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A REALISATION.

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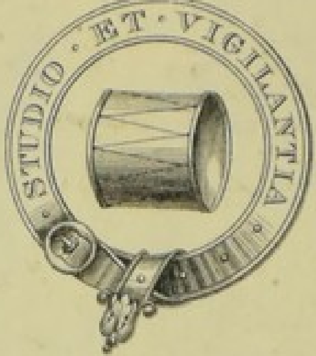
STUDIO · ET · VIGILANTIA

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BY

LIEUT.-COLONEL W. SEDGWICK,

LATE OF THE ROYAL ENGINEERS,

AUTHOR OF "FORCE AS AN ENTITY," ETC.

"And if Natural Philosophy in all its Parts, by pursuing this Method shall at length be perfected, the Bounds of Moral Philosophy will also be enlarged. For so far as we can know by Natural Philosophy what is the First Cause, what Power he has over us, and what Benefits we receive from him, so far our Duty towards him, as well as that towards one another, will appear to us by the Light of Nature."—Sir Isaac Newton, "Opticks," 3rd edition, p. 381.

LONDON:

W. B. WHITTINGHAM & CO., LIMITED,

91, GRACECHURCH STREET.

1896.

W. B. WHITTINGHAM & CO., LTD.,
PRINTERS,
91, GRACECHURCH STREET, E.C., AND
"THE CHARTERHOUSE PRESS,"
43, 44 AND 45, CHARTERHOUSE SQUARE,
LONDON.

PREFACE.

"*To tell us that every species of things is endowed with an occult specific quality by which it acts and produces manifest effects is to tell us nothing. But to derive two or three general Principles of Motion from phenomena, and afterwards to tell us how the properties and actions of all corporeal things follow from those manifest Principles, would be a very great step in Philosophy.*"—Newton, "Opticks," 3rd edition, p. 377.

THE discovery of Argon and Helium is, without doubt, an extraordinary event. In fact, it is an event so extraordinary that the President of the Chemistry Section at the last meeting of the British Association is reported to have prefaced the remarks referring to it in his opening address by saying that "the past year has been such an eventful one in the way of startling discoveries."—*Nature*, September 12th, 1895, p. 483.

Possibly, some still cherish the hope that Argon may turn out to be N_3 or some other allotropic form of nitrogen, notwithstanding the arrival of a second inactive element in the shape of Helium.

All, however, will now admit that Argon and Helium show that inactive elements of some kind are in existence.

That admission will be quite sufficient for my purposes, as I hope to show that the properties of active elements, *i.e.*, valent elements, afford circumstantial evidence of the existence of a class of inactive elements so wonderfully clear that there can be no room for reasonable doubt as to what kind of things inactive elements really are.

And this is not a case of being wise after the event. For the evidence, in fact, is so strong and clear that I was able to discover and point out in Chapter III. of my book, "Force as an Entity," the probable existence of inactive elements four years before Argon was ever heard of.

The case is, indeed, as I shall hope to show in the present book, far stronger than I put it in "Force as an Entity"; but this, too, I had discovered, and was on the eve of pointing out, as explained in my article in *The Chemical News* of the 22nd March, 1895, when Argon itself appeared.

The case, therefore, is in no way one of being wise after the event.

With this explanation I will now proceed to explain the object of the investigation, in the course of which inactive elements come in as necessary features.

The object then of this investigation is to endeavour, on the lines laid down by Newton, and to the extent which he considered possible, to demonstrate experimentally, *i.e.*, by arguing from well-known facts in a way which everyone can understand, that this wonderful Universe of ours is a reality, and that we ourselves and all other living creatures within it are doing real work consciously or unconsciously therein.

So that, if possible, we may understand the situation in which we—as individuals—are placed, and perceive clearly why we are here and what we have to do, and thus no longer work unconsciously, if we have been working unconsciously hitherto.

The method adopted is to endeavour to show that the Universe is a building put together with materials shaped for building purposes, so as to fit together in certain positions and in certain positions only; but, at the same time, so hard and solid as to be unbreakable and unalterable under any conditions which obtain now.

Having shown thus by the forms of visible things the forms these invisible materials—these minute hard atoms—take, so that anyone can model them or get models of them made, and thus understand clearly what can be done with them, the next step is to endeavour to show that they are put together with a binding material which unites them atom to atom by minute subtle joints, as bricks are united by mortar, or wooden things by glue, with large, coarse joints; and thus to show that atoms are put together in a way which everyone can understand, though the joints are so minute that they could not be examined even with a microscope more powerful a thousand times than any now obtainable.

Having in this way arrived at the forms the materials take, and at the way in which they are put together, an endeavour will then be made to show how they are built up into groups and masses and bodies, and thus a complete universe built up in ways which all can follow who are prepared to go over the steps carefully, and think them over.

After explaining thus the way in which the universe has been built up, an endeavour will in the last place be made to show that all forms of life take part in the operation of building it or in hindering the building, either by building up or pulling down, or by superintending; and to show the bearing of the work of each upon the whole, as well as the significance of the work of each.

Having explained thus the scope of the inquiry, and the fact that the inquiry proceeds on lines laid down by Newton himself, and no further than he contemplated; and therefore shown that it is one which distinctly has Newton's authority, it becomes necessary to explain also that Newton does not seem to have made any attempt to arrive at the form of the atom; and did not form any conclusions whatever in regard to the existence of such things as the fluid corpuscles with which we work so largely.

At the same time it should not be overlooked that Newton had clear ideas in regard to the existence of hard atoms, and as to the fact that they had sizes and figures, and therefore forms. Neither should it be overlooked that Newton held atoms to be "moveable," and also had indistinct ideas in reference to the existence of something by which atoms were either impelled towards each other, or repelled; and sometimes even seems to have inclined to the idea that this something was a fluid.

All this will presently be made quite clear. Further than this, however, Newton did not go.

But though Newton's support cannot be claimed for our conclusions in regard to the form of the hard atom, yet other support can be claimed for them, namely, the support of Argon and Helium.

We build, indeed, nothing upon Argon or Helium, or with them. In truth, it is their general unsuitability for employment in any kind of building whatever which makes their support of so much importance; though at the same time we recognise that such unsuitability does not go to the length of complete inability to form part of any structure whatever. We shall, in fact, show in Chapters I. and VI., that though marked unsuitability for building purposes is their characteristic feature, it is, from our point of view, quite possible that they may in some cases be worked into buildings. And in the case of Helium we distinctly recognise on account of the smallness of its atoms the possibility that anomalous combinations may occur with it of the same kind as we conceive occur with hydrogen when it forms water or hydrogen peroxide, in the way shown in Fig. 4, p. 208, though such combinations cannot occur with Argon.

It is plain that so long as materials suitable for building and none others were known to us, there was room for doubt whether the form suitable for building was not one of the necessary conditions of the existence of these things; and whether, in fact, they had not existed from all eternity in that form. But the situation was quite changed as soon as materials were discovered which were unsuited for building operations. For the strong evidence brought forward in

Chapter III. of "Force as an Entity," that valent metalloid atoms had all undergone a process of shaping, and had been formed out of the atoms of pre-existing inactive elements, acquired quite a new significance when Argon and Helium came to show that inactive elements of some kind are in actual existence, and that such things are not mere creations of our own imagination.

We have now the assurance that we shall be able ere long to show, not only that the materials of which this universe has been built have all been specially shaped for building purposes, but also the quarry, as it were, from which each kind has been extracted.

We do not build with Argon and Helium therefore, but we have room for them. We have vacant places which they alone, or things like them, can occupy. And what is more, their places were ready before Argon and Helium appeared.

We were not only ready to welcome Argon and Helium directly they arrived, but had been looking out for them, or things like them, some time before they came, though scarcely venturing to hope that we should ever see them.

Now that they have come we do not, it is true, know as yet exactly which of the many available places to assign to them; because investigation has not yet determined whether each is not in reality a mixed company which will want several places instead of one only.

If, however, it should turn out that they are not mixed companies, then we shall have no doubt whatever as to where they ought to go. We have, in fact, their places quite ready, as will presently appear.

Argon and Helium, then, afford us exactly the kind of support we wanted, and, moreover, have come just at the time when the building was high enough to need support. With them, and a sufficient number of other elements like them, we have good hope that the building will stand firmly.

We may remark here that one of the chief difficulties attending work of this kind is the difficulty of obtaining the quietness which is essential for it. The supply of facts for building is ample. The difficulty is to put them exactly into their right places. This cannot be done without perfect quietness.

The Greeks, we may remark, had a tradition in regard to the great thinker, Democritus, of Abdera, which, however exaggerated it may be, well expresses the difficulty to which we allude.

Democritus was engaged largely upon a portion of the work which is before us here, *viz.*, the determination of the form of the atom.

The Greek tradition was that he put out his eyes to avoid being distracted from thinking.

Carlyle, in his own rugged way, puts the difficulty very bluntly in another form. His view is that if any man takes to thinking, "new Emissaries are trained, with new tactics, to, if possible, entrap him, and hoodwink and handcuff him."—"Sartor Resartus," Book II., Chapter IV.

Whatever the cause may be, the difficulty of obtaining perfect quietness is undoubtedly great; and we have to plead it. For the structure we present in these pages, though not wanting as we believe in any way in stability, comes very far short in point of finish of what we had hoped to achieve.

[The question of reality, if it admits of solution, is manifestly one which concerns vitally every individual man and woman in the universe.

But the question has national aspects as well as individual aspects. If the whole situation is real; if right and wrong have a real significance, and are not mere matters of opinion; if this world has sore need of a power mighty for right, and able to speak out when wrong is done, and say with a voice which shall compel attention that the thing shall not be so; if the dark parts of the world have sore need of the strong rule of righteousness which our executive officers, English, Scotch, and Irish alike, exercise over some parts of them in a way none have ever done for any lengthened period before; if it be true that it is impossible to rule righteously, or act at all times rightly without adequate strength;—then manifestly the situation is one for us Britons with our millions of Mussulman and Hindoo fellow subjects, and for our brother Americans, Australians, and South Africans, to lay to heart.

We of this brotherhood outnumber all other nations by far; excel them, too, far more in material resources even than we do in numbers.

Why under such circumstances is there no preponderating power upon this earth?

Is it not a worthy cause, this cause of right, of progress, and of the welfare of mankind?

Would it not be an inestimable benefit to us all to be drawn closer together; for us Britons to have American energy to help us in developing our dominions; for America to have more of our resources to help her in developing, and to have the wider field we can open to her?

It would bring with it at the outset employment for all our unemployed who are able to work.

We need something more than a navy.

We need to be so strong, and so strongly posted, that any combination of other powers against us could be met.

We need first of all a great fortified camp in mid-England in which our militia and volunteers can collect, and find stores and ammunition ready to hand.

We want with our long coast line a position which will make it an impossibility for any foreign power to attempt to rush our defences before we are ready, and plant suddenly a force in our midst which will cut off North from South, and hold us at its mercy—whether after a naval reverse, or after a storm, or in a fog with pilots able by long practice to effect a crossing in a fog, or under any other circumstances.

The works which we need, and the army and armament which we need, will give employment to our unemployed.

If the situation is a real one, then it may be inferred that it will not always be open to us to neglect it. For we know that real situations of this kind have arisen again and again before; and we know what the result has been when they met with no recognition.

We know, for example, that such a situation opened before the commercial colonizing Phœnicians, and found no recognition either in the mother country or in its colonies, but only disunion, distrust, and self-seeking everywhere rampant; until at length Carthage, with the situation completely in its grasp, under splendid Hannibal, contemptuously disregarded it in mean jealousy, not knowing that it was a life and death matter until those terrible words rang out, "Carthage must be destroyed." We know, also, that a situation of this kind opened before the colonizing Greeks, again finding no recognition, but only disunion, distrust, and self-seeking everywhere, both in the mother country and in its colonies. And, anon, captive Greece had to look on while another appropriated all that was hers. We know, too, that a like situation opened before Spain and Portugal. And we have the result before us. The situation is not, then, a new one. Ah, no, it is not new.

Just a few words more. At p. 201 of "Force as an Entity," the need of Miracles of Science to rouse us by throwing a flood of "light on the whole inner man" was fully pointed out. May we not see in Röntgen rays a Miracle of the kind required?]

10*th March*, 1896.

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CHAPTER I.

INTRODUCTION.

"*It is those who know little, and not those who know much who so positively assert that this or that problem will never be solved by science.*"—Darwin, "Descent of Man," Vol. I., p. 3, 2nd edition.

THE strangest thing about Argon and Helium plainly is the fact that they are elements characterised by an extreme reluctance to form any kind of association whatever, whether by combining or cohering.

Nevertheless, the occurrence of elements with this strange inactivity was not altogether unexpected, inasmuch as in "Force as an Entity," which was published in 1890, elements of this particular kind are introduced in Chapter III., in the course of an inquiry into the form of Newton's hard atom, and play a very important part.

They are described there simply by their atoms, which are stated at pp. 65 and 66 to be "spherical bodies . . . .

unaffected either by chemical affinity or cohesion"; the reason for describing them as "unchipped atoms," or as "perfect spheres," and not as elements being that the term element did not seem quite appropriate to things which do not ordinarily combine.

The whole of the conclusions in Chapter III. in regard to the form of the atom postulate the existence of elements of this kind in the past; but at the same time the possibility that some are still in existence is clearly pointed out at pp. 68 and 69.

The existence of elements of this kind is, however, not only postulated by the form obtained for the atom, but is also incidentally demonstrated by evidence, adduced from the Periodic Law, from the four remarkable series which the metalloid elements form; and at the same time the atomic weights of four of these inactive elements are deduced by calculation from the same four series in the Tables on pp. 64 and 65, and in the context.

The fact that these very series point to the existence of elements of no valency, and at the same time can be used to deduce the atomic weights of three such elements, has been independently noticed by Lord Rayleigh and Professor Ramsay, and pointed out in Paragraph XVI. of their paper on "Argon: a New Constituent of the Atmosphere," which was read before the Royal Society on the 31st January, 1895. In that paper the discoverers of Argon make the following remark: "The series which contains Si_{n}^{IV}, $P_{4}^{III. and V.}$, $S_{8 to 2}^{II. to VI.}$ and $Cl_{2}^{I. to VII.}$, might be expected to end with an element of monatomic molecules of no valency, *i.e.*, incapable of forming a compound, or if forming one, being an octad."—*Chemical News*, 1st February, 1895.

It will be seen that the series used in this remark is the second of the four series given in the Table on p. 65 of "Force as an Entity," referred to above.

It will be seen also that in the same paragraph of the same paper, the discoverers of Argon have manifestly used the same series along with the first and third of the four series in the Table at p. 65 of "Force as an Entity," in deducing by interpolation the atomic weights of three elements of no valency, and that the values obtained are as follows, viz., with the first series a value between 19 and 23, with the second a value of 37, and with the third a value of 82.

The same three series have been, as already pointed out, used in the Tables on pp. 64 and 65 of "Force as an Entity" and context for the same purpose, *i.e.*, to deduce the atomic weights of three elements of no valency, as well as for another purpose.

The values obtained from them in "Force as an Entity" by calculation are, however, not quite the same as the values obtained by Lord Rayleigh and Professor Ramsay by interpolation, but are simply 20, 40, and 80, instead of a value between 19 and 23, another of 37, and a third of 82, which are the values obtained by the discoverers of Argon as already stated.

The chief reason of the discrepancy is because corrected values are used in "Force as an Entity" instead of the indicated values. And the reason for taking corrected values is because of the remarkable tendency towards an arrangement by multiples of 20 which the three values exhibit, and also because of the remarkable symmetry from a periodic point of view of the arrangement, viz., that of 20, 40, and 80, when the values are made multiples of 20.

And it is noteworthy that by correcting the values in this way we get Argon itself, if Argon is homogeneous and not a mixture, as the element of no valency connected with the second series of the four tabulated in "Force as an Entity" at p. 65. For we get an element of no valency of atomic weight 40, which is plainly none other than Argon, if Argon is homogeneous, since the atomic weight of Argon is 40. And if then Argon turns out to be homogeneous we shall have the correctness of our method vindicated.

It is noteworthy also that if Helium turns out to be homogeneous it will, since its atomic weight lies between 4 and 5, afford further proof of the correctness of our method when extended to the series formed by the metal elements; since the first of the metal series indicates by this method the existence of an element of no valency of atomic weight 5. Moreover, the fact was chronicled by us in an article in the *Chemical News* of the 22nd March, 1895, before the discovery of Helium was announced.

Any proof, however, which Argon and Helium can afford in that way of the correctness of our work is, after all, of small importance in comparison with the proof of the soundness of our work afforded by their presence as elements differing from all other known elements, by having an extreme reluctance either to combine or to cohere, and thus affording strong support to our conclusions in "Force as an Entity," in regard to the existence of a class of elements with this characteristic inactivity.

Investigation into the inactivity of Argon and Helium will, doubtless, go on for many years to come.

It should, however, be remembered that the form, viz., that of a perfect sphere, obtained in "Force as an Entity" for the atoms of elements with this characteristic inactivity in no way precludes all possibility of combination or cohesion taking effect amongst them.

