THE NATIONAL COLLEGE OF ART AND DESIGN

THE HISTORY OF ELECTROTHERAPY

A THESIS SUBMITTED TO:
THE FACULTY OF HISTORY OF ART AND DESIGN & C S

FACULTY OF DESIGN
DEPARTMENT OF INDUSTRIAL DESIGN

BY

STEPHEN LENNON

MAY 1981

TABLE OF CONTENTS

[illegible] .... [illegible]

Chapter

INTRODUCTION .... [illegible]

I. THE EARLY YEARS .... [illegible]

II. THE NEW ERA .... [illegible]

III. TECHNICAL DEVELOPMENTS .... [illegible]

BIBLIOGRAPHY .... [illegible]

TABLE OF CONTENTS:

ILLUSTRATIONS....................................4

Chapter:

I INTRODUCTION.......................5

II THE EARLY YEARS....................12

III THE NEW ERA.......................22

IV TECHNICAL DEVELOPMENTS.............27

BIBLIOGRAPHY...................................32

ILLUSTRATIONS:

Fig 1 GUERICKE'S ELECTRICAL GENERATOR Page 13

(From Oho Von Guericke, Experimenta Nova 1672)

Fig 2 THE LEYDEN JAR Page 15

(From J H Winkler, Staeike Der Elektrichen Kraft, 1746)

Fig 3 ELISHA PERKINS SHOWN "EXTRACTING" MALIGNITY Page 19

(Gillray Cartoon, 1801)

Fig 4 VOLTA'S ELECTROCHEMICAL PILE Page 25

(From Transactions of the Royal Society, June 1800)

Fig 5 FARADAY'S ELECTRIC GENERATOR Page 29

(Courtesy of Burndy Library)

CHAPTER I

INTRODUCTION

The term electrotherapy denotes the use of electricity in the treatment of disease. The various modes of application include - muscle and nerve stimulating currents, ultra-violet light, micro-wave therapy, ultrasonics, helio-therapy (therapeutic use of suns rays) and others. Treatment by electrotherapy is even to-day not widely known, although its history spans almost 5,000 years.

The purpose of this thesis is to give a broad account of the history of electrotherapy from its conception in 3,000 B C (approx), to present day devices. There are two main streams of development in this field; the scientific, consisting of the doctors and researchers who tried to expalin the physical phenomena relating to electricity; and the technological, consisting of men who built the machines and instruments relating to the new knowledge.

It will be seen by the end of this introductory chapter, that from the conception of electrotherapy to the latest researchers of our day, science and technology in this field have been virtually inseparable.

Since the project (Section II) is primarily concerned with muscle and nerve stimulating currents, these will constitute the main part of this thesis.

An outline history of electrotherapy has been given below as it provides the reader with a helpful introduction to subsequent material of a more detailed nature. The principle events are given in chronological order, enabling one to form a broad mental picture of the history as a whole.

3,000 BC (approx) - The application of cautery was recorded in the treatment of disease.

600 BC - The Greeks discovered that a piece of amber attracted small bodies when it was rubbed. Sebsequently the Romans poured hot oils on the body in preparation for massage and recommended immersion in warm mineral springs.

1,600 AD - William Gilbert studies and names electricity from the Greek wrod "electron" meaning amber.

1,620 - Lord Bacon investigated heat and thought it to be molecular motion.

1746 - The Leyden Jar was devised by Musschenbroek.

1774 - Faure applied hot bricks in the treatment of rheumatic pains.

1780 - Luigi Galvani began his studies on animal electricity. He continued these and in 1786 -

1786 - Galvani reported on his famous experiments on the twitching of a frogs legs when it came in contact with a conductor.

1794 - Spallanzani recognised a "sound" which was not audible to the human ear.

1798 - Rumford showed that a steady supply of heat could be obtained by the abrasion of metal.

1800 - Volta described the volatic pile. - Vaquelin passed a current of electricity through an iron wire which became red hot. - Herschel showed that red rays heated three times as fast as violet, and also the presence of infra-red rays beyond the red end of the visible spectrum.

