



HAL
open science

Figures and institutions of the neurological sciences in Paris from 1800 to 1950. Part II: Neurophysiology

Jean-Gaël Barbara, E. Broussolle, J. Poirier, F. Clarac

► To cite this version:

Jean-Gaël Barbara, E. Broussolle, J. Poirier, F. Clarac. Figures and institutions of the neurological sciences in Paris from 1800 to 1950. Part II: Neurophysiology. *Revue Neurologique*, 2012. halshs-03090655

HAL Id: halshs-03090655

<https://shs.hal.science/halshs-03090655>

Submitted on 11 Jan 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Figures and Institutions of the neurological sciences in Paris from 1800 to 1950. Part II: Neurophysiology

Les figures et institutions des sciences neurologiques à Paris de 1800 à 1950. Partie II: Neurophysiologie

Jean-Gaël Barbara¹, Emmanuel Broussolle², Jacques Poirier³, François Clarac⁴

1 : CNRS, UMRS 7102, Laboratoire de neurobiologie des processus adaptatifs ; Université Pierre et Marie Curie ; CNRS UMR 7219, Laboratoire SPHERE, Université Denis Diderot ; Paris, France

2 : Université Claude Bernard Lyon I ; Hospices Civils de Lyon, Hôpital Neurologique Pierre Wertheimer, Service de Neurologie C ; CNRS UMR 5229, Centre de Neurosciences Cognitives ; Lyon, France

3 : Professeur Honoraire, Hôpital Pitié-Salpêtrière ; Paris, France

4 : CNRS, UMR 6196, Laboratoire Plasticité et Physiopathologie de la motricité, Université Aix-Marseille II, Marseille, France

Correspondance : Pr. Emmanuel Broussolle, Service de Neurologie C, Hôpital Neurologique Pierre Wertheimer, 69677, Bron Cedex, France

Email : emmanuel.broussolle@chu-lyon.fr

Key words: History, Paris, Neurosciences, Anatomy, Physiology, Neurology, Psychiatry, Psychology

Mots-clés: histoire, Paris, neurosciences, anatomie, physiologie, neurologie, psychiatrie, psychologie

Abstract

We present a short historical review of the major figures and institutions that contributed to make Paris a renowned centre of physiology and neurology during the XIXth and the first half of the XXth century. We purposely chose to focus on the period 1800-1950, as 1800 corresponds to the actual beginning of experimental physiology of the nervous system – what is here referred to as “neuroscience” – and 1950 marks its exponential rise. Our presentation is divided into four chapters, matching the main disciplines which have progressed and contributed the most to the knowledge we have of the brain sciences: anatomy, physiology, neurology, and psychiatry-psychology. The present article is the second of four parts of this review which includes the chapter on neurophysiology with selected biographical sketches of François Magendie, Marie Jean Pierre Flourens, Claude Bernard, Charles Edouard Brown-Séguard, Etienne Jules Marey, Alfred Fessard and Denise Albe-Fessard.

Résumé

Nous présentons une brève revue historique générale sur les principales institutions et personnalités ayant contribué à faire de Paris un centre renommé de physiologie et de neurologie au cours du XIX^e siècle et de la première partie du XX^e siècle. La raison du choix de cette période allant de 1800 à 1950 s'explique par le fait que 1800 marque les débuts des neurosciences, et 1950 leur développement exponentiel. Notre présentation est divisée en quatre chapitres, correspondant aux principales disciplines ayant progressé et contribué le plus aux connaissances que nous avons sur les sciences du système nerveux : anatomie, physiologie, neurologie, et psychiatrie-psychologie. Le présent article est la seconde des quatre parties de cette revue générale, qui concerne le champ de la neurophysiologie. Après un chapitre d'introduction est présentée une sélection de biographies résumées de François Magendie, Marie Jean Pierre Flourens, Claude Bernard, Charles Edouard Brown-Séguard, Etienne Jules Marey, Alfred Fessard et Denise Albe-Fessard.

Introduction

The present article – which deals with neurophysiology - is the second of four parts of a short historical review of the major institutions and figures who contributed to make Paris a renowned centre of physiology and neurology during the XIXth and the first half of the XXth century.

The experimental physiological studies of the nervous system in France developed in the XIXth in France with François Magendie (1783-1855). His contribution and also controversies with the great British neurophysiologist Charles Bell (1774-1842) have already been described at length. The *Collège de France* in Paris was one of the most renowned places for physiological studies during all this period. In his famous 1865 *Introduction à l'étude de la médecine expérimentale* (Introduction to the Study of Experimental Medicine), Claude Bernard (1813-1878) insisted on the major importance of experiments in medical sciences: “*La méthode expérimentale, considérée en elle-même, n'est rien autre chose qu'un raisonnement à l'aide duquel nous soumettons méthodiquement nos idées à l'expérience des faits... L'expérimentation ou l'art d'obtenir des expériences rigoureuses et bien déterminées est la base pratique et en quelque sorte la partie exécutive de la méthode expérimentale appliquée à la médecine*” («Considered in itself, experimental method is nothing but a reasoning which helps us methodically to submit our ideas to the experience of facts... The experimentation, or art of obtaining rigorous and well-determined experiments is the practical basis and to some extent the executive part of the experimental method applied to medicine”).

Neurophysiology had close links with chemistry and physics. This is the case of Etienne-Jules Marey (1830-1904), a remarkable man whose main goal, as a physician, was to record biological phenomena in the best possible manner. He invented all kinds of devices which allowed him to apprehend either slow or extremely fast phenomena. Marey did not develop most of his experiments and left this task to others.

Much later, Alfred Fessard (1900-1982) created the first major *laboratoire de physiologie nerveuse du CRNS* (National Center for Scientific Research laboratory of nervous physiology) in the 1950s, on the premises Marey had obtained nearly 50 years before, for his photographic studies.