A sphere may lodge in a depression, and even have a firm seat in a cup-shaped hollow which fits it accurately.

It is quite possible, therefore, from our point of view, that suitable seats may be found on M. Berthelot's or some other plan, for Argon atoms, amongst the atoms on some complex hydrocarbon or other molecules and combination be thus brought about.

And since with the case of Saturn's rings before us, it does not seem impossible that a spherical atom should be loaded with a girdle of molecules; therefore also with our explanation of abnormal valency, as given in Chapter III., it does not seem impossible from our point of view that the Argon atom should have abnormally the octad valency which on speculative grounds Lord Rayleigh and Professor Ramsay consider possible for it.

Our conclusions, therefore, do not point to the existence of a class of elements entirely without valency. Nor do they point to the existence of a class of elements entirely without coherence. We know that a pile can be built with round shot if the bottom course is confined so as to be prevented from spreading. It is not, therefore, impossible to make a stack of round shot, but at the same time it is more difficult to make one than it is to make a stack of bricks.

And if, therefore, Argon and Helium are confined in tubes, it should not from our point of view be impossible to condense them into liquid or solid masses; but at the same time it should be a more difficult matter to condense them than it is to condense other gases of the same density.

Our conclusions, therefore, point to the existence of a class of elements differing markedly from all known elements in having less valency and less coherence.

And from the published accounts of the behaviour of Argon and Helium we find that investigation has gone quite far enough to show that they do differ from all other known elements in these very ways.

In this connection we may point, in the matter of valency, to Professor Ramsay's statement in the paper by himself conjointly with Dr. Collie and Mr. Travers, which was read before the Chemical Society on the 20th June, 1895.

In that paper it is stated that "It cannot be doubted that a close analogy exists between Argon and Helium. Both resist sparking with oxygen in presence of caustic soda; both are unattacked by red hot magnesium; and if we draw the usual inference from the ratio between their specific heats at constant volume and at constant pressure, both are monatomic gases. These properties undoubtedly place them in the same chemical class, and differentiate them from all known elements."—*Nature*, Vol. LII., p. 333.

While on the matter of cohesion we may point to Professor Ramsay's letter, dated 23rd September, in *Nature*, of the 3rd October, 1895, in which it is stated that Professor Olszewski, of Krakau, "has been unable to detect any sign of liquefaction" in a sample of Helium exposed "to the same treatment as was successful in liquefying hydrogen—namely, compressing with a pressure of 140 atmospheres, cooling to the temperature of air boiling at low pressure, and then expanding suddenly."

We may point also to Professor Olszewski's results in his paper on the "Liquefaction and Solidification of Argon," in which it is shown that the boiling point of Argon is — 187·0, while that of oxygen is — 182·7.

The significance of these results will be apparent if it is remembered that the density of Helium is more than twice as high as that of hydrogen, and the density of Argon higher by one-fourth than that of oxygen.

Thus we find that investigation has already gone far enough to show that Argon and Helium do differ markedly from all other known elements in having less valency and less coherence than they; and by so differing afford strong support to the conclusions in "Force as an Entity," in regard to the existence of a class of elements differing from all others in these very ways.

For us the importance of the fact that Argon and Helium should have made their appearance—and moreover should have made their appearance at the time when the support they are able to give us was most wanted, viz., at the time when our further investigations into the form of the atom and into that of the fluid corpuscle were just completed, as explained in our article in the *Chemical News* of the 22nd March, 1895—lies in the bearing which such a fact must have upon the rest of our work.

If our conclusions in regard to the form of the atom arrived at by arguing from phenomena have been strengthened by the advent of Argon and Helium, then likewise must our conclusions in regard to the form of the fluid corpuscle which also have been arrived at by arguing from phenomena be to some extent strengthened too, and thus the whole cause of reality be advanced.

At all events Argon and Helium do manifestly afford to the extent our knowledge of them goes a guarantee that we are not altogether unfitted to undertake the task Sir Isaac Newton assigned to science, when he said that the "main business of Natural Philosophy is to argue from phenomena without feigning hypotheses, and to deduce causes from effects till we come to the very First Cause which certainly is not mechanical."—"Opticks," 3rd edition, p. 344.

We have laid stress upon this point, because "Force as an Entity" in reality undertakes the task which Newton thus assigned to science, and actually accomplishes it; does, in fact, actually work by arguing from phenomena, and deducing cause from effect right up to the great First Cause.

Hence, as a book, it is perhaps unique. At all events, no other book has attempted to do the like to our knowledge.

This, therefore, is the explanation we would offer to our critics who were unable to understand the book.

But to those who have laid much stress upon the short cuts and shortcomings of the book, as did in particular our critics in *Iron*, of the 18th April, 1890; and in *The Engineer*, of the 6th June, 1890, we would point out that Argon and Helium are now present to testify in person to the soundness of the materials in the foundations of the work. In fact, it would be difficult to conceive it possible that a reply, more complete, could be made to criticism in any case, than that which is suggested in the case of these criticisms in *Iron* and *The Engineer* by the two words Argon and Helium.

In regard to the superstructure, and in particular to the fact that the correctness of our deductions from the first law of motion is called in question by both of these critics, we would remark that the point we wished to bring out was that all true motion is due to force, and that this was Newton's teaching. We would, therefore, refer to Newton's own words in the "Principia" on the subject, which are quite unmistakable, and run as follows, according to Andrew

Motte's translation:—"True motion is neither generated nor altered, but by some force," Book I., Scholium, p. 14.

Thus we have Newton to speak for the soundness of this particular portion of the superstructure. In regard to another part of the superstructure, namely, the highest part in which we rise to the great First Cause, we can appeal to the old Greek philosophers for a voucher as to its soundness. Thus Aristotle says:—"Anaxagoras declares Good to be the principle as movent; for in his theory Nous causes motion. . . . . My Prime Movent acts like an *ἐρώμενον* in causing motion in the celestial substance. The motion of this last is pure Good without any mixture of Evil. But when this motion is transmitted to the sublunary elements it becomes corrupted by *ὕλη* and *στέρησις*, so that Evil becomes mingled with the Good."—Grote's "Aristotle," p. 628.

Since Newton has established—as we have just seen—the fact that motion is due to force, it is plain that the conclusions in "Force as an Entity" simply reproduce Aristotle's idea in an extended form, reached not by hypotheses but by arguing from phenomena, and extended so as to include the Biblical position as well as the positions taken up by all forms of religion. For these conclusions exhibit the motion or force of attraction which brings things into association in a regular and orderly way as identified with the operations of a supreme power of Good, introducing law and order, and form and beauty; and likewise the motion or force of repulsion which dissociates things, and resists and undoes the work of attraction, as identified with the operations of an antagonistic but subordinate power of Evil tending to bring back the reign of lawlessness and disorder and a return to chaos, and generally to mar and disfigure.

Thus our work in "Force as an Entity" is shown to be not altogether unsound; at the same time, we are fully aware that there is much in it which requires to be strengthened, owing to a great extent to the hurried way in which it was, as explained in the preface, compiled.

We intend, therefore, to go over the ground again, commencing with the work done by Newton and others in the same direction, which could not, from want of time, be dealt with in "Force as an Entity"; and after connecting thus our work with the work of others, to proceed then to review the whole position by the light thrown upon it by the recent discoveries of science.

We hope in this way to discover the weak points as well as the strong points of the position, and then to strengthen the weak and enlarge the strong, so as in every way to improve and extend it.

We shall hope to be able to show, as we go along, that proofs accumulate and difficulties disappear, and that the whole case gets stronger and clearer at every stage.

CHAPTER II.

NEWTON AND OTHERS.

"*This habit of recognising principles amid the endless variety of their action . . . . tends to rescue our scientific ideas from that vague condition in which we too often leave them, buried among the other products of a lazy credulity.*"—J. Clerk Maxwell, "Scientific Papers," edited by Niven, Vol. II., p. 242.

In the preface to his "Principia," Newton writes as follows: "All the difficulty of philosophy seems to consist in this, from the phenomena of motions to investigate the forces of Nature, and then from these forces to demonstrate the other phenomena . . . ."

"For I am induced by many reasons to suspect that they may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually impelled towards each other, and cohere in regular figures, or are repelled and recede from each other; which forces being unknown, philosophers have hitherto attempted the search of Nature in vain."—"The Mathematical Principles of Natural Philosophy," translated into English by A. Motte.

And here, then, we plainly have Newton enunciating the view that all phenomena are due to force of two kinds acting upon matter in the form of particles.

It is plain also that with Newton, force and matter were separate entities.

In regard to matter he says plainly: "It seems probable to me that God in the beginning formed matter in solid, massy, hard, impenetrable, movable, particles . . . . and that these primitive particles being solids are . . . . so very hard as never to wear or break in pieces . . . . the changes of corporeal things are to be placed only in the various separations and new associations and motions of these permanent particles." —"Opticks," 3rd edition, pp. 375 and 376.

It is therefore perfectly certain that Newton believed in the reality of matter in the form of the hard atom.

In regard to force, he says:—

"How such very hard particles, which are only laid together and touch only in a few points, can stick together, and that so firmly as they do without the assistance of something which causes them to be attracted or pressed towards one another, is very difficult to conceive."—*Ibid.*, p. 365.

At another place he says:—

"The parts of all homogeneal hard bodies which fully touch one another stick together very strongly. And for explaining how this may be some have invented hooked atoms, which is begging the question; and others tell us . . . . that they stick together by conspiring motions, that is, by relative rest amongst themselves.

"I had rather infer from their cohesion that their particles attract one another by some force . . . ." *Ibid.*, pp. 363 and 364.

In the case of cohesion, therefore, Newton is clearly of opinion that the particles of matter attract each other by something, and that that something is force, but does not tell us exactly whether force is separate from matter or not.

In the case of gravitation, however, he has very clearly stated his opinion that bodies act upon each other by some material which is not innate, inherent and essential to matter, as will be seen from his third letter to Bentley, in which he says :—

"It is inconceivable that inanimate brute matter should, without the medium of something else, which is not material, operate upon and effect other matter without mutual contact, as it must do if gravitation, in the sense of Epicurus, be essential and inherent in it . . . .

"That gravity should be innate, inherent and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it."

The same opinion is expressed in Advertisement II. of the 2nd edition of his "Opticks," where he says :—

"And to show that I do not take gravity for an essential property of bodies, I have added one question concerning its cause."

And then in his letter to Boyle, dated February 28th, 1678-9, he gives a practical shape to the same idea by putting forward at the end of his letter a fluid explanation of gravitation, by referring it to the motion of "an æthereal substance . . . . like air in all respects, but far more subtil."

Finally he reviews, as it were, the whole situation in a passage in his "Opticks," where he says :—

"And thus Nature will be very conformable to herself, and very simple, performing all the great motions of the heavenly bodies by the attraction of gravity which intercedes those bodies, and almost all the small ones, of their particles by some other attractive and repelling powers which intercede the particles."—"Opticks," 3rd edition, p. 372.

There can therefore be no doubt whatever, that Newton held that gravity was due to something which had a separate existence from the bodies on which it acted.

Also, there can be no doubt whatever that Newton put cohesion and other forms of force on the same footing as gravity, and held them to be due to some thing or things having a separate existence from the particles acted upon, but *interceding* those particles just as gravity *interceded* the bodies on which it acted.

In this connection it may be pointed out, that at a meeting of the Physical Society, on the 26th May, 1893, Professor Minchin is reported to have said that "the first fundamental axiom of dynamics postulates the existence of *force* as an entity distinct from *matter*, *space* and *time*, and this was the object of Newton's First Law."

And Professor Oliver Lodge is reported to have stated on the same occasion that "he agreed with what Professor Minchin said about force and the first law of motion."—*Nature*, 15th June, 1893, pp. 166 and 167.

These, then, were the views held by Newton in regard to matter and force, and they represented atoms when viewed by themselves, as perfectly bare, solid masses of certain sizes and figures; and force as a separate entity, which by its operations upon the atoms in impelling them towards each other and making them "cohere in regular figures," or in repelling them and making them "recede from each other," gave rise to all the phenomena of Nature.

At the same time it must not be supposed that Newton originated these views, for he did nothing of the kind; Newton's part was to give them precision and exactness.

The same views, in fact, as to atoms were held by the great thinker, Democritus, who flourished 2,100 years before Newton's day. And Democritus did not originate them.

In regard to the views of Democritus and the old Greek philosophers who held with him, Professor Adolf Stahr tells us that "the atomists derived all definiteness of phenomena, both physical and mental, from elementary particles, the infinite number of which were homogeneous in quality, but heterogeneous in form. This made it necessary for them to establish the reality of a vacuum or space, and of motion."

And then he goes on to say that the atomists held that "all phenomena arise from the infinite variety of the form, order, and position of the atoms in forming combinations." —Article, "Democritus," Dictionary of Greek and Roman Biography.

Newton's views were therefore in substance those of Democritus, but stated in a more precise and exact form. And Newton was quite aware of this; for in pointing out that from the regularity and duration of the motions of the planets and comets, it is plain that space cannot be filled with "a dense fluid," he says, that "for rejecting such a medium, we have the authority of those, the oldest and most celebrated philosophers of Greece and Phœnicia, who made a *vacuum*, and atoms, and the gravity of atoms, the first principles of their philosophy, tacitly attributing gravity to some other cause than dense matter."—Newton, "Opticks," 3rd edition, p. 343.

These views, therefore, which fructified in Newton's brain, and have given us practically all we know about gravity, and given us also Newton's "Principia: or, The

Mathematical Principles of Natural Philosophy," were very ancient views—a seed sown long ago by great thinkers.

And if these views had yielded no other crop but gravity, they would have been extremely fertile; but, indeed, they have yielded far more.

In this connection we may notice that these were the views with which Dalton worked, as he himself has explained.

For he says, "There are three distinctions in the kinds of bodies, or three states . . . . which are marked by the terms *elastic fluids, liquids,* and *solids* . . . . These observations have tacitly led to the conclusion which seems universally adopted, that all bodies of sensible magnitude, whether liquid or solid, are constituted of a vast number of extremely small particles, or atoms of matter bound together by a force of attraction."—"New System of Chemical Philosophy," p. 141.

And then he goes on afterwards to say that "besides the force of attraction, which, in one character or another belongs universally to ponderable bodies, we find another force that is likewise universal, or acts upon all matter which comes under our cognisance, namely, a force of repulsion. This is now geneıally, and, I think, properly ascribed to the agency of heat. An atmosphere of this subtle fluid constantly surrounds the atoms of all bodies and prevents them from being drawn into actual contact." —*Ibid.*, p. 143.

After this, he adds that "we are now to consider how these two great antagonist powers of attraction and repulsion are adjusted, so as to allow of the three different states of *elastic fluids, liquids* and *solids*."—*Ibid.*, p. 144.

There can, therefore, be no possible doubt that Dalton viewed force as an entity, and, in fact, took the same view of it as Newton did, and we may notice specially, that while Newton tried, as we have seen at p. 15, to explain gravity by the motion of a fluid in the shape of "an æthereal substance . . . . like air in all respects, but far more subtle," Dalton in his turn tries to explain the force of repulsion by an "atmosphere" of a "subtle fluid," as shown above.

Dalton's real work, however, lay with the atom, which he took in hand after a great advance in chemical knowledge had taken place, and at a time when a great body of facts were available.

Dalton may be said to have viewed the atom entirely through its weight.

He takes first the phenomena connected with specific gravity, and points out that, from the fact that homogeneous substances have constant specific gravities, "we may conclude that the *ultimate particles of all homogeneous bodies are perfectly alike in weight, figure,* &c. In other words, every particle of water is like every other particle of water, every particle of hydrogen like every other particle of hydrogen."—*Ibid.*, p. 143.

Then he turns to the combining weights of the elements, and makes the following remarks, viz., "In all chemical investigations it has justly been considered an important object to ascertain the relative weights of the simples which constitute a compound. But unfortunately the enquiry has terminated here; whereas, from the relative weights in the mass, the relative weights of the ultimate particles or atoms of the bodies might have been inferred, from which the number and weight in various other compounds would appear."—*Ibid.*, pp. 212 and 213.

After this he proceeds to determine, in the way he thus points out, the relative weights of the atoms of some of the commonest elements.

Dalton's ideas were adopted by chemistry, and when the relative combining weights of the atoms had been worked out in Dalton's way, and then the weights of the atoms of the halogens, with that of hydrogen taken=1, had been compared with the densities or gas specific gravities of the halogens, with the density of hydrogen taken=1, "the astonishing result," to use the words of Professor von Richter, was "seen that the two series are identical."—"Inorganic Chemistry," translated by Professor Smith, 4th edition, p. 73.

It was also discovered that the same relation between density and atomic weight exists in the cases of all "of the elements whose molecules consist of two atoms," and is connected with a wider fact, that gas densities of all substances "bear the same ratio to each other, as the molecular weights."—*Ibid.*, p. 79. And thus a ready way of arriving at the weight of the molecule, and through it of the atom was obtained. In fact, Dalton's service to science consisted in showing that the atom can be viewed through its weight.

