Development of Medical Technology

The Example of Neurology

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The brain has remained an enigma through millenia despite the fact that the vast progress in medical technology has helped to visualies it and for its functions to be studied directly and indirectly. This article traces the impact of medical technology on our current understanding of the brain and its role in the developments in neurology. It points out that while some innovations in different branches such as physics, electronics, etc definitely aided the physicians' understanding, often tools which have evolved have ended up being overused. Moreover, even its necessary use has come to be confined to the class which can afford to pay the fancy prices that are charged. Medical technology is thus neither value neutral in its evolution nor in its use.

THE explosion of medical technology in the last century, especially the past 25 years has irreversibly changed the face of medical practice all over the world. This phenomena, greatly accelerated by the advent of the transistor and miniaturised electrical gadgets was rooted in the Cartesian school with the question of mind and soul separated from the body, dealing with the latter as a machine to be understood and treated as a sum of its parts. If its philosophical origins are found in Descartes its ability to discover, probe, explore, remove, and sometimes cure illness is almost wholly due to the enormous advances in human understanding and knowledge about the nature of the electromagnetic spectrum.

Medical technology is no more value neutral than any other technology. It arose in the dynamic expanding world of an aggressive, confident European mercantilism. Today it is still only available at a price and with priorities set by the successors of those merchants. It has benefited from the European Renaissance, the scientific revolutions of the 17th and 18th centuries and the atomic age. This article will review at some length the history of the development of medical technology emphasising its philosophical origins. It will comment on the impact of modern medical technology on diagnosis and treatment, and discuss the advantages as well as problems accruing from its ascendency. I shall use the example of neurology for two reasons; first being a neurologist I felt competent to comment critically on the development and impact of technology on neurologic practice; secondly, the nervous system has presented medical technology with its geatest challenge as this organ system has been virtually inacessible to human manipulation until a few decades ago. Also the correlation between structure and function of the brain is rudimentary compared to other organs like the heart, liver or kidney.

While a review of development of technology in many important aspects of the neurosciences has been attempted some topics like neurophysiology and neuroradiology have been covered extensively, others like neurosurgery rather cursorily. This uneveness, partly due to personal interest in the early history of the discovery and investigation of electricity and its role in neurology, reflects the difficulty of reviewing such a vast topic except at inordinate length.

Development of Neuroscience

The function of the brain, its effect on consciousness and limb movements must have been evident to hunters even in the Paleolithic age. The first recorded description of the brain and its coverings are found in Egyptian papyri written around 500 BC (McHenry 1969, p e). In ancient Greece, Pythagoras (582 BC-500 BC) taught that the brain was concerned with reasoning. His discovery of mathematical principles underlying music and the three sides of a right angled triangle for which he is renowned represent the first examples of the human mind's ability to give theoretical concepts a reality of their own (Bergland, 1986, p 10). A student of Pythagoras, Alcmaeon performed one of the earliest recorded dissections of the human body (sixth century BC) and described the optic nerves. Further progress about knowledge of brain structure and function took a tortuous course. Some of the prominent authorities on brain function like Aristotle (384-322 BC) and later Galen (130-200 AD) seem not to have dissected a human brain (Spillane, 1981). Their ideas of the brain as a cooling organ (Aristotle) or as the transformer of the quintessence of life or pneuma into an animal spirit which in turn was carried through the tubular nerves to the body (Galen) may have arisen because of their ignorance of its structure. Dissecting the human body was frowned on at various points in history in Greece (Spillane, 1981, p 7), in India (Basham 1967), and later by the Catholic Church (Bergland, 1986 p 54). However many observers were aware that the brain was the seat of intelligence, dreams and thought. Hippocrates of Cos (400-370 BC) wrote:

> Men ought to know that from the brain, and from the brain only, arise our pleasures, joys, laughter and jests, as well as sorrows, pains, griefs, and tears. Through it . . . we . . . think, see, hear, and distinguish the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant. (Bergland, 1986, p 28).

Erasistratus of Chios (circa 310 to 250 BC) was struck by the greater number of convolutions in the human brain compared to animals. He related this difference of the superior intelligence of humans. But for nearly two centuries the heart was considered the organ of rational thought in Europe and curiously also in India (Basham 1967; Winter 1975). In Europe, Aristotle's views reigned supreme: pneuma from heaven came to the heart via the trachea and lungs. The brain was a cooling gland that regulated the temperature of the pneuma brought to it by the arteries.

In addition to mistaken ideas about brain function, knowledge of brain structure was limited by the peculiar biologic properties of the organ. The brain is extremely soft and friable with its components easily distorted or destroyed unless the organ is frozen or hardened by the addition of a fixative like alcohol or formalin. (EScourolle and Poirier, 1973). Only in the eighteenth century was the technique of fixation of brain tissue by alcohol developed which allowed adequate dissection of brain tissue (Spillane, 1981, p 18). Thus neuroanatomy illustrates a feature common to all aspects of neuroscience and even science in general: the observation of Thomas Kuhn regarding the dependency of creative thought on technological advancs (Kuhn, 1962). Prior to the fixation of the brain by additives one can only speculate on the reactions of observers to brain tissue "oozing like porridge from the skull in a battlefield or even when delivered promptly with the severed head from an executioner". Covered by membranes, full of convolutions and cavities it must have appeared " a most mysterious object of exploration" (Spillane, 1981, p 18).

Along with countless other branches of knowledge, medical science grew by leaps and bounds with the coming of the Renaissance (1440-1540 AD). Printing allowed technical advances to be disseimated rapidly and effectively. Andreas Vesalius' (1515-1564), *De Humani Corporis Fabrica (The Fabric of the Body)*— the most complete and accurate description of the human body was published in the same year (1543 AD) as Nicolas Copernicus' *De Revolutionibus Orbium Coelestium (on the Revolution of the Celestial Orbs).* Earlier Leonardo da Vinci (1452-1519 AD) had drawn an outline of the ventricles of the brain. He had first inserted a needle in the ventricles, filled them with melted wax and used the casting techniques of bronze sculptors to delineate the shape of the cavities of the brain. Vesalius' anatomical studies led him to question Galenic physiology though he refrained from criticising Galen. Later, in 1629, William Harvey, a student of the School of Medicine at Padua founded by Vesalius, discovered the pump-like function of the heart, described the circulation of blood and helped overthrow Galenic concepts of the pneuma and other mysterious spirits. In the opening year of the seventeenth century Giordano Bruno (1548-1600) was burnt to death for his vision of an infinite universe. When the century ended science had come of age, Galileo (1564-1642) had displaced the earth to its modest position in the solar system, Aristole had been dethroned, his dynamics discarded.

