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Semicentennial Tribute to the Ingenious Neurobiologist Christfried Jakob (1866–1956)

1. Works from Germany and the First Argentina Period, 1891–1913

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Key Words
Christfried Jakob · Comparative neuro-anatomy · Evolutionary neuroscience · Cognitive neuroscience · Circuit of Papez · Neural correlates of consciousness · History of neuroscience

Abstract
This study, and the companion paper that follows, pays homage to the life and work of Christfried (also Christian or Christofredo) Jakob, a German-born neuropathologist who adopted Argentina as his country of vocation. Rated by von Economo and Koskinas among the three most important pre-1925 cortical neuro-anatomists, alongside Ramón y Cajal, Jakob is little known in the English literature. He has left an impressive record of publications, 30 richly illustrated monographs and 200 articles that span over a vast array of neurological themes, including cortical development and evolution, and the visceral brain. The present paper reviews works from his German years and the first visit to Argentina in 1899–1910. The companion paper covers his works (all in Spanish) during his 'second Argentina period', after 1913.

Introduction

This year marks half a century since the death of Christfried Jakob (fig. 1), a German-born neuropathologist who spent the best part of his prolific scientific life in Argentina. There is a remarkable paradox between the magnitude and relevance of his contributions to neuroscience on the one hand, and the complete absence of any reference whatsoever in the contemporary English medical literature on the other. Aimed at rectifying this lingering omission and the regrettable obscurity to which works not written in English seem to be condemned, the present study and the companion paper that follows survey the diverse contributions by a multifaceted brain scientist of the twentieth century.

Jakob is considered the father of neurobiology [1], neurology [2], and forensic histopathology [3] in Argentina, his chosen country of residence and vocation (his forename was first 'gallicized' to Christian and later 'castillianized' to Christofredo). Physician, philosopher, artist and educator, he is likely the only neuro-anatomist in the world to have a lake named after him: Lago Jakob, which he explored in 1934, is located 1,600 m above sea level, near Bariloche in the Argentinian Nahuel Huapí region of Western Patagonia (approx. 41°S, 71°W).

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Fig. 1. a Adolf von Strümpell (1853–1925). **b** Christfried Jakob (1866–1956). Strümpell, the son of the philosopher Ludwig Strümpell, was professor and director of the medical clinic in Erlangen between 1886–1903, in Breslau between 1903–1909 and in Leipzig between 1910–1925; his photo and signature are from the textbook of pathology [11]. Jakob's photo is from Orlando [7], courtesy of the Library of Congress; Jakob's signature facsimile is from the 1924 textbook of pathological anatomy and physiology (complete reference given in the companion paper [58]), courtesy of the Staatsbibliothek Berlin.

The only mentions of Jakob we found in the general English literature are two books [2, 4]. On the contrary, references to his life and works abound in Argentinian print [1, 3, 5] and electronic (http://electroneurobio.secyt.gov.ar) scientific journals. Two frequently consulted and documented biographies are those written by his disciples Luis López Pasquali [6] and Jacinto Carlos Orlando [7].

Jakob's published works exceed the 8,000 page mark [8] and comprise 30 monographs and about 200 articles, the result of apparently studying over 20,000 brains (as Jakob himself relates on November 15, 1939, in the preface to the second volume of his massive *Folia Neurobiológica Argentina* atlas). Jakob has been called a giant of science of the calibre of Cajal. In their monumental opus on cerebral cyto-architectonics, von Economo and Koskinas [9] express the view that future research on the cortex would have to be based on the fundamental works of three investigators: Theodor Kaes (1852–1913), Santiago Ramón y Cajal (1852–1934) and Christfried Jakob; they go on pronouncing Jakob's ideas on cortical phylo-ontogeny 'ingenious'.

Biographical Note

Christfried Jakob was born to Gottfried Jakob and Babette Körber on Christmas Day (hence his Christian name), Tuesday, December 25, 1866, in Wörnitzostheim (48.83°N, 10.65°E), east of Nördlingen-im-Ries, Bavaria, Germany. Jakob entered medical school at the University of Erlangen in 1886 and graduated on July 18, 1890, with a prize of 1,000 DEM, offered by the faculty to the most distinguished student [5, 7]. He completed his doctoral thesis on aortitis syphilitica [10] under Friedrich Albert von Zenker (1825–1898). In 1892 Jakob was second and in 1893 first assistant at the Erlangen Medical Clinic headed by Professor Adolf von Strümpell (1853–1925) (fig. 1), author of many well-known works, including a two-volume textbook of pathology [11] and founding editor of the *Deutsche Zeitschrift für Nervenheilkunde*. By 1895, Jakob had started a private medical practice in Bamberg. Both of his mentors had served as Prorectors at the University of Erlangen, von Zenker during the academic year 1869–1870, and von Strümpell in 1892–1893 (www.uni-erlangen.de/inforcenter/uniarchiv/materialien/rektoren).

In 1898, through the initiative of Domingo Cabred (1859–1929), Professor of Psychiatry in Buenos Aires, who had embarked on a European trip on a lookout for ways to promote neuro-anatomy in psychiatric research, Jakob was summoned to a 3-year contract with the national government of Argentina to direct the Laboratory of the Psychiatric and Neurological Clinic at Hospicio de las Mercedes, after von Strümpell refused the offer [7]. A key motive was the prospect of obtaining 300 brains annually for pathological study, when in Germany the corresponding number was 2–3 brains.

