PART X

ON THE STRUCTURE OF ‘MATTER’

Rather against my better judgment I will try to give a rough impression of the theory. It would probably be wiser to nail up over the door of the new quantum theory a notice, “Structural alterations in progress—No admittance except on business”, and particularly to warn the doorkeeper to keep out prying philosophers.

(149) A. S. EDDINGTON

CHAPTER XL
THE OLDER ‘MATTER’

> And yet when I hear to-day protests against the Bolshevism of modern science and regrets for the old-established order, I am inclined to think that Rutherford not Einstein, is the real villain of the piece. (149) A. S. EDDINGTON

> Micro-mechanics appears as a refinement of macro-mechanics, which is necessitated by the geometrical and mechanical smallness of the objects, and the transition is of the same nature as that from geometrical to physical optics. (466) E. SCHRÖDINGER

From the dawn of history, man has had to deal with different bits of materials, some hard and solid like stones, some soft like fruit or flesh, some liquid. In remote antiquity air and gases were not considered as ‘matter’.

In those days ‘matter’ was structurally only what could be seen, or felt, or touched . : anything else was some kind of ‘spirit’, and everything ‘existed’ in an ‘absolute void’. But even in remote antiquity our primitive ancestry could not miss the fact that the bits of materials they dealt with could be divided into smaller bits. Naturally, if we can subdivide bits into smaller bits, an interesting question arises: How far can this division be carried on ? It seems that Democritus (about 460-360 B.C.) was the first man on record to formulate an atomistic theory. He already postulated structurally a subjective world picture, to be contrasted with an ‘absolute’ or objective world in which ‘motion’ was all important. This theory started us on the mechanistic road formulated for macroscopic events, and also on the road of individualization, the study of smaller and smaller bits of materials and the search for some unit bricks out of which this world appeared to be built; all of which was already a search for *m.o* structure.

With the advent of chemistry some further fundamental structural light was thrown on the problem of individualization. It was found that certain materials, as, for instance, iron, copper. , remain one material, no matter how far we carry our subdivision. These were called ‘elements’. At present we recognize 92 elements, a number which is supposed to represent all possible elements. Out of these a remaining few were at first predicted theoretically, and just the other day discovered experimentally. All other materials do not stand division so well. At some stage they decompose into their elements. The smallest bit of one of these last materials which still has the characteristics as the bulk, is called a molecule. The molecule is found to be built up from atoms of the elements. For instance, the molecule of water still has the characteristics of water, and consists of two atoms of hydrogen and one atom of oxygen, which are no longer water but elements of entirely different characteristics.*

Electrochemistry taught us in the meanwhile an important structural lesson; namely, that definite electrical charges are combined with the atoms. Such electrified atoms are called ‘ions’ (Greek for traveller). For instance, a

* The above statements are over-simplified, but satisfactory for my purpose.

molecule of water is broken up into a positively charged hydrogen ion consisting of two hydrogen atoms, and a negatively charged oxygen ion consisting of one oxygen atom.

But electricity had more structural surprises in store for us. About 1880 new facts were discovered. One of them was that a moving electrical charge has the effect of an electrical current; namely, it can deflect a magnet just as a current does. Such moving electrical charges were called convection currents, and the fact that they produce effects similar to an electric current led J. J. Thomson to a surprising conclusion. According to the Maxwell theory of electromagnetism a certain amount of energy must be associated with every electric or magnetic field. If an electrical charge in motion can produce magnetic effects, hence energy, it was concluded, and verified by experiment, that energy was required to set an electrical charge in motion. From which it follows structurally that an electrical charge possesses a characteristic in common with other materials; namely, inertia, which can be overcome only by the application of energy. This inertial mass of the electric charge was called electromagnetic mass.

Here we see two fundamental structural issues involved. One is that electricity seemingly has an inertial mass similar to that of ‘matter’. The other is, that in convection currents, we find means to study electromechanical parallelism, and so discover the relationship between electrical and mechanical theories.