The phenomena of magnetism was described at length by William Gilbert (1544-1603) in *De Magnete* published in 1600. Gilbert was a court physician to Elizabeth I. Magnets, he showed, possessed the virtue of attraction. Force could be exerted by material bodies which were not in contact with one another. Gilbert exemplified the experimenter scientist who Francies Bacon (1561-1626) deemed necessary for the advancement of learning. Speculation was to be replaced by observation, vitalism by mechanisms. Magic lost its hold as an explanation for natural phenomena in the seventeenth century as science unravelled some of these mysteries. It was the era of mercantile capitalism, of the formation of the Bank of Amsterdam in 1609, the Bank of England 85 years later, of the Dutch and British East India Company, of the horrific Middle Passage which for over three centuries carried some 13 million African slaves to the New World. With the development of trade over long sea routes to the Americas, India, China and Indonesia came the imperatives of more accurate navigation charts, skilled shipbuilding, of better implements of war, of a union between merchant and scientist, of education no longer under the aegis of the church but of new colleges which quickly became centres of science. Gresham College, in London, founded in 1579 with monies provided by the will of Thomas Gresham, a financial agent to the Crown and founder of the Royal Exchange, was where the Royal Society first met (Bernal, 1971, p 459). The scientific revolution had begun, everywhere old dogmas crumbled. Descartes' (1596-1650) *Discourse on Method* (1637) discussed a new system which "exhibited that individual arrogance which was one of the great liberating features of the Renaissance, the same arrogance that expressed itself in the great navigators, in the conquistadores, in all the defiances of authority that characterised the end of the feudal period and the beginning of one of individual enterprise" (Bernal, 1971, p 443). "I think therefore I am"—mind became more certain than matter, Aristotle's three souls were dispensed with, only one, the rational soul existed and that too only in the human. It resided in the pineal gland. Descartes' philosophy completed the dualism of mind and matter. Later Cartesians dropped the emphasis on the pineal gland and sought to explain living organisms by the laws of physics. "If all movement of matter were determined by physical laws, mental events must be equally determinate" (Russell, 1945). Even the soul was composed of atoms, thought came from the movement of atoms. Descartes also commented on the conditioned responses that would be described by Ivan Pavlov (1849-1946) over 200 years later. "If you whip a dog five or six times to the sound of a violin he would begin to howl and run away as soon as he heard that music again" (Brazier, 1984, p 24). Descartes recognised the need to explain how the contraction of one muscle must be accompanied by the relaxation of its opponent. His legacy was the mechanically operating model of the human body, a model very influential in medical science even today.

Antoni van Leeuwenhoek (1632-1732 AD) opened the world of small things with his microscope just as Galileo had uncovered some secrets of the stars with the telescope. His study on nerves, hampered by lack of hardening or staining techniques, left him a convinced Galenist—nerves were little canals which carry humor. So the first use of the microscope did not clarify nerve structure. Indeed the issue remained unresolved even a century later (Brazier, 1984, p 37).

Arguments continued about the release of spirits down the nerves, spirits that led to muscle contraction. Outstanding physicians like William Croone (1633-1684) and Thomas Willis (1621-1675) did not "confront the problem defined by Nicolaus Steno (1635-1686); The (muscular) heart continued to beat when taken out of the body, cut off from its nerves and blood supply (and from the soul)" (Brazier, 1984, p 62). Giovanni Borelli (1608-1679) found that when an animal was submerged in water, and its muscles were slit open no bubbles appeared in spite of vigorous muscle contraction by the struggling animal. Therefore he felt, muscle contraction could not be due to gaseous spirits. As the Seventeenth Century drew to a close science had become organised in the manner suggested by Bacon. Powerful scientific societies replaced groups meeting in private homes, scientific journals were started and publishing houses were established that brought out only science related books.

The eighteenth century established science as an indispensable feature of what was to become the Industrial Revolution. Capitalism was transformed from a "phase dominated by merchants and small manufacturers to one dominated by financiers and heavy industry" (Bernal, 1971, p 503). The age of European colonisation was about to begin. The history of America, Africa and Asia would now reflect indelibly the consequences of those ships that had come to their shores over 200 years ago. For Europe would discover from this century onwards the principles governing essential properties of matter like electro-magnetism, it would harness the power of steam and achieve its dominance of other continents aided by the knowledge of these powerful forces in nature. In addition, the seventeenth century had seen the first revolution in Europe; the Civil War and the execution of Charles I of England. These were only the most dramatic manifestations of a world in ferment. In the ideas of the Levellers and the Diggers the seed of a society equal and free from exploitation was eloquently expressed by Gerard Winstanley:

> Freedom is the man that will turn the world upside down, therefore no wonder he hath enemies... the earth should be made a common treasury of livelihood to whole mankind, without respect of persons" (Hill, 1975).

These revolutions would recur in America and France in the eighteenth century, the questions raised and problems faced by them continue to confront us today, from general societal issues to the availability, relevance and effectiveness of modern medical technology.

The intellectual advances of the eighteenth century made that period famous as the Age of Enlighenment. Theories about brain function changed and the nervous system could be explained without the existence of a soul. D'Alembert (11717-1783) one of the co-editors of the Encyclopedia shared John Locke's (1632-1704) view of the nervous system; all knowledge was derived from sense experience, hence the sciences should be based on actual perception. The relationship of the brain to the spinal cord was still a puzzle. The function of the nerve roots that were attached to the cords was unkown. Jacques-Benigne Winslow (1669-1760) introduced the concept of a 'sympathetic' system made of 'small brains' or ganglia that were centers for communication between the nerves and various organs. Jiri Prochaska (1749 1820) proposed a purpose for unconsciously initiated movements—preservation of the individual. Such a purpose made the teleological significance previously ascribed to these movements irrelevant.

Discovering Electricity

Many experiments began investigating the new and mysterious phenomena of electricity. Perhaps it was related to nerve conduction. By the early 18th century it was already known that the human body could be charged electrically if it was insulated from the ground. At first it was thought that a layer of air had to be present between the subject and the ground. The characteristics of conductors and non-conductors were only beginning to be understood (Brazier, 1984, p 176). More knowledge about the nature of electricity was necessary before its action on an animal's body could be studied. Also if animal tissue itself produced electricity, the current produced would be very small and need exquisitely sensitive instruments to detect it. These gadgets designed crudely at first by Alessandro Volta (1745-1827) would be modified later by Waller (1887) and Einthoven (1903), (Cooper, 1986), Adrian (1929) and Berger (1929), (Licht, 1971) to herald the use of electrocardiography, (EKG), electromyography (EMG) and electroencephalography (EEG) respectively.

These developments came slowly. Initially a technique for sorting an electric charge had to be discovered. It happened accidentally to Petrus van Musschenbroek (1962-1761) at the University of Leyden. Musschenbroek had been trying to conserve electricity in a conductor and delay the loss of its charge to the air. He thought electricity was a fluid and tried at first to fill an empty glass jar, then one filled with water with this fascinating effluvium. He charged the water with electricity with a wire leading from an electrostatic machine, but to no avail. The electricity dissipated once the electrostatic machine stopped running. One day, his assistant, Andreas Cuneas picked up the jar containing charged water in one hand and at the same time reached out to remove the wire from the electric machine with the other hand. On touching the wire he got an electric shock—his hand had formed one 'plate', the charged water another, and the glass jar the intervening dielectric. A condenser was born (Brazier, 1984, p 180). The Leyden jar as it was called later contained no water, instead it was coated on its inner and outer surface by a tin foil. The jar became a source of entertainment. The Abbe Nollet (1700-1770) used it for a spectacular demonstration of electrical power. He lined up a human chain of 180 soldiers at Versailles for the benefit of the King of France. The entire line of soldiers leapt into the air when the men at each end touched the poles of a Leyden jar. The Abbe repeated this experiment for the Monks of Chartreuse this time using a human chain 3 kilometers long! (Skilling, 1948). The Leyden jar was used by all kinds of 'medical' men to treat a variety of nervous ailments. John Wesley, the Methodist-reformer who wrote a pamphlet on the subject said that he was "firmly persuaded there is no remedy in nature for nervous disorders of every kind, comparable to the proper and consistent use of the electrical machine" (Schiller, 1982, p 4). Electrotherapy persists today in many forms as ECT or electroconvulsive therapy for some psychotic disorders, as trancutaneous and spinal cord stimulation for relief of pain and for relaxing spastic muscle and the EEG is used in biofeedback therapy. The scientific basis of these therapies are unclear, their usage sometimes as in the case of ECT, being based on the erroneous observation that since epilepsy and schizophrenia never occurred in the same patient, convulsions might result in elimination of the symptoms of that psychosis (Solomon and Patch, 1974).

