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Swedenborg, Linnaeus and Brain Research – and the Roles of Gustaf Retzius and Alfred Stroh in the Rediscovery of Swedenborg's Manuscripts

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Abstract

Emanuel Swedenborg (1688–1772) at the end of his long life became famous as a visionary mystic and founder of a new religion. However, at younger age, he was recognized as a prominent mining engineer and natural philosopher, particularly interested in geology, mineralogy, cosmology, paleontology and last but not least physiology of the brain. In his Oeconomica regni animalis (1740) and in several posthumously published extensive manuscripts, he described and analyzed e.g. the structural and functional organization of the cerebral cortex, the hierarchical construction of the nervous system, the localization of the cerebrospinal fluid and the secretory functions of the pituitary gland. In these fields, he presented remarkable insights and far reaching conclusions which in some cases have been experimentally verified in modern times.

In spite of family relations Swedenborg rarely met the 19 years younger Linnaeus. Linnaeus was not only the founder of the systemic botany but as physician a keen and to some extent original observer of neurological symptoms; one of the first who adequately described motor aphasia. To regard these two men, among the few Swedish authors of the 18th century whose names are still internationally well known, as early precursors of neurological research, seems justified.

The young Canadian, Alfred H. Stroh (1878–1922), had a crucial importance for the research on the works of Swedenborg, and the rediscovery of his manuscripts. His work was supported and financed to a large extent by professor Gustaf Retzius, at that time the most prominent Swedish researcher in anatomy and histology.

There are many reasons to be thankful for the important contributions made by Alfred Stroh and Gustaf Retzius to stimulate the interest for Emanuel Swedenborg in Sweden and internationally.

The foremost internationally known Swedish literary men of the eighteenth century were the visionary and founder of religion, Emanuel Swedenborg (1688–1772), and Carl von Linnaeus (1707–1778), professor of medicine and "Princeps Botanicorum", author of "Systema Naturae" which ran to sixteen editions. Both natural philosophers were well informed, empirically inclined, enthusiastic and assiduously active. This was the impression they gave from their youth to the autumn of their life, when especially Swedenborg, but also Linnaeus, yielded to strongly mystical and speculative views. Swedenborg's intuitive talent and wealth of ideas

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Emanuel Swedenborg at the age of 46 in 1734.

and Linneus' ingenious powers of observation were expressed in their zeal to solve the mysteries of the nervous system at a time when technical aids essential for brain research hardly existed.

The rapid, unexpected advancement of the neurosciences in recent decades were achieved by the use of a broad spectrum of techniques, such as neuro- physiological and psychological analyses, the cerebral blood flow of selected zones, electrical activity of individual nerve cells and molecular biological and genetic aspects of the nervous system in health and disease. Similar investigations can be made of the structure and function of components. These technical advances enabled the DNA researcher and Nobel prize winner Francis Crick to state: "There is no scientific study more vital to man than the study of his own brain. Our entire view of the universe depends on it."

With the help of available information, the purpose of our survey is to shed light on the personal relationship between the anatomically knowledgeable "neurophilosopher" Swedenborg, and Linnaeus, the keen observer of the signs of neurologi-

Linnaeus the bridegroom 1739. Painting by J H Scheffel.

cal diseases, and try to discern in what respects Swedenborg's thoughts and conclusions concerning the brain can be regarded as independent and original and valid in the light of the results of subsequent research.

Swedenborg meets Linnaeus in "the Town between the bridges"

As far as we know the two talented Swedes seldom met which is surprising since they had a similar background, mutual interests and disposition to the outside world. Swedenborg and Linnaeus's father-in-law, Johan Moraeus, the doctor for the mine in Falun, were cousins but family ties had not made any closer bonds. Swedenborg was nineteen years older than Linnaeus; the difference in age and Swedenborg's

frequent visits abroad for several years doubtlessly accounted for the dearth of communication. The only proof of their meeting was from November 1740 to September 1741 when both lived in the Old Town of Stockholm.

To lend this meeting a semblance of their time, imagine being in Stockholm in the autumn of 1741, the historical "Period of Liberty". Linnaeus, the Admiralty doctor , was in May this year appointed professor of Practical Medicine at Uppsala University. After having returned from his travels to Öland and Gotland at the end of August, he handed over his Stockholm residence to Swedenborg. Linnaeus', dwelling was the beautiful white stone- house, number 48 in the Achilles district on Skeppsbron between Dryckesgränd and Slussplan and had an extensive view over Saltsjön. It remains almost unchanged from its appearance in Elias Martin's painting of the "View over Stockholm from Mosebacke" at the end of the 18th century. Now it houses the State institute of Employment. The massive vaults of its cellars, now the dining hall of the personnel remind us of bygone days. Here, Linnaeus saw some 60 patients every day. It was here, too, that Swedenborg completed his second large manuscript on the structure and function of the brain which posthumously, at the end of the nineteenth century was translated into English under the title, "The Brain Considered Anatomically, Physiologically and Philosophically" and published in 4 volumes at the cost of the Royal Academy of Science.

In Swedenborg's time, Stockholm had some 50,000 souls. In its oldest part between the two bridges, a noisy motley life held sway. On the quays flanked by the tall masts of floating vessels, busy hands discharged and loaded countless bales and barrels. The narrow alleys and small market places were thronged with people from far and near. The air was pervaded by strong smells and noise and the clatter of horse drawn carts and the carriages of the nobility. Periodically the dull toll of the church bells would remind us of life's short span. In July 1741, the Russian war of revenge undertaken at a time of evil foreboding was inspired by the hatted, conservative party whose dream was the renewed role of Sweden as a great power. Despite the rumblings of war on the Kingdom's eastern borders in Finland, trade and manufacturing blossomed in the commercial sense. The closely set, small public houses were bustling with people. Scholars were esteemed as never before under the protection of the youthful Swedish Academy of Science whose first president was Linnaeus.

