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THE CORTICAL GLAND AND ITS RELATIONSHIP TO THE MODERN NEURON

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In discussing the relationship between the modern concept of brain cells and the cortical gland as described by Swedenborg, it is not my intention to demonstrate the correctness of his concept nor to give the reader one more example of Swedenborg's anticipation of modern research.

The interest which I have in the subject of the cortical gland stems from such statements, found in the Writings, as:

> They who know these things (concerning the fibers) either from the study of the science of anatomy or from those skilled in it, can see that the beginnings of life are nowhere else than the commencements of the fibers themselves....[DLW 366]

and also:

> What a man thinks, goes through the fibers from their beginnings (in the brain) to their ends; this is the source of the senses. [HH 212]

There is no question that fibers exist and that the soul operates into the body by means of them. It is our desire, however, to study the science of anatomy that we may actually see the operation of the soul illustrated in the natural forms within the brain.

In the anatomical works Swedenborg draws our attention to the fibrous constitution of the brain, saying that the brain is a composite of lesser brains, called cortical glands, each producing its own fiber. But more important, through his doctrine of degrees, he carries us beyond the nerves and the medullary fibers of which the nerves are composed to the knowledge that the cortical gland and the medullary fiber it produces are themselves woven of still finer threads. These finest threads ultimately communicate with the purest and most universal substances in the body, which in turn constitute the interface between the body and the mind.

In the work entitled *The Cerebrum*, we find:

> Nor does nature seem to rest here (at the cortical gland); on the other hand she goes further and produces a substance still purer and of most perfect form, being in turn the cortex of the cortical gland. In other words, nature germinates numerous more subtle spherules. [Cer. 32]

And the fibers exist in corresponding degrees, each fiber being compounded to form the next lower in the series (Cer. 85).

Thus we are to look for fibers and the fibers within fibers in order to discover the essential determinations of the mind within the body.

Understanding and visualizing the cortical gland as presented by Swedenborg has proven to be a challenge to most students of the brain. A detailed summary of the cortical gland, complete with an interpretive drawing, may be found in Hugo Lj. Odhner's *The Human Mind*. In the next section I will review the structure of the cortical gland with respect primarily to the fibrous elements, as they are the base of the present comparison.

The Cortical Gland

In general, there are three degrees of cortical glands, the gland of each degree being a composite of the cortical glands in the preceeding degree. The brain and its appended fiber, the spinal cord, represent the third degree. The cortical gland proper, the one usually referred to by Swedenborg when the cortical gland is mentioned, is the second degree. The cortical gland of the first degree Swedenborg called the *Intellectory*, so named because it is the first abode of the intellect (RPsych. 301).

To understand the configuration and arrangement of the interiors of the glands and their appended fibers, it would be useful to briefly describe their development in the embryo (See Cer. 74).

Swedenborg describes the development of the embryo as a series of discrete stages, the first of which is the delineation of the brain by means of a fluid, the spirituous fluid. As a first step in this process of delineation, the purest and most universal substance, the Intellectory, is formed, a substance which "knows no higher form except what is spiritual..."(R.Psych. 301). And the spiritual acts into this form as its first organ.

These Intellectories form the cortical substance of the first degree. They are not woven of fibers. Swedenborg describes them in *The Cerebrum:*

> But the inmost organic substance, or last organism, does not seem to put forth any fibrils,—and this for various reasons, to wit: because it is the last thing, which, when conceived, at once flows into the recipient and ambient fibers;...[Cer. 83]

Thus apparently fibers, the simple fibers, are raised up concomitantly with the Intellectories by a form of perpetuo-spiral motion, and together they constitute cortical glands of the first or inmost degree, the Intellectories being determined into their use by means of the simple fibers. These first cortical glands are ordered into groups which constitute the simple cortex of the cortical gland proper while the simple fibers gather to form the simple medulla. The adjective 'simple' used in conjunction with these inmost organs may be misleading; and it should be remembered that, while the substances here may be less compound, contained within them is a foreknowledge of the vast complexity of uses later to be represented in the body as a whole. The simple cortex is a highly ordered organ, and the fibers through which it acts are equally well organized.