Meanwhile, in the eighteenth century research began on the torpedo fish whose power to shock was known to fishermen and whose ability to cause pain was thought by Ibn Rushid (Averroes) (1126-1198) to be similar to the effect of a lodestone. In 1972 Abbe Lazzaro Spallanzani studied the anatomy of the torpedo in terms of its ability to shock. He was convinced the shock was electrical, a fact which Luigi Galvani (1737-1798) later confirmed. Galvani cut the nerve supply to one side of the electric organ of the torpedo and found that this side failed to discharge. On svering the head of the fish the discharge was destroyed even though the heart was intact. The mechanism of electrical discharge thus was independent of the circulation. Electric fish aroused sustained scientific interest for here was an animal that produced electricity. But was animal electricity similar to the one physicists studied? Was it triggered by the brain? Michael Faraday (1791-1867) gave an ambivalent answer to the first question, he was not convinced that nervous fluid is only electricity. The second question remained unanswered for a century because there were no instruments to detect the passage of small currents.

Galvani's *Commentary on the Effects of Electricity on Muscular Motion* was published in 1791. Although Galvani was only one of several individuals like Caldini and Fontana who had directly stimulated nerves with electricity, and his discovery came about accidentally like the Leyden Jar, his commentary enabled the science of electricity and physiology to come together and 'each took a great leap forward' (Spillane, 1981, p 147). On 20th September 1786 Galvani had dissected out a nerve-muscle preparation of a frog and placed it on a table on which an electrically charged frictional machine lay at some distance. In Galvani's words "when by chance one of those who were assisting me gently touched the point of a scalpel" to the exposed nerves of the frog "immediately all the muscles of the limbs seemed to be so contracted that they appeared to have fallen into violent tonic convulsions. But another of the assistants, who was on hand when I did electrical experiments, seemed to observe that the same thing occurred whenever a spark was discharged from the conductor of the machine" (Spillane, 1981, p 146). An electrical charge had been transferred to the insulated nerve-muscle preparation by induction from the machine nearby. Galvani then studied 'atmospheric' electricity lightning in a thunderstrom to excite frog legs. The lightning conductor was invented by Benjamin Franklin in 1753. Interestingly Franklin's rebel tendencies had irritated George III who insisted that the lightning conductors at his palace should have round knobs instead of the sharp points Franklin had suggested! (Bernal, 1971, p 602). Galvani attached one end of a frog's leg to an iron wire antenna under the roof of his house and to the other end a wire that led to the water of a nearby well. When lightning flashed in the sky the frog muscles contracted. Later he found that frog muscles contracted when hung on iron gratings by bronze hooks that penetrated the spinal cord, irrespective of atmospheric conditions (O'Leary and Goldring, 1976). Though Galvani was aware that the muscle contraction arose because of contact between dissimilar metals he saw it as proof of animal electricity. In 1975 Volta showed that the frog leg merely served as an electroscope. Volta produced electricity without any animal at all, he simply put two plates of metal one of copper, the other zinc with liquid between them and invented the first electrical battery.

Galvani and Volta differed in their attitudes to Napolean who was then the first consul of France. Napolean conquered the area of Lombardy coverting it into the Cisalpine Republic with himself as its president. Galvani refused to take the oath of allegiance to the Republic and lost his position at the University of Bologna, while Volta supported Napolean and was honored with medals, and a title (Brazier, 1984, p 215; Skilling, 1948, p 44).

The French Revolution resulted in the formation of the Ecole de Medicine and the Ecole Polytechnique which became models for scientific teaching and research. Only the most eminent scientists were employed as salaried professors. The gentlemen amateur and the patronised client scientists of the past were thus replaced. In the Napoleanic period the first counsul turned emperor took a personal interest in science. He saw the utility of science for industry and war.

With the nineteenth century came revolutionary advances in the knowledge of electricity. In 1820 Oersted (1757-1851) accidentially found that electric current deflected a magnetic compass needle at a right angle to the current. Ampere (1775-1836), Gauss (1777-1855) and Ohm (1787-1854) studied the magnetic fields produced by currents. Faraday showed that a magnet moved near an electric conductor produced a current, a discovery of enormous practical significance because electricity could be produced by mechanical action and used to operate machines. The science of electromagnetism was born. It is striking that the Leyden Jar, Galvani's animal electricity and Oersted's observation of magnetic deflection were accidental discoveries. Thomas Kuhn has commented that the difficulty in science is not in making a discovery, but to know one has made it (Kuhn, 1962). This is particularly true when existing theory cannot explain or predict phenomena. The people who are likely to succeed are generally "sufficiently broadminded, and sufficiently critical or ignorant of orthodox theories to make the discovery" (Bernal, 1971, p 608). The belief that electricity is the 'stuff of thought' began with Benjamin Franklin who wondered whether it was the unseen force that extended through our universe. The study of brain electricity was pursued from Galvani onwards. It has helped to understand some aspects of brain function but has been sadly ineffective in solving the problems of brain disease (Bergland, 1986).

The first half of the nineteenth century saw an increase in knowledge about the internal structure of the brain. Johann Reil (1759-1818) studied the lobes of the cerebellum, and by soaking the brain in specific salt solutions was able to separate bundles of nerve fibers that carry specific messages from the body to the brain and vice versa. Luigi Roland (1773-1831) described the cerebral convulutions, Charles Bell (1774-1842) demonstrated that the anterior nerve roots of the spinal cord carried messages that led to movements of muscles, while Francois Magendie (1783-1855) showed that the posterior nerve carried sensation of pain, pressure, heat and cold. The laminated structure of the brain with six layers of nerve cells was recognised by Robert Remak (1815-1865), who besides showing continuity of the axons (nerve fibers) with neurons or nerve cells of the spinal cord, also noted that some nerve fibers were not white (myelinated) but grey (unmyelinated). Camrillo Golgi (1843-1928) developed a silver chromate method of staining neurons which gave the first pictures of the architecture of these cells. Silver salts for reasons yet unknown bind only to the surface of nerves. Theodore Schwann (1810-1882) who described the myelin sheath that surrounds most nerve fibers was much influenced by Rudolph Virchow's (1821-1902) cellular basis of disease. Virchow wrote "every animal is a sum of vital units, each of which posseses the full characteristics of life. The character and unity of life cannot be found in one definite point of the higher organisation for example, in the brain of man, but only in the definite, constantly recurring disposition shown individually by each single element" (Bergland, 1986, p 64). Schwann while accepting Virchow's idea that organisms consisted of individual cells which functioned symbiotically argued that brain cells had to know what their neighbours were up to. He conceived of the brain as a gaint spider web with every neuron *directly* connected to every other neuron. His microscopic methods did not allow him to see the synapses (Greek: to clasp) later described by Ramon y Cajal (1852-1934). Cajal, using Golgi's stains, found that every nerve fibre was seperate, ending in tiny bulbs (boutons terminaux) rather like little hands that were *contiguous* with similar bulbs from other axons but lacking any *continuity* between them. But Cajal's discoveries did not lessen the belief in the notion of the brain as a giant-circuit of nerve cells.