On January 8th 1741 when dusk began to fall and candles were lit behind the small,chequered, wooden framed window panes, little more than a dozen men could be seen and among them Linnaeus and Swedenborg wandering towards the Riddarhuset (The House of Nobles) where the Swedish Academy of Science had its weekly sessions for the first 25 years of its being. Initially the meetings were held in the newly renovated and furnished amphitheater, the Auditorium Illustre but later in the adjacent Laboratorium Mechanicum; both were on the upper floor of the eastern part facing Riddarhusgränd.

At Linneus' request, Swedenborg was inaugurated as a member of the Academy at a simple ceremony. Linnaeus was present at the meeting on January 17th when Swedenborg delivered his work "De cerebri motu et cortice et de animo humano:

Picture of the Old City of Stockholm. Abode of Linnaeus then Swedenborg.

The house to the far left at the corner of Södra Dryckesgränd (!), Skeppsbron (48) and Slussplan, was occupied by Linnaeus 1739–1741, then Swedenborg 1741-spring 1743, where the latter completed De Cerebro.

anatomice, physice et philosphice perlustrata" published in Amsterdam in 1740. It describes the movement of the brain due to breathing, which Linnaeus held as very important in his lectures on the nervous system to his students in Uppsala.

Anatomy theatres in Paris and Stockholm

Swedenborg and Linnaeus acquired their knowledge of the anatomy of the brain by attending public dissections of cadavers: Swedenborg at the end of the 1730ies while on a visit to Paris lasting 18months and Linnaeus in Stockholm 7 years earlier while on study leave for 5 weeks. In their writings, they hardly base their knowledge upon their own practical experience at the dissection table. Swedenborg states that at an early stage, he decided to give up using instruments to evade being deceived by his own findings and instead examine and compare critically the writings and statements of acknowledged authorities. As doctor to the admiralty, Linnaeus requested the permission of Fredrik the First to carry out autopsies on patients who died in the naval hospital; this was granted. Linnaeus may have noted changes in the anatomy of the brain but written evidence of this has not been preserved for posterity. Many say that during his long stay in Paris, Swedenborg studied literature assiduously and principally in the libraries which even then had a great assortment of well illustrated

treatises on the anatomy of the brain and its different parts. Although Swedenborg lived only a stone's throw from Maison S.Come, where the Académie de Chirurgie held its meetings and anatomical demonstrations for a large, but closed circle of French and foreign surgeons, there is no preserved written evidence that Swedenborg attended them. One would wish that the opposite were the case. If you round the corner of the short street Rue Antoine Dubois (formerly Rue de l'Observance) where Swedenborg once lodged and take the Rue de I'École de Médecine and slip through the door to L'Ecole Pratique de Médecine with its residential part facing the garden, the eye beholds a spiritual relation of Swedenborg, the bust of Jaques Benigne Winslow (Jakob Benignus Winslow) the famous Danish anatomist with his Socrates-like physiognomy. There is firm evidence of their personal acquaintance. Swedenborg owned Winslow's newly published book on anatomy and from Swedenborg's own statements, he attended the public anatomical demonstrations in the Jardin du Roi at which Winslow presided. Like Swedenborg, Winslow thought that studying the human body served the pursuit after God. If we return to Rue Antoine Dubois, another association to Swedenborg is coming about: in the middle of the street is a statue of Vulpian, the neurophysiologist and pathologist and the friend of Pasteur and Charcot. Like Swedenborg, Vulpian maintained that personal spiritual life was dependent on the brain and thus aroused the wrath of clerics and conservatives. Swedenborg journeyed from Paris to Venice, where in 14 months, he wrote the lengthy manuscript on the brain; part of it is included in Oeconomia regni animalis, Part II. Two hundred years later the entire work was translated into English and published under the title The Cerebrum (see below). Swedenborg's writings on the anatomy of the brain make a methodical conclusion to his systematic survey of inorganic and organic nature, and with the intention to trace the seat of the immortal soul in the brain. Conforming with his mechanical way of thinking, he regarded the soul as confined in space and consisted of extremely fine particles in perpetual motion. Influenced by Liebnitz and Wolff, he introduced the possibility of a "Philosophia mathematica universalis" to express factual knowledge including that of the brain and soul in mathematical terms. On the threshold of old age when "heaven and hell stood ajar" these dream desires swiftly vanished to be replaced by a completely opposite view that the world of material things merely corresponded to and reflected a spiritual life beyond. Therewith Swedenborg's motivation for research on the brain vanished forever.

In Linneus' youth, public dissections in Sweden were exceedingly few and when he studied medicine in Uppsala, Rudbeck's Anatomy Theatre stood unused and Linneus had to study anatomy in Stockholm. At the end of the seventeenth century, the Collegium Medicum organized public dissections in a large room with an amphitheatre on the upper floor at South City Hall (now Stockholm's city museum). Linnaeus attended the 6 demonstrations that were a part of the fifth and last of these public dissections to be held. On February 11th 1729, when the surgeon Evald Riba Jr. a former pupil of the famous Herman Boerhaave of Leyden demonstrated the anatomy of the eye and brain, Linnaeus aged 22 years was present and took detailed notes which are preserved. Evald Ribe Jr. was 8 years older than Linnaeus who also

became a pupil of Herman Boerhaave. Linneus notes stated that Boerhaave's view was that the function of the white matter was supreme over that of the grey matter, a view which rooted and persisted lifelong in Linneus' mind. Swedenborg had a completely different opinion on this topic, which long afterwards proved to be correct.