He himself says, in reference to his "New System of Chemical Philosophy," "that it is one great object of this work to show the importance and advantage of ascertaining the *relative weights of the ultimate particles, both of simple and compound bodies*."—"New System of Chemical Philosophy," p. 213.

This view has been fully accepted by science, and no pains have been spared in determining the weight of the atom with the utmost accuracy in the cases of all the valent elements known to us. And now text books of chemistry are able to give a complete list of the atomic weights of all of the valent elements known.

The result of getting out a complete list of atomic weights has in Professor Mendeleeff's hands been to bring out more clearly than ever the importance of the weight of the atom as a means of viewing the atom. For Professor Mendeleeff has, to use Professor von Richter's words, demonstrated by the periodic law that "the *properties of the elements* and their compounds present themselves as *periodic functions of the atomic weights*."—"Inorganic Chemistry," translated by Professor Smith, 4th edition, p. 246.

Since, then, the other properties of the elements are functions of the atomic weights, it is plain that Dalton's way of viewing the atom by its weight must be the clearest way of viewing it. The view, however, which

Dalton obtained of the atom was very indistinct. It shows in fact that there is an atom, but it leaves room for doubt whether it is a hard atom or an atom of motion. Dalton clearly held it to be Newton's hard atom, for he comes to the conclusion, as we have seen above, that it has a figure of some kind. But he was not able to show what its shape really was, and thus to make the atom a reality. He has left that to us.

In any case it is perfectly clear that it was with Newton's views in regard to the atom, as well as in regard to force, that Dalton's work was done; and also that the marvellous extension of our knowledge of chemistry, which has been the direct outcome of Dalton's work, is another of the magnificent crops yielded by the views which have given us all we know about gravity. These, however, are by no means the only crops which the same views have yielded.

We have yet to tell of the work done by Faraday, Clerk Maxwell, and others, with the same views, and of the crops which have resulted; and while taking, as we must, the opportunity of pointing out that the later crops have in no case quite equalled the earlier under Newton, and Dalton may take also the opportunity of pointing out that a possible reason for the shorter yield may be found in the fact that later workers have not accepted Newton's views in their entirety, but have endeavoured to get rid of the hard atom at a manifest sacrifice of reality.

This comes out very clearly in Faraday's work.

Faraday, as we have seen in "Force as an Entity," p. 1, says himself: "I go with Newton when he speaks of the *physical lines of gravitating force*."—"Life of Faraday," by Dr. Bence Jones, Vol. II., p. 367.

And again,

"The view which I am so bold as to put forth considers, therefore, radiation as a high species of vibration in the lines of force, which are known to connect particles and also masses of matter together."—"Researches in Chemistry," p. 370.

While Professor Tyndall has given us the following statement of Faraday's views, viz.: "Let it then be remembered that Faraday entertained notions regarding matter and force altogether distinct from the views generally held by scientific men. Force seemed to him an entity dwelling along the line in which it is exerted. The lines along which gravity acts between the sun and earth seem figured in his mind as so many elastic strings."—"Faraday as a Discoverer," p. 126.

Hence Faraday was quite clear as to the reality of force, and succeeded in making out one of the forms which it takes, namely, the line of force.

But at the same time he denied the reality of matter, and spoke "of particles of matter" as "being themselves only centres of force."—"Researches in Chemistry," p. 369.

Thus he endeavoured to make force the only reality, and to distribute it throughout space in the form of lines running between accumulations of force, and to make atoms merely the mathematical centres of the accumulations of force between which the lines of force ran.

It seems marvellous that he did not see that in doing away with the atom he was cutting away the very ground from under his own feet. In fact, the hard atom is absolutely essential to give an explanation, such as his, reality.

Given matter as an entity in the form of hard atoms distributed throughout space, and force as a separate entity connecting the atoms together, then the distribution of force in fine lines is a perfectly natural and reasonable one, if force has to make its way through a resisting medium to get to the minute atoms.

But, without the atom to form an attachment for the lines of force, there is no conceivable way in which force as an entity could be divided up into a system of fine lines and accumulations in the first instance, or maintained afterwards in that state of division, in a universe where all things are in motion.

In the case of electricity, Faraday was able to demonstrate the existence of lines of force by the linear arrangement adopted by iron filings when a magnet is brought under a piece of paper on which iron filings have been strewn; but still did not see that in that experiment force was doing with the filings on a large scale just what it was doing with the atoms on a small scale—on an exceedingly minute scale, in fact. He thus missed one of the points illustrated by the experiment, and that, too, the very point which, if brought out, would have made his views available for universal application; for the filings showed not only how atoms could be joined together in chemical combination, by lines of force; and molecules in cohesion; but also how moons could be connected with planets, and planets with suns, by gravitation; by showing how masses of matter could be bound together by force alone.

He proved, indeed, his case as far as electricity was concerned, and succeeded in getting his views adopted and in reaping a great harvest of results in the field of electricity, nevertheless the yield was scanty in comparison with what might have been obtained with Newton's views in regard to the atom.

The mistake made by Faraday in discarding the hard atom comes out more distinctly, still, in Clerk Maxwell's work.

Clerk Maxwell took up Faraday's views in regard to the line of force, and made a most earnest, and as far as it went successful, attempt to give them reality in a paper read before the Cambridge Philosophical Society on the 10th December, 1855, and 11th February, 1856, in which he points out that if we consider lines of force "not as mere lines, but as fine tubes of variable section, carrying an incompressible fluid, then, since the velocity of the fluid is inversely as the section of the tube, we may make the velocity vary according to any given law, by regulating the section of the tubes, and in this way we might represent the intensity of the force, as well as the direction, by the motion of the fluid in these tubes." He then adds that "this method of representing the intensity of a force by the velocity of an imaginary fluid in a tube is applicable to any conceivable system of forces, but it is capable of great simplification in the case in which the forces are such as can be explained by the hypothesis of attractions, varying inversely as the square of the distance, such as those observed in electrical and magnetic phenomena."—"Scientific Papers of James Clerk Maxwell," edited by Niven, Vol. I., pp. 158 and 159.

He also points out that by means of lines of force we may "obtain a geometrical model of the physical phenomena," and then proceeds to work out on these bases a "Theory of the motion of an incompressible fluid," and a "Theory of the uniform motion of an imponderable, incompressible fluid through a resisting medium," and apply the theorems so obtained to explain a "Theory of Dielectrics," a "Theory of Permanent Magnets," a "Theory of Paramagnetic and Diamagnetic Induction," a "Theory of Magnecrystallic Induction," and a "Theory of the Conduction of Current Electricity"; also to explain "Electro-motive Forces," "The action of Closed Currents at a Distance," and "Electric Currents produced by Induction," "by referring everything to the purely geometrical idea of the motion of an imaginary fluid," as he says.—*Ibid.*, pp. 160—186.

In giving thus an "outline of Faraday's electrical theories as they appear from a mathematical point of view," he says: "I can do no more than simply state the mathematical methods, by which I believe that electrical phenomena can be best comprehended and reduced to calculation, and my aim has been to present the mathematical ideas to the mind in an embodied form, as systems of lines or surfaces, and not as mere symbols, which neither convey the same ideas, nor readily adapt themselves to the phenomena to be explained."—*Ibid.*, p. 187.

He had pointed out as we have seen in the extract on p. 26, that the method of representing the intensity of a force by the velocity of an imaginary fluid is applicable to any conceivable system of forces, and had applied it successfully to explain "some of the less complicated phenomena of electricity, magnetism and galvanism."

Why, then, we may well ask, did he abandon this method in his subsequent work, and take to the use of "mere symbols, which neither convey the same ideas nor readily adapt themselves to the phenomena to be explained," as he says himself in the extract given above?

His abandonment of this method seems at first sight the more strange, because he was convinced of the necessity of looking upon lines of magnetic force as "something real," and showing their connection with lines of force of other kinds. This is plainly shown by the fact that he states in effect that the object of his paper on "Physical Lines of Force," is "to clear the way for speculation in this direction." Moreover, the method which he thus abandoned not only represented lines of magnetic force as something real, but also provided a means of showing their connection with other lines of force, since it was, as he himself has shown in the quotation given at p. 26, "applicable to any conceivable system of forces," and above all, it was a sound mathematical method, as he himself has shown also.

Now on turning to Clerk Maxwell's article on "Attraction," in the "Encyclopædia Britannica," it will be seen that he objects to Sir William Thomson's (now Lord Kelvin's) fluid illustration of gravitation simply because "the conception of a fluid constantly flowing out of a body without any supply from without, or flowing into it without any way of escape, is so contradictory to all our experience, that an hypothesis of which it is an essential part, cannot be called an *explanation* of the phenomenon of gravitation," although he admits that with it "we have a hydrodynamical illustration of action at a distance, which is so far promising that it shows how bodies of the same kind may attract each other."

And if while keeping this case in mind we now turn back to Clerk Maxwell's paper on "Faraday's Lines of Force," it will be apparent that his "Theory of the Motion of an Incompressible Fluid" is open to the very same objection as the one he himself brought against Sir William Thomson's illustration of gravitation, inasmuch as it requires a system of "sources" capable of producing a fluid from nothing, and of "sinks" capable of reducing it to nothing. This is clear from Clerk Maxwell's own explanation, which is to the following effect:—"The properties of the fluid are at our disposal; we have made it incompressible, and now we suppose it produced from nothing at certain points, and reduced to nothing at others. The places of production will be called *sources* . . . . The places of reduction will, for want of a better name, be called *sinks*."—"Scientific Papers," edited by Niven, Vol. I., p. 162.

And it is quite clear also that "sources" and "sinks" of such a kind involve conceptions contradictory to all our experience.

It cannot be doubted, therefore, that Clerk Maxwell rejected his own method of giving reality to force, because it involved a conception "contradictory to all our experience," and was therefore unreal.

At the same time, there can be no doubt that he abandoned this method—by which he was enabled, as he says, "to present mathematical ideas in an embodied form as systems of lines or surfaces, and not as mere symbols"—most unwillingly, and tried for a long time to arrive at, or elicit ideas which would enable him to resume its use. For not only has he expressly stated, as already shown, that his object in writing his paper on "Physical Lines of Force" "was to clear the way for speculation in this direction"; but also he has stated unreservedly his opinion that the "advance of the exact sciences depends upon the discovery and development of appropriate and exact ideas, by means of which we may form a mental representation of the facts."—*Ibid.*, Vol. II., p. 360.

In addition to this, he has made in the fragmentary preface, which he left for his "Elementary Treatise on Electricity," his last work on electricity, the following statement, viz., "In the larger treatise, I sometimes made use of methods which I do not think the best in themselves, but without which the student cannot follow the investigations of the founders of the Mathematical Theory of Electricity. I have since become more convinced of the superiority of methods akin to those of Faraday."

We thus learn that Clerk Maxwell succeeded in obtaining an explanation, which gave the line of force complete reality, "by making," as he himself states in his paper on "Physical Lines of Force" ("Scientific Papers of James Clerk Maxwell," edited by Niven, Vol. I., p. 452), "use of the conception of currents in a fluid"; and also an explanation, "applicable to any conceivable system of forces."

And yet he was obliged to abandon this explanation, though greatly against his will, simply because he could not obtain supplies of the fluid to furnish the necessary currents, or to dispose of the supplies brought by the currents after they had done their work, and were no longer required without resorting to the device of "sources" capable of creating supplies of the fluid from nothing, and "sinks" capable of reducing the supplies so obtained to nothing, which manifestly involved conceptions contrary to all our ordinary experience, and took all reality out of the explanation.

The point now to notice is this, viz., that much of the difficulty arose from the fact that Clerk Maxwell followed Faraday in leaving the atom out of consideration in his explanation. Had he brought in Newton's hard atom, it would, by furnishing a lodgment on which supplies of the fluid could accumulate, have furnished a reservoir in which, or rather on which, supplies of the fluid could accumulate after the same way as, on a vast scale, our earth furnishes a reservoir in which the water of the great oceans can collect. The reservoir so furnished by the atom would have served when occasion required both as a "source" and as a "sink"; namely, as a source, ready to overflow in any direction and furnish supplies, and as a sink, ready to take an influx from any direction, and store up supplies no longer required.

A fluid with a tendency to attach itself to atoms of matter would flow in upon the nearest atom and accumulate upon it, and would overflow on the close approach of any other atom, which had a smaller accumulation of fluid upon its surface than the one on which it was seated had; and, therefore, could have been set in motion whenever it was required, and stored up when it was no longer wanted by the simple expedient of bringing atoms of matter into the field. It is, therefore, in our opinion, clear that the real reason why Clerk Maxwell did not succeed in his earnest attempt to give reality to the line of force, was the failure to connect the line of force with the hard atom.

Like Faraday, Clerk Maxwell did great things with the line of force, for the splendid work done by Hertz is the acknowledged and direct outcome of Clerk Maxwell's work.

But Clerk Maxwell had to work with symbols, which restricted his work, instead of working with real lines of force applicable to all branches of science.

Reference has been already made to Sir William Thomson's (now Lord Kelvin's) fluid illustration of gravitation in a paper read before the Royal Society of Edinburgh, on the 7th February, 1870, in which, amongst other points, Sir William Thomson showed that "through fluid pressure, we can have a system of mutual action, in which like attracts like with force varying inversely as the square of the distance."—Proceedings R.S.E., 1869-70, p. 62.

Clerk Maxwell's explanation of this illustration of gravitation is as follows:—"Sir William Thomson has shown that if we suppose all space filled with a uniform incompressible fluid, and if we further suppose either that material bodies are always generating and emitting this fluid at a constant rate, the fluid flowing off to infinity, or that material bodies are always absorbing and annihilating the fluid, the deficiency flowing in from infinite space, then, in either of these cases there would be an attraction between any two bodies inversely as the square of the distance. If, however, one of the bodies were a generator of the fluid, and the other an absorber of it, the bodies would repel each other."—Article "Attraction," "Encyclopædia Britannica," 9th edition.

Clerk Maxwell's difficulty in connection with this illustration has been given at p. 28. The point is that both illustration and difficulty have a special interest for us, as we hope to show further on, quite apart from the interest which attaches to them on account of their respective authors.

Amongst those who, at times, have striven to give reality to force or energy in some particular case are Le Sage and Fourier.

Le Sage's theory that gravitation is due to a bombardment of extra-mundane corpuscles flying in all directions, which tends to drive bodies together when they are near enough to shield each other on one side from the bombardment, while on all other sides they are fully exposed to it, is from a general point of view extremely interesting, but at the same time does not immediately concern us here.

We are closely concerned, however, with Fourier's work, of which the following explanation is given by Clifford, viz. :—

" Fourier, in trying to find the laws of this spread of heat from one part of a body to another part, made the hypothesis that heat was a fluid which flowed from the hot end into the cold as water flows through a pipe. From this hypothesis the laws of conduction were deduced."

To this Clifford adds the following remark:—" In fact, whatever can be explained by the motion of a fluid can be equally well explained either by the attraction of particles or by the strains of a solid substance: the very same mathematical calculations result from the three distinct hypotheses; and science, though completely independent of all three, may yet choose one of them as serving to link together different trains of physical inquiry."—"Lectures and Essays," by W. K. Clifford, p. 86.

Thus we have Clerk Maxwell's fluid explanation of the simpler problems of electricity and magnetism, Sir William Thomson's (now Lord Kelvin's) fluid illustration of gravitation, and Fourier's fluid explanation of the conduction of heat, all in the form of mathematical investigations.

It is therefore perfectly clear that a fluid explanation of force is quite sound from a mathematical point of view.

It is plain also that the main difficulty in connection with a fluid explanation of force is to obtain supplies of the fluid when wanted, and to dispose of the surplus when it has done its work, and is no longer wanted without making use of conceptions contrary to all our ordinary experience, and thus depriving the explanation of all reality.

And it is here then that "Force as an Entity" comes in, and while taking the same view of lines of force as Clerk Maxwell at one time took, viz., that they are currents in an incompressible fluid, utilises also the other fluid forms, viz., the *pool*, the *film*, and the *wave*, as well as the *stream*, or current, making them available by the simple expedient of introducing the hard atom into the field along with the line of force, and thus adopting Newton's views in their entirety. The hard atom supplies at once an allurement to set the fluid in motion in streams or currents flowing out of its pools, or through its pools, and an attachment upon which the fluid can accumulate in pools, and remain quiescent until the close approach of other atoms sets it in motion once more in the stream form, after the same manner as our earth supplies an attachment for the oceans of salt water which accumulate upon it. While the fluid supplies by its streams a means of transporting the atoms, and bringing them together, or removing them to a distance; by its pools a means of collecting the atoms in one place; and by its films a means of binding the atoms together in molecules and masses, after the same manner as a film of water spread out between two clean sheets of glass binds the two sheets of glass together, in an old and well-known experiment.

In this way the pool supplies both "sources," out of which streams can be obtained, and "sinks" into which streams can be discharged.

In this way, too, by the simple device of bringing Newton's hard atom into the field, and thus by taking Newton's views in their entirety, instead of in a mutilated form, we get a complete fluid explanation of energy or force, applicable not only to gravitation, electricity and heat, but also to cohesion and chemical affinity.

