

Usually our articles on the history of physics describe ideas or people whose contribution to our modern views is obvious and direct. Here's an article about a very intelligent and influential thinker, a contemporary of Newton who was familiar with the Newtonian world view, who nevertheless saw and described experience in a way that we now consider to be very strange and unproductive. All of us who teach physics should be aware that our modern science is a very thin veneer, and that its methods and assumptions are not universally held or apparent.

Emanuel Swedenborg - An 18th century cosmologist

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The Newtonian method of describing nature with the substantial aid of mathematics has become traditional and dominant in physics. Yet during Newton's era the mathematical method was only one of several in science. A second was the empirical method involving observation and experimental work as advocated by Bacon (and also practiced by Newton). Both of these traditions have persisted and correspond approximately to the present day practice of theoretical and experimental physics. However, there was also a third tradition at least as old as either of the others but less overtly evident in modern physics. This method might be called the philosophic or rationalist approach. That is, philosophers of nature would hypothesize systems of nature or cosmologies, by reason alone, without the help of extensive calculations or experiment. Such rationalist cosmologies appear early in the history of thought: for example, the atomic theory of Democritus,¹ and continue to flourish even into Newton's era with the vortices of Descartes and the monads of Leibniz.²

Because the rationalist cosmologies lacked the ingredients of mathematization and experimentation their impact on the development of physics is indirect. (For example, the vortices of Descartes are generally not discussed in a physics curriculum today.) Yet the natural philosophers did provide a sphere of inquiry and speculation out of which modern science flourished. And furthermore, in as much as the modern physicist desires to see beauty and coherence in nature he exhibits characteristics of a rational cosmologist.

In this paper we present a rationalist cosmology developed by the 18th-century Swedish philosopher Emanuel Swedenborg, together with a biographical note. Some commentary will be made on the relation of Swedenborg's ideas to contemporary views of nature. In following this program we hope to contribute to an increased awareness of our intellectual history.

Biographical note

Emanuel Swedberg was born in Stockholm, January 29, 1688, the son of Jesper Swedberg, a prominent clergyman, chaplain to the royal family and later bishop of Skara, and Sarah Behm Swedberg who later died when Emanuel was 8 years old. (In 1719 the family name was changed to Swedenborg by a royal act of ennoblement customarily bestowed on the families of bishops.)

Apparently Swedenborg was quite bright and entered the University of Uppsala (Sweden's pre-eminent university) at the tender age of 11, in the year 1699. At that time Sweden was somewhat removed from the main intellectual climate which shaped ideas in the more southerly parts of Europe, but in 1649 Queen Christina had persuaded the famous rationalist Rene Descartes to join a group of leading intellectuals which the queen was forming in Stockholm. Although Descartes died the following year, "as a result of the Swedish climate and the rigorous schedule demanded by the Queen,"³ his ideas soon generated controversy between the theologians and the more liberal minded philosophers. When Swedenborg arrived at Uppsala the atmosphere had cleared somewhat with the faculties of medicine and philosophy (the latter including science and mathematics) able to pursue their research less impeded than in the past by men of theological orthodoxy. Swedenborg enrolled in philosophy and, during his ten



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years stay, studied Latin, Greek, Hebrew, classical literature, mathematics, and natural science. At his graduation in 1709 he read his thesis entitled "Selected Sentences from Publius Syrus Mimus and L. Annaeus Seneca," typical in that it defended one of his professor's classical views. The work follows in the footsteps of his father's classical approach rather than anticipating Swedenborg's later studies in science.

As was the custom of those times, Swedenborg followed his formal education with travel abroad, especially to England where he was to stay two and a half years. He found lodgings in the homes of tradesmen: a watchmaker, a cabinet maker, and later a manufacturer of brass instruments. Swedenborg studied these men's crafts and increased his proficiency with the English language until he felt ready to use his letters of introduction to some of the noted English men of learning. He spent a great deal of time with John Flamsteed, the royal astronomer and director of the Greenwich observatory. During this period one of the great practical problems was the determination of longitude when navigating at sea and the young Swedenborg took up the challenge with energy. He proposed a method based on lunar positions but the appropriate tables were not available and his scheme was held to be impractical.

