fusion of all the sensory and motor products elaborated in the regions of the cortex, respectively the seats of special sensory and motor functions; it is the organ of the synthesis, present and past, of the two great components of the mind, the somatic-emotive and the intellectual, and is thus the organ of physiological connection of all the sensory and motor products of the other regions of the cortex. [...] The concrete images are synthetized in man in conceptions or abstractions. The conceptions are nothing else than the product of the synthesis of a number of sensory and motor components and their derivatives, elaborated in the perceptive and the motor areas of the cortex, and moulded into symbolic forms in the zone of language. [...] This process of neuropsychological synthesis, raising the personality and the consciousness above the purely sensory field, is the principal function of the frontal lobes"[n].

In support of this hypothesis, the neuropsychiatrist from Naples produced experimental data obtained from animal studies and his clinical experience. In monkeys deprived of their frontal lobes, he found "defect in the perceptive power [...], defect of memory [...], and a complete absence of any initiative; [moreover] the associative power is greatly reduced [...]. [Furthermore] the behaviour of monkeys that have suffered mutilation of the frontal lobes is strongly indicative of a suppression of all the manifestations of initiative and curiosity. This goes to prove that the experiment has resulted in suppression of the imaginative capacity, the evocative power and the determinism to think." This describes a precise clinical picture, known today as *frontal lobe disorder*. "The syndrome" - specifies Bianchi - "is complicated by irrational fear, errors of judgments, indifference towards persons and things."

Regarding damage to the frontal lobes observed in humans he goes on to write: "Persons seriously injured in this region of the brain perceive through the individual senses the impressions of the external world, and react to the individual sensation with comparatively well-adapted movements. They are defective, however, in the power of reawakening and associating the images from whose union result more accurate and complex judgments, and of forming intellectual syntheses of a higher order"[o].

It is possible therefore to conclude that in "experimental ablations in monkeys or [...] severe bilateral lesions of the frontal lobes in man [...] the evocative capacity is defective and, consequently, the activity designated as phantasy or imagination is suppressed or much reduced, even in its simplest form, such as that excited by desire and the appetites".

[n] Bianchi L. *A Text-book of Psychiatry for Physicians and Students*. W. Wood, New York (USA), 1906.

[o] Bianchi L. *A Text-book of Psychiatry for Physicians and Students*, ibid.

From all these considerations, Bianchi deduces correctly that frontal lobes are "the organs of the ontogenetic and phylogenetic experience of the consciousness, nourished by records of the effects of previous actions, which undergo useful variations of adaptation; they are consequently, as already indicated, evocative and directive organs of thought and of action related to the end in view".

Bianchi believed in the existence a *lower consciousness* that "moves in the shorter circuits of the sensory fields where prevail sensations, images, relatively simple mental constructions, emotions, desires, acts of self-protection, and instincts, which sometimes flame into passions", and a *higher consciousness* that "moves in wider circuits, forming with the former a more extensive network of notions and experiences, being open to currents which come from all parts of the cerebral mantle. The pre-frontal portion of the mantle contributes to the higher consciousness with the weighty factors of reason and the more lofty and evolved sentiments, as summed up in the sentiment of sociality."

In this way, according to Bianchi, the frontal lobe "may sparkle with unexpected light, beaming forth to illuminate new paths of life"[p].

□ CONCLUSIONS

Leonardo Bianchi's work on the function of the frontal lobes, with particular reference to the concept of the consciousness, made a great contribution to the biomedical perspective that characterized the mind-brain debate in the late 19th century and early 20th. In this period, physicians and physiologists who concerned themselves with the functions of the brain (neurologists) and the mind - or, more precisely, behaviour - (psychologists), began to offer their opinions, alongside the philosophers who had dominated the discussion in the 1600s and 1700s. In the prospective of a new "philosophy of nature", which explored biological phenomena from an increasingly more positivist perspective towards the end of the 19th century, the biophysiological view characterized the work of a naturalist like Ernst T. Haeckel (1834-1919) who, following in the rationalist and materialist tradition of Baruch Spinoza (1632-1677), like the vigorous defender of the theories of Charles Darwin (1809-1882) that he was, considered that matter is blessed with life, or rather a "spiritual" property. His scientific materialism (monism) dictated that all natural phenomena could be explained by the laws of causality, and that matter and spiritual properties are one and the same (the mind, neuropsychological phenomena, soul and consciousness are synonymous); another, equally important, physiobiological viewpoint was that behind the experimental investigations that led scholars like Angelo Mosso (1846-1910), Luigi Luciani (1840-1919) and Charles S. Sherrington (1857-1952) to investigate the physiological substrates of reflexes and the higher functions[q].

In this neurophysiological context, destined to lay the foundations for the modern neurosciences, emerged the studies of Leonardo Bianchi on the role of the frontal lobes in processing thoughts and emotions. His contributions at times complemented and at times contrasted with those of John H. Jackson (1835-1911) regarding the concept of neuronal "irritation" and the identification of the cerebral functions, as well as work by Ivan Pavlov (1849-1936) on conditioned reflexes, and the neurophysiology of the higher functions in the accounts by Carl Wernicke (1848-1905) focussing on classification of the aphasias and identification of the "language centres".

The positivist neurophysiologists at the turn of the 20th century were all researching the "brain machine", whose responses to stimuli occur in a mechanical fashion. The reflex arc model (peripheral stimulus that conveys a central input and subsequent output that leads to a response) was assumed as a theoretical explanation of the dynamic functioning of the entire nervous system. The idea of direct neurophysical activation dominated the neurophysiological scene at that time. This appeared to go hand in hand with the neurochemical idea that had also begun to emerge, but which would not take precedence until the mid 1900s. Only at the end of that century would the neurobiological model, assuming a logical complex of variable and modifiable responses, come to the fore.

Leonardo Bianchi's "frontocentric" idea of the seat of the higher mental functions slotted neatly into the neurophysical logic of the brain machine, and undoubtedly had a significant theoretical influence on the work of Antonio Egas Móniz (1874-1955), who in 1936 performed the first prefrontal leucotomy to treat serious neuropsychological disturbance. Bian-

[p] Lambiase M, Salomone G, Bianchi VD. *Leonardo Bianchi: "La meccanica del cervello"*, cit., p. 210.

[q] Sironi VA. *Il problema mente-cervello: la prospettiva storica*, cit., p. 4.

chi's theories were also confirmed by Wilder G. Penfield (1891-1958), whose cerebral localization studies (it was he who created the famous "*cortical homunculus*") also provided important information about the areas of the brain potentially connected to emotions and "thought". The studies of Roger W. Sperry (1913-1994), who developed a new concept of the "mind" after his demonstration of the changes induced in the behaviour of patients subjected to *split-brain* surgery (severing the corpus callosum, the bundle of fibres that connects the two cerebral hemispheres) were also influenced by Bianchi's works. Sperry also proffered the "theory of the three Rs": *rattomorphism* (the cerebral mechanisms of the rat are not dissimilar to those of humans), *reductionism* (the entire brain is a physicochemical event) and *reflexism* (behaviour is a process arising in reaction to a stimulus). José M.R. Delgado, Michael S. Gazzaniga and Ragnar A. Granit also took such reductionist neurobiological positions. Last but by no means least, the most detailed and original neuropsychological theory by Alexander Luria (1902-1977), according to whom the primary functions of the cerebral areas generate by integration the higher functions, which, as such, are destined to evolve over time in each individual, also owes a debt to the Neapolitan neuropsychiatrist[r].

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