Apart from Paris, several leading countries in Europe and North America took major steps in neurophysiology during the XIXth and the first half of the XXth century. Although the present paper is not focused on this topic, we will briefly mention some of the most important contributors. In Germany, Ernst Heinrich Weber (1795-1878) and Gustav Fechner (1801-1887) founded the psychophysical method. Wilhelm Wundt (1832-1920) became one of the pioneers in experimental psychophysiology. Johannes Peter Müller (1801-1858) did his famous experiments on sensory and perceptive senses. Several of his pupils did their own renowned research, notably Hermann von Helmholtz (1821-1894), Emil du Bois-Reymond (1818-1896), Theodor Schwann (1810-1882), Friedrich Gustav Jakob Henle (1809-1885), Carl Ludwig (1816-1895) and Ernst Haeckel (1834-1919). In Russia, Ivan Petrovich Pavlov (1849-1936) was professor of physiology in Saint-Petersburg. He invented the conditioned reflex for which he received the Nobel Prize in 1904. In the United Kingdom, Charles Sherrington (1857-1952) and Edgar Adrian (1889-1977) made major findings on the functions of neurons for which they received the Nobel Prize in 1932. Henry Dale (1875-1968) and Otto Loewi (1873-1961), formerly German, and then American citizens, received the Nobel Prize in 1936 for their discovery of the chemical function of acetylcholine in neurotransmission. In the USA, Walter Bradford Cannon (1871-1945) expended the experimental theories of Claude Bernard. In 1944 Joseph Erlanger (1874-1965) and Herbert Spencer Gasser (1888-1963) won the Nobel Prize for their work on the peripheral nerve fibers.

We present below the biographical sketches of some of the most important historical figures among Parisian neurophysiologists.

François MAGENDIE (1783-1855)

Magendie ([Figure 1](#)) was born in Bordeaux and studied medicine in Paris (Albury, 1977; Bloch, 1989; Breathnach, 1983; Clarac and Boller, 2010; Fenton, 1951; Haas, 1994; Lazorthes and Campan, 1984; Olmsted, 1952; Schiller, 1971; Shampo and Kyle, 1987; Stahnish, 2009; Tubbs et al., 2008). He was appointed resident and defended his thesis in 1808 (Magendie, 1808). As an assistant in anatomy of Guillaume Dupuytren (1777-1835), he was involved in research on the spinal cord and spinal nerves. During the following decades, Magendie invested his time to the study of physiology (Gallistel, 1981; Gans, 1972; Magendie, 1816, 1817, 1834, 1839; Saavedra-Delgado, 1991). He favoured the new trend in France of using instruments such as the sphygmomanometer, the thermometer or the aerometer. In 1809, he analyzed the poison contained in the strychnos (a tropical shrub) (Magendie, 1809), which enabled him to isolate strychnine in 1818. He introduced it as a medicinal drug, as well as emetine, morphine, iodides and bromides. His research was continued and corroborated shortly after by Henri Milne-Edwards (1800-1885). In 1821, he founded the first journal dedicated to physiology, the *Journal de Physiologie expérimentale*. Magendie is best known for the laws named after him and for his argument with Charles Bell (1774-1842), the famous British neurophysiologist (Jørgensen, 2003). In 1822 he dissected a litter of puppies and dissociated - in the spinal roots - the efferent motor conduction in the ventral root from the sensory afferent conduction in the dorsal root.

He was nominated *médecin des hôpitaux de Paris* in 1818 and headed a department of medicine at the *Hôtel-Dieu* hospital in 1830. In 1831, he became Professor at the *Collège de France*, where he met Claude Bernard his assistant. Magendie explored the functions of the cerebellum and of the 4th ventricle and studied the pressure applied by the cerebrospinal fluid with a *sphygmomètre* (sphygmomanometer) designed by Jean-Louis Poiseuille (1799-1869) (Magendie, 1842; Sourkes, 2002; Stahnish, 2008).

From a philosophical point of view, Magendie was a materialist and conceived of the human intellect in a scientific manner escaping the comfortable religious belief of the divine nature and immortality of the soul. He thought scientists should study human intellect as if it resulted from a single organ, the brain, according to the general laws of physiology (Magendie, 1817).

Marie Jean Pierre FLOURENS (1794-1867)

Flourens ([Figure 2](#)) was born at Maureilhan in Hérault *département* (County) in the south of France and studied medicine in Montpellier, where he graduated in 1813 (Yildirim and Sarikcioglu, 2007). He was the assistant of Georges Cuvier (1769-1832), became a member of the *Académie des Sciences* in 1828 and then a professor of comparative anatomy at the *Collège de France* in Paris. He was elected at the *Académie Française* in 1840 in a contest with Victor Hugo. Flourens was an accomplished experimenter and developed the techniques of ablation and of selective stimulation of the brain, which enabled the study of walking, swimming and flying of numerous animal species, notably in birds, following and translating the work of Italian anatomist Luigi Rolando (1773 -1831) (Clarac, 2008; Flourens, 1823, 1825, 1844). He described his results in his famous 1824 book ([Figure 3](#)) entitled: *Recherches expérimentales sur les propriétés et les fonctions du système nerveux chez les animaux vertébrés* (Experimental Studies of the Properties and Functions of the Vertebrate Nervous System) (Flourens and Rolando, 1824). Flourens was asked by Napoléon Bonaparte to assess the doctrine of Gall which he initially followed and soon rejected. Many of his studies were made in this context, fighting the doctrine of localisation in the cortex. Flourens clearly showed the role of the cerebellum in motor coordination (Boling, et al. 2002; Fine et al. 2002; Manto, 2008, Pearce, 2009; Tizard, 1959), and the function of the ear labyrinth in equilibrium using ablation studies. He adopted the 1812 experiments of César Julien Legallois (1770-1814) and localized with more accuracy the respiratory centre that he located at the apex of the calamus on the floor of the fourth ventricle within the *medulla oblongata* (Pearce, 2009; Tizard, 1959). He defined *le nœud vital* (vital node) situated at the apex of the *calamus scriptorius* and no larger than a pin head. He was one of the fiercest opponents to Franz Joseph Gall (1758-1828) and phrenology (Flourens, 1842, 1863;

Flourens and Meigs, 1846). His ideas on the unity of the brain suggested its plasticity. In 1847, he described the effects of chloroform and ether on the nervous system at the *Académie des sciences*. He is also known as the master of the physiologist, anatomist and neurologist, Alfred Vulpian (1826-1887).