In the year 1895 Lorentz proposed the electron theory. He assumed structurally that moving molecules contain electrical charges and so produce convection currents. These charges are further assumed to be one electrical quantum and were called electrons. The electron theory proved to be enormously fruitful and all further advance in our structural knowledge is intimately connected with it.

As knowledge advanced, the more convincing became the structural evidence for some electronic theory. As already noted, a moving electrical charge produces magnetic effects. So also should a moving electron, whence we succeeded in accounting for magnetic effects in terms of moving electrons which in this case represent molecular convection currents.

Granting this, a revolving electron should represent also a small magnet and a mechanical gyroscope as well. Einstein in 1915 verified this assumption by an experiment. If these structural assumptions were true, then, by a quick reversal of magnetism, a soft iron rod should turn by a slight but definite amount. The reverse effect has also been verified; namely, a soft iron rod when rotated rapidly around its axis becomes magnetized.

The discovery of radioactive materials was also of enormous structural importance, as it gave us a means of studying directly the rays emitted from these materials. The rays were found to be of three kinds and were called by the first letters of the Greek alphabet. The α-rays have been found to be similar to positive rays, the β-rays similar to cathode rays, and finally the γ-rays to Röntgen-rays. Further investigation revealed that the α-rays were atoms of helium charged with a double positive charge of electricity, and that the β-rays were negatively charged particles with the charge of an electron.

These few remarks already make apparent the structural fact that electromagnetic phenomena exhibit characteristics quite similar to those of ‘matter’, some of their processes are atomic, they have inertia , .

In the older days we tried to apply macroscopic mechanical structural laws to electromagnetic phenomena, but were not very successful. The laws which applied to those sub-microscopic levels were seemingly different from those which applied to gross macroscopic levels, just as the psycho-logics of the individual differ from the psycho-logics of the mob.

An epoch-making semantic step was taken by Rutherford when he formulated the electromagnetic theory of the structure of ‘matter’. In this theory the atoms represent complex structures built up of positive and negative electrons, and their number and arrangements (structure) determine the chemical and physical characteristics of the atom in question. The old structural dogma of the immutability of the elements became untenable; and today, theoretically, and in a few instances experimentally, it has been established that a transmutation of elements is not only a possibility but a rather well established structural fact of 1933.

It should be noticed that once more one of the fanciful linguistic, structural, ‘infinities’ has been abolished. The elements appear as transitory processes with a ‘life’ of a *limited* span of years. The experimental structural evidence which physicists and chemists have gathered is overwhelming and, though the *positive* theories (verbal structures) may not always be satisfactory, the *negative* results leading to the rejection of the older theories are conclusive. This point is of supreme structural importance to us.

A short description of the different atomic models comes later in this chapter, but first something must be said about the old quantum theory, which represents at present the central problem in science and out of the solution of which the most revolutionary consequences are bound to follow.

The main problems of the quantum theory may be described and contrasted somehow as follows. If we take a line *X'X* and select a point *O* as the origin, we may fix the position of a point *P* on this line by the co-ordinate *x*. In practice we find the values of *x* by measurement. If we assume that *x* varies *continuously* we can expect that by refined measurements we can find values of *x* as close together as we please.

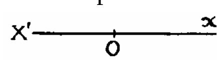


FIG.

Experiments show that for the processes going on ‘inside of the atom’ the structural conditions are somehow radically different. In comparing them with the above example, we should have to give our point only the freedom of occupying certain discrete points, let us say 1, 2, 3. , but all fractional values, such as 1/2 or 2/3, would be impossible. If the only possible values of *x* are whole numbers, then the possibility of finding values of *x* as close together as we choose in order to make more precise measurements is excluded. If we find, for instance, that our *x* is neither 1 nor 2 nor 4, and cannot be larger than 4, the only solution is that our *x* must be 3.