Swedenborg traveled to Oxford to confer with the astronomer Edmund Halley (eventual successor to Flamsteed) on the longitude problem, but apparently Halley discouraged Swedenborg, again on the basis that the lunar orbits were not sufficiently well known. (In 1718 Swedenborg dedicated his short treatise "Finding the East and West Longitude by means of the moon" to Halley.⁴ It is interesting to note that Halley was also responsible both financially and otherwise for the publication of Newton's *Principia*.)

One could hardly be interested in scientific studies in England of the early 18th century without being cognizant of the *Principia* of Isaac Newton. Uppsala, on the other hand, was still essentially Cartesian in its view of the universe, a completely filled universe with continual circular and vorticular motion of all its parts. Cartesian philosophy had no place for the Newtonian vacuum or the action-at-a-distance type of force suggested by Newton's theory of gravity. While in England, Swedenborg did study Newton's work. In correspondence with his brother-in-law, Eric Benzelius, Swedenborg wrote, "I read Newton daily and I wish to meet and to hear him."⁵ Then later, in discussion of the longitude problem, Swedenborg reported (possibly referring to Book III of the *Principia*) that "Newton has laid a good foundation to regulate the irregularities of the moon; he has not, however, given out tables but a bare theory."⁶ The tables he wanted were probably those needed to make practical Swedenborg's own solution to the longitude problem. Later one of Swedenborg's professors at Uppsala wrote to him asking "What the learned mathematicians think of Newton's principles concerning the motion of the planets, inasmuch as they seem to be pure abstraction and not physics, namely as to how the one body of the planet shall gravitate to another, etc., which seems to be unreasonable."⁷ Swedenborg sent a reply through a letter to Benzelius, "Prof. Elfvius asks the judgment of Englishmen concerning *Newtonii Principia*, but in this matter may no Englishman be consulted because he is blind when it comes to his own countrymen and it were a crime to bring them (Newton's principles) into doubt."⁸ Perhaps this last quotation reflects Swedenborg's growing

frustration with the lack of acceptance for his longitude solution among English scientists. Despite this exposure to Newton's work the very different Cartesian view was to remain a primary influence in Swedenborg's cosmology.

Swedenborg eventually left England for further travel and study in France and Holland. In Holland he learned the art of glass grinding for the purpose of constructing a microscope. He was especially impressed with the newly built brass quadrant at the observatory in Leiden, and hoped to return at a later time to make a series of lunar observations to establish his solution to the longitude problem.

Upon his return home Swedenborg contributed significantly to the vitalization of scientific life in Sweden. In 1716 he began publication of *Daedalus Hyperboreus*, Sweden's first scientific or technical journal. As well as presenting many of Swedenborg's projects this journal included the inventions of Christopher Polhem who was Sweden's foremost mechanical talent at that time. King Charles XII took official note of Swedenborg's mechanical interests by appointing him to the Royal Board of Mines as assessor *extra ordinem*.⁹ During these next two decades Swedenborg published many works, ranging from short papers to books, such as his *Algebra* (the first algebra book published in Swedish.)¹⁰ His views on the physical world eventually crystallized in a work entitled *Principia* and subtitled *The First Principles of Natural Things*¹¹ published in 1734. It is this work, containing the general outline of Swedenborg's cosmology, which is described in the next section.

Cosmology

Swedenborg begins his *Principia* with a prescription for the attainment of wisdom in natural philosophy. The ingredients are experience, or accumulated factual knowledge; geometry, in the general sense of symmetry or patterns; and reason, which achieves the synthesis of experience and geometry. With this method as an ideal, he formulated his world views. (In fact Swedenborg, like Descartes, appears to downplay somewhat the "experience" aspect in that there is little reference to observation in the development of his views.)

Swedenborg's cosmology is a description of nature from two perspectives which are then related to each other. First he pictures the microscopic world as a system of elementary corpuscles or particles. Then this microscopic world is incorporated into a model of the evolution of the solar system from the sun.

A. General structure

The physical world is considered to be arranged in levels of increasing complexity. At the deepest layer Swedenborg proposes a starting point or link connecting the material and immaterial worlds. This connection is labeled the "First Natural Point" – natural because it is of the material world and a point in the sense of a mathematical point. Swedenborg has trouble formulating a precise description of this Janus-like object which faces both the physical and unphysical world simultaneously. The first natural point plays a role even more fundamental than the atom of Democritus or the monad of Leibnitz. This first entity is barely material, a primitive concept which stands beyond definition. Yet as a starting point it is, in Swedenborg's view, a philosophical necessity.