Claude BERNARD (1813-1878)

Claude Bernard ([Figure 4](#)) was born in Saint-Julien in the Beaujolais area near Lyon. After an aborted career as a writer, he started medical studies and was appointed *interne des hôpitaux de Paris*. He became a *docteur en médecine* (MD) in 1843 and worked under the direction of Magendie at the *Collège de France*. He defined the role of the pancreas in digestion in 1846, by showing that it secretes a substance allowing the digestion of fats (Bernard, 1846). He later carried out the *expérience du foie lavé* (“washed liver experiment”) which described the transformation, storage and use of sugar within the body (Bernard, 1853; Kahn, 1996; Rodriguez de Romo et al., 1999; Swan, 1997). He also examined the functions of the autonomous nervous system (Reader, 2005) and discovered, in opposition to Charles Brown-Séguard (1817-1894), the function of the vasomotor nerves, responsible for blood flow regulation by contraction or dilatation of the blood vessels. In order to provide an explanation to the chemical balance that exists in every organism, he was the first one to suggest the concept of *milieu intérieur* (“internal medium”, that is to say the internal environment) (Wasserstein, 1996), better known as homeostasis and defined by Walter Bradford Cannon (1871-1945) in the 1930s (Cooper, 2008; Jeanrenaud et al., 1998).

Claude Bernard took over the chair of experimental physiology created for him at the Sorbonne University in 1854 (Bernard and Tripier, 1858a, 1858b). He succeeded Magendie at the *Collège de France* after the latter’s death in 1855, and became a professor at the *Muséum* (National Museum of Natural History) in 1868. He laid the foundations of experimental medicine in *L’Introduction à l’étude de la médecine expérimentale* (An Introduction to the Study of Experimental Medicine), published in 1865 (Bernard, 1858, 1865a, 1865b; Noble, 2008; Normandin, 2007; Tan and Holland, 2005). He then became a member of *Académie Française* and a person of international reputation. He died in 1878 and had a state funeral, thus becoming the very first Frenchman of science to receive such an honour. Claude Bernard was a great physiologist and professor who attracted young students from all over the world including Russian anatomists and physiologists. He is mentioned in the novel by Dostoyevsky, *The brothers Karamazov*. He was highly praised and respected worldwide as a pioneer of experimental physiology and founder of the first great physiology school in France. However, historical analyses of his students and of early XXth century science reveal the limits of his epistemology and that of his faith in physiological determinism, his rejection of Darwin’s theory and his rejection of statistics in biological sciences.

Charles Édouard BROWN-SÉQUARD (1817-1894)

Born in Mauritius, to an Irish-American officer from Philadelphia and a French mother from Marseille, Brown-Séguard ([Figure 5](#)) spent his life between France, England, Mauritius and the USA (Bonduelle, 2001; Dubb, 1995; Haas, 1998; Jay, 1999; Koehler, 2001; Laporte, 2006; Rengachary et al., 2008, Simonetti, 1994). He was a student of Armand Trousseau (1801-1867) and worked at the Charité hospital where he became the protégé of Pierre-François-Olive Rayer (1793-1867). He described what is known as the Brown-Séguard syndrome (Brown-Séguard, 1861; Tattersall and Turner, 2000), a lateral hemisection of the spinal cord (Aminoff, 1996; Brown-Séguard, 1855a, 1855b), in his 1846 medical thesis in Paris (Brown Séguard, 1846) His second major contribution is related to the sympathetic nervous system (Brown-Séguard, 1954). In 1852, in collaboration with Claude Bernard he demonstrated the constriction of blood vessels of the ear after stimulation of the cervical nerve (Laporte, 1996).

With the support of Paul Broca (1824-1880), Brown-Séquard gained a position in Philadelphia but left for Mauritius to cure a cholera epidemic in 1854. He then moved from Mauritius to Boston in 1856 and decided to live at London's Royal College, where he inspired the young John Hughlings Jackson (1835-1911). Brown-Séquard took part in the founding of the London school of neurology at Queen Square. He succeeded Claude Bernard in Paris at the *Collège de France* after the latter's death in 1878 and was helped in his work by his student Arsène d'Arsonval (1851-1940).

Brown-Séquard did several major studies on the physiology and pathophysiology of the nervous system (Brown-Séquard, 1853, 1856b, 1865, 1868, 1871). With Jean-Martin Charcot (1825-1893) and Alfred Vulpian (1826-1887), Brown-Séquard founded the *Archives de physiologie normale et pathologique*, a scientific journal succeeding the *Journal de la physiologie de l'homme et des animaux* (Journal of Human and Animals Physiology) (1858-1863), edited under his direction. As an opponent of the cerebral localizations he debated with Charcot at the *Société de Biologie* (1875-1876) (Goetz, 2000). One of the other major contributions of Brown-Séquard was to show the importance of internal secretions and the role of adrenal glands. In 1856 he discovered adrenalin/epinephrine and published *Recherches expérimentales sur la physiologie et la pathologie des capsules surrénales* (Experimental Researches on the Physiology and the Pathology of Adrenal Capsules) (Brown-Séquard, 1856a). In 1889, he went as far as presenting a report claiming he had rejuvenated himself thanks to subcutaneous injections of animal testicular extracts. However extravagant this publication may seem, it undoubtedly stimulated the research on sex hormones (Rengachary et al., 2008).

