

John F. Fulton (1899-1960): neurophysiologist, bibliophile, and historian. His relationship with Spain

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ABSTRACT

John F. Fulton was one of the leading figures internationally in neurophysiology and history of medicine between the early 1930s and 1960. Working at the laboratory of physiology at Yale University, he was a pioneer in the study of the functional localisation of the cerebral cortex in primates. His 1938 treatise *Physiology of the nervous system* was a milestone in the development of neurophysiology. Fulton created a working environment at the laboratory where training was provided to important scientists who later directed centres in their home countries. He stood out as speaker, editor, communicator, and member of several committees, and established many links with foreign figures, including the Spanish physicians José Manuel Rodríguez Delgado, Jaume Pi-Sunyer, Rafael Lorente de Nó, Josep Trueta, and Francisco Guerra. Fulton was a student of Charles Sherrington and Harvey Cushing and showed a special interest for the world of Santiago Ramón y Cajal. A great bibliophile, he dedicated the last years of his short but intense life to the history of medicine, publishing studies on Michael Servetus.

KEYWORDS

John F. Fulton, history of medicine, neurophysiology, Spanish neuroscience, José Manuel Rodríguez Delgado, Yale University

Fulton personified the old adage that if you want something done give it to a busy person. A man of boundless energy and ebullient enthusiasm, he could recognize a good idea and pursue it to the end with vigor, never letting protocol impede his progress.¹

Introduction

John Farquhar Fulton was one of the leading neurophysiologists internationally from the early 1930s to 1960. He created a pioneering primate laboratory in the United States where important studies were conducted on functional localisation of the cerebral cortex. He was also a great bibliophile and medical historian, who argued for the integration of science and

the humanities. Fulton was able to surround himself with important researchers who later developed their own projects elsewhere. A Renaissance man, he was an open-minded and generous intellectual who was a close friend of scientists from all over the world, including Spanish researchers, some of whom worked with him in the laboratory of physiology at Yale.

The main aim of this work is to analyse the figure of John Fulton as a neurophysiologist, bibliophile, and historian, his relationships with other scientists (including Spanish scientists), and his interest in Spanish medical personalities.

Methods

To study John Fulton's complex life, we conducted an extensive literature review and selected the most relevant studies on his life and scientific work. A valuable source of information was the journals edited by Yale University, such as the *Yale Journal of Biology and Medicine* and the *Journal of the History of Medicine and Allied Sciences*, as well as the main physiology journals of Fulton's time; we also consulted the numerous obituaries published after his sudden death at a relatively young age in 1960. To study his life, we preferentially used texts by authors who were personally acquainted with him; to analyse his work, we focused on studies by himself and his group.

The article also briefly presents the scientists who were important in his life and his laboratory, including Spanish scientists, as well as the context of these relationships.

Development

Early years. First stay at Oxford

John Farquhar Fulton was born in Saint Paul, Minnesota, on 1 November 1899. His father, whose name he shared, was a prominent ophthalmologist who helped found the University of Minnesota and its Medical School. John graduated from his hometown's secondary school at the age of 16 and sat the University of Harvard entrance examination, but was unsuccessful.^{2,3}

He returned to Saint Paul and started university in 1916, but he dropped out after one year to perform military service; after completing this, he sat the Harvard examination once more, but this time was admitted as a veteran, without having to pass a second examination.⁴ During secondary school, he had worked the night shift as assistant at the Saint Paul Public Library, where he discovered his passion for books. His initial failure in the Harvard entrance examination was probably because he spent so much time reading, rather than studying.³

Fulton joined Harvard University as a second-year student of biology; during the summer, he participated in research projects at the Bermuda Biological Station for Research, which led to many scientific publications, including one dedicated to neuromuscular transmission. In 1921, he graduated with the highest honours.^{2,5,6}

The same year, he was awarded the Rhodes Scholarship to study biology in Oxford, at the prestigious Magdalen College, carrying with him a letter of introduction for

Professor Charles Sherrington, one of the institution's most outstanding members, from Professor Walter B. Cannon. Once in England, he stayed in Cambridge for several months to collaborate with Sir Arthur Shipley on the drafting of his classic work on elemental biology, *Life: a book for elementary students*; the book was dedicated to "J.F.F."^{3,7} In Oxford, after graduating with honours in 1923, Fulton was awarded the Christopher Welch scholarship for two years and employed as physiology demonstrator, and had the privilege of working in the laboratory of Sir Charles Sherrington (1857-1952).^{2,3}

In a comprehensive historical context, and in the atmosphere of Oxford, he became interested in experimental physiology, focusing on neuromuscular physiology. He analysed the electrical behaviour of nerves, the nature of the monophasic action potentials, chronaxie, and the nature of muscle contraction. He made an unfortunate over-emphasis on the "angle," an abrupt termination of the contractile phase of the graphic record, which not too long afterwards was shown to be an artefact of the myograph. With this research, he earned his doctorate (DPhil) in 1925, and the results were published in his first book, *Muscular contraction and the reflex control of movement. A monograph*. This extensive work, with 644 pages and 1066 references, was published in 1926, soon after Fulton's return to Harvard.^{2,8,9}