And, in addition, by utilising the remaining fluid form that of the wave, we obtain a fluid explanation of the undulations of light, heat, and electricity.

Besides this, we have in this fluid explanation, the pool supplying *potential energy*, and the stream supplying *kinetic energy*, and thus a complete generalisation applicable to every form of *energy* or *force*.

But though with the aid which we thus obtain of streams to transport atoms of matter, of pools in which to collect them, and of films by which to bind them together in molecules and masses, we can obtain a real explanation of the construction of the universe; yet the universe so constructed would manifestly not be a universe of the same kind as that in which we live, since our universe manifestly has been, and is being built up in the face of strenuous resistance and opposition, whilst this would be built up quietly with no strife to mar and scar it, and no discord to rend it, and with action without re-action.

In order, therefore, to get a real universe, such as ours, we have to take one other step, viz., the step taken in "Force as an Entity" of importing Antagonism into the construction of the universe.

And this is done in "Force as an Entity" by simply dividing up the great fluid abyss into portions differentiated from each other, solely by having the tendency to lay hold of matter in different degrees of strength, so that the tendency to lay hold of matter is so much stronger in one portion than in another, that the portion with the stronger tendency is able to displace the portion with the weaker tendency, and dislodge it from its position about any atoms of matter to which it has previously attached itself. By putting then the portion with the weaker tendency in prior possession, by letting it acquire this tendency before the other portion acquires it, so that it may take possession off hand of the whole stock of atoms of matter in the universe, we get Antagonism imported into the situation in a simple and natural way; since the portion with the stronger tendency to attach itself to atoms of matter has then no way of satisfying this tendency, except by displacing and dislodging the portion with the weaker tendency, which has the whole stock of atoms of matter in its possession. Under such circumstances, the portion with the stronger tendency to lay hold of the atoms of matter has to make its way through a resisting medium in the shape of the portion with a weaker tendency, which has disposed itself about the atoms of matter, and is unwilling to let them go.

Since the portion with the stronger tendency is present in overpowering strength, and able to overcome all the resistance the portion with the weaker tendency is able to offer, we shall have a universe built up by the portion with the stronger tendency as surely as if the portion with the weaker tendency were absent altogether. The difference will be that it will be built up much more slowly, and with much more difficulty than it would be if there were no resistance or opposition to be encountered.

The only thing now wanting is a supply of atoms of a suitable form for building the molecules, masses, and bodies of which our universe is made up. The form must be such that the atoms will drop of themselves into the right positions for the formation of molecules, when they are brought in by the streams and collected in the pools of the stronger portion of the fluid. And at the same time it must be such as to allow certain kinds of combinations only to be made, and those the kinds which will give molecules of the proper form only; in fact, it must be such that the atom cannot take up a wrong position.

The atom will plainly fulfil the necessary conditions if it can come to rest permanently in certain positions only, and those the right positions for the combinations which have to be made, and if in all other positions it will roll and will not rest permanently; because atoms can roll upon each other and can come to rest upon each other just as well as upon any other hard surface. And, moreover, we have in the film form of the fluid a material for binding atoms together when they are in a position of rest, much in the same way as (in a well-known experiment) a film of water binds two clean sheets of glass together; but, at the same time, we have a material which is unable to bind atoms together when they are rolling. If, therefore, atoms are of the right form, they will be built up in the right way by the fluid which we have already got.

Now the metalloid atom shows us by its hydrogen valency, or in other words, by the number of hydrogen atoms which it can take on in combination, the number of positions in which the atom must be able to come to rest.

In the case of the *monovalent*, which takes only one atom of hydrogen, there must be one position of rest only; in the case of the *divalent* which takes two, there must be two such positions; in the case of the trivalent, there must be three; and in the case of the tetravalent, there must be four.

Thus we have clear indications of the form the atom must take, and in view of these indications have been able, in Chapter III. of "Force as an Entity," to arrive at a form which answers all requirements in the case of the metalloid atom.

The form obtained is that of a chipped sphere—a sphere chipped so as to have flat places on its surface, corresponding in number to the hydrogen valency of the atom; and so that the valent atom will have one flat place for each hydrogen atom it can take on in combination.

Hence, the form of a monovalent atom is that of a sphere with one flat place; the form of a divalent atom that of a sphere with two flat places; of a trivalent, a sphere with three flat places; and of a tetravalent, a sphere with four.

It is manifest that a perfect sphere will not stand steady in any position, but if a sphere has a flat place of considerable extent on its surface, then it will stand steady when resting on that flat place, but in no other position; also another chipped sphere of the same kind will stand steady upon it, if its flat place is turned up and brought into a horizontal position, and the flat place of the other sphere is brought down upon it.

If the sphere has two such flat places, then there will be two positions in which it will stand steady, and two only, and also two positions in which another atom can steady upon it; and if it has three such flat places, then there will be three such positions; or if it has four such flat places, then four such positions.

Thus the number of flat places will determine the number of positions in which the sphere will stand steady, and also the number of positions in which other chipped spheres can stand steady upon it.

It is plain that in the chipped sphere with flat places corresponding in number to the valency of the atom, we have got at all events the right form for the valent metalloid atom, which combines with hydrogen to form hydrides. For, in the first place, it is quite plain that with atoms of this form we should have molecules of the right form built up, since atoms of that particular form would, when shaken up along with hydrogen atoms of a similar form, but having each one flat place only, by the struggle between the two fluids over the possession of the atoms, come of themselves into the right positions for forming molecules of the right kind: and since, also, the strong fluid would be present to bind the atoms together by its films, and thus secure them as soon as they were in the right positions for forming molecules; but at the same time would be unable to bind them when they were in any but the right position, because they would roll upon each other and come apart. And then, in the next place, it becomes evident on viewing the atom in Dalton's way, by its weight, that the atomic weights of the metalloid elements show most clearly that this is a possible form for the atom. For when the metalloid elements are viewed by their atomic weights and arranged according to the Periodic Law, it becomes apparent that they run in series, each containing a monovalent, a divalent, a trivalent, and a tetravalent member, and originating from an element without valency, from which the series is derived by a process of taking off portions from the weight of its atom, one portion being taken off to make the monovalent, two to make the divalent, three for the trivalent, and four for the tetravalent. It becomes thus plain that the atomic weights of valent atoms correspond very closely with the view that valent atoms are derived from non-valent spherical atoms by a process of detaching portions from the spheres corresponding in number to the valency of the atom, one portion being detached for each valency; and therefore also that the form we have obtained is a possible form for the atom.

We can obtain the atomic weights of the elements without valency from which valent elements are derived by replacing the portions taken off in forming the atoms of the valent elements.

Determinations arrived at in this way of the atomic weights of four of these inactive elements, which necessarily have perfectly spherical atoms, are given at p. 64 of "Force as an Entity." Their atomic weights, with a correction to bring them to multiples of 20, are 20, 40, 80, and 120 respectively. In addition, therefore, to determining the form of the valent metalloid atom, we determine also in this way the form of the non-valent atom and the atomic weights of four elements without valency from one or other of which the valent metalloid elements are all derived.

Elements without valency, therefore, come in necessarily with this explanation, and the fact that one of the very elements required to make our case perfectly complete, viz., the element without valency of atomic weight 40 with perfectly spherical atoms, has now been discovered in the form of Argon of atomic weight 39·98, according to the latest determination, affords as far as it goes confirmation of the correctness of our conclusions. At all events, Argon and Helium, whether they are exactly the inactive elements we require or only mixtures of inactive elements, place, as pointed out in Chapter I., beyond doubt the fact that inactive elements do exist, and thereby show most clearly the soundness of our work which enabled us to discover and point out the probable existence of inactive elements in Chapter III. of "Force as an Entity" before Argon and Helium made their appearance.

We have, therefore, got atoms which can be put together to form molecules, and, in fact, will drop of themselves into the proper positions for forming molecules, but only for forming molecules of the right kind for the structures in our universe and no others, so that none but the right molecules can be formed with these atoms; in fact, there is only one way in which these atoms can be fitted together to form molecules at all, and that the way which will give molecules of the exact forms we require.

We are sure, therefore, that we have got the right kind of atoms. We are able to view them in Dalton's way, by their weights, and thus satisfy ourselves that they are the right atoms. And now, in addition to the atoms, we have in Argon and Helium a portion of the raw material from which valent atoms have been derived.

We have got also a system of streams for transporting the atoms, and of pools for collecting them, and, moreover, a conflict raging over them by which they will be tossed to and fro, and shaken up together until they come into the right positions for forming molecules. And then, too, we have a binding material, which will bind them together when they come into the proper positions for forming molecules, and afterwards keep them together through all the vicissitudes of the strife about them, so that they will not be able to part company again except under extraordinary circumstances. We have thus a complete arrangement for building a universe such as ours, and an arrangement which, when once set going, will go on of itself automatically.

The theory of energy or force thus developed is practically a two-fluid theory with a stronger and a weaker fluid, differing only in the strength of the tendency to lay hold of matter, which tendency is impressed upon both, but not in the same strength upon both. The stronger fluid represents attractive energy or the force of attraction, of which gravitation is the type; and the weaker fluid represents repulsive energy or the force of repulsion, of which heat is the type.

In broaching such a theory we are confronted at once with Davy's celebrated experiment, in which he showed that two pieces of ice can be melted by simply rubbing them together without communicating any heat from surrounding matter.—"Essay on Heat, Light, and the Combinations of Light," Experiment II.

This experiment may indeed be conclusive as against a one-fluid theory of heat, but if we look closely into the details, we shall see that it is completely in accordance with a two-fluid theory.

Let us look into this point. Davy states that "the fusion took place only at the places of contact of the two pieces of ice." Let us, therefore, endeavour to make out what really happened at "the places of contact of the two pieces of ice."

Well, in the first place, we notice that ice is of necessity very loose in structure, being bulk for bulk lighter than water, which always contains large quantities of air and other gases, and is, therefore, by no means homogeneous. Hence, a piece of ice must have air spaces between the crystals of which it is built up; and the surface of a piece of ice must be covered with minute pits or prominences, though to the eye it appears quite smooth; this being the case, it necessarily follows that when two pieces of ice are in contact, the prominences in the surface of the one will in some cases sink more or less deeply into the pits on the surface of the other, and *vice versâ,* and thus portions of the two surfaces will be more or less interlocked. This, of course, is more or less the case with solids of every kind when their surfaces are in contact, but there is a special reason in the looseness of the structure of ice why it should be a more pronounced feature in the case of ice than in other cases. The effect then of rubbing two pieces of ice together is to grind off some of the prominences on their respective surfaces against the sides of the pits in which they are caught, and also to compress and thereby heat the air in these pits. In cases in which the prominences fit the pits so closely that there is no escape for the air, and in cases in which air is imprisoned among the particles of ice in the accumulation of ice dust formed by the process of rubbing, the result is to bring together in these pits finely divided particles of ice—ice dust, in fact—and heated air; and, consequently, to melt the ice.

Davy concluded that the heat by which the ice was melted in this experiment necessarily came from the ice, and overlooked the enormous supply of latent heat in the air in and about the ice. In fact, there is an old and well-known experiment in which a piece of tinder in a tube closed at one end is set on fire simply by compressing by a piston the air with which the tube is filled. And this will serve to remind us how necessary it is in this experiment to avoid overlooking the large supply of latent heat in the air in and about the two pieces of ice.

From our point of view then, the case is simply one of transfer, in which heat is transferred from compressed air to finely-divided ice particles, and therefore to particles in the right condition for receiving heat; and thus is one of the many cases in which there is a temporary reversal of the ordinary course, in which the strong fluid dislodges the weak. For here we have the weak fluid representing repulsive force typified by heat able to dislodge the strong fluid representing attractive force in part from about the ice molecules, when they are separated by the act of rubbing the two pieces of ice together.

If we keep our eyes steadily fixed on the main operations in the universe, by which the strong fluid representing attraction is steadily dislodging the hold of the weak fluid representing repulsion, and tightening its own grip upon matter, we shall not be led astray by temporary reverses such as the one exhibited in Davy's experiment, but shall very soon come to see that they are a necessary feature in the later stages of the struggle between the two fluids.

Davy's experiment then, though possibly conclusive, as against a one-fluid theory of heat, in no way militates against the two-fluid theory which we are advocating. And we may remark before proceeding further that our two-fluid theory is in accordance with Sir Isaac Newton's own views, so far as they went, as will be seen from his letter to Boyle, dated 22nd February, 1678-9.

In that letter he explains that he considers the ether to be "in a word, much like air in all respects, but far more subtil," and therefore, of course, a fluid.

In order to explain gravity he differentiates, in the second of the two explanations which he gives in the letter in question, this fluid into two parts, a "grosser ether" and a "finer ether," "differing from one another in subtilty"; and thus practically gets a two-fluid theory as we do. Then he assumes that "in the pores of bodies there is less of the grosser ether in proportion to the finer than in open spaces, and consequently that in the great body of the earth there is much less of the grosser ether in proportion to the finer, than in the regions of the air"; and thus practically puts the finer ether in prior possession of matter, much in the same way as we put the weak fluid in prior possession of matter.

He goes on to assume that "yet the grosser ether in the air affects the upper regions of the earth, and the finer ether in the earth the lower regions of the air"; and thus practically gives the grosser ether a stronger tendency to lay hold of matter than the finer ether, much in the same way as we give the strong fluid a stronger tendency to lay hold of matter than the weak fluid has. Finally he says:— "Imagine now any body suspended in the air or lying on the earth; and the ether being by hypothesis grosser in the pores which are in the upper parts of the body than in those which are in its lower parts, and the grosser ether being less apt to be lodged in these parts than the finer ether below, it will endeavour to get out, and to give way to the finer ether below, which cannot be without the body's descending to make room above for it to go out into." He therefore practically makes the grosser ether dislodge the finer from its position about atoms of matter, much in the same way as we make the strong fluid dislodge the weak fluid from its position about the atoms of matter. We shall understand the analogy between his views and ours better if we remember that by pores he simply means the intervals between atoms of matter which he considered to be "solid, massy, impenetrable, moveable, particles, and therefore quite distinct from the ether.

He recurred afterwards in his book on "Opticks" to a two-fluid theory, and showed that an undulatory theory of light was possible if "one might suppose that there are in all space two ethereal vibrating mediums, and that the vibrations of one of them constitute light." But then he starts the following objections:—"But how two ethers can be diffused through all space, one of which acts upon the other and by consequence is reacted upon without retarding, shattering, dispersing, and confounding one another's motions is inconceivable. And against filling the heavens with fluid mediums, unless they be exceeding rare, a great objection exists from the regular and very lasting motions of the planets and comets."—"Opticks," 3rd edition, p. 339.

Now the difficulty to which Newton here alludes is entirely obviated with our two-fluid theory by the fact that one fluid is stronger than the other, while at the same time the fluids are incompressible, and space is filled quite full, without interstices, with the two fluids along with atoms of matter. And when, therefore, one fluid moves in any direction, the other must move too in the opposite direction, in order to occupy the place vacated by it, there being no other available for occupation. Every stream, therefore, of the strong fluid will have a similar stream of the weak fluid flowing alongside of it in the opposite direction.

Thus, instead of "shattering, dispersing and confounding one another's motions," the two fluids with our theory will move in strict conformity with each other.

We have thus a two-fluid theory which, while being free from the objections brought by Newton against any two-fluid theory of an ordinary kind, gives effect in their entirety to Newton's own views both in regard to matter and in regard to force, and also to Faraday's views in regard to the existence of the "line of force as a reality," and to Clerk Maxwell's view that the line of force is a current in an incompressible fluid.

Above all, it makes this universe of ours a reality, and gives us a real explanation, by ideas which the mind can grasp, of the constitution of this universe, and an explanation, too, which takes us up to the great First Cause by the way, which Newton indicated, as we have seen in the preceding chapter, viz., by arguing from phenomena without feigning hypotheses, and by deducing cause from effect.

The case, however, as set forth in "Force as an Entity," is very incomplete, and in many respects very unsatisfactory, owing largely to the hurried way in which the book had to be brought out during an interval of furlough.

In fact, it merely represents a preliminary statement of our conclusions.

Nevertheless, in spite of all the shortcomings of "Force as an Entity," it must not be forgotten that it stands out distinguished from all other books, not only by the fact that it alone heralded the advent of Argon, and heralded it too in quite clear and unmistakable terms, at a time when the existence even of such things as inactive elements was unsuspected; but also by the fact that it alone of all books has undertaken the task assigned to science by Newton, when he said that "the main business of Natural Philosophy is to argue from phenomena without feigning hypothesis, and to deduce cause from effect until we come to the very First Cause," as we have already seen in Chapter I.

In view, then, of what is left undone in "Force as an Entity," and in view also of what has been done in it in demonstrating the existence of inactive elements before Argon was ever heard or thought of, we intend now to make an earnest attempt to strengthen and improve the case in every way, commencing with a re-determination of the form of the atom, and proceeding then to attempt a determination of the form of the fluid corpuscle, which, besides the atom, is the other entity in the universe. After considering the two separately, we propose next to bring them together, and to show that the fluid corpuscle is able to build up a universe such as ours unaided if supplied with bricks in the shape of hard atoms of certain "sizes and figures."