Étienne-Jules MAREY (1830-1904)

Marey (Figure 6) was born in Beaune in Burgundy and studied medicine in Paris (Baron, 1983; Campan, 1978; Debru, 2004; Lefebvre, 2002; Lüderitz, 2005; McIntyre, 2005; Merlen, 1985). He was appointed *interne des hôpitaux de Paris* in 1854 and defended his medical thesis *Recherches sur la circulation du sang à l'état physiologique et dans les maladies* (Research on Blood Circulation in Normal and Pathological States) in 1859 (Marey, 1859). He was a physician but he did not practice much and turned to research (Marey, 1875). For the measure of different sort of physiological phenomena, Marey invented a great number of apparatus that have been used in France in the majority of physiological laboratories and by generations of students. He measured the electrical activity of the heart using a mercury Lippmann electrometer. One of his most important inventions was the sphygmograph: a device recording pulse waves measured by arterial catheterism in horses (Lawrence, 1978; Marey, 1860). This was presented to the *Académie des Sciences* in 1860. Marey published *Du Mouvement dans les fonctions de la vie* (On Movement in Life's Functions) in 1868 (Marey, 1868). He was appointed professor of physiology at the *Collège de France* in 1869 and dedicated his life to any possible movement. As many of these phenomena are invisible to the naked eye, he invented two techniques that foreshadowed the cinematograph (Michaelis, 1966; Silverman, 1996) and greatly influenced the academic art of the XIXth century and the beginnings of modern art: the graphic method (Figure 7) and the chronophotography (Laporte, 1998; Mannoni, 2004). He published in 1873 *La Machine animale. Locomotion terrestre et aérienne* (Animal Mechanism: a Treatise on Terrestrial and Aerial Locomotion) (Marey, 1873; Marey and Demery, 1883). In 1874, the astronomer Jules Janssen designed the photographic revolver, intended to capture the movement of celestial bodies. Marey developed the chronophotographic gun in 1882 (Marey, 1882). Thanks to this famous invention he could photograph a bird's flight on 12 consecutive frames by the graphic method and chronophotography. In 1882, Marey created the *Station Physiologique du Bois de Boulogne* (Physiological Laboratory of Bois de Boulogne in Paris), funded by the French government, to which the Marey Institute was later added. This institute was the basis for the new research laboratory of electrophysiology created by Alfred Fessard before the Second World War (Barbara, 2010).

Alfred FESSARD (1900-1980)

Alfred Fessard ([Figure 8](#)) was both a physicist and a physiologist (Buser, 1982; Buser and Naquet, 1983). He was influenced by the psychologist Henri Piéron (1881-1964) and was a *préparateur* (assistant) in his psychophysiology laboratory of *l'École Pratique des Hautes Etudes* (Practical School of Higher Studies), an institution of higher learning created in 1868, which offered post-graduates studies in a variety of highly specialized fields in Paris. He worked with Daniel Auger (1900-1940) at the Tamaris-sur-Mer marine biological laboratory near Toulon on the Mediterranean Sea coast. They carried out various electrophysiological recordings on preparations of invertebrates. There Fessard met Angélique Arvanitaki (1901-1983) and discovered the giant neurons of the mollusc *Aplysia*. They studied the electrical activities of crustacean nerves. It was the subject of Angélique Arvanitaki thesis. Alfred Fessard's works of 1935, on the EEG, in collaboration with Gustave Durup showed the conditioning of the blocking of the alpha rhythm (Durup and Fessard, 1935). Fessard was influenced by the renowned British neurophysiology school and revived neurophysiology in France and tried to develop researches on both cellular and integrated levels (Fessard, 1936a, 1936b, 1939). He was appointed professor at the *Collège de France* and director of the Marey Institute. In 1939, he invited Siegmund Feldberg (1900-1993) and David Nachmansohn (1899-1983), two Jewish researchers escaping the Nazi government in Germany, to the marine biological laboratory of Arcachon (located on the Atlantic Ocean shore near Bordeaux). Together, they showed the cholinergic nature of the transmission in the electrical lobe of torpedo, an argument in favour of the chemical theory (Feldberg and Fessard, 1942). Since then, the international reputation of Fessard has never been contested.

Fessard became a member of the *Académie Nationale de Médecine* and of the *Académie des Sciences* and after World War II, assembled all the scientific and institutional conditions required to create a French school of neurophysiology of high international standard (Fessard and Posternak, 1950; Lopicque et al., 1950). He wrote an article on the neuronal networks and consciousness entitled *Mechanisms of Nervous Integration and Conscious Experience* at the international congress of Laurentides in 1953 (Fessard, 1954). He made his laboratory one of the most important scientific places in Europe, owing to the presence of renowned students and researchers such as his wife Denise Albe-Fessard, Pierre Buser, Jacques Paillard (1920-2006), Ladislav Tauc (1926-1999) and others (Albe-Fessard and Fessard, 1975; Bullock and Fessard, 1974; Fessard, 1976; Fessard and Lelord, 1973; Fessard et al., 1973; Morin and Buser, 1973). In the 1960s, Fessard took part in the foundation of the International Brain Research Organization (IBRO), and he became a member of its executive committee and of the governing council.

Denise ALBE-FESSARD (1916-2003)

Denise Albe-Fessard ([Figure 8](#)), an emblematic figure of French neuroscience, obtained her diploma from *l'École de physique et chimie de la Ville de Paris* (Paris School of Physics and Chemistry) and was associated with the works carried out at Marey Institute from the beginning. In 1942, she married Alfred Fessard, who headed the CNRS Center of nervous physiology and electrophysiology. She defended her thesis on the electrogenesis of the electrical discharge in electric fishes, gymnotus, torpedo and ray in 1950 (Albe-Fessard, 1950). In the 1945-1950s, Denise Albe-Fessard and her husband carried on their researches on these particular electric fish at the marine biological laboratory of Arcachon (near Bordeaux), and in Rio de Janeiro with Carlos Chagas (1879-1934). Albe-Fessard was one of the first to succeed in recording intracellularly neurons of the cat cortex, after having refined her method on the nuclei of Torpedo (Albe-Fessard et al., 1961a, 1961b; Albe-Fessard and Kruger, 1962; Korn et al., 1966; Massion et al., 1965a, 1965b). In 1961, she began to collaborate with Gérard Guiot (1912-1998), a neurosurgeon at the Foch hospital in Paris metropolitan area and recorded, after craniotomy, the evoked potentials and the unitary neuron responses in the thalamus of parkinsonian patients who have had thalamotomy. In the mean time, she obtained new results on the mechanisms of pain and somatic representations in

the human thalamus (Albe-Fessard, 1996; Albe-Fessard and Iggo, 1973; Albe-Fessard et al., 1963, 1966a, 1966b, 1967; Berkley, 2004; Guiot et al., 1962a, 1962b, 1964). She then focused her research on the thalamus and studied its intralaminar nerve nets in monkeys. Her activity at Marey Institute allowed several of her students to pursue a very successful career (Chalazonitis et al., 1978; Massion et al., 1962; Naquet et al., 1962).