The young Fulton frequently visited Oxford's libraries and was admitted by Lady Osler to her house "The Open Arms," where he helped Osler's nephew William W. Francis and Reginald Hill of the Bodleian Library to compile the *Bibliotheca Osleriana*, owned by William Osler (1894-1919).³ There, in 1924, he met Harvey Cushing (1869-1939), who would become his friend and mentor. At that time, Cushing was writing his biography of Osler.^{6,9} The initiative was started by a group of Osler's students who imposed themselves the task of cataloguing his impressive library. Fulton joined this group and followed the examples of Osler, Sherrington, and Cushing, who were science historians and great collectors of old books.¹⁰

In 1923, he married Lucia Pickering Wheatland in Oxford; she belonged to a rich family from Maine and shared his love of books. At Magdalen College, he met Howard Florey (1898-1968), who discovered the clinical effects of penicillin and became his long-life friend.¹⁰



Figure 1. John F. Fulton at the Peter Bent Brigham Hospital in Boston, 1928.⁸²

Return to Harvard

In 1925, after graduating from Oxford, John Fulton returned to Boston and joined Harvard Medical School to finish his doctorate in medicine, which he earned *summa cum laude* in 1927. There he once more met Harvey Cushing, who helped him complete his medical studies in only three years. He became Cushing's assistant during the following year at Peter Bent Brigham Hospital, where he learnt neurosurgical techniques that he would use several years later in his physiological research (Figure 1).^{2,6,10}

At the Harvard physiology laboratory, under the fruitful and paternal mentorship of Walter Cannon (1871-1945),¹¹ Fulton worked with Jaume Pi-Sunyer (1903-2000), a travelling fellow from the Institute of Physiology at the Barcelona medical school, researching tendon reflex mechanisms and stretch reflex receptors

in decerebrate cats between 1926 and 1927.¹² They also published studies on the influence of hindlimb nerve terminals on the posture of the forelimbs, analysing locomotion mechanisms¹³ and the crossed extensor reflex.¹⁴

During his neurosurgical training under Harvey Cushing, he became interested in the autonomous nervous system and the hypothalamus. In collaboration with Percival Bailey, he published a study on tumours affecting the floor of the third ventricle and their association with sleep-wake rhythm alterations. This study is considered the first published reference in the scientific literature to suggest that the sleep-wake cycle is linked to a specific area of the brain.¹⁵

At Harvard in 1927, Fulton attended a patient with an unresectable occipital arteriovenous malformation who, when focusing on such visual tasks as reading, presented an audible bruit in the region proximal to the lesion. Fulton interpreted that the bruit was caused by increased blood flow within the lesion. By local auscultation and electrophonogram, he observed that during the performance of some visual exercises, occipital blood flow increased as well as the bruit; intensity increased with the complexity of the exercises, with the bruit becoming inaudible during rest with the eyes closed. This finding represents a precursor to modern techniques for the study of cerebral blood flow.^{16,17}

The laboratory of physiology at Yale

In 1928, the new dean of Yale Medical School, Milton Winternitz, offered John Fulton the Chair of Physiology; Fulton turned down the offer and returned to Magdalen College in Oxford to continue working with Charles Sherrington. In late 1929, he accepted Winternitz's offer on the condition that he be allowed to stay in Oxford for another year.^{2,10} Sherrington and Harvey Cushing were pleased with their student and friend's new position (Figure 2). Cushing had worked with Sherrington, who pioneered the study of cortical functions in primates in his laboratory in Liverpool, and encouraged Fulton to study the physiology of the cerebral cortex.⁹

In 1931, after his second stay in Oxford, Fulton was appointed Sterling Professor and made responsible for the laboratory there, as well as Chair of Physiology of Yale Medical School; he held both positions for 20 years, the most fruitful period of his professional career.¹⁸ The same year, the Department of Physiology was restructured



Figure 2. From left to right: Sir Charles Sherrington, Harvey Cushing, William Henry Welch, Thomas Graham Brown, and John F. Fulton in Les Terraces, Nyon (Switzerland), 1931.⁸³

with three independent divisions: a laboratory of neurophysiology, directed by J. G. Dusser de Barenne; a laboratory of comparative psychobiology, directed by Robert Yerkes, and a laboratory of physiology, directed by John F. Fulton.¹⁹

Fulton wanted this new laboratory of physiology to resemble Sherrington's in Oxford, and to incorporate the neurosurgical skills he acquired under Cushing. It was the first laboratory in the United States to be dedicated to the research of brain physiology in primates, which were difficult and prohibitively expensive to obtain. However, the laboratory minimised the deaths of animals by using modern surgical techniques.^{2,6}

He hoped to reproduce the neurological states encountered in clinical practice in the higher primates in order to analyse the underlying mechanisms. Because of his early interest in muscle contraction, he started his research by analysing motor representations in the cerebral cortex with stimulation and ablation techniques,

following careful protocols. He promoted a clinical approach to physiology, with careful observation of behaviour and minimal instrumentation, and encouraged the development of advanced instrumentation in psychobiology and electrophysiology²¹; he pioneered the research of brain function at the anatomical, physiological, and behavioural levels.²²