> The surface of the cortical gland consists of fibrils, the most delicate of all (simple fibers), coordinated together in the most exact manner. [*Fiber* 249]

The simple fibers, having been formed and associated with the Intellectories, proceed under the direction of the Intellectories to weave together and form a composite fiber. The form of the simple fiber is described in *The Fiber* 259:

> Now as regards the form of fluxion of the simple fiber...this form cannot be simply spiral but must be superior to the spiral.

This superior form Swedenborg calls the perpetuo-spiral or vortical.

These simple fibers then proceed together outward, forming the next or compound fiber, which is described thusly:

> As regards the form of the fluxion of the medullary or nerve fibers, (from the second degree cortical glands) this is not simply circular, but is a form superior to the circular, and to be called the perpetuo-circular, or, properly speaking, the spiral. [Fib. 258]

The raising up of the composite fibers from the cortical glands continues. They begin to associate together to form the medulla of the brain itself while the glands constitute the overlying cortex. Thus the brain, or cortical gland of the third degree, has been essentially delineated. It only remains for the arteries to be formed, and ascend upward into the brain, there forming an intricate conjunction with the cortical glands to complete the third and final degree in this series, that is, the brain itself. To effect this conjunction the arteries, in ascending to the brain, ramify into minute capillaries, which capillaries further ramify into capillaries so fine that the red blood may no longer enter them without first being resolved into the finest substances. When these finest capillaries encounter the second degree cortical glands they weave together a membrane covering over the simple cortex and without interruption continue over the fiber as well. The result of this process then is a vast, highly complex and continuous system of fibers, the fibers of each degree being a compound of fibers of the prior or superior degree.

In addition to the fibers and the capillaries or vessels, there also exists a vessel which is emulous of the fiber as in the following:

> Vessels of a middle nature are those stamens of which the tunics of the cerebral arteries consist, and of which the pia mater is contextured. But because they are not fibers nor vessels...but are of another origin, nature and function, therefore we call them vessels emulous of the fiber. [Fib. 167]

and later:

> When the cortical glands have thus been germinated, purest stamens of a like nature, drawn from the pia mater, superadd themselves, forming and weaving the most tender menix of the cortical gland. [Ibid.]

Although it is not my intention to go into a detailed discussion of the spirituous fluid, nor its series of derivative fluids, it must be remembered that the form of any particular fiber is in fact the combined effect of a fluid and its fiber, the fluid being the active and the fiber being that through which the active is determined into its use. In regard to this, Swedenborg says:

> What in itself...is fluid precedes what is solid; for in order that a solid may exist...it must be determined and formed by a fluid and according to the nature of a fluid. Thus every solid must in its infancy have been fluid. The simple fiber is ever in its infancy and flower of its youth, because all other fibers and vessels... exist, subsist, move and live by means of it. Therefore, if the simple fiber were solid it would be impotent of action, and this would be the veriest death of the whole system. [Fib. 295]

The simple fiber then tends more toward a fluid state than a solid state. It must, however, maintain some generally constant form in order that the lower forms may be maintained.

This, then, is the general form of the cortical gland as regarding the disposition of its fibrous elements.

The Neuron

As the neuron is a cell, it may be best to begin with a brief review of the structure of a cell. The cell consists of a nucleus, which is a membrane-enclosed organelle, surrounded by the cell "substance," called the cytoplasm, which is in turn surrounded and enclosed by the cell membrane. These membranes, the nuclear and the cellular, are now believed to consist of lipid molecules derived from fat molecules. Because lipids are made up of fats they act in a similar fashion as oil; they are hydrophobic liquids. The membranes then are essentially liquid in nature and that which holds the membranes in their proper form is, in part, the subject of the present paper. The cytoplasm is filled with organelles which perform various uses to the cell.

The nerve cell, or neuron, is the special cell from which the nervous system is built. It is a cell from which extend many fine processes, termed dendrites, which bring impulses to the cell. A single axon, finer than the dendrites, conveys impulses away from the cell.

The cortex of the brain, the grey matter, consists of cell bodies of neurons and their dendrites, while the white matter is built up from the axons produced from the neuronal cell bodies. The neurons, however, are not alone in the brain. They are accompanied by another cell type called glial cells; in fact, with respect to the glials, the neurons constitute a minority, being outnumbered (some estimate) by a ten to one ratio. The glials are distinguished from neurons by their appearance and their inability to conduct nervous impulses.