Acknowledgements

The authors would like to thank for their tremendous help Chloé Loiraud, Yann Bregeras, Sandrine Jamen and Jessica Moreau from Bibliothèque Médicale, *Hôpital Neurologique Pierre Wertheimer*, Lyon, France, Chantal Barbara, Marjorie Lorch (ISHN), the *École des Neurosciences de Paris*, the *Club d'Histoire des Neurosciences* from the *Société des Neurosciences* and the BIU Santé (*Bibliothèque Inter Universitaire de Santé de Paris*) and the *Académie Nationale de Médecine and Académie des Sciences* for the reproduction of photographs.

Conflicts of interest : none

References

- Albe-Fessard D. Recherches électrophysiologiques sur la décharge du gymnote, de la torpille, de la raie. Étude des facteurs centraux et périphériques de son organisation. Thèse de médecine: Paris; 1950.
- Albe-Fessard D. La douleur : ses mécanismes et les bases de ses traitements. Paris: Masson; 1996.
- Albe-Fessard D, Arfel G, Guiot G, Derome P, De La Herran, Korn H, et al. Activités électriques caractéristiques de quelques structures cérébrales chez l'homme. *Ann Chir* 1963;17:1185-1214.
- Albe-Fessard D, Arfel G, Guiot G, Derome P, Guilbaud G. Thalamic unit activity in man. *Electroencephalogr Clin Neurophysiol* 1967;Suppl 25:132.
- Albe-Fessard D, Arfel G, Guiot G, Derome P, Hertzog E, Vourc'h G, et al. Electrophysiological studies of some deep cerebral structures in man. *J Neurol Sci* 1966;3:37-51.
- Albe-Fessard D, Fessard A. Recent advances on the neurophysiological bases of pain sensation. *Acta Neurobiol Exp* 1975;35:715-740.
- Albe-Fessard D et Iggo A. Somatosensory system. Berlin: Springer; 1973.
- Albe-Fessard D, Kruger L. Duality of unit discharges from cat centrum medianum in response to natural and electrical stimulation. *J Neurophysiol* 1962;25:3-20.
- Albe-Fessard D, Mallart A, Aléonard P. Réduction au cours du comportement attentif de l'amplitude des réponses évoquées dans le centre médian du thalamus chez le chat éveillé libre, porteur d'électrodes à demeure. *C R Séances Soc Biol Fil* 1961;252:187-189.
- Albe-Fessard D, Mallart A, Aléonard P. Réponses cérébrales évoquées enregistrées chez le chat éveillé libre et comportement attentif. *J Physiol (Paris)* 1961;53:244-245.
- Albe-Fessard D, Stutinsky F, Libouban-Letouze S. Atlas stéréotaxique du diencéphale du rat blanc. Paris: Éditions du Centre national de la recherche scientifique; 1966.
- Albury WR. Experiment and explanation in the physiology of Bichat and Magendie. *Stud Hist Biol* 1977;1:47-131.
- Aminoff MJ. Historical perspective. Brown-Séquard and his work on the spinal cord. *Spine* 1996;21:133-140.
- Barbara JG. L'institut Marey. *La lettre de la société des neurosciences* 2004;27:3-5.
- Baron JB. Étienne-Jules Marey. *Acta Belg Med Phys* 1983;6:187-197.
- Berkley KJ. Madame Albe-Fessard: a meaningful legacy. *Eur J Pain* 2004;8:95-97.
- Bernard C. Des différences que présentent les phénomènes de la digestion et de la nutrition chez les animaux herbivores et carnivores. Paris: impr. de Bachelier; 1846.

- Bernard C. Nouvelle fonction du foie considéré comme organe producteur de matière sucrée chez l'homme et les animaux. Paris: J.-B. Baillière; 1853.
- Bernard C. Cours de médecine du Collège de France. Leçons sur la physiologie et la pathologie du système nerveux. Paris: J. Baillière et Fils; 1858.
- Bernard C. De la physiologie générale. Bruxelles: Culture et civilisation; 1865.
- Bernard C. Introduction à l'étude de la médecine expérimentale. Paris: J.-B. Baillière; 1865.
- Bernard C, Tripier A. Leçons sur la physiologie et la pathologie du système nerveux. Tome I. Paris: J.-B. Baillière et fils; 1858.
- Bernard C, Tripier A. Leçons sur la physiologie et la pathologie du système nerveux. Tome II. Paris: J.-B. Baillière et fils; 1858.
- Bloch H. François Magendie, Claude Bernard, and the interrelation of science, history, and philosophy. *South Med J* 1989;82:1259-1261.
- Blöde KA, Flourens P. Dr. F. J. Gall's system of the functions of the brain. London: Routledge/Thoemmes Press; 2000.
- Boling W, Olivier A, Fabinyi G. Historical contributions to the modern understanding of function in the central area. *Neurosurgery* 2002;50:1296-1309; discussion 1309-1310.
- Bonduelle M. Histoire de la Neurologie - Charles-Édouard Brown-Séguard. *Rev Neurol* 2001;157:234-238.
- Breathnach CS. Biographical sketches No. 34-Magendie. *Ir Med J* 1983;76:471.
- Brown-Séguard C. Recherches et expériences sur la physiologie de la moelle épinière. Thèse de médecine: Paris; 1846.
- Brown-Séguard C. Experimental researches applied to physiology and pathology. New York: H. Bailliere; 1853.
- Brown-Séguard C. Sur les résultats de la section et de la galvanisation du nerf grand sympathique au cou. Paris: E. Thunot; 1854.
- Brown-Séguard C. Deux mémoires sur la physiologie de la moelle épinière. Paris: Académie des sciences; 1855.
- Brown-Séguard C. Recherches expérimentales sur la transmission croisée des impressions sensibles dans la moelle épinière. Paris: V. Masson; 1855.
- Brown-Séguard C. Recherches expérimentales sur la physiologie et la pathologie des capsules surrénales. Paris: Rignoux; 1856.
- Brown-Séguard C. Recherches expérimentales sur les voies de transmission des impressions sensibles. Paris: impr. Thunot; 1856.