These conditions, which are actually found in the atomic mechanics, represent an entirely new and unexpected structural state of affairs. The whole of the older quantum mechanics can be summarized in the statement, that its peculiarity consists in the fact that structurally characteristic *discrete numbers* make their appearance, and that the processes ‘inside the atom’ are to be described by *discrete* numbers.

The usual classical quantum mechanics demands that *x* be allowed to take all possible continuous values, but that the *integral values* of *x* represent the so-called stationary states through the quantum conditions. Under such conditions the intermediate fractional values had no meanings.

It is safe to say that, when in 1900 Planck formulated his quantum theory along the structural lines sketched here, it meant a complete and revolutionary structural and semantic departure from all accepted standards in life and science, for studying this world.

Planck has shown that it is impossible to explain the spectral distribution of the energy radiated by a black body under the older assumptions that energy can be divided indefinitely into smaller and smaller parts, but that it may be explained on the structural assumption that the energy exists in quanta of finite size $h\nu$, where ν is the frequency of the radiation and h is a constant ($h=6.54\times10^{-27}$ erg sec.),

These observations lead to the revolutionary structural conclusion that the emission of radiation occurs *discontinuously*, and so the characteristic discrete numbers make their appearance.

It seems natural that because of this peculiar appearance of whole numbers, periodic processes such as rotations or oscillations should be closely related structurally with the quantum theory. As a matter of fact the most important structural and semantic reconciliation of continuous differential equations of the older mechanics with the appearance of discontinuous whole numbers has been solved by the newer quantum mechanics on this basis as explained in the following chapter.

The kinetic theory of heat and the atomistic theory of electricity have shown an enormous productivity. It is quite natural that these theories (verbal structures) should be highly workable, considering the structure of our nervous systems, as explained in the foregoing chapters. It was this principle of individualization which helped so greatly. The quantum theory is a structural attempt to extend this method of individualization, or the atomistic principle, to processes themselves.

As in the older days we introduced units or elementary quanta of mass, and later, an elementary quantum of electric charge, so in our newer knowledge we have need for an elementary quantum-of action. Action is defined as energy multiplied by ‘time’, or $A=Et$.

Naturally such a product as energy multiplied by ‘time’ must play an extremely important structural and semantic role in this world of space-time, where nothing happens ‘instantaneously’, but all action requires ‘time’. If we could discover some unit of action, we could change from the language of ‘energy’ and ‘time’ to the language of ‘action’ and ‘times’. This language, by the way, is much more satisfactory and structurally closer to experience than the old languages. ‘Action’ as structurally defined (product of ‘energy’ by ‘time’) is one of the two fundamental entities of pre-relativity physics which have survived the Einstein revolution. It is really a universal term which we can apply without danger of degrading science into private gossip. From the neurological standpoint, as it deals with definite units and times, such a term has all the structural earmarks of an abstraction of highest order and of being really semantically important. Energy in space-time must by necessity be reformulated as ‘action’. The quantum theory posits structurally that the action of physical processes is built up of a number of elementary quanta of action.

From the fact that electromagnetic waves and light-waves have one velocity, Maxwell concluded that light-waves are of an electromagnetic character, a conclusion which further experiments have fully justified. Einstein, in 1905, successfully applied the quantum structural principle to the theory of light, and in 1907 to the theory of heat of solid bodies.

The evolution of our theories concerning the internal structure of atoms has, until lately, closely followed our astronomical theories, but with the newest quantum mechanics this structural analogy seems less useful. The first atomic model on an electrical basis was proposed by J. J. Thomson. He assumed the atom to consist of a uniformly dense spherical volume charge of positive electricity, within which electrons described circular orbits. But the discovery of radio-activity and the fact that the alpha-rays could pass through several centimetres of atoms (which means penetrating through many thousands of atoms), without their direction being altered made these assumptions structurally untenable.

