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The first Experiments in Magnetic Stimulation – a History of Discoveries within two Parallel Lives

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Abstract: The paper contains a history of the first effective experiments in magnetic stimulations of human tissues, which started in the second half of XIX century due to two scientists. They were Jacques-Arsene d'Arsonval and Silvanus P. Thompson, both of them born in 1851. The experiments which were carried out by these pioneers are of great importance for nowadays activity in medical applications of electromagnetic field.

Keywords: Jacques Arsene d'Arsonval, Silvanus P. Thompson, bioelestromagnetics, magnetophosphenes

1. Introduction

The real and effective experiments in magnetic stimulations of human tissues and nerves started in the second half of XIX century due to two scientists – both were born in 1851. They were:

- Jacques-Arsene d'Arsonval, French physician and physicist (1851–1940)
- Silvanus P. Thompson, British engineer (1851–1916) (Figure1).

Figure 1. Jacques-Arsene d'Arsonval and Silvanus P. Thompson

Both of them created the fundaments for therapeutical action of electromagnetic field as well as found the phenomenon called magnetophosphene (gr. magnet + *phōs,* light +

phainein, to show). The experiments which were carried out by these pioneers are of great importance for nowadays activity in bioelectromagnetics.

2. Jacques Arsene d'Arsonval

Jacques-Arsene d'Arsonval was born at La Borie, France on June 8, 1851. He came from a noble French family. His grandmother's godfather was Napoleon I. His grandfather and father were physicians. The paternal line of d'Arsonval's family for seven centuries bore the title of Count. He studied classics at the Lycée Imperial de Limoges and later at the Collège St.-Barbe. Having obtained a baccalaureate degree from the Université de Poitiers in 1869, d'Arsonval decided upon a career in medicine and commenced his studies at Limoges. He attended the universities at Limoges and Paris – at the College de France he was under influence of Claude Bernard (1813–1878), the great experimental physiologist and creator of the concept of a constant internal environment (*milieu interior*), which leads to the notion of homeostasis. As Claude Bernard was also the great methodologist of science, d'Arsonval could grasp from him the spirit of research experiments. D'Arsonval got his medical degree in Paris in 1877. After Bernard's death he assisted Charles-Édouard Brown-Séquard (1817–1894), giving the latter's winter courses, and replaced him at the Collège de France when Brown-Séquard died in 1894. In the same year he became a professor and was elected to the Academy of Sciences where in 1917 was nominated as its president.

Minister of public education enabled Collège de France to establish a laboratory for biophysics at rue St.-Jacques. D'Arsonval directed the laboratory until 1910, when he moved to the new laboratory at Nogent-sur-Marne directed by him till his retirement in 1931. He died on December 31, 1940 at the same place he was born almost ninety years earlier.

D'Arsonval was a member of the Society of Biologists, the Academy of Medicine and the Academy of Sciences. He also was an active member of a few other societies dealing with:

- electrotherapy,
- physics,
- electronics,
- engineering.

D'Arsonval's most outstanding scientific contributions, however, involved the biological and technological applications of electricity. Much of this work concerned muscle contractions. In 1882 d'Arsonvel together with French scientist Étienne-Jules Marey (1830–1904) and French electrical engineer Marcel Deprez (1843–1918) invebted a new device, called later the Deprez-d'Arsonval galvanometer. The invention came after he had studied muscle contractions in frogs using an extremaly weak current comparable with physiological current. In 1881, Arsène d'Arsonval suggested for the first time harnessing the temperature difference in the tropical seas for the generation of electricity. In 1902 d'Arsonval worked with his student Georges Claude (1870–1960) on industrial methods for the liquefaction of gases.

In his scientific activity d'Arsonval applied the laws of physics to solve bioelectromagnetic problems, such as:

- inductive and capacitive heating human body (diathermy),
- magnetic stimulation of excitable tissues by eddy currents.

In 1891 he created nis first variable-frequebcy stimulator (Figure 2.), consisted on potentiometer (P), series of electrolytic cells (V) and a graphic recorder (K-kymograph) on which muscle (M) contraction and the frequency (f) were displayed. His first results showed that as frequency was increased, the intensity had to be higher to obtain a muscular response. Because of the frequency limitation, he used an alternator that provided sinusoid voltage up to 10 kHz. With this stimulator he obtained similar results.