- Brown-Séguard C. Lectures on the diagnosis and treatment of the principal forms of paralysis of the lower extremities. London: Williams and Norgate; 1861.
- Brown-Séguard C. On the Importance of the Application of Physiology to the Practice of Medicine and Surgery. Dublin: John Falconer; 1865.
- Brown-Séguard C. Lectures on the diagnosis & Treatment of functional nervous affections. Philadelphia: Lippincot; 1868.
- Brown-Séguard C. Quelques faits nouveaux relatifs à l'épilepsie qu'on observe à la suite de diverses lésions du système nerveux. [s. l.]: [s. n.]; 1871.
- Bullock TH, Fessard A. Electoreceptors and other specialized receptors in lower vertebrates. Berlin: Springer-Verlag; 1974.
- Buser P. Alfred Fessard (1900-1982). C R Séances Soc Biol Fil 1982;176:244-247.
- Buser P, Naquet R. Tribute: Alfred Fessard. Electroencephalogr Clin Neurophysiol 1983;55:615-618.
- Campan L. Marey et la capture des temps physiologiques. Agressologie 1978;19:233-238.
- Chalazonitis N, Boisson M, Albe-Fessard D, et al. Abnormal neuronal discharges. New York: Raven Press; 1978.
- Clarac F. Some historical reflections on the neural control of locomotion. Brain Res Rev 2008;57:13-21.
- Clarac F, Boller F. Chapter 40. History of Neurology in France. In : Aminoff MJ, Boller F, Swaab DF eds. Handbook of clinical neurology - History of Neurology. Vol 95. Amsterdam: Elsevier; 2010. p. 629-656.
- Conti F. Claude Bernard: primer of the second biomedical revolution. Nat Rev Mol Cell Biol 2001;2:703-708.
- Cooper SJ. From Claude Bernard to Walter Cannon. Emergence of the concept of homeostasis. Appetite 2008;51:419-427.
- Debru C. Étienne-Jules Marey: l'innovation médicale. Bull Acad Natl Méd 2004;188:1413-1419; discussion 1420-1421.
- Dubb A. C E Brown-Séguard (1817-1894) - multi-national neurologist. Adler Mus Bull 1995;21:21-24.
- Durup G, Fessard A. L'électroencéphalogramme de l'homme. Observations psychophysologiques relatives à l'action des stimuli visuels et auditifs. L'année psychologique 1935;36:1-32.
- Feldberg W, Fessard A. The cholinergic nature of the nerves to the electric organ of the Torpedo (Torpedo marmorata). J Physiol 1942;101:200-216.
- Fenton PF. François Magendie (October 6, 1783-October 7, 1855). J Nutr 1951;43:3-15.

- Fessard A. Propriétés rythmiques de la matière vivante. I, nerfs isolés. Première partie, nerfs myélinisés. Paris: Hermann; 1936.
- Fessard A. Propriétés rythmiques de la matière vivante. II, nerfs isolés. Deuxième partie, nerfs non myélinisés. Paris: Hermann; 1936.
- Fessard A. Organes des sens. Paris: Hermann; 1939.
- Fessard A. Mechanisms of nervous integration and conscious experience. In: E. D. Adrian, F. Bremer & H. H. Jasper editors. Brain mechanisms and consciousness. Springfield, III: Charles C Thomas; 1954. p.200-236.
- Fessard A. Sur la complexité hiérarchisée du système nerveux et ses modèles d'organisation. Rev Electroencephalogr Neurophysiol Clin 1976;6:481-487.
- Fessard A, Lelord G. Colloque de neurophysiologie humaine appliquée à la psychologie et à la psychiatrie. Activités évoquées et leur conditionnement chez l'homme normal et en pathologie mentale. Paris: Institut national de la santé et de la recherche médicale; 1973.
- Fessard A, Paillard J, Massion J. Colloques internationaux du Centre national de la recherche scientifique. Comportement moteur et activités nerveuses programmées. Aix-en-Provence;1973.
- Fessard A., Posternak J. Les mécanismes élémentaires de la transmission synaptique. J Physiol (Paris) 1950;42:319-445.
- Fine EJ, Ionita CC, Lohr L. The history of the development of the cerebellar examination. Semin Neurol 2002;22:375-384.
- Fischgold H, Gastaut H, Fédération internationale d'électroencéphalographie et de neurologie clinique. Conditionnement et réactivité en électroencéphalographie. Paris: Masson; 1957.
- Flourens P. Recherches physiques sur les propriétés et les fonctions du système nerveux dans les animaux vertébrés. Arch Gén Méd 1823; 2: 321-370.
- Flourens P. Expériences sur le système nerveux: faisant suite aux Recherches expérimentales sur les propriétés et les fonctions du système nerveux dans les animaux vertébrés. Paris: Crevot; 1825.
- Flourens P. Examen de la phrénologie. Paris: Paulin; 1842.
- Flourens P. Mémoires d'anatomie et de physiologie comparées. Paris: Baillière; 1844.
- Flourens P. De la phrénologie et des études vraies sur le cerveau. Paris: Garnier Frères; 1863.
- Flourens P, Meigs CD. Phrenology examined. Philadelphia: Hogan & Thompson; 1846.
- Flourens P, Rolando L. Recherches expérimentales sur les propriétés et les fonctions du système nerveux dans les animaux vertébrés. Paris: Crevot; 1824.
- Gallistel CR. Bell, Magendie, and the proposals to restrict the use of animals in neurobehavioral research. Am Psychol 1981;36:357-360.

