light of modern points of view" and of large cooperative efforts by study groups supported by national and private foundations. But the kind of things arising in electronic, atomic, molecular, and nuclear studies, not to mention "radiative" phenomena not only in electromagnetism but in gravitation, are fundamentally different in kind. Science has not merely grown. It is now concerned with things either denied or unknown in 1900.

PHILOSOPHICAL NOTES

Early Twentieth Century Activity in the Atom. Since 1900 it has become increasingly apparent that the particles of nature not only have a considerable activity but they also have an internal structure which consists of various states which can change rapidly from one to the other. The motion or activity referred to is beyond that ordinarily referred to as thermal.

Strangely, the study of motion in the atom has been ahead of that of motion in the molecule—strange because the molecule is a larger object and closer to the portal of the submicroscopic world. But the origin of the study of atomic activity was in the effort to explain the optical spectra of atoms.

What were these specific motions? At the turn of the century they took place in what is now called the Thomson atom, named after Sir J. J. Thomson. Thomson pictured the atom as consisting of a sphere of positive electricity in which were imbedded what he called "the corpuscles"—now of course called electrons. Some people disrespectfully, and I might add ignorantly, called this the raisin pudding theory. I say "ignorantly" because a model consisting of raisins in a pudding completely fails to convey any idea of something capable of the kind of activity that must exist to produce the phenomena one obtains when experimenting with atoms.

When I took physics back in the twenties, Thomson's expression was still in use, that "the electrons are quasi-elastically bound" in a positive sphere of electricity. This use of *quasi,* that is "as if," is a sophisticated way of saying not very much. The power of this expression, enhanced as it is by the sphere of history, is not in what it does say but in what it may be trying to say.

It was not pretended that the electrons are imbedded elastically—but "as if." Clearly, at the beginning of the century, the model, although still an ideal, was becoming very much a problem itself. Models can be conceived only in terms of sense perceptions. The atom is something which transcends sense perceptions. And yet what can mind comprehend in nature except in terms manifested by sense perceptions? Clearly the "as if" transcends the ordinary concept of elasticity manifested, say, in a steel spring. A steel spring consists of billions upon billions of atoms. How are we to describe the components and the arrangements of those fine parts of matter which by their nature and arrangement produce what our senses sense as elasticity? Thomson does not pretend to do this—for he makes a clear distinction. He says they are "quasi-elastically bound."

But then one asks, What is the purpose of this? Its purpose was to construct some kind of mental model that would picture the atom as having the ability to produce a manifestation of a motion to the senses, even though indirectly. According to this model, an atom in an excited state resulted from some outside influence disturbing electrons from their quasi-elastically bound neutral position. In an effort to regain the neutral position, the elastic property caused them to vibrate, and it was this vibration which accounted for the emission of energy, giving rise to spectral lines.

By the time Thomson delivered the Silliman Lectures at Yale in 1910 he had developed the details of this model to the place where it could account in a fairly good qualitative manner for some line spectra.

The Thomson Atom vs. The Swedenborg Particles. Not only was the nature of the activity as conceived in the early twentieth century different in nature from the activity of Swedenborg's particles, but also their bases were different, and they had a different importance in the history of thought.

The Swedenborg particles not only were possessed of innate translational activity but within each of them there was a dynamic little world of motion. Over one hundred and fifty years after Swedenborg wrote his *Principia* postulating a Creator who acts through cause and effect relations through discrete degrees, and showing that the end product must be a world such as our senses perceive, that obeys the mechanical laws known to man—over 150 years later came finally some realization that there are activities that transcend our sense perceptions. How, while acknowledging natural law, can we come to see what goes on in the interior of nature? That was the problem posed in those 150 years. How to do this without knowing or acknowledging that such an interior exists; much less knowing that a consequence of this idea is that there are activities there?

This is the importance of the Thomson atom in the history of thought. Ever since chemistry had distinguished between atoms and molecules, a world of subtle parts could be accepted on grounds more firm than speculative. But these particles or corpuscles were solids, mass points. They had to obey Newton's laws of motion even as the earth and a baseball do. Now these corpuscles themselves became objects of scientific inquiry. Men sought to know and understand not only their structure but the activity taking place within that structure.

The importance of the Swedenborg particles to the history of thought is clearly quite different. The nature and the basis for their existence even according to Swedenborg is speculative. Nevertheless, these ideas are not spun out of the air. Their base rests upon the acceptance of certain principles: that God is Creator, that the mind can somehow come to grips with the way in which the creation process takes place, that there are certain doctrines which prevail in this process such as the doctrine of cause and effect, of discrete degrees, etc.

