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NUMBER 2.

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THE LUMINIFEROUS ETHER:  
(I) ITS RELATION TO THE ELECTRON AND TO  
A UNIVERSAL INTERSTELLAR MEDIUM;  
(II) ITS RELATION TO THE ATOM

BY  
FRANK W. VERY



BOSTON: THE FOUR SEAS COMPANY





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*By Frank W. Very*

OCCASIONAL SCIENTIFIC PAPERS OF THE WESTWOOD

ASTROPHYSICAL OBSERVATORY: NUMBER I

LUNAR AND TERRESTRIAL ALBEDOES



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ABSTRACT

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## HISTORICAL NOTE

This paper was presented in abstract at the twenty-second meeting of the American Astronomical Society at Harvard College Observatory, August 20, 1918, and is here reprinted in full from the *New-Church Review* for October, 1918 (Vol. XXV, pages 528 to 576). It is an elaboration of a view put forth in my critique and appreciation of Swedenborg's *Principia* which appeared in the same publication in April and July, 1913 (Vol. XX, pages 161 to 197, and 392 to 436), where a return to Swedenborg's scientific doctrine of a limited ether, and of light as consisting of discrete vibrating ether-particles, was advocated. The present paper includes much additional material, especially in respect to the connection of the ether with a fundamental electronic unit and the universal medium out of which both the electron and the ether-particle are supposed to be formed. Incidentally, further details are included from my papers on the cause and limitation of gravitation which have not, as yet, been published elsewhere.



THE LUMINIFEROUS ETHER: (I) ITS RELATION TO THE ELECTRON AND TO A UNIVERSAL INTERSTELLAR MEDIUM.

THERE has arisen at the present time a new doctrine which declares that there is no ether, or universal atmosphere consecrated to the propagation of luminous waves, but that light consists of discrete "quanta" of luminous energy, thrown off from vibrating electrons and originating in their disturbed motion. This proposition appears to be well founded; but it does not therefore do away with the necessity for a universal medium, though this medium should no longer be called "the luminiferous ether." I have adopted for the universal interstellar atmosphere the name of "aura," a term which I have borrowed from Swedenborg, who uses it sometimes to designate a universal atmosphere, a "purer ether," assigning to it in the end a gravitational function, and placing it as an antecedent to the light-bearing ether.

While the universal aura, or "ether of space," as Sir Oliver Lodge calls it, has no mass, the case is different with the electrically organized "ether," of which Sir J. J. Thomson in his "Electricity and Matter" has said: "All mass is mass of the ether, all momentum, momentum of the ether, and all kinetic energy, kinetic energy of the ether." Here, however, he points out that "the concentration of the lines of force on the small negative bodies—the 'corpuscles' [or electrons]—is so great that practically the whole of the bound ether is localized around these bodies"; and this follows because the energy per unit volume in the magnetic field of the moving electrons diminishes in proportion to the inverse fourth power of the

distance.\* This alone shows that gravitation can not reside in the electrically bound ether, since the efficacy of gravitative force is related to the inverse *square* of the distance; nor can gravitation depend upon the mere revolutions of the electrons, though these, if uncompensated, may generate an atomic *magnetic* field. On this account and because the magnitudes of the electric and gravitational forces are of a totally different order, we are driven to seek for some mechanism for gravitation different from the disturbance produced by a simple electronic revolution *per se*.

It is assumed by Thomson that his corpuscles are spheres. It does not appear possible that electrons can have the ring-vortex form which Lord Kelvin assigned to his vortex-atoms; for these could not unite into vortex filaments, or unite in any way except by two neighbors alternately threading each the other periodically.

\*William Sutherland has considered the reason for this law in an article on "The Electric Origin of Molecular Attraction" (*Philosophical Magazine*, Ser. 6, Vol. IV, p. 625, December, 1902). "The theory of magnetism familiarizes us with an inverse fourth-power force between magnets at distances great compared with their lengths. In applying this known magnetic result to account for molecular attraction, we are at the outset confronted with the difficulty that in the case of magnets the force is as often repulsive as attractive, the nature of the force depending on the relative direction of polarities in the magnets, whereas the molecular forces required to account for cohesion must be preponderatingly attractive." On further examination, however, he finds that "the attractive forces by their own operation tend to increase themselves, while the repulsive forces tend to decrease themselves." Thus if neighboring magnets, or electric doublets approach each other, the "axes tend to take the same direction, and therefore on this account they exercise a stronger attraction on one another; and also because attracting forces varying inversely as the fourth power of the distance produce motion which increases their strength, there are two causes which make the attractive forces amongst a number of moving doublets of more dynamical importance than the repulsive." The applicability of the law to any medium rests upon the magnetic properties of its least constituents.

Swedenborg's "ethereal particle" was also supposed to be spherical, and was thus fitted to receive all kinds of vibration without distinction. "The ethereal particles thus formed can subsist under any form of motion and with perfect aptitude to it" (*Principia*, Part III, Chap. V, No. 6.) But more noteworthy was his conception of a peculiar sort of vortex-particle, to which we shall return, having a structure of such a nature that similarly rotating particles may unite into vortex filaments. Such a structure lends itself admirably to the explanation of several phenomena, such as the polarization of the magnetic medium under the influence of an electric circuit, and leads especially to an idea of the way in which ether-particles are formed by electrons out of the aura through the aid of forces in this medium; and as if foreseeing such a relation, though there were then few facts on which to base it, Swedenborg assigned an ethereal origin to electricity as well as light, and had a vague idea of a distinction between "warm and cold light," or, as we should now say, between the radiation of a heated body and electrically produced luminescence, linking the "cold light" with electricity. He also assigned both a vibratory and a corpuscular nature to his luminous "ethereal particle," thus combining the Newtonian and Huyghenian hypotheses—a view to which we are in a fair way to return.\* After several speculations of this sort, he restrains himself with the words: "Much more might be said, but which I omit, as I have no experiments to prove my statements."

The vortical form in question was assigned to a particle of the magnetic medium. It had a rational basis in the fact of the obvious existence of vortex motion in that medium, as revealed in the magnetic phantom; and some of its properties have seemed to be too valuable to be laid on the shelf of unverified hypothesis. There is an opportunity for a resuscitation and modification of this scheme today. From the same mine of suggestions, now happily capable of a

\*For a fuller account of this subject, see my "Prevision of Scientific Progress." Boston: B. A. Whittemore, 1914.



certain amount of confirmation by experiment, I think we may borrow, with some modifications, a working plan of an atom.

Let us assume that there is around an electron a condensation of the aura in which its electric properties reside; that the electron both rotates on an axis and also pulsates with a radial, regular, and uniform motion at all points of its surface, being urged to this motion by an internal resilience; and that its shape is that of an approximate sphere with a central core, for which a reason will be given later. The electron is incapable of further compression, but is surrounded by its own ethereal "atmosphere" in which the pressure diminishes outwardly at a very rapid rate. During steady motion, this atmosphere moves with the electron and virtually forms a part of it; but the adhesion is so slight that under sudden shock the envelope is stript off and becomes a spherical ethereal particle which pulsates and oscillates within limits, but does not rotate. The naked electron immediately takes to itself a new atmosphere formed out of the illimitable aura, and may almost immediately lose its garment again at the next shock. Thus a single electron can undergo a succession of shocks which generate a series of ether-corpuscles, each with a different, but harmonically related variety of vibration, which could not happen if the electron as a whole were immediately converted into an ether-corpuscle.

Professor W. H. Bragg, who was the first to indicate the probable corpuscular nature of the Röntgen rays, suggested that "an electron of given energy may be converted — into a light-quantum of equal energy and *vice versa*." This at first seemed a permissible interpretation of the experimental evidence; but now that it is known that *the X-rays carry with them the peculiar vibrations of the electrons characteristic of the atoms composing the anti-cathode*, it becomes evident that this is not an immediate conversion of electrons in the cathode stream into ether, but that the electrons from the cathode are absorbed by the target and in this process they produce disturbances in the electrons

and the ether already attached to its atoms. The electron therefore preserves its identity, and is *associated* with the ether, rather than converted into it.

The ether-particle thus formed is a sphere of the same size as the electron. Its pulsation gives it mass which, together with its onward motion, causes it to have momentum. Its oscillation gives it alternating positive and negative electric sign and a reciprocating magnetic field, the whole constituting a least quantum of electro-magnetic energy. Because the electrons everywhere repel each other, and because radiation is an affair of surfaces, the emission of radiant ether by any portion of matter, from its origin, takes the form of a spherical wave.

Conjoined with its electron, the ether-particle may be said to have had a previous existence of a relatively quiescent sort, but as a free entity it necessarily moves onward with the velocity of light, carrying with it its own invariable quantum of energy. Consequently, the energy of radiation is measured by the number of ether-particles in the unit of volume. This follows from Planck's epochal discovery that the radiant quantum is a fundamental constant of nature. Eventually, the ether-particle, which has been formed out of the aura, is re-absorbed by the medium; but because the frictional resistance of the aura is very minute, the progress of absorption is excessively slow.

*The Assumption that the Ether-Particle is derived from an Electronic Envelope.*—A fundamental difference between a free ether-particle and an electron is that the latter rotates on an axis, and has polarity, but the former does not rotate and, having a perfectly spherical surface, is thereby free to take up any form of oscillation and transmit it with complete identity as to all of its phases.

The electrons which issue from the cathode of an X-ray tube, strike the atoms of the target; whereupon certain electrons attached to these atoms have the rotations of their envelopes transformed into a rocking motion, and the stripped-off envelopes proceed as vibrating ether-corpuscles; for the X-rays, no less than the luminous rays, are

corpuscular "quanta" of radiant energy, characterized by an extraordinary rapidity of vibration, which, since it originates in an electronic oscillation, I conceive to be an *oscillatory* vibration.

An advancing electron, moving in the direction of its axis, produces by its rotation and carries along with it a vortex-filament of the aura which is the electron's magnetic field, due to its motion and made up of circular "lines of magnetic force", or currents of minute size in the adjoining aura, concentric with the axis of the electron. Sir J. J. Thomson supposes that the electron is also accompanied by radial vortex-filaments which are its *electric* lines of force; and that when the velocity in the axial direction increases, these lines crowd towards the equatorial plane thus giving greater resistance to motion, or greater "inertia." According to my present proposition, the steady orbital motion of the electrons within the atom is *always* substantially in the direction of their axes of rotation, but at speeds much less than that of light.