Fibres and small globular bodies

The technique of examining the complex architecture of the brain was completely undeveloped until the close of the nineteenth century. Then the microscope with suitable lenses became available and with it the means of cutting and staining thin sections to depict nerve cells, myelin and glial cells. In the time of Swedenborg and Linnaeus there were two procedures by which the morphology of the brain could be obtained. One was to boil parts of the brain in water or oil and from the white matter, bundles of fibres could be prepared which sometimes ran parallel, sometimes converged or diverged or crossed over each other. The other was to inject coloured wax into the blood vessels and visualize the dense network of fine blood vessels in the grey matter. Malpighi, a pioneer in microscopical anatomy thought he saw small rounded oval bodies around the blood vessels and deduced they were analogous to glandular structures which he had found previously in skin, liver and kidney; hence he called these bodies "glandulae". In Swedenborg's texts, they were called "spherulae" or "cerebellula". Clarke and Beam (1968) showed by a method which they termed "practical history" – which states that the original conditions of observation should be recreated as faithfully as possible; they considered the small gobules were artefacts due to inadequate, deformative, processing of the brain tissue. The magnification used, up to 60 times, was actually adequate to identify giant pyramidal and Purkinje nerve cells but the inadequacy of the preparatory techniques made this impossible. What Malpighi and Swedenborg saw or thought they saw in the cortex of the brain was not nerve cells. The defective techniques were incapable of demonstrating the supposed continuity of individual cerebellula and the "white" fibres proceeding from them. It happened however, remarkably enough, that on the basis of these false observations, Swedenborg draw conclusions which experimental evidence some 200 years later proved to be correct. How could this possibly have happened ? We should like to imagine that besides Swedenborg's extensive reading and attendance at anatomical demonstrations, certain personality traits and previous experiences contributed to his amazing deductions. We shall attempt to comment on the latter statements.

Structural and functional organisation of the cortex of the brain

Aged eleven years, Swedenborg (Swedberg before being raised to the nobility) was enrolled as a student at Uppsala University almost half a century after Décartes

died in Stockholm, a victim of influenzal pneumonia. Décartes was one of the most brilliant French intellectuals of the period and was a founder of philosophy and analytical geometry. The backlash of the ardent disputes which raged around Décartes' philosophy in Uppsala had been laid to rest and the mechanical interpretation of the universe and the human frame as clockwork wound up by our Lord had broken through on all fronts except among the orthodox theologists.

Initially Swedenborg devoted himself to the humanities but due to the versatile, learned librarian, his brother-in-law, later Bishop Erik Benzelius, Swedenborg soon became dedicated to the study of the natural sciences of the period. When Sweden in 1710 was ravaged by the plague, the exceptionally gifted, knowledge thirsty youth set out on his first of his big European study travels and it lasted for 5 years. The first three years Swedenborg spent in England where he studied mathematics, physics and astronomy and came in contact with prominent members of the Royal Society including Flamsteed and Halley.

Swedenborg acquired practical knowledge in applied physics in London where he lodged with the clock and instrument maker and in Holland he visited a workshop where lenses were polished. On his return to Sweden, Swedenborg was assistant to Polhem, the brilliant inventor and pioneer in engineering. Polhem with his Cartesian way of thinking and metaphysical bent exerted a strong influence on his young pupil whose talent for mechanical constructions aroused Polhem's interest. It is easy to assume that Swedenborg's knowledge of experimental physics, extensive experience of mechanical instruments and familiarity with the interpretation and design of constructional diagrams influenced his ability to make "mind models" of possible relationships and communication pathways between different parts of the brain. Furthermore, unlike Déscartes who as the basis of his natural philosophy pictured primordial primitive matter as homogeneous, Swedenborg chose the mathematical point lying at the transition between the infinite and the finite in the universe. The association of movements, "tremulationes", with the mathematical outlook gave birth to the three dimensional of the material world, to be interpreted by the senses. Likewise, Swedenborg considered "the immortal soul" to occupy space and to consist of the finest imaginable particles existing in motion. It was therefore reasonable to ask where was the soul located in the body. In accordance with Malpighian's thesis on the 1:1 relationship between glands and the fibres arising from there, Swedenborg considered that all motor and sensory fibres of the white matter of the brain terminated in individual cerebellula and that most of these were in the grey cerebral cortex. The voluntary motor impulses such as tremulations whose fine particles according to the ancient postulation were carried by nerve juice, spiritus animalis, and thought to circulate in nerve channels and were initiated and perceived by the senses originated in the cerebellula of the cortex of the brain. Thus the "sensorium commune" which in Swedenborg's time was generally thought to be located in the brain stem and the "motorium commune voluntarium" earlier located in the white matter of the brain, lay according to Swedenborg in the cortex of the brain which acted as the dominant structure , "the brain itself". Swedenborg went even further in his speculation. He conjec-

tured that each external sensory modality had its internal correspondence in the brain in a group of cerebellula where each individual part was autonomous and has its individual blood supply, part was in association with other cerebellula in groups and with more distally situated groups of cerebellula also such representing other sensory modalities. Each group of cerebellula was arranged in successively larger groups of similar cerebellula corresponding to particular cerebral convolutions and several which had greater but at present indefinable areas of the outer surface of the cortex.