1801 - Ritter discovered rays outside the visible spectrum at the violet end, which he termed ultra-voilet rays.

1802 - Sir Humphry Davy made the first carbon arc.

1816 - Roeberemer discussed the use of light baths in treatment.

1820 - Oersted stated the laws relating electric current to its magnetic field.

1831 - Michael Faraday discovered electromagnetic induction by demonstrating an electromotive force in a conductor which he moved in a magnetic field. (Faraday's work led to the development of much of the apparatus seen in daily life, such as transformers, Electric bells, electric motors and dynamos).

1850 - Joule established the relationship between mechanical and heat energy.

1868 - Maxwell presented his wave theory of light.

1877 - Downes and Blunt discovered that light could kill bacteria. - Joule enumerated the laws relating electricity and light.

1878 - Edison developed the carbon filament lamp. This was used originally for lighting, but later as a source of radient heat.

1881 - Lippman produced longitudinal oscillations in a quartz crystal by electrical means.

1882 - Edison noted that electrons "boiled off" a heated filament wire (thermionic emission) suspended in a vacuum would pass to a positively charged plate. This is called the Edison effect.

1888 - Hertz discovered the existance of waves that could pass through stone and wooden floors which were known as Hertizian waves - (later to be called radio waves).

1891 - Kellog built and used a radient heat cabinet. - Tesla observed the heating effect of high-frequency currents.

1892 - Arons discovered the mercury arc. - D'Arsonval passed a high-frequency current through himself and his Assistant.

1893 - Finsen used the carbon-arc for ultra-voilet treatment.

1896 - Marconi produced the fore-runner of the wireless receiver.

1897 - Thomsen discovered cathode rays and called the charged particles electrons.

1899 - Van Zeynek observed tissue heating by high-frequency currents.

1903 - Rollier instituted treatment of patients by exposing them to graduated doses of natural sunlight at Leysin. This was the origin of heliotherapy.

1904 - Fleming invented the diode thermionic valve.

1905 - Kuch succeeded in making quartz glass which would transmit untra-violet light. This led to the use of the mercury vapour lamp for treatment and in 1906 -

1906 - The water-cooled Kromayer lamp was introduced.

1913 - Reyn used ultra-violet light for general irradiation of the body.

1917 - Langevan developed the piezo-electric generator which was used for making ultrasonic waves.

1919 - Rutherford discovered the proton.

1928 - Schliephake reported on the treatment of patients with short-wave diathermy.

1930 - Carpender and Page described the use of short-wave therapy for fever treatment.

1932 - Anderson discovered the positron and Chadwick the neutron.

1938 - Pohlman treated sciatic pain with ultrasonics.

1946 - Krusen investigated micro-wave diathermy for heating living tissue.

1950 - Crystal-controlled self-tuning was used in the short-wave diathermy generator originally designed by Bauwens and Styles.

1956 - Styles incorporated the "pot resonator" into a short wave generator and thus reduced the radio and television interference caused by this treatment.

CHAPTER II

THE EARLY YEARS

The origin of the word electricity is attributed to Dr William Gilbert (1544 - 1603), who was the Physican to Queen Elizabeth I, and President of the Royal College of Physcians in London. It was the Ancient Greeks who in approximately 600BC, first noticed the power of attraction that rubbed amber had over light bodies; but no more advances were made in a massing knowledge on the subject until 1600, when Gilbert published his work - "De Magnete". In this he investigated the powers of attraction of other substances which he called "electrics". When these were rubbed they displayed the same attractive power as amber (Greek electron).

Behind Gilbert stretched two millennia of indifference and superstition with regard to the emission of sparks, or the crackling noises produced when certain clothes were rustled. In his book he not only presented the most comprehensive study which has yet been made in static electricity and magnetism, but also used for the first time, a procedure of thoroughly analyzing the problems by a series of experiments.

It was this procedure, enquiry through the "scientific method" that helped discredit the mystical and often contradictory notions regarding "electrics" and "magnetics" held by natural philosophers and navigators of his time. These he replaced with an accumulation of data proven and confirmed by repeated experiments. Although Dr Gilbert did not apply this knowledge to medicine he will be remembered by doctors as the pioneer of the scientific method of investigation in this field.