If the lines of electric force about an electron are vortex-filaments, this would seem to imply that the magnetic aura is itself composed of particles still smaller than the electrons, which are also rotating and which become polarized, or arranged in radial filaments under the strain in the medium set up by the rotation of the electron, perhaps combined with some other form of motion. This suggests that electrical attractions and repulsions may be associated with the rotations of the electrons, attended by vortices in the aura, but that gravity originates from waves of longitudinal vibration in the aura (the counterpart of sound waves in the air) produced by the rapidly alternating expansion and contraction of the electrons. This explanation requires that there must be a perpetual elastic action and reaction in alternation between the inner contents of the spherical electrons and the volume of aura which fills an "aural cell," at an electronic surface of transition which is not far from spherical and of fixed dimensions determined by some property of the aura yet to be investigated.

On the supposition that an electron is a rotating sphere, or near sphere, of aura when translated at moderate speed, it does not follow that the shape will be retained at higher speeds. More probably any accentuation of the progressive motion will be accompanied by increased resistance with transition from a sphere to an oblate spheroid, and final dissipation by centrifugal force if the speed were to exceed the velocity of light, for which the resistance would be infinite with the lines of electric force compressed into an infinitely thin sheet. But a spherical particle of ether which is without any rotation, moves at once with the velocity of light by virtue of the properties of the aura out of which the ether is made. I shall show further on that the electronic rotation is so rapid that the shape is probably not merely spheroidal, but is that of an annulus or cored vortex-ring.

The electric field of an electron is therefore made up of static radial lines of strain in the aura, which are accompanied by a magnetic field of kinetic lines of flow whenever the electron advances, both together constituting a consistent electro-magnetic dynamic system in the aura.

Just as the larger Faraday tubes of electric force between oppositely electrified bodies are composed of stretched chains of polarized *atoms*, where the individual members of the chain are kept in connection by streams of moving electrons, so the finer threads of electric force about the electrons, repeating the structure on a smaller scale, require chains of still finer polarized particles of the aura,—the entire electric system comprising three orders of magnitude, namely, atoms, electrons, magnetons. Here, however, by an alternation of properties which seems to be inevitable in the relation and connection of these different orders of magnitude, the connecting lines of the aura are not lines of flow, but are made up of rotating magnetons held together by magnetic attraction; for all the properties of the aura, as a whole and as to its least units, are magnetic. The magnetons lend themselves as naturally to *rotations* as the electrons do to the *flow* of electric current.

Thus the normal motion of an unrestrained electron is a rectilinear electric flow, carrying with it always an accompanying orbital circulation of magnetons. The latter is the magnetic field due to the progressive motion of the electron, while any magnetically originated flux is, first of all, either a circulation or a rotation of magnetons which constrains the electrons to flow according to their own peculiar mode.

According to Sir J. J. Thomson's view, X-rays, and therefore we may now say all luminous rays, since it has become obvious that there is no distinction of form between the two, are propagated rectilinearly as kinks in a universally present system of ether tubes. But a discrepancy immediately appears, because, as we have seen, the ethereal structure "is localized," according to the same authority, and is by no means universal.

But Bragg has shown that the X-rays are probably of a corpuscular nature equally with the cathode rays, and since the electrons disappear in producing X-rays, while the latter, in turn, are capable of "generating," or more probably of setting free electrons anew, since the light-rays, when they meet an electronic system which can execute the same rhythm, or dance to the same tune, are absorbed, and the energy of the light is communicated to the electronic system, it seems fairly demonstrated that electrons and ether-corpuscles are structurally connected; and that they are identical as to magnitude is very probable, the chief difference between them being the presence or absence of axial rotation.

In regard to Thomson's fibrous ether, Professor Millikan, in his book on "The Electron" (p. 230), raises the objection that "When we maintain the field constant and vary the charge on the drop [of liquid to which an electron is attached, where the motion of the suspended drop is controlled by the electric field], the granular structure of electricity is proved by the discontinuous changes in the velocity, but when we maintain the charge constant and vary the field, the lack of discontinuous change in the velocity disproves the contention of a fibrous structure in



the field, unless the assumption be made that there are an enormous number of ether strings ending in one electron." This seems to him improbable, but perhaps the ethereal envelope, attached to an electron, has an analogous structure formed out of the aura. If the aura is composed of polar particles which are minute in respect to the size of an electron, the radial filaments of polarized magnetons, attached to an electron and which constitute its electric field, are very numerous, fulfilling Professor Millikan's proviso in this respect; and if the convergence of these vortex-filaments is what produces the surface condensation to balance the relatively enormous centrifugal force of the whirling electron, they act like so many compressed springs.

The shaking off of the electronic envelope gives to the ether-particle thus formed an oscillatory springiness and provides it with an analogous system of vortex filaments by which it takes hold of the aura in transit, or else has its energy transferred to a new electron upon absorption. A considerable amount of energy becomes latent in the generation of an ether-corpuscule and is not included in the "radiant energy" which it conveys. This energy of formation is derived from the constitutional energy of the electron, and is proportional to the frequency of the luminous vibration, but *not to the radiant intensity*. This, it seems to me, is the meaning of Einstein's equation:

$$h/e = \Delta V / \Delta \nu$$

where  $h$  is Planck's energy-constant,  $e$  is the charge on an electron,  $\Delta V$  is the change of the electrical potential, and  $\Delta \nu$  is the corresponding range of frequency, the higher frequency requiring a correspondingly greater electric potential for its production. Lenard's discovery (*Annalen der Physik*, (4), Bd. VIII, S. 149, 1902) that in the photo-electric effect, the energy with which electrons are thrown off from a metal on exposure to ultra-violet light is wholly independent of the intensity of the light, requires that there

must be an independent source of energy which is presumably structural. This structural energy of the ether was originally derived from the electrons, and may be returned to them.

The ether-corpuscle is a distinct entity, but it has a structure which has extension into a surrounding field of potential energy; and once organized, this structure can experience vicissitudes which are the "radiant energy" of the combination.

*Distinction between Radiation from Satellite Electrons and from those of the Nucleus.*—For a uniform revolution of electrons in an orbit, with a constant radius vector, there is no acceleration and no production of electro-magnetic radiation. The latter arises through perturbations which change the radius vector of the orbit, just as a uniform electric current in a conducting wire produces no induced current, but the latter arises when the first current is made or broken, thus as a result of a sudden *change* of current. Similarly, the removal of a satellite electron takes place by a series of jumps from one stable orbit to another, each explosive dislocation of the uniform orbital motion and substitution of a new orbit producing a radiant vibration of a special wave-length; and a succession of such dislocations causes a series of discrete, but harmonically related vibrations appertaining to a set of associated orbital distances and constituting a spectral series.

On the other hand, thermal shocks arising in the interrelations of the molecules in a solid or liquid, or in a highly condensed gas, and which are powerful enough to affect the entire spherical shell of electrons of the nucleus of an atom, produce continuous changes in adjoining electronic orbits distributed in parallel over the surface of the spherical shell. Thus if the nucleus of the atom expands, all of the nuclear orbits enlarge. The combination of expanding orbits is like an ever varying spiral motion with a continually changing radius vector. Whatever shocks these electrons of the general atomic sphere receive will generate a whole range of gradually varying frequencies



giving rise to a continuous spectrum. Hence the continuous spectrum of a radiating solid must be attributed wholly to the vibrating nuclei of its atoms, consisting each of thousands or tens of thousands of electrons. As a rule (with a few partial exceptions as in the case of erbium, etc.) there are no linear intensifications in such spectra, that is, the satellite electrons play such a subordinate part in the transformation that their periods are not in evidence. The nuclear perturbations are a function of the body's thermal state. On the contrary, electrically produced *luminescence* arises from disturbances which affect the satellite electrons, and which do not necessarily touch the electrons of the nuclear sphere. The bright-line luminescence spectrum may proceed from comparatively cool material. Somewhat similar to this is the radiant emission of the firefly, where considerable radiation of short wave-length in the form of a broad spectral band, which if it were thermally produced would correspond to a temperature of several thousand degrees, is actually given off at the temperature of the living body without the corresponding infra-red rays of much greater total power which are ordinarily associated with low-temperature emission. This was determined by direct spectro-bolometric observations of the entire energy-spectrum from the visible rays through the infra-red.\*

*The Dual Aspect of the Rotating Electrons becomes the Ultimate Origin of the "Two Electricities."*—The proposed hypothesis of the internal structure of an atom assumes that the atom consists solely of electrons revolving in orbits, that there is but one sort of electron, though it has two aspects, because it is a rotating spherical mass, or what is more likely, a cored vortex, or near-sphere, of the universal medium, and has a definite volume and rotational energy determined by the properties of this medium. There is but one *known* sort of electron, and if the foregoing definition be accepted there can be no other. The

\*See Langley and Very, "The Cheapest Form of Light," *American Journal of Science*, Vol. XL, p. 97, August, 1890.

hypothetical "positive electron" has never been isolated simply because it does not exist. The conception needs but a few minor details to make it perfectly definite and simple. It remains only to trace the consequences of these assumptions, and here there is room for much variety in the compounding of motions. Whatever atomic scheme is proposed, however, must conform in its results and properties to certain well established physical and chemical facts. The chemical and spectroscopic facts are already well on the road towards explanation through the hypotheses in respect to the orbits of satellite electrons which are accepted today. Naught but the nucleus need be considered here.

An aggregation of electrons which all have the same electric properties will evidently tend to expand by the mutual repulsion of the several entities, and will be dispersed unless controlled by some form of consentaneous motion which shall overcome this dispersive tendency. Given some mode of limiting the dispersal, the mutual repulsion of the parts will nevertheless tend to distribute them into a spherical shell. Hence an atom composed of electrons probably has the form of a hollow sphere, and must necessarily possess an even number of layers arranged in pairs with opposite electrification.

The electron itself has an analogous structure, since it is a spherical vortex by close approximation, as we shall see, formed from the aura by rotation and condensed at the surface where it sustains the whole pressure of the aura by the centrifugal force of this rotation, but rarefied within.

The interior of the atom is filled with aura, that is, the entire atom is an electronic and ethereal structure finited by motion out of the aura; and the aura itself (except in the immediate vicinity of the electrons) passes freely through the interstices of the structure and serves to nourish it, to animate it with energy (for the aura is a great reservoir of energy), and to govern and define the modes and properties of the structure.