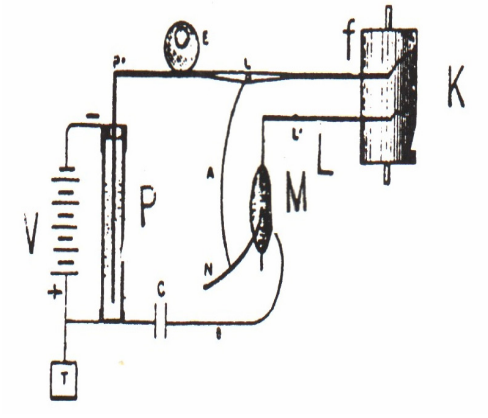


Figure 2. Variable-frequency stimulator

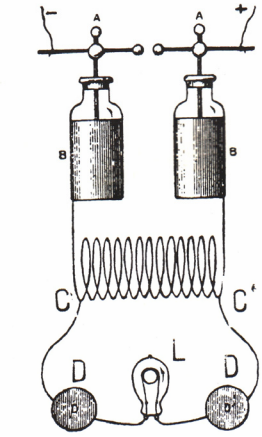


Figure 3. High frequency stimulator

One of the most important experiment in his life was that showed in Figure 3. He used a Hertz oscillator, two Leyden jars an air-core coil. The ends of coil were connected to a circuit in series, which consisted of a 100 W light and two subjects (humans). The current flowing through the subjects was about 1 A. D'Arsonval noticed that the subjects felt thermal sensation, but they did not feel pain. He demonstrated that a human organism could conduct an alternating current strong enough to switch on an electric lamp.

D'Arsonval showed that current could be passed through the human body by capacitive coupling (Figure 4.). Coil of the high-frequency oscillator was connected to an electrode in the human hand. D'Asonval noted that more than 300 mA can be passed through the body with this method.

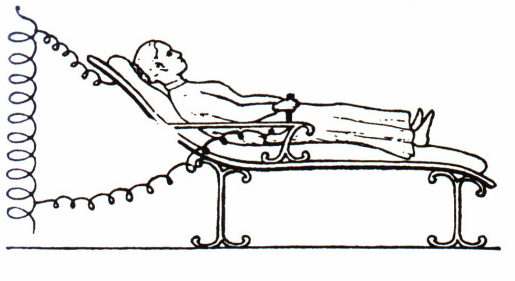


Figure 4. Method of capacitive coupling

D'Arsonval was also interested in an inductive heating (Figure 5.). A man or a rabbit were placed inside long solenoid with current. He realized himself that the current induced in the body was not confined to the surface. This experiment shows that d'Arsonval performed first medical diathermy.

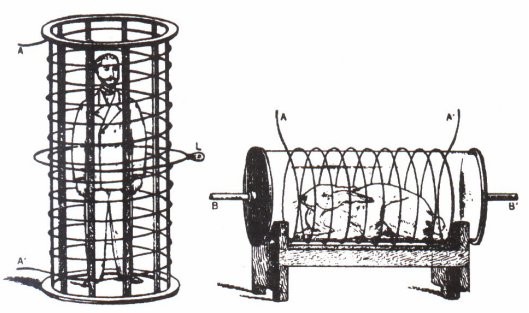


Figure 5. Inductive heating of a man and rabbit

In the twentieth century the techniques, recently named *darsonvalisation* was performed using two methods: general and local. General treatments bases on inductive heating, using a stationary solenoid with a height of ca. 2 meters, formed as a thick coil of copper wire. Patient during the procedure remains inside the solenoid using a wooden chair. The procedure is realized every two days, approximately the treatment is twenty-fold one. For cosmetic purposes one uses local treatments.

D'Arsonval showed in his demonstration that a strong, low frequency electromagnetic field can induce eddy currents into living tissue and thereby cause stimulation. Using generator of 42 Hz, the frequency used at that time for energy transmission, he discovered the phenomena which links electromagnetic field with visual sensations which have been called magnetophosphenes . He wrote about his discovery:

„There occurs, when one plunges the head into the coil, phosphenes and vertigo, and in some person, syncope... Alternating magnetic field modifies the form of muscular contraction and produces in living beings other effect…"

In 1933 the Ministry of Education held an official jubilee for d'Arsonval at the Sorbonne. He was created knight of the Legion of Honour in 1884, and received the Grand Cross in 1931.