The 1930s were a golden age for Fulton's laboratory, where he aimed to achieve minimal direction and maximal stimulation.²¹ He placed greater emphasis on learning than on teaching, creating an atmosphere that was the same for students, interns, and graduates, encouraging personal initiative. Several generations of neurologists, neurosurgeons, and physiologists from the United States and abroad, who later became leaders in their future centres, worked in his laboratory.^{9,21}

Over the years, in addition to neurophysiology, the laboratory also conducted studies on electrocardiology, endocrinology, and aviation physiology.²¹



Figure 3. John F. Fulton with the chimpanzee Yama in the laboratory of physiology at Yale, 1933.⁵

The frontal cortex

In 1932, John Fulton and Margaret Kennard (1899-1975) began studying the motor functions of the frontal cortex in primates, using ablation techniques (Figure 3). They analysed the effects of lesions to the motor and premotor cortices on posture, forced grasping, and perseveration²³; neurological signs after lesions to the primary motor and premotor areas²⁴; motor representation of the autonomous nervous system in the premotor area²⁵; and premotor syndrome in adults.²⁶ Margaret Kennard stayed at Yale until 1943 and also studied lesions to immature brains of monkeys and the process of functional recovery. She is considered the founder of developmental neuropsychology.¹⁹

John Fulton and Carlyle Jacobsen (1902-1974) were two of the pioneers of modern cognitive neuroscience.¹⁰

Jacobsen, who had previously worked with Robert Yerkes, provided Fulton's laboratory with techniques to train primates to resolve complex problems. They soon observed that lesions to the premotor areas caused minimal motor deficits, followed by a significant disorganisation of acquired behavioural patterns; therefore, animals needed retraining after surgery. With more anterior frontal lesions, they began to observe truly intellectual alterations in association with behavioural alterations. One chimpanzee presented experimental neurosis and had to be progressively retrained. Neurosis reappeared after frontal lobectomy, but with bilateral lobectomy, the chimpanzee became less aggressive and showed absence of temper tantrums.^{9,27,28}

In August 1935, Fulton and Jacobsen attended the 2nd International Neurological Congress in London, where they presented the results of frontal ablation in two chimpanzees, Becky and Lucy, in a symposium. Egas Moniz, who attended the symposium, was impressed by the calming effect of the technique, especially in Becky and in a patient of Walter Dandy's who underwent bilateral frontal lobotomy during the removal of an extensive olfactory groove meningioma. Several months later, Moniz began to perform prefrontal lobotomies in humans with the help of the neurosurgeon Almeida Lima.^{6,28,29} This practice became generalised, and Fulton, who was initially in favour of the procedure, progressively became concerned by the associated abuses. In a meeting held in 1947 he bitterly criticised Walter Freeman, who introduced this surgical technique in the United States.²⁹

The path started by Fulton and Jacobsen was followed by other neuroscientists, including Bucy, Livingston, MacLean, Pribram, Kaada, and Rodríguez Delgado, who all worked at his laboratory at some point.⁹

The neurophysiological community at Yale in the 1930s

To talk about Fulton, we must make reference to some of the people he brought together at Yale, whom he stimulated in their research and provided with the necessary means. He was comfortable with life at the laboratory, but with his success came many invitations to meetings and lectures, as well as administrative tasks that robbed time from his everyday tasks and in the long term led to a move away from direct experimentation.¹⁰

In parallel to John Fulton, the Dutch scientist Johannes Gregorius Dusser de Barenne (1885-1940) joined

the Yale faculty in September 1930, also as Sterling Professor of Physiology. As director of the laboratory of neurophysiology, he performed pioneering studies on the organisation of the cerebral cortex, until his sudden death due to a heart attack. He had previously worked at Sherrington's laboratory in Oxford in 1924, where he coincided with Fulton, who was a doctoral student at the time. Between 1924 and 1927, they applied strychnine to the sensory cortex and thalamus of experimental animals, and were able to describe the central system controlling sensory function.^{30,31}

Once at Yale, he researched the excitability of the cortex and the functional organisation of the cerebral hemispheres in primates; he and his main student Warren McCulloch (1898-1969) reported the extinction and facilitation phenomena. They were among the first to observe the divisions of the sensory cortex. Using anaesthetised animals, they applied strychnine to the cortical surface and simultaneously recorded information from multiple cortical electrodes. They also developed laminar coagulation for the analysis of cortical layers and other techniques for analysing the interactions between specific cortical areas. Their research group studied the relationships between the sensory cortex and the motor cortex, thalamus, and other areas of the brain. McCulloch, who worked at Yale from 1934 to 1941, continued researching the functional relationships between different cortical areas after the death of Dusser de Barenne, and conducted pioneering studies for the development of modern cybernetics.^{22,30,32}

Harvey Cushing retired from Harvard in 1932, and Fulton persuaded him to work in Yale; the following year, Cushing became Sterling Professor of Neurology, transferring his extensive collection of brain tumour samples to his new destination.^{2,10}

In 1936, the New Zealand-born neurologist Derek Denny-Brown (1901-1981) arrived in Yale from England and stayed until 1939, working with John Fulton and Harry Botterell to perform experimental surgery on monkeys. He developed techniques of subpial resection by suction and published a monograph with Botterell on the motor functions of the agranular frontal cortex.³³