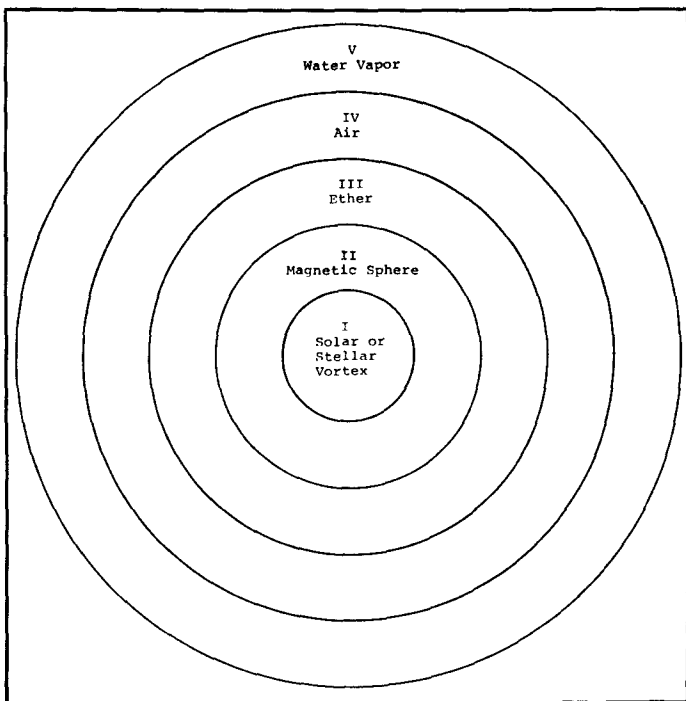


Fig. 1. Hierarchy of elements in Swedenborg's cosmology. The concentric circles are meant to illustrate two features. First the idea of levels in nature is represented, somewhat analogous to a modern hierarchy such as proton, nucleus, atom, molecule, and so forth. Second, the circles indicate Swedenborg's geography of the solar system in which planetary material of elements IV and V is separated from the stellar material I and II, by an Ether element. Swedenborg's terminology is used for labeling the elements.

Once the first natural point is established the various levels can be built up. The major categorization is in terms of the "elements" shown in Fig. 1 where the evolution of the solar system starts to become evident. Stellar objects in

general and the sun in particular are composed of "first element particles" in a state of extreme vortical motion. The grosser elements of nature emanate from stellar objects, eventually giving rise to the elements of air and vapor which are considered to be primitive substances for the planets. With this hierarchy in nature, Swedenborg seeks not only to explain the deeper levels but also to give a geography to the levels.

B. Construction of the elements

While the main ingredients of Swedenborg's cosmology are the "elements" which have their origin in the first natural point, there are also intermediate substances or building blocks which help to generate the series of elements. The first natural point is a mathematical point and therefore Swedenborg suggests a transition particle called a "finite" which develops from the motion of the first natural point. This finite is the first thing which is definitely placed in the material world and, unlike the first natural point, the finite is definitely considered to be a physical object. In the construction of the "first element" Swedenborg is not content to simply lump finites together. Instead he postulates inner and outer sections of the element particles and suggests that these parts are composed of finites in two different modes. As represented schematically in Fig. 2 the finite either occupies a larger volume in space through high speed motion or it may (by an unstated mechanism) be compressed to a "passive" state referred to as the "second finite." The latter mode for the finite makes up the covering of the element and the former "active mode" provides the element's interior substance. In this way Swedenborg achieves structure for his first or solar element.