In the course of the argument, we shall have elements without valency of the Argon type taking their proper positions amongst the elements each at the head of a group of valent elements derived from itself. We shall see the other members of the group busily engaged in forming connections of various kinds with other elements, and taking part in many sorts of associations, but these keeping steadfastly aloof as solitary restless things which acknowledge no tie of any kind, and form no union except under the strongest compulsion, simply because they have spherical atoms with no flat places on their surfaces on which to rest.

Professor Olczewski can force Argon to be companionable, but only by imprisoning it in a tube and then subjecting it to a pressure of 50·6 atmospheres under the intense cold of a temperature of $-121°$, and under such conditions can liquefy it; and can even solidify it at a temperature of $-189°$.—See Professor Olczewski's paper on "The Liquefaction and Solidification of Argon," read before the Royal Society, on the 31st January, 1895.

M. Berthelot, too, may succeed in getting it into a cage of hydrocarbon molecules under the influence of a silent electric discharge inside a tube.

But except under conditions such as these, it steadfastly declines companionship of any kind.

Helium, however, shows, as Professor Olczewski finds no signs of becoming liquid under the treatment with which he succeeded in liquefying hydrogen, viz., a pressure of 140 atmospheres at the temperature of air boiling under low pressure.—See a letter dated 25th September, 1895, by Professor Ramsay, in *Nature*, of 3rd October, 1895.

They are, in fact, a material entirely unsuited for building structures of any kind, but still a material admirably suited to fill interstellar space owing to its being free from all the restraints of cohesion, while acknowledging at the same time the sway of gravity.

CHAPTER III.

THE FORM OF THE ATOM.

All these things being considered, it seems probable to me, that God in the beginning formed matter in solid, many, hard, impenetrable, movable particles, of such sizes and figures, and with such other properties and in such proportion to space, as most conduced to the end for which He formed them; and that these primitive particles being solids, are incomparably harder than any porous bodies compounded of them; even so very hard, as never to wear or break in pieces . . . . And, therefore, that nature may be lasting, the changes of corporeal things are to be placed only in the various separations and new associations and motions of these permanent particles."— Newton, "Opticks," 3rd edition, pp. 375 and 376.

In the extract from Newton's "Opticks," with which this chapter is headed, we have Newton's views in regard to the hard atom very clearly set forth, as already pointed out in the preceding chapter.

These views are of such importance that the extract which explains them will, we think, very well bear repetition.

They represent the best that Newton could do with the scanty materials at his command.

Newton could make a mathematical investigation in the case of force. But without any of the information we now possess in regard to the constants of the atom, he could do nothing in the same way with the atom.

All that he could do, therefore, was to arrive at the conclusion that atoms were of different sizes and figures, without making any attempt to arrive at the actual form of the atom.

It is our privilege to take the atom in hand.

We have seen in the preceding chapter that Dalton demonstrated the existence of atoms of some kind by weight phenomena, and thus showed that the atom could be viewed by its weight.

We have seen there that he first showed that from the phenomena of specific gravity we may conclude that "the ultimate particles of all homogeneous bodies are perfectly alike in weight, figure," etc. "In other words . . . . every particle of hydrogen is like every other particle of hydrogen." And then by arguing from the proportions by weight, in which the elements combine to form compounds of different kinds, proceeded to determine the relative weights of the atoms of the commonest elements.

We have seen, also, that as the direct outcome of Dalton's work we now possess a complete table of the atomic weights of all of the valent elements known to us.

Dalton showed, however, no way of arriving at the form of the atom, though he held, as we have seen above, that it had a figure of its own. And thus, though he succeeded in showing that there was an atom of some kind, did not make it clear whether the atom was Newton's hard atom or only an atom of motion or of some other kind.

But we know much more about the atom than was known in Dalton's day. We are, therefore, able to attack the problem of the "Form of the Atom" under much more favourable circumstances.

The atom, then, with which we are going to deal is Newton's hard atom, and, being so, is a minute solid mass incapable of further division or of alteration in any way, whether by compression or expansion, or by wear and tear, or in any other way. This minute mass when stripped of its surroundings is perfectly inert, but at the same time perfectly homogeneous throughout, and also exactly like every other atom except in size and shape.

In size and shape the atom is exactly like every other atom of the same kind as itself, but differs from all other atoms which are not of the same kind as itself, so that all the distinguishing properties by which we recognise the elements are due either to a difference of size amongst the atoms which renders some more mobile or more easily stopped than others, or to difference in shape which enables atoms of one kind to be put together in groups which cannot be formed with atoms of another kind.

But if the distinguishing properties of the atom depend upon differences of size and shape, it is plain that we can make use of the distinguishing properties of the atom to determine the differences in size and shape between the atoms, or, in other words, to determine the form of the atom.

And this, we may remark, is no new idea—this of deducing the form of the atom from its properties, inasmuch as it occurred to the old Greek philosophers to do the very same thing some 2,300 years ago. And in this way the well-known hooked atoms to which Newton refers in the passage we have quoted at p. 13 were arrived at. Newton, indeed, failed altogether to appreciate this attempt to arrive at the form of the atom; but we may remember that Professor Roscoe (now Sir Henry Roscoe) once remarked that "singularly enough, we have even come back again to the old notion of certain claws or points of attachment by which the atoms are fixed together."—"Science Lecture for the People," 6th series, 1874, p. 25.

This, at any rate, was the best approximation the old Greek philosophers could make with the means at their disposal. But we have the constants of the atom to guide us, atomic weight, valency, specific heat, etc., etc.

And then, too, we have inactive elements in Argon and Helium—elements with no valency, and without cohesion, and elements, too, which show, both of them, by the ratios of their specific heats that they have spherical atoms, as was, in the case of Argon, most clearly pointed out by the President of the Physical Society, Professor Rücker, at the meeting of the Royal Society on the 31st January, 1895, at which the paper by Lord Rayleigh and Professor Ramsay on "Argon: a New Constituent of the Atmosphere," was read.

On that occasion, Professor Rücker is reported to have made the following remark in regard to Argon :—" It must be accepted as certain that the element has that particular ratio of specific heats. Well, then, the question arises, what follows from this? I think that it has not perhaps been quite sufficiently pointed out, that, in order that this ratio may be obtained, if we are to use the ordinary mechanical theory of gases, it is necessary that the atom with which we are dealing should be regarded as spherical."—*Chemical News*, Vol. LXXI., No. 1836, p. 62.

Now here we plainly have something to start with. Here we have the Argon atom revealing its form by its properties; and thus a case quite to the point showing clearly that we are on no idle quest in seeking to arrive at the form of the atom from its distinguishing properties.

The Argon atom, therefore, would manifestly serve splendidly as an opening to our inquiry. Nevertheless, we are not going to make use of it in that way. We are, in fact, going to work up to it, not from it.

We start, therefore, with the great class distinction between the elements, which divides valent elements into the two classes of metals and metalloids. And we note that one of the features which distinguish metals from metalloids, is the fact that for the most part metals are ductile and tenacious, and can be drawn out into wires of greater or less fineness, or rolled out into sheets; while the metalloids for the most part have neither ductility nor tenacity.

Now we find amongst visible bodies a kind of ductility which is clearly dependent upon form.

For example, any heap of fibrous material has a kind of ductility, provided that the fibres are very long; for if any part of such a heap is laid hold of it can be drawn out; and if the portion so caught is twisted while it is being drawn out, it can be spun into threads comparable with wires in length and fineness if the fibres are fine. But in this case the whole of the ductility, such as it is, which the heap possesses, is dependent upon the form of the fibres.

This can be shown by simply cutting up the fibres into very short lengths, for it becomes apparent at once that nothing in the way of drawing out the heap can be done when it consists of chopped-up fibres.

The whole ductility of the heap of fibrous material depends thus upon the form of the fibres, that is to say, upon their length; they must be long to have any kind of ductility; cut up in very short lengths they have none.

We have now a first approximation, though an exceedingly rough one, towards the form of the atom. With it we obtain an elongated form as the probable form of the ductile metal atom, and a docked or very short form as the probable form of the metalloid atom, which has no ductility. And we arrive at the conviction that it is quite possible to account for the ductility shown by some of the metals, and for the absence of ductility amongst the metalloids, simply by a difference in the form of the atom.

But we know also that there is a kind of tenacity amongst visible bodies due entirely to form, from our ordinary experience of the provoking way in which things with projecting parts stick together when we are trying to separate them, especially if they are things of considerable length. And our experience further teaches us that this kind of tenacity does not exist among bodies which have no projecting parts or roughness of any kind on their surfaces.

Hence, we obtain for the ductile and tenacious metal an elongated atom with projections on its surface, and for the metalloid devoid of tenacity and ductility a short atom without projections.

And now we will take one more of the features which distinguish metal from metalloid, viz., the fact that while among the fourteen or fifteen metalloids no less than four, viz., nitrogen, oxygen, fluorine, and chlorine are gases at the ordinary temperature and pressure of the atmosphere, and five more, viz., phosphorus, sulphur, arsenic, bromine, and iodine are gases at a temperature of 500° C.; there is not among the metals a single gas to be found in the whole fifty of them at ordinary temperature; and very few of them become gases until temperatures far above 500° C. are reached.

The fact thus brought out, that the metalloids are as a class more easily gasified by far than the metals, plainly indicates that the metalloid atom is more mobile than the metal atom.

At the same time, it is clear that the superior mobility of the metalloid atom cannot be due altogether to superior lightness, because the lightest of the gaseous metalloid atoms, viz., the nitrogen atom, is twice as heavy as the lightest of the solid metal atoms, viz., the lithium atom.

Seeing, then, that the difference in mobility between the metalloid and the metal atom cannot be due entirely to difference in weight, it will naturally occur to us to ask whether it may not be due in part to difference of form, especially as we know that mobility depends largely upon form in the case of visible bodies.

We know, for example, how readily spherical bodies, such for instance as marbles, roll on any hard surface; and how difficult it is to build even a pyramid with such bodies without confining in some way the bottom course; and also that it is utterly impossible to pile them, except in confinement, in any but a pyramidal heap, simply because of their tendency to roll due to their mobile form.

On the other hand, we know also that lofty walls and quite thin walls can be built with flints, though their surfaces are rounded, simply because they have an elongated form with irregularities which catch against each other.

We can easily understand, therefore, that the mobility of the metalloid atom which enables the metalloid to be easily gasified, and the immobility of the metal atom which keeps the metal solid even at very high temperatures may be due largely to a difference of form, such as that we have already arrived at, by reference to the ductility and tenacity of the metal atom and absence of ductility and tenacity in the metalloid atom, which gives us for the metal an elongated form with projecting parts, and for the metalloid a short atom without irregularities.

In fact, we have only to substitute, for the short atom free from irregularities obtained by viewing the metalloid atom by its absence of ductility, an atom short in every direction, and thus approximately spherical, and at the same time free from irregularities, in order to get the same form as that indicated when it is viewed through its mobility. Thus we obtain by both ways for metals an elongated atom with projections on its surface, and for metalloids an approximately spherical atom free from irregularities.

We may pass on now to another of the features which distinguish metal from metalloid, viz., the remarkable fact that the metalloids without exception have hydrogen valency, and the metals almost without exception have none. That is to say, the metalloid atom is able to combine singly with one or more hydrogen atoms and the metal atom is not.

The only exceptions as far as is known at present are the metals boron and copper, which combine with hydrogen to form unstable hydrides and potassium and sodium, which form alloys with hydrogen.

It is manifestly a most extraordinary fact that there should be this sharp distinction between metals and metalloids in the case of hydrogen valency, when metals and metalloids alike have chlorine valency. In view of this remarkable difference between metal and metalloid the inquiry is a natural one whether it can in any way be due to difference of form.

On looking into this point we begin to see at once that there are other remarkable facts about hydrogen valency, since the metalloids not only differ from the metals in having hydrogen valency, when the metals have none, but also differ from one another in the matter of hydrogen valency very considerably. Thus we find that some of the metalloids can take only one atom of hydrogen, and are called accordingly, monovalent; others cannot take more than two, and are called divalent; others again, not more than three, and are called trivalent; and, lastly, others cannot take more than four, and are called tetravalent; whilst four is the maximum number of hydrogen atoms which can be taken by any single atom. Then, again, we find that out of the fourteen metalloids, four are monovalent, four divalent, and four trivalent, but only two tetravalent, so that with the exception of two tetravalents which are missing, there are exactly the same number of each. And we further find that there is a reason for this regularity of distribution, inasmuch as with two tetravalents only wanting, the fourteen metalloids form four distinct series, each containing a monovalent, a divalent, a trivalent, and a tetravalent connected together by having atomic weights, so nearly alike as to suggest very strongly the idea that all the members of each series have had a common origin. But when we also find that in each of the four series the monovalent has the highest atomic weight, the divalent the next highest, the trivalent the next highest, and the tetravalent, though wanting in two series, the lowest; and further that the relation between the members of a series is such that rise in valency is attended with loss in weight, a definite amount being lost for each degree of valency gained, the belief that all the members of a series have had a common origin is deepened into conviction.

So clear indeed is the case, that we can tell almost exactly what the loss of weight is for each degree of valency gained, and, thus, if given the atomic weight and valency of any member of a series, can calculate the values of the atomic weights of all the other members of the series from their respective valencies.

This will be plain from the first series, which runs thus:—

Fluorine monovalent	of atomic	weight	...	19
Oxygen divalent	,,	,,	...	16
Nitrogen trivalent	,,	,,	...	14
Carbon tetravalent	,,	,,	...	12

In this series, the only member which exhibits any divergence is fluorine, and as it is one of the most difficult of the elements to isolate, we may be excused, perhaps, for taking liberties with its atomic weight, and correcting its value from 19 to 18.

With this correction we obtain a series uniform throughout, inasmuch as the values of the atomic weights of all the members exhibit a loss of 2 in weight for each gain of 1 in valency.

Thus, starting from the monovalent fluorine of atomic weight 18, we have oxygen divalent with atomic weight 16, thus gaining 1 in valency by a loss of 2 in weight; next we have nitrogen trivalent with atomic weight 14, thus gaining 1 more in valency by a further loss of 2 in weight; and lastly, we have carbon tetravalent with atomic weight 12, and thus in its turn gaining 1 more in valency with a loss of 2 more in weight.

The series thus shows unmistakably that each gain of 1 in valency is attended with a loss of 2 in weight, and therefore that the gain of monovalency in the case of the first member, fluorine, was attained like valency of every kind, by a loss of weight; and further, that the loss occurred in an element of no valency of atomic weight 20.

Correspondence so complete cannot possibly be accidental. The conclusion therefore is irresistible that the whole series originated from an element of no valency of atomic weight 20, and was derived by a process of taking off from the weight of the atoms of the non-valent, one portion weighing 2 to make the atoms of the monovalent of atomic weight $18 = 20 - 2$, two portions weighing each 2, to make the atoms of the divalent of atomic weight $16 = 20 - 2 \times 2$, three portions weighing each 2, to make the atoms of the trivalent of atomic weight $14 = 20 - 2 \times 3$, and four portions weighing each 2 to make the atoms of the tetravalent of atomic weight $12 = 20 - 2 \times 4$. Remembering now that monovalency simply means the power of taking on one atom in chemical combination, divalency that of taking on two atoms, trivalency that of taking on three atoms, and tetravalency that of taking on four, we perceive that the number of portions weighing each 2, which are taken off from the weight of the non-valent atom, exactly corresponds to the number of atoms which can be taken on by the valent atom. Hence we perceive that the relation between the members of the series is such that all have a common origin in an element of no valency of atomic weight 20, and have been derived by a process of taking off from its non-valent atoms one portion of weight 2, for each atom of hydrogen, which can be taken on by the valent atoms.

For the sake of clearness we corrected the atomic weight of fluorine from 19 to 18, but the correction is in no way necessary except for purposes of demonstration.

For if we take the atomic weight of fluorine as 19, the only difference it will make will be that fluorine, though still derived from a non-valent of atomic weight 20, will be derived from it by taking off a portion weighing 1, instead of a portion weighing 2, and in this respect will differ from the other members of the series which are derived by taking off portions which in every case weigh 2.

The relation between the different members of the series is therefore just the same, and also just as clear, and just as simple with the uncorrected as with the corrected value of the atomic weight of fluorine. The only practical difference is that with the uncorrected value the uniformity is less complete.

The first series therefore shows us unmistakably that the whole of the members belonging to it are related by having a common origin in a non-valent element of atomic weight 20, and are derived from it by taking off a separate portion weighing usually 2 for each atom of hydrogen which the valent atom can take on in chemical combination.

Thus, then, we have clear evidence of the existence of an inactive element of atomic weight 20, in the first of the metalloid series.