More attention was placed on the electricity that flows along the surface of cells than in the activity that went on inside the cell. The synapses became circuit-breakers. Charles Sherrington (1856-1952) who had learnt Virchow's cellular theory in Berlin, continued the work begun by Stephen Hales (1677-1761) 200 years before. Hales had found that the hind legs of a decapitated frog would move if the cut end of the spinal cord was compressed—a type of reflex action. Incidentally Hales made the first direct measurement of arterial blood pressure. Marie Flourens (1794-1867) correctly placed the vital centers of breathing in the medulla, and noted that the cerebral hemispheres received and controlled sensation while the cerebellum co-ordinated body movements. Marshall Hall (1760-1857) showed that reflex action consisted of three parts: a nerve leading from the irritated part to the spinal cord, the cord itself and a nerve going from the cord to the involved body part. Sherrington, known as the father of modern neurophysiology, outlined the sensory nerve supply of the body in terms of the appropriate level of the spinal cord to which the nerve conveyed information about sensibility, and performed several experiments that demonstrated the nature of the tone that is present in normal muscle at rest.

Meanwhile in 1825 C L Nobili's astatic galvanometer increased the sensitivity of measuring electric current by a multiplier effect. Increasing the number of turns made by coil of wire increased the deflection of a magnetic needle when the wire carried electric current. The astatic galvanometer was further refined by William Thompson—later Lord Kelvin—in 1858 into the mirror galvanometer used to receive telegraphic signals. A tiny steel piece, smaller than a sewing needle was suspended by a single fibre. It was a permanent magnet hung at the center of a coil of many turns of wire. When current flowed this tiny magnet swung to one side or another depending on the direction of flow of current. The magnetic force required to turn this needle was very small. A small mirror attached to the needle reflected a beam of light thrown on it onto a screen. The screen had a scale of degrees by which the amount of current in the coil could be measured by the deflection of the spot of light reflected from the mirror. The mirror galvanometer was to be used by Hans Berger in recording the first EEG in 1928. DuBois Reymond (1818-1896) who had built a galvanometer with more than 4000 turns of wire described the resting current seen in excised nerves and muscles and postulated on electromotive force that preexisted in tissues. Edward Hitzig (1828-1907) and David Ferrier (1843-1928) used electrical stimulation to localise the control of body movement by the cerebral cortex. As the recording of electrical potential of the nerves continued Claude Bernard (1813-1878) who demonstrated the paralysing action of the poison curare selectively on motor nerves, spoke of the nervous system as the highest expression of the mileu interior "which inter-connects all the tissues of the organism and makes them react one upon the other" (Spillane, 1981, p 265).

New Tools and Techniques

The latter half of the nineteenth century saw the invention of many tools and techniques now considered essential in medical diagnosis and treatment. Needles and syringes were invented in 1865 (Bergland, 1986, p 39). Herman Helmholtz (1821-1894), who measured the velocity of the nerve impulse, invented the opthalmoscope in 1851. It was now possible to look into the eye, the Shakespearean 'window of the soul'. The swelling of the optic nerves that occurred with brain tumours was observed within a few years, haemorrhage and pallor of the optic discs were also noted. Lister's aseptic surgery and the use of chloroform accelerated the use of surgical techniques; the pocket thermometer was introduced in 1896; Pasteur and Koch established the microbial basis of many diseases and in 1895 Wilhelm Roentgen (1845-1923) discovered the x-ray (De Jong, 1982).

The flowering of clinical neurology also took place during that half-century. In France Guillame Duchenne (1806-1875) who had no formal appointment to any hospitals in Paris, but was allowed to visit outpatient clinics, made major contributions to modern neurology (Dubowitz, 1982). He used electrical methods to study muscle disease, introduced biopsy as a technique in clinical medicine, designed an ingenious needle for muscle biopsy, and described several muscle diseases for the first time including the dystrophy that carries his name. Jean Charcot (1825-1893) founded clinical neurology and psychiatry came into use in the decade of the 1860s when Charcot began his work in earnest. The history of the Saltpêtrière itself serves to highlight the intimate connection between the larger society and the medical world. It was built in 1603 as an arsenal, deriving its name from saltpeter, the principal ingredient of gunpower, that was once manufactured at the site. In 1656 it was converted into a asylum for infirm and abandoned women, in the eighteenth century it housed the 'infirm and insane'. Pinel and Esquirol conducted their psychiatric studies on these hapless victims of France's industrialisation. At the end of the eighteenth century its inmates were described by Coguel as "madwomen seized with fits of violence—chained like dogs at their cell doors and separated from keepers and visitors alike by a long corridor protected by an iron grille; through this grille is passed their food and the straw on which they sleep; by means of rakes part of the filth that surrounds them is cleaned out" (Foucalt, 1965). In McHenry's laudatory version, "Charcot, who took charge in 1862, saw this motley collection as a veritable mine of neurological material. Containing some five thousand inhabitants of whom three thousand were neurotic paupers and epileptics, the Saltpêtrière offered Charcot a source of case material that was unique in the history of neurology" (McHenry, 1969, p 284). Indeed it did. Charcot described the lesions of multiple sclerosis, motor neuron disease and an inherited nerve disorder now known as Charcot-Marie-Tooth's disease. Charcot is notorious for his role as the charlatan of the Saltpetriere in his preoccupation with hysterical seizures, which according to him occurred exclusively in woman, and which he claimed to cure by compressing their ovaries with his own invention: an ovarian compressor (Veith, 1965, p 232).

In England, Hughlings Jackson (1835-1911), William Gowers (1845-1915) and Charles Brown-Sequard (1817-1894) laid the foundations of clinical neurology at the National Hospital for the Paralysed and epileptic. Jackson is remembered for his seminal work on epilepsy which he defined as "sudden, excessive, temporary discharge" of neurons. He pointed out that lesions of the brain produced a duality of symptoms; loss of function like loss of speech, movement, consciousness and positive symptoms like increased muscle tone, increased reflexes, or uncontrolled motor activity (McHenry, 1969, p 309). Jackson argued for a hierarchical manner of functioning within the nervous system, being heavily influenced by Herbert Spencer's picture of organised societies where primitive lower orders (the spinal cord and nerves and muscles) were kept in their place by the more highly developed upper echelons (the brain). Recent research however reveals that the brain though highly organised does not have a command post at the apex. When Jackson lectured on cerebral function he would draw a pyramid to represent the hierarchy he considered present in the brain. Modern analysis of visual function however shows that neurons of the cerebral cortex operated in parallel not in series. There is no master decision-maker and the brain it seems functions in a democratic and interactive fashion (Ferry, 1986). William Gowers was like Jackson a clinician but differed from the latter's analytical and physiological approach. Gowers was a keen observer of symptoms and signs and described many entities for the first time including myotonic dystrophy, sleep paralysis, and palatal myoclonus.

American neurology began with studies of *Injuries to Nerves and their Consequences* by S Weir Mitchell (1829-1914) who had followed with interest the cases of nerve damage brought forth in such large numbers by the civil war. Mitchell's study of gunshot wounds published in 1864 is but one of a long line of publications and advances in medicine that have occurred through history by the close alignment of the medical profession with the services required of them and rendered by them to the state. As Bernal states "much medical knowledge and pratical treatment was learned in the hard world of the military surgeon" (Bernal, 1971, p 393). From the shaman of yore ordering the rain or sun for the welfare of the tribe to Ambroise Pare (1510-90) unlettered writing in coloquial French about gunshot wounds, Weir Mitchell is but one link in a chain. The United States' Public Health Services' connection with US imperial policy overseas and racism at home is well-documented in Walter Reed's (1851-1902) typhoid and yellow-fever related research following the US occupation of Cuba after the Spanish-American War of 1898 (Bean 1983; Lyons and Petrucelli 1978) and the scandalous study of the natural history of syphilis exclusively in black men, a study that ended only in 1970. (Jones, 1981).