Swedenborg also uses the notion of the finite as an intermediate step for the construction of the other elements. However, he supposes that the more interior ele-

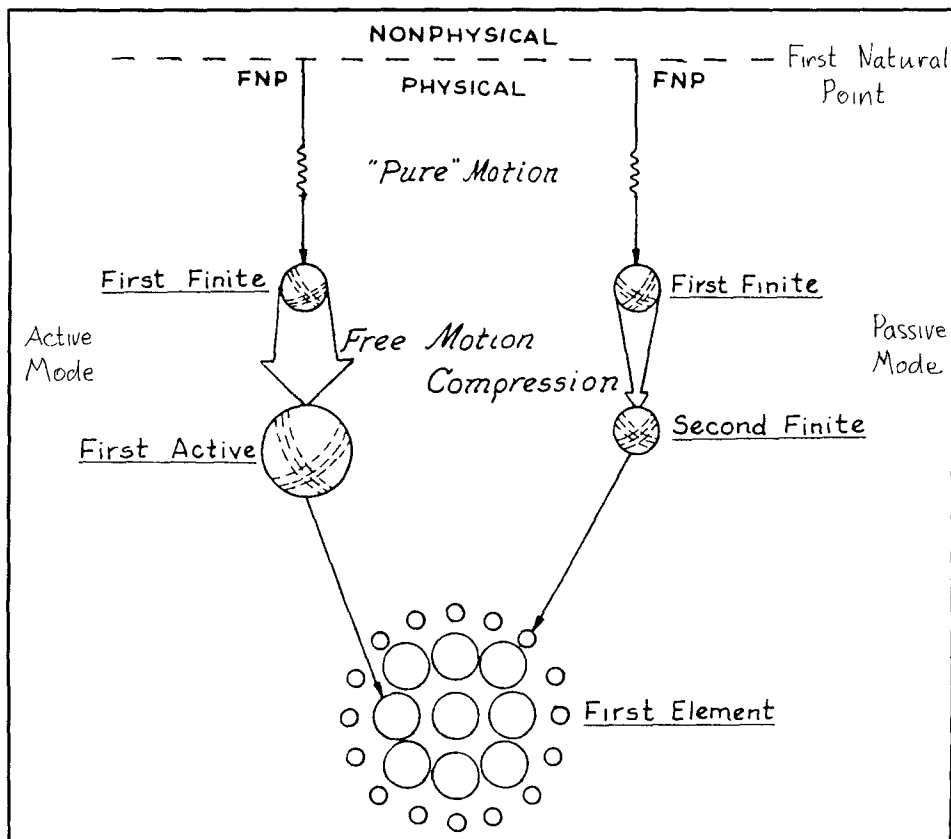


Fig. 2. Development of the first element from the first natural point. The finites are generated by the "pure motion" of the first natural point. In turn, the finites become the components of the element. The first element undergoes modification to become a grosser finite which will be part of a grosser element. The process continues in this manner through the construction of the five elements.