We pass on now to the second of these metalloid series, which runs as follows, putting atomic weights as before in round numbers:—

Chlorine monovalent	of atomic	weight ...	35·5
Sulphur divalent	,,	,, ...	32
Phosphorus trivalent	,,	,, ...	31
Silicon tetravalent	,,	,, ...	28

We can see at once that there is the closest correspondence between this series and the first series. In both we have the remarkable fact that gain in valency entails loss in weight revealing itself in a most striking way. In fact, the loss of weight for each degree of valency is nearly the same in the two series. Thus divalency is attained in the case of oxygen, in the first series, by a loss of 3 in atomic weight, which is reduced from 19, in the case of monovalent fluorine, to 16; while in the case of sulphur, in the second series, it is attained by a loss of 3·5, and a consequent reduction in atomic weight from 35·5, in the case of monovalent chlorine, to 32.

Again, trivalency is attained in the case of nitrogen, in the first series, by a total loss of 5 in weight, and atomic weight is thus reduced from 19 to 14; while in the case of phosphorus in the second series, it is attained by a total loss of 4·5 in weight, and atomic weight is accordingly reduced from 35·5 to 31.

Lastly, tetravalency is attained in the case of carbon in the first series by a total loss of 7 in atomic weight, which is reduced from 19 to 12; while in the case of silicon in the second series, it is attained by a total loss of 7·5 in atomic weight, which is accordingly reduced from 35·5 to 28.

The average loss in weight for each gain of 1 degree in valency is 2·61 in the first series, while in the second series it is 2·75.

The third of these metalloid series is incomplete, since the tetravalent is wanting. In its incomplete form it runs thus:—

Bromine	monovalent of atomic weight		...	80
Selenium	divalent	,, ,,	...	79
Arsenic	trivalent	,, ,,	...	75
,,	tetravalent	,, ,,	...	? 73

The same remarkable fact that gain in valency entails loss in atomic weight is brought out just as strikingly in this series as in the other series.

In this series, however, divalency is attained with a loss of 1 only in atomic weight, instead of entailing a loss of 3 or 3·5, as it does in the cases of the first and second series.

But trivalency in the third series is attained in the case of arsenic with a total loss of 5 in atomic weight or with exactly the same total loss as nitrogen attains it in the first series.

If it were possible to include the tetravalent germanium which has an atomic weight of 73 in the third series the correspondence between the first and third series would be still more complete, for we should have tetravalency also attained in the third series with precisely the same loss, namely, a loss of 7 in atomic weight—as that by which it is attained in the first series.

The average loss in atomic weight for each degree gained in valency is 1·75 in the third series, and therefore smaller than the value indicated by the first series when the atomic weight of fluorine is altered from 19 to 18, as shown at p. 63.

The correspondence, therefore, between the three series is well marked.

The fourth and last of these metalloid series is also incomplete, having, like the third series, no tetravalent member. It runs thus:—

Iodine	monovalent of atomic weight		...	127
Tellurium	divalent	,,	,, ...	125
Antimony	trivalent	,,	,, ...	120
,,	tetravalent	,,	,, ...	? 118

In this series we have, still, the same remarkable fact that gain in valency entails loss in atomic weight as prominent as ever. But in it we have divalency attained with a loss of 2 in atomic weight in place of the loss of 3 with which it is attained in the first series, and trivalency attained with a total loss of 7 in atomic weight, against the total loss of 5 with which it is attained in the first series.

Moreover, the average loss in weight for each degree gained in valency is 2·75 in the fourth series; while it is 2·61 in the first series, 2·75 in the second, and 1·75 in the third.

On the whole, however, the correspondence between the four series is most remarkable and unmistakable.

In fact, if the numerical value of the atomic weight of chlorine could be reduced from 35·5 to 35; that of phosphorus from 31 to 30; that of selenium from 79 to 77; and that of tellurium from 125 to 124; and if at the same time the numerical value of the atomic weight of antimony could be raised from 120 to 122, the correspondence between the four series would be complete and enact.

The fact that the maximum deviation from complete correspondence, exhibited by any member is 2, shows how close the correspondence really is.

In regard to the maximum amount of loss in attaining one degree of valency, we may remark that it occurs in the fourth series in which the atomic weight of the trivalent antimony differs from that of the divalent tellurium by 5, and from that of the monovalent iodine by 7. Hence the maximum loss is 3·5 if we work back from iodine.

But while there is a considerable difference in the amount of loss in atomic weight sustained in gaining a degree of valency, since the numerical value of the loss ranges between 1 as a minimum, and 3·5 as a maximum, there is absolutely no deviation from the rule that gain in valency, in excess of monovalency, is attained always by loss of a definite portion of the weight of the atom ranging in numerical value from 1 to 3·5 for each degree of valency gained.

The existence of a rule so remarkable pointing, as it does, to the fact that ability to take on in chemical combination atoms of hydrogen in excess of one has been conferred upon each atom by taking off from it a definite portion of its weight, never less in numerical value than 1, and never more than 3·5 for each additional atom taken on; and at the same time conformed to by all the series of metalloids without any exception or reservation, plainly suggests that atoms have a history written in characters which may not impossibly be deciphered.

At all events we are able to show that loss of weight is not a consequence or a result of taking on atoms of hydrogen in chemical combination. For the chemist is able, for example, to obtain a supply of oxygen by heating red mercuric oxide HgO, and in other ways, and after ascertaining its density by weighment can, with suitable apparatus for its combustion in hydrogen, cause it to combine with hydrogen, and form water H_2O.

Then he can take the water so formed, and by electrolysis dissociate the hydrogen from the oxygen. Having thus separated the oxygen from the hydrogen he can once more weigh the oxygen, and ascertain by comparing the density of the oxygen before it combined with the hydrogen with its density afterwards, whether the fact of taking on the two atoms of hydrogen in any way affected the weight of its atom. In this and in similar ways which when adopted show in every case that the weight of the metalloid atom undergoes no alteration from taking on the atom or atoms of hydrogen, it is possible to demonstrate the fact that the remarkable loss of weight which the metalloid atoms suffer in connection with the gain of additional valency for hydrogen is not a consequence or result of taking on an atom or atoms of hydrogen, but instead that the ability to take on the atom or atoms is the result of a previous loss of weight. So that valency for hydrogen is as the periodic law teaches us a function of atomic weight, and atomic weight not a function of valency.

We are, therefore, arguing from phenomena in concluding that ability to take on in chemical combination any number of atoms of hydrogen in excess of one atom, has been conferred upon the metalloid atom by taking off from it a definite portion of its weight, the value of which is in no case less than 1 or more than 3·5 for each additional atom it is able to take on.

We are able, therefore, to show in this way, by arguing from phenomena that hydrogen divalency or the power of taking on two atoms of hydrogen in chemical combination, has been conferred upon the divalent atom by taking off a definite portion from the weight of the atom; that trivalency or the ability to take on three atoms has been conferred by taking a further portion from the weight of the atom; and similarly that tetravalency or the ability to take on four atoms has been conferred by taking off a further portion from the weight of the atom. Hence, we are plainly arguing from phenomena in concluding that monovalency or the ability to take on one atom has also been conferred upon the monovalent atom by taking off a definite portion, weighing not less than 1 and not more than 3·5, from the weight of an atom which has no valency until at least one portion of this kind is taken off; and thus that each of the metalloid series is derived from an inactive element with non-valent atoms.

And we can plainly arrive at the atomic weight of the inactive element from which each of the metalloid series is derived by adding to the value of the atomic weight of the monovalent member of each series the portion taken off in making it monovalent.

We have already arrived in this way at the atomic weight of the inactive element from which the first metalloid series is derived, and found it to be 20.

We pass therefore to the second series, which has for its monovalent member chlorine of atomic weight 35·5; and since the weight of a portion taken off in conferring valency, ranges between 1 and 3·5, we find that this series is derived from an inactive element of atomic weight not less than 36·5 or more than 39 in value. The third series has for its monovalent member bromine of atomic weight

80; we find, therefore, that it is derived from an inactive element of atomic weight not less than 81 or more than 83·5 in value.

Lastly, the fourth series has for its monovalent member iodine of atomic weight 127; we find, therefore, that it is derived from an inactive element of atomic weight not less than 128, or more than 130·5 in value.

We thus arrive at a determination of the values of the atomic weights of the inactive elements from which the four metalloid series are derived within certain limits of error.

But we can state these values in another way. For we can say that with an error which in no case exceeds 5, the values of the atomic weights of the inactive elements, from which the four metalloid series are derived, are 20, 40, 80, and 130, by readjusting the atomic weights of bromine and selenium in the third series from 80 and 79, respectively, to 79 and 78 respectively. We select these particular values in preference to others which might have been selected, because the first three give from a periodic point of view a perfectly regular sequence in place of a haphazard arrangement of the values.

We arrive, too, in this way at the same values as were obtained for these inactive elements at p. 64 of "Force as an Entity," except that the values there used were taken as multiples of 20 instead of multiples of 10, and thus the fourth value made 120 instead of 130.

The discovery of Argon in the form of an inactive element of atomic weight 40 will, if Argon proves to be homogeneous, tend very strongly to show the correctness of this method of deducing the values of the atomic weights of the inactive elements in question. Nevertheless, we shall find when we come to deal with the metals, that some modification in these values is necessary, or some modification of the values of the atomic weights of some of the metals.

We have thus got, as it were, the raw material in the shape of four inactive elements, from which the whole of the metalloid elements have been derived. Let us now, therefore, endeavour to make out the details of the process by which the non-valent atoms of these inactive elements have been converted into the valent atoms of the metalloid elements.

We know from Definition I. of the "Principia" that Newton established the fact that weight is a measure of the mass, or quantity of matter in a body. And we know from weight phenomena and our ordinary experience in making weighments, that whenever a body shows loss of weight some portion of matter has been removed from it, whether by cutting, or breaking, or scraping, or heating, or drying, or dissolving it, or in some other way. It may be only water which is removed from it, but in any case we know that if it shows loss of weight, some portion of matter has been removed from it. And if, for example, we find on weighing some body, such as an ivory billiard ball, which does not ordinarily lose much of its weight by drying, that it is much lighter than it was on some other occasion when we weighed it before, we shall ordinarily be quite certain, without even looking more closely at it, that it has been chipped, or worn, or reduced in size in some way; and thus that some portion has been removed from it. And on examining the ball, we shall find that our conclusions were perfectly correct.

Now we have specially selected the case of the billiard ball to illustrate our point, not because it is the aptest illustration we could take, for it is by no means such, but because it will help us to illustrate another point. For, if on examining the light billiard ball, we find that its loss of weight is due to its having been badly chipped, so that a great piece has been knocked off it, and a large flat place made upon its surface we know at once that it is quite useless as a billiard ball, because it will no longer run as truly and easily as before; and we know also that if it comes to rest upon the flat place a harder blow will be required to drive it than would have been required if it had been unchipped. In fact, we know that the ball with this large flat place on its surface will be steady when resting on this flat place, whereas in all other positions it will roll away at the slightest tap; and thus that with the gain of this flat place it has gained stability in the form of the power of standing steady in one position by a loss of weight.

If the ball should happen to be badly chipped at two places instead of at one only, so that it has two large flat places on its surface, we shall find that it will stand steady on either of these two flat places, but in no other position;

and thus that the ball has gained the power of standing steady in a second position at the expense of a further loss of weight.

And if a third flat place is made in the same way upon its surface, it will have three positions in which it can stand steady, instead of two only as before, and will thus have gained another position in which it can stand steady by a further loss of weight. And so on.

The principal points for us to notice are the facts that each gain of a position in which the ball can stand steady is the direct result of a previous loss of weight in the form of a portion detached from its surface in making a flat place on which it can stand steady; and that the number of flat places on the ball determines exactly the number of positions in which it can stand steady.

Here, then, we have a case in which a gain results directly from a previous loss of weight. And remembering, now, that in valency we have also, as pointed out already, a case in which gain results from a previous loss of weight, we shall be encouraged to proceed.

We have now to try and make out whether there is any possible way of connecting the gain in the power of standing steady in one or more positions which the chipped billiard ball acquires from the loss of weight it suffers in being chipped, with the gain in valency, that is to say, in the power of taking on in chemical combination one or more atoms of hydrogen which the metalloid atom acquires from the loss it suffers in becoming valent.

Now, in this connection we notice that the billiard ball acquires by being chipped, so as to have a large flat place made on its surface, the power of standing steady on this flat place, not only on a billiard table, but on any other flat surface which is in a horizontal position, and thus also upon a similar flat place upon another billiard ball, provided that the ball is held so that its flat place is kept in a horizontal position.

We notice also that if some cement of a suitable kind is applied to the balls while one ball is standing steady upon the other with its flat place down upon the flat place of the other, so as to bind the two balls together by a thin joint, they will afterwards remain firmly united together. They cannot, however, be united by a thin cement joint in any position other than one in which their flat places are in close contact; because their rounded surfaces will roll upon each other, and cannot therefore be stuck together by a thin cement joint.

From this we learn that a ball which has one flat place upon its surface of large extent, formed by detaching a portion from its surface, has gained the power of taking on one other ball, having a similar flat place upon its surface, if it is coated with any cement capable of binding the two balls together when their flat places are in close contact; and moreover has gained this power by a loss of weight.

We further learn that a ball which has two such flat places on its surface, formed in the same way by detaching two portions from its surface, has gained the power of taking on two other balls, having each a similar flat place on its surface, under similar circumstances, and has thus gained the power of taking on an additional ball by an additional loss of weight.

Similarly, a ball which has three such flat places, has gained the power of taking on three such balls under similar circumstances, and has thus gained the power of taking on one ball more by a further loss of weight.

Lastly, a ball which has four such flat places, has gained the power of taking on four such balls, and thus also the power of taking on another ball by a further loss of weight.

Hence the number of flat places on a ball determines exactly the maximum number of other balls which the ball can take on provided that the flat places are not large enough to accommodate more than one ball at a time.

At the same time, the ball may have some of its flat places unoccupied, and thus it may have less than the maximum number of balls it can take; but the point is that the number of balls attached to it firmly can never exceed the number of flat places on its surface.

Hence the chipped billiard ball has a kind of valency or power of uniting with other chipped balls due entirely to its form.

But the hydrogen valency of the valent metalloid atom, is nothing else than the power of taking on a certain maximum number of hydrogen atoms in the state of firm union, known as chemical combination, and thus exactly corresponds to the power possessed by the chipped billiard ball, of taking on a certain maximum number of other chipped billiard balls in the state of union, which is brought about by a thin cement or glue joint between two flat surfaces.

The correspondence between the two cases is, as far it goes, exact, because, while in both the power, as we have seen, of taking on is gained by a previous loss of weight of a definite amount for each atom or ball, which can be taken on ; in neither need the full number necessarily be taken on; and if it has not been taken on, additions to bring the number up to the full can afterwards be made, or if the full number has been taken on deductions up to the full number, or of any number short of the full number can from time to time be made.

The correspondence is also the more complete and exact because we have already arrived by arguing from phenomena at the conclusion that the metalloid atom is approximately spherical in form.

In both cases, therefore, we are dealing with spherical balls, though in the case of the atoms we are dealing with exceedingly minute balls ; so minute, in fact, that a row of several millions of them placed close together would not measure an inch.

We shall, of course, need an exceedingly *subtle* material for uniting balls so minute as atoms are, but this will be dealt with in the next chapter.

Arguing, therefore, from the phenomena presented by the chipped billiard balls, in connection with the phenomena of weight and valency exhibited by the metalloid atom, as shown on pp. 63 to 69, we conclude that the form of the valent metalloid atom is that of a chipped sphere—of a sphere chipped so as to have one flat place on its surface for each atom of hydrogen the atom is able to take on by detaching at each of these places a portion weighing never less than 1 and never more than 3·5 units.

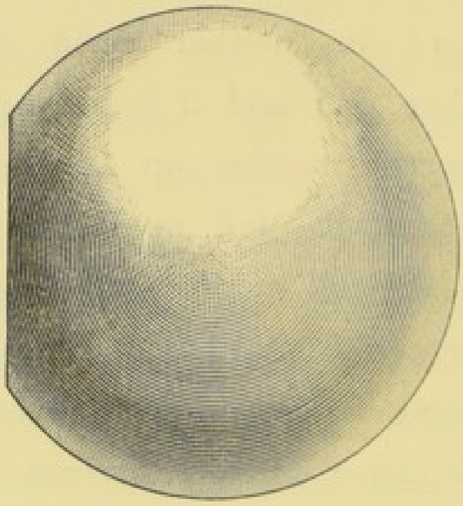

FIG. 1.

A MONOVALENT METALLOID ATOM

Enormously enlarged, giving a side view of the flat edge of its depressed crater.

Hence the form of the monovalent metalloid atom which takes one atom of hydrogen only, is that of a chipped sphere with one flat place only; that of the divalent atom which takes two atoms of hydrogen, a chipped sphere with two flat places; that of the trivalent atom which takes three atoms of hydrogen, a chipped sphere with three flat places; and lastly, that of a tetravalent atom, a chipped sphere with four flat places.

Fig. 1 shows a monovalent atom of the form indicated, that is to say, an atom in the form of a chipped sphere with one flat place on its surface; while in Fig. 4 in Chapter VI we have the form of a divalent oxygen atom with two flat places shown. We can easily see how such an atom could have three such flat places on its surface, and thus picture to ourselves the form of the trivalent atom; and also how it could have four such flat places, and thus picture to ourselves the form of the tetravalent atom.