Swedenborg did appeal to experiment, but only after the largest part of his system had been described. The kind of experiments he could depend upon in his day were magnetic—the electromagnetic experiments available through spectroscopy were not yet known in his day.

The importance of Swedenborg's particles can be appreciated only when considered together with his universal principles and his entire system involving not only the physical world but also the animal kingdom. People who accept Swedenborg's *Principia* ideas usually accept them not as isolated cosmological ideas but as a part of a whole.

Activity in the Bohr Atom. The Bohr concept of the atom with its nucleus and its electron orbits was originated in 1912 and is now well known to all. Its place in physics was taken by the new quantum theory of Heisenberg and Schroedinger in 1926. And yet people still disagree on the significance of the Bohr atom. Teachers still find it necessary to give its history as an introduction to modern quantum theory. Hofstadter wrote not so long ago:

> Today the most backward schoolboy knows that atoms are real. He even knows what they look like. The picture of a little round nucleus surrounded by a cloud of electrons is practically the trademark of our time.
>
> It is not just a popular emblem. Physicists also have a mental image of the atom which is much like this one.

Edward Teller, in a book written about the same time, included a diagram of the Bohr atom with the caption "This is how the atom does not look."

Nevertheless the development from 1912 to 1926 of the Bohr atom endowed the atom with activities far beyond anything involved in the Thomson atom.

What of the modern quantum theory? An end result of this theory applied to the hydrogen atom with its single electron is that the most probable location of the electron is at a distance of 0.528 Å from the proton which is the nucleus. However, there are probabilities that the electron might be much closer and also as far away as 3 Å. It is a dictum of quantum theory that where there is a probability of something happening it will happen some time.

Therefore it seems fair to conclude that the volume defined by this probability describes all possible places for the electron to be, according to this theory. It is in this very region where electrostatic forces of attraction due to the positive charge on the proton and the negative charge on the electron are largest. Therefore we can wonder what prevents catastrophic collapse of all hydrogen atoms. Some other force must be acting. The diameter of the nucleus is of the order of 10^{-13} cm and that of the electron only about three times as large. But they are separated by the relatively enormous distance of 10^{-8} cm—100,000 times the diameter of the nucleus. And so our wonder continues. What is the purpose, the meaning—what have you—of a playground 100,000 lineal times as large as the players; or as to volumne 10^{15} times as large —especially when there are only two players! What kind of static model satisfies such a set of conditions? There is no such model—nor in fact any dynamic one. People still use the outmoded Bohr atom. Some kind of activity there must be. Since the Bohr activity is inadequate, what kind can be imagined that is more suitable? No such activity has been imagined.

Nuclear Magnetic Resonance (NMR). A third example of activity has to do with a motion of protons. A proton is the nucleus of an hydrogen atom. It carries an electric charge equal to that of the electron, but positive rather than negative. If it is assumed that this electrical charge is distributed uniformly over the surface of the proton and also that the proton is spinning on its axis, this charge acts like an electric current and hence a magnetic field is produced. It is possible to measure the resonance of the spinning proton because of this magnetic field. This is known as nuclear magnetic resonance.

What is happening can be understood by one who is familiar with spinning tops. A spinning top not only spins but has a secondary motion, which in a very rapidly spinning example appears as a slight wobble. As the top slows down the wobble becomes more noticeable. One who has played with spinning tops knows that if the top is pushed from the side, the top walks away with an increase in the wobble. This wobble is known as precession.

In the case of the nucleus, not only the spin but the precession is held to with much greater precision than in the case of the top. The top of course is restricted greatly by the friction of its point as it grinds into the floor, and so the pure gyroscopic action is greatly complicated.

In nuclear resonance experiments with protons, the sample might well be the hydrogen atoms in a drop of water. The magnetic fields of the spinning protons are first lined up in a magnetic field. A second magnetic field, which varies with a certain regular frequency, affects the precessional rate of the spinning magnet. This second magnetic field is analogous to the push from the side in the top example.

It can be shown by quantum mechanics that the proton has two stable positions or directions of spin within the aligning magnetic field which was first applied. That is, the proton does not act like the top, which gradually increases its wobble until it falls over. The proton spins either, as it were, right side up in the magnetic field or upside down—not with its axis pointing at some intermediate direction. As the auxiliary magnetic field has its frequency varied, there will be a critical frequency at which there is a noticeable extra power drain upon the source supplying the coils which are responsible for this field. This is the resonant condition. The motion involved here is a flipping of the proton from one possible spin state to the other.

All of the elements in the above rough description can be measured by various means. Numerous applications of nuclear-magnetic resonance seem to be a confirmation that what is here described is in agreement to a considerable degree with what is actually going on within the submicroscopic level of creation.