Concerning voluntary motor function, it was shown that a closer localisation was probably demonstrable. The Uppsala anatomist, Ramström pointed out at the beginning of the twentieth century that Swedenborg was well acquainted with Vieussen's surveys which showed that the motor function in certain parts of the body were correlated to the topographical distribution of the nerve fibres in the cerebral hemispheres, medulla oblongata and spinal cord. Swedenborg knew from his literary studies that apoplexy, trauma and experimental lesions of the frontal lobe especially anterior to the central fissure could cause clinical symptoms of paralysis and epileptic fits which were related to the damaged region of the cerebral cortex. Further, on this basis Swedenborg advanced the concept of the inverse representation of voluntary movements in the motor cortex , the face and head movements being represented inferiorly, the trunk and thorax in the middle and the legs and soles of the feet rostrally on the crown. This thesis, which was verified experimentally and by neurosurgery 140 years later, has often been advanced as Swedenborg's most important and first generally appreciated contributions to brain research. It is forgotten however, that Swedenborg was a pioneer also when it came to the localisation of what are now often called "highest level cortical functions". He was concerned with the correlation of clinical and pathological changes involving the psychological functions such as intellect, imagination, judgement, volition and initiative which were located in the anterior and not the posterior part of the brain. Swedenborg regarded emotional life in its entirety and its reflection in conscious sensory and motor reactions as the result of cooperation and integration of myriads of cerebellula throughout the cortex of the brain. Swedenborg also anticipated the possibility of fundamental experimental knowledge of the functional pattern of localisation in the cerebral cortex. He reasoned thus: when each individual muscle fibre is linked by its innervation to an individual counterpart of cerebellula, then the muscle fibres of the fascicles and entire muscle must be represented in the motor cortex by even larger groups of cerebellula. By removal or stimulation of small regions of the cortex, it could be discovered where the different muscles, extensors and flexors are represented in the cortex. There was to be a delay of another one and a half century before Swedenborg's flight of ideas were tested by researchers, that probably had no knowledge about the theories advanced by Swedenborg.

The hierarchical structure of the nervous system

Between 1860–70, John Hughlings Jackson, the doyen of British Neurology, suggested that the seat of voluntary movements lay in the corpora striata, in other words voluntary movements originated in them. Some years later Jackson changed his mind and pointed out that the frontal cortex anterior to the central sulcus was the region from which voluntary impulses proceeded to the various parts of the body. It is interesting to note that in the seventeen forties, Swedenborg had presented the same view as Jackson.

This thought was later verified by applying electrical stimuli to different parts of the posterior region of the frontal cortex in the dog in 1870 (Fritsch and Hitzig), and soon thereafter in man (Ferrier). Another view advanced by Jackson was that the hierarchically active motor part of the brain consisted of a series of layers of phylogenetically different ages superimposed on each other. The lowest and oldest was represented in the brain stem and spinal cord followed by the region of the motor cortex lying anterior to the central sulcus and the last stage lying superior to the above named was represented by the phylogenetically youngest part of the brain the prefrontal cortex. Similar evolutionary ideas of the hierarchical structure of certain parts of the brain have been expressed by MacLean when he introduced the term "triune brain" which includes the brain stem, or "reptile brain", the phylogenetically oldest part which was subordinated to the limbic system which was in turn subordinate to the highest control by the neopallidum, phylogenetically the youngest part of the brain.

Swedenborg had also hierarchical lines of thought which did not stipulate an evolutionary but a functional consideration. He regarded the corpora striata as an intermediary way between the cerebral cortex and the brain stem and spinal cord. Further all automatic and habitual movements such as playing instruments, gesticulating, mimicking, and intonation etc. were transformed as in "Olympia's Mercury" by the corpora striata which not merely controlled all outgoing and incoming impulses intermediary between the cerebral cortex and other parts of the brain, but the striata themselves could also initiate and control motor activities, thereby unloading and freeing the cerebral cortex from stereotyped activities. Swedenborg's view on the physiology of the upper and lower brain stem is also fascinating. He thought he had discovered bundles of fibres proceeding from the cerebral hemispheres, cerebellum and fibres which originated in the brain stem itself and converged and congregated for coordinated activities. In the corpora quadrigemina he postulated a structure which had connections with the optic thalamus, cerebellum and eye and it could regulate the width of the pupil as required; an astonishing intuition foreseeing the efferent innervation of the sense organ, the eye. Swedenborg's speculations are also interesting on the discontinuous course of the motor fibres from the frontal cortex through the white matter, corpora striata, brain stem, spinal cord and peripheral nerves to the muscles and their individual muscle fibres. Swedenborg assumed that "halts" were found at different levels and that the last halts before the muscle fibres were in the anterior grey matter of the spinal cord. Even if it would be an anach-

ronism to suggest that Swedenborg had advanced ideas on the two neurone chain (the neurone theory was put forward in 1891), nevertheless he had views on such an association which would prove to be correct. Likewise, Swedenborg's views regarding the inner organization of the spinal cord, show that they were amazingly apposite. He speaks of fibres which arise in the spinal cord and cross each other and fibres which arise from peripheral tissue and terminate at different levels of the spinal cord-remarkable suppositions on the structural basis for integrated functions of the spinal cord! These extraordinarily important views were first analysed experimentally by Sherrington and are important today in neurophysiological research.

Swedenborg and Einstein, a comparison

The authors while dealing with Swedenborg as a brain researcher, concluded independently that as a researcher (into nature not mysticism) Swedenborg's methods of treating fundamental problems of the physiology of the brain have a certain similarity to Einstein's way of dealing with the problems of cosmic physics. The constituent elements in Einstein's world of ideas were according to himself "Bild und Spiel". The ability to think in pictures and sort them at will into a pattern, a jig saw puzzle which provides a plausible interpretation was probably a personality trait of both. On the intellectual background which gave rise to the theory of relativity Einstein stated in a letter to a well known gestalt psychologist friend: "I very rarely think in words at all. A thought comes, and I may try to express it in words afterwards .... During all these years there was a feeling of direction, of going straight towards something concrete. It is, of course, very hard to express that feeling in words .... But I have it in a kind of survey, in a way visually". Swedenborg's picture of the world since his youth in Uppsala, London and Paris was stamped and governed by laws of mechanics such as those proposed by Descartes, Newton and others.

