A (not so) brief history of electrocardiography.

Find out how electrocuting chickens (1775), getting laboratory assistants to put their hands in buckets of saline (1887), taking the ECG of a horse and following it to the slaughterhouse (1909), induction of indiscriminate angina attacks (1931), and hypothermic dogs (1953) have helped to improve our understanding of the ECG as a clinical tool. And why is the ECG labelled PQRST (1895)?

17th and 18th Centuries	The harnessing of electricity, observations of its effects on animal tissues and the discovery of 'animal electricity'.

1600


William Gilbert

William Gilbert, Physician to Queen Elizabeth I, President of the Royal College of Physicians, and creator of the 'magnetic philosophy' introduces the term 'electrica' for objects (insulators) that hold static electricity. He derived the word from the Greek for amber (electra). It was known from ancient times that amber when rubbed could lift light materials. Gilbert added other examples such as sulphur and was describing what would later be known as 'static electricity' to distinguish it from the more noble magnetic force which he saw as part of a philosophy to destroy forever the prevailing Aristotlean view of matter. *Gilbert W. De Magnete, magneticisique corporibus, et de magno magnete tellure. 1600*

1646

Sir Thomas Browne, Physician, whilst writing to dispel popular ignorance in many matters, is the first to use the word 'electricity'. Browne calls the attractive force "Electricity, that is, a power to attract strawes or light bodies, and convert the needle freely placed". (He is also the first to use the word 'computer' - referring to people who compute calendars.)*Browne, Sir Thomas. Pseudodoxia Epidemica: Or, enquiries Into Very Many Received Tenents, and Commonly Presumed Truths. 1646: Bk II, Ch. 1. London*

1660

Otto Von Guericke builds the first static electricity generator.

1662


Descarte's reflex
©BIU

The work of Rene Descartes, French Philosopher, is published (after his death) and explains human movement in terms of the complex mechanical interaction of threads, pores, passages and 'animal spirits'. He had worked on his ideas in the 1630s but had abandoned publication because of the persecution of other radical thinkers such as Galileo. William Harvey had developed similar ideas but they were never published. *Descartes R. De Homine (Treatise of Man); 1662: Moyardum & leffen, Leiden.*

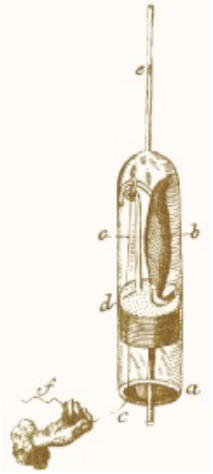
1664

Jan Swammerdam, a Dutchman, disproves Descartes' mechanistic theory of animal motion by removing the heart of a living frog and showing that it was still able to swim. On removing the brain all movement stopped (which would be in keeping with Descarte's theory) but then, when the frog was dissected and a severed nerve end

stimulated with a scalpel the muscles twitched. This proved that movement of a muscle could occur without any connection to the brain and therefore the transmission of 'animal spirits' was not necessary.

Swammerdam's ideas were not widely known and his work was not published until after his death. However, he wrote many letters and his friend, Nicolaus Steno, did attack the Cartesian ideas in a lecture in Paris in 1665. Boerhaave published Swammerdam's 'Book of Nature' in the 1730s which was translated into English in 1758.

1668



electrical stimulation? ©BIU

Swammerdam refines his experiments on muscle contraction and nerve conduction and demonstrated some to notable figures such as the Grand-Duke Cosimo of Tuscany who was visiting Swammerdam's father's house on the Oude Schans in Amsterdam. One experiment suspended the muscle on a brass hook inside a glass tube with a water droplet to detect movement and 'irritated' the nerve with a silver wire. This produced movement of the muscle and it may have been due to the induction of a small electrical charge - although Swammerdam would have been unaware of this.

In the diagram opposite - a) glass tube, b) muscle, c) sliver wire, d) brass wire, e) drop of water, f) investigator's hand.

1729

Stephen Gray, English scientist, distinguishes between conductors and insulators of electricity. He demonstrates the transfer of static electrical charge to a cork ball across 150 metres of wet hemp thread. Later he found that the transfer could be achieved over greater distances by using brass wire.

1745


Leyden Jar

Dutch physicist Pieter van Musschenbroek discovers that a partly filled jar with a nail projecting from a cork in its neck can store an electrical charge. The jar is named the 'Leyden Jar' after the place of its discovery. Ewald Georg von Kliest of Pomerania invented the same device independently.

Using a Leyden jar in 1746, Jean-Antoine Nollet, French physicist and tutor to the Royal family of France sends an electrical current through 180 Royal Guards during a demonstration to King Louis XV.

1769

Edward Bancroft, an American Scientist, suggests that the 'shock' from the Torpedo Fish is electrical rather than mechanical in nature. He showed that the properties of the shock were similar to those from a Leyden jar in that it could be conducted or insulated with appropriate materials. The Torpedo fish and other species were widely known to deliver shocks and were often used in this way for therapeutic reasons. However, electrical theory at the time dictated that electricity would always flow through conductors and diffuse away from areas of high charge to low charge. Since living tissues were known to be conductors it was impossible to imagine how an imbalance of charge could exist within an animal and therefore animals could not use electricity for nerve conduction - or to deliver shocks. Furthermore, 'water and electricity do not mix' so the idea of an 'electric fish' was generally not accepted. *Bancroft, E. An essay on the natural history of Guiana, London:T. Becket and P. A. de Hondt, 1769.*

1773


John Walsh

John Walsh, fellow of the Royal Society and Member of Parliament, obtains a visible spark from an electric eel *Electrophorus electricus*. The eel was out of water as it was not possible to produce the spark otherwise. He used thin strips of tin foil and demonstrated his technique to many colleagues and visitors at his house in London. Unfortunately he never published his eel experiment though he did win the Copley medal in 1774 and 1783 for his work. The observations of Walsh, and Bancroft before him, added to the argument that some form of animal electricity existed. *Walsh, J. On the electric property of torpedo: in a letter to Ben. Franklin. Phil. Trans. Royal Soc. 1773;63:478-489*

1774

The Rev. Mr Sowdon and Mr Hawes, apothecary, report on the surprising effects of electricity in a case report of recovery from sudden death published in the annual report of the newly founded Humane Society now the Royal Humane Society. The Society had developed from 'The Institution for Affording immediate relief to persons apparently dead from drowning'. It was "instituted in the year 1774, to protect the industrious from the fatal consequences of unforseen accidents; the young and inexperienced from being sacrificed to their recreations; and the unhappy victims of desponding melancholy and deliberate suicide; from the miserable consequences of self-destruction."