The next advance in electrical knowledge was brought about by Robert Boyle (1627 - 1691), who added new electrical relationships to the work of Gilbert, which he published in 1675.

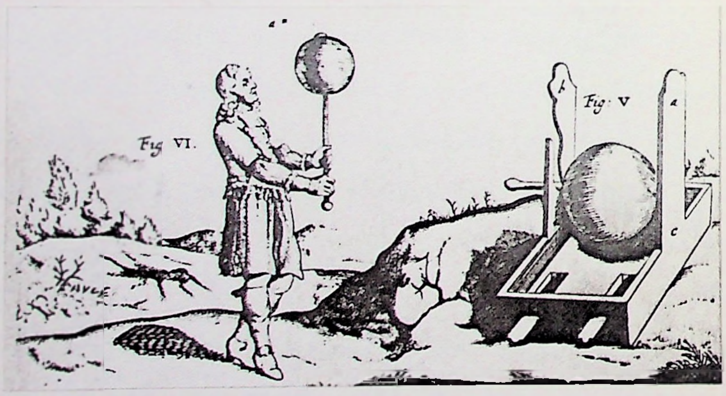


Fig 1. Guericke's Electrical Generator

The earliest operating mechanism which used static electricity is credited to Otto Von Guericke (1602 - 1686) burgomaster of Magdeberg. The machine that he built is described in his "Experiment Nova" which he published in Amsterdam in 1672. (see fig 1).

From the illustration it can be seen that Guericke cast a sulphur globe which could be turned on its bearings. He noticed that if a dry hand was held against it during this operation an electric charge was set up in its surface. If the globe and its shaft were then lifted from its supports it could attract a floating feather. Guericke observed that when the feather touched the globe it was immediately repelled. More importantly perhaps, he noted the small sparks emitted from the globes surface and their accompying crackling sound. (These were the first credited to man-made electricity). He also observed that an electric charge travelled out of the end of a linen thread and that bodies became charged when brought in close contact with a nearby charged sphere. We therefore have instances of electrical conduction and induction.

To the observer these may seem to be trivial steps, but the evolution of science was brought about by inquiring minds, puzzling over seemingly insignificient matters.

When news of Guericke's "electrical generator" spread, other pioneers in this field such as Stephen Gray and Francis Hauksbee in England were soon at work. The next major advance was made in Leyden in 1746 by Professor Pieter Van Musschenbroek (1692 - 1761). He found that an electricialy charged glass jar, partly filled with water and held in the hand, drew an electric charge from a gun barrel and struck with, "such violence that my whole body was shaken as by a lightening stroke". (This was the first recorded occurance of an electric shock).

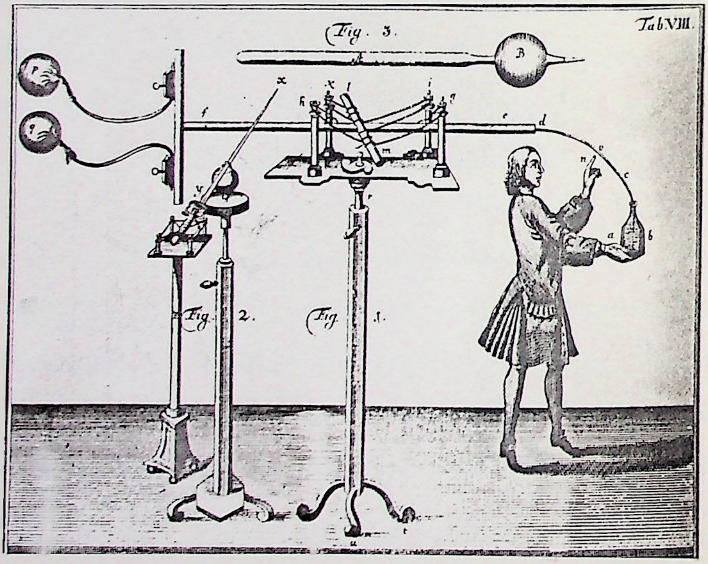


Fig 2. The Leyden Jar

The Leyden Jar (see fig 2) consisted of a glass jar coated inside and out with tin foil; with a metallic rod attached to the inner foil and passing through the lid. This was the first condenser for static electricity.