The neurons are the first clearly identifiable cells to arise from the primitive neural tube in the developing embryo. Growing along with the neurons are the glial cells, identifiable by their clearer cytoplasm (with relatively fewer organelles than the neuron), and because they continue to divide as they move outward into the expanding brain, while a neuron once produced from its parent cell never divides again. It is this multiple dividing of the glials which causes them to so completely outnumber the neurons in the adult brain. As embryo-genesis continues, the arteries are forming, ramifying into capillaries, and entering the cortex of the brain. The glial cells now produce fibers from themselves, fibers which closely resemble, but are still distinguishable from, the dendrites and axons of the neuron. The glial fibers meet the approaching capillaries and surround them, weaving a membrane about them. These minute fibers also extend out to envelope the nearby neurons, creating a similar membranous coating, and finally reach upward to form a membrane underlying the pia mater. (See "Development of Neurons and Glia," *Journal of Comparative Neurology*, Volume 133). The glial cells thus become interposed between the vessels and the fibers.

Modern investigations into the interior of the neuron, aided by the electron microscope, revealed at first a bewildering array of minute filaments coursing through the cytoplasm of each individual neuron. As study continued, a most remarkable picture developed, a picture of helical fibers flowing through the neuron in spiraling bundles, the bundles or fascicles constantly exchanging the minute threads among themselves, then spreading out to shape the cell and its processes, imbuing its membranes with activity. Filaments are distributed throughout the body, as noted in this research paper:

> Filaments are a universal structure found in all cells. Their structure is, however, more striking in neurons than in other cells. [*Journal of Cell Biology*, Vol. 43]

Minute fibers are not only universal to all cells, but are in fact found universally between the cells as well; and there are many different types of fibers even within a single neuron. Referring to one type of filament found in the neuron, termed the neurofilament, researchers report in another research journal:

> Helical bundles of neurofilaments extend into the finest processes of the axons and dendrites. [*Journal de Microscope et de Biology Cell*, Vol. 24]

Dr. J. Metuzals writes in another journal:

> A neurofilamentous network extends as a continuous, three-dimensional, semilattice structure throughout the ectoplasm (the cytoplasm)...and the perinuclear one...[*Journal of Cell Biology*, Vol. 61]

Most of the research on which the following descriptions are based is that of Dr. Metuzals. In this work he attempted to demonstrate how the cell surface of the neuron is functionally connected to the neuronal nucleus. The belief that there is a connection and communication between these membranes stems from the observation that neurons frequently respond to a nervous impulse by the activation of gene expression from within the nucleus. Dr. Metuzals published his findings in 1974 in the *Journal of Cell Biology*. In his introduction he states:

> At present one of the most important problems in neurobiology is to determine how the activities of the neuronal surface are linked to the genetic machinery in the nucleus of the neuron. A description of the structures and mechanisms responsible for such a transduction is essential for an understanding of the functioning of the neuron.

A filamentous network spreading from the nucleus to the cell surface is, he believes, the structure responsible for this communication. The basic picture he gives us has two thin filamentous membranes woven of fibers called microfilaments. One of these membranes lies beneath the cytoplasmic membrane, while the other surrounds the nuclear membrane. These two membranes are then connected with each other by the neurofilaments. In studying this filamentous network Dr. Metuzals has developed a theory postulating its structure. Although he could not directly demonstrate a continuity between the communicating neurofilaments and the membrane-forming microfilaments, he suggests the possibility that they are indeed continuous. He demonstrates that the neurofilaments are helical or spiral in configuration and that they are produced from the helical intertwining of at least two still finer filaments. These finer filaments are possibly the microfilaments which have unwound to interact with the cytoplasmic filamentous membrane. If this interpretation is true, then we have a situation in which the helical microfilaments surrounding the nucleus intertwine to form a lesser number of helical neurofilaments. The neurofilaments, in progressing outward, "intertwine in a super helix" called a neurofilamentous bundle (or fascicle). On reaching the cytoplasmic membrane they unwind to form the outer fibrilar membrane. Thus there would exist in the cytoplasm one continuous, helical network of fibers and fibrous membranes.