A Mr Squires, of Wardour Street, Soho lived opposite the house from which a three year old girl, Catherine Sophia Greenhill had fallen from the first storey window on 16th July 1774. After the attending apothecary had declared that nothing could be done for the child Mr Squires, "with the consent of the parents very humanely tried the effects of electricity. At least *twenty minutes* had elapsed before he could apply the shock, which he gave to various parts of the body without any apparent success; but at length, upon transmitting a few shocks through the thorax, he perceived a small pulsation: soon after the child began to sigh, and to breathe, though with great difficulty. In about ten minutes she vomited: a kind of stupor, occaisioned by the depression of the cranium, remained for some days, but proper means being used, the child was restored to perfect health and spirits in about a week.

"Mr. Squires gave this astonishing case of recovery to the above gentlemen, from no other motive than a desire of promoting the good of mankind; and hopes for the future that no person will be given up *for dead*, till various means have been used for their recovery."

Since it is clear she sustained a head injury the electricity probably stimulated the child out of deep coma rather than providing cardiac defibrillation (see also 1788, Charles Kite). *Annual Report 1774: Humane Society, London. pp 31-32*

1775

Abildgaard shows that hens can be made lifeless with electrical impulses and he could restore a pulse with electrical shocks across the chest. "With a shock to the head, the animal was rendered lifeless, and arose with a second shock to the chest; however, after the experiment was repeated rather often, the hen was completely stunned, walked with some difficulty, and did not eat for a day and night; then later it was very well and even laid an egg." *Abildgaard, Peter Christian. Tentamina electrica in animalibus. Inst Soc Med Havn. 1775; 2:157-61.*

1786


Luigi Galvani

Italian Anatomist Luigi Galvani notes that a dissected frog's leg twitches when touched with a metal scalpel. He had been studying the effects of electricity on animal tissues that summer.

On 20th September 1786 he wrote "I had dissected and prepared a frog in the usual way and while I was attending to something else I laid it on a table on which stood an electrical machine at some distance from its conductor and separated from it by a considerable space. Now when one of the persons present touched accidentally and lightly the inner

crural nerves of the frog with the point of a scalpel, all the muscles of the legs seemed to contract again and again as if they were affected by powerful cramps."

He later showed that direct contact with the electrical generator or the ground through an electrical conductor would lead to a muscle contraction. Galvani also used brass hooks that attached to the frog's spinal cord and were suspended from an iron railing in a part of his garden. He noticed that the frogs' legs twitched during lightening storms and also when the weather was fine. He interperated these results in terms of "animal electricity" or the preservation in the animal of "nerveo-electrical fluid" similar to that of an electric eel. He later also showed that electrical stimulation of a frog's heart leads to cardiac muscular contraction. *Galvani. De viribus Electritatis in motu musculari Commentarius. 1791*

Galvani's name is given to the 'galvanometer' which is an instrument for measuring (and recording) electricity - this is essentially what an ECG is; a sensitive galvanometer.

1788

Charles Kite wins the Silver Medal of the Humane Society (awarded at the first Prize Medal ceremony of the Society co-judged with the Medical Society of London) with an essay on the use of electricity in the diagnosis and resuscitation of persons apparently dead. This essay is often cited as the first record of cardiac defibrillation but the use of electricity suggested by Mr Kite is much different. For example, on describing a case of drowning from 1785 where resuscitation had been attempted with artificial respiration, warmth, tobacco, "volatiles thrown into the stomach, frictions, and various lesser stimuli" for nearly an hour, he then recalls the use of electricity. "Electricity was then applied, and shocks sent through in every possible direction; the muscles through which the fluid [electricity] passed were thrown into strong contractions." He concluded that electricity was a valuable tool that could determine whether or not a person, apparently dead, could be successfully resuscitated. *Annual Report 1788: Humane Society, London. pp 225-244. Kite C. An Essay on the Recovery of the Apparently Dead. 1788: C. Dilly, London.*

1792


Alessandro Volta

Alessandro Volta, Italian Scientist and inventor, attempts to disprove Galvani's theory of "animal electricity'" by showing that the electrical current is generated by the combination of two dissimilar metals. His assertion was that the electrical current came from the metals and not the animal tissues. (We now know that both Galvani and Volta were right.) To prove his theory he develops the voltaic pile in 1800 (a column of alternating metal discs - zinc with copper or silver - separated by paperboard soaked in saline) which can deliver a substantial and steady current of electricity. Enthusiasm in the use of electricity leads to further attempts at reanimation of the dead with experiments on recently hanged criminals. Giovani Aldini (the nephew of Galvani) conducts an experiment at the Royal College of Surgeons in London in 1803. The executed criminal had lain in a temperature of 30 F for one hour and was transported to the College. "On applying the conductors to the ear and to the rectum, such violent muscular contractions were executed, as almost to give the appearance of the reanimation". *Aldini, J. Essai: Théorique et expérimental sur le Galvanisme, Paris (1804)*, *Giovani Aldini. General Views on the Application of Galvanism to Medical Purposes Principally in cases of suspended Animation (London: J. Callow, Princes Street and Burgess and Hill, Great Windmill Street, 1819)*. Mary Shelly's *Frankenstein* was published in 1818. *Louis Figuier, Les merveilles de la Science (Paris, 1867), p.653*

1800 to 1895	The design of sensitive instruments that could detect the small electrical currents in the heart.

1819

While demonstrating to students the heating of a platinum wire with electricity from a voltaic pile at the University of Copenhagen, Danish physicist Hans Christian Oersted notices that a nearby magnetized compass needle moves each time the electrical current is turned on. He discovers electromagnetism which is given a theoretical basis (with remarkable speed) by André Marie Ampère.

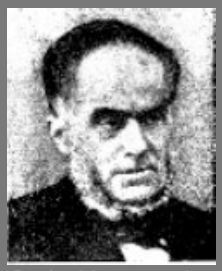
1820

Johann (Johan) Schweigger of Nuremberg increases the movement of magnetized needles in electromagnetic fields. He found that by wrapping the electric wire into a coil of 100 turns the effect on the needle was multiplied. He proposed that a magnetic field revolved around a wire carrying a current which was later proven by Michael Faraday. Schweigger had invented the first galvanometer and announced his discovery at the University of Halle on 16th September 1820.