Further experiments resulted in improvements in the shape of lining of the jars. Consequently heavier charges could be obtained. Leyden Jars were also arranged into groups - (called batteries) - set on metallic bases with multiple connections resulting in greater discharge power.

With the Leyden Jar as a new storage facility and the physiological effects of an electric shock noted, its application to the body for therapeutic use became almost meritable.

Credit for its first use as a medical agents is a matter of some dispute. Duchenne* giving it to J G Kruger (1715 - 1759) Professor of Medicine at Halle and later at Helmstadt. While Priestly History of Electricity 1767, accords the subject in 1745. Yet another publication by Vinaj claims its first use to be by Padman E Pivati in 1747. Of these three men Pivati seems to be the most authentic, since the other two claims occur before the Leyden Jar. Which of these men was indeed responsible is less significant than peoples attitude towards medical electricity in these its infant years.

There is little doubt that in the latter half of the 18th Century the virtues of electricity were to put it mildly exaggerated. The early volumes of physiological transactions

* (Duchennes involvement in electrotherapy will be dealt with later in this paper).

and other contemporary publications contained the most marvellous accounts of cures effected by electricity.

One such cure was reported to have been effected on Signor Donadoni, the seventy year old bishop of Sebenice who was treated by Pivati for a severe attack of gout, from which he was hopelessly crippled. The bishop was electrified for two minutes by a cylinder filled with discutient medicines. These medicated tubes which were introduced by Pivati, were essentially Leyden Jars filled with various substances such as Peruvian balsm, cathartics, sudorifics and diuretics. They were widely used in Italy (1747 - 1798), and by Winkler at Leipsic. Pivati included this cure in an essay he published in (1750) on medical electricity.

When Abbe J H Nollet who pioneered the use of electricity in paralysis, read these accounts he was so amazed that he went to Italy to visit Pivati. Having questioned him for a while Nollet became suspicious of the validity of his claims. When asked to produce the successful cylinder, Pivati claimed it was broken and could not even produce a piece of it. Under cross-examination he finally confessed to having administered the "odours" only twice (definitely not long enough to have effected a full cure as was claimed). When Abbe asked about the bishop's condition he was reported to be as bad as ever.

Some of the cures seemed to do the patients more harm then good. Dr Cheny Hart (1772), treated a girl with a paralized arm with electric shocks and made her totally paralytic. When another doctor brought the disease back to its original state, Hart was allowed to administer electricity again with the same results.

Besides trying to treat congestive ailments, fevers and lameness, doctors tried electricity in the most unusual circumstances. The following is a case reported from Hunter's <u>Treutise on the Venereal Diseases</u>:-

"A dragoon who received an injury from the pommel of a saddle of so considerable and obstinated a kind that castration was resolved on, was eventually cured by slight shocks continued every day for six weeks".

At this time, doctors had no firm physiological knowledge of the effects of an electric shock. Any cures which were effected were mostly a matter of chance. It seemed the "scientific method" of experimentation did not as yet apply to the medical profession. A number of patients were reported as having stopped electrical treatment because they felt they would rather endure their illness than the pain of an electric shock.

Elisha Perkins shown "extracting" malignity." (Gillray cartoon, 1801.)

Fig 3.

This was definitely the era when a great deal of quackery was associated with electrotherapy. Some even claimed that the charge was the panacea for all ills. Dr Bianchini's book - Recueil of Experences Faites a Venise, was mainly responsible for exposing at least some of these absurdities. However, throughout all this there was still a number of eminent men such as Dr Halm (1745), Jallabest (1748), Abbe Nollet and Benjamin Franklin (1758) in America, who were trying to gather reliable data on static electricity and apply it to medicine. The foremost of these was perhaps Benjamin Franklin (1706 - 1790), who not only worked in the medical field, but also extended sone of the theories of electricity.