In 1903 Eichenwald repeated Rowland's experiment with modifications, by causing an electrified glass disk, coated on both faces with metal, to revolve. If the dielectric carries the magnetic aura along with it, there should be compensation between the dielectric and metallic influences upon the aura, and an absence of magnetic effect. But the magnetic effect was found, which proves that the aura is immobile in respect to the motion of matter through it. The sun and planets are not floating in the aura which immediately surrounds them, like corks in a stream of water. If the universal magnetic medium flows through matter, or is not set in motion by the motion of matter in material progressions, the medium may nevertheless suffer a slight retardation in the vicinity of the matter. This will have the effect of a condensation of the aura. It is not necessary that the general motion of the aura shall coincide with that of the matter which is contained within the same volume of space; for the matter takes hold of an immense volume of aura by its gravitational lines of force and is thus connected with and controlled by the general aural movement, but is independent of the aural movement in the immediate vicinity. Thus the aura moves in its own vast galactic sweep and exercises a large-scale, or general control over the movements of matter, but is independent, or as if immobile to its lesser motions.

*The "Saturnian Atom" and the "Moseley Number."*—The spherical surface of the atom may be deformed into an oblate spheroid by a sufficiently rapid translation in the direction of the atomic axis, but any marked distortion from a symmetrical form would lead to a breaking up of the atom. Such distortion, however, becomes difficult if the electrons are in exceedingly rapid orbital revolution. It is supposed by Bohr that certain electrons occupy a circumferential position, arranged in rings about the nucleus in a common plane so as to have some analogy with the rings of Saturn, whence the arrangement has been called the "Saturnian atom," that they are thus revolving in orbits around a central nucleus, and that the frequencies of line

spectra are determined by perturbations of these satellite revolutions. It is also known that the atom contains an enormous amount of energy which is invariable except in radio-active disruption of the atom. I assume that this inner invariable energy of atomic constitution is that of still other orbital electronic revolutions of great velocity within a central nucleus in which resides by far the larger part of the mass, and whose stability is far greater than that of the satellite orbits. The latter are relatively few, and we may assume that their number is that of the Moseley number, characteristic of each element, which varies between 1 for hydrogen and 92 for uranium. For the moment we may leave in abeyance the question whether the orbits of the characteristic electrons which give the Röntgen rays of the K series are within or outside of the nucleus. For illustration assume them to be inside. Presumably in this case the satellite system of hexavalent uranium is composed of six concentric rings of electrons, composed successively from the inmost to the outmost ring of

6, 11, 15, 18, 20, 22 = 92 satellites.

This gives the number six to the inner ring in agreement with the valency.

The nuclear electrons, on the other hand, reach into the thousands (uranium, about 439,000), and the mass of the atom is practically that of its nucleus. This implies that the electron is the fundamental gravitational unit, and that its power of gravitational attraction is independent of its position in the atom, though the resultant inertia is connected with the gyrostatic properties of the revolving and rotating electrons.

*Origin of the Gravitational Impulse.*—The remaining problem is to find a mode of electronic interaction, diverse from the electrical one, which is capable of producing a gravitational impulse, and one which shall not only not endanger, but which shall conduce to the stability of the atom. Stability may conceivably be maintained electrically, if this were all, by the juxtaposition of two concentric

spherical shells of electrons revolving in parallel circular strands in the same direction and with the poles of the electrons juxtaposed in the direction of the orbital motion as aforesaid (since it is obvious that the planes of rotation of the electrons must set themselves at right angles to the directing attractive forces) forming as many superficial circular vortex-filaments by their combined motions of revolution and rotation; while the electronic rotations are opposite on the inner and outer shells, giving to the members of a pair of shells opposite electricities. Since the inner shell is slightly the smaller of the two, we may suppose that it has fewer electrons and that the satellite electrons which agree in electric charge, or direction of axial rotation, with those of the inner shell of the pair, are left over and are needed to make up a number equal to the sum of the electrons in the outer shell, thus providing for the precise equalization of electric charges in the neutral atom.

It has been held by several theorists that gravity is of the nature of a longitudinal wave of compression in a universal medium. The simplest way to account for such a wave is to suppose that the electrons are pulsating rapidly, that is, that they alternately expand and contract equably on all sides. I can not see that this will interfere in any way with the simultaneous movements on which the electric and magnetic properties of the atom depend, while the need of a wholly independent origin for gravity seems obvious. But for the urgent call for some working gravitational hypothesis of a mechanical sort to complete the scheme resulting from the new electronic conceptions, I should have no wish to add one more suggestion to the rash, but ambitious conjectures on this subject which have been relegated to the mausoleum for dead whales in the depths of the sea of knowledge.

If the foregoing hypothesis is to be accepted, it seems necessary to distinguish clearly between inertia and mass. An ether-particle may be pulsating like an electron and may thus have mass, but it lacks inertia in its own right, unless vibrating with an oscillatory motion and driven



forth with the velocity of light as *luminiferous* ether. Being assumed to possess "mass" in a certain limited sense, we must ask in what way an atmosphere of bound ether can be attached to, or condensed around the atoms. If the bound ether were that of interatomic radiation, cold matter should cease to refract which is not borne out by observation. The presence of bound ether is not manifested except in so far as it is revealed in the refraction of light, where the velocity of light in the denser transparent media is slower because the "bound ether" which interpenetrates their substance and is never absent whether the matter is radiating or not, is denser, being more strongly attracted by their heavier ultimate particles. Thus this shell of ether, while held to the electrons by attraction, acts almost as if emitted by them up to a certain compensating density, and it is only flung off when some sudden change of orbital motion occurs. The supposition that the shell is at once reformed at the expense of the surrounding aura relieves the dilemma arising from its continual loss in the generation of radiation. That there is an intimate relation between the refractive and the electric properties of matter is because ether-corpuscles and electrons are also most intimately related.

Nothing definite is known at present as to the nature of static electric charges upon a solid body, though much is known about the electrification of a gas. The beautiful curled filamentary structure of certain high-tension electrical discharges in air is presumably connected with the viscosity of highly heated gases and a tendency to the formation of complex aerial vortex-rings. The testimony of the electrical stress-figures in resin obtained by J. W. Swan,\* where the positive stresses simulate motion under attraction from every direction towards a center, and the negative stresses suggest an attempt at the formation of vortex-rings, or outgoing explosive puffs in a resistant medium, can be interpreted on my present hypothesis to mean that the electrons have poles of different sorts;

\**Proc. Roy. Soc. London*, Vol. LXII, p. 38, 1897.

that there is an indrawing of aura through a central core at one pole and outflow at the other pole; that in positive electrification there is a superficial electric shell in which the electrons are so placed as to have their indrawing poles pointing outwards, while in negative electrification the opposite poles are on the outside and there is outflow towards the exterior; and that thus the distinction between positive and negative electrification is that between right-handed and left-handed rotations in the superficial electrons which give the charge. Though the electrons forming the static charge are exceedingly few compared with those making the mass of the solid body, yet the electrical attractions of the charge are comparable with the gravitational attractions of the entire mass.

*Definite Statement and Illustration of the Electric Nature of Matter.*—As a basis of atomic structure, let it be assumed, then, that the atom is formed wholly of rotating, revolving, and pulsating electrons, and that there is but one kind of electron, which consists of a definite volume of the universal medium in rapid rotation. This rotation of the electron can be viewed in either of two aspects; and two right-handed whirls with their equators in one plane will repel each other if, when moving in opposite directions, they meet and are forced into contact, thereafter assuming opposite directions of motion at right angles to the original line of approach. But right-handed and left-handed whirls, that is, electrons which have opposite rotations, can have their equators juxtaposed in the same plane and will mutually attract each other. It follows that there are *two electricities* which may be formed the one from the other by a simple gyroscopic uptipping (at least in theory, whatever may be the obstacles to the change); and thus, in order that there may be stable equilibrium, the positive electricity in an atom must be closely conjoined with an equal amount of negative electricity; for as soon as one of the corpuscles of the atom is set free, it becomes indistinguishable from any other electron, whether coming from a positive or a negative source. The loss or gain of even a single electron



destroys electric equilibrium and converts an atom into a positive or a negative ion with strong chemical affinity.

Next, since we have adopted the theory that the mass of the atom is wholly electrical, it follows that a hydrogen atom consists of 1,844 electrons,\* this being the ratio of the mass of a hydrogen atom to that of an electron.

According to Bohr's theory,† a hydrogen atom consists of a single satellite electron in orbital revolution around a central nucleus which has a positive charge, and with a frequency of 3,290 million million revolutions per second‡ given by Lyman's measurement of the shortest wave-length in the hydrogen spectrum. This may be accepted, but it is not necessary to suppose that the nucleus is simple. According to the preceding supposition, the nucleus must consist of 922 electrons rotating so as to give positive electric charge (if they were disposed after the manner of a surface charge), combined with 921 of the opposite rotation which would give negative electrification if similarly disposed, so that the two opposite charges existing in potency are almost exactly neutralized, but with a small positive residual which is the equivalent of the negative charge of the satellite.

If the satellite revolves just outside the equatorial circle of the nucleus, the positive charge of the outer layer pre-

\*In his book, "The Universe and the Atom," Marion Erwin has given an ingenious but complicated scheme of an atom which accounts for the Balmer series in the spectrum of hydrogen very well, but demands as a corollary that the hydrogen atom shall contain precisely  $(12)^3 + 4 = 1732$  electrons. Millikan's latest result for the mass of the electron, which has been obtained by methods of extraordinary accuracy, definitely condemns this hypothesis. Moreover, by an application of Kepler's laws to the electronic revolutions in the atom, Millikan derives Rydberg's number  $N$ , or the fundamental frequency constant, with an accuracy of one part in one thousand, and thus not only gets the Balmer series, but explains it in a remarkably simple way.

†*Philosophical Magazine*, Ser. 6, Vol. XXVI, p. 1, July, 1913.

‡See R. A. Millikan, *Science*, N. S., Vol. XLV, p. 327, April 6, 1917.

vails sufficiently to direct the orbit of the satellite and to keep it in the equatorial plane; but stability requires that the satellite's rotation shall assume the relation of negative electricity to the outer shell of positive electricity and that the direction of revolution shall be the same in both. They would also be true if the extra electron were inside the atom. All of the revolutions must be congruous to avoid eventual disruption.