- Gans H. An early example of the use of surgical techniques in solving a physiologic problem (François Magendie). *Surg Gynecol Obstet* 1972;135:616-622.
- Goetz CG. Battle of the titans: Charcot and Brown-Séguard on cerebral localization. *Neurology* 2000;54:1840-1847.
- Griffin JP. Famous names in toxicology. Claude Bernard 1813-1878. *Adverse Drug React Toxicol Rev* 1993;12:213-214.
- Guiot G, Albe-Fessard D, Arfel G, Derome P. Dérivations d'activités unitaires en cours d'intervention stéréotaxiques. *Neurochirurgie* 1964;10:427-435.
- Guiot G, Albe-Fessard D, Arfel G, Hertzog E, Vourc'h G, Hardy J, et al. Interprétation des effets de la stimulation du thalamus de l'homme par chocs isolés. *C R Séances Acad Sci* 1962;254:3581-3583.
- Guiot G, Hardy J, Albe-Fessard D. Precise delimitation of the subcortical structures and identification of thalamic nuclei in man by stereotactic electrophysiology. *Neurochirurgia (Stuttg)* 1962;5:1-18.
- Haas LF. François Magendie (1783-1855). *J Neurol Neurosurg Psychiatry* 1994;57:692.
- Haas LF. Claude Bernard (1813-78). *J Neurol Neurosurg Psychiatry* 1996;61:345.
- Haas LF. Charles Édouard Brown-Séguard (1818-94). *J Neurol Neurosurg Psychiatry* 1998;64:89.
- Jay V. A portrait in history: The extraordinary international career of Dr Brown-Séguard. *Arch Pathol Lab Med* 1999;123:662.
- Jeanrenaud B, Cusin I, Rohner-Jeanrenaud F. De Claude Bernard a la boucle régulatrice reliant l'hypothalamus à la périphérie: implications dans l'homeostasie du poids corporel et dans l'obésité. *C R Séances Soc Biol Fil* 1998;192:829-841.
- Jørgensen CB. Aspects of the history of the nerves: Bell's theory, the Bell-Magendie law and controversy, and two forgotten works by P.W. Lund and D.F. Eschricht. *J Hist Neurosci* 2003;12:229-249.
- Kahn A. Entre dogmatisme et empirisme: la découverte de la fonction glucoformatrice et glucosecretrice du foie par Claude Bernard. *C R Acad Sci III Sci Vie* 1996;319:753-761.
- Koehler PJ. Charles-Édouard Brown-Séguard (1817-1894). *J Neurol* 2001;248:345-346.
- Korn H, Wendt R, Albe-Fessard D. Somatic projection to the orbital cortex of the cat. *Electroencephalogr Clin Neurophysiol* 1966;21:209-226.
- Lapicque L, Fessard A, Monnier AM. Colloques internationaux du Centre national de la recherche scientifique. *Électrophysiologie*. Paris: CNRS; 1950.
- Laporte Y. Brown-Séguard and the discovery of the vasoconstrictor nerves. *J Hist Neurosci* 1996;5:21-25.

- Laporte Y. Etienne-Jules Marey, fondateur de la méthode graphique. C R Acad Sc. III Sci Vie 1998;321:351-354.
- Laporte Y. Charles-Édouard Brown-Séquard: an eventful life and a significant contribution to the study of the nervous system. C R Biol 2006;329:363-368.
- Lawrence C. Physiological apparatus in the Wellcome Museum. 1. The Marey sphygmograph. Med Hist 1978;22:196-200.
- Lazorthes G, Campan L. François Magendie (1783-1855). Bull Acad Natl Méd 1984;168:105-111.
- Lefebvre T. La longue marche d' Étienne-Jules Marey. Rev Prat 2002;52:705-707.
- Lüderitz B. Étienne Jules Marey (1830-1904). J Interv Card Electrophysiol 2005;12:91-92.
- Magendie F. Essai sur les usages du voile du palais, avec quelques propositions sur la fracture du cartilage des côtes. Thèse de médecine: Paris; 1808.
- Magendie F. Examen de l'action de quelques végétaux sur la moelle épinière. Institut de Paris. Paris; 1809.
- Magendie F. Précis élémentaire de physiologie. Paris: Méquignon-Marvis; 1816.
- Magendie F. Traité élémentaire de physiologie. Paris: Méquignon; 1817.
- Magendie F. Handbuch der Physiologie. Nach der dritten vermehrten und verbesserten Ausgabe aus dem Französischen. 1. Eisenach : J. F. Baerecke; 1834.
- Magendie F. Recherches physiologiques et cliniques sur le liquide céphalo-rachidien ou cérébro-spinal. Paris: Méquignon-Marvis fils; 1842.
- Magendie F, James C. Leçons sur les fonctions et les maladies du système nerveux. Paris: Ébrard; 1839 ; Paris : Lecaplain 1841.
- Mannoni L. Étienne-Jules Marey, de la méthode graphique au cinématographe. Rev Prat 2004;54:2314-2317.
- Manto M. The cerebellum, cerebellar disorders, and cerebellar research-two centuries of discoveries. Cerebellum 2008;7:505-516.
- Marey É. Recherches sur la circulation du sang à l'état physiologique et dans les maladies. Thèse de médecine: Paris; 1859.
- Marey É. Recherches sur le pouls au moyen d'un nouvel appareil enregistreur, le sphygmographe. Paris: Thunot; 1860.
- Marey É. Du mouvement dans les fonctions de la vie: leçons faites au Collège de France. Paris: Germer Baillière; 1868.
- Marey É. La machine animale: locomotion terrestre et aérienne. Paris: Germer Baillière; 1873.