1825

Leopold Nobili, Professor of Physics at Florence, develops an 'astatic galvanometer'. Using two identical magnetic needles of opposite polarity, either fixed together with a figure of eight arrangment of wire loops (in earlier versions), or one moveable needle with a wire loop and one with a scale (in later versions), the effects of the earth's magnetic field could be compensated for. In 1827, using this instrument, he managed to detect the flow of current in the body of a frog from muscles to spinal cord. He detected the electricity running along saline moistened cotton thread joining the dissected frog's legs in one jar to its body in another jar. Nobili was working to support the theory of animal electricity and this conduction, transmitted without wires, he felt demonstrated animal electricity.

1838


Carlo Matteucci

Carlo Matteucci, Professor of Physics at the University of Pisa, and student of Nobili, shows that an electric current accompanies each heart beat. He used a preparation known as a 'rheoscopic frog' in which the cut nerve of a frog's leg was used as the electical sensor and twitching of the muscle was used as the visual sign of electrical activity. He also used Nobili's astatic galvanometer for the study of electricity in muscles typically inserting one galvanometer wire in the open end of the dissected muscle and the other on the surface of the muscle. He went on to try and demonstrate conduction in nerve but was unable to do so (since his galvanometers were not sensitive enough). *Matteucci C. Sur un phenomene physiologique produit par les muscles en contraction. Ann Chim Phys 1842;6:339-341*

1840

Dr Golding Bird, a Physician, accomplished chemist and member of the London Electrical Society, opens an electrical therapy room at Guy's Hospital, London treating a large range of diseases. Although the application of electricity was popular it was not considered a subject worthy of serious investigation. Because of Bird's reputation as a researcher electrical therapy achieved popularity amongst London Physicians including his mentor Dr Thomas Addison. *Bird G. Lectures on Electricity and Galvanism, in their physiological and therapeutical relations, delivered at the Royal College of Physicians, in March, 1847 (Wilson & Ogilvy, London, 1847)*

1843

German physiologist Emil Du bois-Reymond describes an "action potential" accompanying each muscular contraction. He detected the small voltage potential present in resting muscle and noted that this diminished with contraction of the muscle. To accomplish this he had developed one of the most sensitive galvanometers of his time. His device had a wire coil with over 24,000 turns - 5 km of wire. Du Bios Reymond devised a notation for his galvanometer which he called the

Emil Du bois-Reymond

'disturbance curve'. "o" was the stable equilibrium point of the astatic galvanometer needle and p, q, r and s (and also k and h) were other points in its deflection. *Du Bois-Reymond, E. Untersuchungen uber thierische Elektricitat. Reimer, Berlin: 1848.*

1850

Bizarre unregulated actions of the ventricles (later called ventricular fibrillation) is described by Hoffa during experiments with strong electrical currents across the hearts of dogs and cats. He demonstrated that a single electrical pulse can induce fibrillation. *Hoffa M, Ludwig C. 1850. Einige neue versuche uber herzbewegung. Zeitschrift Rationelle Medizin, 9: 107-144*

1856

Rudolph von Koelliker and Heinrich Muller confirm that an electrical current accompanies each heart beat by applying a galvanometer to the base and apex of an exposed ventricle. They also applied a nerve-muscle preparation, similar to Matteucci's, to the ventricle and observed that a twitch of the muscle occured just prior to ventricular systole and also a much smaller twitch after systole. These twitches would later be recognised as caused by the electrical currents of the QRS and T waves. *von Koelliker A, Muller H. Nachweis der negativen Schwankung des Muskelstroms am naturlich sich kontrahierenden Herzen. Verhandlungen der Physikalisch-Medizinischen Gesellschaft in Wurzberg. 1856;6:528-33.*

1858

William thompson (Lord Kelvin), Professor of Natural Philosophy at Glasgow University, invents the 'mirror galvanometer' for the reception of transatlantic telegraph transmissions. A small, freely rotating mirror, with magents stuck to its back is suspended in a fine copper coil and a reflected spot of light from this mirror 'amplifies' the small movements when electrical current is present. The whole apparatus was suspended in an air chamber and the pressure inside could be adjusted to vary the damping seen on the signals. This galvanometer was sensitive enough for transatlantic telegraphy.

1867

Thompson improves telegraph transmissions with the 'Siphon Recorder'. Before d'Arsonval (1880), Thompson uses a fine coil suspended in a strong magnetic magnetic field. Attached to the coil but isolated from it by ebonite (an insulator) was a siphon of ink. The siphon was charged with high voltage so that the ink was sprayed onto the paper that moved over an earthed metal surface. The siphon recorder could therefore not only detect currents it could also record them onto paper.

1869-70

Alexander Muirhead, an electrical engineer and pioneer of telegraphy, may have a recorded a human electrocardiogram at St Bartholomew's Hospital, London but this is disputed. If he had he is thought to have used a Thompson Siphon Recorder. Elizabeth Muirhead, his wife, wrote a book of his life and claimed that he refrained from publishing his own work for fear of misleading others. *Elizabeth Muirhead. Alexander Muirhead 1848 - 1920. Oxford, Blackwell: privately printed 1926.*

1872

French physicist Gabriel Lippmann invents a capillary electrometer. It is a thin glass tube with a column of mercury beneath sulphuric acid. The mercury meniscus moves with varying electrical potential and is observed through a microscope.

1872

Mr Green, a surgeon, publishes a paper on the resuscitation of a series of patients who had suffered cardiac and / or respiratory arrest during anaesthesia with chloroform. He uses a galvanic pile (battery) of 200 cells generating 300 Volts which he applied to the patient as follows "One pole should be applied to the neck and the other to the lower rib on the left side." *Green T. On death from chloroform: its prevention by galvanism. Br Med J 1872 1: 551-3*. Although this has been reported as an example of cardiorespiratory resuscitation it is unclear what the exact mechanism seems to be. It is unlikely to be electric cardioversion or external pacing. It seems to be another example of electrophrenic stimulation (See also Duchenne 1872).

1872


An 'electric' smile.