The satellite is relatively free, and it is the one electron which may be easily displaced and lost to the atom, when the nucleus thus stripped becomes a positive ion. The revolving electron which has become free is, I repeat, like any other electron, simply because it is emitted from what we have agreed to call the negative pole of a source of electric current; but actually it has electric sign solely from its association with other electrons. This becomes evident if we trace the consequences of a meeting of a nominally "positive" ion which has lost its satellite, with a neutral atom. Immediately, if the revolutions of the electrons are congruous, the satellite of the normal atom is shared by the two nuclei and serves to bind them together into one molecule, forming the single *bond* of chemical union. The normal, or neutral, atom behaves as if it were negative in respect to the positive ion and there is the electrical attraction of chemical affinity between them; though, but for the shared electronic satellite, the two nuclei would be mutually repellant from the similarity of their electric charges.

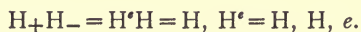
If a normal atom meets with another normal atom having its orbital electronic revolutions facing the same way, can the two unite into a molecule with *two* satellite electrons either satellite being displaced towards the intermediate plane parallel to the two equators, and perhaps coming into equilibrium on opposite sides of a common orbit? Apparently this is possible, but with diminished affinity owing to a divided attraction.\* Two normal hydrogen atoms with

\*If  $H_+$  represents an atom of hydrogen which has lost a satellite electron, and  $H_-$  represents a hydrogen atom which still retains its extra negative electron, the constitution which Bohr attributes to the hydrogen molecule, namely,  $H-H$  (or the above problemati-

congruous electronic orbits, placed on either side of a hydrogen ion, make the unstable molecule ( $H_3$ ) having two satellites, for whose existence under favorable circumstances there is satisfactory evidence.

*Probable Explanation of the Thermal Periodicity of the Elements.*—The theory of complex concentric vortices, elaborated by Hicks, gives a possible explanation of some of the thermal properties of the elements; but it rests upon the hypothesis of a continuous irrotational fluid whose vorticity changes at certain concentric surfaces within the atom, and takes no account of discrete electrons, each a precise replica of all the others. In the effort to see whether the conception of Hicks might not be adapted to the new knowledge I was led to consider that a group of electrons of the same name must tend to expand into a shell by mutual repulsion of the constituents of the group; yet this shell might be restrained from dissipation by further expansion, if it were conjoined with a concentric shell of opposite electrification. Moreover, such a structure may be repeated several times, thus giving the several repetitions in the thermal properties demanded by the thermo-chemical relations of the elements. To hold such

cal molecule), is hardly likely to exist permanently according to accepted electro-chemical doctrine, because the two negative electrons repel each other and tend to split the molecule. But the molecule.  $H_+ H_-$  should be entirely stable, and it serves the purpose of Bohr's theory equally well if we suppose that, in the ionization of the molecule, the negative atom alone loses its extra negative electron by the step-to-step process of orbital shifting, becoming in this way similar to its companion atom. If a single electron ( $e$ ) is shared between two atoms, the successive stages of ionization are:



The intermediate stage gives no spectrum, but the last or actively transitional one gives the Balmer Series. It is also probable that under certain rare conditions, the hydrogen atom may retain two negative electrons and give the series of lines in the spectrum of V Puppis.

an assortment together as one piece in spite of the tremendous energies demanded by internal revolutions, is not a simple proposition; but possibly the thing may be accomplished if we postulate a medium back of the electrons with a complex vortical flow, somewhat analogous to the Hicks plan, which controls the electronic motions. It is necessary to assume that at each reversal of vorticity, there is an uptilting and reversal of spin in the electrons, considered to resemble gyroscopes, if the expansive force acts at right angles to the directive force. According to gyroscopic analogies, the electrons can rotate either right-handed or left-handed with equal facility as long as the plane of rotation is normal to the direction of revolutionary motion which is that of the directive force; but if shifted radially in the instantaneous direction of the plane of rotation, the electron so urged is liable to be overturned as in a well-known gyroscopic experiment. The reversal of the electron's rotation requires the expenditure of one of Planck's units of work.

Of the hypothetical system of concentric vortices which has been mathematically computed for an assumed irrotational medium, Hicks himself says: "If vortex atoms are realities, the exact quantitative theory developed in this paper can not accord with actual facts, because it is developed with reference to a surrounding irrotational ether, which can not be the case in nature. Nevertheless, many of the general properties would doubtless be similar."\*

In the atom which we are considering, the stream lines are "lines of flow" of the electrons, but not of their constituent medium, because the components of electronic rotation, or spin, do not vanish as they are supposed to do in irrotational motion, and stream and vortex lines can not "fold together, cross, and expand" in continuity at a limit. Still, even though the gyroscopic reversals are sudden, there is a decided analogy to the condition postulated

\*"Researches in Vortex Motion. Part III. On Spiral or Gyrostatic Vortex Aggregates." By W. M. Hicks, F.R.S. *Proc. Roy. Soc. London*, Vol. LXII, p. 335, February 3, 1898.

by Hicks. I will merely note that the alkali metals which are placed at the maxima of Lothar Meyer's curve of atomic volumes, or in positions which, according to my supposition, mark strong intensification of those thermal properties which are given by nuclear constitution, are of all the elements those which are most prone to give a mixed flame spectrum in which the bright lines are accompanied by a strong superposed continuous spectrum, and they are *thermally expanded atoms*. These atoms are therefore at nodal points of the interior organization of their nuclei, each corresponding to the successive addition of a new pair of electronic shells in the order of increasing steps in the atomic weight.

Professor W. M. Thornton\* finds that "the periodic curves of density and atomic volume both have the inflection characteristic of hysteresis. They can be built up on the assumption that the internal force by which atoms are held together passes through a simple periodic change and that in the resultant change of atomic volume there is structural hysteresis." Hydrogen, boron, aluminum, copper, ruthenium and osmium, which are the densest atoms of their respective thermal periods, have their atomic weights proportional to the cubes of the first six natural numbers. Presumably, the most complex atom, uranium, has six rings of supernumerary electrons, arranged in one orbital plane, and six pairs of electronic concentric spherical shells, or what may be likened to a twelve-storied structure, and it is doubtful if any larger number of stories can exist in an atom.

The thermal relations of the atoms appear to be those of their central nuclei, both as to chemical properties and as to those radiations which are especially caused by heat. Perhaps this is what Swedenborg glimpsed when he assigned heat to a "central motion of particles."

\*"The Curves of the Periodic Law," *Philosophical Mag.* for July, 1917, p. 70.



## THE LUMINIFEROUS ETHER: (II) ITS RELATION TO THE ATOM

The particles of ether may be produced out of the aura by some modification, perhaps involving a virtual condensation of the aura; but the process has not reached any final limit, for the ether-particles remain highly elastic, and if there is a shell of ether around each atom, it is compressible since the density of the bound ether in matter varies. It may be admitted that we do not know just what ethereal "density" means, and that it is probably a concentration of some electrical property. Just as spongy platinum, by the powerful attraction of its atoms and the large surfaces of its porosities, condenses gases in its pores, and thus by its presence has the same effect as an increase of pressure and favors chemical union of certain gases where this union is facilitated by pressure;—so the heavier atoms condense the so-called ether in the interatomic spaces, and this is done so nearly in proportion to the atomic weight that it is possible to predict the refractive index with approximation from the known atomic constitution of a substance in unit volume, though more closely from the electric properties. It is indifferent whether different atoms are chemically united or merely mixed, as far as refractive properties are concerned. Hence the ability to condense ether resides directly in the atoms. The denser "bound ether" exerts greater electric inductance on the vibrating ether which traverses it and thus retards the passage of light. Though readily thrust aside, the bound ether "particles" can not be dispelled by other particles of their own order of magnitude without suffering some oscillatory disturbance; and this oscillation of the bound ether-particle is itself electro-magnetic and reacts on the electric oscillation of the light-bearing ether-particle\* with its

\*If we call the direction of advance the "polar" axis of the particle, any oscillation in the equatorial plane would be equally divided between transverse and parallel vibrations in respect to a meridional plane, and polarization in this case would be impossible; but a meridional oscillation may be either transverse or parallel to a given meridional plane. The fact of luminous polarization there-

reciprocating magnetic vortex in such a way as to retard its onward progression.

Since oscillating or rotating ether not only possesses ethereal mass, but also electro-magnetic inertia, the ether, considered as an interatomic medium, is a substance which offers no resistance to the mechanical motion of atoms which do not set it rotating, or oscillating in the special luminous mode, but possesses electro-magnetic inertia for luminous motions which cause its particles to oscillate luminously. Similarly, though the advance of a broad surface composed of many molecules with their atoms and electrons can not cause a single ether-particle to rotate (because the dimensions of the two are on a totally different scale of magnitude), motions of individual electrons which are of a like order of magnitude with the ether-particles and which are not self-compensatory, are competent to impart to the ether temporary electric inertia and momentum. Thus the supposed ether, though having no inertia of its own, is bound to matter by having imposed upon it a portion of the inertia of electronic movement sufficient, at any rate, to cause some adhesion of the bound ether to material particles.

There is also some temporarily associated ether of another sort, for even in solid bodies at ordinary temperatures, there is, in addition to the thermal energy of molecular vibrations mechanically transferred, some low-temperature radiation between the molecules; and as I have shown elsewhere in treating of gaseous radiation, this internal radiation becomes of exceptional prominence and importance in the gaseous atmosphere. To this extent, at any rate, even the radiant ether may be bound to matter.

Various theorists have speculated as to whether the light-bearing ether does or does not possess mass. Clerk Maxwell has assured us that light has momentum and

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fore decides that the vibration of the polarized light is a meridional oscillation. The plane of vibration may, however, be magnetically rotated in an equatorial direction as in the Kerr effect.



therefore the ether must have both mass and inertia as long as it transports light; and he even went so far as to assign to the free ether a definite density in\* the ordinary sense.

Luigi d'Auria,† considering the extent of space and assuming it to be filled with ether, thought that the gravitative action of the whole ether would suffice to account for stellar motions; but since he enormously underrated the immensity of space (in confining it to a radius of about 2,000 light-years) and also misunderstood Maxwell whose ethereal density was referred to water as unity and not to air, d'Auria's computation is of no value. Maxwell's density also contained a small numerical error, as I pointed out in my "Cosmic Cycle"‡, but this is a mere bagatelle compared with the gratuitous assumptions which he has made in getting any density at all of the material sort for the interstellar medium.