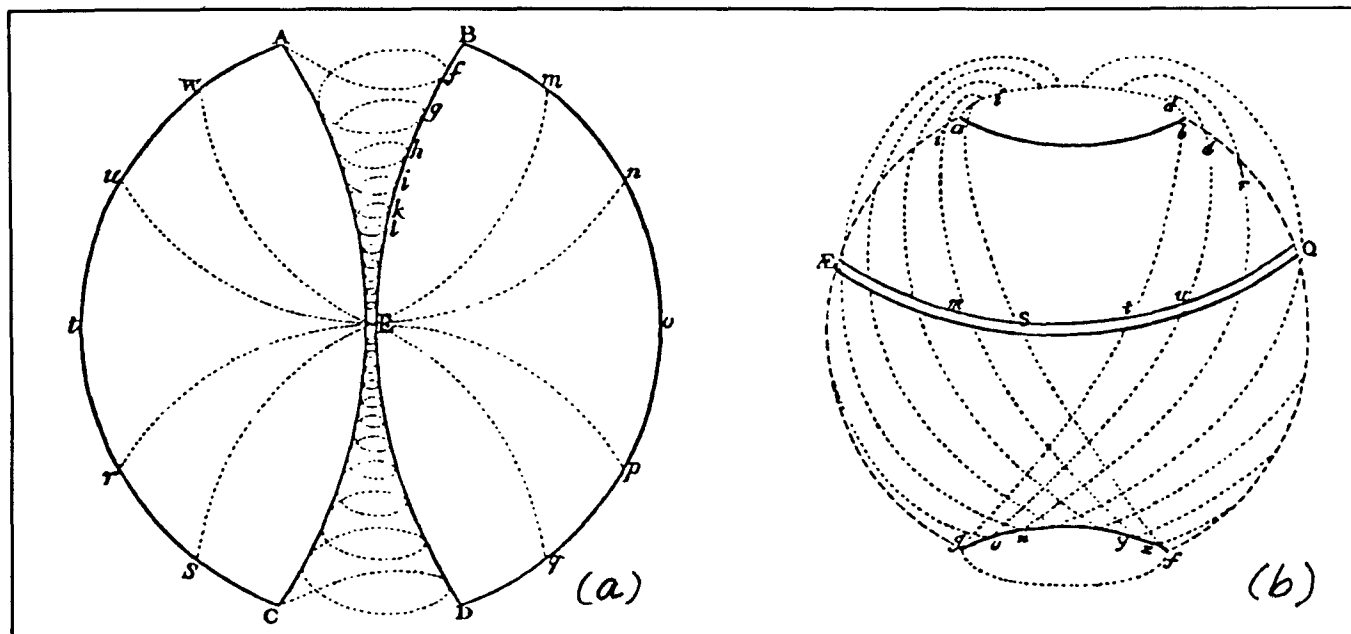


Fig. 3. An inside (a) and outside (b) view of the geometry of the finite "particle" as found in the *Principia* (reference 7, Vol. I, p. 173 and p. 191). These two diagrams were reproduced in the work by J. G. Burke, *Origins of the Science of Crystals* (University of California Press, Berkeley, 1966), p. 47; but were identified differently as an element and active respectively. However, the discussion on pp. 189-192 of the *Principia* seems to support the present interpretation.

ments become the finites, again in active and passive modes, for the composition of the grosser elements. (As before the mechanism for the modification of the finites into their modes is not specified.) In this way a chain of compound elements is developed from the stellar particle down to the vapor particle.

C. Motion

Like others, Swedenborg viewed motion as a fundamental property of the universe. He first introduced a kind of potential motion or "pure and total motion"¹² for his first natural points. However, this motion is hardly physical since the points themselves are more metaphysical than real. Nevertheless it is the motion of these points which apparently generate the shape of the finite particle as shown in Fig. 3. This figure depicts a spherical envelope as the outer boundary of the finite as well as a spiral motion which goes into a vortex at the poles as the motion continues inside along the axis of the poles. Swedenborg describes the shape as having "an equator, ecliptic, meridians, and their perpendicular circles."¹³ Probably his earlier work on the longitude problem had a pronounced effect on his notion of the appropriate geometric form.

The general form of the motion in the grosser elements and finites seems to be approximately the same as that of the first finite particles. However, as more particles aggregate in the grosser elements there is a compression of the constituent particles and a subsequent reduction in the energy of the motion. For example, the solar-element particle would be much more active than the vapor-element particle. However, the entire schema is based upon continual and connected motion by all the parts, a kind of dynamic equilibrium.

D. Planetary evolution

In the chapter entitled "Solar and Planetary Nebular Matter" Swedenborg describes a theory of the evolution of the solar system somewhat within the context of his scheme of elementary and finite particles. In characteristic

fashion, he reasons that the planets must have their origin near the sun. "This may in some measure be deduced *a priori*; as for instance, that the sun is the first moving power in its universe; that it is the parent of its own vortex; that everything in the vortex owed its origin and subsistence to the sun . . ."¹⁴ As indicated in Fig. 1, the solar vortex was initially surrounded by "magnetic" second-element particles which rotate with the same period as the solar vortex. Through a kind of compression the second-element particles become finites of a grosser order. These finites form a shell around the solar vortex which gradually moves away from the sun and develops into a "zodiacal circle" which "surrounded the sun like a belt or broad circle."¹⁵ The belt continues to be stretched until it breaks rather abruptly into large and small pieces. Figure 4f is a reproduction of Swedenborg's drawing of the belt. Planets and satellites are evolved from the large pieces, and the small pieces, which are assumed to fall back toward the sun, Swedenborg refers to as "erratic bodies straying around the sun, such as we are accustomed to call solar spots (sun-spots)."¹⁶

Swedenborg suggests his theory of planetary evolution as a general mechanism to explain the appearance of new stars. For as the planetary material leaves the solar vortex the star becomes visible to the observer. As evidence for this he quotes part of the work *Astronomiae, Physicae and Geometricae, Elementa* written in 1701 by David Gregory, Savilian professor of astronomy at Oxford. Gregory's book cites the observations of new stars by many workers including Tyco Brahe and Kepler.¹⁷