3. Silvanus P. Thompson

Silvanus Philips Thompson was born on June 19, 1851 in Settle, UK. The family were Quakers and consisted of mother Bridget and 8 children, 5 boys and 3 daughters with Silvanus Philips being their second child. After schooling he went to the Quakers Training College at Pontefract, where he studied to be a teacher and obtained a baccalaureate degree at the age of 19. After trying his hand as a teacher, he studied chemistry and physic in Royal School of Mines art South Kensington. After graduation he was appointed at Bristol University Collage and very soon he has got the scholarship at the University of Heidelberg, Germany. In 1878 he was elected to Chair of Physics. At age of 27 he had assumed higher academic responsibility, that of a professorship. His first publication appeared in 1876 in "Philosophical Magazine" and was titled "On some

phenomenon of induced electric spark". A year later he published the paper "On improved lantern galvanoscope" and the paper was highly evaluated by William Thomson, later Lord Kelvin. Starting with these two papers he published every year a couple of papers as well as he presented lectures to special auditoria.

He was described as a competent and skilled speaker both in scientific debate and social occasions. William Hale White said about him: *"The audience was thrilled... Silvanus Thompson was a prince among lecturers. I have never heard a better demonstration or attended a more memorable medical meeting."*

Thompson was the first President of the Roentgen Society (now The British Institute of Radiology) founded in 1897. He described the society as being between medicine, physics and photography. Since 1918 they have an annual Silvanus Thompson memorial lecture for which they award a silver medal.

He was also the President of the IEE (Institution of Electrical Engineers) and he was a member of the Royal Society and of the Royal Swedish Academy of Sciences.

Figure 6. Silver medal of Silvanus P. Thompson

He was a recognised authority upon electricity, magnetism and acoustics.
Thompson wrote a few scientific books on electricity, such as:

- Elementary Lesson in Electricity and Magnetism (1881)
- Dynamo Electrical Machinery (1896)
- Calculus Made Easy (1910),

which ran through some 40 editions and reprints.

He also wrote biographies of Michael Faraday and Lord Kelvin as well as biography of William Gilbert, the physician of Queen Elizabeth I. He prepared an edition of Gilbert's opus vitae *De Magnete* at the Chiswick Press in 1900. In 1912 Thompson published the first English translation of *Treatise on Light* by Christian Huygens.

All his activity was concentrated on, using the contemporary notions, bioelectromagnetic phenomena. In the next 30 years Thompson's research was prolific, mainly in the fields of electricity, magnetism and optics. He was deeply involved in exploring Roentgen's X Rays and fluorescence phenomenon. He is also considered to be the precursor of transcranial magnetic stimulation (TMS) – in 1910 he started to investigate magnetic field effects on the brain.

Silvanus P. Thompson was admired in academic world for his outstanding way of lecturing . His lectures gathered a lot of students and other listeners.