G. A. Hirn, in his "Constitution de l'Espace Celeste," has given elaborate computations of the action of a resisting medium upon the motion of the planets and has demonstrated that the large material mass assigned to an interplanetary medium by Siemens and others, is an impossibility. But the conclusion that the light-bearing ether has no mass does not follow. The work of Hirn, however, proves that an ether possessing such *ethereal* mass as is required for the various ethereal functions does not fill all space in the form of a continuous medium as was formerly supposed. Whatever ethereal atmospheres there may be are strictly limited to the immediate vicinity of massive bodies. An atmosphere of free ether particles, since these have mass but not inertia, might be expected to follow a planet, but not to share in its rotation. Such an atmosphere might be somewhat more extensive than the atmosphere of air.

\*In his article "Æther" in the 9th edition of the Encyclopædia Britannica.

†*Journal of the Franklin Institute*, October, 1897.

‡*American Journal of Science* [4] Vol. XIII, p. 192, 1902.

This doctrine of the limitation of ethereal atmospheres to spheres greater than the aerial, but still confined to the neighborhood of the heavenly bodies, was held by Swedenborg, was formerly peculiar to him, and probably contributed to the rejection of his theory of the luminiferous ether for nearly two hundred years, because, at least during the Nineteenth Century, it was accepted almost as an axiom that light is propagated through a *continuous* medium filling all space, and by transverse waves in this medium; and therefore, since the stars send us light, it was supposed that the luminiferous medium must extend beyond them. We need not abandon the idea of a universal interstellar atmosphere, but it is *not the atmosphere which conveys light*. The new doctrine of discrete light "quanta," though it may be non-committal as to the precise nature of the luminous entity, rejects the supposed continuity of a luminiferous medium, but harmonizes well with Swedenborg's definition and with the function which he attributed to the ethereal particle.

The revival of a modified corpuscular theory of light no longer compels us to explain the aberration of light on the undulatory theory by "the rather startling hypothesis that the luminiferous æther passes freely through the sides of the telescope and through the earth itself";\* and while the meaning of the Michelson-Morley experiment has been much debated, its result is at least in harmony with the supposition that a shell of bound ether is attached to, and is carried along by every atom and thus, by summation, by the earth as a whole in its motion (though not as a rotating external atmosphere which, however, does not enter into the light equation); but this bound ether is not the ether which conveys light from outside sources. This follows also from the result of Lord Rayleigh's inquiry: "Does Motion through the Æther cause Double Refraction?"† confirmed with even more delicate precau-

\*G. G. Stokes, *Philosophical Magazine*, [3] Vol. XXVII, p. 9, July, 1845.

†*Philosophical Magazine*, [6] Vol. IV, p. 678, December, 1902.

tions by D. B. Brace.\* These experiments show that the ether concerned in refraction is bound to the earth and travels with it through space.

As Stokes pointed out in the above paper, the adoption of a corpuscular theory of light makes the aberration of light a very simple thing, while the hypothesis of luminous transverse vibrations in a quasi-solid and yet fluid medium, puts a heavy strain on our credulity.

Foucault's experiment which showed that light travels more slowly through transparent bodies of greater density, than it does through bodies of feeble density, demonstrated that the density of the included ether must vary through a considerable range according as it is associated with dense or with rarified matter. This "density of the ether," however, does not refer to that of the particles themselves. They may be not only elastic, but expansile and contractile, though through a very minute range. As light-quanta in free space, they presumably have the same size as electrons, according to the hypothesis of their origin which has been presented in this paper, though the electron is rendered rigid by its rapid axial rotation, while the non-rotating ether is yielding.

Fessenden, assuming that the electronic charges are the sole cause of the mass, and their motions, of the inertia of matter, calculates from J. J. Thomson's formula for the electrically produced inertia of a charged sphere, that the electron is "about  $\frac{3}{4} \times 10^{-13}$  cms.† in diameter. The ionic equivalent being about  $4 (\pm 1) \times 10^{-10}$  e. s. units [now more accurately fixed by Millikan at  $e=4.774 (\pm .005) \times 10^{-10}$ ] we find the electrostatic tension and pressure at the surface of the corpuscle, about  $2 \times 10^{32}$  dynes."‡ The revised measurement of the electron's radius makes this more nearly  $10^{33}$  dynes. With this relatively enormous pressure at the surface of the electron, it is necessary that the volume-

\* *Philosophical Magazine*, [6] Vol. VII, p. 317, April, 1904.

† J. J. Thomson gives for the radius of an electron "about  $10^{-13}$  cm." (Conduction of Electricity through Gases. 2d Edn.. p. 655). Millikan (The Electron, p. 251) gets for this radius,  $1.9 \times 10^{-13}$  cm.

‡ *Science*, N. S., Vol. XII, p. 743, November 16, 1900.

elasticity shall be as great as  $10^{73}$ , if the electron is not to collapse entirely; and this represents the electronic volume-elasticity *resulting from the elasticity of the aura*. It is by virtue of this wonderful, almost infinite elasticity that the aura is able to vibrate gravitationally with a periodicity comparable to that of light, through space of galactic dimensions.

The force required to produce the electric condensation at the surface of the electron must be balanced by the equal internal spring of the electron's volume-elasticity. The numerical ratio of volume to surface being that of the cube to the square, and since the surface of an electron is about  $10^{-25}$  sq. cm., we have approximately

$$\begin{aligned} \text{volume-elasticity of electron} &= \frac{(\text{surface pressure})^{3/2}}{\text{surface of electron}} \\ &= \frac{(10^{32})^{3/2}}{10^{-25}} = 10^{73}. \end{aligned}$$

Professor Fessenden suggests that the size of an electron is determined by the fact that the breaking strain of the ether is reached at this point, so that any further electric condensation is impossible. I would also suggest that probably the rotation of the electron at its surface boundary attains the speed of light, and that this is why when the electron is stripped of its superficial layer of ether, the latter is flung off with the same speed. Also that the velocity of electronic rotation is the same at all points of the surface of the particle, so that the angular velocity increases from the equator to the poles, being

$$\frac{2.999 \times 10^{10}}{2\pi \times 1.9 \times 10^{-13}} = 1.660 \times 10^{22} \text{ revolutions per second}$$

at the equator, if we adopt Millikan's value of the radius of the electron. This is about 1,000 times as great as the frequency of the characteristic vibrations of the lighter atoms. Hence the angular velocity of the orbital revolutions of these electrons is presumably less than that of their rotations.

The configuration of this superficial electronic motion is similar to that which Swedenborg assigns to his elementary vortical particles (mentioned *ante* p. 9). An example of a particular case of such motion may be seen in my notes to the new English edition of the *Principia*.\* In his doctrine of forms Swedenborg describes a fifth natural form, superior to the vortical, "by which one thing regards another as well as itself, nor is there anything but what consults the general strength and concord."† On the lowest plane of nature, this form exhibits itself in the gravitational wave by which each particle is united and consociated with all the particles in its galactic cell. Thence comes the interaction and universality of natural law. Nature is not diverse, here of one sort, but elsewhere totally different and unrelated. Nature is one and the same throughout her vast complexes, and this unity appears to require some such fundamental singularity as that of the form of motion and the size of the electrons which must everywhere be precise duplicates.

The origin of a light-quantum I conceive to be the gyroscopic uptilting and reversal of an electron, accompanied by reversal of electric sign. If the center of rotation of a gyroscope is revolved in the direction of no resistance, there is no uptilting; but revolution in the opposite direction experiences resistance which reverses the spin. Similarly, a rotating electron may be carried around an orbit and brought back to its original position without performing work; but to reverse the plane of the electron's rotation requires the expenditure of one of Planck's least quantities of energy, and this means that resistance has been encountered. The quicker the reversal, the more intense is the radiation; but the period of the vibration appears to depend on some function of the radius of the electronic orbit. The simplest supposition is that the

\*Appendix A. Vol. II, Fig. 4 *a*, p. 623.

†For illustrations of this see my paper in the *New-Church Review*, Vol. XIX, p. 256.



radiant period is the same as that of the electronic revolution, but this does not necessarily follow.

Where many electrons are closely associated, it is difficult, or almost impossible to overturn a single electron without at the same time effecting a similar overturning in a multitude of others; but the few electrons whose group is denoted by the Moseley number, are relatively free. Each executes its own period, though, even here, the mutual relations of attraction and repulsion which tend to preserve stable relative positions, can not be disturbed by the misplacement of a single electron without starting a series of vibrations which give complicated line-spectra through the complex perturbations of the group. Ionization of the atom is an inevitable concomitant of the operation, that is, the radiating atom either loses or gains one or more electrons.

The adoption of the assumption that the electron represents the greatest possible condensation of electric force, and that there is only one kind of electron, along with Fessenden's conception that its size (and therefore its electric charge) is conditioned by the breaking strain of the ether, leads readily to my thesis that the electron has a rotation and a peculiar form of vortical motion similar to Swedenborg's elementary particle, and furnishes a reason why it should have this peculiar form. In fact, no other form would fit the demand that the surface shall everywhere have the rotary velocity which is fundamental in the physics of the ether and definitive of the relation between electrostatics and electromagnetics. My further proviso that an ethereal electronic sheath is cast off under shock at the moment of reversal of electric sign, which reversal is the origin of the reciprocating magnetic field of the luminous particle, and that the sheath becomes an ether-particle having the same significant rectilinear velocity as the circulatory velocity of the electron's surface, also accounts for the fixed value of the energy-constant, equivalent to the light-quantum, and defines it as the energy required to overturn and change the sign of an electron.

The same is in perfect agreement with, and satisfactorily interprets the well known law that "positive and negative electrical charges always appear simultaneously and in exactly equal amounts"; for if positive and negative electricity are but two different aspects of one and the same electric unit, the separation of a pair of electrons must inevitably give equal and opposite electrical charges.

Though not expressed in identical terms, my supposition that Planck's least quantum of energy represents the resistance which an electron offers to a gyroscopic uptilting with reversal of electric sign, agrees in a general way with Fessenden's hypothesis that Planck's " $h$ " represents a gyroscopic reversal of vorticity.\*

Swedenborg had the idea of "small corpuscles which float in the ether and continually issue from the hard body; thus the ether is urged into a whirling motion at a distance from its body, and this causes light, and to a certain degree, electricity. For no bodies exist which are not in some way or other penetrated by the ether."† Though somewhat vaguely stated, if the "whirling motion" is thought of as a vortex filament in the *magnetic* medium, and the "corpuscles" as Thomsonian corpuscles, or electrons, this corresponds to the present conception of a static electrical charge on the surface of a "hard body" with its attendant Faraday "lines of force." Swedenborg's version, that "in order for anything to be electric and attract very light bodies, a certain circular motion is necessary in the ether," also accords with Sir J. J. Thomson's interpretation of an electric line of force, namely, that electric attraction is to be ascribed to the tendency of vortex filaments in an intervening medium to shorten themselves.