The Wilson photographs (Fig. 2) show clearly that a single atom can deflect the alpha-particle by a large angle which makes it clear that the nucleus of an atom must be considered as a very small part of the volume of the atom. The large deflections of the alpha-particles show also that the mass of the nucleus must be much larger than the mass of the deflected particles. Observations show also that the deflections increase with the atomic weight of the deflecting materials. These and similar facts led to the structural assumption that the mass of the atom is principally concentrated in the nucleus and that the mass of the electrons must be very small in comparison with that of the nucleus.

As the atoms are in general electrically neutral, we had to assume that the positive charges of the nucleus are compensated by the negative charges of the electrons. These and other structural considerations led Rutherford to propose a different atomic model, which was much more successful for a while.

The Rutherford atom is supposed to be composed of a nucleus of positive electricity surrounded by negative electrons. The simplest atom is that of hydrogen, and was assumed to consist of one electron revolving around the simplest positive nucleus or proton, each having a charge, e=4.77×10^{-10} *e.s.u.*, and different masses, the mass of the nucleus or proton being 1845 times the mass of the electron. The other atoms represent more complex structures built up of protons and electrons, into the details of which we need not enter here. But this theory encountered difficulties of theoretical as well as of experimental character. Niels Bohr eliminated most of them by the application of the quantum theory to the atom.

For simplicity of writing in that which follows, I will use a descriptive language omitting in each statement ‘we assume’. , but the reader should be continuously aware, that when we deal with the sub-microscopic levels we deal any with inferential units the representation of which involves a great many assumptions. For my purpose it is enough to stress: (1) the *negative* fact, that the structure of materials is definitely different from that which was assumed before the advent of the quantum theories, (2) that *in science,* inferential units represent abstractions of higher order and are as reliable as the lower order abstractions which we gather on the macroscopic levels, *if* they are treated semantically as *hypothetical* units. The layman should realize that his ‘world outlook’ appears as full of assumptions as any scientific one, except that his assumptions are not conscious and cannot be verified, whereas most of the scientific assumptions are conscious and are *continually verified.*

In the older theory the orbits of the electrons were supposed to be arbitrary; in the Bohr theory the orbits have precedence, for which a definite magnitude, a whole number multiple of the elementary quantum of action is specified. We posit one-quantum orbits, two-quantum orbits. , to which definite values of the orbits, the velocity, the number of revolutions, and the energy correspond. In a one-quantum orbit, for instance, the velocity is supposed to be equal to c/140, that is one 140th of the velocity of light, and the number of revolutions equal to 6000 billions a second.

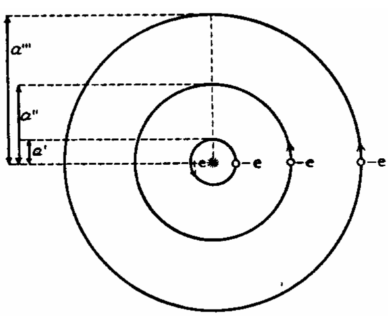
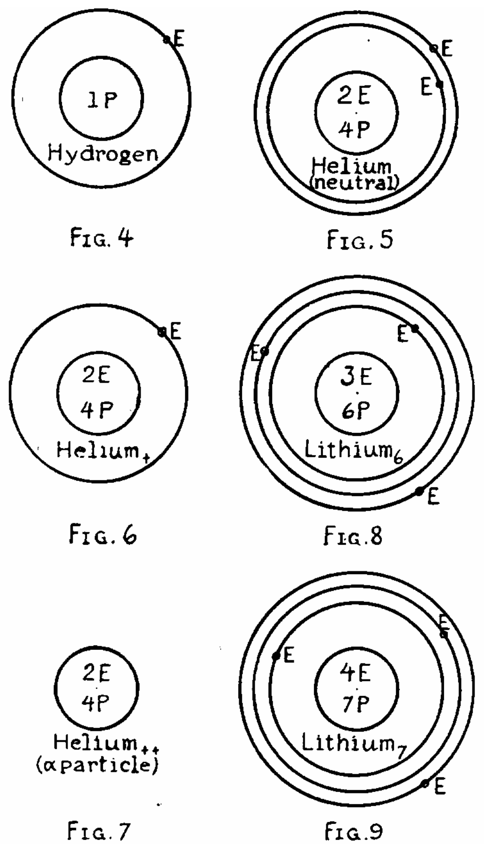