Over 6 months in 1933, Paul Bucy (1904-1992), a neurosurgeon from Chicago, led an intensive training programme on neurophysiological research at the laboratory at Yale; Bucy maintained a long-term friendship with John Fulton. Both men believed that

inducing brain lesions in experimental animals was the best method for studying brain function.^{34,35}

After two years lecturing in physiology at the University of Santiago de Chile, Jaume Pi-Sunyer (Figure 4) once more collaborated with John Fulton during the 1933-1934 academic year as a research assistant in Fulton's laboratory, later returning to Spain.³⁶

The Spanish neurosurgeon Sixto Obrador (1911-1978) was also a participant in this innovative setting. After a period at Sherrington's laboratory in Oxford, he worked from February to July 1936 at the Yale laboratory of physiology, researching the functions of the cerebral cortex. As a result of his research, he and the Swiss researcher Oscar Wyss, another intern at the laboratory, published an article on the proper electrical stimulation of the cerebral motor cortex.^{37,38}

The laboratory of physiology at Yale in the 1940s and 1950s

Studies on brain physiology continued during the 1940s, a decade initially marked by the outbreak of the Second World War, in which Fulton revealed himself as an enthusiast of the military effort, participating from his laboratory and sitting on several committees.

Hsiang-Tung Chang (1907-2007), who came to Yale from China in 1943, developed a new field of research after obtaining the first recordings of cortical cells using microelectrodes. He was a pioneer in the study of dendritic potentials and in identifying the physiological properties of dendrites and dendritic spines. He stayed at Yale until 1952, returning to China in 1955. He was also the first to propose the distinction between axosomatic and axodendritic synapses.³⁹

The British researcher Patrick Wall (1925-2001) worked at Yale between 1948 and 1950, researching the cerebral cortex of primates and pain mechanisms. During the 1960s, he and Ronald Melzack developed the gate control theory of pain. In his memoirs, Wall describes Fulton as a great organiser who was able to bring together in Yale a series of first-line researchers and made his laboratory a Mecca for young neuroscientists; however, he also mentions some errors in Fulton's research on the frontal lobe and in his work as editor of the *Journal of Neurophysiology*, which led him to argue with such significant personalities as Rafael Lorente de Nó, Ralph Gerard, and Derek Denny-Brown.⁴⁰



Figure 4. Jaume Pi-Sunyer i Bayo (Source: Image database of Spanish medicine. Spanish Royal Academy of Medicine).

Paul MacLean (1913-2007) came to Yale in 1949 and participated in the study of lobotomised monkeys and humans. He studied the limbic areas, and in 1948 coined the term “limbic system.” He postulated that humans have three brains: the reptilian brain (the oldest); the limbic system, a second brain inherited from the lower mammals; and a third brain characteristic of developed mammals. In 1957, he joined the National Institutes of Health, where he led research into the cellular basis of emotions and other limbic functions. MacLean was one of Fulton’s closest friends.^{4,41,42}

The neurosurgeon Karl Pribram (1919-2015), who studied under Bucy, Bailey, and McCulloch in Chicago, worked at Yale between 1948 and 1958. He studied the structure and function of the cerebral cortex, associating the human clinical experience with his neurophysiological and behavioural research in non-human primates. He discovered the visual functions of the temporal lobe and the relationship between the frontal cortex and the limbic system.⁴³ In 1956, he began to develop his ideas on the holographic nature of the cerebral function.¹⁰

Robert Livingston (1918-1952) worked with John Fulton between 1946 and 1952, and had a special interest in linking brain anatomy and function. Stimulated by several interests, he created the Department of Neurosciences at the University of California, San Diego, with an integrating approach to specialties similar to that taken by Fulton at the laboratory of physiology at Yale. In the 1970s, his group created the first three-dimensional image of the human brain.⁴⁴

José Manuel Rodríguez Delgado

José Manuel Rodríguez Delgado (1915-2011) spent his first fellowship at Yale under the direction of John Fulton and Robert Livingston, working there from late 1946 until the summer of 1947; he returned in 1950 and stayed another 22 years.⁴⁵ He had studied medicine at Universidad Central in Madrid, and had connections with the laboratory of physiology of Juan Negrín and the Cajal Institute. During the Spanish Civil War, not yet having completed his studies, he served as an army physician in Valencia and lieutenant of the medical corps on the Teruel front, eventually reaching the rank of captain. Rodríguez Delgado was held for five months in a Francoist concentration camp after the war ended. It is surprising that with this Republican background, he managed to be so well-regarded in academia after the war, receiving numerous awards and a James Hudson Brown fellowship to work in the United States.^{46,47} When he got to Yale, Fulton asked him about his role during the Spanish Civil War, to which Rodríguez Delgado answered that it was irrelevant to science. Fulton later learnt that his fellows believed the Spanish researcher to have been a doctor for Franco’s nationalist side and had decided to marginalise him. When he explained that Rodríguez Delgado had served as a captain in the Republican medical corps, their attitude changed and he was welcomed by the group (Figure 5).⁴⁶

Delgado, as he was known in the United States, had the support of Fulton, who appointed him assistant professor (1953-1955) and later associate professor. His experiments using electrodes to stimulate the brain represented a more sophisticated and less destructive version of Fulton's studies on the ablation of brain areas; Rodríguez Delgado continued this research from the chair of physiology and the directorship of the laboratory of neurophysiology, both of which he assumed in 1966.^{45,47}