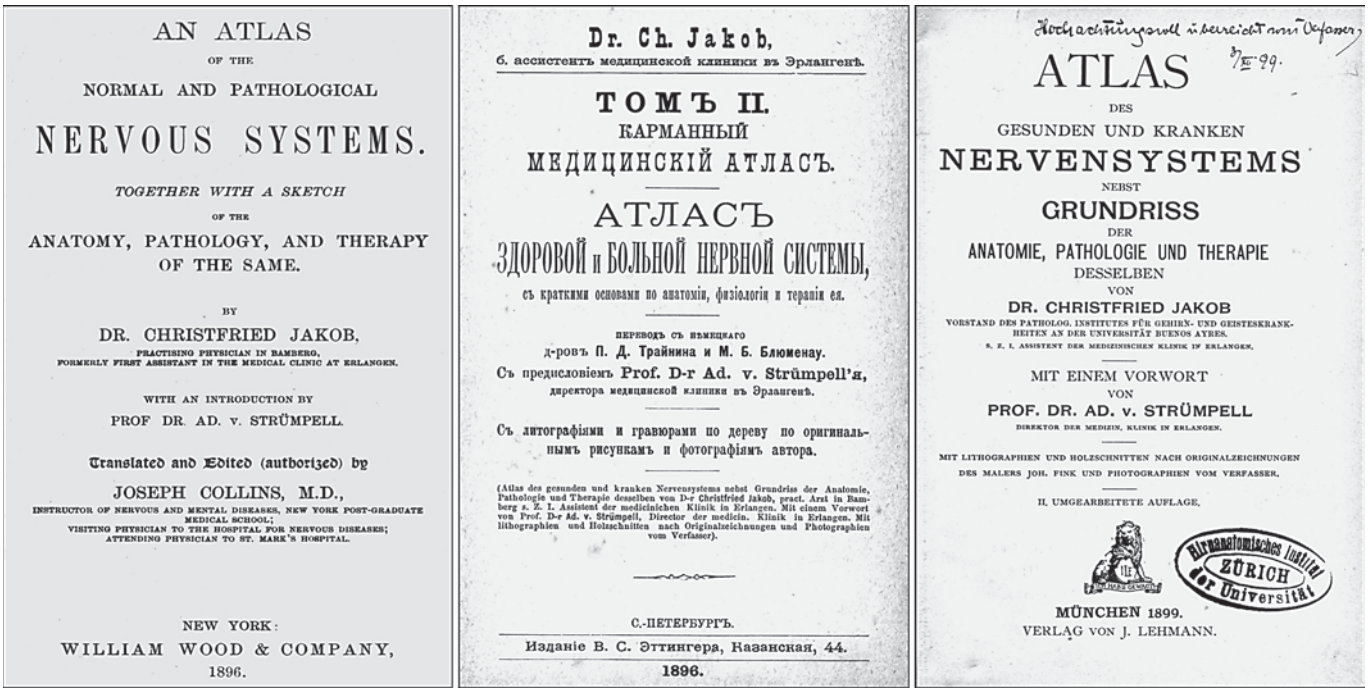


Fig. 2. Title pages of various editions of the *Atlas of the Nervous System* [12, 13]. English (left) and Russian (centre) translations of the first edition, and second German edition (right), the latter with the author's handwritten inscription.

Jakob left Germany via Hamburg and arrived in Buenos Aires on July 17, 1899. For the dozen years that followed, he produced works in neurology, psychopathology, biology, anthropology and paleontology [3]. His collaborators included psychiatrist-philosopher José Ingenieros (1877–1925), paleontologist Florentino Ameghino (1854–1911), naturalist Clemente Onelli (1864–1924) and anthropologist Roberto Lehmann-Nitsche (1872–1938). Jakob's initial contract had been renewed through 1910. Sometime afterwards, he went back to Germany to stay there for about 2 years before his second – and permanent – move to Argentina.

Monographs

Jakob published his first book at the age of 29, an atlas of the normal and pathological anatomy of the nervous system [12] with 78 plates and a preface by von Strümpell; it was speedily translated into English, Russian and French (fig. 2). In 1899, the work went through a second German edition [13] with 84 plates, appearing in French in 1900 and English in 1901. The handbook was illustrated with black-and-white woodcuts and colour lithographs made from Jakob's original drawings (fig. 3, 4). Amidst the many figures, one (fig. 4c) appears to depict the beading of myelinated nerve fibres, a phenomenon revived in the 1960s thanks to the efforts of Sidney Ochs [14].

The atlas was a clear exposition of the neurological knowledge available at the time, and a testimony to the profound versatility of its author in histological techniques employed to study the brain [8]. Jakob concluded the book by mentioning five approaches, which he thought could help achieve a better knowledge of the structure of the nervous system: (1) serial section reconstruction of adult human brains; (2) the study of pathological cases; (3) comparative anatomy and embryology; (4) developmental studies, and (5) experimentally induced lesions [12, 13].

In his preface, von Strümpell wrote:

'Dr. Jakob has been occupied in a most industrious manner with the normal and pathological anatomy of the nervous system. Having an extensive collection of histological preparations, which he prepared according to the most reliable research methods, along with his uncommon drawing talent, the author was able to compile this