In a later study published in the same journal, Dr. Metuzals makes an extensive examination of the filaments in the cytoplasm of the axon. As one conclusion of this study he writes:

> A continuous three-dimensional network consisting of threadlike elements extends on the inner side of the axon. [*Journal of Cell Biology*, Vol. 78]

He states further that the ability of the axon to conduct a nervous impulse is dependent upon this fibrillar membrane. Other investigators have made similar statements. A report in *The Neurosciences, a Study Program*, states:

> The unique properties of the axon surface membrane appear to be determined by the inner protein component (the filamentous membrane)...responding to electrical or ionic changes with fast conformational changes of the protein molecules.

Conformational changes in one part of our continuous network must necessarily alter the shape of the network as a whole, thus conveying the change to the nucleus.

But what happens to the information when it arrives at the nuclear membrane? It is well-known that this membrane has unusual structures embedded in it known as nuclear pores. Dr. Metuzals postulates a connection between the cytoplasmic fibers and these pores. Besides providing a means of transporting large molecules between the nucleus and the surrounding cytoplasm, the pores may serve as mechanical junctions between the cytoplasmic fibers and the interiors of the nucleus.

In a recent study of the nuclear membrane involving a new method of preserving nuclear structure, a group of scientists found a fibrous network lining the interior surface of the nuclear membrane, which until then (1978) remained undetected. They report the following:

> This surface (the inner nuclear) appears as a fibrous network...overlaid by particles. Chromatin strands, which can be distinguished from the fibrous network by their characteristic beaded appearance, are occasionally found associated with the inner surface of the nuclear envelope (membrane). The fibrous matrix is interrupted by holes with diameters (approximately the same) as the diameter of the pore complexes. [*Journal of Cell Biology,* Vol. 77]

Once again we find fibers weaving a membrane adjacent to an outer lipid membrane. This intricate membrane apparently communicates with the chromatin fibers. The chromatin fibers are extremely long fibers which, when a cell divides, condense down into the familiar chromosomes associated with heredity. The disruptive process of division, however, does not occur in the neuron. The chromatin fiber is a long double helix of deoxyribonucleic acid (DNA) which is essentially encased in protein. That the chromosomes hold the hereditary information is a well-established idea. In them is contained all of the information necessary for the formation and maintenance of a living cell and the body as a whole. But do they serve another use as well?

Synthesis

We have seen from Swedenborg's philosophical and theological works that the mind operates into the brain by means of a complex and continuous network of fibers, the smallest or most interior of which is called the simple fiber, this simple fiber, in conjunction with the Intellectories, weaving the cortical gland and continuing on to form the medullary fiber. The medullary fibers, in descending into the body, fasciculate into nerves and the nerves form the arteries, heart, and the rest of the body. The arteries return then to form the arterial meninx of each cortical gland.

In looking at the modern information we find something analogous to an arterial meninx, but it is altogether lacking a direct continuation of the arteries into the neuron. As described above, in the section on the cortical gland, the cerebral capillaries diminish into minor capillaries which ultimately engage the cortical gland. Although anatomically dissimilar, the developmental and functional order in the neuron is the same, with the glial cells remaining quiescent until the arrival of the capillaries and only then elaborating their membranous coating of the neurons. But further, the glials release from themselves substances, which then are formed into still finer filaments between the neurons and the glial covering (*Journal of Supramolecular Research*, Vol 11). Further research will have to be done before the arrangement and function of these filaments will be understood. Without question the glial cells are intermediaries between the capillaries and their neurons, clearly distinguishing themselves as vessels of a middle nature which are emulous of the fiber. And the extraneuronal contribution of the membranes and the filaments by the glial cells is in accord with the order and form of the cortical glands. Thus the modern study suggests that there are discrete degrees, the neuron being prior to and discrete from the vessels, while the physiological works of Swedenborg would have continuous degrees. That the vessels are continued into the cortical glands is, however, not mentioned in the Writings themselves.

Proceeding more interiorly into the neuron, we have seen a complex network of fibers. In the neuron, however, again we do not see a continuous series of compoundings from a unit simple fiber to form all succeeding degrees of fibers. Instead of continuity there is contiguity, for there are fibers in the nucleus which are apparently discrete from those in the cytoplasm, while the fibers of the cytoplasm are discrete from those found outside the neuron.