We can also easily understand this explanation of valency from our ordinary experience of the readiness with which things with rounded surfaces roll away, and from the steadiness with which things with large flat bases stand.

We can therefore understand how two atoms, each with one flat place on its surface of the form shown on Fig. 1 would continue to roll upon each other until their flat places came together; and then if cemented together in this position by a film of the fluid which connects atoms together, would afterwards remain glued together by the cement joint between their flat places.

We can also easily understand how, if one of the atoms had two such flat places on its surface, two other valent atoms could be attached to it by cement joints, or if it had three such flat places, how three other valent atoms, or if it had four such flat places, how four other valent atoms could be attached to it.

We can also readily understand how if the flat places are in no case large enough to allow of two atoms sitting side by side on one flat place, the number of flat places on an atom will determine exactly how many atoms it can take on; since all atoms which lodge upon the atom without finding flat places on which to seat themselves will roll off.

And since valency of this kind depends entirely upon the existence of these flat places; and since they are made by cutting down the spherical surface of the atom, and thus reducing the weight of the atom by a definite amount for each flat place, we can easily understand by this explanation how this kind of valency must always be associated with loss of weight of a definite amount for each degree of valency attained.

In this way, then, we arrive at a complete and exact explanation of the hydrogen valency of the metalloid elements which is applicable to all the metalloids without exception; since we can bring boron in by giving it a series to itself if we wish to include it.

With this explanation we have each of the four series on pp. 63 to 68, derived from a separate non-valent atom in the form of a perfect sphere. The weight of the non-valent atom exceeds the weight of the monovalent member of the series, by the weight of the portion detached in making one flat place, and thus by an amount ranging between a minimum of 1 and a maximum of 3·5, and having an average in the first series of 2·61, as shown at p. 67, in the second series of 2·75, and in the third series of 1·75.

In this way, then, we arrive at an exact explanation of the hydrogen valency of the metalloid atoms, and are able to show that it depends entirely upon the form of the atom.

In this way also we are able to arrive at a precise form for the metalloid atom by weight phenomena, by comparing its relative weight with its valency, and thus viewing the atom through its weight, and therefore in the way in which Dalton taught us to view it.

But the metalloids after all form but a small part of the elements, though a very important part; and there still remain the whole of the metals to be dealt with.

The metals differ markedly from the metalloids; and we have already deduced for them from some of their distinguishing properties an atom with an elongated form in contradistinction to the spherical atom of the metalloids.

The metals differ also from the metalloids in having, as we have already seen at p. 61, no hydrogen valency; though at the same time, the metals have chlorine valency.

We have succeeded in deducing the form of the metalloid atom by comparing its relative weight with its hydrogen valency; let us try, therefore, if we can deduce the form of the metal atom by comparing its chlorine valency with its weight.

On making the comparison, it becomes plain at once that the metals when arranged in order, according to the numerical values of their atomic weights, run like the metalloids in series, each of which contains a monovalent, a divalent, a trivalent, and a tetravalent member; but that there is a most remarkable difference between the metal and the metalloid series, inasmuch as the monovalent member has the highest atomic weight in the metalloid series, while in the metal series it has the lowest, and the tetravalent member which has the lowest atomic weight in the metalloid series has the highest atomic weight in the metal series.

Thus the first of the metal series runs in this way, putting the numerical values of the atomic weights in round numbers, viz.:—

Lithium monovalent of atomic weight			... 7
Beryllium divalent	,,	,,	... 9
Boron trivalent	,,	,,	... 11
— tetravalent	,,	,,	... ? 13

The tetravalent member of this series is wanting; but so far as it goes the series is perfectly uniform throughout, inasmuch as the values of the atomic weights of all the members exhibit a gain of 2 in weight for each gain of 1 in valency.

Thus, if we start with the monovalent lithium of atomic weight 7, we have beryllium divalent with atomic weight 9, thus gaining 1 in valency by a gain of 2 in weight; and then we have boron trivalent with atomic weight 11, thus gaining 1 more in valency with a further gain of 2 in weight.

In this connection we may call to mind the fact that we showed at p. 63, that if the atomic weight of fluorine is altered from 19 to 18, we have a precisely similar uniformity in the first of the metalloid series. In that series, however, each gain of 1 in valency is attained by a *loss* of 2 in weight; while in the first of the metal series, with which we are now dealing, each gain of 1 in valency is attained by a *gain* of 2 in weight.

A correspondence such as this is plainly most remarkable and pregnant with information in regard to the form of the metal atom, in view of our conclusions in regard to the form of the metalloid atom.

The second of the metal series runs thus:—

Sodium	monovalent	of atomic	weight	... 23
Magnesium	divalent	,,	,,	... 24
Aluminium	trivalent	,,	,,	... 27
—	tetravalent	,,	,,	... ? 29

In it we have the tetravalent member again wanting; but we have gain in valency attended with gain in weight appearing as the prominent feature, with the same distinctness as in the first series.

There is not, however, the same uniformity in the second series as in the first. Moreover, the average gain in weight for each gain of 1 in valency is 2 in the first series, and 1·5 in the second.

The third of the metal series runs thus:—

Potassium	monovalent	of atomic	weight	... 39
Calcium	divalent	,,	,,	... 40
Scandium	trivalent	,,	,,	... 44
Titanium	tetravalent	,,	,,	... 48

The fourth runs thus:—

Copper monovalent	of atomic weight	...	63
Zinc divalent	,, ,,	...	65·5
Gallium trivalent	,, ,,	...	70
Germanium tetravalent	,, ,,	...	72

The fifth thus:—

Rubidium monovalent	of atomic weight	...	85·5
Strontium divalent	,, ,,	...	87·5
Yttrium trivalent	,, ,,	...	89
Zirconium tetravalent	,, ,,	...	91

The sixth thus:—

Silver monovalent	of atomic weight	...	108
Cadmium divalent	,, ,,	...	112
Indium trivalent	,, ,,	...	114
Tin tetravalent	,, ,,	...	118

The seventh thus:—

Cœsium monovalent	of atomic weight	...	133
Barium divalent	,, ,,	...	137
Lanthanum trivalent	,, ,,	...	138·5
Cerium tetravalent	,, ,,	...	140

It is scarcely necessary to go into a detailed examination of these series, since it will be seen at once that they exhibit, everyone of them, gain in valency, attended with gain in weight, with the same clearness and distinctness as do the first and second series.

It will be noticed also that for a gain of 1 in valency the smallest gain in weight is 1 and the largest gain 4; and thus that the range in the case of the gain in weight shown by the metal atom is nearly the same as the range in the case of loss of weight shown by the metalloid atom, viz., a range between 1 and 3·5 inclusive, as shown above.

We shall then perceive that divalency, trivalency, and tetravalency are conferred upon the metal atom by putting a separate portion weighing in the case of the first series 2, and of the second series not less than 1 or more than 2, and of the series generally not less than 1 or more than 4, upon a monovalent atom for each additional degree of valency, or, in other words, for each additional atom of chlorine which the atom is able to take on. And since divalency, trivalency, and tetravalency are all attained in this way, and in this way only, we are arguing from phenomena in concluding that monovalency is attained in the same way also, viz., by putting a portion weighing 2 in the case of the first series, not less than 1 or more than 2 in that of the second, and not less than 1 or more than 4 in that of the series generally upon an atom which has no valency until at least one such portion is put on; and thus that each of the metal series is derived from an inactive element with non-valent atoms just as each of the metalloid series is derived (as we have seen at page 73) from an inactive element with non-valent atoms.

And we can plainly arrive at the atomic weight of the inactive element from which each of the metal series is derived by taking off from the atomic weight of the monovalent member of each series the portion put on in making it monovalent.

In this way, we find that the first series, since its monovalent member lithium is of atomic weight 7, is derived from an inactive element of atomic weight $7-2=5$; similarly that the second series, which has the monovalent sodium of atomic weight 23, is derived from an inactive element of atomic weight not less than 21 or more than 22; that the third, with the monovalent potassium of atomic weight 39, is derived from an inactive element of atomic weight not less than 35 or more than 38; that the fourth, with the monovalent copper of atomic weight 63, is derived from one of atomic weight not less than 59 or more than 62; that the fifth, with the monovalent rubidium of atomic weight 85·5, is derived from one of atomic weight not less than 81·5 or more than 84·5; that the sixth, with the monovalent silver of atomic weight 108, is derived from an inactive element of atomic weight not less than 103 or more than 107; and lastly, that the seventh series, with the monovalent cœsium of atomic weight 133, is derived from one of atomic weight not less than 129 or more than 132.

Having obtained in this way the atomic weights of the inactive elements from which the metal series are derived, we perceive at once the remarkable fact that the second, third, fifth, and seventh metal series are derived from the same inactive elements as those from which the four metalloid series are derived.

Thus, the first of the metalloid series is derived, as we have seen, from an inactive element of atomic weight 20, while the second of the metal series is derived from one of atomic weight not less than 21 or more than 22, and therefore manifestly the two series have a common origin in an inactive element of atomic weight 20 or 21.

Again, the second metalloid series is derived, as we have seen, from an inactive element of atomic weight not less than 37 or more than 39, while the third metal series is derived from one of atomic weight not less than 35 or more than 38. Thus the two series have manifestly a common origin in an inactive element of atomic weight 37 or 38.

Again, the third metalloid series is derived, as we have seen, from an inactive element of atomic weight not less than 81 or more than 83·5, while the fifth metal series is derived from one of atomic weight not less than 81·5 or more than 84·5. And thus manifestly the two series have a common origin in an inactive element of atomic weight 82 or 83.

Lastly, the fourth metalloid series is derived, as we have seen, from an inactive element of atomic weight not less than 128 or more than 130·5, while the seventh metal series is derived from one of atomic weight also not less than 129 or more than 132. And therefore manifestly these two series also have a common origin in an inactive element of atomic weight 130 or thereabouts.

At p. 73 we endeavoured, in the case of the metalloid series, to find some principle to serve as a guide in determining which of the possible values for the atomic weights of the inactive elements from which the metalloids are derived should be selected, and we found such a principle in the fact that all could be stated as multiples of 10.

But if we endeavour to treat the metal series in the same way, we see at once that some modification is necessary, and that we shall have to substitute multiples of 5 for multiples of 10, since the first metal series is derived from an inactive element of atomic weight 5.

Taking the values of the atomic weights of the inactive elements from which the metal series have been derived as multiples of 5, we obtain the following values: 5, 20, 35 or 40, 60, 80, 105, and 130 as possible values, or values very near to possible values.

It will be seen that the values thus obtained show that the second, third, fifth, and seventh of the metal series have a common origin with the first, second, third, and fourth of the metalloid series if we take on periodic grounds 40 as the right value in the case of the third metal series.

In the values 20, 40, 60, 80, thus obtained from the metal series, we plainly have, from a periodic point of view, a very perfect sequence. If, however, 40 is the true weight of the inactive element from which the third metal and the second metalloid series are derived, some revision of the accepted values of the atomic weights of potassium and calcium in the third metal series will be necessary. This is the main difficulty in accepting a value which would make the arrangement of the values of the atomic weights of the inactive elements very symmetrical. If, however, no modification in atomic weights of the elements is possible, then 37 or 38 must be taken as the atomic weight of the inactive element from which the second metalloid and third metal series are derived.

In any case it is perfectly plain that there is a most remarkable correspondence between the metal and the metalloid series. In fact, the only difference between them in four cases is that gain in valency is attained by loss of weight in the metalloids and by gain of weight in the metals. The series have the same form in all cases, each having a monovalent, a divalent, a trivalent, and a tetravalent member. They also have, as we have seen, a common origin in four cases. Moreover, the weight of the portion taken off in the case of the metalloid and put on in the case of the metal, in order to confer valency, is practically the same in all cases, *i.e.*, in the case of the metalloids the weight varies between 1 and 3·5, and in that of the metals it varies between 1 and 4, so that the process of conferring valency is reduced, as it were, to the simple operation of taking portions off a number of spherical atoms on one side and transferring them to another set of spherical atoms of the same size and weight on the other side.

But now the question naturally arises, How does this fit in with the explanation of the form of the metalloid atom at which we have arrived?

It is manifest that one explanation must suit both cases, otherwise it cannot possibly be correct.

Now the form at which we have arrived for the metalloid atom, at p. 80, is that of a sphere chipped so as to have flat places formed upon its surface, and so that there is one flat place on its surface for each hydrogen atom it is able to take on in chemical combination, and no more. And in this way we account for the fact that gain in valency, or in other words, gain in the number of hydrogen atoms which can be taken on is attended with loss in weight—a loss, that is to say, of the weight of the portion, or portions, chipped off from the atom in forming the requisite number of flat places or seats on its surface to give one seat for each hydrogen atom.

But there are two ways of forming flat places on the surface of a sphere, viz., by cutting down the surface so as to form depressed flat places by reducing the weight of the sphere; and secondly, by building up the surface so as to form elevated flat places about some point, or points, upon the surface, and thus adding to the weight of the sphere.

In the first of these two ways, we have the way in which the valent metalloid atom is formed from a non-valent spherical atom by removing a portion, weighing not less than 1 or more than 3·5, from the spherical atom in order to make one flat place for each hydrogen atom which the metalloid atom takes on.

And in the second of these ways, we plainly have the way in which the valent metal atom is formed from a non-valent spherical atom, by adding a portion weighing not less than 1 or more than 4 to the spherical atom, in order to make one elevated flat place or seat on its surface for each chlorine atom which the metal atom is able to take on in chemical combination.

In Fig. 1 we have given an illustration of the form of the monovalent metalloid atom, with its depressed flat place.

We are now able to give, in Fig. 2, an illustration of the form of a monovalent metal atom, which has, with its elevated flat place, the form of a pear, with its stalk cut off.

We can easily picture to ourselves the form of the divalent metal atom, with two elevated flat places projecting on opposite sides of it; also the form of the trivalent metal atom, with three such elevated flat places; and the form

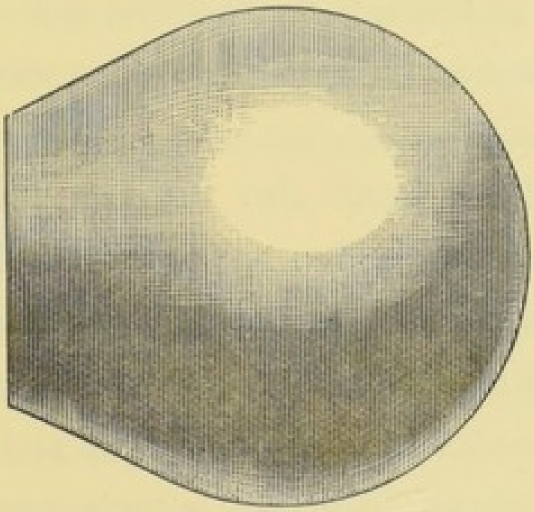

Fig. 2.

A MONOVALENT METAL ATOM

Enormously enlarged, giving a side view of the flat edge of its elevated crater.

of the tetravalent metal atom, with four such elevated flat places.

In reference, however, to the two illustrations of the form of the atom we have thus given, we may point out that in the sphere with elevated flat places we get an elongated form, and a form with projections upon its surface in the cases of trivalent and tetravalent atoms; and also that the elongation will be specially marked in the molecule, which is made up of two or more of the elongated atoms united by their projecting flat places.

Hence the form at which we have arrived by viewing the metal atom through its weight and valency is the general form at which we arrived on p. 59, by viewing it through its ductility and tenacity. We may call to mind the fact that we arrived at an elongated form for the metal atom when viewing it at p. 58 through its ductility, and at an elongated form with projections on its surface when viewing it through its tenacity.

We may call to mind also the fact that at p. 61 we obtained for the metalloid atom a shortened and more or less spherical form, and that the requisite form is manifestly supplied by the chipped sphere at which we have arrived by viewing the atom through its weight and valency.

By viewing atoms, then, in Dalton's way, through their relative weights, we have arrived at forms for the metal and metalloid atoms, which so far explain the distinguishing properties of the metal and metalloid elements.

But we have manifestly also in the chips detached from spherical atoms in the form of segments of spheres each with one flat face a possible form for the monovalent hydrogen atom, which differs so markedly from other elements by reason of its extreme lightness. And though from the fact that portions put on in making metal atoms have the same weight as the portions taken off in forming metalloid atoms, we are compelled to conclude that the portions taken off in forming metalloid atoms are to a large extent utilised in forming metal atoms, we can still believe, from the abundance in which the metalloids oxygen and silicon occur in nature, that there is a surplus sufficient for supplying hydrogen atoms.

In this way, we have hydrogen with a place of its own on the outskirts of the metals and metalloids.

It is, however, by no means impossible that hydrogen may have originated from one of the constituents of Helium of atomic weight 2 or 3 by cutting its spherical atoms in two, or otherwise cutting them down so as to make a flat place on the surface of each, supposing that Helium is a mixture, and not homogeneous.