Developments in Physics

As the twentieth century dawned, James Maxwell's (1831-79) electromagnetic theory established a unity between light, electricity and magnetism. Electromagnetic oscillations gave rise to waves in a hypothetical ether, similar to those of light but with much lower frequencies. In 1881 michelson and Morley proved the non-existence of ether. Soon light itself was explained as a low-energy photon or a packet of energy virtually massless moving at an incredible but definite speed. Thomas Edison's (1847-1931) discovery in 1884 of the Edison effect that a glowing filament of an electric bulb could retain a positive but not a negative charge, i e, current would flow only one way from a heated metal plate to a filament, led to the invention of the electronic valve. Electricity could travel without any wires through empty space. In 1905 Lee de Forest (1873-1961) mounted a piece of a zig zag wire between the filament and plate. This electric screen when negatively charged would repel electrons which could not get past this grid. However when the grid was positive or neutral electrons could flow on through to the metal plate. A very small current could change the voltage of the grid—a weak current could control a relatively strong current. The triode was born and with it the revoluntionary possibilities of amplification and of power based on information. Radio and television, high-tension vacuum and valve techniques that followed integrated physics and electricity into the new applied science of electronics.

Cathode ray oscilloscopes provided electronic amplification of very weak signals even very tiny such as occurred between synapses. The Cathode ray tube in which a beam of electrons flashed across a tube on a horizontal axis could be used for on-line recording of a signal on a vertical axis. The string galvanometer, used by Richard Caton (1842-1926) in 1875 to directly record currents from the surface of the brain and 60 years later by Hans Berger, was replaced. It is noteworthy that Berger's publications were initially dismissed as artefacts and his records though carefully assembled were met with "monumental indifference, disbelief or even hostility" (Gloor 1971). Berger's work was ignored for several reasons. Neurophysiologists held a deeply felt belief in the brain as a highly complex neural network. Surely brain activity could not be the simple, regular waves Berger demonstrated. Also, Berger's reticent personality, and his refusal to cooperate in building Hilter's New Order unlike the bulk of the German medical establishment, (Light, 1985) forced him into retirement in 1938 and suicide three years later. Equipment to record EEG was further improved in the United States. Using a recorder developed by Western Union for writing on a ticker tape with an ink stylus, replacing its magnets with more powerful ones of nickel, aluminium and cobalt alloy and by providing stiffer springs, it was possible to electrically record the human brain's normal background rhythm called alpha waves with frequencies of 8-13 per second at a paper speed of 3/8th of an inch per second. Brain waves would now be recorded easily; the action potentials of individual muscle fibres, and the velocity of nerve impulse could also be studied by using amplifiers and cathrode ray oscillographs.

These advances in neurophysiology made possible by the improved radio and amplifying equipment, oscilloscopes and computers forged in "the furnace of human conflict" during the two world wars, (Walter 1971) were instruments designed for destruction transformed in neurology for more benign purposes. EEG has contributed to knowledge about epilepsy, sleep disorders, brain tumors and altered states of consciousness. But the test has not been anywhere as helpful as the volume of words written about it, well over ten million in the *Journal of Electrophysiology and Clinical Neurophysiology* alone, would suggest (Williams, 1974). Used indiscriminately to bolster physicians incomes, the EEG and EMG have been aptly described as wasteful, and pretentious (Menken and Sheps, 1984); or that as "most single records would best be reported thus: this record departs slightly from accepted standards of normality; nobody knows what this means" (Matthews, 1973). Similar caution has been expressed about the overuse of evoked potential techniques (Eisen and Cracco, 1983). This technique uses computers to store many elicited responses, averaging them and enabling one to record signals as small as one-hundredth of background activity. The electrical route of studying brain function which began in the eighteenth century has done very little for patient care (Bergland, 1986, p 76). Structural abnormalities of the brain are more easily and accurately uncovered by radiological techniques to the development of which we now turn.

As far back as 1838 Faraday had observed a luminous glow which (William Crookes (1833-1919) in 1876 called cathode rays, as they seemed to consist of particles torn out of the cathode or negative end of a highly evacuated glass tube. Nine years later Wilhelm Roentgen noticed something happening *outside* such a tube. It could fog photographic plates, pass through sheets of rubber, through human skin and flesh, but not through bone. Roentgen had discovered x-rays—a scientific discovery with a vengeance (Bernal, 1971, p 73). It unlocked doors in medical diagnosis, and many branches of physics. X-rays are photons with an energy level greater than 100 electronvolts (eV). (For comparison visible light photons have energies of 2 to 3eV). X-ray machines spread rapidly in Europe and the US as the high voltage generators and evacuated bottles necessary to produce x-rays were already available in many laboratories. It soon became clear that x-rays were useful only in differentiating gas from soft tissues and bone. They could not reveal useful structural details in most soft organs like the brain.

The brain posed special problems to clinical medicine. Generally physicians like to visualise the structures they deal with. In addition to vision, physicians till the nineteenth century would palpate, and percuss the part of the body considered involved in disease. However the brain is inaccessible, being surrounded by the rigid bony skull, to the senses of sight, hearing, smell, or feeling, and it is very fragile. Palpating the brain, where there is no skull, would irreversibly destroy brain tissue! Thus the skull which protects the brain from mechanical insults also prevents it from being reached by the physician. Table 1 indicates the presently available means of imaging the brain. Even a quick glance at this table reveals the intimate connection between neuroimaging techniques and usage of some part of the electro-magnetic spectrum (See Table 2). Neuroimaging has advanced because of contributions from many fields of science: neorology, neurosurgery, clinical radiology, radiation and nuclear physics, engineering, mathematics, computer science, mechanical engineering and biochemistry to name a few.

Progress in neuroimaging though rapid was often acciden-

Table 1: Neurological Imaging Techniques*

Procedure	Image of brain that results
Neurological consultation	Imaginary construct of possible pathology
Electroencephalogram	Surface electrical activity below 80 Hz
Skull films	Distribution of crystallized calcium in head
Ultrasound midline	Position of 3rd ventricle
Isotope scan	Distribution of blood-brain barrier
Pneumoencephalogram	Location of cerebrospinal fluid compartment
Cerebral agiogram	Location of blood compartment
Computerized tomogram	Distribution of tissue radiodensity
Positron tomogram	Distribution of brain metabolism and blood flow
Nuclear magnetic resonance imaging	Distribution of brain water

(from Oldendorf, 1980)

Note * All of the special neurodiagnostic procedures mentioned can be considered ways of imaging the brain. Each produces images of the brain in a unique way, isolating some more or less restricted characteristic of the brain and constructing an image from it, thereby providing a restricted conceptualisation of the structure and function of the brain.

