so many practical men." The same can be said and for the same reason in 1972.

You will have noticed from this brief essay that Swedenborg always treats money as a means of exchange or a measure of value.

It is perhaps fitting to end with a quotation from the *Spiritual Diary*, 2450, of 30th June 1748.

Swedenborg writes, "I spoke with spirits concerning the possession of money without use. Certain spirits are of such a character derived from the life of the body, that they wish to possess money for money's sake, not for any other use. . . . When I have inquired, on account of what use, whether on account of garments, houses or food, they have said that on account of delight at the sight of monies, silver and gold, therefore on account of no use from these. Such a cupidity is called avarice, and is most base, because most gross; *for money is for the sake of use.* . . ."

BEYOND THE LUMINIFEROUS ETHER

GREGORY L. BAKER *

INTRODUCTION

There is little doubt that the role of atmospheres and auras is central to the philosophy of both the scientific and theological writings of Emanuel Swedenborg. The entire process of creation and the consequent existence of spiritual and natural life clearly have their basis in the various spiritual and natural atmospheres.

In this essay we will be concerned with the questions and problems related to that atmosphere which is known as the ether; the medium of electromagnetism or light. An attempt will be made to give a summary of Swedenborg's ether as outlined in his *Principia* and later in the Writings. Following this description we will trace some of the main developments in the theory of the luminiferous ether; a theory which exerted a strong influence on the thinking of physical scientists for over 300 years. The final section of this essay will contain some relevant results of modern physical theory and some speculations which we hope are not completely idle.

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Our interest in the ether is derived from a wish to determine if Swedenborg's thoughts contained the seeds for a larger and more complex description of the reality of nature. In other words, are there constructs in scientific thought which can be related to the ether concept and therefore provide further insights into the nature of the physical world? Practically all modern physicists reject the ether concept as irrelevant and totally unnecessary. We propose to examine the validity of this proposition.

Before proceeding to the discussion itself, it is useful to obtain some perspective on the subject with a perusal of the New Church collateral literature. Interestingly enough most of the articles were published after some of the implications of Einstein's relativity theory became known in the Church. Einstein's work seemed to be especially revolutionary in view of the following quotation taken from the introduction of his first classic paper on relativity; namely "The introduction of a luminiferous ether will prove to be superfluous. . . ." [1]

Wilfred W. Howard published several articles in THE NEW PHILOSOPHY [2] attempting to show the continuing validity of Swedenborg's ether in view of the Michelson-Morley ether drift experiment. Numerous quotations of the positions of several British etherists are given to bolster the scientific concept of ether. Notable among these physicists is Sir Oliver Lodge who led the British defense of ether for some time following the publication of Einstein's work. For a more recent assessment of Lodge we have the following comment:

> To a modern scientist, reading Lodge's work is similar to falling to the bottom of Lewis Carroll's rabbit hole. But it would be too easy to dismiss Lodge's work as the fantastic creation of an over-imaginative individual. I think it is important that Lodge's assessment of the place and importance of the ether be taken quite seriously as a barometer of the thinking of many of his British colleagues. . . .[3]

The success of Mr. Howard's defense of Swedenborg's ether is somewhat doubtful. (Furthermore there does not seem to be an exact one-to-one correspondence between Swedenborg's ether and

[1] "On the Electrodynamics of Moving Bodies," A. E. Einstein, 1905. Quoted in *The Principle of Relativity,* Dover.

[2] NP 1926, p. 108; 1936, p. 132.

[3] "In Defense of Ether," Stanley Goldberg, from *Historical Studies in the Physical Sciences.* Edited by R. McCormmach, Vol. 2, p. 104, Univ. of Penn. Press, 1970.

the luminiferous ether). Nevertheless he does mention the possibility of a re-interpretation of the physical constitution of the ether. A further and perhaps more significant contribution is the following quotation from his 1957 article in THE NEW PHILOSOPHY,

> . . . the New Church scientist . . . cannot therefore dismiss the doctrine of the atmospheres, and the ether in particular, as one of Swedenborg's scientific errors, as he might be inclined to do in relation to such questions, for instance, as the hibernation of swallows, or the color of children produced by a Moorish father and a European mother. The doctrine of the atmospheres and of the ether is too fundamental to be so dismissed, for the whole structure of Swedenborg's doctrine of creation and sustentation of both worlds rests on these atmospheres.
>
> On the other hand, we cannot rest our case simply on the assumption of the earlier students of the church, as contained in *Words for the New Church,* namely: "That true science comes from Heaven and agrees with revelation whilst false science comes from Hell and disagrees with revelation" (p. 373). For while it is true that our essential beliefs may not have changed in regard to our traditional attitude toward science and scientific hypothesis, our approach to our scientific colleagues has at least become more respectful.
>
> As was, of course, always recognized by us, and is amply stated in *Words for the New Church,* our problems are not with science, but with false interpretations derived from science.[4]

Such a statement indicates the importance of a continuing examination of the ether question.

The emphasis of the work of Reginald W. Brown differs from that of Mr. Howard. Swedenborg's theories of light and color are the focal points of two articles by Dr. Brown.[5] The ether of Swedenborg is mentioned only in connection with the creation of light and the passage of light as being a streaming of the ether. However, Dr. Brown did not discuss the challenge to the ether raised by Einstein.

During the 1940's Dr. Charles R. Pendleton contributed to the discussion with a survey of relativity theory and a strong criticism of its treatment of centrifugal force and circular motion. He further suggested that, while the usual concept of a continuous ether seems to be no longer valid, it may be possible to conceive of light photons and "other radiations" which fill space as forming an ether similar to Swedenborg's ether.[6]

[4] NP 1957, p. 131.
[5] NP 1925, p. 405; 1926, p. 99.
[6] Duplicated paper 1946. ANC Library.