Finally, Swedenborg considers his cosmology to be universal and he states a primitive cosmological principle as follows. "Nevertheless, in every world-system, the principles are the same; and also nature and mechanism, as to first principles and motive forces; the diversity consists only in the diversity of the series, in respect to degrees, ratios, and figures."¹⁸

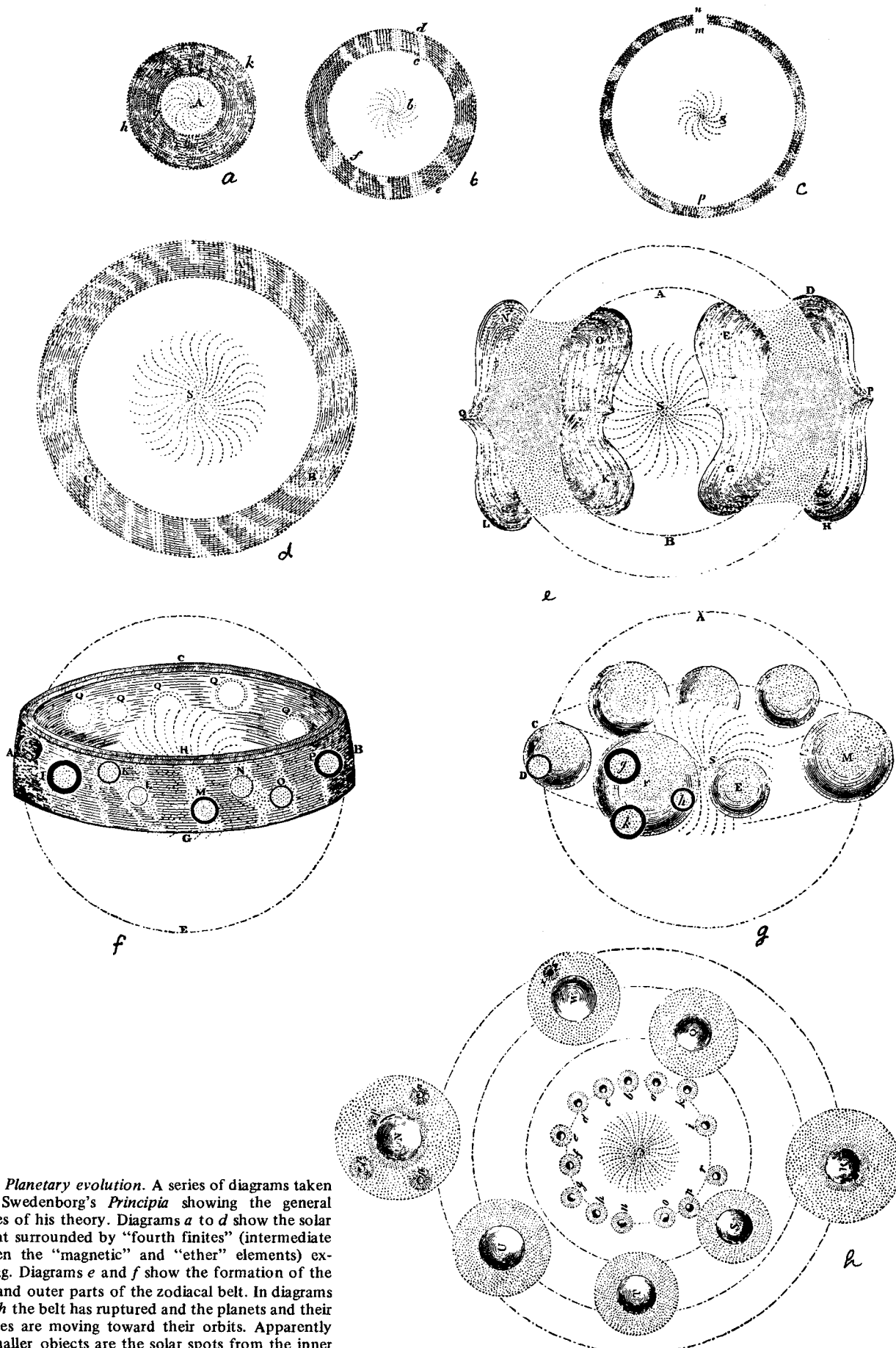


Fig. 4. Planetary evolution. A series of diagrams taken from Swedenborg's *Principia* showing the general features of his theory. Diagrams *a* to *d* show the solar element surrounded by "fourth finites" (intermediate between the "magnetic" and "ether" elements) expanding. Diagrams *e* and *f* show the formation of the inner and outer parts of the zodiacal belt. In diagrams *g* and *h* the belt has ruptured and the planets and their satellites are moving toward their orbits. Apparently the smaller objects are the solar spots from the inner belt.