Electron Spin Resonance (ESR). A related kind of motion is that of the electron. If it is assumed that the electron has a spin capable of assuming two distinct states, all of the resonance phenomena associated with the proton would similarly take place with the electron. This has proven to be the case, and electron spin resonance technique has also developed to the place where it has become a wonderful tool for probing nature. Furthermore, since the electrons and protons occupy different regions within the atom, the magnetic environment which they inhabit is different. Not only does this show up in different patterns for NMR and ESR, but for this very reason their practical uses are different.

Models of Activities in Particles only Representations? While all that is said here concerning motions of and within the molecule, the atom, the proton, and the electron is in a sense true, the deeper truth is that in all likelihood these motions as described above are only correspondential or representational. They are pictures in the mind and are limited in every physical sense. Measurements depending upon resonance depend upon a change of state. What is happening while the particle is in one state or another remains a mystery.

Already events in the history of physics have done away with the Bohr electron orbits, although they are still useful for elementary introduction into quantum theory. Because these motions in the Bohr orbits are better known than other motions I discuss, I will use them to illustrate how remote the invented models are from the things they are intended to explain.

Already in the gross world of sense perceptions it is difficult to distinguish between that which is subjective or mental in science and that which is objective or cosmological. To distinguish between these two not only raises issues in every scientific statement, but at the same time concerns us with questions raised in idealism by the philosopher Berkeley.

One must come to see even on the macroscopic level that the mental picture is not the same as the physical object. Consider for example the geometrical concept circle as compared to circles which appear as wheels or even as lines drawn with a compass. If our mental pictures of gross sensual objects are so remote from physical reality, how much more must be the case with those objects which transcend immediate perception?

This presents a problem of the first order. Nevertheless it is not the most serious one. A more serious one has to do with the full implication of the words "immediate perception" as compared to "mediate perception." When we touch a wheel or look at a wheel we feel that we have gained some sort of direct or immediate perception of the application of the mental concept of circle to a physical object. But even if we believe that electron orbits in atoms exist, we never expect to come into any perception of them in any direct way. It seems, according to present physical theory, that we will never come into any contact with them even by any intermediate physical means whatsoever.

Such activity as may exist in a steady state or in an excited state within the atom can never become an object of scientific experimentation according to present theory. It is necessary to understand this in order to understand what can be subjected to scientific experimentation in the particles. What is it that is the object of study when one is dealing with electronic orbits or states by the indirect methods which are applied to extend our perceptions into the atom?

We are studying, by these indirect methods, changes of states. What is the actual physical representation to our senses? It is a line on a spectrogram on a photographic plate. The presence of these lines is caused by energy. Somehow electromagnetic energy has been either emitted or absorbed by millions of atoms in order to create this single gross sensual representation.

These lines are caused by resonance of light waves. An interesting illustration is the presence of dark lines in the spectrum of the light coming directly from the sun. These lines are known as

Fraunhofer lines. They are explained by regarding the surface of the sun as being the source of light of all wave lengths. In passing through the hot gases surrounding the sun, light of certain frequencies is absorbed in these gases. The experiment can be performed in the laboratory using a sodium flame, a volume of hot sodium gas, and a spectroscope.

The appearance of lines in certain definite places in the spectrum results in arrays or series of lines. Why are the lines where they are? And why are they arranged at a certain place with respect to each other as they are? These were the questions with which the atomic physicists of the last half of the nineteenth century concerned themselves. Bohr's atomic theory was a supreme effort to give an explanation of what happens within the atom to account for spectral lines. In this he was enormously successful—but not without sacrifices to the dictates both of good sense and of good science. If one expects to maintain an unqualified adherence of his imaginations to these two dictates, one can never understand Bohr's theory.

First, concerning the challenge to good sense. What we see in spectra is due to jumps from one state to another in the atom. What happens during that jump? Is it instantaneous? Does it take place in zero time? And what is it that takes place in that time? What is that which cannot be explained, that takes place in zero time, that accounts for the marvels of atomic spectra? I have heard physicists of the highest rank ask this question—"Now here, now there! What happened in transit?" An explanation that leaves this much for one to wonder at seems to leave much else unsatisfied. In this level of creation we seem to be at the very limit of the power of explanation itself.