Benjamin Franklin, according to Millikan ("The Electron," p. 15), was the first to express his belief in the existence of a definite electrical particle, where he says: "The electrical matter consists of particles extremely subtle,

\*R. A. Fessenden on "Gyroscopic Quanta," *Science*, N. S., Vol. XXXIX, p. 533, April 10, 1914.

†*Principia*, new English edition, Vol. II, p. 221.



since it can permeate common matter, even the densest, with such freedom and ease as not to receive any appreciable resistance." I have not been able to verify this quotation in any work by Franklin to which I have access. In his note on "Protection from Lightning," written at Paris in September, 1767, Franklin says: "The matter of lightning, or of electricity, is an extreme subtle fluid, penetrating other bodies, and subsisting in them equally diffused." This says nothing about electric particles.

Swedenborg, at any rate, declared that the light-bearing ether was made of corpuscles and associated them in an indefinite way with certain other "corpuscles" which somehow were connected with electricity. This is exceedingly vague; but in my view it contains an adumbration of the truth. Meanwhile, in the gradual dawn of the scientific day, Swedenborg's "corpuscles" and Franklin's particles of "electric matter," more subtle than common matter, have become the "electrons" of Johnstone Stoney, and the "corpuscles" of J. J. Thomson; and at the hands of the latter investigator vague hypothesis has given way to experimental demonstration and exact quantitative measurement.

*Is Entropy always One-Sided?*—For the last half century it has been recognized that a certain sum total of energy may be divided into two parts, namely, the free or available energy, and the entropy; and that the available energy of sun or earth is continually diminishing, while more and more of energy escapes into the aura, there to be stored up as entropy which, according to Clausius, is a continually increasing quantity tending to a maximum, while the free energy of every material configuration either remains the same, or diminishes. It can in no wise be increased by human effort.

The thermal mechanism of matter has been likened to a clock which is slowly running down; but as Sir Oliver Lodge has said: "It would seem as if the second law of thermodynamics must be somewhere disobeyed—at least if the age of the universe is both ways infinite—else the final consummation would have already arrived." This

dilemma has been considered in my paper: "What becomes of the Light of the Stars?"\* and I think it is now fairly certain that matter is gradually destroyed and converted into ethereal energy of radiation, which, in turn, is gradually absorbed as it passes through the universal medium, or aura, again originating matter in its incipient forms.†

We have then to recognize a reversal of the original entropy proposition, namely, a building-up at this stage, in place of a tearing-down; for how would it be possible for the universe to endure unless both operations were actual? We may admit that in the part of the universe in which we are placed, the tearing-down operation is going on; but it follows on any rational supposition that there must be other parts of the universe where the building-up of a renewed system takes place, where the first rudiments of matter are coalescing and developing into gaseous atoms and molecules, or into meteoritic crystals and are aggregating into nebulae, stars, and groups of stars, star-clusters and galaxies.

*Gravitational Relationships.*—This is not the place to discuss at length the origin of matter, but something must be said concerning the gravitational fields of the electrons and ether-particles, which there is reason to suppose are

\**Popular Science Monthly*, Vol. LXXXII, p. 289, March, 1913.

†Mr. Harlow Shapley has announced (*Proc. National Academy of Sciences*, Vol. II, p. 14, Nov. 17, 1915) that the frequency of colors in the star cluster Messier 13 shows conclusively that there is no *selective* absorption of light in space (a conclusion which I had already reached on other grounds in my paper, "What becomes of the Light of the Stars?"). But his further statement that "in the light of this result we are probably justified in assuming that the non-selective absorption in space (obstruction) is also negligible" (*Op. cit.*, p. 15), though it may be justified if by "obstruction" is meant a non-selective cutting out of light by particles too coarse to exert any selective influence, fails to cover the more general non-selective absorption of light by the aura which fills all space. The existence of *this* absorption is shown in my examination of the white nebulae, "Are the White Nebulae Galaxies?" quite as strongly as the non-existence of selective absorption is shown by the other argument.

limited to a single galactic cell.\* Lodge computes that if there could be substituted for the gravitational pull of the sun which holds the earth in its orbit, an elastic pull through steel rods and within their breaking strength, it would take "a million million round rods or pillars each thirty feet in "diameter" to stand the strain.† This strain is not carried by a narrow beam of aura intervening between the two bodies, but is the resultant of the interaction of fields of force which fill an entire galactic cell. Though seemingly impalpable, the aura is stronger than steel, but this strength results from its intimate connection with an infinite source of energy which is spiritual. So does the invisible spirit control the body; and even so public opinion, a seemingly intangible thing, is stronger than the most powerful autocrat, and in the end will prevail. Because of the universal relationships of the aura, it has the strength of the many in one; and the wonderful thing about the electron, considered as the gravitational unit, is that through its gravitational field of force it is everywhere present (at least within the boundaries of its own aural cell) and receives into itself an impulse from and an impress of all that transpires in a vast galactic environment.

The electrons are like little organisms, or least hearts, whose synchronous systole and diastole make the life of the universe, perpetually receiving and transmitting energy from an inexhaustible source. The aura is the "fundamental substance." As Sir Oliver Lodge says of it in his searching analysis: "It cannot really *be* ordinary matter, because ordinary matter is definitely differentiated from it, and is presumably composed of it; but the inertia of ordinary matter, however it be electrically or magnetically explained, must in the last resort depend on something parentally akin to inertia in the fundamental substance which fills space."‡

\*See my paper: "On a Possible Limit to Gravitation," Publications of the American Astronomical Society, Vol. III, p. 335.

†"The Ether of Space," p. 128.

‡"The Ether of Space," p. 135.

At the center of each aural cell is a galactic nucleus from which issue either two spiral streams of stars, or else concentric spheres of stars with but little spiral structure.

*Galactic Dimensions.*—In regard to the actual status of the galaxies Mr. Gore has shown,\* and I have shown independently,† that the nebula in *Andromeda* must be an object of truly galactic dimensions. On the supposition that the nova which appeared near the center of the nebula in 1885 had an absolute brightness equal to that of *Nova Persei* 1901, I found that the nebula must be at least at a distance of 1600 light-years. If the star in the nebula had an absolute brightness of the same order as that of Tycho Brahe's star, it may have been still more massive and something like five times as far away as the first estimate, or at 8,000 light-years; but anything brighter than this or any larger distance seems improbable, for *Nova Persei* was itself an object of phenomenal size, for which (in *Astronomische Nachrichten*, Nr. 3771) I deduced a mass 1149 times that of the sun. Mr. Curtis gets 10,000 light-years as an average value for the distance of certain white nebulae not more than one-tenth of the angular diameter of the great *Andromeda* nebula.‡ If these objects have approximately the same real size, this would agree fairly with my first value; but my second value gives dimensions to the nebula which are more nearly comparable with those of our own Galaxy. If all the galaxies, including our own, have somewhat similar real diameters, the Curtis nebulae should be more nearly 80,000 light-years distant, and this seems to me a very reasonable assumption.

Admitting that the white nebulae are galaxies,§ or somewhat widely separated aggregations of double spiral form, composed of both stars and nebulous material, and in some cases (as in

\*T. Ellard Gore in *Knowledge*, N. S., Vol. 6, p. 247, July, 1909.

†In *Astronomische Nachrichten*, Nr. 4536.

‡*Publications of the Astronomical Society of the Pacific*, Vol. XXVII, p. 218, 1915.

§As is indicated in my statistical study in *Astronomische Nachrichten*, Nr. 4536.

N. G. C. 4594 and 5746) with annular annexes of dark meteoritic material, it becomes of interest to ask whether gravitation also holds sway from one galaxy to another, or whether there is a limit to the extent of the gravitational field around a given galaxy.

*Galactic Distribution and Gravitational Properties Which May Be Inferred Therefrom.*—Considering that the parallax of the nearest star is almost one second of arc, if we represent the disk of a star 1,000,000 km. in diameter by a little circle of 1 mm., we should have to place a similar dot representing the next nearest star at a distance of  $(92.9 \times 206,265) / 10^6$ , or about 192 km. away; and granting that there may be regions in the Milky Way where the star-density is 1,000 times as great as in our neighborhood, yet even there the dots would be almost 20 km. apart. This gives a startling picture of the sparsity of stellar material, and affords very little ground for the supposition that the lucid stars owe their high temperature to collisions with other stars, since the chances of their meeting are almost infinitesimal.

On the other hand, if we let a millimeter dot stand for a galaxy, neighboring galaxies will be represented by similar dots sprinkled only a few centimeters apart; and since these objects have velocities of upwards of 1,000 km. per sec., frequent collisions are inevitable unless there are mutual repulsions which develop upon arriving at too close proximity. This result might, however, be produced in another way, provided gravitational attraction by which we assume the stellar movements are given, is not universal, but is limited in its action to definite volumes around each galactic center, within which gravity is controlled by definitely limited currents of the aura. In fact, the great velocities which are exhibited by certain of the white nebulae do not necessarily imply that the motions have been imparted by the attraction of masses enormously greater than that of our Galaxy. The entire field of gravitational potential energy belonging to a given galaxy being borne by a limiting volume of surrounding aura, we may presume that if



this volume of aura has a motion of its own, the system of enclosed material particles will necessarily follow. The galactic multitude will be carried along as if it were so much floating material borne on a supporting current of the universal medium to which each particle is intimately attached by its very constitution, though the cause of the motion is not to be sought by pressure in currents of immediately juxtaposed aura, but in more extensive aural currents, with which the matter is connected through fields of force. Moreover, as each portion of aura, attendant upon a given galaxy, constitutes, as it were, a single compartment, or cell, in a great multi-galactic organism, while it is conceivable that occasionally a fragment of aura with its enclosed matter may be torn off from a given cell, and may invade a neighboring cell, we might rather anticipate that, as a rule, the individual compartments will retain their individuality. In general, an entire block of aura with its contained galaxy will not penetrate a neighboring block as one mass, but if it must move in that direction, it will do so by thrusting the other to one side. Except for certain gaseous nebulae of bizarre forms which appear to be entangled among stellar masses belonging to our own Galaxy, the other, or white nebulae, as a rule, exhibit a general similarity of type; and in only a very few cases is there any appearance whatever of that reckless disarray which might be charged to interpenetrating or colliding galaxies. I think we may infer that in spite of what is geometrically a very close proximity, these galactic masses, while moving among each other freely, do not collide; and if occasionally a fragment of the mass is torn off and sent far afield, together with its enclosed matter, there is produced at most only a lone wandering star, moving with the velocity of the original fragment, which may for a while thread the intergalactic spaces, or even pass through foreign galaxies as a "run-away star," but which will eventually be subdued by the persistent lagging of its attached aura, just as the relics of a tornado go on whirling for a while, but

are at last absorbed in the more general movements of the atmosphere.