For many years his practical experience was in the technical field, of water, wind mills, distilling apparatus, plans and constructional drawings. Questions and opinions on "effects, causes and principles" (his own terms) concerned inorganic and organic reality and were stimulated and inspired by the material available whether being machine or the appearance of the human brain on the dissection table or in engravings. Reasoning by the use of pictures induced Einstein and Swedenborg to make models whose accuracy and efficiency had to be demonstrated experimentally. These experimental trials of the soundness of ideas were done usually by other research workers. Einstein's ideas were tested without delay and found successful whereas Swedenborgs' hypotheses lay buried in dusty folios and voluminous manuscripts which few or no one read. They were undisturbed from their prolonged "sleeping beauty" slumber till one and a half century later by which time, their accuracy had been established by others whose background and methods were completely different.

The cerebrospinal fluid and movements of the brain

Swedenborg appears to have been the first to describe correctly that cerebrospinal fluid lies in the subarachnoid space. Hippocrates (about 460-370BC) however mentioned the cerebrospinal fluid in his classical description of congenital hydrocephalus ".... the water around the brain...". Of Swedenborg's more immediate predecessors, Thomas Willis decribed in 1664 that the fourth ventricle was filled with fluid and demonstrated the channel between the third and fourth ventricles, and Valsalva (1666–1723) found fluid "which is similar in every way to that found in the joints" when he dissected the spinal cord of a dog.

In the history of medicine, it is often stated that the cerebrospinal fluid was discovered by the Swiss anatomist, physiologist and botanist, Albrecht von Haller (1708–77), who stated as we know today not fully correct, that the fluid lies extra-arachnoidally, between the subarachnoid and dura mater membranes. Domenico Cutugno whose treatise was published in Naples in 1764 some twenty years after Swedenborg wrote on the same topic and he often gets the honour of being the first to describe in detail the cerebrospinal fluid and its pathways in the brain and spinal cord.

When Swedenborg wrote his work on the nervous system, the general conception was in a not very well defined way, that the fluid sometimes occurred in parts of the ventricular system. In accounts of the cerebrospinal fluid, its location and its circulation were not discussed. In this sphere Swedenborg made his contribution. In the introduction of "De Cerebro" written between 1740 and 1745, a long citation from previous and contemporary literature occurs. On the basis of these writings, Swedenborg then makes his analysis. He asserts that "The fourth ventricle which some of our modern anatomists regard as unimportant, is called by Varolius the principal ventricle. From it, the spiritus lymphaticus (the cerebrospinal fluid) is distributed to almost the whole of the nervous system. This fourth ventricle also makes a noble and highly endowed fluid which is distributed more widely along the length of the marrow and particularly the spinal cord". Swedenborg also considers the cerebrospinal fluid as an extremely refined fluid, the essence of the supreme organ – the brain – and possibly the seat of the "spirit of life". Earlier writers such as Ridley (1653–1708) spoke of the cerebrospinal fluid more prosaically as "water". Swedenborg describes also how liquor is secreted from the choroid plexus lining both sides of the fourth ventricle. He appears also to have been the first to describe the outflow of cerebrospinal fluid from the roof of the fourth ventricle, a membrane which previously was thought to be intact. He makes it clear also that "this fluid which accounts of the barrier provided by the arachnoids membrane cannot be dispersed between the membranes of the brain, but is flowing over the cortical spherules. Thereafter, it (the cerebrospinal fluid) will surround the medulla oblongata and thence flow through the foramen magnum of the skull and run down over the posterior surface of the spinal cord". Further, Swedenborg was the first to observe the central canal of the spinal cord and the presence therein of cerebrospinal fluid. His assertions on the cerebrospinal fluid, do not seem to have been fruits of

philosophy or theoretical hypotheses, but instead based upon well-founded conclusions after scrupulous perusal of the literature and, reasonably, observations.

As stated, Swedenborg considered that the soul had materialistic characteristics, and obeyed the laws of mechanics. He speaks of the soul's elastic membranes which consisted of very fine particles which one day would be studied by the microscope. This "material soul" was nevertheless eternal since it consisted of small indestructible structures, which at death were compressed and gathered by the angels. In these "soul's membranes" to which those of the brain belong, our perceptions arise because of tremors or "tremulationes" in the nerve fibres. Swedenborg had written about this in 1719, "Tremulationes", in a philosophical work in which he wanted to show that life itself and the perceptions consisted of such tremors. This work, shows that at the age of 30 years, Swedenborg had considerable knowledge of anatomy. In a letter to his brother-in-law Erik Benzelius, he refers to "Tremulationes" and explains that he had applied himself thoroughly to the anatomy of the nervous system and membranes of the brain so that he could accomplish his work.

Swedenborg explains in "Tremulationes" that the brain has a "reciprocal or undulatory motion" which should be the cause of the heart's movements. Gradually he abandons this view and points out that the movements of the brain are synchronous with breathing and that the brain expands on expiration and gets less on inspiration. This can nowadays be demonstrated at every surgical procedure on the brain, which expands into the wound when the intrathoracic pressure is raised during respiration. He also states that this movement of the brain will propel the cerebrospinal fluid throughout the nervous system and also serve as a type of pump for the circulation of cerebrospinal fluid. Present-day investigations endorse that the third ventricle to a certain extent has a similar function. Of course, Swedenborg was completely wrong in his conclusions in many instances. Among many other things he thought that the cerebrospinal fluid flowed from the third ventricle via the infundibulum into the hypophysis, and that the fluid had an important role in the formation of blood which, at least so far, is not the case.