Second, what of the challenge to good science by the Bohr theory? An essential postulate of that theory is that orbits exist. Their dimensions enabled Bohr to assign a fixed amount of energy to each electron in its orbit. This value depends upon a severely disciplined mathematical calculation which in turn depends upon classical mechanics and classical electrostatics. But the postulate threw into the face of classical theory a challenge that could hardly be understood. According to this theory, an accelerated electric charge emits energy. This is a fundamental law basic to all electrical applications in radio, power transmission, etc. Now a particle in a closed orbit is constantly accelerated. If that particle carries a charge, then such a particle must radiate energy. Calculations show that electrons in orbits would have very short lifetimes in those orbits. Losing energy they would spiral immediately into the nucleus under the electrostatic force due to the positive charge on the nucleus and the negative charge on the electron.

But Bohr overcame this necessary self-annihilation of all atoms in the universe by making the assumption that there were certain discrete orbits in the atom in which the electron could revolve without radiating energy.

The double remoteness referred to above as applied to models of the atom becomes even more pronounced for particles on a more interior level. To repeat, because of its importance: The first remoteness arises because the senses cannot probe directly into the submicroscopic world because of intrinsic limitations of the senses themselves. The second degree of remoteness arises because the probes which extend those senses interact with the particles under investigation so that it is impossible to examine even indirectly activities in the normal state. This is a limitation within objective nature itself that prevents immediate sensation of phenomena by scientific instruments whether they be rays of light or single electrons or protons.

Concerning Pejorative Terms. One who has tried to think about some of the things Swedenborg wrote about nature cannot help being affected himself by the opposition in the world to such things as are termed "metaphysics," "speculative philosophy" or "prescientific concepts." We therefore may have some hesitancy in our belief in the actives, finites, and spiral and vortical motions in Swedenborg's philosophy. It is true that we may come to realize that the specific details, especially those which depend upon eighteenth century science, will change as scientific knowledge changes.

Into the Metaphysical Beyond? Nevertheless the activity that is within, the appearance of discrete degrees, the reality of the atmospheres, the necessity of cause and effect, even if we do not always understand the *modus operandi:* all are necessary ideas to New Church philosophy. Most important of all, science should come to confirm the possibility that all of nature as we see it, whether the largest elements of the cosmos, namely the galactic systems, or the smallest particles, are all so constructed and capable of motion and activity as to be able to act as receptacles of influx from the spiritual world.

It is clear now that the strange phenomena discovered during the last 60 years have brought back into science concepts utterly foreign to it during the nineteenth century. Many of these ideas had been cast out by the philosophers of science, first the materialists and then the positivists. Permit me to ramble through some of these things, not to show how stupid scientists are—I can assure you they are not, at least some I have known—but rather to show how mysterious, yes, how metaphysical, how much beyond present day physics, is nature itself. This is to show that in spite of a training against all metaphysical ideas, the results in physics compel people to rethink about concepts which were once discarded.

Eugene Wigner, one of those who shared in the most recent Nobel Prize, just recently reminded us that not so many years ago the nucleus of the atom was explicitly labelled a metaphysical concept; and another leading nuclear physicist, Robert Hofstadter, wrote:

> Not much more than [60] years ago it was still possible for leading physicists and chemists to argue whether atoms really exist. (*Scientific American,* July 1956. I changed his "50" to "60" because I am quoting him in 1965.)

If atoms and nuclei were metaphysical, then we may well ask what are the metaphysical ideas today? I will rush along rapidly, just to give you a number of them.

> The positrons are members of electron-positron pairs which are continually being created out of vacuum at all points and then vanishing again by recombining with each other. (*Elementary Particles,* Frisch and Thorndike, p. 2.)

They continue

> For a short time in which they exist, some of the positrons are drawn close to the negative electron which we placed there, attracted by the electric force between the positrons and the electron. The other negative electrons, those created as members of the pairs, are repelled to a greater distance. It is as if the otherwise empty space around the original electron has been polarized electrically, much like a piece of ordinary matter which gets an excess of positive electric charges on one end and negative charges on the other end when placed in an electric field. (*Elementary Particles,* p. 2.)

And a little further on they say, "The electron's bare charge is probably very large—perhaps even infinite!"

Now I ask you, what kind of language is that for a sober scientist?

I have not in these remarks mentioned another kind of activity —that which accounts for gravity. The active suggestions of the present day are that gravity is accounted for by a particle which acts between masses as the mesons do in the nucleus to hold nucleons together. There is a place for this particle in the most recent charts of the particles of physics, and that particle, although it has not yet been discovered, already has a name; it is called the graviton.

And we cannot leave this suggestion without referring to a whole family of other suggestions that many other existants are to be looked for—they are called "virtual particles." As is said in a text:

> As we go along, we shall notice that the virtual existence of particles throughout space is a most striking feature of this theory. (*Elementary Quantum Theory,* Henley and Thirring, p. 49.)