We are thus led to look upon the galaxies as local knots of aggregation, separated by considerable spaces, but not by spaces which are enormous compared with the galactic diameters; and these intermediate spaces need not be wholly devoid of stars. It has been surmised that some of the faintest stars shown on photographic plates may be at distances of something like 50,000 light-years. This is possible, but if so far away, it is improbable that these stars have any connection with our Galaxy whose condensations occupy a much smaller space.\*

*Pulsations and Revolutions of Electrons in the Atom.*—If the pulsation of the electron involves an elastic reciprocating vibration between the whole vast body of aura in an aural "cell" reacting upon the elastic resistance of the rotating aura circumscribed by the surface of an electron, the superficial condensation need not be great, but at any rate the interior resilience must be enormous. In fact, we should infer as much from the wholly independent result obtained by Fessenden for the pressure at the surface of an electron. The atoms in their most condensed form in liquids and solids have equally an enormous interior resistance and are practically incompressible. This property will have to be referred back to the great resistance to pressure of the constituent electrons.

*The Pulsating Electron and Its Relation to the Universe.*—According to the experiments of Bjerknæs with pulsating spheres, if the results are applicable to gravitation, since negative gravitation is unknown, it is necessary that all of the pulsators shall pulsate synchronously with identical periods and phases. The gravitational pulsation must therefore be the unique origin of time and its most fundamental expression. It also constitutes a most amazing evidence of the absolute unity of the created universe. Hicks

\*As is shown in my paper: "On Stellar and Nebular Distances," *Knowledge*, Vol. XXXV, No. 530, September, 1912, pages 329-332; and No. 531, October, 1912, pages 373-376.



remarks on this point: "All we have to suppose is that atoms pulsate with a constant period, and that none have phases differing by more than  $90^\circ$ , or that if such once existed they have been eliminated." No suggestion has been offered, however, as to any means by which this elimination can be effected.

Now in spite of an infinite diversity, there is in the universe a unity which suggests a consistent plan and universal correlation of parts. Spiritual philosophy attributes this unity to the Oneness of a divine Creator. If the synchronous pulsations of the electrons can be demonstrated, it will be the nearest approach that science has ever made to the acknowledgment by the magicians of Egypt, the very dust having become alive: "This is the finger of God" (Exodus, viii, 19). Verily, the mystery of the infinitely little is as overwhelming as that of the outstretched heavens.

Hicks says: "If the theory offered is the true one for the explanation of gravitation it would be possible to have celestial systems, the parts of which in each would obey the law of gravitation, but which would not influence each other, or would repel each other." Evidence has now been adduced which seems to me powerful in confirmation of this conception. The relative crowding of the galaxies is so great that it argues a mutual repulsion between these larger parts in a system of another order.

Various investigations of the pulsatory gravitative hypothesis have been made, notably those of the mathematicians, Hicks, Burton, and Leahy. In these studies it has been found necessary to assume the existence of points which are sources or sinks of fluid motion. Swedenborg also predicted the beginnings of the universe from "points" which are centers of "conatus," which may perhaps be translated "energy." But however permissible the assumption of these "sinks" and "sources" may be as mathematical devices, it is impossible to conceive of them as actually existent, except as the outcome of a hyper-space of whose reality several eminent mathematicians have speculated, and for which even a semblance of experimental evidence has been given by Zöllner in his "Transcendental

Physics." The existence of properties which transcend those of matter and tridimensional space is forced upon our attention whenever we approach the boundaries of the material universe.

While the enormous velocity of gravitation indicates that the transmitting medium is almost incompressible, the atom and the electron must be regarded as definitely limited volumes within which a diminution of the "density" of the aura arises through the centrifugal force of a rapid rotation. Burton assumes that "the nucleus of an electron, instead of being vacuous, is merely a region of somewhat diminished density. . . . This assumption as to the nature of the electronic nucleus is admittedly gratuitous, but apart from the difficulty regarding mobility which it was designed to remove, it has the advantage of greatly simplifying the dynamics of the problem proposed." (*Philosophical Magazine*, [6], Vol. XVII, p. 74, 1909). By admitting the existence of local variations of density in a nearly incompressible and highly elastic medium, the transfer of such centers of density-variation becomes comprehensible, and likewise the interaction of atomic pulsations may be grasped.

In order that a mass of matter, that is, a partial vacuity in the aura, may move from position  $a$  to position  $b$ , there must be an inflow of aura at  $a$  and an outflow at  $b$ , which requires that there shall be a gradient of pressure in the aura between  $a$  and  $b$ , and that work shall be performed by the aura at the expense of its potential energy.

Mr. A. H. Leahy has urged an objection against the theory we are considering, and in regard to the proposition "that all atoms are pulsating in phases not differing from one another by more than a quarter period, and that the intervening medium is an incompressible fluid" he says: "If this were the case, the law of universal attraction according to the law of the inverse squares would follow; but unless the medium is supposed to be absolutely incompressible, in which case all pulsations would be instantaneously diffused throughout space, there would on this theory be repulsion between bodies at distances greater

than a quarter wave-length, and bodies would at certain distances repel one another, which is contrary to observation."\* Since in the present paper, evidence is adduced showing that presumably bodies of galactic magnitude, and separated by intergalactic distances, do repel each other, we have only to predicate of the gravitational quarter-wave a length of the order of the radius of an aural cell, and we shall have a theory of pulsating matter which accounts for both the atom and the galaxy as necessarily interrelated parts. Thus in the light of the new evidence, the supposed incompatibility between observation and theory becomes, on the contrary, a powerful argument in favor of the new theory.

As to the direction of propagation of the gravitational wave, if the direction is strictly radial, it is necessary to suppose that the wave is reflected directly back upon itself at the remote boundary of the cell; or else we must presume that the radial direction is eventually diverted into a circulatory path. The latter accords better with magnetic analogies. In neither the magnetic nor the gravitative fields is there any direct flow of the medium along lines of force as conditioning the potential; but conditions of magnetic polarization, or of pressure strain, are involved, either of them following lines controlled by the peculiar properties of the organ of transmission. Since equal numbers of electrons, having by their positions and rotations the properties of positive and negative electricity, are associated together in the atom, it may be proper to consider the gravitational unit as a pair of electrons, each pair constituting an electric doublet. The immediate electric attractions of the components of the doublet being thus very nearly satisfied, gravitation becomes a secondary residual effect of relatively very inconsiderable importance, compared with the major electrical forces from which the inner energy of the atom springs. Even if independent sources

\* *Transactions Cambridge Philosophical Society*, Vol. XIV., p. 61, 1889.

must be assigned to the gravitational and the electrical effects, the latter being especially manifested in chemical affinity, nevertheless, the two are so intimately associated in the atom that they can not be entirely divorced. On the whole, however, it seems more reasonable to attribute cohesion to the attraction of such electric doublets, but to assign gravitational attraction to the interaction of the pressure fields of pulsating electronic rings.

*"Bound Ether."*—It is now pertinent to explain my conception of the "bound ether" more fully. In the first place, by "ether" in the passage quoted from Sir J. J. Thomson, is not to be understood the specially organized entity which conveys light, but a condensation of the universal aura in the immediate vicinity of matter, which is governed by the fourth-power law appropriate to the fundamental magnetic substance; and it would perhaps be permissible to call it bound *aura*, rather than "bound ether," though if it is desired to look upon the "atmospheric" sheath of the electron as a sort of attached particle which, when detached, becomes an ether-particle, it is also permissible to do that. The ether which conveys light, however, is not so governed or hampered in its progress through interstellar space, but, like the electrons, it is free, corpuscular, and possesses radiant energy which diminishes with the inverse square of the distance as it moves onward with the speed of light, simply by spreading its field of force over a wider area. Inherently, the energy of the ether-particle does not change until it is ready to be reabsorbed, either by matter, or by the universal aura in the reconstitution of matter in its incipient nebular form.

The rays of light are not deflected by passing through the bound ether attached to matter, because they readily penetrate this ether; but they are *retarded* by it through electromagnetic forces developed in the medium. Thus aberration of light is entirely independent of the bound ether, nor can the rotation of a mass of matter impart a like rotation to the aura. The attached ether moves with its attracting matter from one locality to another. This

moving attached ether accompanying a transparent body in its motion does not carry with it, control, or push aside any radiant ether which may enter it by the crude mode of a bodily displacement. Yet in a more subtle way, through induced vibrations and the drag which they impose upon the passing rays, the bound ether, whether quiescent or moving (and independently of its state of relative motion or rest) does exert a retarding influence on the passing radiant ether, but one which is determined by the density and electro-magnetic state, and not by the motion of the bound ether. Thence comes refraction.

*Is there a More Extensive Atmosphere of Ether Attached to the Earth?*—The argument of Sir J. J. Thomson, noted above, which limits the extent of the bound ether shell (consisting of bound aura) to the immediate vicinity of matter, is conclusive as regards an *electronic* atmosphere. Swedenborg, however, imagined that there might be atmospheres of ether encompassing the heavenly bodies and much more extensive than the aerial atmospheres, but also everywhere penetrating between the grosser particles of solid matter. In his futile attempt to improve the Cartesian vortical scheme for explaining the planetary motions, he at first ascribed their cause to the interaction of vortices in these extended spheres of *ether*, though distinguishing the ether from a universal interstellar atmosphere consisting of still finer particles. After explaining that the earth was thrown off from the sun and at first moved near the solar surface and performed "its axillary revolutions more rapidly than it does at a farther distance from the sun, where a considerable portion of it is consumed in the formation of ether, air, water and terrestrial material,"\* Swedenborg proceeds† to develop this theory. The correct translation here is a matter of more importance. Clissold's English translation conveys a wrong impression.‡ Rightly rendered,

\* *Principia*, Part III, Chap. XI, n. 2.