Guillaume Benjamin Amand Duchenne de Boulogne, pioneering neurophysiologist, describes the resuscitation of a drowned girl with electricity in the third edition of his textbook on the medical uses of electricity. This episode has sometimes been described as the first 'artificial pacemaker' but he used an electrical current to induce electrophrenic rather than myocardial stimulation. *Duchenne GB. De l'electrisation localisee et de son application a la pathologie et la therapeutique par courants induits at par courants galvaniques interrompus et continus. [Localised electricity and its application to pathology and therapy by means of induced and galvanic currents, interrupted and continuous] 3ed. Paris. JB Bailliere et fils; 1872*

1875

Richard Caton, a Liverpool Physician, presents to the British Medical Association in July 1875 in Edinburgh. Using a Thompson 'mirror galvanometer' in animals he shows it was possible to detect 'feeble currents of varying direction ... when the electrodes are placed on two points of the external surface, or one electrode on the grey matter and one on the surface of the skull'. This is the first report of the EEG (or electroencephalogram). Caton was proving another Physician's hypothesis, John Hughlings Jackson, who suggested in 1873 that epilepsy was due to excessive electrical activity in the grey matter of the brain. *Caton R: The electric currents of the brain. BMJ 1875; 2:278*, *Mumenthaler, Mattle Eds. Neurology. 4th Edition. Stuttgart, Thieme: 2004.*

1876

Marey uses the electrometer to record the electrical activity of an exposed frog's heart. *Marey EJ. Des variations electriques des muscles et du couer en particulier etudies au moyen de l'electrometre de M Lippman. Compres Rendus Hebdomadaires des Seances de l'Acadamie des sciences 1876;82:975-977*

1878

British physiologists John Burden Sanderson and Frederick Page record the heart's electrical current with a capillary electrometer and shows it consists of two phases (later called QRS and T). *Burdon Sanderson J. Experimental results relating to the rhythmical and excitatory motions of the ventricle of the frog. Proc R Soc Lond 1878;27:410-414*

1880

French physicist Arsène d'Arsonval in association with Marcel Deprez, improves the galvanometer. Instead of a magnetized needle moving when electrical current flows through a surrounding wire coil the Deprez-d'Arsonval galvanometer has a fixed magnet and moveable coil. If a pointer is attached to the coil it can move over a suitably calibrated scale. The d'Arsonval galvanometer is the basis for most modern galvanometers. *Comptes rendus de l'Académie des sciences, 1882, 94: 1347-1350*

1884

John Burden Sanderson and Frederick Page publish some of their recordings. *Burdon Sanderson J, Page FJM. On the electrical phenomena of the excitatory process in the heart of the tortoise, as investigated photographically. J Physiol (London) 1884;4:327-338*

1887

British physiologist Augustus D. Waller of St Mary's Medical School, London publishes the first human electrocardiogram. It is recorded with a capilliary electrometer from Thomas Goswell, a technician in the laboratory. *Waller AD. A demonstration on man of electromotive changes accompanying the heart's beat. J Physiol (London) 1887;8:229-234*

1889

Dutch physiologist Willem Einthoven sees Waller demonstrate his technique at the First International Congress of Physiologists in Bale. Waller often demonstrated by using his dog "Jimmy" who would patiently stand with paws in glass jars of saline.

1890

GJ Burch of Oxford devises an arithmetical correction for the observed (sluggish) fluctuations of the electrometer. This allows the true waveform to be seen but only after tedious calculations. *Burch GJ. On a method of determining the value of rapid variations of a difference potential by means of a capillary electrometer. Proc R Soc*

Lond (Biol) 1890;48:89-93

1891

British physiologists William Bayliss and Edward Starling of University College London improve the capillary electrometer. They connect the terminals to the right hand and to the skin over the apex beat and show a "triphasic variation accompanying (or rather preceding) each beat of the heart". These deflections are later called P, QRS and T. *Bayliss WM, Starling EH. On the electrical variations of the heart in man. Proc Phys Soc (14th November) in J Physiol (London) 1891;13:lviii-lix* and also *On the electromotive phenomena of the mammalian heart. Proc R Soc Lond 1892;50:211-214* They also demonstrate a delay of about 0.13 seconds between atrial stimulation and ventricular depolarisation (later called PR interval). *On the electromotive phenomena of the mammalian heart. Proc Phys Soc (21st March) in J Physiol (London) 1891;12:xx-xxi*

1893

Willem Einthoven introduces the term 'electrocardiogram' at a meeting of the Dutch Medical Association. (Later he claims that Waller was first to use the term). *Einthoven W: Nieuwe methoden voor clinisch onderzoek [New methods for clinical investigation]. Ned T Geneesk 29 II: 263-286, 1893*

1895 to date	The first accurate recording of the electrocardiogram and its development as a clinical tool.

1895

Einthoven, using an improved electrometer and a correction formula developed independently of Burch, distinguishes five deflections which he names P, Q, R, S and T. *Einthoven W. Ueber die Form des menschlichen Electrocardiogramms. Arch f d Ges Physiol 1895;60:101-123*

Why PQRST and not ABCDE? The four deflections prior to the correction formula were labelled ABCD and the 5 derived deflections were labelled PQRST. The choice of P is a mathematical convention (as used also by Du Bois-Reymond in his galvanometer's 'disturbance curve' 50 years previously) by using letters from the second half of the alphabet. N has other meanings in mathematics and O is used for the origin of the Cartesian coordinates. In fact Einthoven used O ..... X to mark the timeline on his diagrams. P is simply the next letter. A lot of work had been undertaken to reveal the true electrical waveform of the ECG by eliminating the damping effect of the moving parts in the amplifiers and using correction formulae. If you look at the diagram in Einthoven's 1895 paper you will see how close it is to the string galvanometer recordings and the electrocardiograms we see today. The image of the PQRST diagram may have been striking enough to have been adopted by the researchers as a true representation of the underlying form. It would have then been logical to continue the same naming convention when the more advanced string galvanometer started creating electrocardiograms a few years later.

1897

Clement Ader, a French electrical engineer, reports his amplification system for detecting Morse code signals transmitted along undersea telegraph lines. It was never intended to be used as a galvanometer. Einthoven later quoted Ader's work but seems to have developed his own amplification device independently. *Ader C. Sur un nouvel appareil enregistreur pour cables sous-marins. C R Acad Sci (Paris) 1897;124:1440-1442*

1899


Karel Wenkebach

Karel Frederik Wenckebach publishes a paper "On the analysis of irregular pulses" describing impairment of AV conduction leading to progressive lengthening and blockage of AV conduction in frogs. This will later be called Wenckebach block (Mobitz type I) or Wenckebach phenomenon.