Not only was the resonance phenomenon applied, as was indicated earlier in these remarks, to macroscopic reality and to submicroscopic particles at the very entrance of this wonderland, but resonance in nuclear and higher energy physics is so important that there are now "particles" so called, which are referred to as "pure resonance." Speaking of such things, two of our authors say:

> The most fascinating of our rules are, however, not to any material substance, but to immaterial fields, the excitations of which appear to us as elementary particles. There are many examples—among them, quantum electrodynamics and the theory of "weak interactions." . . . These problems are among the most challenging that face physicists today. (Henley and Thirring, *ibid.,* p. 154.)

Our remarks have hinted from time to time at concepts of the structure of the particles. What could be meant by this? Above, when speaking of nuclear magnetic resonance, we used an idealized picture of a spherical shell in which the mass and electrical charge were uniformly distributed. This was good enough to account for nuclear magnetic poles. But now there is the evidence of more penetrating probes to contend with. The basic idea of the electron microscope has been extended through the use of beams of very high energy electrons, and the structures of such things as the proton have been subjected to more detailed investigation. In these investigations we hear nothing more about uniform charge distribution, but we hear rather about charge density and charge distribution unmodified by "uniform." We read one description of the proton, now already eight years old,

> According to present theory, the model of the proton obtained from the scattering experiments may not really represent a single, smeared-out particle. Instead, the proton may actually consist of a point-like "bare nucleon" intermittently surrounded by a cloud of mesons. It is probably the meson cloud that we are probing.
>
> The theory says that the proton erupts from time to time, emitting a meson which whirls about for an unimaginably short period and then is sucked back into the proton again. The process of emission and reabsorption is considered to be an ever-present, essential activity of the proton (and the neutron as well). One problem has been to decide what fraction of the total time the meson spends outside the proton. (*Scientific American,* July 1956, "The Atomic Nucleus," Robert Hofstadter.)

Creation and Annihilation. There is another phenomenon which at first was astonishing but by now has been observed so often as to be commonplace if not understood. This goes by the name of pair creation and pair annihilation. For every kind of particle in nature it is now assumed that there is a corresponding counterparticle called an "antiparticle." Several of these antiparticles have been discovered. The antiparticle of the electron is the positron. Evidence of pair production and pair annihilation of an electron-proton pair is a familiar event in pictures of particle tracks in photographic emulsion or bubble chambers.

Tremendous energy is required for pair production. Also when pairs are annihilated, tremendous energy reappears. When a positron and an electron unite and disappear in annihilation, two high energy gamma rays traveling in opposite directions appear.

If one is unable to explain exactly the nature of molecular and atomic activities, then surely guesses can run wild as to how and in what manner activity takes place in creation and annihilation. But who would claim that there is no activity? A long time ago the click of the billiard ball was found to be completely inadequate. All sorts of spins and local motions have been used up. Meson clouds of activities around nucleons, the proton, and the neutron have caused us to spend our imagination in another direction. Where can we go from here?

During the progress of physics in the effort to describe the particles of nature people have used not only prose, but mathematics, and as in these notes, models. One still has recourse to poetry.

Some Poetry. Frisch and Thorndike in their interesting book *Elementary Particles* have this to say about pair annihilation.

> Such annihilation has only been observed in processes involving individual elementary particles. If large quantities of matter and anti-matter were to annihilate, the results would surely be impressive, as expressed in the following quotations: (from *The New Yorker,* November 10, 1956.)

Perils of Modern Living

"A kind of matter directly opposed to the matter known on earth exists somewhere else in the universe, Dr. Edward Teller has said. . . . He said there may be anti-stars and anti-galaxies entirely composed of such anti-matter. Teller did not describe the properties of anti-matter except to say there is none of it on earth, and that it would explode on contact with ordinary matter." (*San Francisco Chronicle*)

Well up beyond the tropostrata
There is a region stark and stellar
Where, on a streak of anti-matter,
Lived Dr. Edward Anti-Teller.

Remote from Fusion's origin,
He lived unguessed and unawares
With all his anti-kith and kin
And kept macassars on his chairs.

One morning, idling by the sea,
He spied a tin of monstrous girth
That bore three letters: A.E.C.
Out stepped a visitor from Earth.

Then, shouting gladly o'er the sands
Met two who in their alien ways
Were like as lentils. Their right hands
Clasped, and the rest was gamma rays.

H. P. Furth

Anti-Matter on Earth? On the day I wrote *The New Yorker* to obtain permission to reprint the above, physicists announced the artificial creation of the anti-deuteron. This is the first observed bit of anti-matter—if by "matter" we mean "constituted of at least two basic particles."

E. F. A.