A later paper by Dr. Robert M. Cole [7] stated the idea that human perceptions of the objective world are often incorrect because all nature is experimental from a space-time framework. He argued in favor of a material world whose ultimate, objective reality consists of energy. Swedenborg's ether then becomes identified, not with the medium for light transmission, but with light itself or the all-pervasive electromagnetic field. This possibility will be explored in more detail later in this essay.

Finally Professor Edward F. Allen, in a passing reference to ether, has proposed that light itself is somehow a discrete degree removed from ordinary experience. Light has manifested itself in the laboratory as having both wave and particle-like properties. Professor Allen feels that these two aspects of light can be reconciled only by proceeding to a deeper level of nature.[8]

This brief survey indicates some of the steps which various authors in the Church have taken to meet the challenge of the ether. It is hoped that this essay will be a continuation and extension of this tradition of inquiry.

The Ether of Swedenborg

We will treat of Swedenborg's ether first from his *Principia* and then from the Writings. The reason for this arrangement is that the *Principia* ether discussion may provide some illumination for the later more general and less detailed description in the Writings.

It is quite reasonable to assume that Swedenborg was strongly influenced by the scientific and philosophic "gestalt" of his era. His immediate predecessors and contemporaries included Descartes, Leibniz, Huygens, Newton, Hooke, and many other very talented workers in the general field of natural philosophy.[9] The approach to natural philosophy used by Swedenborg bears a strong resemblance to that of Descartes. Like Descartes, Swedenborg tended to leave the experimental work to others, relying on his powers of reason and general philosophic goals to provide a rational explanation of nature. The similarities between Descartes' and Swedenborg's schema are often striking and we will sketch very briefly Descartes' system of nature.

[7] NP 1958, p. 357.

[8] NP 1960, p. 154.

[9] For a chronological ordering of well known scientists see Appendix I of *Basic Concepts of Physics* by R. B. Lindsay 1971. Van Nostrand Reinhold Co., N. Y.

Descartes' universe originated in several equal pieces which somehow achieved a state of motion, both a local circular motion or spin and some type of orbital motion in a vortex about an unspecified center. By collision, these original pieces of matter gradually became spherical and, in their final form, are called particles of the second element. The "shavings" from this process eventually accumulated, filling the spaces between the spheres of the second element and these shavings are designated as the first element. The various kinds of motion of the spherical second element particles continue creating further shavings and eventually there is a spreading apart or motion away from the centers and a subsequent dispersion of the second element particles. Although the process is not clearly defined, a further third element is eventually formed whose motion is much more restricted than that of the second element particles and whose positioning in the "universe" seems to be far removed from the centers of the second element's vortical motion. The phenomenon of light is explained as due to an "effort" of the second element particles away from their centers of motion.[10]

Swedenborg's cosmogony (as given in the *Principia*) is similar to Descartes' system in that there are various levels of matter, that matter is corpuscular and that the fundamental levels of matter are in a state of incessant and varied motion. Nevertheless there are non-trivial differences between the systems.

A consideration of Swedenborg's cosmogony may be facilitated by the use of the accompanying diagram, Figure 1. According to the *Principia,* the infinite was finited by the Creator as "first natural points" which are pure motion and may be said to represent a medium between the infinite and the finite. The first natural points have motion which is said to be spiral and their very existence seems to be a kind of elementary geometry.

The simple or first finite is made up of a collection of the first natural points and is said to "originate by means of the motion of points among one another."[11] Because the first finite is active it is characterized by a state of motion referred to as spiral motion which is reciprocal, that is, moving from the center to the circumference and back again in a continuous manner. The *Principia*

[10] Based on a recent (1971) translation by P. E. Funk of Part III of Descartes' *Principia,* vol. 2. (Private communication.)

[11] *Principia,* Tansley translation, London, 1912, Vol. I, p. 79.

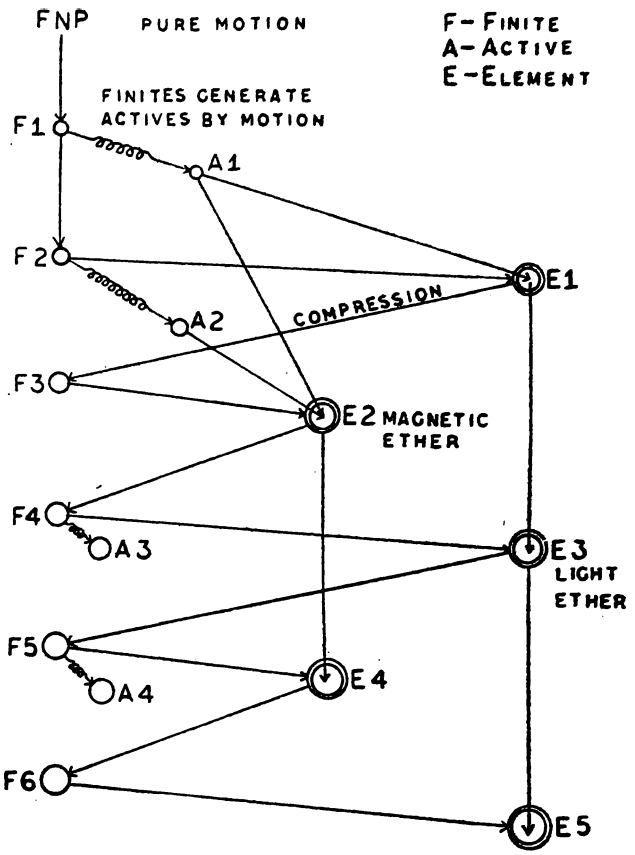

FIG. 1. Schematic diagram of the *Principia* cosmogony. This schema was originally developed by Dr. H. Lj. Odhner.

speaks of the spiral figure as having an "equator, ecliptic, meridians and other perpendicular circles." [12] In other words the first finite seems to have the vorticular structure.