1899

Jean-Louis Prevost, Professor of Biochemistry, and Frederic Batelli, Professor of Physiology, both of Geneva discover that large electrical voltages applied across an animal's heart can stop ventricular fibrillation. *Prevost JL, Batelli F: Sur quelques effets des descharges electriques sur le coeur des mammiferes. Acad. Sci. Paris, FR.: 1899; 129:1267-1268.*

top

1901

Einthoven invents a new galvanometer for producing electrocardiograms using a fine quartz string coated in silver based on ideas by Deprez and d'Arsonval (who used a wire coil). His "string galvanometer" weighs 600 pounds. Einthoven acknowledged the similar system by Ader but later (1909) calculated that his galvanometer was in fact many thousands of times more sensitive. *Einthoven W. Un nouveau galvanometre. Arch Neerl Sc Ex Nat 1901;6:625-633*

1902

Einthoven publishes the first electrocardiogram recorded on a string galvanometer. *Einthoven W. Galvanometrische registratie van het menschilijk electrocardiogram. In: Herinneringsbundel Professor S. S. Rosenstein. Leiden: Eduard Ijdo, 1902:101-107*

1903

Einthoven discusses commercial production of a string galvanometer with Max Edelmann of Munich and Horace Darwin of Cambridge Scientific Instruments Company of London.

1905

Einthoven starts transmitting electrocardiograms from the hospital to his laboratory 1.5 km away via telephone cables. On March 22nd the first 'telecardiogram' is recorded from a healthy and vigorous man and the tall R waves are attributed to his cycling from laboratory to hospital for the recording.

1905

John Hay of Liverpool, publishes pressure recordings from a 65 year old man showing heart block in which AV conduction did not seem to be impaired since the a-c intervals on the jugular venous waves was unchanged in the conducted beats. This is the first demonstration of what we now call Mobitz type II AV block. *Hay J. Bradycardia and cardiac arrhythmias produced by depression of certain functions of the heart. Lancet 1906;1:138-143.*

1906

Einthoven publishes the first organised presentation of normal and abnormal electrocardiograms recorded with a string galvanometer. Left and right ventricular hypertrophy, left and right atrial hypertrophy, the U wave (for the first time), notching of the QRS, ventricular premature beats, ventricular bigeminy, atrial flutter and complete heart block are all described. *Einthoven W. Le telecardiogramme. Arch Int de Physiol 1906;4:132-164 (translated into English. Am Heart J 1957;53:602-615)*

1906

Cremer records the first oesophageal electrocardiogram which he achieved with the help of a professional sword swallower. Oesophageal electrocardiography later developed in the 1970s to help differentiate atrial arrhythmias. He also records the first fetal electrocardiogram from the abdominal surface of a pregnant woman. *Cremer. Ueber die direkte Ableitung der Aktionströme des menslichen Herzens vom Oesophagus und über*

das Elektrokardiogramm des Fötus. Munch. Med. Wochenschr. 1906;53:811

1907

Arthur Cushny, professor of pharmacology at University College London, publishes the first case report of atrial fibrillation. His patient was 3 days post-op following surgery on an "ovarian fibroid" when she developed a "very irregular" pulse at a rate of 120 - 160 bpm. Her pulse was recorded with a "Jacques sphygmochronograph" which shows the radial pulse pressure against time - much like the arterial line blood pressure recordings used in Intensive Care today. *Cushny AR, Edmunds CW. Paroxysmal irregularity of the heart and auricular fibrillation. Am J Med Sci 1907;133:66-77.*

1908

Edward Schafer of the University of Edinburgh is the first to buy a string galvanometer for clinical use.

1909

Thomas Lewis of University College Hospital, London buys a string galvanometer and so does Alfred Cohn of Mt Sinae Hospital, New York. Thomas Lewis publishes a paper in the BMJ detailing his careful clinical and electrocardiographic observations of atrial fibrillation. At one point Lewis identified a fibrillating horse using the string galvanometer's electrocardigram recording. He then followed the horse to the slaughterhouse where he could visually confirm the fibrillating atrium. *Lewis T. Auricular fibrillation: a common clinical condition. BMJ 1909;42:1528.*

1909

Nicolai and Simmons report on the changes to the electrocardiogram during angina pectoris. *Nicolai DF, Simons A. (1909) Zur klinik des elektrokardiogramms. Med Kiln 5;160*

1910

Walter James, Columbia University and Horatio Williams, Cornell University Medical College, New York publish the first American review of electrocardiography. It describes ventricular hypertrophy, atrial and ventricular ectopics, atrial fibrillation and ventricular fibrillation. The recordings were sent from the wards to the electrocardiogram room by a system of cables. There is a great picture of a patient having an electrocardiogram recorded with the caption "The electrodes in use".*James WB, Williams HB. The electrocardiogram in clinical medicine. Am J Med Sci 1910;140:408-421, 644-669*

1911

Thomas Lewis publishes a classic textbook. *The mechanism of the heart beat. London: Shaw & Sons* and dedicates it to Willem Einthoven.

1912

Einthoven addresses the Chelsea Clinical Society in London and describes an equilateral triangle formed by his standard leads I, II and III later called 'Einthoven's triangle'. This is the first reference in an English article I have seen to the abbreviation 'EKG'.*Einthoven W. The different forms of the human electrocardiogram and their signification. Lancet 1912(1):853-861*

1918

Bousfield describes the spontaneous changes in the electrocardiogram during angina. *Bousfield G. Angina pectoris: changes in electrocardiogram during paroxysm. Lancet 1918;2:475*

1920

Hubert Mann of the Cardiographic Laboratory, Mount Sinai Hospital, describes the derivation of a 'monocardiogram' later to be called 'vectorcardiogram'. *Mann H. A method of analyzing the electrocardiogram. Arch Int Med 1920;25:283-294*

1920

Harold Pardee, New York, publishes the first electrocardiogram of an acute myocardial infarction in a human and describes the T wave as being tall and "starts from a point well up on the descent of the R wave". *Pardee HEB. An electrocardiographic sign of coronary artery obstruction. Arch Int Med 1920;26:244-257*

1924

Willem Einthoven wins the Nobel prize for inventing the electrocardiograph.