Appraisal

It is clear, even from this brief description, that Swedenborg's structure of elements does not fit, in any exact sense, the models of present-day elementary particle physics. Furthermore, his theory of planetary evolution, based on the elements seems vague and lacking in empirical support. However, Swedenborg's work should be viewed in the context of the contemporary natural philosophy, and most noteworthy in this regard is the essential agreement of Swedenborg's rational cosmology with the previously developed Cartesian world view. Both Descartes and Swedenborg proposed a filled universe or plenum of several elements. Both men described mechanisms for planetary evolution, with special emphasis on the vortex as a primary motion in nature.

Yet Swedenborg's work did contain elements of originality. He worked hard to describe the "first natural point" as the connection between the physical and non-physical worlds. Swedenborg saw this starting point as logically important to a world system and representative of the absolutely deepest parts of nature. The Swedenborgian system of elements is more complex than the three-element system of Descartes. While further complexity does not necessarily imply progress, Swedenborg's scheme of elements with their inner and outer parts, and their construction through the intermediate steps of the finites, is an attempt at greater differentiation of levels and motion in nature. An analogous set of levels occurs in physics with the proton, nucleus, atom, molecule, and lattice, together with their different associated ranges of energy (from billions of electron volts down to a fraction of an electron volt.)

Perhaps most intriguing is Swedenborg's theory of planetary evolution. A prominent theory of planetary generation is the Kant-LaPlace nebular hypothesis of the gradual evolution of planets from the sun. Both Swedenborg and Descartes proposed theories which resemble this hypothesis but whereas Descartes' planets developed from their own interior suns,¹⁹ Swedenborg's planets broke off from the belt of matter which spread from the sun. Therefore Swedenborg's theory is closer to the nebular hypothesis and was published some 20 years before Kant presented his thesis in 1754.²⁰ The Swedish physical chemist Svante Arrhenius noted this priority in his work on the history of cosmology,²¹ but Swedenborg is not always mentioned in connection with the origins of the nebular hypothesis.²²

There are limitations in Swedenborg's work on natural philosophy. His style of writing is often lacking in clarity, at least from the viewpoint of the modern reader. Perhaps more surprising is the fact that despite his admiration for Newton, Swedenborg does not incorporate Newton's methods or ideas into his work, and his attempts at mathematization of concepts are unproductive. Furthermore, the Cartesian influence is so clearly evident in the *Principia* that it is often difficult to delineate the extensions and modifications which are Swedenborg's own. Yet these shortcomings do not erase the value of the original contributions he did make.

Epilogue and comment

By 1740 Swedenborg seemed to have lost interest in the exclusive consideration of the physical world. He turned to medical sciences concentrating on the blood and especially on the brain. His work on the cortical localiza-

tion of mental activity, the importance of the pituitary gland to the body's economy, and general observations on the nervous system are regarded as important developments in physiology.²³ In all this effort Swedenborg was particularly concerned with the connection of the finite to the Infinite – a connection alluded to in the *Principia* but now approached through a consideration of human neurology as the biological foundation of the human soul. In the final period of his life, from about 1745 to 1772, Swedenborg dropped his scientific work altogether and concentrated on religious studies, the effort for which he is best known today.

Acknowledgments

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22. But note the following quotation: "Not until the middle of the eighteenth century did astronomers consider the possibility that the stars might be arranged into a system of one or more 'Island Universes.' The very remarkable works of Thomas Wright, Immanuel Kant, Jean Lambert, and an even earlier work by E. Swedenborg, are *by now too well known* [italics added] to require more than mention." From J.D. North, *The Measure of the Universe* (Oxford University Press, Oxford, 1965) p. 3.
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