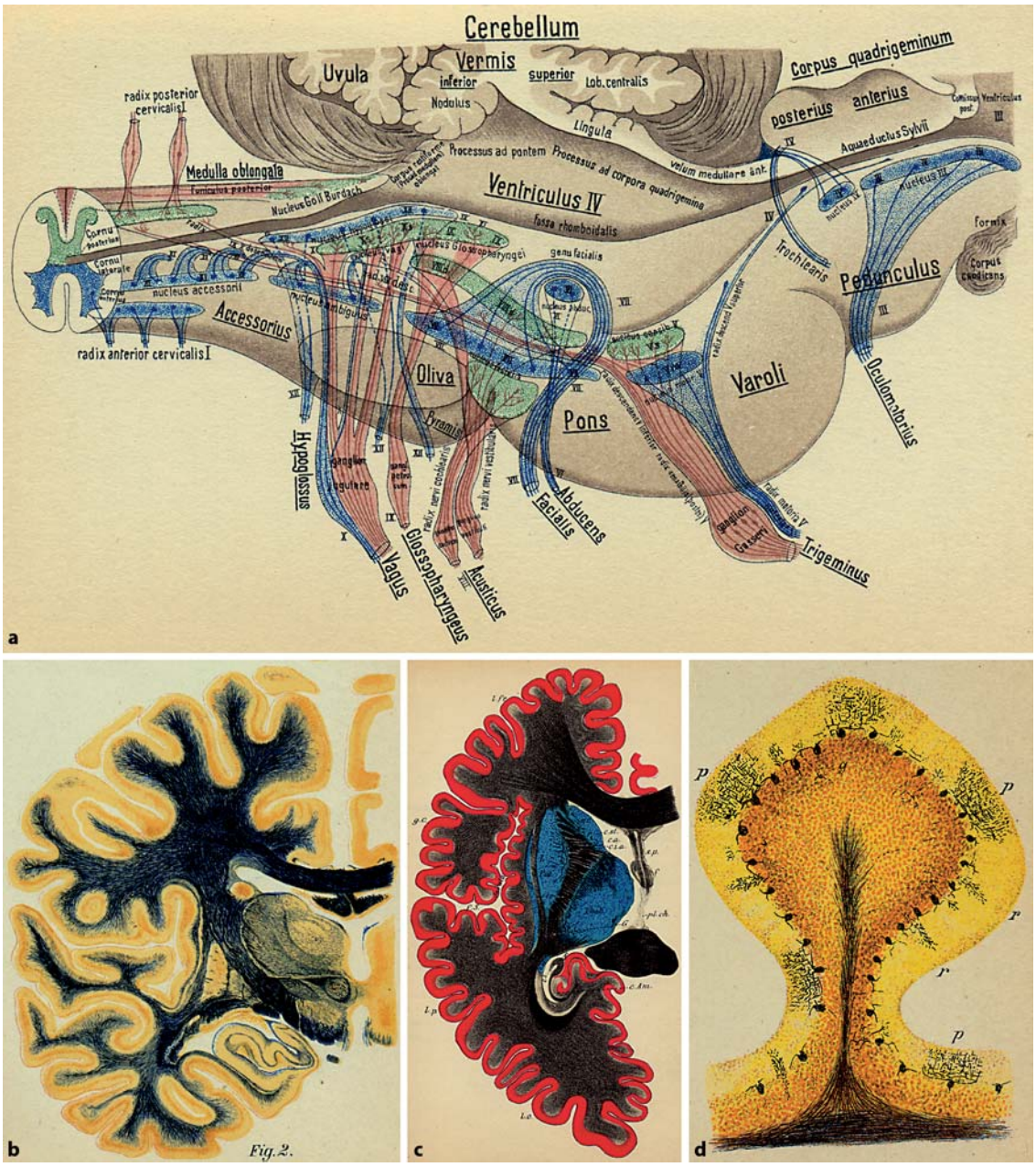


Fig. 3. a Lateral view of the brainstem showing in schematic form the position of the cranial nerve nuclei and the course of cranial nerves [13]. **b** Section of the cerebral hemisphere through the central convolutions [13]. **c** Horizontal section through the entire left cerebral hemisphere at the middle of the basal ganglia [12]. **d** Cerebellar convolution, silver stain [13].

atlas with great care. Any impartial observer will be convinced, as I am, that illustrations accomplish all that one would expect of them to convey. They present the actual conditions lucidly, and depict virtually all the numerous and important discoveries brought forth in studying the nervous system. The student and practising physician wishing to keep in touch with advances made in this field of medical science has the opportunity, with this atlas, of a clear conception of the present state of neurology with little trouble. There is perhaps no other branch of medi-

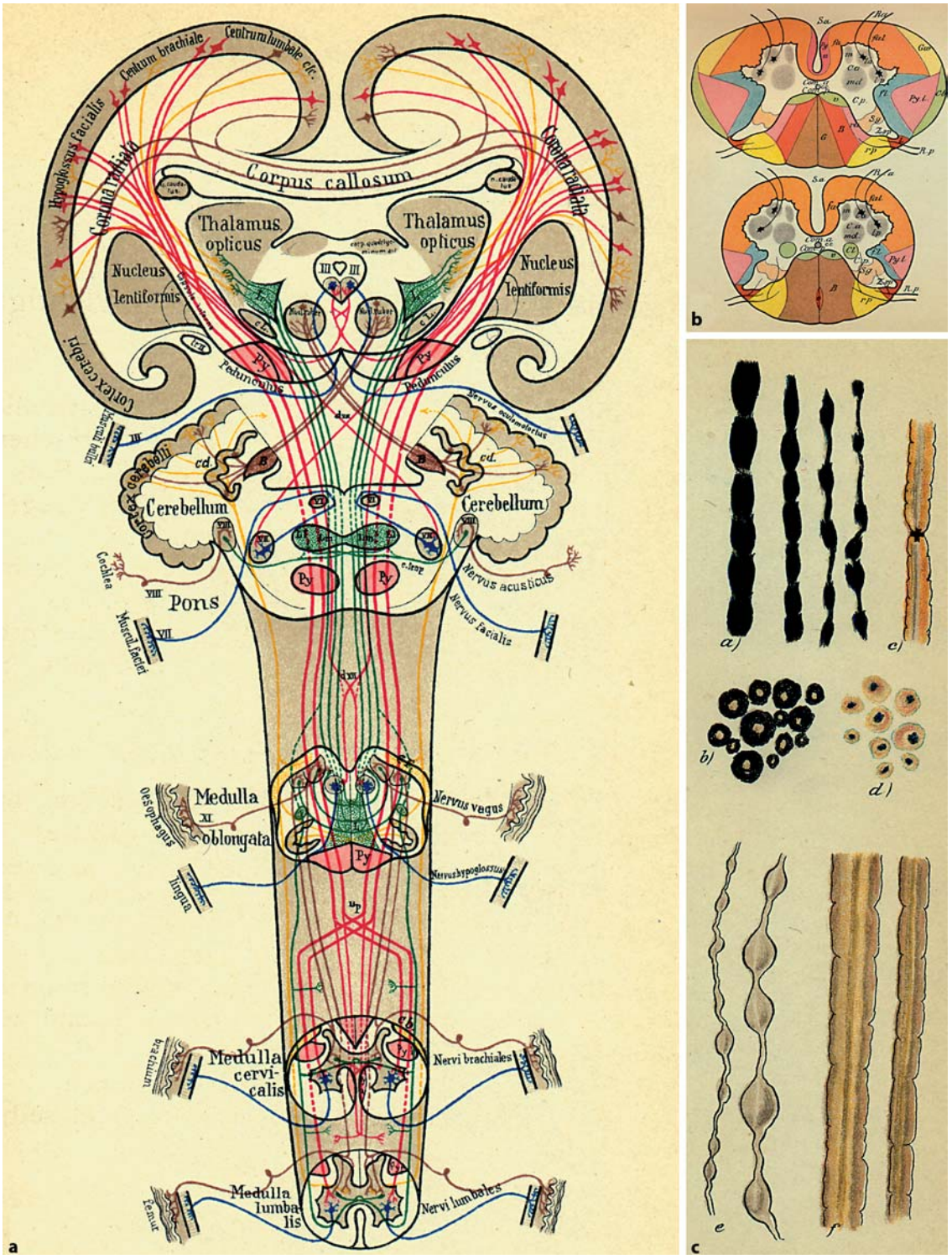


Fig. 4. a Schematic representation of the most important nerve tracts from a clinical point of view, in transverse sections of the cerebral hemispheres, crura, pons, cerebellum, medulla oblongata, cervical and lumbar enlargement, showing motor, sensory, rubral and cerebellar pathways [13]. **b** Diagrammatic representation of the position of the cervical and lumbar enlargements of the spinal cord [13]. **c** Various isolated nerve fibres in longitudinal and transverse section [13]; 'isolated fibres in the recent state, swollen from immersion in salt solution', images that resemble beading phenomena of myelinated nerve fibres observed in stretched mammalian nerve [14].