1924

Woldemar Mobitz publishes his classification of heart blocks (Mobitz type I and type II) based on the electrocardiogram and jugular venous pulse waveform findings in patients

with second degree heart block. *Mobitz W. Uber die unvollstandige Storung der Erregungsuberleitung zwischen Vorhof und Kammer des menschlichen Herzens. (Concerning partial block of conduction between the atria and ventricles of the human heart). Z Ges Exp Med 1924;41:180-237.*

1926

A doctor from the Crown Street Women's Hospital in Sydney, who wished to remain anonymous, resuscitates a new-born baby with an electrical device later called a 'pacemaker'. The doctor wanted to remain anoymous because of the controversy surrounding research that artificially extended human life.

1928

Ernstine and Levine report the use of vacuum-tubes to amplify the electrocardiogram instead of the mechanical amplification of the string galvanometer. *Ernstine AC, Levine SA. A comparison of records taken with the Einthoven string galvanomter and the amplifier-type electrocardiograph. Am Heart J 1928;4:725-731*

1928

Frank Sanborn's company (founded 1917 and acquired by Hewlett-Packard in 1961 and since 1999, Philips Medical Systems) converts their table model electrocardiogram machine into their first portable version weighing 50 pounds and powered by a 6-volt automobile battery.

1929

Sydney doctor Mark Lidwill, physician, and Edgar Booth, physicist, report the electrical resuscitation of the heart to a meeting in Sydney. Their portable device uses an electrode on the skin and a transthoracic catheter. Edgar Booth's design could deliver a variable voltage and rate and was employed to deliver 16 volts to the ventricles of a stillborn infant.

1930

Wolff, Parkinson and White report an electrocardiographic syndrome of short PR interval, wide QRS and paroxysmal tachycardias. *Wolff L, Parkinson J, White PD. Bundle branch block with short P-R interval in healthy young people prone to paroxysmal tachycardia. Am Heart J 1930;5:685*. Later, when other published case reports were examined for evidence of pre-excitation, examples of 'Wolff Parkinson White' syndrome were identified which had not been recognised as a clinical entity at the time. The earliest example was published by Hoffmann in 1909. *Von Knorre GH. The earliest published electrocardiogram showing ventricular preexcitation. Pacing Clin Electrophysiol. 2005 Mar;28(3):228-30*

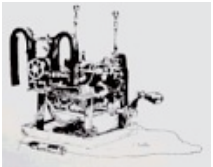
1930

Sanders first describes infarction of the right ventricle. *Sanders, A.O. Coronary thrombosis with complete heart block and relative ventricular tachycardia: a case report, American Heart Journal 1930;6:820-823.*

1931

Charles Wolferth and Francis Wood describe the use of exercise to provoke attacks of angina pectoris. They investigated the ECG changes in normal subjects and those with angina but dismissed the technique as too dangerous "to induce anginal attacks indiscriminately". *Wood FC, Wolferth CC, Livezey MM. Angina pectoris. Archives Internal Medicine 1931;47:339*

1931



first patented pacemaker

Dr Albert Hyman patents the first 'artificial cardiac pacemaker' which stimulates the heart by using a transthoracic needle. His aim was to produce a device that was small enough to fit in a doctor's bag and stimulate the right atrial area of the heart with a suitably insulated needle. His experiments were on animals. His original machine was powered by a crankshaft (it was later prototyped by a German company but was never successful). "By March 1, 1932 the artificial pacemaker had been used about 43 times, with a successful outcome in 14 cases." It was not until 1942 that a report of its successful short term use in Stokes-Adams attacks was presented. *Hyman AS. Resuscitation of the stopped heart by intracardial therapy. Arch Intern Med. 1932;50:283*

1932

Goldhammer and Scherf propose the use of the electrocardiogram after moderate exercise as an aid to the diagnosis of coronary insufficiency. *Goldhammer S, Scherf D. Elektrokardiographische untersuchungen bei kranken mit angina pectoris. Z Klin Med 1932;122:134*

1932

Charles Wolferth and Francis Wood describe the clinical use of chest leads. *Wolferth CC, Wood FC. The electrocardiographic diagnosis of coronary occlusion by the use of chest leads. Am J Med Sci 1932;183:30-35*

1934

By joining the wires from the right arm, left arm and left foot with 5000 Ohm resistors Frank Wilson defines an 'indifferent electrode' later called the 'Wilson Central Terminal'. The combined lead acts as an earth and is attached to the negative terminal of the ECG. An electrode attached to the positive terminal then becomes 'unipolar' and can be placed anywhere on the body. Wilson defines the unipolar limb leads VR, VL and VF where 'V' stands for voltage (the voltage seen at the site of the unipolar electrode). *Wilson NF, Johnston FE, Macleod AG, Barker PS. Electrocardiograms that represent the potential variations of a single electrode. Am Heart J. 1934;9:447-458.*

1935

McGinn and White describe the changes to the electrocardiogram during acute pulmonary embolism including the S1 Q3 T3 pattern. *McGinn S, White PD. Acute cor pulmonale resulting from pulmonary embolism: its clinical recognition. JAMA 1935;114:1473.*

1938

American Heart Association and the Cardiac Society of Great Britain define the standard positions, and wiring, of the chest leads V1 - V6. The 'V' stands for voltage. *Barnes AR, Pardee HEB, White PD. et al. Standardization of precordial leads. Am Heart J 1938;15:235-239*

1938

Tomaszewski notes changes to the electrocardiogram in a man who died of hypothermia. *Tomaszewski W. Changements electrocardiographiques observes chez un homme mort de froid. Arch Mal Coeur 1938;31:525.*

top

1939

Langendorf reports a case of atrial infarction discovered at autopsy which, in retrospect, could have been diagnosed by changes on the ECG. *Langendorf R. Elektrokardiogramm bei Vorhof-Infarkt. Acta Med Scand. 1939;100:136.*

1942

Emanuel Goldberger increases the voltage of Wilson's unipolar leads by 50% and creates the augmented limb leads aVR, aVL and aVF. When added to Einthoven's three limb leads and the six chest leads we arrive at the 12-lead electrocardiogram that is used today.