FIG. 3

Bohr later modified his atomic model structurally by taking into account the movement of the nucleus. The electron was not supposed to revolve any longer around the proton, but both proton and electron were assumed to revolve around their common centre of gravity. In the simplest form the Bohr atomic model is shown in Fig. 3, representing the atom of hydrogen, which we assume to consist of a nucleus with one positive charge and of an electron that revolves about this nucleus. The nucleus is designated by a star, the three circles represent the possible orbits for the electron. The orbit of radius *a'* is the most stable, and usually the hydrogen electron is supposed to be found there, but through the action of heat or electric fields or collisions. , the electron may be removed to one of the outer orbits *a''* or *a'''*. Such a condition is not so stable, and sooner or later the electron is assumed to return to the orbit *a'*. During these transitions of the electron, energy is radiated. This structural model is similar to the copernican planetary system, the planet-electrons revolving around the sun-nucleus.[1]



P = proton *E* = electron

The above diagrams show schematically the supposed structure of some of the simpler atoms. Fig. 4 represents the hydrogen atom, consisting of one proton and one electron revolving around the proton. The mass of the proton is about 1845 times the mass of the electron, and we assume that the proton effectively gives us the mass of the atom.

Fig. 5 represents the neutral atom of helium. Its nucleus consists of four protons and two electrons, and it has two revolving electrons; in all, four protons . with four positive charges and four electrons with four negative charges, the charges just neutralizing each other.

Fig. 6 represents a helium atom which has lost one electron. It has, therefore, four positive charges and only three negative charges. Such an atom has a resultant positive charge, and is denoted by He_{+}. If the helium atom loses two electrons it is doubly charged with a positive charge (He_{++}).The helium nucleus He_{++}, as shown in Fig. 7, represents the particle emitted from radio-active materials.

Lithium consists of two isotopes; that is, two elements which appear extremely similar to each other in physical and chemical characteristics, but differ from each other in the number of electrons and protons. In Fig. 8 is shown lithium$_6$, with 6 protons and 3 electrons in the nucleus, and 3 revolving electrons. In Fig. 9 is shown lithium$_7$, with 7 protons and 4 electrons in the nucleus and 3 revolving electrons.[2]

In general terms, Bohr tried to account for all other atoms on the base of the structure of the hydrogen atom. The next important generalization and extension of the Bohr theory was accomplished by Sommerfeld about 1915. The achievement of Sommerfeld can be compared with the advance which Kepler made over the copernican theory of planetary motions. Copernicus considered the planetary orbits as circular. Kepler* considered them as elliptical, and thus introduced a tremendous structural advance in astronomy. Sommerfeld replaced the circular orbits of Bohr by elliptical ones. The theory became much more complicated, because a circle is given by one magnitude; namely, its radius, while an ellipse needs two data, its major and minor axes, and so two quantum numbers for the specification of an orbit. Sommerfeld also introduced some of the results of the Einstein theory; for example, that the mass of a body also depends on its velocity. Since the velocity of the negative electrons in the atom is supposedly very large it was quite probable that the relativity considerations should be appreciable. According to the Einstein theory, the faster a body is moving the greater is its mass. In an elliptical orbit the electron should have a larger mass at the perihelion than at the aphelion, and so the orbit would not be exactly an ellipse but the perihelion would advance slightly at every revolution.