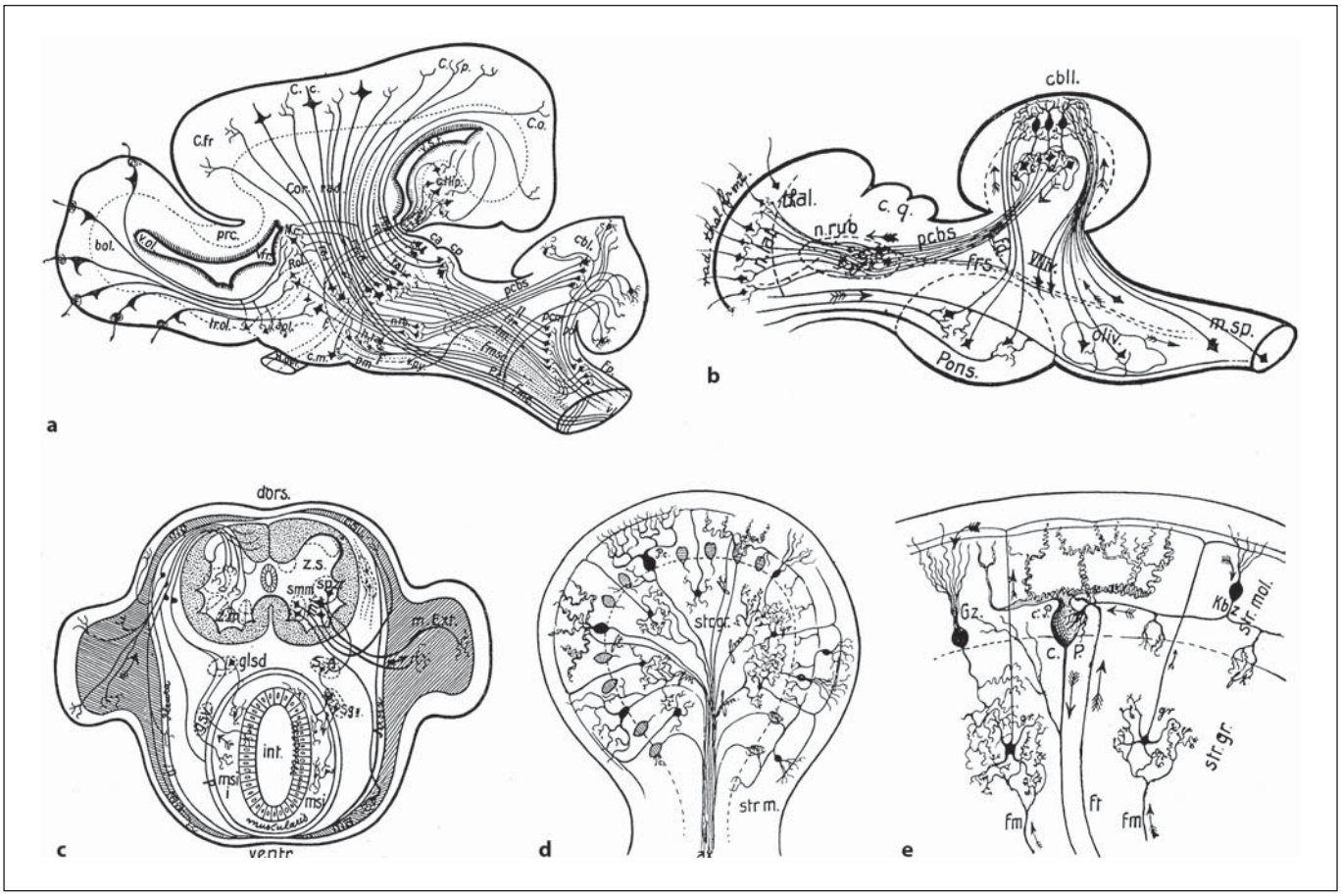
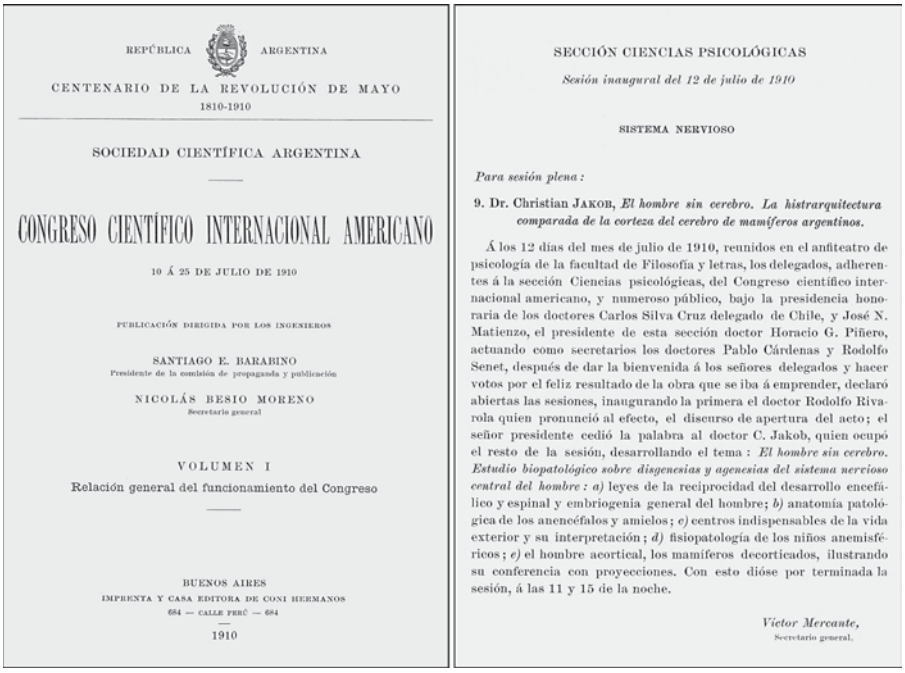