- Marey É. *Physiologie expérimentale: Travaux du laboratoire de M. Marey année 1875*. Paris: Masson; 1875.
- Marey É. Le fusil photographique. *La Nature* 1882;326-330.
- Marey É, Demery G, Pages. *Études photographiques sur la locomotion de l'homme et des animaux*. Paris: Gauthier-Villars; 1883.
- Massion J, Angaut P, Albe-Fessard D. Influence du cervelet sur les différentes composantes de la réponse corticale primaire somatique chez le chat anesthésié au chloralose. *J Physiol (Paris)* 1962;54:377-378.
- Massion J, Angaut P, Albe-Fessard D. Activités évoquées chez le chat dans la région du nucleus ventralis lateralis par diverses stimulations sensorielles. I. Etude Macro-physiologique. *Electroencephalogr Clin Neurophysiol* 1965;19:433-451.
- Massion J, Angaut P, Albe-Fessard D. Activités évoquées chez le chat dans la région du nucleus ventralis lateralis par diverses stimulations sensorielles. II. Etude Macro-physiologique. *Electroencephalogr Clin Neurophysiol* 1965;19:452-469.
- McIntyre N. Claude Bernard (1813-1878). *J Med Biogr* 2001;9:15.
- McIntyre N. Medical statues. Étienne Jules Marey (1830-1904). *J Med Biogr* 2005;13:141
- Merlen JF. Étienne-Jules Marey. *J Mal Vasc* 1985;10:SupplA:3.
- Michaelis AR. É. J. Marey - physiologist and first cinematographer. *Med Hist* 1966;10:201-203.
- Morin G, Buser P. Introduction. *Arch Ital Biol* 1973;111:225-230.
- Naquet R, Denavit M, Albe-Fessard D. Ralentissements et accélérations de l'activité corticale obtenus par refroidissement localisé de la formation réticulée mésencéphalique du chat éveillé. *J Physiol (Paris)* 1962;54:386.
- Noble D. Claude Bernard, the first systems biologist, and the future of physiology. *Exp Physiol* 2008;93:16-26.
- Normandin S. Claude Bernard and an introduction to the study of experimental medicine: "physical vitalism," dialectic, and epistemology. *J Hist Med Allied Sci* 2007;62:495-528.
- Olmsted JM. Bichat vu par Magendie. *Prog Méd* 1952;80:324-327.
- Pearce JMS. Marie-Jean-Pierre Flourens (1794-1867) and cortical localization. *Eur Neurol* 2009;61:311-314.
- Reader AL. The role of Claude Bernard and others in the discovery of Horner's Syndrome. *J Am Coll Surg* 2005;200:815.
- Rengachary SS, Colen C, Guthikonda M. Charles-Édouard Brown-Séquard: an eccentric genius. *Neurosurgery* 2008;62:954-964; discussion 964.

- Rodriguez de Romo AC, Borgstein J. Claude Bernard and pancreatic function revisited after 150 years. *Vesalius* 1999;5:18-24.
- Saavedra-Delgado AM. François Magendie on anaphylaxis (1839). *Allergy Proc* 1991;12:355-356.
- Schiller F. Magendie on medicine. *Calif Med* 1971;115:98.
- Shampo MA, Kyle RA. François Magendie: early French physiologist. *Mayo Clin Proc* 1987;62:412.
- Silverman ME. Étienne-Jules Marey: 19th century cardiovascular physiologist and inventor of cinematography. *Clin Cardiol* 1996;19:339-341.
- Simonetti F, Viviani R, Ceroni M. Charles Édouard Brown-Séquard. *Funct Neurol* 1994;9:303-306.
- Sourkes TL. Magendie and the chemists: the earliest chemical analyses of the cerebrospinal fluid. *J Hist Neurosci* 2002;11:2-10.
- Stahnisch FW. Instrument transfer as knowledge transfer in neurophysiology: François Magendie's (1783-1855) early attempts to measure cerebrospinal fluid pressure. *J Hist Neurosci* 2008;17:72-99.
- Stahnisch FW. François Magendie (1783-1855). *J Neurol* 2009;256:1950-1952.
- Swan PB. The liver forms, stores and secretes glucose (Claude Bernard, 1860). *Nutr* 1997;127:S1019-S1020.
- Tan SY, Holland P. Claude Bernard (1813-1878): father of experimental medicine. *Med J (Singapore)* 2005;46:440-441.
- Tattersall R, Turner B. Brown-Séquard and his syndrome. *Lancet* 2000;356:61-63.
- Tizard B. Theories of brain localization from Flourens to Lashley. *Med Hist* 1959;3:132-145.
- Tubbs RS, Loukas M, Shoja MM, Shokouhi G, Oakes WJ. François Magendie (1783-1855) and his contributions to the foundations of neuroscience and neurosurgery. *J Neurosurg* 2008;108:1038-1042.
- Wasserstein AG. Death and the internal milieu: Claude Bernard and the origins of experimental medicine. *Perspect Biol Med* 1996;39:313-326.
- Yildirim FB, Sarikcioglu L. Marie Jean Pierre Flourens (1794 1867): an extraordinary scientist of his time. *J Neurol Neurosurg Psychiatry* 2007;78:852.

Figure legends

Figure 1. Picture of Magendie. *Portrait de Magendie* (©BIU Santé).

Figure 2. Picture of Flourens. *Portrait de Flourens* (Académie Nationale de Médecine).

Figure 3. Reproduction of the title page of the famous 1824 Flourens treatise. *Reproduction de la page de titre du célèbre traité de 1824 de Flourens.*

Figure 4. Picture of Claude Bernard. *Photographie de Claude Bernard* (©BIU Santé).

Figure 5. Picture of Brown-Séquard. *Photographie de Brown-Séquard* (©BIU Santé)

Figure 6. Picture of Marey. *Photographie de Marey* (©BIU Santé)

Figure 7. Marey's myograph used in measuring muscle contraction in frog. *Myographe de Marey utilisé pour mesurer la contraction musculaire chez la grenouille* (©BIU Santé)

Figure 8. Picture of Alfred Fessard and of his wife Denise Albe-Fessard. *Photographie d'Alfred Fessard et de son épouse Denise Albe-Fessard.* (Fonds Jean Fessard with permission).