Franklin found his keenest interest drawn to the performance of the Leyden Jar. He became convinced that it was the glass of the jar and not the inner or outer foil that held the charge. Further analysing his theories he was led to the conclusion that the old notion of two liquids, could be explained much better as one liquid in a state of imbalance (positive or negative) from its neutral electrical state. Following this "one-fluid" theory, his next major electrical achievement was the realization and experimental proof that lightening was an electrical phenomenon.

In medical circles he will be remembered for his work with palsy victimes. His Experiments in Electricity sponsored by Dr John Forthergill and published in 1753 gave new impetus to medical electricity. With Dr John Pringle, noted hygienist and President of the Royal Society, Franklin discussed the possibility of using electric shocks to cure palsy. Later he conducted some experiments on paralysed victims.

In 1758, he reported that in consequence of this work and cures reported in Italy and Germany, a great number of paralytics were brought to him for treatment from Pennsylvania and neighbouring states. Rumours soon spread that Franklin was able to cure blindness and dropsy. When following news of subtle nerve fluids and magnetic influences, the public were ready to hail a new miracle. However, Franklin admitted that no physical changes were observed in the patients after electric shocks; though there was some "lifting of the spirit ".

Even with Franklin's honesty the same type of treatments were still to continue. G F Rossler (electric bath 1768), Manduyt (1777), William Hanley (1779) and many others continued to utilize statical (static) electricity in the treatment of disease. Static machines were installed in the Middlesex Hospital in 1767, in St Bartholomews in 1777, and in St Thomas's in 1799.

Even with all this activity, the palsy sufferers had to wait over thrity years after Franklin's announcement for the event that would give them renewed hope.

CHAPTER III

THE NEW ERA

The new insight into electrotherapy began quite unexpectedly in the laboratory of an anatomist, Luigi Galvani - (1737 - 1798). While dissecting a frog he noticed a violent twitching in the severed lower half of the frog's body. This was a very unexpected movement since the frog had been dead for several hours.

Galvani retraced the steps that caused the strange phenomenon and observed that an electrical machine was in use nearby, but was in no way connected to the frog. Further investigation showed that merely using the scalpel under certain conditions induced twitching, even without the use of a machine. These results prompted him to believe this action was due to what he termed "animal electricity". Similiar phenomena had been observed in the Torpedo fish by John Walsh in 1773, and in John Hunter's studies of other electric fish; but Galvani was the first to observe this action in other creatures.

Galvani, aware that he had made an important discovery, extended his experiments to include warm-blooded animals. His results and theory were published in the Transactions of the Science Institute of Bolagona in 1791. (This paper earned him the nickname of the Frog's Dancing Master).

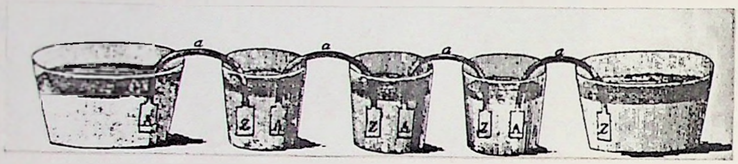
As far as palsy sufferers were concerned, Galvani's experiments seemed to prove that electric currents in the body caused vital action such as contraction of muscles. Consequently, they again looked to electricity as ameans to revive paralized muscles. With this renewed interest unscruplous doctors again promised the public the electrical cures they longed for. Two such men, Graham and Perkins, held what amounted to medical sideshows. The audiences failed to see that they were using the old electrostatic "shock treatment", to seemingly effect new and miraculous cures. However, all Galvani's work did not fall on barren soil, since an offprint of his paper was sent to Professot Volta (1745 - 1790).

Volta, on reading the paper first agreed with Galvani's interpretation of his results - (that the muscular action might indeed be caused by "animal electricity"). However, Volta who was a physicist and not an anatomist, soon became doubtful of the validity of Galvani's conclusions and started experiments of his own. These consisted of turning his attention from the frog to the other elements in Galvani's experiments which could have caused the muscular contraction. His main concern was the possibility that the metal elements that touched the frog's legs, might have been the source of the action.