Table 2: The Electro-Magnetic Spectrum and Neuroimaging

	Wavelength (centimeters)	Photon Energy (electron volts)	Frequency (Hertz)	Neuroimaging Technique
Radio (upto VHF)	$10\text{-}10^5$	0.00001	$10^3\text{-}10^8$	MRI, Ultrasound
Microwave	0.01+10	0.00001 to 0.1	$10^{10}\text{-}10^{20}$	
Infra red	0.0001 to 0.01	0.1 to 1	$10^{13}\text{-}10^{14}$	
Visible	2×10^{5} to 10^{4}	1 to 6	$10^{14}\text{-}10^{15}$	
Untra violet	10^{7} to 2×10^{5}	6 to 1000	$10^{16}\text{-}10^{17}$	
Xray	10^{9} to 10^{7}	1,000 to 100,000	$10^{18}\text{-}10^{20}$	Skull xrays Computerised tomography
Gammaray	10^{9}	100,000	$10^{21}\text{-}10^{22}$	Radioactive Isotope

(modified from Oldendorf 1980; Weinberg 1977; Young 1984) tal. In 1912, an x-ray taken of a man with a skull fracture showed air in the cavities or ventricles of the brain. Six years later, Walter Dandy (1886-1946) "made the quantum intellectual jump from the clinical observation of air in the head resulting from head trauma. . . to its deliberate injection for diagnostic purposes" (Oldendorf, 1980, p 15). The pneumoencephalograph or PEG, used for over 50 years did not show the brain directly. Air injected between the middle (arachnoid) and inner (pia) layers of the coverings of the brain filled the ventricles of the brain and by comparing differences with a normal outline one could infer something about the size and shape of surrounding structures.

A Parisian neurologist Jean Sicard (1872-1929) had been using Lipiodol, an iodized oil for treating back pain. He injected the substance into the lumbar muscles and found that it was well tolerated and produced no serious side effects. He had noticed that Lipiodol was excellent x-ray material and used it to outline the bronchial tree in the lungs. One day one of his pupils injected Lipiodol into the lumbar muscles and was horrified when he found he was withdrawing cerebrospinal fluid (CSF) as he drew back the plunger of the syringe. He rushed off to Sicard, who asked how the patient was and on being told the patient was well, decided to look at the lumbar region on a flourescent screen. Sicard first screened the patient standing up and saw that the Lipiodol had dropped to the bottom of the cavity surrounding the spinal cord (the spinal subarachnoid space). He then had the brilliant idea of tilting the patient head down and seeing the movement of Lipiodol (Bull, 1982). The technique of myelography was born, one which has proven very useful in diagnosing diseases of the spinal cord-like tumors and protruded intervertebral discs. In 1926 Egaz Moniz (1874-1955) performed the first cerebral angiogram in a living patient. A substance opaque to x-rays was injected in the carotid arteries that supply blood to most of the brain. This technique, still in use today, delineates tumors, hemorrhages, blood clots and vascular malformation of the brain. Research now concentrated on the development of a non-toxic contrast-agent. These agents had to confront the blood-brain barrier (BBB) which depends upon certain characteristics of the capillaries in the brain. A capillary, a tube with a diameter of 0.1 mm, length of about 1 mm has a wall of single flat endothelial cells that are about 0.001 mm thick. Blood and soluble substances in the plasma can pass through the walls of non-neural capillaries or diffuse through the intercellular clefts, or pores between two endothelial cells. Molecules up to 40,000 molecular weight can pass through these pores. Pinocytosis is another way of bloodcell exchange. Here the inner walls of the endothelial cell breaks, a small amount of blood enters the cytoplasm and is transported through the width of the cell and dumped into the extracellular space immediately surrounding the capillary. In neural capillaries, on the other hand, there is no intercellular cleft, the endothelial cells form 'tight junctions', and pinocytosis is virtually absent. Thus the blood and brain can exchange material only through the capillary cell. The tight junctions exclude molecules with molecular weights as low as 2000. Water-soluble polar compounds, i.e. those substances which have an electric charge at each end of the molecule, are mostly excluded while lipid-soluble compounds rapidly and easily enter the brain. Paul Ehrlich (1854-1915) had discovered the BBB in 1885 when he noted that aniline dyes injected into an animal stained its body but not the brain or spinal cord. The BBB is 'lost' when the brain suffers any kind of insult like infection, trauma, or a stroke.

The contrast-agents that became widely used were iodinated organic compounds because they were the least toxic, stable in water-solution, with a high molecular weight, but low osmolarity, (1.5 osmolar solution only five times the 0.3 osmoles of brain capilary endothelial cells). Also the iodine atom's innermost shell of electrons (the k-shell) has a binding energy of 33 Kev. Incoming x-rays in computerised tomography have an energy level of 60 to 80 KeV. These rays can be captured by the k-shell electrons of iodine, deleting the x-rays and increasing the radiodensity of the tissue that contains it.

The second world war which sparked the development of nuclear physics resulted in many artificial radioactive substances being avaialble by the mid-40s. In 1947 George Moore then an intern in surgery discovered that radioactive iodine injected intravenously emitted gamma rays which could be detected by a Geiger counter. Radioactive isotope imaging was refined in the next two decades using a thallium-activated sodium iodide crystal photo multipliers. The small amount of thallium breaks up the regularity of the sodium iodide crystals so that they scintillate or generate visible light photons when struck by gamma rays. These photons are amplified by the photomultiplier and the amplitude of the voltage thus produced measured electronically. Radioisotope scanning did not produce sharp images of the brain as attempts to sharpen the image by collimation resulted in many emitted rays being uncounted. Also Compton scatter or deflection of gamma rays by atoms in their path made the rays appear to have a different origin when they reached the detector, these 'incorrect' locations further contributing to a fuzzy image.

Visualising the Brain

By 1971, though the brain could be visualised indirectly by angiography, ultrasound, radioisotope scanning, PEG etc, these tests were either cumbersome, time consuming or very uncomfortable to the patient. W H Oldendorf around 1960 and G N Hounsfield in 1967 independently developed the technique of computerised axial tomography (tomos=a slice) based on tissue specific gravity. The fascinating story of the development of computerised tomography is recounted in Oldendorf's book *The Quest for an Image of Brain*. In 1960, Oldendorf applied for a patent for a device that produced a radiographic cross-section of the distribution of tissue structures based on regional radiodensity. A narrow collimated beam of high energy photons passed through the head and were counted after they emerged from the head by means of a detector fixed in relation to the photon source. Several points on a particular plane of the head were scanned using rotational and translational motions. The observed counts of photons were then processed by a computer which reconstructed the distribution of radiodensities within the plane. Oldendorf was granted a patent in 1963 but found none of the major x-ray manufacturers interested in the device. As he ruefully remarks "their lack of interest was a matter not so much of technical unfeasibility (since they had more information than I had as to whether the idea was workable), but more of economic promise. A letter from one of the world's major x-ray manufacturer ended—even if it could be made to work as you suggest, we cannot imagine a significant market for such an expensive apparatus which would do nothing but make a radiographic cross-section of a head" "Oldendorf, 1980, p 85-6). Success came to Gordon Hounsfield who worked in the research laboratories of EMI Ltd. Hounsfield decided to use sodium iodide crystals rather than the photographic plates used for 50 years in radiology, because the crystals being 100 times more sensitive than the plates, allowed better differentiation of soft tissue density. As his device took five minutes to produce a picture he was advised to study the brain which did not move rather than the chest or abdomen as images produced of these regions would be blurred since no patient could hold his breath for five minutes. Today a picture can be produced in seconds allowing any part of the body to be scanned.