Fig. 5. a Projection pathways of frontal, central, parietal, occipital and temporal sectors in a sagittal section of the hemisphere of a mammalian brain [18, 22]. **b** Anatomical connections between the cerebellum, brainstem and spinal cord [17]. **c** Topographic plan of the lower nervous system and its reflex pathways, with the spinal nuclei, sympathetic ganglia and nerves, and the visceral innervation [17, 22]. **d**, **e** Histological structure of the cerebellar cortex [17].

cine than neuropathology, where the intimate relationship between clinical pathology on the one hand and normal and pathological anatomy on the other is so apparent and consistent. The treatment of normal and pathological anatomical facts, in conjunction with detailed, not schematic, illustrations render the work highly didactical. The author spared no pain devoting himself with untiring industry to achieving a really worthy and lasting goal' [12, 13].

In 1897, Jakob published an atlas of methods of clinical investigation, with an epitome of clinical diagnosis and special pathology and treatment of internal diseases [15], which was translated into French in 1898 and 1899 and English in 1899. In 1897, von Strümpell and Jakob produced an epitome of *Icones Neurologicae,* with 13 folded plates, 80 × 100 cm in size [16]; the plates were later re-edited and expanded by Friedrich Müller and Hugo Spatz in a 1926 edition.

The two classic German monographs of Jakob which are extensively alluded to by von Economo and Koskinas [9] are *The Human Brain* [17] and *From Animal Brain to Human Brain* [18] (large volumes, 30 × 40 cm in size). The former contains a 50-page introduction on the organizational plan of the central nervous system, profusely illustrated with 51 figures and 90 photomicrographic plates of cell and fibre staining. The latter work begins with the quote 'sun and brain are the creators of our world'; it contains 40 pages of text with 54 figures, followed by 48 plates. The two works delineate anatomical, histological, developmental and evolutionary aspects of the nervous system (fig. 5).



REPÚBLICA ARGENTINA

CENTENARIO DE LA REVOLUCIÓN DE MAYO
1810-1910

SOCIEDAD CIENTÍFICA ARGENTINA

CONGRESO CIENTÍFICO INTERNACIONAL AMERICANO

10 Á 25 DE JULIO DE 1910

PUBLICACIÓN DIRIGIDA POR LOS INGENIEROS

SANTIAGO E. BARABINO
Presidente de la comisión de propaganda y publicación

NICOLÁS BESIO MORENO
Secretario general

VOLUMEN I
Relación general del funcionamiento del Congreso

BUENOS AIRES
IMPRENTA Y CASA EDITORA DE CONI HERMANOS
684 — CALLE PERÚ — 684
1910

SECCIÓN CIENCIAS PSICOLÓGICAS

Sesión inaugural del 12 de julio de 1910

SISTEMA NERVIOSO

Para sesión plena :

9. Dr. Christian JAKOB, ***El hombre sin cerebro. La histrarquitectura comparada de la corteza del cerebro de mamíferos argentinos.***

Á los 12 dias del mes de julio de 1910, reunidos en el anfiteatro de psicología de la facultad de Filosofía y letras, los delegados, adherentes á la sección Ciencias psicológicas, del Congreso científico internacional americano, y numeroso público, bajo la presidencia honoraria de los doctores Carlos Silva Cruz delegado de Chile, y José N. Matienzo, el presidente de esta sección doctor Horacio G. Piñero, actuando como secretarios los doctores Pablo Cárdenas y Rodolfo Senet, después de dar la bienvenida á los señores delegados y hacer votos por el feliz resultado de la obra que se iba á emprender, declaró abiertas las sesiones, inaugurando la primera el doctor Rodolfo Rivarola quien pronunció al efecto, el discurso de apertura del acto; el señor presidente cedió la palabra al doctor C. Jakob, quien ocupó el resto de la sesión, desarrollando el tema : *El hombre sin cerebro. Estudio biopatológico sobre disgenesias y agenesias del sistema nervioso central del hombre : a)* leyes de la reciprocidad del desarrollo encefálico y espinal y embriogenia general del hombre; *b)* anatomía patológica de los anencéfalos y amielos; *c)* centros indispensables de la vida exterior y su interpretación; *d)* fisiopatología de los niños anemisféricos; *e)* el hombre acortical, los mamíferos decorticados, ilustrando su conferencia con proyecciones. Con esto dióse por terminada la sesión, á las 11 y 15 de la noche.

Víctor Mercante,
Secretario general.

Fig. 6. The book of abstracts of the 1910 Scientific Congress where Jakob (note the spelling of the forename, 'Christian') presented an overview of his work in a plenary lecture on 12 July [20], and in a joint presentation with Clemente Onelli on 21 July [21], shortly before leaving for Germany.

Jakob had already made a name for himself through his earlier atlases [12, 13, 16]. Both of the new 1911 works presented elegant documentation. *The Human Brain* [17] begins with a systematic, objective and faithful exposition of the histotopography of the grey matter through depictions of the spinal cord, medulla and brainstem, diencephalon and cerebral cortex. There is a section on cortical development. Particular emphasis was placed on detailed descriptions of the relations of the diencephalon with cortical areas, based on retrograde cell degeneration in the thalamus, covering its morphology and physiology. The author communicated numerous new vistas that deviated from previous opinions, e.g. on the projection from the mammillary bodies to the anterior nucleus of the thalamus, and the supracallosal gyrus or 'first sagittal pre-segment' as a 'visceral centre', based on clinical-pathological evidence and experimental data from operations in dogs and apes. Information is given with the purpose of studying the biological foundations of mental activities, such as memory, will, expression and imagination, in association with the underlying cortical structure and function.