The hypophysis – the arch gland

In many respects, Swedenborg's ideas on the function of the hypophysis were visionary. The introduction to "De Cerebro" contains 20 pages on the anatomy of the hypophysis which had been described by Willis and others. The hypophysis consisted of an anterior and a posterior lobe, now called the adeno- and neuro-hypophysis. Hence Willis thought that the gland fulfilled two functions.

In his analysis, Swedenborg thought the hypophysis resulted from the "convergence" of the brain, and was "the definitive organ for the chemical laboratory which the brain provides". Further it – "...receives all the fluid of the brain and transfers the fluid to the blood which it bestows with a special quality vital for all life's processes. If therefore the brain concentrates in this single gland as a definitive goal in its work, the duties fulfilled by the gland must be magnificent, grand

and important for the whole 'regnum animale' – 'animal kingdom' and crucial for its well being. Consequently, the hypophysis can be called deservedly life's gland or the arch gland". Swedenborg continues: – "....the function of the gland is to receive, supply and simultaneously secrete fluids.....".

As seen through our eyes today, we can imagine that Swedenborg had a foreboding of the existence of hormones. This is interesting since till the onset of the twentieth century, the only knowledge of hypophyseal function was that the gland was enlarged in acromegaly. Swedenborg mentions that "the hyphophseal gland has such an important inherent significance and hence it can never be appreciated from the gland itself but seen only in connection with the parts which precede and which accompany it, and accordingly only understood when these are considered". A sort of "feed back system" is described !. Swedenborg held the view that "the product of the brain's secretory activity was an extremely refined lymph which will bestow the blood with its most intimate essence, nature and life". The idea of the brain as a secretory organ, a mucus producing gland was not new; however. It was predominant in Hippocrates' time and in a modified form was reintroduced in the seventeenth century particularly by Marcello Lamplight's in his well known work "De Viscerum Structura Exercitatio anatomica" (1666).

The rediscovery of Swedenborg's anatomical work

Swedenborg's views on the brain and spinal cord had no influence on contemporary or subsequent research on the brain. However von Haller in his second edition of his Bibliotheca Anatomica of 1777 referred in kindly terms to Swedenborg's "Oeconomia Regni Animalis" (1740–41) and "Regnum Animale" (1745). The former was published in Amsterdam under the pseudonym "Aphaneide", the Greek for "The invisible one". The author's name soon became known and the work was published again in 1742 and the new title page bore the author's name, Swedenborg.

There are many reasons why his ideas were never widespread. He held no academic appointment which might have given him the opportunity of presenting his data orally or in writing nor did he ever have any pupils. Except for the above-mentioned treatises, his anatomical work lay unpublished for about 140 years before parts of his writings were edited and published by Rudolph L Tafel, who in 1882 and 1887 compiled two volumes of "The Brain" in English. Swedenborg himself seemed to have lost interest in the anatomy of the brain and after 1745 he was occupied with pure philosophy and mystical works.

After von Haller's mention of Swedenborg's work there is silence in the scientific literature of Swedenborg's anatomical experience until the 9th of April 1845. On that day, the founder of modern anatomical teaching and research in Sweden, Anders Retzius (1796–1860) Professor of Anatomy at the Karolinska Medico-chirurgical Institute held a lecture on "The origin of Anatomy and its development in the Scandinavian north". Anders Retzius states that Swedenborg was a compiler of anatomy and physiology, but except being mentioned by Haller, Swedenborg's

work was unread till recent times. "His (Swedenborg's) Regnum Animale has now miraculously reappeared. It contains ideas belonging to most recent times, in extent, induction and tendency – and can be compared only with Aristotle's. It may be assumed that it will take another decade to appreciate the merit of this work".

Max Neuburger of Vienna, the eminent author of the history of medicine made an important contribution in making Swedenborg's works known by emphasizing their originality and importance in a publication in 1901. Neuburger stressed that Tafel's translations were incomplete and that a great amount of unedited work had been found in the library of the Academy of Science in Stockholm. Neuberger addressed himself to the Swedish Norwegian Legation in Vienna where he expressed his regret that Swedenborg's manuscripts had not been published. The Swedish foreign minister then contacted the son of Anders Retzius, Gustaf Retzius (1842–1919), professor of anatomy at the Karolinska Institute, who was stimulated to deal with this matter. As Chairman of the Congress of Anatomy in Heidelberg in 1903 he recounted how he had dealt with it. Gustaf Retzius declared that Swedenborg's works were not unknown to him, having learnt of them from his father. In connection with his own studies on the nervous system, Gustaf Retzius had studied Swedenborg's Anatomical works in the beginning of the 1870ies and found him to be a very learned and practical man who was-above all-conversant with the current literature on the subject. However, Retzius did not have time to go through the copious material.