If we include the external fibers found between the neurons, then a series of three discrete degrees exists which is in accordance with the doctrine of degrees. And although this system of degrees differs from that given in the philosophical works with respect to the one simple fiber, yet it is similar within each of the successive degrees, because the fibers of each degree have their own simple fiber out of which the succeeding or grosser fibers in its degree are formed; thus in the cytoplasm are the microfilaments, which join together to form neurofilaments, which then join to form the bundles. That the chromatin fibers are of a different composition from the fibers of the inner filamentous membrane presents a problem in this regard. But that subject is relatively new and needs further study which may resolve the difficulty.

That the proper functioning of the mind is in some way dependant upon the filamentous structure of the neuron is, in addition to what has already been mentioned, suggested by means of diseases such as Supranuclear Palsy and Alzheimer's Dementia, diseases which rob their victim of the ability to think or act rationally. Upon examining brain biopsies of such patients, massive tangles of neurofilaments are found, which are clearly aberrant from the normal state of the fibers (*Acta Neuropathologia*, Vol. 48). Thus the mind's rational operation appears to be dependant on the intact cytoplasmic filament network. In addition to the neuron's dependance on the filament network for its nervous activity, it also depends on it for the exact shape of the cell body and its processes. The outward growth of the axon and dendrites toward their proper locations within the brain is an active process of the filaments, bringing to mind such statements as: "For from the simple cortex arises simple fibers which arrange the gland by their own determinations" (RPsych. 126).

It still remains a mystery how the axon of a neuron finds its way through the dense maze of the brain to its ultimate target cell.

We have shown that the chromosomes are long, helical or spiral fibers communicating with the highly organized fibrillar membrane enveloping them, that in turn these fibers communicate through the nuclear membrane with the perinuclear cytoplasmic filaments, which in turn radiate out through the entire neuron, reaching to the cytoplasmic membrane where they either communicate with or actually weave the final fibrous membrane. Dr. Metuzals, then, suggests that the activity imposed upon the cytoplasmic membrane is transmitted into the nucleus by means of this fibrous structure. In the nucleus the chromosomes are induced to activity, activating the genetic machinery and beginning the chain of events associated with genetic expression. After the gene expression the chromosome fibers have completed their function in this system. This suggests a one-way influx. But could there not be another use for this vast complex, communicating network as well? It may be possible that the communication is two-way. Now, the activity imposed on the chromosome fibers would originate from within the nucleus, thus acting back through the same fibrous system to influence the cytoplasmic membrane. This influence then may be to either control the incoming information, or excite the cytoplasmic membrane to send a nervous impulse without any external stimulus. This would confer the control of the nervous activity to the neuron itself as an active process rather than a passive response.

The subject of the motion of the cortical gland was also of primary importance to Swedenborg. The first sixty-eight numbers of the second part of *The Economy of the Animal Kingdom* are devoted to a treatment of this motion. The idea of such a motion is believed today to be false. Returning, however, to Dr. Metuzal's recent work, he states:

> They (the neurofilaments) are associated with each other...through intercoiling, intimate contacts and interchange and appear to be helically ordered. A network of this type may produce a torque on the cell body. [*Journal of Cell Biology*, Vol. 61]

A torque suggests a motion, in this case, a helically-oriented motion. This tells us that there exists a basis for motion within each neuron and consequently for the brain as a whole. Nonetheless, a motion in the brain that is clearly distinguishable from the pulse of the cerebral arteries has not been detected.

Conclusion

Swedenborg's concept of the cortical gland has drawn our attention to and has shed light upon the importance of the helical fibers found not only in the brain but throughout the entire human body. By the aid of such modern developments as the electron microscope, we have been permitted to see more deeply into these hidden forms than Swedenborg thought possible, and with such detail that a far greater understanding of the operation of the mind into the body now appears possible. Almost all of the information concerning the fibers within the neuron is the product of work done in the last decade, and the rate at which research is done, in the coming decade it will be still greater. From our doctrine we know that:

> Universal nature is a theatre representative of the Lord's Kingdom in the Heavens; thence of the Lord's Kingdom on Earth, or that in the Church; and thence the Lord's Kingdom with every regenerate person. [AC 3942]

Hence, the more perfect our knowledge of this "Theatre," the more abundant will be the material clothing for our spiritual understanding of the Lord's Kingdom on Earth, and therefore of Heaven. ■