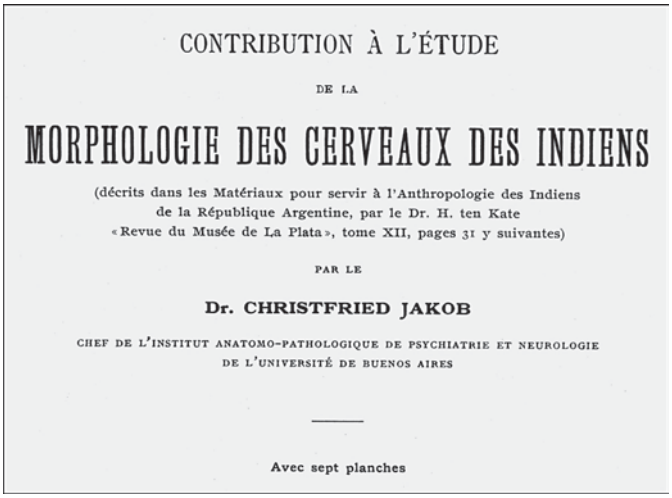
The Animal Brain [18], co-authored with Onelli, constitutes a far-sighted comparative neuro-anatomy and neurohistology with a constant consideration of functional differentiation, in diverse species of the South American fauna little studied until then. Biological details were given on the species, with special consideration for sensory organs and cerebral cortical functions, which form the basis for the morphological and biological understanding of the human cerebrum – 'our noblest organ, to which we humans owe more than any other creature on earth'. Jakob concludes with a description of the *Primatentyp* ('primate type') and compares the orangutan cortex with the human.

In later studies on the opossum brain, Gray [19] credits Jakob and Onelli [18] with providing descriptions of opossum species from South America. The external form of the brain of *comadreja overa* or *Didelphis azarae* and the four-eyed opossum *Metachirus crassicaudatus* [18] bears striking similarities to the Virginian opossum, and the transitional zone to the occipital cortex presents certain features of Gray's area peristriata. Further, brain regions of the Virginian opossum resemble in histological structure piriform, temporal, and prefrontal regions of South American edentates, such as the long-nosed armadillo of the Dasypus genus.

In 1910, Jakob made two keynote presentations at the *Congreso Científico Internacional Americano* (fig. 6): a plenary lecture on dysgeneses and ageneses of the human central nervous system [20] and a joint presentation with Onelli, director of the Buenos Aires Zoological Garden, on the comparative anatomy and phylogeny of the mammalian brain, based on the cortical biology of species of

Argentina's fauna [21]. That presentation was the prelude to *The Animal Brain* [18] and the *Atlas del cerebro de los mamíferos de la República Argentina* [22], subsidized by funds from the congress.

The 1913 Argentinian edition [22] constitutes a gem of the comparative neuro-anatomy literature, combining ontogenetic and phylogenetic concepts. The text of the German edition [18] was tripled with chapters on the biology of each species, classification, and morphological details on cortical sulci and convolutions. It is an invaluable work, covering the morphology of 40 characteristic mammals of South America, including exotic species such as the puma *(Felis puma)*, *aguará-guazú (Chrysocyon jubatus), tucu-tucu (Ctenomys magellanicus), carpincho (Hydrochoerus hydrochaeris)*, *guanaco (Lama huanacus), oso* and *osito hormiguero (Myrmecophaga jubata* and *Tamandua tetradactyla), perezoso (Bradypus tridactylus)* and *mulita (Dasypus hybridus).*


CONTRIBUTION À L'ÉTUDE

DE LA

MORPHOLOGIE DES CERVEAUX DES INDIENS

(décrits dans les Matériaux pour servir à l'Anthropologie des Indiens de la République Argentine, par le Dr. H. ten Kate «Revue du Musée de La Plata», tome XII, pages 31 y suivantes)

PAR LE

Dr. CHRISTFRIED JAKOB

CHEF DE L'INSTITUT ANATOMO-PATHOLOGIQUE DE PSYCHIATRIE ET NEUROLOGIE DE L'UNIVERSITÉ DE BUENOS AIRES

Avec sept planches

Fig. 7. Frontispiece of the article on the external morphology of the brains of South American Indians [25].

Spectrum of Published Articles

In addition to the 30 books that Jakob published (8 of those by 1913), he has left a record of close to 200 articles, dating from 1893 to 1949. We have compiled a comprehensive list based on four main sources: the Index Medicus volumes from 1891 to 1957, the index of the *Archives of Psychiatry and Criminology* edited by José Ingenieros, Jakob's own listings of his papers in his various books, and the list appended in Orlando's biography [7].

About one third of the articles, written in German, French and Spanish, were published before 1913, and about two thirds thereafter, all in Spanish. Some 40 papers deal with anatomy, histology, embryology, phylogeny and evolution, 70 with general pathology and neuropathology, and 50 with philosophy, neurophilosophy, neuropsychology, language functions and the frontal lobe. A 1911 German article is on 'The problem of the impending rise of meat price and its solution' [23]. There are 11 published reviews [24] of books authored by D. D'Arman, A. Cramer, F. Courmont, E. Frohse, E. Kraepelin, A. Mahaim, W. Osler, E. Perregaux, G. Pianese, S. Ramón y Cajal and H. Unverricht.

Brain Morphology in South American Indians

In 1905, Jakob [25] provided the first anatomical description of the brains of South American Indians [4, 26]. Four brains formed the basis of that communication, which had been written in French (fig. 7): two male (Yahgan and Gennaken-Huilliche) and two female (Inacayal and Alakalouf), from the Patagonian pampa and from Tierra del Fuego. As controls, he had by that time a collection of over a thousand brains, as well as the 'precious atlas of Retzius, which one may consider as a treasure for morphological studies' [25]. Before describing his results, Jakob states: 'If, to avoid unnecessary length, I designate such and such descriptions, I do not want to denote deviations of such a kind as non-typical or as inferior. There is not yet, neither will be probably for a long time, an absolute understanding of the opinions on a greater or a lesser inferiority of the different variants.' The study, accompanied by 24 photographs of the external form of the brain in 7 plates, gives data on overall appearance (size, development, convolutions), morphological variations and morphometric details for each lobe of each cerebral hemisphere, including diameters, patterns of gyri and the branching of sulci.