Fig. 10 gives us the relativistic Kepler orbit as introduced by Sommerfeld. *O* is the fixed focus in which the nucleus is situated and *P* is the initial position of the perihelion. The motion of the perihelion occurs in one sense with that of the orbit.[3]

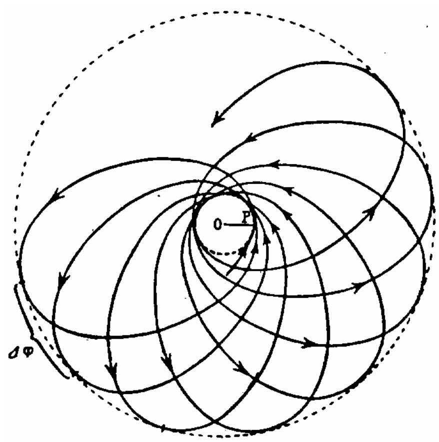


FIG. 10

The last analogy in the structure of the atom taken over from astronomy was introduced in 1925, when Goudsmit and Uhlenbeck proposed their theory of the spinning electron. The electron was supposed to be spinning about its axis like a planet or a top. A similar notion was used by Compton in 1921, in connection with the magneton, but the notion of using the spinning electron for

* Kepler's first law states : 'The planet moves in an ellipse, at one focus of which the sun is situated. Perihelion is that point of a planet's orbit at which it is nearest the sun. Aphelion is that point of a planet's orbit at which it is farthest from the sun.'

the solution of a structural difficulty in the quantum theory, and thus assigning a fourth degree of freedom to the electrons, originated with Goudsmit and Uhlenbeck independently of the work of Compton.[4] It is not necessary for our purpose to follow all the further refinements of the classical theories. Suffice it to say that scientists work under uniquely severe mutual supervision, and that any theories advanced in science are taken under consideration only when the new theories agree better with experiments, and when they also prove structurally fruitful in predicting new experimental facts, which again must stand the test of experiment.

The Sommerfeld orbits have proved to be an advance over the older Bohr orbits, but they had also to be refined to take into account that the electron does not seem to revolve around a simple nucleus but around a *core* consisting of the nucleus and one or more electrons; and so again we had more complex orbits.

For our semantic purpose it is enough to say that to the best of our knowledge (1933), this world appears entirely *different* from what our primitive ancestors knew thousands of years ago, and perhaps from what the average layman knows today. As the problems of 'sanity' represent problems of semantic *adjustment,* and adjustment means adjustment to something—in this case to the structures of the world around and in us—it appears imperative that we should take into account the best knowledge we have of these structures.

The few remarks given above about the structure of 'matter' already show unmistakably that the old 'matter' is not so very 'material', so very 'solid', so very definite as we once assumed it was; but it represents a *process.* We see that our nervous system, because of its gradual growth and evolution, has developed different levels or strata; our 'knowledge' also has different levels or strata, operative as-a-whole, although different aspects of it can be analysed in terms of order. The reader should realize that because of the old *s.r* we still 'need' some 'bits' of something to speak about. It is a *linguistic* semantic consequence of our pre-scientific, *el* language, which posits absolute 'matter', 'space', and 'time'. Thus, through a process of identification, we ascribe to these terms objective existence. In the old manner of speaking the term 'is' of identity played the main semantic havoc.

In the older days electrons were often taken as 'bits' of something or other. For the layman a 'bit' was identified with 'matter'; and here a great deal of confusion comes to light. Even a 'bit' of something is not necessarily material. Materials, by *definition,* are supposed to exhibit colour, temperature, hardness , . A 'bit' which did not have these characteristics would not be material by definition.

Although the 'electron' is defined as an electrical charge, in the older days we had the habit of considering the electrons as some definite 'bits' of something, some kind of 'matter'. Through a process of objectification we made them revolve in definite 'orbits', with definite 'velocities'. , which implies the definite application of *terms* such as 'space' and 'time', derived from *macroscopic gross experience,* but not necessarily applicable to the sub-atomic levels.

What has been said here about the structure of ‘matter’ is quite sufficient for our purpose. Here, as always, the *negative*—the ‘is not’—results count. We are in a position to realize by now that the overwhelming evidence which science gives and which would be impossible to repeat here, shows us a structural picture of the world of tremendous complexity, beauty, and mystery of a structure undreamed of by our primitive ancestors who formulated the current mythological structures which moulded our older *s.r* and languages.