After two years of experiments and testing, he became convinced that Galvani's "animal electricity" could be explained better as "anetallic electricity". Volta ascertained that it was the contact of two dissimiliar metals, moist and touching at one end, in contact with the frogs nerves and muscles at the other, that caused the twitching. Convinced that his theory was correct, he experimented further and found that certain pairs of metals were more effective in their stimulus than others. After his experiments he arranged the metals into a series of relative effectiveness which later evolved into the modern electro-chemical series.

This great difference in interpretation between the natural electrical property of animal tissue as held by Galvani and the purely metallic nature of Volta's electrical source, brought about a great deal of controversy between different school of scientists.

This disagreement finally culminated in Galvani's retirement and general acceptance of Volta's theories. (This need not have been the case, since there was truth in both theories). It was at this time that Volta announced his major invention, the "electrochemical pile".



Volta's crown of cups. The "pile" of pairs of zinc and silver discs that formed Volta's first electric battery was modified to form a series of cups filled with weak acid.

Fig 4. Volta's Electrochemical Pile

He described in his classic paper Transactions of the Royal Society, June 1800; the structure of the pile, (see fig 4), and its most effective combination of elements. He concluded that these were zinc and silver discs seperated by paper or cloth, soaked in brime. Thirty of these elements connected in series was sufficient to cause the sensation of a continuous flow of electricity through a person holding either end of the pile of discs. Because the current tended to decrease as the paper seperators became dryer, Volta devised his "crown of cup", which consisted of a row of cups filled with brime, into which were placed alternate strips of silver and zinc. This was the beginning of the different forms of wet battery.

This should have been an important step in the history of electrotherapy, because it gave doctors a continuous flow of current, rather than the instantaneous discharge of the earlier electrostatic generators. However, this was not the case, since it was still believed that all nervous influences originated at the brain. This meant that nerves and muscles could only be excited through this region. It was not until fifty years later that the concept of applying current directly to the affected parts was implemented.

CHAPTER IV

TECHNICAL DEVELOPMENTS

The threshold that seperated the electric practices of the 1700's and those of the 1800's were indicative of the trend that science and technology were to follow in the succeeding century and a half. The giant electrostatic generators were impressive enough, but proved quite useless beyond introducing the new natual force. The electric battery on the other hand, became a new research and industrial tool, which provided a continuous flow of electricity; soon to be put to many commercial uses. This new usefulness of electricity prompted new discoveries outside the medical field. During the twenty years that followed the electric battery was used in many commercial/industrial applications; such as electric furnaces, gunpowder ignition, and telegraph communications. It seemed incredible therefore, that no one had observed the phenomenon which first attracted the attention of a Professor of Physics at the University of Copenhagan.

During the previous two decades many attempts had been made to understand more fully the chemical and metallurgical characteristics of the voltaic pile and to apply it to more practical use. While demonstrating the properties of the electric battery before his class, Professor Hans Christain Oersted (1777 - 1851) observed something that had eluded many of his colleagues. While placing a conducting wire over and parallel to a pivoted magnetic needle swung perpendicular to the wire. He did not mention this strange occurance at the time, but later repeated the experiment using a stronger battery and a larger conducter; the effect was the same. The results of Oersted's work which remain one of the most important discoveries in science were published on July 21, 1820. They stated that an "electric current in a conductor created a circular magnetic field around the conductor".

The outcome of Oersted's experiments spread quickly to the important scientific centres of Europe. Public demonstrations of the new discovery were held. At one of these in Paris in 1820, an interested member of the audience was Professot Andre-Marie Ampere (1775 - 1836).

Ampere, quick to see its significance, within a week published a paper on the mutual action of two electric currents. He also showed that an electric current, both influences a magnet, and itself produces magnetism. The "electromagnet" was further improved by William Strugen in England in 1825, and in New York by Joseph Henry (1797 - 1878); who produced one capable of supporting a ton of iron. This very impressive product of magnetic effects prompted many investigators to try to reverse the conversion, producing electric effects by use of megnetic effects. It was in October 1831, that Michael Faraday, at the Royal Institute of London, discovered the vital link.