Features that stand out are: brain 1, an extraordinary development of the cap of the third frontal convolution on both sides, and the first temporal on the right: no stigma of inferiority; brain 2, massive with large convolutions, typically eurygyrencephalic, a pronounced development of the inferior parietal convolutions, and an unusual formation in the rostral portion of the calcarine sulcus, found, according to Cunningham, only in 2.3% of cerebral statistics; brain 3, dimensions somewhat smaller with light hypoplasia of the left frontal lobe (without any pathological lesions), and a development perhaps on the

lower end of the average size of its convolutions, but without offering evident detail anomalies in their configuration; brain 4, a pronounced type of eurygyrencephaly, with large convolutions and fairly rich in secondary convolutions, and without any finding of atypical dispositions.

In conclusion, Jakob finds the four brains perfectly at the height of the mean development of European brains; some features are above, other under, the mean line, that is to say, they vary in an ideal way, like all brains, without any notable alteration that had not been encountered in European brains. 'These observations are in agreement with the fact that all nations, which are today considered civilized, would find themselves, for the last 2,000 years, in the same state, plus or minus, as these Indians; further, the so-called mass culture is nothing but a methodical suppression of individual physiological functions; it is nothing but a development of inhibitory centres dictated by the laws of family, society and state.'

Neuropathological and Neuro-Anatomical Articles

During his tenure as assistant at Erlangen, Jakob published a case of acute alcoholic neuritis in a 5-year-old child [27], a neuro-anatomical contribution to the theory of combined systemic diseases of the spinal cord [28], a case of hemiplegia and hemi-anaesthesia with crossed oculomotor paralysis [29] and a contribution to the understanding of cortical and thalamic pathology [30].

His neuro-anatomical and pathological studies from his first period in Argentina include an early article on the state of leucocytosis in infectious diseases [31] and an exchange of commentaries [32] on the histopathology of *coup de chaleur* with Abel Ayerza and Horacio G. Piñero – who, in their 1899 classic paper [33], call Jakob a 'respectable authority'.

Some other works from that period include an article on the development of the cerebral cortex [34] and topical papers on aphasia and the 1906 controversy of Pierre Marie and Jules Déjèrine on the localizationist-holistic debate regarding language centres in the brain [35, 36].

In 1909, Jakob published a case of familial progressive spastic paraplegia or von Strümpell disease [37]. Apparently, the number of neuropathological studies on hereditary spastic paraplegia in the literature is sparse, 15 articles between 1886 and 2001 [38]; Jakob's paper ranks fifth in chronological sequence after the 1886 and 1904 papers of A. Strümpell and the 1904 and 1906 papers of L. Newmark [38].

In poring over a diverse range of topics, Jakob pioneered some important neurobiological concepts. A brief overview follows.

Dual Origin and Ubiquitous Sensorimotor Function of the Cerebral Cortex

At the second annual meeting of the International Society for Medical Psychology and Psychotherapy, organized in 1911 by Oskar Vogt in Munich, Jakob proposed the principle of the dual evolutionary origin and ubiquitous sensorimotor function of the cerebral cortex [39, 40], based on comparative studies of primates and species such as *Caecilia lumbricoides,* an unusual legless amphibian of the Gymnophiona (Apoda) order that resembles a giant earthworm, and *Amphisbaena darwini,* the blind viper. In the article 'Psychology and its relation to cortical biology' [41], he defended the view that all cortical regions contain receptive elements. Most sensory pathways end up in what he calls the 'outer fundamental cortical layer' (small and medium-sized pyramidal cells), which ontogenetically and phylogenetically derives from the sensory rhinencephalic apparatus. The 'inner fundamental layer' contains effector (motor) elements. With advancing evolution, the two fundamental layers become intermingled. According to Jakob, sensory, motor, and associative elements exist in all cortical areas. Thus, he attributes a certain homogeneity to the cortex as an organ, and contradicts the theories of Flechsig and Cajal on association and memory centres.

At the same meeting in 1911, a discussion was held on the nature of hypnosis and amnesia. Following presentations by Bernheim and Claparède, Jakob mentioned an observation upon himself during a time he had been ill with typhoid fever in 1905, while in Argentina: the first 4 weeks had passed normally, and then a relapse came; from all that occurred afterwards, he remembered nothing, but argued that all dream life, on the other hand, was perfectly conscious to him [42].

Hemispheric Rotation around the Sylvian Pivot

Jakob explains the complex structure of the mammalian cortex through two separate events, hemispheric rotation and the formation of *Urwindungen* ('sagittal pregyri') [18].

The concept of hemispheric rotation around the sylvian pivot in the sagittal and coronal planes [18] is an

original idea of Jakob [43, 44]. The rotation, which begins around the insular area as an axis, can directly explain the emergence of the sylvian fissure and the configuration of the remaining cortical sulci, such as the calcarine and parieto-occipital sulcus, and the 'radial or rotation sulcus system'; it results in a maturation gradient that implies heterochrony in cortical differentiation.

Hemispheric rotation, according to Irsigler [44], is one of seven events, upon which morphogenesis rests in the context of evolutionary theory, i.e. the transition from extant allocortical (reptilian and paleomammalian) formations preserved throughout vertebrate phylogeny and considered to be the foundation of species-specific behaviours in the animal scale from reptiles to humans. The other six events are Edinger's allocortical-isocortical contiguity, Spatz's allocortical base folding, hemispheric lateralization, Spemann's morphogenetic induction and metamorphosis, Sperry's chemo-affinity, and cyto-architectonic/connectivity factors.

Formation of Pregyri and Presectors

Jakob suggested the development of four sagittal cortical *Urwindungen* ('pregyri'), laterally to Ammon's formation [18]. He designated them as (I) gyrus callosomarginalis (also gyrus fornicatus, limbicus or splenialis), where he places the visceral cortex, (II) the bodily axis – hind limb zone located between the splenial and ectomarginal sulcus, (III) the forelimb zone between ectomarginal and suprasylvian sulcus, and (IV) the facio-mandibulo-lingual zone between the suprasylvian and marginal sulcus. The formation of these 'segments' has its origin in the base of the marginal sulcus, the insular area of higher mammals.