From the high speed motion of first finites about a center, the surface of the first active is generated. One may find the example of a ball being whirled on the end of a string illustrative. If whirled fast enough the ball seems to describe a circle. The circle itself is non-existent but the motion certainly generates the appearance of a substantial circle. In an analogous manner the motion of the first finite generates the first active.

Groups of first finites may cluster together to produce the second finites which are similar in form and motion to the first finites.

[12] *Ibid.* p. 94.

However, the velocity and therefore the activity of the second finite is considerably reduced and the mass or inertia is increased greatly by comparison with the first finites. Perhaps this represents an example of conservation of energy on a fundamental level. From this second finite, a second active is created in the same manner as the first active arose from the first finite.

Using what might be termed a "natural" philosophical principle Swedenborg combines the first active and the second finite to form what is called the first element. This principle consists in, first, suggesting that compared to an active, the finite is a fairly passive entity; and then, that both active and passive properties of nature are required in order that material bodies have the property of acting and, in turn, being acted upon. The physical arrangement described is that of a shell of finites (passives) enclosing a sphere of actives; together they constitute the first element or elementary particles. Each elementary particle is highly elastic and compressible. In fact, if the elementary particle is compressed to its limit, another finite is formed called the third finite.

As in previous steps of the sequence this third finite, which is only a grosser form of the first and second finites, may form the covering for the second element. The system carries forward in this manner to form more finites, actives and elements. As noted in the diagram the structure of the system changes slightly as one proceeds to grosser elements. The third, fourth and fifth elements are covered with the various passive finites, but the inner parts of the elements are themselves previous elements.

Although the third element is specifically identified by Swedenborg as ether,[13] there is no one-to-one relationship between the ether of science and the *Principia* ether. The scientific ether (at least until the advent of Einstein's relativity theory) was considered to be the medium for the transmission of electromagnetic phenomena of which light was one aspect. On the other hand, Swedenborg's ether or third element is related to light,[14] while his second element is related to magnetism. No doubt this division of function arose because the scientific community of Swedenborg's day was not aware of the essential similarity of electricity and magnetism.[15] Nevertheless our concern in this work is the

[13] *Principia,* Vol. II, p. 200.

[14] *Principia,* Vol. II, p. 219.

[15] Edward M. Purcell, *Electricity and Magnetism,* Berkeley Physics Course, Vol. 2, p. 148.

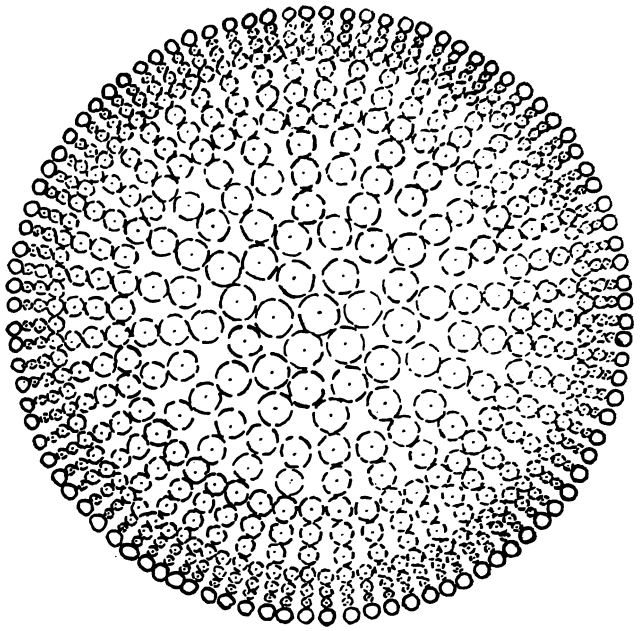

FIG. 2. Third Element. A reproduction of the drawing in the *Principia* of the light ether element.

propagation of light and therefore we will confine ourselves to the third element or ether.

The third element is composed of particles or corpuscles of the first element surrounded by shells of fourth finites. A diagram is given in the *Principia* and reproduced here for convenience [16] (see Figure 2). The particles have elastic qualities as well as dynamic properties. Because of the dependence of "density" of the active inner parts on the distance from the center, the center of gravity is a radial function of the compression. If the ether particle is in a state of rotation, then its angular velocity will increase with a high degree of compression because of the law of conservation of angular momentum.

Light, according to the *Principia,* arises when "motion is diffused from a given center through a contiguous medium, or volume of particles of ether." [17] Concerning the cause of light we read that "minute corpuscles which resemble a kind of effluvia, and which are so small as to be able to move only a volume of ether, . . . these, if spontaneously moved excite light to a certain distance." [18] A definition of these small corpuscles is not given but

[16] *Principia,* Vol. II, p. 215.
[17] *Principia,* Vol. II, p. 218.
[18] *Principia,* Vol. II, p. 219.

there seems to be some comparison with the magnetic second element particles. It seems that these particles may either put themselves into motion spontaneously or, be activated by external vibrations which are communicated to the ether by minute particles which somehow issue from the hard vibrating body.

Light is therefore propagated by undulations of the ether corpuscles or possibly a translational motion of the ether itself through space.

A further possibility in regard to an ether is Swedenborg's first element. In the 1912 edition of the *Principia,* p. xlv, Mr. Tansley remarks in the introduction,

> . . . we conclude that what Swedenborg designated the first element is the equivalent of what science calls ether. It is all pervading, extends through all space, and is the medium by which light from the remotest stars reaches us.

Several arguments may be advanced in favor of this suggestion, one of which is that the first elementary is found throughout space and is not localized on the earth as the third elementary is localized. Secondly, the first elementary is very minute, permeating everything. This description dovetails well with the ether concept as it was described in the scientific world. On the other hand, as has been noted above, Swedenborg specifically associates the third element with light propagation.