We can sum up, for our purpose, what we know about the structure of ‘matter’ somewhat as follows. The bits of materials visible and invisible to the unaided eye seem to be less simple than we assume them to be and to the best of our knowledge (1933) represent extremely complex processes of a dynamic structure. It appears also that our usual forms of verbal representation which were built by our primitive ancestors are not similar in structure to the world and so are not fit to represent the happenings going on on the un-speakable levels. As all our knowledge is due to the structure and function of our nervous system, which represents an abstracting mechanism, all our knowledge therefore, appears as some kind of abstractions of different orders, on different levels, of different character, and of varying precision and intensity, resulting in various definite general or individual *s.r.*

To bring what is said here to the lower level of abstracting; namely, to the level of structural visualization and feeling, we may use the rough analogue of an electric or mechanical fan. When such a fan rotates we *see a disk*, simply because our nervous system was evolved under natural conditions necessitating integration, and so does not discriminate between the rotating blades. The separate rotating blades are visually abstracted by us as a single solid disk, although there is no disk present.

To the best of our knowledge atoms represent very minute energetic configurations or dynamic structures where extremely rapid processes are going on, which our nervous system abstracts as ‘solid’. Judging by our present standards in science and the amount of knowledge we have we may consider that science in the days of Newton (1643-1727) was in its infancy. During that period we knew a little about the shining specks we see in the skies, and more about the rough macroscopic facts of our daily experience. The genius of Newton not only advanced the detailed knowledge of his day in many branches of science, but also formulated two general theories. One was the differential and integral calculus, which he discovered independently of his contemporary Leibnitz, the other was what we call mechanics.

In Newton’s era the problems of macroscopic, microscopic, and sub-microscopic levels of investigation had not yet arisen in the modern sense, although in formulating the differential and integral calculus a theoretical structural step was taken toward the analysis of the processes on the subtler levels. Quite naturally we applied the wisdom we derived from Newton to all phases of life and knowledge. With the advent of more detailed structural knowledge of electromagnetic phenomena which occur on sub-microscopic, as well as macroscopic levels, difficulties began to appear. It seemed as if the newtonian mechanics were not entirely applicable to these new and smaller scale phenomena. Finally Maxwell (1831-1879) produced his famous theory of electromagnetism. This theory appears structurally at variance with the classical mechanics. Attempts were made to reconcile both kinds of phenomena in one theory. The problems of macroscopic, microscopic, and sub-microscopic structure and levels came to the foreground.

With the advent of the quantum theory further difficulties made their appearance. It became quite obvious that neither the classical 'continuous' mechanics, nor the classical electromagnetic theory could fully account for the 'discontinuous' quantum facts. The situation became acute and bewildering. The Einstein theory with its profound structural semantic and methodological revolution liberated us from our semantic delusions of the uniqueness, absoluteness, and 'objectivity' of 'matter', 'space', and 'time'. It built up a new semantic attitude in the younger generation of scientists already educated on this new structure, and therefore unhampered by the old prejudices. New theories are now being formulated along increasingly more constructive and creative lines.

It is true that as yet neither 'psychologists' nor 'philosophers' have paid enough attention to the subjects discussed here, and so have not made us conscious of the structural and semantic problems involved. However, the Einstein theory has had a profound structural influence on the semantic attitudes of the younger scientists, though in the main they are unconscious of this fact.

The main issues at hand are twofold. One is semantic; namely, to inculcate the permanent structural feeling that words are *not* the things they stand for. If applied habitually, this leads to the rejection of the term 'is' of identity. The other is to replace old languages and methods by structurally new languages and new methods, in which when we describe ordered happenings, we describe the functioning; the behaviour. , by speaking more in a language of what something 'does' than in the old language of what something 'is', which as we have seen *must* be always structurally fallacious and semantically dangerous.