† *Op. cit.*, n. 4.

‡ Compare the original: "*Principia Rerum Naturalium sive Novorum Tentaminum Phænomena Mundi Elementaris Philosophice Explicanda*," of which a very carefully edited edition has recently



the text states that the earth, moving among the elementary particles which surround the sun as a medium and fill the whole space of the solar system to the outermost planets, sets in motion, or drives (*agat*) a vortex of its own, which in the early stages of the earth's development was large because the earth then moved more rapidly, and a rapidly moving body can drive a larger vortex than a body which moves slowly. Also a planet of greater mass draws, or retains (*trahat*) a larger vortex, because "the impetus and momentum (*pondus*) are compounded of the mass multiplied into the velocity." This language is applicable to and consistent with no other conception than that of a rotating sphere of bound ether attached to the earth and retained by ethereal friction. Swedenborg supposed that a similar, but immensely greater sphere of bound ether surrounds the sun, its volume having some relation to the *mass* of that body. Since the lesser volume moves in the greater, the two necessarily react.\* It was natural to inquire whether the reaction of these vast volumes of bound ether might not explain the planetary motions. The conception, though evidently suggested by the vortical theory of Des Cartes, is a great improvement on the latter in some respects and much more subtle; but it can not be admitted. The phenomenon, if it were possible, would have an analogy to the invisible support of a soaring bird whose momentum is transferred through aerial viscosity to an immense volume of air, and the weight of the bird by innumerable intermediates rests upon a wide surface of the earth.† It would be inconceivable that a current of ether, circulating around the sun and of no greater section than the earth's, should exercise any immediate directive influence on the earth's motion; but it was plausible that the in-

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been brought out by the Swedish Royal Academy of Sciences in "*Emanuel Swedenborg Opera quædam aut inedita aut obsoleta de Rebus Naturalibus*," Vol. II, *Cosmologica*. Stockholm: 1908.

\* As shown, *Op. cit.*, n. 5.

† See my paper on "The Rôle of Viscosity in Air Support of a Moving Aeroplane," *Technology Quarterly*, Vol. XXI, p. 490, Dec., 1908.



teraction of immense volumes of ether might bind together their respective centers through ethereal viscosity. Swedenborg's design of a flying machine shows that his thoughts had been directed to mechanism of flight and that he had grasped its essential principles. Here, however, analogy failed. The volumes of bound ether accompanying sun and planets, if retained by friction, will be conditioned by the areas and the squares of the velocities of the frictional surfaces. Hence, since the sun's equatorial velocity of rotation is only  $4 \frac{1}{3}$  times that of the earth and  $\frac{1}{6}$  of Jupiter's, the sphere of bound ether surrounding the sun, if it were thus retained, could not extend much farther than that of some of the planets. The supposed interaction of the solar and planetary vortices simply does not exist. When it is recognized that a deep layer of bound ether can not be held by friction, the conception of extensive ethereal atmospheres and of their interaction *as a source of gravity* must be abandoned; but the germ of the idea of gravity conceived as an interaction of interpenetrating fields of force in *one* universal atmosphere is contained in these early vortical theories. Whether there may be an earthly atmosphere of free ether-particles which do not move with the velocity of light, but remain at rest in respect to the earth and therefore are not like ordinary ether, and which outreach the aerial atmosphere, and what the function of such an atmosphere may be, must be left undecided; but the functions are not gravitational. If there be such an atmosphere, it is perhaps the physical basis of exterior thought, which may be said to be "in space," and especially of that telepathic thought which is received by harmoniously attuned instruments.

Later on, this theory of gravity appears to have been given up. Its author still holds to the discontinuity of the ether and its existence as a distinct, though not a universal atmosphere; but he assigns the gravitational rôle to a more subtle atmosphere which extends throughout the celestial spaces: "The three natural atmospheres originating from the sun of the world, are the purer ether, which is universal, and from which is all gravity; the middle ether which

makes a vortex about the planets, in which also is light, in which are the satellites, and from which comes magnetism; and the ultimate ether which is the air." This conclusion, though not reached until near the end of his life and not published until after his death, was not explained at length; but it seems to have been deliberately and carefully thought out, and it is in several respects in accordance with present ideas. If Thomson is right, the sphere of bound ether can extend little farther than the air, and can not include the satellites, since it must not be confounded with the planet's magnetic field.

In an intermediate stage of his thought, Swedenborg considered the possibility of *four* atmospheres, two of them, respectively assigned to gravitational and magnetic activities, being described as universal, but distinct. In his last view, he allows the ether to exercise both electric and magnetic functions and omits the purely magnetic atmosphere. This is in accordance with the salutary rule that it is undesirable to multiply agents where a single one is competent to fill several offices; and a while ago a similar dual, or "electro-magnetic" wave-theory in a single "universal" ether was in vogue. But today, in view of the greater penetrative power of the magnetic field, and the decidedly electrical affinities of the ether, it is in order to assign the dual function of both gravitational and magnetic activity to the universal atmosphere, while grouping electricity and ether together as being two species of an entity always most intimately associated with matter, save when in transit from one part of space to another after having been ejected from its original material source. Both the free electron and the vibrant ether-corpuscle, the one in the lightning-flash, the other in the sunbeam, have been violently disrupted from their association with matter and sent speeding through space; but they had previously existed *in* matter, and, indeed, are its originating constituents. In a word, all matter may be said to be formed out of light in the depths of space.

Sir Isaac Newton formed, but did not publish, a broad

general conception which is somewhat allied to the theory presented in my paper: "What becomes of the Light of the Stars?" He thought that there must be some sort of interstellar atmosphere of an attenuated substance, the "food of the sun and planets. . . . Thus perhaps the whole frame of nature may be nothing but various contextures of some certain ætherial spirits or vapors, condensed as it were by precipitation";\* but this substance was not our so-called ether, nor did he attempt to define either the nature or the activities of this universal medium. His "light-corpuscles" were in no sense the components of a universal atmosphere.

Swedenborg went much farther and labored strenuously at the herculean task of devising a system of interrelated media whose particles should be constituted on mechanical principles, while answering at the same time as a basis for various physical forces. Mathematically, he was poorly equipped for the solution of the problem, but as a philosopher he had no superior, and some of his results are in extraordinary agreement with recent scientific discoveries. Such are his ascription of luminous and electric functions to the ether, and his teaching that the ether is not the same as the interstellar atmosphere; and though he was on a wrong track in supposing that gravity results from the interplay of limited vortices of ether attached to sun and planets, he approached the truth in another way; for the electron which is so closely related to the ether, is now seen to be the first gravitational unit; and even the idea that gravity is produced by the mutual pressure of interpenetrating vortices has a foundation if the theory be transferred from the ether to the aura, or to the "purer ether" of the preceding quotation, and if the vortices are given galactic dimensions. In fact, though I arrived at my conclusion in another way, I now see that eventually Swedenborg probably reached a somewhat similar general conception (in the posthumous passage already quoted).

\*Newton's Letters, etc. *Philosophical Mag.* (3) Vol. XXIX, p. 190, 1846.

Professor R. W. Brown\* concludes that Swedenborg was probably misled into his error of supposing that there are solar and planetary ethereal vortices of opposite sorts which act and react, through his having noticed that the satellites move faster than the surfaces of their planets, but that the planets revolve in their orbits more slowly than the sun's superficial rotational velocity. Instead of attributing this fact to the action of two kinds of vortices, one moving swiftest at the circumference, the other swiftest at the center, it is more reasonable to see in this a reminiscence of the past history of these bodies, and to infer that the planets have developed from the sun successively, or from within, and show their relation to the central body of their parent and to his waning powers in this way; but that the satellites have come from without, thus by capture, and exhibit a wholly different relation.

In further elucidation of this subject, may be mentioned a passage from Swedenborg's "Economy of the Soul's Kingdom" (Vol. I, n. 299): "There are three species of motion, namely: (1) *local* or translatory motion; (2) *undulatory* or modificatory motion; (3) *axillary* or central motion. There is, moreover, (4) *animatory*, or alternately expanding and contracting motion; and to this may be added (5) *conatus* or effort, which is a perpetual tendency to motion."

The separate consideration of "three species of motion," and then the addition of yet a fourth kind, indicates that the latter is thought to be peculiar, or somewhat apart from the obvious sorts of motion. This would apply precisely to the pulsating movements of the electrons from which gravitation presumably arises. These movements can never be observed directly, but must be inferred from their effects.

The final mention of a fifth species which seems to be identical with the most modern conception of what we now call "energy," leads to the recognition of a variety of hidden, interior, or "potential" movements which also have to be inferred

\*In *The Journal of Education*, published at Bryn Athyn, Pa., Vol. XV, p. 148, April, 1916.

from what they do. It is by the eye of reason that we must penetrate more deeply into the hidden recesses of nature.

Having now viewed our subject from various sides, we are in a position to say that, according to present light, the free ether consists of spherical elastic particles, while the electrons are cored vortices whose rigid surfaces are everywhere rotating with the velocity of light; that the ether, in so far as it is atmospheric, appears to consist not so much of a single atmosphere, but rather of innumerable condensations of the universal atmosphere around the electrons from which it is thrown off in radiant emission; that the ether penetrates the structure of all material forms, but with diverse degrees of freedom according to electrical properties, and is everywhere closely associated with matter, sharing with the electrons in a gravitative pulsatory motion of its individual particles by which both are continually connected with the source of their sustenance in the universal aura, and having besides, when free, a peculiar oscillatory motion of its own; that in this way the tiny electrons are most intimately conjoined with the vast galactic spirals and like them endure for ages, while the light of the stars, though dimmed, is not extinguished after traveling for millions of years; but as light-bearer, the ether is not an atmosphere, but an emanation of discrete particles, images of vibrating electrons, involving in their inception least quanta of energy, formed out of the electronic or intra-atomic "atmospheres," and possessing innumerable varieties of specific vibrant form which reflect the electronic motions at epochal moments of perturbation and inversion, and which are accompanied by electromagnetic fields of force in the universal aura. These extended fields interpenetrate and sometimes interfere. This is an apparently simple statement, but without the discussion which precedes, it would be unintelligible.

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