Faraday, set up an experiment with two coils of wire:- one connected to a voltaic battery and the other to a galvonometer. He noticed that when the battery position was closed, the galvonometer needle swung out and returned to the zero position. When the circuit was broken the needle swung in the opposite direction and then returned. Pursuing this connection, he mounted a copper disc between the poles of a powerful magnet and showed that a steady voltage was generated between the outer rim and the axle of the disc, when it was rotated (see fig 5).

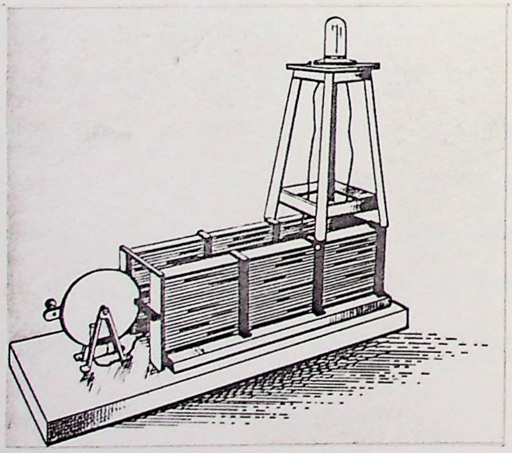


Fig 5. Faraday's Electric Generator

He also demonstrated that a voltage was induced when either the magnet or the conductor moved in relationship to each other.

With Faraday's induction coil a new form of sinusoidal current was discovered which could be used in electrotherapy. It was used in therapy with marginal success by Addison (1837), Golding Birt (1841), and Gull (1852), at Guy's Hospital in England. The problems with these treatments was that they were being employed, using the old methods for static electricity.

It was not until the later 1850's that Remak and Duchenne laid the foundation for modern modes of treatment by battery, (Galvanism, named after Galvani), and by induction coil (Faradism, named after Faraday).

It was Duchenne who first used the principle of applying the currents to the effected parts. He also showed that muscles could be excited at certain points on the surface of the body, which he called dilection points. These concepts were further rationalized by Remak who showed they were the sites at which the motor nerves enter the muscles. (they are now called motor points).

Further developments in the physiological effects of electric current occured in 1850, when Du Bois Reymond and Pfluger demonstrated the electrical phenomena of living nerve; and established the laws of electrotonus. (Contraction of muscles and the existance of muscle currents).

From this point there were no more major developments in this particular aspect of electrotherapy. There was of course developments in technology - (e.g. the mass distribution of electricity), and understanding the effects of electric currents, but the methods and modes of treatment remain even to this day virtually unchanged.

When reading this history it is worth considering the number of years which often passed between the first discovery of a physical agent, its investigation, and eventual use in therapy. On the other hand, recent treatments, such as micro-wave diathermy have been set in their rightful place with commendable speed.

BIBLIOGRAPHY:

(1) The Principles and Practices of Electrotherapy and Actiontherapy
BY: Bryan O. Scott
PUBLISHED: William Heinmann Medical Books
First edition 1959

(2) A Pictorial History of Medicine
BY: Ottol Bettmann
PUBLISHED: 1976 - Volume 20

(3) The All Electric Age
BY: A. Gowans Whyte
PUBLISHED: Constable and Company Ltd 1922

(4) History of Medicine
BY: Garrison
PUBLISHED: Second edition printed in England
1922

(5) A History of Medicine
BY: Arturo Castilion
PUBLISHED: Alfred A. Knope New York 1941

JOURNALS:

(6) Dublin Quarterly Journal of Medical Science Volume II Page 388-414, Volume III Page 102-128

MICHAEL DONOVAN
"On the efficiency of electricity, Galvanism, electromagnetism and magnet-electricity in the cure of disease and on the best method of application.

(7) Dublin Quarterly Journal of Medical Science Volume XLVIII Page 53-68 Ave 1869

WALTER G SMITH
"On certain forms of paralysis and their treatment by electricity".