The reader should not take lightly these most general structural and semantic issues. They are unusually important for sanity. When they are formulated we can pass them on, and train children in the new *s.r* quite easily. It is much more difficult, after training a child thoroughly in the *old* vicious structural semantic habits of identification, eventually to have to appoint a guardian angel to watch him day and night to remind him that a word *is not* an object, . Such a procedure would lay a terrific strain on us and on the guardian angel. It would probably be also very expensive, judging by our present earthly substitutes for the 'heavenly powers'.

Once this is realized and applied, the second issue becomes a purely structural linguistic one. There is no *a priori* reason why a language which applies to one level should apply to another.

With these two main issues in view, it is readily understood why modern science tries so hard to develop functional languages and methods in order to be able to describe in terms of order happenings and processes which are observed. Something similar could be said about *all* theories which postulate too much of a definite mechanism, usually involving some identification somewhere.

The slightest discrepancy between such a theory and observation eliminates the theory as structurally unsatisfactory; while theories which succeed in not postulating mechanisms, and so are formulated in a functional language, last much better. One of the enormous advantages of the Maxwell magnetic theory is the fact that it describes the behaviour of electricity and magnetism while hardly positing any mechanism at all ! A similar statement applies also to the Einstein theory.

The above general remarks are extremely well illustrated by the newer quantum mechanics.

The classical theories, as usual with scientific theories, were very satisfactory in many respects, but not in all; which is an unattainable ideal always demanded from a good scientific theory. They also postulated too much of a definite mechanism, which was the result of, and led to, the semantic disturbance called identification. Indeed, I have read an address by a prominent physicist in which he claims to have 'seen', and invites everybody else to 'see', an 'electron'. He challenges his critics, and seems to feel like fighting—a quite usual result of identification. Electrons represent *inferential entities,* and as such cannot be 'seen', but only inferred, which does not detract at all from the importance of the 'electrons'. The 'seeing' business was good enough in the infancy of science, but not in 1933. We 'see' the stick broken in water, the camera records it as broken, and yet it is not broken. We 'see' the fan as a disk, the camera records it so, but there is no disk. We 'see' a 'solid' piece of wood or stone, which under the microscope proves to have a very different structure, .

In the older days the electrodynamics of moving bodies presented difficulties quite similar to the difficulties encountered in the quantum mechanics. Einstein by an epoch-making stroke of genius solved the problem by observing that, in the languages in question, we operated with a notion of 'simultaneity' which did not correspond to any observable structural phenomenon in the physical world. He discovered that it is impossible to establish the simultaneity of two events occurring at different places, and that a thorough revision of our old theories is necessary in this connection. Einstein formulated a procedure, a method for measurements, taking into account the known laws of the propagation of light and electromagnetic phenomena. He once more established the most important semantic thesis that the laws of nature are relations which are discovered between events which are actually observed, or which are *fundamentally observable.*

It appears that in the older quantum mechanics there were introduced some objectified entities which were never observed, as, for instance, the positions, velocities, and periods of 'electrons' inside the atom. How indeed could we find lengths and 'times' *inside* the atom ? Such a procedure requires the introduction of rods and clocks, which themselves consist of atoms; so that *inside* the atom such a procedure cannot be applied. We see clearly that all such conclusions are of an indirect character; but of course such conclusions should be based on some observable facts, and not only on our freedom to use words in any manner whatsoever. It follows that we must give up a language that speaks in terms of the ‘position’ of an electron at a given ‘time’. , and use instead a language that describes observable characteristics, as, for instance, energy levels which are directly measurable by electron impacts and the frequencies which are derivable from them, the intensity and polarization of the emitted waves . ; instead of electronic ‘motions’ inside the atom, which never are and never *can be* actually *observed.* It is structurally indispensable to look for such data which are actual or at least can be observed.

As words are not the things we speak about, and structure is the only link between them, structure becomes the only content of knowledge. If we gamble on verbal structures that have no observable empirical structures, such gambling can never give us any structural information about the world. Therefore such verbal structures are structurally obsolete, and if we believe in them, they induce delusions or other semantic disturbances.