He conducted studies applying electrical stimulation to the brains of cats, macaques, and chimpanzees to demonstrate changes in behaviour and sleep. Certain stimuli may cause foreseeable behaviours, and feelings of fear, anxiety, memory, pleasure, aggressiveness, pain, and phobias may be induced or modified.⁴⁸ Some of his experiments, such as controlling the aggressiveness of a fighting bull or the stimulation with brain electrodes of 25 patients with epilepsy and mental illnesses at a Rhode Island asylum, as well as statements made to the press,⁴⁹ brought about a series of controversies that ultimately ended his academic career in the United States. Fifty years later, he has been recognised as a pioneer of modern techniques for the implantation of brain electrodes in the treatment of several neurological disorders.^{46,50}

Neurophysiology communicator

Since arriving at Yale, John Fulton developed his passion for writing about the history of physiology. In 1930 and 1932, respectively, he published *Select readings in the history of physiology* and *The sign of Babinski*.^{51,52}

In 1938, he published the first edition of his treatise *Physiology of the nervous system*,⁵³ which was very well received by clinicians and was translated into six languages, including into Spanish by his friend Jaume Pi-Sunyer. The Spanish-language version was published in 1941 by Atlante in Mexico, with a special prologue and review by the author. In the chapter on the cerebral cortex, he collaborated with the Spanish neuroanatomist and neurophysiologist Rafael Lorente de Nó (1902-1990), the youngest student of Ramón y Cajal. A researcher at the Rockefeller Institute in New York since 1936, Lorente de Nó had published several works on the cellular architecture of the cerebral cortex, and presented new findings in chapter 15 of the book ("The cerebral cortex. Architecture, intracortical connections and motor projections"), also providing



Figure 5. Members of the laboratory of physiology. From left to right, back row: John F. Fulton and Eric A. Turner; front row: Robert B. Livingston, Bal Krishan Anand, José Manuel Rodríguez Delgado, Hsiang-Tung Chang, and Rajinder S. Sikand. Yale Medical School, 1952.⁵

text and illustrations. In this chapter, he summarised his anatomical studies and presented new, insightful functional interpretations. This was a very laborious task, as he verified every detail he wrote or drew in his collection of brain sections. He meticulously described the laminar and cellular organisation of the cortex, with six layers that were present in all cortical areas; compared the anatomy across different regions; characterised the area where thalamic afferents terminate, and the axonal and dendritic distribution of pyramidal cells and interneurons through different layers; and included a basic diagram of cellular connections. He described the fast, flexible operational dynamics of neuronal groups in cell assemblies. His concept of ongoing, or reverberating, activity through connected neurons would become central to Hebb's thinking when he eventually broke away from the strictly Pavlovian tradition of stimulus-response associations.^{22,54} The distribution of cortical neurons in columns, as postulated by Lorente de Nó, was corroborated in 1957 by Mountcastle in the sensory cortex, and in the 1960s by Hubel and Wiesel in the visual cortex.⁵⁵

After the success of *Physiology of the nervous system*, John Fulton was asked to update the 15th edition of

Howell's classic *Textbook of physiology*, published in 1946. Two editions later, in 1955, the title changed to *Fulton's textbook of physiology*. Jaume Pi-Sunyer and Antoni Oriol i Anguera translated the 16th edition (1949) into Spanish, and the Spanish-language version was published in 1951.^{2,5,56}

In 1949, he also published the book *Functional localization in the frontal lobes and cerebellum*, based on a lecture given the year before, which represented the culmination of two decades of research, and for which he was awarded a Pulitzer Prize.^{6,57}

John Fulton devoted considerable efforts to his work as the editor of scientific journals. Given the growing interest in physiology, and motivated by editor Charles C. Thomas, he and Dusser de Barenne founded the *Journal of Neurophysiology* in 1938; this was the second international journal on the nervous system, with an editorial board composed of the leading neurophysiologists of the time.²⁰ As proposed by the Chilean neurosurgeon Alfonso Asenjo, in 1944, he founded the *Journal of Neurosurgery*, with the collaboration of Paul Bucy and under the auspices of the Harvey Cushing Society, established in 1932.^{1,58} In the field of history, he became chief editor of the *Journal of History of Medicine and Allied Sciences* in 1951.⁶

Political ideas. The Second World War and penicillin

John Fulton was a man of liberal ideas, and was concerned by the outbreak of the Spanish Civil War and the Second World War. In June 1941, he admitted to Henry Sigerist (1891-1957) that his mood had declined due to the events in Europe. During that time, he helped several European refugees, including the Italian medical historian Arturo Castiglioni (1874-1953), whom he sheltered for seven years at Yale, and Adolf Magnus-Levy (1865-1955), a physiologist of Jewish descent from Berlin.^{11,59}

He actively participated in his country's war effort during the Second World War, participating in several committees of the National Research Council. As a member of the Committee on Aviation Medicine and Chairman of the Sub-Committee on Decompression Sickness, he recognised the importance of studying the effects of altitude and gravity on brain function; to do this, he built a decompression chamber in his laboratory at Yale, which worked until 1948,^{2,10,20} and published his findings in 1951.⁶⁰