The interest for Swedenborg increased in Sweden when Tafel published "On the Brain" in 1882 but receded again until 1901, when under Neuberger's influence Retzius renewed with enthusiasm his attempt to edit Swedenborg's works. Retzius realized that this would entail an excessive amount of time and labour. However, the outlook brightened in 1902 when Retzius met the Canadian Alfred Stroh, a Swedenborg enthusiast both interested in the work on the natural sciences as well as the religious writings. It was Stroh who undertook the deciphering and editing of the manuscripts. The interesting relation between Retzius and Stroh will be described further in the following. In December 1902, at the recommendation of the Academy of Science, Retzius set up a committee of five professors, Christian Loven: physiology, Alfred Nathorst: paleontology-biology, Salomon Henschen: medicine and brain research, Svante Arrhenius: physics and Gustaf Retzius. Stroh was seconded to the committee whose purpose was to examine all Swedenborg's manuscripts and decide in what form they should be published. Since Tafel's death a thorough scrutiny of the manuscripts had not been made. In 1903 Retzius, the chairman of the committee advised the Academy to publish a selection of the earlier unpublished manuscripts and those already published but no longer available. It was recommended that the works on physics, chemistry, and geological paleontology should be published, firstly those on anatomy. The Academy confirmed the motion and publishing was commenced. Stroh accomplished a vast amount of work and on the basis of his translations, a series of Swedenborg's manuscripts were published by the Academy of Science. In addition, with the support of the Academy of the Swedenborg Church's and the Swedenborg Scientific Association in Philadel-

phia. In 1938, there appeared "The Cerebrum" in three volumes by Alfred Acton. The greater part of Swedenborg's manuscripts has been published now even if still more remains unpublished.

In 1908 Gustaf Retzius was invited to give the Croonian lecture to the Royal Society, London. In his lecture Emanuel Swedenborg is mentioned as a pioneer in neuroanatomy and Retzius stressed that Swedenborg's hypotheses were not vague guess-work but clear definite opinions not based on mere speculations but by deep insight into natural phenomena and by actual experiments and dissections. Further, Gustaf Retzius designated Swedenborg "not only as a learned anatomist and keen-sighted observer, but also in many respects an unprejudiced keen and deeply thinking anatomist".

A central person concereded with Swedenborg's research was Martin Ramström (1861–1930), professor of anatomy at Uppsala University. He assembled in several publications Swedenborg's results and made an astute analysis of the sources exploited. Ramström presented an account at the Swedenborg Congress in London in 1910.

Subsequently, Swedenborg's achievements as an anatomist of the brain seem to have been forgotten and only sporadic mention is made of him in the later decades of the past millennium (see David Otto son "Physiology of the Nervous System", 1983, the MacMillan Press Ltd.).

The relation between Alfred Stroh and Gustaf Retzius

The young Canadian, Alfred H. Stroh (1878–1922), had a crucial importance for the research on the works of Swedenborg, and the rediscovery of his manuscripts. He arrived to Sweden, 22 years old, sent out from The Swedenborg Church in United States, supported also from the Swedenborg Society in London.. His mission was , for the account of the New Church founded on Swedenborgs ideas, to trace and copy the original manuscripts written by Swedenborg, in the first place the philosophical and religious. The majority of the manuscripts were known to be owned by the Swedish Royal Academy of Science. He should translate them from Latin to English. He came to spend the rest of his life in Sweden. The fate of Alfred Stroh is fascinating and touching, and deserves its own chapter.

Alfred Stroh was born in Berlin, Ontario, Canada, 1878. His parents, Henry Stroh and Elisabeth Rothaermel Stroh, were of German origin. They were deeply religious, and members of a Swedenborg community. The society was bilingual, and the first language in the home was German. When the next child was born the parents changed to English. Stroh probably has good use for his German language when he came to Sweden. At the age of 16, Stroh studied at a college in Philadelphia, which was and still is a center for the New Church, the religion founded by Swedenborg. He passed the B.A. examination in theology in the year 1902 at the New Church's Academy, Bryn Athyn, Pennsylvania, and graduated as M.A. at Pennsylvania University 1906.

Alfred Stroh came to Sweden 1902. As mentioned above, the same year the Royal Academy of Science had decided to translate, edit and publish Swedenborg's manuscripts on natural science. There were however no individual available, having the knowledge and time to carry out the enormous work required to accomplish this task. But, like as sent from above, the right person, Alfred Stroh, happened to appear in the right time, in the right place!

Gustaf Retzius was at that time one of Sweden's most prominent scientific profiles, and, by means of his marriage to Anna Hierta, one of the richest persons in the country. The first meeting between Retzius and Stroh is a fascinating story, as documented in the Retzius archives. On one of his first days in Stockholm, Stroh visited the antiquarian bookshop Björck and Börjesson, at Drottninggatan. He struck up a conversation with an unknown gentleman, and the discussion became interesting, lively and long lasting. Finally Stroh asked the other person: – Are you a learned man? The gentleman, who was Gustaf Retzius, answered: – Yes. With this, a collaboration between the two, that would last for almost 20 years had started, during which Retzius came to be the mentor and mecenate of Stroh. Retzius at once included Stroh in the newly founded Swedenborg Committee of the Royal Academy of Science.

Probably, Retzius looked upon Stroh as a man for the future. He defrayed in 1903 a painting portraying Stroh, made by Jean Haagen at the Academy of Fine Arts in Stockholm. At the picture Stroh holds a Swedenborg book in his hand, "The Worship and Love of God". Stroh appreciated this book very much, and he had translated it from Latin to English together with Frank Sewall, one of the leaders of the Swedenborg Church.

Stroh worked very hard, and several manuscripts were found, interpreted from Swedenborg's hand writing that was quite difficult to read, and translated from Latin to English or Swedish. Both the Swedish Royal Academy of Science and the Swedenborg Church were happy with the result. Retzius personally financed most of the work of Stroh, and spent extensive amounts of money, more or less a fortune, on the project. Financial support also came from The Swedenborg Church in Bryn Athyn and from The Swedenborg Society in London. It is clear that Stroh made an outstanding, and still up to our days important contribution for the research about Swedenborg. Without him much of the works of Swedenborg would probably not have been found, copied, translated, and published. Except for the numerous publications he produced as a member of the Swedenborg Committee of the Royal Society of Science, he published for e.g. "Emanuel Swedenborg as a scientist" (1908–11), "A chronological bibliography of Emanuel Swedenborg's publications 1700–1772" (1910), and was the editor of "The Swedenborg Archives" 1912–18. He was, together with Retzius, one of the driving forces to bring back Swedenborg's mortal remains from England to Sweden in 1908.