Whether the first or third element is the light "medium," the point is that the elements are regarded as corpuscular and dynamic, both internally and externally. I suggest that the actual form of the motion is not particularly important since it is unlikely that Swedenborg would have had a completely correct view of the mechanics involved. However, it is important to note that Swedenborg's *Principia* cosmogony did include several layers of material existence, a corpuscular and dynamic model for matter, and a definite association of matter with light propagation. These points summarize the relevant concepts from the *Principia.*

Turning to the Writings we find a less detailed and less mechanical picture. One of the most frequently referred to descriptions is as follows:

> There are three natural atmospheres arising from the sun of the world, and there are three spiritual atmospheres arising from the sun of heaven, which is the Lord. The three natural atmospheres arising from the sun of the world are the purer ether, which is universal, from which is all gravitation; the middle ether, which forms the vortex around the planets, in which

also is light, in which are the satellites, and from which comes magnetism; and the ultimate ether which is air. By these three atmospheres all the corporeal and material things of the earth are held together, which is so composed as to be applicable to those three degrees . . . (LJ post. 312).[19]

This statement gives some definition to the various "ethers" which permeate the physical universe, and, as does the *Principia,* the Writings seem to present two possibilities for an ether of light. While the second atmosphere seems to be explicitly associated with light, it is only a planetary atmosphere. Therefore the first atmosphere, which is universal in space, is also a suitable candidate for a medium of light.

The ambiguity in assignment of a light ether to a specific atmosphere is presently a real one. However, in view of the present limited knowledge of science we cannot be more definite. Nevertheless the important concept of the existence of the various subtle atmospheres make the search for the "ether" worthwhile.

In various passages throughout the Writings there are also statements that nowhere in nature is there "nothingness." A total vacuum is considered to be unthinkable and, when speaking of a vacuum, we are, in reality, suggesting a simple lack of the third atmosphere, namely air or some other gaseous substance. When speaking to Newton in the spiritual world Swedenborg reports,

Concerning a vacuum he (Newton) said, that in the world he had believed in the existence of a vacuum; but when angels perceived that he had an idea of a vacuum, as an idea of nothing, they turned themselves away, saying that they cannot bear the idea of nothing, since when there is an idea of nothing the idea of the essence of things perishes. And when the idea of the essence of things perishes, the idea of thought, understanding, affection, love and of will with men and angels perishes, which things are not given in nothing (LJ post. 266).

Beyond the fact of the existence of the ethers there are further teachings to the effect that while these atmospheres or ethers are

[19] There is some question relating to the translation of this number. In the text the doubtful line reads, "around the planets, in which also is ***light,*** . . ." Both Dr. Odhner in *Creation* and the Potts *Concordance* give the interpretation of the Latin edition of Tafel. However, while the Latin edition has "lux" which *is* "light" it seems that the manuscript may use the word "luna" or moon, although the handwriting is not very clear. Therefore in the Whitehead English translation of 1947 the questionable phrase is rendered as ". . . in which are the ***moon*** and. . . ." Nevertheless, in this essay we are using "light" because there are numerous other references throughout the Writings to the association of the ether and light. See DLW 147, 185, 302; TCR 32:8; SD 222, 4063; AE 726.

devoid of life and therefore "dead," they nevertheless are extremely active, being infilled with motion and receptive to a "non-living" conatus to motion from the natural sun. Furthermore these atmospheres may become ultimated as, for example, liquids and solids in the case of the third atmosphere.[20] Quite possibly there are analogous substances which may be derived from the ether or second atmosphere.

In summary, the Writings speak of a scheme of three natural atmospheres in which the ether of light is given as the middle atmosphere. This ether has dynamic properties and is associated with magnetism as well as light. Finally, it is emphasized that, no matter what the specific composition of the ethers, the natural world possesses no such entity as a complete vacuum or void. It is reasonable to conclude that the statements of the Writings are definitive. Yet these same statements seem to be vague and difficult to interpret from the viewpoint of the modern physicist. Nevertheless it would be too optimistic to conclude that the detailed mechanical description of the *Principia* would add substantially to our knowledge. Rather, the purpose of this essay is to examine the concepts of modern physics with a view to attempting a speculative correlation with the principles outlined above from the Writings.

The Luminiferous Ether

In this section we will briefly outline the developments which lead to the mature classical theory of light. The luminiferous ether and classical theory of light were intimately connected and mutually suggestive until the destruction of the ether theory in the first decade of the twentieth century and the somewhat later rise of the quantum theory of radiation as a more fundamental explanation of electromagnetic behavior.

Our discussion will be from the viewpoint of physical science, a viewpoint which differs from the more philosophic approach used by Swedenborg.[21] Nevertheless, the progress in the devel-

[20] AC 5173, 5116; DLW 311.

[21] It is perhaps worth noting that this divergence in viewpoint was only beginning to become apparent in Swedenborg's epoch. In those times a natural philosopher could still attempt a statement of the fundamental causes of natural phenomena despite an inability to substantiate his claims with experimental data. Today we regard that type of speculation as bad science. Instead we demand that each scientific theory explain the known experi-

opment of a theory of light has occurred in physics, not philosophy, and therefore we must follow the scientific approach with all its strengths and weaknesses.

The study of light has occupied a major portion of the time of those physicists whose names regularly appear in histories of physics. Although optics has always maintained a strong basis in experiment, the evolution of the subject is characterized by the debate between the corpuscular and wave *theories* of light.