When Howard Florey was working to develop the industrial production of penicillin in the United States, he had the invaluable help of his old friend John Fulton, in whose house in New Haven Florey's sons had lived since the German bombing of London. Fulton played a central role in the first administration of penicillin to an American patient at the Yale Medical Center. In March 1942, John Bumstead, who was treating Fulton for a severe case of pulmonary coccidioidomycosis he contracted during a visit to a microbiology laboratory in California two months earlier, and aware of Fulton's friendship with Florey, asked Fulton if he could procure penicillin to treat the wife of Ogden Miller, who had contracted streptococcus septicaemia secondary to miscarriage. After several telephone calls, Fulton was able to obtain a small sample of the antibiotic; after intravenous administration of the drug, symptoms rapidly resolved. After this therapeutic success, penicillin was manufactured on a large scale to treat allied soldiers during the Second World War. Although Fulton's coccidioidomycosis resolved slowly, he resumed the usual frenetic pace of his activities.⁶¹

John Fulton defended Henry Sigerist, who since the early 1940s had been excluded from the country's academic and philanthropic elite due to his left-wing political ideas; this isolation was aggravated by the outbreak of the Cold War. Fulton understood Sigerist's decision to leave Johns Hopkins University in 1946, considering the political situation in the country, and to return to Switzerland. Fulton provided him with the necessary means to work independently in his country of origin, appointing him associate researcher of Yale Medical School's Historical Library and enabling him to dedicate time to his book, *A history of medicine*.^{59,62}

Fulton also showed a friendly attitude towards the Soviet Union. Thus, during the Second World War, he accepted Sigerist's suggestion to become a member of the American-Soviet Medical Society and collaborated between 1943 and 1947 in the publication of the *American Review of Soviet Medicine*, a periodical compilation of medical articles and news from the USSR.^{59,62} In a letter dated August 1953, he shared his concern with Sigerist about the possibility that the senate investigation committee directed by Joseph McCarthy would pursue them for having promoted the *American Review of Soviet Medicine*. He believed that McCarthy had no capacity to harm Yale or other universities, although they should be ready to meet any contingency that may arise. He

concluded the letter by stating that “in every century there are men of inquisitorial mind.”⁵⁹

John Fulton and the Spanish Republicans

Fulton had planned to attend the International Congress of the History of Medicine in Madrid in September 1935, but finally was unable to. Henry Sigerist, who did participate in the Congress, expressed regret in one of his letters at not having the chance to meet him.⁵⁹

Fulton’s friendship with Jaume Pi-Sunyer also extended to his father, and so he commented in a letter to Henry Sigerist, dated 1949, that his friend August Pi-Sunyer had gone to Caracas for six months and finally remained there for six years of his exile.⁵⁹

Fulton’s excellent relationship with the Catalan physiologists was also patent in 1930 when he joined the Catalan Society of Biology as a corresponding member.⁶³ Proof of this friendship is an undated letter from 1938, hand-written by Juan Negrín, asking that the necessary steps be taken to send Professor Joseph [sic] Fulton from New Haven a book on blood circulation written by a Catalan author during the 17th century. There were only two copies of this book in Barcelona, one in the Academy of Medicine and another in the School of Medicine.⁶⁴ The letter does not mention the title of the book, but it could be *Medicinale patrociniū in sanguinis circulationem* by Francesc Morelló, published in 1678, or *Corde hominis disquisitio physiologico-anatomico* by Joan d’Alós, published in 1694. We do not know if the book was finally sent. This was probably on the initiative of Jaume Pi-Sunyer, who in 1955 had already published an article on these two 17th-century Catalan texts in the *Yale Journal of Biology and Medicine*.⁶⁵ John Fulton was concerned by the Spanish Civil War and showed sympathy to the Republicans, but he did not defend them so openly as Walter Cannon.^{46,59,66}

Josep Trueta, renal circulation, and Michael Servetus

After the German bombing of London in 1940, Josep Trueta discovered that traumatic shock due to crushing of the limbs was associated with acute kidney failure with anuria; autopsy studies revealed ischaemia in the renal cortex and congested medulla. A hypothesis suggesting the presence of a blood flow deviation outside the renal glomeruli (Trueta shunt) caused by a nervous mechanism, probably due to a reflex mechanism, was proposed; this would support the concept of a nervous

intervention in the regulation of the cardiovascular system. Trueta proposed the existence of two circulatory beds: a major (or cortical) circulation and a central (or medullary) circulation; this theory was confirmed by other authors.⁶⁷⁻⁶⁹

Upon arriving in Oxford, Trueta worked at Howard Florey’s laboratory. Fulton, an old friend of Florey’s, took an interest in Trueta’s studies on the renal circulation, and they became friends due to their shared interest in the history of medicine. Fulton recommended the Catalan surgeon for the Moseley Chair of Surgery at Peter Bent Brigham Hospital in Harvard, which became vacant in 1947, and invited him to give several lectures in Yale and Harvard. Ultimately, Trueta was not able to take the chair; in 1949, he was granted the chair of orthopaedic surgery in Oxford, leaving aside his research on the kidney.⁶⁹ Among their historical interests, both studied the figure of Michael Servetus and his discovery of the pulmonary blood circulation.^{70,71} Servetus obviously attracted Fulton not only because of his peculiar position in the history of physiological thought, but also because he endured prolonged martyrdom to proclaim the dignity of man and the freedom of the human spirit.¹⁸