The first successful years passed, and Stroh's Swedenborg project actually grew more and more, and did not come to an end. The financers became over time more reluctant in their support to Stroh. The Swedenborg Church thought that Stroh focused too much at Swedenborg's manuscripts on natural sciences, and Retzius,

Alfred Stroh (1878–1922).

who was not religious, was not so interested in supporting the philosophical and religious ones. This process can be followed in the numerous exchanges of letters between Stroh and Retzius, during 15–20 years.

At the outbreak of the first world war, Retzius lost his faith in mankind, and seems to have fallen into a mental depression. His wife Anna now took over the contacts, and she gradually stopped the financial support. In parallel, the war made the communication with the Swedenborg Church problematic, and the support faded out from that source as well. Stroh's situation became at times problematic.

He became a Swedish citizen in 1915 in connection with his marriage to Signe Elisabet Bergquist. He and the family lived in Stockholm and Uppsala. After some years of compromised health, he died in March 9, 1922. The Stroh family has remained in Sweden, and has continued to give contributions to many fields of the Swedish society-humanitarian, cultural and military. There are many reasons to be thankful for the important contribution Alfred Stroh made to stimulate the interest for Emanuel Swedenborg in Sweden and internationally.

Concluding remarks

Sten Lindroth, in his "History of Swedish Scholarship", stated that Swedenborg as a scientist was too committed to the intellectual climate of his time and hence was forgotten completely. Certainly Lindroth's contention is correct if attention is paid to the old-fashioned language used by Swedenborg to express his thoughts. On the other hand, astonishingly many of his fundamental ideas were elaborated with admirable consistency and have shown that he anticipated later developments particularly in the fields of mineralogy, geology and brain research. They have been confirmed largely by experiments which Swedenborg contemplated and sometimes outlined but could not accomplish because of his peculiar personality and the poverty of technical help in his days. The influence of Swedenborg's ideas on neurophysiology was indeed limited not to say non-existent since they were written in a style lacking the art of composition: he also stammered, hence, verbal communication was difficult. Further, he was never concerned with academic teaching and accordingly had no pupils. Like the well known British astronomer and historian of science, Herbert Dingle, one may wonder whether the chief reason for the non-recognition of Swedenborg was that ".. his eyes were fixed on a point too far ahead. He leaped to the goal by intuition, but was unable to explain the way in such terms that his contemporaries could tread it". Swedenborg relied on his own intuition and the observations of others. He avoided the laborious argumentation which proceeds step by step. A clear distinction between philosophy and science did not exist for Swedenborg who would not have accepted Bertrand Russel's view that – "Science is what you know and philosophy what you don't know". Today the enormous complexity which characterises the intricate structure of the brain, its chemistry and physiology have become all the more evident and entail the cooperation of neuroscientists and philosophically orientated theoretical scientists. To cover this field of knowledge, the term neurophilosophy has been proposed (cf. Patricia Smith Churchland: Neurophilosophy. The MIT Press 1986). Swedenborg can with certain justice be seen as a pioneer in the endeavour to unite philosophy and neuroscience.

Linnaeus' speculations on the nervous system were not founded on any deep insight into anatomy and physiology but as a clinical observer of disturbed cerebral function, his own proud opinion of himself can be accepted that his excellence lay in that he was "one of the best observers we had". An example of his talent is one of the earliest recordings of motor aphasia published in the Proceedings of the Swedish Royal Academy (1745). Although the paths of Swedenborg and Linnaeus seldom crossed, literary connections do exist certainly concerning Linnaeus. According to Broberg (1975), Linnaeus in his lectures to medical students, cited Swedenborg's conception of the movements of the brain in relation to respiration. Broberg also quotes that Linnaeus' view on the foetal development of the nervous system was influenced by Swedenborg's account of the development of the chick embryo. Both were opposed to the time honoured view that the foetus occurs as a completely developed "homunculus" in the fertilized egg and only by growth does it assume the dimensions of the adult.

From observations of the fertilized hen's egg during the first two days of incubation, the nervous system appears as a white streak and is followed later by the two rudiments which fuse to form the pulsatile heart. Both shared the view that ontogenesis involves successive differentiation and the formation of a new organ – expressed in current terms: epigenesis instead of preformation. Linnaeus did not attach any importance to Swedenborg's views of the supremacy of the cortex of the brain. Linnaeus regarded the white matter or marrow as the counterpart of the marrow of plants and attributed to it production, growth, activity, perception of touch and alertness" – in short, life itself. Linnaeus introduced the concept that "encephalum" included all the white matter: that of the brain, spinal cord and peripheral nerves. Since the white matter reached the ovaries of the mother, and was visible in the first 24 hours of foetal life, Linnaeus advanced the hypothesis that the nervous system is inherited from the mother (and all the other organs from the father). It was striking that from these wild ideas Linnaeus' assumption arose of the electrical nature of the function of nerves: "Encephalum is maintained and nourished by essentials for the continuance of life by extremely fine and volatile electrical forces, this Vestal fire which ignites in the first humans and shall burn continuously". Further Linnaeus believed that electricity is taken up from the air when breathing and transported by the lungs and circulating blood to the nervous system and cerebellum where it is stored as in a Leyden jar. Despite these bizarre notions in his outlook, one perhaps may dare to claim that Linnaeus' premonition of the biological significance of electrical phenomena is proof of a similar clairvoyant intuition which characterizes Swedenborg. Not even Swedenborg dreamt of the electrical nature of nervous activity!

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