Probably the first protagonist in this controversy was Robert Hooke (1635–1703) who suggested that light was of a vibratory character propagated in straight lines with a small amplitude. Previous to Hooke there was little in the way of a mechanical picture of light although Gassendi (1592–1655) re-introduced the atomistic theory of matter and by inference the corpuscular theory of light. It is commonly believed that the corpuscular theory was propounded by Newton despite the fact that Newton merely suggested this theory as one possibility. Nevertheless his disciples took a more dogmatic position.[22]

The particle and wave concepts represent the two most fundamental conceptual models of physics. Light, as a particle, was conceived as little bundles of energy emitted from a source and impinging on the eye thereby producing the sensation of sight. An ether or medium was not a requirement for the transmission of light particles.

The wave concept is less familiar in the sense of being less well understood dynamically, by the non-professional. For the physicist a wave is a type of motion which may be characterized by a

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mental data and, if the theory is to remain respectable, it must also account for future physical experience. At the same time, the theory must not go too substantially beyond the known facts. The intellectual pressures which caused this mutation in the scientific ground rules were many. In fact, by the twentieth century most of those physicists who were active in the creation of the quantum theory explicitly stated that their sole interest was a theory about the "observables" of nature rather than nature herself.

[22] Undoubtedly Newton's supporters disliked the attacks of Hooke and others on many aspects of Newton's work including his famous law of gravitation. The implication of Newton's gravity was the action of forces at distance without any medium of communications between the interacting bodies. Naturally the etherists would reject this notion as well as a tentative suggestion about a corpuscular theory of light. Under this pressure Newtonian proponents adopted a more rigid position than Newton himself took thereby initiating what became a rather protracted controversy.

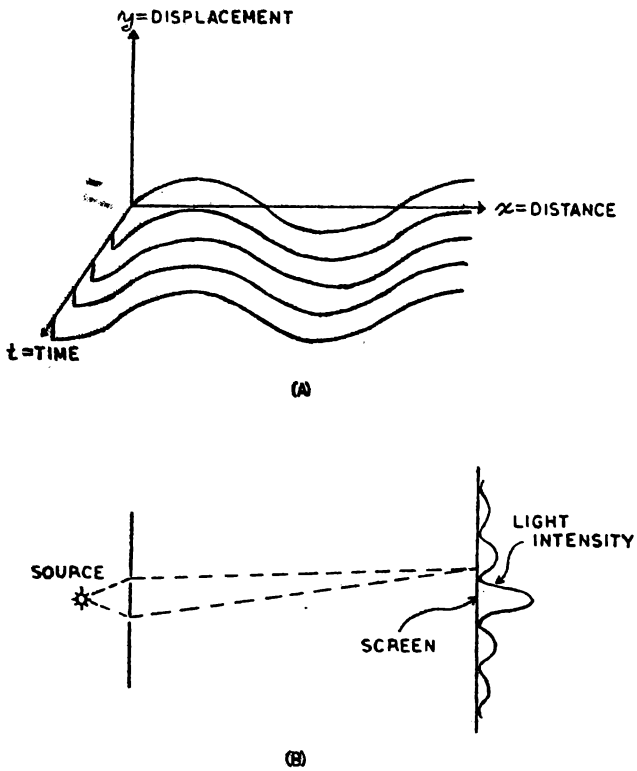

FIG. 3. (A) Graphical representation of traveling waves. If two out-of-phase waves are superposed cancellation will result. Similarly, reinforcement occurs if two in-phase waves are added. These effects are illustrated by the two-slit interference experiment illustrated in (B).

differential equation, called, for obvious reasons, the wave equation:

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}.$$

y represents the displacement of the wave which is both a function of time (t) and position (x). v is the velocity of the wave and depends upon the physical conditions. The solution to the wave equation gives the mathematical form of the displacement. Many solutions are possible and a simple "traveling" wave is shown in the diagram, Figure 3. A medium *is* usually required for the transmission of waves, and a type of displacement similar to that shown may be observed in water waves. It is intriguing to realize that both these physical models (wave and particle) provided plausible explanations of the phenomena studied in the early optics experiments.

The particle-wave debate was concluded in the following manner. In 1801, the French Academy of Science offered a prize for a dissertation which would decide the matter. A young medical man, Thomas Young, suggested that since the property of interference was unique to waves, a demonstration of interference between two light beams would be conclusive. The experimental facts are as follows. A wave front from a single source is split into two beams which travel slightly different paths. Ultimately they are superposed again, one on the other, at the same place (on a screen or more recently a photographic plate). The intensity of the resulting beam is either essentially zero or brighter than the intensity of either single beam depending on the *difference in path* between the two beams at the screen. Over a region of the screen one finds a series of dark and light spots. This rather striking result is re-discovered by thousands of undergraduate physics majors every year.

With Young's brilliant work the corpuscular theory was dealt a seemingly fatal blow, and the ether theory became entrenched as conventional wisdom. However the actual composition of the ether remained a problem. Many types of substances were proposed whose suggested compositions had rather strange properties. These properties were constantly changing because of the increasing data from the optics experiments. Each new result had to be incorporated into the current ether model.

One of the more persistent ether models was that of the *elastic solid ether*. Light travels in transverse waves; that is, the direction of the displacement is perpendicular to the direction of propagation. Of the three states found in nature, gaseous, liquid, and solid, only a solid medium allows for the possibility of transverse waves. (Solids can also carry longitudinal or compression waves.) Therefore it was supposed that the entire universe was filled with some fine substance that was a solid. Furthermore the solid must be elastic (as most real solids are to a first approximation) in order that there be a displacement or wave motion. If one then writes out the dynamic equation of motion of the elastic solid it turns out that a wave equation results with a characteristic wave propagation velocity given by the formula:

$$v = \sqrt{\frac{T}{\rho}}$$

where T is the tension or stiffness of the material and ρ is the mass density. For ordinary solids the velocity of a transverse

sound wave is of the order of 3×10^4 cm/sec, which is a million times less than the speed of light. For a light carrying medium we can see that either the mass density ρ must be incredibly small or the coupling implied by the tension constant T must be extremely strong. Since ether is considered to be a very ephemeral substance we would expect that the former possibility, small density, might be more realistic, if indeed, either possibility can be termed realistic. A more serious objection is the non-existence of longitudinal waves in light propagation, although these are inherent in the elastic solid model. For these and other more technical reasons the elastic solid theory of the ether was ultimately rejected.