1942

Arthur Master, standardises the two step exercise test (now known as the Master two-step) for cardiac function. *Master AM, Friedman R, Dack S. The electrocardiogram after standard exercise as a functional test of the heart. Am Heart J. 1942;24:777*

1944

Young and Koenig report deviation of the P-R segment in a series of patients with atrial infarction. *Young EW, Koenig BS. Auricular infarction. Am Heart J. 1944;28:287.*

1947

Gouaux and Ashman describe an observation that helps differentiate aberrant conduction from ventricular tachycardia. The 'Ashman phenomenon' occurs when a stimulus falls during the relative or absolute refractory period of the ventricles and the aberrancy is more pronounced. In atrial fibrillation with aberrant conduction this is demonstrated when the broader complexes are seen terminating a relatively short cycle that follows a relatively long one. The QRS terminating the shorter cycle is conducted 'more aberrantly' because it falls in the refractory period. The aberrancy is usually of a RBBB

pattern. *Gouaux JL, Ashman R. Auricular fibrillation with aberration simulating ventricular paroxysmal tachycardia. Am Heart J 1947;34:366-73.*

1947

Claude Beck, a pioneering cardiovascular surgeon in Cleveland, successfully defibrillates a human heart during cardiac surgery. The patient is a 14 year old boy - 6 other patients had failed to respond to the defibrillator. His prototype defibrillator followed experiments on defibrillation in animals performed by Carl J. Wiggers, Professor of Physiology at the Western Reserve University. *Beck CS, Pritchard WH, Feil SA: Ventricular fibrillation of long duration abolished by electric shock. JAMA 1947; 135: 985-989.*
Wiggers CJ, Wegria R. Ventricular fibrillation due to single localized induction in condenser shock supplied during the vulnerable phase of ventricular systole. Am J Physiol 1939;128:500

1948

Rune Elmqvist, Swedish engineer who had trained as a doctor but never practiced, introduces the first ink jet printer for the transcription of analog physiological signals. He demonstrates its use in the recording of ECGs at the First International Congress of Cardiology in Paris in 1950. The machine (the mingograph) was developed by him at the company that later became Siemens. *(Luderitz, 2002)*

1949


modern 'Holter' Monitor

Montana physician Norman Jeff Holter develops a 75 pound backpack that can record the ECG of the wearer and transmit the signal. His system, the Holter Monitor, is later greatly reduced in size, combined with tape / digital recording and used to record ambulatory ECGs. *Holter NJ, Generelli JA. Remote recording of physiologic data by radio. Rocky Mountain Med J. 1949;747-751.*

1949

Sokolow and Lyon propose diagnostic criteria for left ventricular hypertrophy i.e. LVH is present if the sum of the size of the S wave in V1 plus the R wave in V6 exceeds 35 mm. *Sokolow M, Lyon TP. The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial and limb leads. Am Heart J 1949;37:161*

1950

John Hopps, a Canadian electrical engineer and researcher for the National Research Council, together with two physicians (Wilfred Bigelow, MD of the University of Toronto and his trainee, John C. Callaghan, MD) show that a coordinated heart muscle contraction can be stimulated by an electrical impulse delivered to the sino-atrial node. The apparatus, the first cardiac pacemaker, measures 30cm, runs on vacuum tubes and is powered by household 60Hz electrical current. *Bigelow WG, Callaghan JC, Hopps JA. "General hypothermia for experimental intracardiac surgery." Ann Surg 1950; 1132: 531-539.*

1953

Osborn, whilst experimenting with hypothermic dogs, describes the prominent J (junctional) wave which has often been known as the "Osborn wave". He found the dogs were more likely to survive if they had an infusion of bicarbonate and supposed the J wave was due to an injury current caused by acidosis. *Osborn JJ. Experimental hypothermia: respiratory and blood pH changes in relation to cardiac function. Am J Physiol 1953;175:389.*

1955

Richard Langendorf publishes the "rule of bigeminy" whereby ventricular bigeminy tends to perpetuate itself. *Langendorf R, Pick A, Winternitz M. Mechanisms of intermittent ventricular bigeminy. I. Appearence of ectopic beats dependent upon the length of the ventricular cycle, the "rule of bigeminy." circulation 1955;11:442.*

1956

Paul Zoll, a cardiologist, uses a more powerful defibrillator and performs closed-chest defibrillation in a human. *Zoll PM, Linenthal AJ, Gibson P: Termination of Ventricular Fibrillation in Man by Externally Applied Countershock . NEJM 1956; 254: 727-729*

1957

long QT syndrome

Anton Jervell and Fred Lange-Nielsen of Oslo describe an autosomal recessive syndrome of long-QT interval, deafness and sudden death later known as the Jervell-Lange-Nielsen syndrome. *Jervell A, Lange-Nielsen F. Congenital deaf mutism, functional heart disease with prolongation of the QT interval and sudden death. Am Heart J 1957;54:59.*

1958

Professor Ake Senning, of Sweden, places the first implantable cardiac pacemaker designed by Rune Elmqvist into a 43-year-old patient with complete heart block and syncope (Arne Larsson).

1959

Myron Prinzmetal describes a variant form of angina in which the ST segment is elevated rather than depressed. *Prinzmetal M, Kennamer R, Merliss R, Wada T, Bor N. Angina pectoris. I. A variant form of angina pectoris. Am J Med 1959;27:374.*

1960

Smirk and Palmer highlight the risk of sudden death from ventricular fibrillation particularly when ventricular premature beats occur at the same time as the T wave. The 'R on T' phenomenon. *Smirk FH, Palmer DG. A myocardial syndrome, with particular reference to the occurrence of sudden death and of premature systoles interrupting antecedent T waves. Am J Cardiol 1960;6:620.*

1963

Italian paediatrician C. Romano and Irish paediatrician O. Conor Ward (the following year) independently report an autosomal dominant syndrome of long-QT interval later known as the Romano-Ward syndrome. *Romano C, Gemme G, Pongiglione R. Aritmie cardiache rare dell'eta pediatrica. Clin Pediatr. 1963;45:656-83.*
Ward OC. New familial cardiac syndrome in children. J Irish Med Assoc. 1964;54:103-6

1963


Excercise ECG

Robert Bruce and colleages describe their multistage treadmill exercise test later known as the Bruce Protocol. "You would never buy a used car without taking it out for a drive and seeing how the engine performed while it was running," Bruce says, "and the same is true for evaluating the function of the heart." *Bruce RA, Blackman JR, Jones JW, Srait G. Exercise testing in adult normal subjects and cardiac patients. Pediatrics 1963;32:742*
Bruce RA, McDonough JR. Stress testing in screening for cardiovascular disease. Bull. N.Y. Acad Med. 1969;45:1288

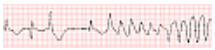
1963

Baule and McFee are the first to detect the magnetocardiogram which is the electromagnetic field produced by the electrical activity of the heart. It is a method that can detect the ECG without the use of skin electrodes. Although potentially a useful technique it has never gained clinical acceptance, partly because of its greater expense. *Baule GM, McFee R. Detection of the magnetic field of the heart. Am Heart J. 1963;66:95-96.*