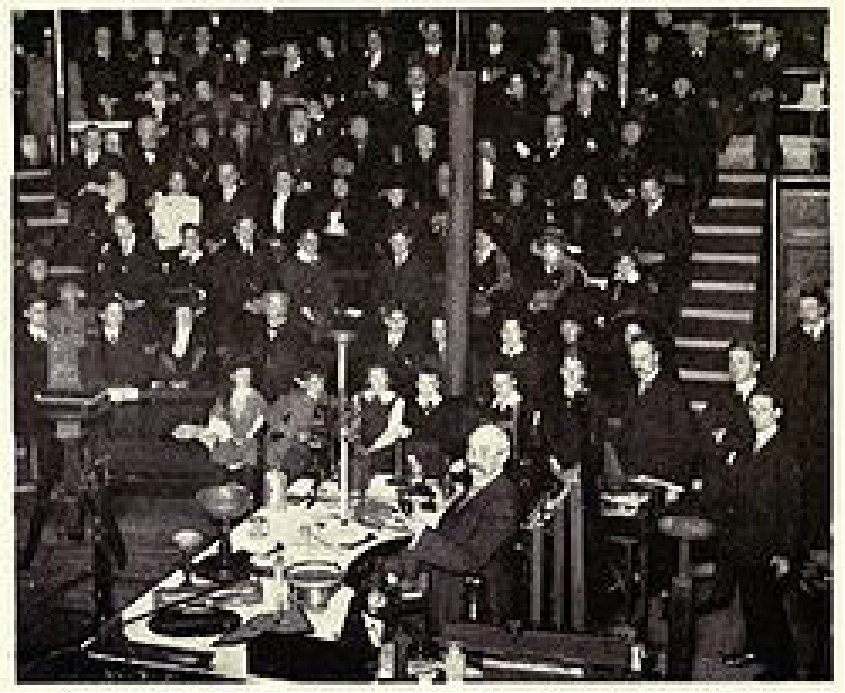


Figure 7. Silvanus P. Thompson during lecture

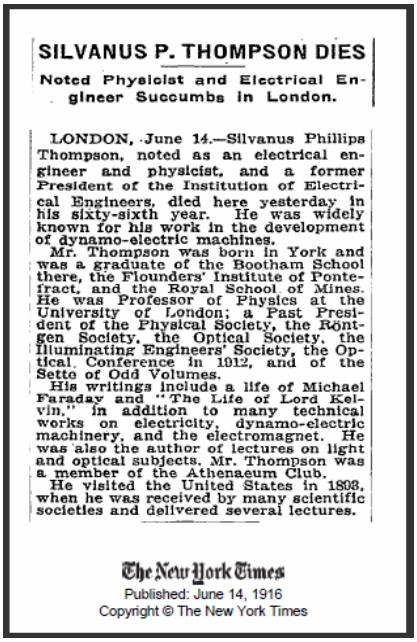
William Hale White (1857–1949), a distinguished British physician and medical biographer, after one of Thompson's lectures said: *The audience was thrilled... Silvanus Thompson was a prince among lecturers. I have never heard a better demonstration or attended a more memorable medical meeting.*

In 1910 he published the article *A Physiological Effect of an Alternating Magnetic Field* (Proceedings of Royal Society B July 21, 1910 82:396-398) in which, independently of d'Arsonval, the visual sensations of electromagnetic field were described. They were magnetophosphenes again. It is very interesting to notice that he made experiments on himself (Figure 8.). The parameters of his experiment were as follows: peak value of magnetic flux density up to 140 mT, frequency 50 Hz. The contemporary studies show that retina is the structure which can be stimulated by much weaker magnetic field – magnetophosphenes can be obtained with 10 mT (rms) and frequency 20 Hz.

Figure 8. Stimulating retinal light by magnetism

The last years of the Silvanus P. Thompson life were dominated by the First World War. As he was a Quaker he had difficulties with all the kinds of violence. The first problem he had was the Boer War, but the time of the First World War was more difficult for him. He gave up any technical and scientific activity, which he believed to be militaristic. He looked at mainland Europe with great anxiety and sorrow, but he carried on working and death overtook him in 1916 at the relatively young age of 65.

Silvanus P. Thompson was known all over the world – just in a couple of days after his death the special obituary announcement was published in The New York Times (Figure 9.).



SILVANUS P. THOMPSON DIES

Noted Physicist and Electrical Engineer Succumbs in London.

LONDON, June 14.—Silvanus Phillips Thompson, noted as an electrical engineer and physicist, and a former President of the Institution of Electrical Engineers, died here yesterday in his sixty-sixth year. He was widely known for his work in the development of dynamo-electric machines.

Mr. Thompson was born in York and was a graduate of the Bootham School there, the Flounders' Institute of Pontefract, and the Royal School of Mines. He was Professor of Physics at the University of London; a Past President of the Physical Society, the Röntgen Society, the Optical Society, the Illuminating Engineers' Society, the Optical Conference in 1912, and of the Sette of Odd Volumes.

His writings include a life of Michael Faraday and "The Life of Lord Kelvin," in addition to many technical works on electricity, dynamo-electric machinery, and the electromagnet. He was also the author of lectures on light and optical subjects. Mr. Thompson was a member of the Athenaeum Club.

He visited the United States in 1908, when he was received by many scientific societies and delivered several lectures.

The New York Times
Published: June 14, 1916
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Figure 9. Obituary published in NYT

4. Conclusion

The magnetic stimulation of tissues proposed and investigated by Jacques Arsene d'Arsonval and Silvanus P. Thompson was the precursor of the magnetotherapy and transcranial magnetic stimulation, the electromagnetic techniques used in contemporary medicine. Therefore, it is very important for the researchers who deal with electromagnetic medicine nowadays to know how the problem began more than 100 years ago.

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