Concurrent with the theoretical and experimental work in optics, great strides were taken in the development of electromagnetism. Certainly one of the high points in this development was the statement by Maxwell of his famous four equations. In effect, these equations summarize all of electromagnetism until Maxwell's time. While the general solution to these equations depends upon the particular charge or current distribution, we can for our purposes, consider the space which is free of charges and currents: the so-called free field case. Then it is possible to apply some elementary vector analysis to Maxwell's equations with the result

$$\nabla^2 \mathbf{E} = \frac{1}{c^2} \frac{\partial^2 \mathbf{E}}{\partial t^2}$$

which is merely the three-dimensional form of the wave equation. The similarity between this result and the differential equation for wave motion is striking.

We now know the light is produced by accelerated electric charges and that there is an intimate connection between light and electromagnetism. The question "Of what does the displacement consist in the wave motion of light?" may now be partially answered. The displacement is the electric vector **E** which is a field property of space and time.[23] The usual interpretation of **E** is the force exerted by a charge Q on a unit charge placed at a distance from Q if that unit charge existed. In the New Churchman's terminology the electric field **E** is a kind of "conatus" to force provided by the charge Q. If the charge Q were to move

[23] For the sake of simplicity of the discussion we ignore the accompanying magnetic field **H**.

through space then obviously its effect, **E**, would be a function of time as well as position. A very liberal interpretation of **E** would be as a space "geometry" derived from the presence of Q.

Maxwell, himself, would not have been particularly pleased with the above interpretation. He was a confirmed atheist who exerted his not inconsiderable intellectual powers toward the creation of a mechanistic world in which the propagation of electromagnetic disturbances proceed in a very "common sense" manner.[24] Vortices, gears with connecting rubber bands, and elastic solids with special properties were all considered by Maxwell and his contemporaries. From these sustained efforts of the 19th century mechanists only the mathematical forms remain. The ether seems to have been the scaffolding which helped to build the mathematical structure that now stands on its own merits.

As the theoretical work on the ether and electromagnetism reached new peaks of sophistication, experimental work was beginning to raise serious doubts about the existence of a light medium. These doubts arose from the experimental answers to the following types of problems. Assuming there is an ether, does it have a motion relative to the earth or the stars, or some other stellar object? More generally, is there a special frame of reference, the ether frame, which is a kind of absolute frame, completely at rest? For example, is the earth's frame special in some way? Such a frame of reference must be regarded as somehow different from every other frame which is moving relative to the absolute frame. If light travels in a medium then one would expect that various features of light wave propagation would depend on the frame of reference the observer found himself in.

The notion of a special frame became the basis for a great many experiments, some electrical and some optical in nature. Two experiments were of special importance in the attempt to locate the ether. As a wave motion, light has a speed which is dependent only on the medium and not on the source speed. Let us consider an ether which is fixed in the frame of reference of the stars. An astronomer observing a given star from a position which is stationary with respect to that star observes the light coming directly at him. Now if the astronomer is located on the earth which is moving in its orbit relative to the stars, then he must tilt his

[24] E. T. Whittaker, *History of the Theories of Aether and Electricity* (New York: Philosophical Library, 1951), Vol. I, chapters 8 and 9.

sound wave is of the order of 3×10^4 cm/sec, which is a million times less than the speed of light. For a light carrying medium we can see that either the mass density ρ must be incredibly small or the coupling implied by the tension constant T must be extremely strong. Since ether is considered to be a very ephemeral substance we would expect that the former possibility, small density, might be more realistic, if indeed, either possibility can be termed realistic. A more serious objection is the non-existence of longitudinal waves in light propagation, although these are inherent in the elastic solid model. For these and other more technical reasons the elastic solid theory of the ether was ultimately rejected.

Concurrent with the theoretical and experimental work in optics, great strides were taken in the development of electromagnetism. Certainly one of the high points in this development was the statement by Maxwell of his famous four equations. In effect, these equations summarize all of electromagnetism until Maxwell's time. While the general solution to these equations depends upon the particular charge or current distribution, we can for our purposes, consider the space which is free of charges and currents: the so-called free field case. Then it is possible to apply some elementary vector analysis to Maxwell's equations with the result

$$\nabla^2 \mathbf{E} = \frac{1}{c^2} \frac{\partial^2 \mathbf{E}}{\partial t^2}$$

which is merely the three-dimensional form of the wave equation. The similarity between this result and the differential equation for wave motion is striking.

We now know the light is produced by accelerated electric charges and that there is an intimate connection between light and electromagnetism. The question "Of what does the displacement consist in the wave motion of light?" may now be partially answered. The displacement is the electric vector **E** which is a field property of space and time.[23] The usual interpretation of **E** is the force exerted by a charge Q on a unit charge placed at a distance from Q if that unit charge existed. In the New Churchman's terminology the electric field **E** is a kind of "conatus" to force provided by the charge Q. If the charge Q were to move

[23] For the sake of simplicity of the discussion we ignore the accompanying magnetic field **H**.

through space then obviously its effect, **E**, would be a function of time as well as position. A very liberal interpretation of **E** would be as a space "geometry" derived from the presence of Q.