EMI pursued the development of the CT scanner as Oldendorf explains, being previously uninvolved in medically-oriented research they were not aware that the limits of technology had already been explored. The production of the CT Scanner illustrates a feature common to technological and scientific advancement under capitalism. The large x-ray manufacturers behaved in a manner similar to wireless manufacturers: too intent on immediate profits to indulge in expensive development (Bernal 1971, p 717) whereas the unorthodox approach of the inexperienced musical company led it to market one of the truly revolutionary diagnostic techniques in medicine. Two other brain imaging techniques have become available since 1971. They are positron emission tomography (PET) which measures regional metabolism of glucose or oxygen and magnetic resonance imaging (MRI) in which the magnetic property of hydrogen atoms is utilised. The hydrogen atoms of the brain are made to resonate in a strong magnetic field. They partially align themselves with the field and absorb energy which is subsequently reradiated. Images of hydrogen density and relaxation time allow striking pictures of the brain and spinal cord making virtually all parts of the central nervous system accessible to the human eye without tissue ionisation, injection of contrast material or radioactive substances being involved (Oldendorf, 1984).

C T and MRI scans have proliferated in the US, the number of C T scanners rising from none in 1973 to 800 in 1978 representing a capital investment of 400 million dollars (Oldendorf, 1980), while MRI scanners rose from none in 1978 to about 200 in 1985 leading the industry's two dozen firms collectively looking to annual·sales worth 2500 million dollars worldwide in 1988 (*Lancet* 2:1169, 1984). Separate buildings, each costing as much as 1.5 millions dollars, have been constructed to 'contain' the magnetism surrounding the MRI equipment financed by 'venture-capital' groups who see them as tax shelters or investment opportunities (Goldsmith, 1984).

So the high-tech revolution in medical diagnostics is expensive, becomes obsolete rapidly and by virtue of the financial stakes involved, available at a stiff price therefore largely only to the affluent (see Table 3). Though the technology provides diagnosis more accurately at a crucial early stage of some diseases, and the greater precision of pinpointing lesions leads to a reduction in other tests (see Table 4) it is cost-effective in a rather narrow sense: to those able to get the test done. The issues of cost-effectiveness deserves a full discussion on its own. Suffice to say here that in the US corporatisation of health care promotes the use of capital intensive technology while ignoring the question of access to these services by the 35 million Americans who are either under and uninsured.

Improvements in neurodiagnosis aided the growth of neurosurgery. Injury to the head had been regarded as a surgical problem since antiquity (Flamm, 1982), but removal of tumors of the brain and spinal cord was first attempted only about a century ago. Victor Horsley (1857-1915) a pioneer who contributed to many neurosurgical techniques

Table 3: Costs of Various Neurodiagnostic Procedures in Relation to Discomfort to Patient, and Information Obtained

Procedure	Discomfort form Procedures	Information Obtained	Cost (US Dollars)
Neurologic Consultation	—	+++++	80-100
Skull xrays	—	+	55- 75
EEG	—	++	75-150
Ultra-sound (midline ECHO)	—	+	25- 50
Pneumoencephalogram	++	++	300-500*
Caroted angiogram	++	+++	550-1200*
Digital Subtraction Angiography	+	++	300-400
Radioisotope Scan	–	+++	150-250
C T scan (head)	–	++++	300-500
C T scan (spine)	–	++++	325-600
MRI scan (head)	–	++++	600-800
MRI scan (spine)	–	++++	600-800

Note: * If costs of hospitalisation are included these procedures would me much more expensive—daily room charges vary from $ 175-250 1 day.

(modified from Oldendorf 1980; Gunby 1983)

Table 4: Effect of Various Procedures AT Dent Neurological Institute, Buffalo, N Y

Procedure	1973 (pre-CT)	1976 (post-CT)
Echoencephalograms	189	0
Pneumoencephalogram	39	5
Isotope brain scan	579	157 (16)*
Lumbar punctures	425	167
EEGs	1,047	731
Angiograms	111	87
Hospital admissions	355	351
Patients seen in ER	222	291
Office consultations	668	1,087

Note: * Sixteen tests were required by neurosurgeons and neurologists. The numbers below the line indicate that, despite the reduction of tests, the total clinic work load increased between 1973 and 1976.

(from Oldendorf 1980)

including decompressive surgery for brain tumors, laminectomy for removal of spinal cord tumors, nerve section for relief of exquisite facial pain (tic doloureux), etc deserves mention for his championing of social causes. He was an aovwed agnostic who worked for Votes for Women (the Suffragette Movement) demanded equality for women in medicine, sought proper recognition for the nursing profession and urged health legislation that would benefit the poor (Cooper, 1982). He was disliked by the British medical establishment who feared his socialism (Taylor, 1986). A remark of William Osler's illustrates the attitude of the medical establishment then (and I suspect it would not be very different today) to Horsley's politics: "What demon drove a man of this type into the muddy pool of politics?" (Osler, 1916). Horsley though appointed to the staff of the National Hospital in 1886 was given no beds of his own in the thirty years he worked there.

Neurosurgery progressed rapidly in the twentieth century keeping pace with developments in neuroradiology. Harvey Cushing (1864-1939), a leader in modern neurosurgery, investigated the role of the pituitary gland and established that it secreted growth hormone. He linked the brain with endocrine function, a link that appears increasingly important as the number of neuropeptides discovered grows, their actions playing a pivotal role in memory, emotions, sleep, and the perception of pain. Indeed Bergland (1986) argues that we have come full circle. The brain may be what the Greeks imagined it to be: a hormonally modulated gland with the "stuff of thought" being large molecules or peptides and not electricity. The discovery of neuropeptides would have been difficult without a simple and safe technique to examine cerebrospinal fluid (CSF). Such a technique was invented by Heinrich Quincke (1841-1922) who was searching for a way to remove CSF from children with hydrocephalus. He inserted a needle with a stylet in the lumbar intervertebral place and removed CSF. He used the lumbar puncture to examine the constituents of CSF and described the changes in the latter in purulent meningitis (McHenry 1969, p 366).

The role of special chemicals or neurotransmitters that conveyed messages across a synapse was first described by Henry Dale in the 1930's. Acetyl choline, released by the vagus nerve which supplies the heart, slowed the rhythm of the heart. Soon other neurotransmitters were discovered and by 1975 it was known that the brain produced morphine like substances or endorphans. Presently over 45 neuropeptides are known and their effects on degenerative diseases of the brain like senile dementia and Parkinson's disease under active study. Tools used in peptide research include radioimmunossay, immunocytochemistry and complementary DNA probes. Usage of monoclonal antibodies, introduced in the last decade, has made possible knowledge about the internal structure of the neuron. Disciplines that were unknown till the early seventies flourish in their own right today. Neuroimmunology, molecular genetics and neuropeptide research bring together branches of science outside the field of clinical medicine. Advances in knowledge are dependant upon a sophisticated and wide technological base. Often new techniques are developed for reasons other than what they are used for later. For instance monoclonal antibodies developed out of Milstein and Kohler's attempts to learn more about the genetic control of synthesis of antibodies (Sattaur, et al, 1984). Presently brain function is accepted as both hormonal and electric, without a brain-body dualism. Both are dependant on and influenced by the other. A basic operation or function common to all areas is suspected but the manner in which integration of thought and behaviour occurs is unknown. Neither are we able to correlate structure and function at the level of a single cell (Philips et al, 1984).