Centenary of Santiago Ramón y Cajal

In September 1953, John Fulton attended the International Congress of Neurology in Lisbon, where he participated in the general session with a presentation on the limbic system and subsequently in a satellite meeting held in Madrid, dedicated to the centenary of the birth of Santiago Ramón y Cajal and to the neuron doctrine. Sir Walter Russell Brain, André DeWulf, Oscar Trelles, and Fernando de Castro also participated in the Madrid meeting. As he did not speak Spanish,¹ he spoke in French of the impact of Cajal’s discoveries and the neuron doctrine on Charles Sherrington’s work, as well as the friendship between the two neuroscientists.^{72,73}

The meeting took place on 14 September 1953 and was presided over by Juan José López Ibor. Attendees visited the Cajal Museum in the morning, and the official meeting took place during the evening. During his 3-day stay in Madrid, he attended a bullfight, went to El Escorial, and visited the Prado Museum on five or six occasions, which captivated him and made him wish he could have stayed longer.⁵⁹

The lecture Fulton gave in Madrid was published seven years later, in 1960. In the lecture, he mentioned the long-



Figure 6. John F. Fulton. Oil painting by Sir Gerald Kelly, 1957 (Royal College of Physicians Museum, London).

standing relationship between Cajal and Sherrington and how the Spanish scientist stayed at Sherrington's house in 1894 when he delivered his Croonian Lecture of the Royal Society on the minute structure of the nervous system. The careers of both scientists ran in parallel and, while Cajal continued studying the structure of the nervous system, Sherrington studied functional aspects of the neuron doctrine.⁷²

In 1955, Cajal's monograph on the structure of the limbic system, translated by Lisbeth Kraft of Yale University, was published in the United States; the book included a preface by John Fulton and an introduction by Paul MacLean.⁷⁴

Other Spaniards connected to John Fulton

In 1942, the Spanish researcher Francisco Guerra Pérez-Carral (1916-2011) arrived in Yale for the first time with a pharmacology grant from the Rockefeller Foundation, obtaining a master's degree in 1944. During this period, he was in close contact with Arturo Castiglioni, John Fulton, and the staff of Yale Medical School's Historical Library. He returned to Yale and stayed between 1958 and 1961 with a grant from the J.S. Guggenheim Foundation,

as a lecturer and research associate in history of medicine. Guerra enjoyed a well-deserved recognition for his work on the history of Spanish colonial medicine in the Americas; during his second stay at Yale, he studied the literature on colonial medicine in North America.^{75,76}

In 1946, a book was published on the history of the cinchona tree, with a preface by John Fulton; the book was written by María Luisa Durán-Reynals (1908-1986), wife and collaborator of the Catalan oncologist Francesc Durán-Reynals (1899-1958), who worked at Yale. Durán-Reynals, whose maiden name was María Luisa de Ayala, was born in Galicia and was already living in the United States before 1936.^{77,78}

John Fulton also collaborated with Félix Martí Ibáñez (1912-1972), a Spanish medical publisher living in New York, to draft the preface to a work published in 1960 that collected a selection of articles by the medical historian Henry Sigerist.⁷⁹

His last years. Medical historian

John Fulton authored approximately 400 articles and 20 books on physiology and the history of medicine (Figure 6).⁵ His passions included reading and book collecting, and he created an extensive personal library inspired by the Bibliotheca Osleriana, including more than 10 000 scientific books that he bought during his trips abroad, published from the 16th century onwards. Furthermore, he invested royalties from his publications, conference honoraria, and even part of his salary as Sterling Professor to expand his library.^{4,6,18}

Fulton, together with Harvey Cushing and Arnold Klebs, planned the future Yale Medical Library, to which the three bibliophiles donated their collections. Cushing had envisioned the creation of an institution equipped with medical and scientific texts that would be more than a cemetery of books; in 1939, soon before his death, he wrote to Arnold Klebs entrusting John Fulton the task of organising the new library, which opened its doors in 1941,^{2,6} in a building on Cedar Street in New Haven.¹⁸

Fulton's first work as a historian was *A bibliography of the honourable Robert Boyle*, published in 1932.⁸⁰ Throughout his life, he also wrote biographies of Benjamin Silliman, Michael Servetus, Luigi Galvani, Richard Lower, John Mayo, and Joseph Priestley; the bibliography of Fracastoro's poem "Syphilis"; and the history of the early days of anaesthesia in medicine and odontology.^{3,6}

Just as Cushing had written the classic biography of William Osler, Fulton and his collaborators Madeleine Stanton and Elizabeth Thompson authored *Life of Harvey Cushing*, on the life of his mentor, which was published in 1946. He started work on the book soon before the outbreak of the Second World War, but his dedication to the war effort prevented him from continuing; however, he kept gathering material, and was able to finish the manuscript after the end of the war.^{10,20,81} From then on, he spent less and less time in the laboratory and dedicated more to the history of medicine.²