Maxwell, himself, would not have been particularly pleased with the above interpretation. He was a confirmed atheist who exerted his not inconsiderable intellectual powers toward the creation of a mechanistic world in which the propagation of electromagnetic disturbances proceed in a very "common sense" manner.[24] Vortices, gears with connecting rubber bands, and elastic solids with special properties were all considered by Maxwell and his contemporaries. From these sustained efforts of the 19th century mechanists only the mathematical forms remain. The ether seems to have been the scaffolding which helped to build the mathematical structure that now stands on its own merits.

As the theoretical work on the ether and electromagnetism reached new peaks of sophistication, experimental work was beginning to raise serious doubts about the existence of a light medium. These doubts arose from the experimental answers to the following types of problems. Assuming there is an ether, does it have a motion relative to the earth or the stars, or some other stellar object? More generally, is there a special frame of reference, the ether frame, which is a kind of absolute frame, completely at rest? For example, is the earth's frame special in some way? Such a frame of reference must be regarded as somehow different from every other frame which is moving relative to the absolute frame. If light travels in a medium then one would expect that various features of light wave propagation would depend on the frame of reference the observer found himself in.

The notion of a special frame became the basis for a great many experiments, some electrical and some optical in nature. Two experiments were of special importance in the attempt to locate the ether. As a wave motion, light has a speed which is dependent only on the medium and not on the source speed. Let us consider an ether which is fixed in the frame of reference of the stars. An astronomer observing a given star from a position which is stationary with respect to that star observes the light coming directly at him. Now if the astronomer is located on the earth which is moving in its orbit relative to the stars, then he must tilt his

[24] E. T. Whittaker, *History of the Theories of Aether and Electricity* (New York: Philosophical Library, 1951), Vol. I, chapters 8 and 9.

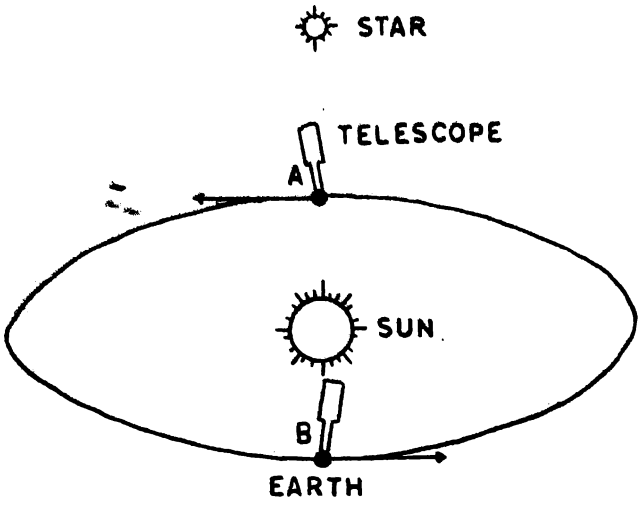

FIG. 4. Bradley's aberration effect. The telescopes must be tilted slightly from the earth-star line because of the non-zero velocity of the earth.

telescope at a small angle to offset the "aberation" effect (Bradley 1727) caused by the earth's motion of 30 km/sec (see Figure 4).

Experimentally he finds the magnitude of the tilt angle to be the same at both positions, A and B, in the earth's orbit. There are two possible explanations: first, that the ether is fixed to the earth, and second, that the ether is fixed to the stars (or that particular star). If the ether were stationary with respect to the earth it would be necessary to endow the ether with unusual velocity properties to account for the observed effect. There is also no reason to select the earth as a "special" planet or celestial body in the physical sense. Hence, the explanation in terms of an earthbound ether remains unconvincing.

The second experiment soon dispelled the notion of an ether fixed in the stars which the earth was somehow passing through. Michelson and Morley [25] carried out an interference experiment to demonstrate that the earth never traveled in a preferred direction through an ether. The details of the work are described in practically any text on relativity. The conclusion from these two experiments (and many similar tests) is that the luminiferous ether is at rest neither in the earth's frame nor in some frame fixed in the stars.[26]

[25] Am. J. Sci. 34, 1887, p. 333.

[26] For example: *Special Relativity* by A. P. French, Norton, 1966, N. Y. French's book lists thirteen different trials of the Michelson-Morley experiment between 1881 and 1930.

After the results of the Michelson-Morley experiment were known the thought of the scientific community gradually evolved to that of Poincaré who suggested that it is impossible to discover the ether by physical experiments.[27] Such a statement seems to be only a short step from denying the existence of ether altogether. In fact, in 1905 Einstein did just that in his famous first paper on relativity. Einstein further showed that Maxwell's equations were invariant under the relativistic transformations and therefore did not require a physical basis in a hypothetical ether. In other words, Maxwell's equations of the wave formulation of light did not require a special frame of reference.

With the publication of Einstein's notions on special and general relativity the ether concept rapidly became unpopular and at this day has been virtually abandoned by physicists.

Beyond the Luminiferous Ether

The supposedly small step which Einstein took in going from the "unknowability" of ether to a denial of its existence may be rather larger than it appears at first sight. Undoubtedly Einstein made progress in the pragmatic sense; certainly science is concerned with that which is knowable. Nevertheless, a re-interpretation of "ether" may be possible especially in view of the quantum aspects of present day theories of nature.

In the previous section of this essay it was noted that Einstein and others stated that there was no necessity to postulate a vibrating ether from an operational viewpoint. Maxwell's equation explained all the experimental results of light behavior in the macroscopic world. Nevertheless the classical theory leaves us with the concept of a communication via an undulating motion that seems to rest on no physical matter. The fact that an electric field is propagated does not explain how it is propagated.

On the other hand, these difficulties might be largely eliminated by a particle theory of light. Just as the discus thrower does not require a medium for a trajectory, so also would a particle theory not require an ether. However, the work of Young and others with experiments using interference, diffraction and double refraction had clearly refuted the old corpuscular theory of light. It was not until the early years of the 20th century that a series of experiments were reported which indicated that a corpuscular theory of light had a valid claim equal to that of the wave theory.