Conclusion

The brain then remains the enigma it has been through millenia. It can however be visualised, directly and indirectly, its functions studied and modified by chemical, electrical and surgical means. Progress in medical technology and knowledge about basic biologic structure and function, which permit these interventions in the nervous system, records even more spectacular advances in other organs—the heart, the liver, the kidney and bone marrow can be transplanted. Machines can do the job of the heart, the lungs and the kidney. No part of the gastrointestinal tract remains hidden from the human eye with the use of fibre-optics. Setting broken bones, stitching up torn arteries, controlling bacterial, fungal and parasitic infection, these are but some of the techniques taken for granted by a majority of the citizens of Europe and North America. But the availability and relevance of this technology to a large section of humanity remains tied in to the social, philosophical and economic realities which govern our planet. Flowering first in Europe, and later North America, medical technology has concentrated on a cellular and clockwork like approach to the body. Preventive measures have generally received scant attention particularly those that focus on industrial pollutants as likely carcinogens or of individual habits like smoking that are promoted by big corporations. Prevention by innoculation against disease no longer has universal applicability.

Recently developed hepatitis and malaria vaccines are enormously expensive and intended only to aid soldiers of the "free world" as they are called to save democracy in tropical and equatorial climes. The electronic razzmatazz available at the beck and call of physicians follows the road of most commodities—the more, the better! Marketed expertly by companies out to make quick and big profits much of the application of medical technology is prohibitively priced and even unnecessary (Angell, 1985). Certainly it is difficult to account for the number of intensive care units, CT scanners, coronary artery bypass grafts in the United States without considering the links between medicine and the health care industry.

A society that cares neither for adequate prenatal care, nutriton, education, housing, and old-age security exhibits sudden concern for end-stage renal disease and elderly patients when government programmes assure physician, hospitals and biotech industries of sustained high income. A modern intensive care unit reflects uncannily the society from which it has emerged. Notwithstanding the underlying disease, modern death bed rituals are mounted. Every index of body function is tracked and treated without any attempt at considering the patient's prognosis or the futility of these costly heroic efforts. Blood gases, body pH, electrolytes, urine output, continuous electrocardiographic monitoring and arterial blood pressure recording, respirators, nothing is ignored in this relentless pursuit of information.

Macabre though it may sound, patients die, but not before they are made biochemicaly and haematologically normal! The same system of hospital based technological intensive medicine is sought worldwide, an acknowledgement in part of its limited, but definite success in combating disease and relieving suffering. The control of infection proudly acclaimed as an achievement of medicine probably has more to do with better nutrition, sanitation and hygiene (McKeown, 1976). The efficacy of antibiotics has depended on the integrity of the body's defence mechanisms against disease. They are ineffective in infections such as the AIDS virus, which derives its lethal nature from its ability to destroy the immune system of the body. The AIDS epidemic illustrates the complex multifaceted nature of modern medicine. Though the medical establishment is baffled by the disease and presently unable to help its victims adequately, a remarkable amount of knowledge has been acquired in the five years since the disease became known. The medical profession not particularly noted for its compassion towards those society rejects or ignores, has been free of panic and prejudice while AIDS high risk groups consisted largely of drug addicts and male homosexuals. In fact, it has campaigned against hysterical and unwarranted measures such as quarantine very effectively. Medical technology helped uncover the human immunogenic virus as the cause of AIDS and may give us a vaccine in the next decade. Yet AIDS illustrates the limitations of modern medicine. It concentrates on treating disease not in learning more about why only a few acquire it. In any epidemic the disease affects a much larger proportion of the populace than is either incapacitated or killed by it. Factors that protect most individuals are only now beginning to be studied.

Finally and very importantly comes the question of resource allocation. It would cost a fraction (about 30 billion dollars) of the amount spent on arms (800 billion dollars a year) to feed, clothe and educate every person on earth. CT scanners and MRI equipment co-exist within a stone's throw of people scouring through garbage cans for food. Drugs that can save human lives are controlled by corporations notorious for overcharging poor countries. As Martin Ryle put it in a letter written several months befor his death in 1984: "The benefits of medical research are real, but so are the potential horrors of genetic engineering and embryo manipulation. We devise heart transplants, but do little for the 15 million who die annually of malnutrition and related diseases. Our cleverness has grown prodigiously—but not our widsom" (Ryle, 1985).

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(Continued on p 35)

But none of this is relevant to whether Whitehead is 'unfit' to raise her child. What is relevant is that she gave birth to the child and began raising that child.

What are Society's Responsibilities?

In the struggle to end women's oppression and guarantee children the best care possible, the working class needs a twofold approach. It needs to fight for women's right to enter the work force and all arenas of society without any restrictions or discriminatory treatment because of their childbearing capacities. It also needs to fight for the government to carry out its responsibility to provide care for children and all other dependent human beings, instead of allowing the burden for this care to fall on individuals, especially on women.

The government should provide lowcost child care from infancy on up. It should guarantee an education, medical care, decent housing, and recreation for all the young, aimed at helping them develop into independent human beings. All laws or practices that discriminate against children—based on class, race, sex, handicaps, or 'legitimacy'—should be eliminated.

The working class must also challenge any disqualification of women based on their having or not having children.

This being with championing the right of women themselves to freely decide when and if to bear children. It means the right to safe, legal abortion and birth control, as well as sex education in the public schools. It means protection of women from forced sterilisation.

Women's physical ability to bear children should not be used as a pretext to super-exploit them on the job paying them less than men, excluding them from certain jobs, or denying them emoloyment if they are pregnant or already have children. The working class should demand equal pay for equal work and affirmative action so women can achieve full equality in employment and education.

Workers should demand full maternity benefits for women, including the right to return to the same job—without loss of accrued seniority time—after the birth of a child. Absence from work because of pregnancy should be treated exactly like other contractual situations related to leaves from work.

For women who have children, the working class should demand all the state aid they need to care for them. And it should defend their right to have the courts compel men who walk away from shared responsibility for children to pay child support.

The struggle for these demands is part of the fight for a different type of government, one that acts in the interests of workers and farmers, not a handful of capitalist families. By bringing such a government to power, working people will lay the basis for further measures to provide care for children and to achieve equality for women

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puterised tomography nor nuclear imaging are tested in the same way as drugs are required to.

Not only instruments but many medical and surgical procedures are also introduced without adequate trails. For instance results of the systematic trial of amniocentesis were published only last year after its extensive use for over a decade. The chorion villi biopsy is already extensively used without any scientific trial. Because of such a situation many innovations like gastric freezing, high concentration oxygen for neonates, the use of hyperbaric oxygen in intensive care, insulin coma for the treatment of schizophreniae etc were introduced without evaluation, used and subsequently abandoned after they were proved ineffective or unsafe.

Amniocentesis and chorian villi biopsy remind us their large scale misuse for female foeticide in India. In fact some of the technological innovation appear explictly geared towards use of sexist and racist cultural practices to gain fast currency and early returns on the resultant technology.

Every country that is attemtping to meet the genuine needs of people, has to take crucial decision about selecting appropriate technologies as an alternative to the costly, rendering services to few and profit oriented technologies. In the field, activists are also required to select and develop alternative technologies to provide immediate relief to people. Therefore, in addition to the technology being a political question, it is also a direct practical problem in political practice. This has led many to experiment with various alternative methods of medical care using simple but effective technology and develop models to prove their feasibility. This question is also linked with proliferation of the non-government organisations and needs detailed discussion.

Such experiments in alternative technologies are not limited to using different physical tools but encompass the way medical care is delivered and attempts to humanise it.

—Amar Jesani

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