1966

Mason and Likar modify the 12-lead ECG system for use during exercise testing. The right arm electrode is placed at a point in the infraclavicular fossa medial to the border of the deltoid muscle, 2 cm below the lower border of the clavicle. The left arm electrode is placed similarly on the left side. The left leg electrode is placed at the left iliac crest. Although this system reduces the variability in the ECG recording during exercise it is not exactly equivalent to the standard lead positions. The Mason-Likar lead system tends to distort the ECG with a rightward QRS axis shift, a reduction in R wave amplitude in lead I and aVL, and a significant increase in R wave amplitude in leads II, III and aVF. *Eur Heart J. 1987 Jul;8(7):725-33*

1966



Torsade de pointes

François Dessertenne of Paris publishes the first case of 'Torsade de pointes' Ventricular Tachycardia. *Dessertenne F. La tachycardie ventriculaire a deux foyers opposes variables. Arch des Mal du Coeur 1966; 59:263*

1968

Journal of Electrocardiography, the Official Journal of the International Society for Computerized Electrocardiology and the International Society of Electrocardiology, is founded by Zao and Lepeschkin.

1968

Henry Marriott introduces the Modified Chest Lead 1 (MCL1) for monitoring patients in Coronary Care.

1969

Rosenbaum reviews the classification of ventricular premature beats and adds a benign form that arises from the right ventricle and is not associated with heart disease. This becomes known as the 'Rosenbaum ventricular extrasystole'. *Rosenbaum MB. Classification of ventricular extrasystoles according to form. J Electrocardiol 1969;2:289.*

1974

Jay Cohn, of University of Minnesota Medical School, describes the 'syndrome of right ventricular dysfunction in the setting of acute inferior wall myocardial infarction'. *Cohn JN, Guiha NH, Broder MI. Right ventricular infarction. Am J Cardiol 1974:33:209-214*

1974

Gozensky and Thorne introduce the term 'Rabbit ears' to electrocardiography. Rabbit ears describe the appearence of the QRS complex in lead V1 with an rSR' pattern (good rabbit) being typical of Right Bundle Branch Block and an RSr' (bad rabbit) suggesting a ventricular origin i.e. ventricular ectopy / tachycardia. *Gozensky C, Thorne D. Rabbit ears: an aid in distinguishing ventricular ectopy from aberration. Heart Lung 1974;3:634.*

1976

Erhardt and colleagues describe the use of a right-sided precordial lead in the diagnosis of right ventricular infarction which had previously been thought to be electrocardiographically silent. *Erhardt LR, Sjogrn A, Wahlberg I. Single right-sided precordial lead in the diagnosis of right ventricular involvement in inferior myocardial infarction. Am Heart J 1976;91:571-6*

1988

Professor John Pope Boineau of Washington University School of Medicine publishes a 30-year percpective on the modern history of electrocardiography. *Boineau JP. Electrocardiology: A 30-year Perspective. Ah Serendipity, My Fulsome Friend. Journal of Electrocardiology 21. Suppl (1988): S1-9*

1992

Brugada syndrome

Pedro Brugada and Josep brugada of Barcelona publish a series of 8 cases of sudden death, Right Bundle Branch Block pattern and ST elevation in V1 - V3 in apparently healthy individuals. This 'Brugada Syndrome' may account for 4-12% of unexpected sudden deaths and is the commonest cause of sudden cardiac death in individuals aged under 50 years in South Asia. The technology of the electrocardiogam, which is over 100 years old, can still be used to discover new clinical entities in cardiology. *Brugada P, Brugada J. Right Bundle Branch Block, Persistent ST Segment Elevation and Sudden Cardiac Death: A Distinct Clinical and Electrocardiographic Syndrome. J Am Coll Cardiol 1992;20:1391-6*

1992

Cohen and He describe a new non-invasive approach to accurately map cardiac electrical activity by using the surface Laplacian map of the body surface electrical potentials. *He B, Cohen RJ. Body surface Laplacian ECG mapping. IEEE Trans Biomed Eng 1992;39(11):1179-91*

1993

Mac 5000,
15-lead ECG

Robert Zalenski, Professor of Emergency Medicine, Wayne State University Detroit, and colleagues publish an influential article on the clinical use of the 15-lead ECG which routinely uses V4R, V8 and V9 in the diagnosis of acute coronary syndromes. Like the addition of the 6 standardised unipolar chest leads in 1938 these additional leads increase the sensitivity of the electrocardiogram in detecting myocardial infarction. *Zalenski RJ, Cook D, Rydman R. Assessing the diagnostic value of an ECG containing leads V4R, V8, and V9: The 15-lead ECG. Ann Emerg Med 1993;22:786-793*

1999

Researchers from Texas show that 12-lead ECGs transmitted via wireless technology to hand-held computers is feasible and can be interpreted reliably by cardiologists. *Pettis KS, Savona MR, Leibrandt PN et al. Evaluation of the efficacy of hand-held computer screens for cardiologists' interpretations of 12-lead electrocardiograms. Am Heart J. 1999 Oct;138(4 Pt 1):765-70*

2000

Physicians from the Mayo Clinic describe a new hereditary form of Short QT syndrome associated with syncope and sudden death that they discovered in 1999. Several genes have since been implicated. *Gussak I, Brugada P, Brugada J, et al. Idiopathic short QT interval: a new clinical syndrome? Cardiology. 2000;94(2):99-102*

2005

Danish cardiologists report the successful reduction in the time between onset of chest pain and primary angioplasty when the ECG of patients is transmitted wirelessly from ambulance to the cardiologist's handheld PDA (Personal Digital Assistant). The clinician can make an immediate decision to redirect patients to the catheter lab saving time in transfers between hospital departments. *Clemmensen P, Sejersten M, Sillesen M et al. Diversion of ST-elevation myocardial infarction patients for primary angioplasty based on wireless prehospital 12-lead electrocardiographic transmission directly to the cardiologist's handheld computer: a progress report. J Electrocardiol. 2005 Oct;38(4 Suppl):194-8*

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Comments, corrections or additions are very welcome.

This page was first written on 4th December 1996, last updated 3rd January 2006 and the links were working when I last tried them. From here you can go back to the *ECG* library contents or email me, Dean Jenkins.