Some of these experiments were related to the emission and

[27] Whittaker, Vol. II, p. 30.

absorption of light by atoms. The atoms appeared to accept and emit radiation in bundles of energy which were later called photons.[28] Each photon was characterized by a definite frequency, ν, and the energy in every case was found to be given by

$$E = h\nu$$

with h being the famous Planck constant used in Planck's theory of quantized radiation. The photon was held to travel at the speed of light which is only possible if the photon 'rest mass' is zero. Furthermore, the special theory of relativity would also assign a specific momentum (represented by the letter "p") to the photon

$$p = E/c = \frac{h\nu}{c} \qquad (c = \text{speed of light})$$

This formula represents a meshing of both a 'particle' theory of radiation and the special theory of relativity in a pleasingly simple manner.

One of the crucial tests of the corpuscular theory was the *Compton* effect where light photons were elastically scattered from electrons: a kind of billiards game with photons and electrons. The results were easily interpreted in terms of the corpuscular model.

The resurgence of a particle theory of light brought an interest in the question "Under what circumstances is each theory of light valid?". While a completely precise answer is difficult to express, one can be confident in using the wave picture for the macroscopic world and the particle or quantum theory for the microscopic world of electrons and other elementary particles.

While the details of the quantum theory of radiation or quantum electrodynamics are highly technical, some of the main results can be expressed very briefly. In particular the energy of the radiation field is found to be given by the expression

$$E = \sum_{k} (n_k + \tfrac{1}{2})h\nu_k.$$

[28] What is a photon? This difficult question can be partially answered by mathematics. A photon is described by a plane wave which is completely unlocalized in configuration space and time but is completely localized in "momentum space"; in other words one never knows where the photon is but one may (in principle) know its wave length and frequency very well. Those properties are consistent with Heisenberg's uncertainty principle.

The summation is taken over all possible values (there are infinite possibilities) of the wave vector **k**. This wave vector is simply related to the wave length of the light and the direction of propagation. The frequency $\nu_{\mathbf{k}}$ depends on the wave vector as indicated by the subscript **k**. The numbers $n_{\mathbf{k}}$ are integers which have different values for each value of **k** and $n_{\mathbf{k}}$ is interpreted as the number of photons of energy $h\nu_{\mathbf{k}}$ and wave vector **k**. For example there would be $n_{\mathbf{k}_1}$ photons of energy $h\nu_{\mathbf{k}_1}$, $n_{\mathbf{k}_2}$ photons of energy $h\nu_{\mathbf{k}_2}$, and so on, in a given radiation field.

For our purposes it is more interesting to discuss the case where *no* photons are present; all the $n_{\mathbf{k}}$ values are zero. Under this condition the energy reduces to

$$E_0 = \sum_{\mathbf{k}} \tfrac{1}{2} h\nu_{\mathbf{k}}.$$

In other words the lowest possible energy state in a radiation field has no photons (no light) but still an infinite energy. One might think of this ground state as an infinite "sea" of energy from which the photons (like bubbles) arise. This ground state (or vacuum state) is always in existence as a basis for radiation.

The infinite vacuum state energy E_0 is considered by some authors [29] to be merely a base line from which to calculate finite measurable effects from finite measurable energies of finite numbers of photons. No physicist likes to have unexplained "infinities" in his theories; however, quantum mechanics, which is a very comprehensive theory, demands that such a ground state be real despite the difficulties of interpretation.

It is not unreasonable to suggest that this so-called vacuum state is an acceptable candidate for an ether. We find that out of the vacuum state come fluctuations in the field strengths **E** and **H**. as well as the "particles" of light; and, perhaps because the vacuum state is an energy phenomenon, rather than a space-time phenomenon, it is discretely different from Swedenborg's third atmosphere which we know as the gaseous state (DLW 176). The vacuum state is in a condition of incessant fluctuation, thereby possessing the dynamic property which we would like to associate with one of the more interior atmospheres.

[29] For example see Heitler's *Quantum Theory of Radiation*, Oxford Univ. Press.

Conclusion

A concept which is based primarily on a few mathematical equations must be a tenuous idea at best. The reality of the vacuum state seems reasonable although an understanding of that reality does not come easily. However, it is interesting to note that physics has come almost a full circle in the strangeness or profundity of the accepted concepts within the discipline. Swedenborg, Descartes, and others propounded views about layers of existence which were later rejected as unexaminable and therefore unnecessary. But the almost bizarre results of twentieth century physics seem to be reminiscent of the early theories of cosmogony.

Whether the interpretation of the vacuum state radiation field as an ether is acceptable remains to be seen. Undoubtedly other interpretations are possible and may be more meaningful. For example, the work of T. A. Wheeler in the field of geometrodynamics is full of promise for a deeper level of existence. Wheeler interprets fields and particles as geometric properties of space. By invoking Heisenberg's uncertainty principle Wheeler suggests the possibility of very high activity over minute distances; in fact at dimensions of the order of 10^{-33} cm (the Planck length) space consists of a kind of geometric "foam." This author hopes to explore these ideas further in another essay. Certainly they have relevance to our concepts of atmospheres and degrees.

While it cannot be concluded that Swedenborg predicted modern physics, nevertheless it is still possible to claim science as an ally in the effort to confirm revelation through natural enquiry.

IMAGINATION AND RATIONALITY

George de Charms *

Imagination and Reason

All truth is a form of love. It is an embodiment of love selected and organized out of sense experiences stored in the memory, and pictured in the imagination. Of this process man is not in the least conscious. It takes place instantaneously, miraculously, and with marvelous perfection, so far as the sense-material available may permit. So far as knowledge is lacking, the mental image

* Fourth and last installment of a series based on lectures delivered in 1947.