As the final most important principle in the organization of the cerebral cortex Jakob considered the *Sektorenentwicklung* ('development of sectors'), already noted in the brains of lower vertebrates such as the edentates [18]. With this concept, he explained regional variations in cortical architectonics, which he ascribed to five *Ursektoren* ('presectors'), i.e. frontal, central, parietal, occipital and temporal, and a rich *Untersektorengliederung* ('subsector conformation'). The entire cortical mantle was viewed as a system of similarly constructed radiating sectors in a fan-shaped form *(fächerförmig)*, with their tip oriented towards the insula, and their expansions towards the upper hemispheric edge.

Based on the pattern of projection and association fibre growth, he reckoned that the sectors, with no exception, possess centripetal virgate parts in their coronae *(Stabkranzanteilen),* with centrifugal segments appearing only in certain areas, consistently across species. All sectors are receptively active, serving simultaneously both projection and association functions. Jakob rejected the separation of the cerebral cortex into independent projection and association centres [18].

In accordance with the sector principle *(Sektorenprinzip),* Jakob made a provisional attempt to cyto-architectonically partition the human cortex into 5 frontal, 3 central, 3 parietal, 2 occipital and 5 temporal sectors. Apart from those, he separated Ammon's formation, the uncus, the splenial formation ('visceral cortex') and the insular cortex [17].

Anatomical Centres of Emotion

Jakob suggested that the supracallosal gyrus is associated with the 'visceral cortical centre' [17, 18]. Here exist and have their highest central location the feelings from the visceral organs, especially in association with food intake, digestion, defecation and the sexual organs, that is, functions directly connected with the preservation of the individual and mating.

In 1964, Orlando [45] exposed succinct arguments in favour of a chronological and conceptual priority of Jakob over neuro-anatomist James W. Papez (1883–1958) on the formulation of the anatomical basis of the visceral brain. In 1937, Papez [46] suggested an anatomical basis of emotion, abiding in the mammillary bodies, anterior nucleus of the thalamus, cingulate gyrus, hippocampus and their interconnections, in what became later known as 'circuit of Papez'.

It is a fact that, based on clinical and patho-anatomical data from senile dementia and general paresis cases, as well as experimental evidence from retrograde degeneration and comparative anatomical and phylo-ontogenetic studies, Jakob had arrived at the conclusion, already in 1911 [17, 18], that the superior limbic (supracallosal or cingulate) gyrus is linked to afferent pathways that convey visceral thoracic-abdominal-pelvic sensations of the body and subserve internal feelings related to emotion. He wrote that 'the limbic cortex [cingulate gyrus] constitutes the hitherto unknown visceral cortical centre' and pinpointed to the involvement of the mammillary peduncles, mammillary bodies, mammillothalamic bundle of Vicq D'Azyr, thalamus, and the triangular system of the hypothalamus. The splenial zone of the reptilian brain, which corresponds to the superior limbic gyrus

from lower mammals to primates, conveys visceral sensations from the mammillary bodies via the mammillothalamic bundle to the anterior nucleus of the thalamus.

It seems therefore that Jakob preceded Papez by more than a quarter of a century on the existence of a visceral zone in the brain. In his 1913 monograph [22], Jakob concluded that 'from opossum to humans, hunger and love reside in the limbic cortex, and from there they emit categorical imperatives that form individual temperament and affection', conclusively coupling the temporal rhinencephalon with emotional and affective behaviour.

Cerebral Cortical Organization

The cyto-architecture of the mammalian cerebral cortex has been classically described as having an orthogonal organization. According to Colombo et al. [47], a vertical pattern or 'ensemble' was envisaged and schematically illustrated by Jakob and Onelli [22] in a concept similar to that later formalized by Lorente de Nó, Powell and Mountcastle, Hubel and Wiesel, Szentágothai, and Goldman and Nauta, currently recognized as a key characteristic of cortical organization [48].

Already in 1906, Jakob was teaching in his classes that cerebral microcircuits and the neuropil formed electrical interference models, which he described as reverberations, similar in certain ways to what are today termed 'holograms' [49, 50]. Again, Jakob's ideas may have anticipated by some six decades neurophysiological concepts brought forth at a much later time in the English bibliography [50–53]. These ideas touch upon the topic of consciousness, with concepts of brain dynamics related to oscillations. Jakob viewed psychic activity in the scope of an integrated structural-functional context, sustained by reverberating neural 'macrocircuits' and 'microcircuits' in an oscillatory coupling, which he termed 'representational atomicities' [54].

In the transition of physiological events to the integrative experience of consciousness, the integration of multiple levels of messages into a coherent picture in a process known as 'binding' [55] has been compared to the physical phenomenon of resonance, associated with 30- to 80-Hz oscillations or γ-waves, to which Crick and Koch [56] had at one time attributed the neural basis of consciousness. Synchronous neural oscillations occurring globally throughout the brain might lead us towards a theory of cognition to explain how conscious awareness arises from neural events [57].

Recapitulation

Jakob is said to have established, in his time, one of the most important neurobiological laboratories in the world [8]. He dedicated his life to the investigation of unknown areas of nervous system biology. His initial work touched upon zoology, comparative and pathological neuro-anatomy and histophysiology with a special emphasis on the natural history of the cerebral cortex.

By the age of 46, that is, until his permanent move to Argentina, Jakob had steadily built a record of solid neurological works and concepts that echoed in the standard literature at the time. His knowledge and understanding of the nervous system helped him approach concepts of evolution, development and function in tandem and in a comprehensive context.

Jakob's work is extraordinary in quality, quantity and diversity; his ways of probing into cerebral themes may as well justify the intensifier 'ingenious'. That proclamation in the present article's title is rooted in the celebrated *Cytoarchitektonik* by von Economo and Koskinas [9], who reserve the use of similar terms only on three occasions: Jakob's ingenious idea *(geniale Ansicht),* Cajal's use of the Golgi method (*ganz glänzend* = 'totally brilliant'), and Meynert's association of the granularity of the area striata in the calcarine cortex with sensory function (*geniale Intuition* = 'ingenious intuition'). Moyano [5] also resorts to the word 'ingeniosas' to characterize two small books of satirical poems published by Jakob in Buenos Aires under the pseudonym *Dr. Aussenseiter* ('Dr. Outsider'): *Die Apotheose der Null* (1932) and *Die Apotheose des Unendlichen* (1944).

The culmination, during the latter part of Jakob's career, of topical ideas that are relevant to modern cognitive neuroscience and neurophilosophy is covered in the companion paper [58].

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