Fulton practised several sports as a young man and enjoyed good health, but the pulmonary coccidioidomycosis he contracted in 1942 left him with sequelae, together with the diabetes and cataracts he developed later, and he was hospitalised several times from the late 1940s.^{4,10,61} His frequent excessive consumption of alcohol, which began in his Oxford days and continued as part of his intense social life, also took its toll.^{10,58} Jaume Pi-Sunyer also notes that Fulton's health partly worsened due to a serious accident that occurred during an atmospheric depression experiment.¹¹

In 1950, the president of Yale University, Alfred Whitney Griswold, proposed the creation of a new chair if Fulton would accept the position of Sterling Professor of History of Medicine, possibly intending to move him away from the laboratory of physiology, which had become a centre of international relevance and whose management was becoming increasingly complex. Fulton, who was facing some administrative issues and problems in his relationships with his colleagues, and whose health had been delicate for a long time, accepted the offer and the chair was established the following year; this project had already been planned since Cushing's death and the creation of the medical school's Historical Library. Fulton's neurophysiology experiments continued, as did his lectures, but he published no further scientific articles after 1954, despite always closely following research into the brain and behaviour.^{2,10,11} The endocrinologist Cyril Norman Hugh Long replaced him as director of the laboratory of physiology.⁴¹

Once installed in this new role, he could have rested on his laurels, but instead he soon started to fight for his department to become a centre of reference, and became editor of the *Journal of History of Medicine and Allied Sciences*.^{2,3} In the final stage of his life, he expanded the department to include the history of

science, with an additional chair for Derek Price of Cambridge,^{3,18} and a graduate degree programme on the history of medicine and science was created.^{2,4}

Throughout his life, John Fulton always remained close to his colleagues and students, whom he invited to his house in Mill Rock, on the outskirts of New Haven, which had magnificent views of the city and harbour. His Christmas cards included especially warm greetings.^{2,35,59} He was an open person, without malice in his criticism, and stimulated the initiatives of young scientists, academics, and librarians, with whom he shared his concerns.^{9,18}

In June 1957, he was hospitalised in London due to a severe disease. He had travelled to celebrate the tercentenary of William Harvey and to receive the degree of Doctor Honoris Causa from Oxford University for his contribution to the history of medicine. During the ceremony, he was unable to march in the academic procession and had to wait in the auditorium. His convalescence was prolonged, but he experienced a miraculous recovery and in the summer of 1959 returned to England after giving lectures on history in Spain and on physiology in Argentina. He planned to go back to Britain in June of the following year for the celebration of the tercentenary of the Royal Society.^{4,18,82}

John Fulton died suddenly from a stroke on Sunday, 29 May 1960 at his home.^{3,18} Jaume Pi-Sunyer wrote: "He died in his home, full of books, high on a hilltop, with wide and open views, open to all, as were his life, work, and friendship."¹¹

After his death, 20 obituaries were published in different international journals,⁵⁹ although none of his close friends wrote his biography, perhaps due to his struggles with alcohol.¹⁰

John Fulton was an active member of many physiological, neurological, and historical organisations. He was awarded many honorary degrees, medals, and academic, university, and governmental distinctions. He was named an honorary officer of the Order of the British Empire and awarded a distinction of the French Legion of Honour, as well as 35 honorary degrees from around the world, nine of them from universities including Yale, Oxford, Uppsala, and Leuven.^{10,11,18,20} The Society for the History of Medical Science honoured him in 1955 by establishing the John Fulton Medal, of which he was the first recipient.⁶ He was especially proud of being an honorary member of the Royal

Society of Medicine and the Harvey Cushing Society, of which he was the second president (1933-1934).²

Discussion

John Fulton was a great humanist and a Renaissance man; he enjoyed a short life in which he was able to combine two careers, one as a physiologist and another as bibliophile and historian. As a physiologist, he enjoyed an international reputation for his research, teaching activity, and scientific works. The names of his distinguished students constitute an impressive list. In the study of his second passion, he was known as a biographer and bibliophile, which should come as no surprise in someone who had worked in the Oslerian atmosphere of Oxford.¹⁸

His physiology laboratory represented the first conscious attempt to establish links between different medical specialties, especially between neurophysiology and neurology, neurosurgery, and psychiatry, with the inherent difficulties of incorporating physiological findings into clinical observation. Yale was one of those unique places where a complete, open communication between specialists was possible, with a global conception of medicine. In parallel, Fulton was also a promoter of interdisciplinary collaboration between historians and scientists.

His influence on physiology went beyond his contributions as researcher and communicator. He was a stimulating instructor, a brilliant researcher, a scholar, an original thinker, and an outstanding historian. But above all, he was a man of great generosity and firm convictions, but tolerant to others' opinions at the same time.^{9,11}

He was initially a brilliant and innovative researcher, but with time, his multiple responsibilities as editor, speaker, and committee member forced him to gradually move away from his activity at the laboratory, although he always performed supervision tasks despite his increasing dedication to the history of medicine.

Within his broad range of international connections, his contact with Spanish scientists was relatively intense. Worth mentioning are his relationships with José Manuel Rodríguez Delgado, who directed his laboratory in the 1960s, and his long-time friend Jaume Pi-Sunyer, as well as Rafael Lorente de Nó, Josep Trueta, and Francisco Guerra, among others. As a historian, he was

also interested in Ramón y Cajal and his relationship with Charles Sherrington, as well as in Michael Servetus.

Conflicts of interest

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