At the same time, we have with this form for the valent atom inactive elements with spherical atoms coming in necessarily and naturally, and taking very prominent places amongst the metals and metalloids.

Seven of these inactive elements show up very clearly and distinctly, viz., one of atomic weight 5, another of atomic weight 20, another of atomic weight 37 to 40, another of atomic weight 60, another of 80 to 82, another of 105, and another of 130. And there are others besides these, which we cannot notice here, because they are not necessary to our explanation.

The seven, however, which we have named are absolutely essential to us. For our explanation postulates the existence of inactive elements nearly, if not exactly, of the atomic weights assigned above at the first stages in the formation of our universe, and cannot stand without them.

At the same time, it plainly would be quite possible for the whole stock of some, if not of all of them, to be used up in the formation of the valent atoms of the active elements, and therefore inactive elements need not necessarily be in existence now. But manifestly the fact that inactive elements have been shown to be in existence by the discovery of two of them, viz., Argon and Helium, with spherical atoms, and with atomic weights, which apparently identify them with two of the inactive elements in our list, viz., the first of atomic weight 5, and the third of atomic weight 37 to 40, affords the very strongest possible confirmation of the correctness of our conclusions.

If, therefore, we can surmount the difficulties which present themselves in connection with our explanation, we shall have a very complete case.

The first of these difficulties is that the entire weight of a hydrogen atom is only 1, while the weight of the portion detached from a spherical non-valent atom to make a seat for it on a metalloid atom is usually between 2 and 3, and in two cases is 3·5.

Hence, each seat ought in the ordinary course to be large enough to accommodate 2 or 3 hydrogen atoms seated side by side upon it; and, therefore, atoms with one flat place ought to be divalent or trivalent for hydrogen, instead of being monovalent.

To meet this difficulty we may point to the fact that when we want articles made of some hard material, such as glass or china, to stand firmly, we do not give them flat bases, but hollow bases with a flat edge or flat rim. Thus, our cups, and jugs, and bottles, are not given flat bases usually, but generally stand on a rim or upon a hollow base with a flat-edge, as we all know.

We are, therefore, arguing from our ordinary every-day experience in concluding that the seat for a hard atom will be a flat-edged hollow, and not be flat all over. And we conclude that in the formation of one of these seats on a metalloid atom a flat place is first formed of sufficient size to accommodate a hydrogen atom, which, according to our explanation, is a chip or segment of a sphere, and, therefore, comparatively wide and shallow, and then a hollow is scooped out so as to give the seat the form of a flat-edged hollow.

Some of these seats may have very slight depressions, others may have the form of deep craters.

In this way we have a natural explanation of the differences which are discernible in the weights of the portions detached or added in making seats upon valent atoms.

Our conclusion, therefore, is that the flat places on metalloid and metal atoms are in reality flat-lipped craters, and not places flat all over.

When we deal, in the next chapter, with the form of the fluid corpuscle by which atoms are held together, we shall see the advantage of having seats in the form of craters instead of having them flat all over.

We shall also, in the next chapter, see that in addition to having craters of comparatively large size at the seats upon the valent atom, it is necessary to have the surface of the atom pitted with minute depressions and not perfectly smooth.

The next difficulty which confronts us is that the chlorine valency of an atom differs very greatly in many cases from its hydrogen valency. Thus, for example, phosphorus takes only three atoms of hydrogen, while it takes five of chlorine in forming phosphorus pentachloride PCl_5, and thus phosphorus is trivalent for hydrogen, as shown in the series at p. 66, while it is pentavalent for chlorine. Here, therefore, we have phosphorus not only exhibiting two valencies, but also exhibiting a valency—viz., pentavalency—for which there is no room in our explanation since it requires five seats, while the maximum number which our explanation allows is four.

And thus, apparently, our explanation is completely upset.

In connection with this difficulty, the first point to notice is the fact that phosphorus makes another compound with chlorine besides PCl_5, viz., phosphorus trichloride PCl_3, in which it takes three atoms only of chlorine, and thus exhibits in this case with chlorine, the same trivalency as it exhibits with hydrogen. We learn, further, that the trichloride is the compound which it ordinarily makes, and that the pentachloride is only made when there is an excess of chlorine; and when it has been made its molecules are easily broken up again into the trichloride and chlorine molecules, so that at a temperature of 236° C., the dissociation is complete.—Von Richter, "Inorganic Chemistry," translated by E. F. Smith, 4th edition, p. 141.

Hence, we conclude that the normal compound which phosphorus forms with chlorine is phosphorus trichloride, and that phosphorus pentachloride is an abnormal compound.

We therefore conclude also that phosphorus is normally trivalent with chlorine, just as it is trivalent with hydrogen, as shown in the second metalloid series at p. 66; but at the same time also abnormally pentavalent with chlorine. Thus we are introduced by phosphorus pentachloride to *abnormal* valency, and having been introduced to it, we shall have no difficulty in understanding how it comes about with our explanation of the form of the atom. For it is plain that if the hydrogen atom is a mere chip off a spherical atom in the form of the segment of a sphere, as according to our explanation it is, it will lie very low down on any atom on which it is seated, and thus will not project in such a way as to make it likely in the ordinary course to get caught by the hydrogen atoms in other molecules, or in its turn to catch any hydrogen molecules, which may happen to be about it.

But the case will evidently be far otherwise with the comparatively large chlorine atom, weighing 35½ times as much as the hydrogen atom, if we remember that weight is a measure of the mass or quantity of matter in a body. Such an atom will project far out from the surface of any other atom on which it is seated, and readily catch against the atoms of any other molecules about it other than small hydrogen atoms.

And when three such chlorine atoms are seated, as in the case of the phosphorus trichloride molecule, upon a phosphorus atom derived, as shown on p. 66, from the same inactive element, and, therefore, being of the same size as themselves, it is easy to see that there will be intervals between the chlorine atoms just large enough on the average to admit a chlorine molecule, consisting of two chlorine atoms bound closely together, if it is caught fairly in the middle. Under the conditions under which phosphorus pentachloride is formed, there is an excess of chlorine about the molecules of phosphorus trichloride. The circumstances therefore are just such as to ensure that chlorine molecules will be caught in the intervals between the chlorine atoms on the phosphorus trichloride molecules, when they are agitated by heating.

If it should be objected that with this explanation we ought to have phosphorus heptachloride as well as phosphorus pentachloride, it may be pointed out that when one chlorine molecule has been caught so as to lie crosswise between the chlorine atoms normally seated upon the phosphorus atom, the mobility of the molecule will be greatly reduced, and therefore it will be unlikely to catch a second chlorine molecule. In this connection it may be pointed out that the phosphorus pentachloride molecule is in reality less mobile than the phosphorus trichloride molecule, as is shown by the fact that phosphorus pentachloride is a solid, while the trichloride is a liquid.

A rough calculation will show that the intervals between the three chlorine atoms on a phosphorus trichloride molecule will, on the average, be large enough to take a chlorine molecule in the way this explanation requires. Let the diameter of a chlorine atom $= d$, then d will be also the diameter of the phosphorus atom measured between the unchipped portions of its surface, because it is derived from the spherical atoms of the same inactive element as that from which the chlorine atom is derived, as shown at p. 72.

Hence, the circumference of a circle drawn with the centre of the phosphorus atom as a centre through the centres of the three chlorine atoms seated upon the phosphorus atom in the trichloride molecule will be nearly $= 2d \times 3{\cdot}1415 = 6{\cdot}2830\,d$, supposing the chlorine atoms to sit not very closely down on the phosphorus atom, and to have their centres in one and the same plane. But the diameter of the three chlorine atoms will together $= 3\,d$.

Therefore, the average length of the intervals between the chlorine atoms will be approximately $= d$, being less or more according as the chlorine atoms sit tightly or loosely upon the phosphorus atom.

Hence, there will certainly be room for a chlorine molecule between the chlorine atoms on a phosphorus trichloride molecule if the chlorine atom is caught in the middle.

With this explanation of abnormal valency, the three chlorine atoms of the phosphorus trichloride molecule are normally seated on the three seats on the phosphorus atom, with three intervals between them, in one of which a chlorine molecule is caught in the middle. The two atoms in this chlorine molecule being bound together by their flat places, and thus holding together sit saddlewise down upon the phosphorus atom, without having any flat places on which to sit, thereby increasing abnormally the valency of the phosphorus atom, or, in other words, the number of chlorine atoms it is able to take on.

In this particular case the chlorine molecule which gives rise to abnormal valency by lodging on the phosphorus atom, without having any seat on which to sit, is caught, as we have seen, between two chlorine atoms which are regularly seated.

But we may have cases in which the chlorine molecule, which gives rise to abnormal valency, is caught by a single atom regularly seated on the single flat place on a monovalent atom. Thus iodine, which is monovalent and takes only one atom of hydrogen, is able to take three atoms of chlorine, and form the compound iodine trichloride ICl_3.

But here, again, we have two compounds formed; for iodine combines with chlorine to form iodine chloride ICl, as well as iodine trichloride ICl_3, and in iodine chloride it takes one atom only of chlorine just as in hydrogen iodide it takes one atom only of hydrogen.

Hence, according to our explanation, iodine is normally monovalent, and at the same time abnormally trivalent, since in iodine trichloride a single chlorine atom is regularly seated upon the one flat place on the monovalent iodine atom, and a chlorine molecule holds on to it with its two atoms sitting saddlewise upon the iodine atom without any regular seats, thus making the iodine atom abnormally valent. In this case, a single atom regularly seated holds a molecule in position which has no seat, but only sits saddlewise on the iodine atom.

But we may even have cases in which a single atom, regularly seated on a flat place, is able to hold two molecules in position instead of one only. Thus, if we take fluorine valency instead of chlorine valency, we find that iodine is able to form with fluorine the compound iodine pentafluoride IFl_5.

Hence, we have iodine which is normally monovalent exhibiting abnormal pentavalency by forming a compound in which one atom of fluorine regularly seated upon its one flat place holds in position two molecules which have no seats, but sit on either side of it, each with its two atoms saddlewise on the iodine atom.

So far the highest valency with which we have had to deal has been abnormal pentavalency; but manifestly we may have abnormal hexavalency also when the two atoms regularly seated on the two flat places on some divalent atom each hold a molecule which has no regular seat upon the atom, or when a single molecule is caught in one of the intervals between four atoms seated upon the four flat places on a tetravalent atom.

Thus we have tungsten showing abnormal hexavalency in tungsten hexachloride WCl_6.

The points in regard to this explanation which seem to deserve special notice are, first, the fact that light hydrogen atoms show no abnormal valency, a fact which accords completely with our explanation that they are in the form of spherical segments, which fit closely down upon the flat places on the atoms upon which they sit, and therefore do not catch against other atoms.

And secondly, the fact that halogen valency differs from hydrogen valency by whole molecules, and not by single atoms when it does differ.

This fact, which has led chemists to the idea that there is a difference between atomic and molecular compounds, has plainly the closest bearing upon our explanation of the difference between normal and abnormal compounds, in which the difference between atomic and molecular compounds is plainly brought out.

With our explanation that valency depends upon the number of seats upon the surface of an atom on which other atoms can lodge, it manifestly is not necessary that all the seats should be occupied. If sufficient atoms are available to occupy all the seats, and if circumstances favour their occupation, all will be occupied, otherwise some may be occupied while others are left unoccupied. We may have, therefore, a tetravalent with four seats of which one only is occupied. In this way we explain the formation of such compounds as carbon monoxide (CO), in which the tetravalent carbon atom with four seats takes only one atom of oxygen, and thus has only one of its seats occupied.

Carbon monoxide is formed, as we learn, when the supply of oxygen is scanty. If the supply of oxygen is abundant, carbon dioxide (CO_2) is formed, but even with CO_2 the carbon atom has half of its seats unoccupied, for it has only two oxygen atoms. And so far it has not been found possible to get carbon to take more than two atoms of oxygen. Whatever the reason of this may be, it plainly is not because the four seats on the carbon atom are fully occupied by the two oxygen atoms; for in one of its other compounds, formic acid CHOOH, the carbon atom takes two hydrogen atoms in addition to two oxygen atoms, thus showing plainly that in carbon dioxide (CO_2) two of its seats are unoccupied. It would, in fact, appear that the two oxygen atoms in the oxygen molecule cannot be separated sufficiently to get round and seat themselves on opposite sides of a carbon atom when two other oxygen atoms are already seated upon it, and also that the same difficulty occurs with other atoms besides the carbon atom.

This, however, is a difficulty of small importance in comparison with the two other difficulties with which we have dealt.

Having disposed of the two great difficulties which threatened to overwhelm us, we have practically a complete case which, amongst other advantages, gives a simple and natural explanation of valency.

We may remember that it has not been possible to find any explanation of valency with the current views in regard to the atom.

Thus, Professor Victor von Richter tells us that "we possess no conceptions upon the nature of valence," and also that "the nature of chemical union and the cause of the valence of the atom are entirely unknown to us."—"Inorganic Chemistry," translated by E. F. Smith, 4th edition, pp. 174—176.

While Professor Ira Remsen says: "The chemical atom . . . . is not only a minute particle of matter . . . . which has a definite mass and the power of combining with other atoms, but it also has some power which determines how many atoms of another kind it can combine with. At present, we cannot form a clear conception as to the cause of this power, and no hypothesis has as yet been proposed to account for it." — Article on "Equivalency," Watt's "Dictionary of Chemistry," revised by M.M. Pattison Muir and H. Forster Morley.

We have, therefore, to go to Newton's hard atom for an explanation of valency; in fact, without the hard atom there is no getting an explanation of it.

And it is manifestly no slight service which the hard atom renders in putting thus a simple and exact explanation of valency within our reach.

Then, too, it enables us to get a simple and clear explanation of the nature of chemical union.

Moreover, it must not be forgotten that the explanation which it furnishes has been tested, and not found wanting. For it was manifestly a severe test to employ it, as was done in Chapter III. of "Force as an Entity," as already explained at p. 1, to deduce the existence of inactive elements before anything of the kind was ever heard of; and not only to deduce the existence of such things, but also to determine the atomic weights of some of them, and also the form of their atoms.

And manifestly it has stood the test, for Argon and Helium are now with us—inactive elements, both of them—with atoms apparently of the precise form deduced for them, and with atomic weights agreeing well with the values deduced. And even if this should be merely a coincidence, and Argon and Helium should turn out to be mixtures and not homogeneous, the fact will still remain that inactive elements of some kind are shown by them to be in existence, and thus the correctness of our conclusions placed beyond question. But this has been already pointed out in Chapter I., only it is something which ought not, we think, to be overlooked.

We have thus worked completely up to inactive elements with spherical atoms—and thus to Argon and Helium—and have thus got a stronger case than could have been obtained by working down from inactive elements with spherical atoms.

CHAPTER IV.

THE FORM OF THE FLUID CORPUSCLE.

"*But we are not to suppose that the calculations and equations which mathematicians find so useful, constitute the whole of mathematics. The calculus is but a part of mathematics. The geometry of position is an example of a mathematical science established without the aid of a single calculation.*"—T. Clerk Maxwell, "Scientific Papers," edited by Niven, Vol. II., p. 360.

In the preceding chapter, we were able by arguing from phenomena to deduce the form, both of the metalloid and of the metal atom.

And now with these forms, we have Newton's hard atom exhibited as a real thing, as a thing which can be drawn or modelled, and thus made familiar to all.

Newton himself held that atoms were so hard, as never to wear or break in pieces.

And Faraday tells us, as the result of his experimental researches, that "a particle of oxygen is ever a particle of oxygen—nothing can in the least wear it. If it enters into combination and disappears as oxygen—if it pass through a thousand combinations, animal, vegetable, mineral—if it lie hid for a thousand years and then be evolved, it is oxygen with its first qualities, neither more nor less."—" Experimental Researches in Chemistry and Physics," p. 454.

We thus have some seventy different kinds of atoms, each having a form which never varies, and a weight which never varies, and also a mass or quantity of matter which never varies since weight is a measure of the mass or quantity of matter in a body (" Principia," Definition I.), in addition to other distinguishing properties which never vary. We, therefore, conclude that in the atom we have something absolutely constant and unalterable, and something which always occupies the same amount of space in the same way wherever it is at the time situated.

We know, however, from our own experience, as well as from the observations and experiments of the physicist, that the masses of matter which are made up of aggregations of these atoms are in no case unalterable, but can be altered in all kinds of ways. They can be melted, vaporised, solidified, can be broken up, united, enlarged, diminished, compressed, expanded, elongated, contracted. We conclude, therefore, that these masses must have something else in their composition besides these unalterable atoms, and that the other component must be something of variable form which is able to move the atoms by changing its form so as to be able to draw them together, or to force them apart.

We find, however, that in many cases masses of matter are elastic, and can recover their shape after being compressed or expanded; and therefore may conclude that the variable component is able to grip atoms of matter, and retain its hold upon them when they are forced together by compression or driven apart by expansion, and afterwards bring them back again to their original positions when the disturbance is at an end.

And since charges of heat, pressure, electricity, etc., can accumulate in masses of matter, and can also be dissipated, we further conclude that different portions of the variable component must be able to lay hold of each other as well as to lay hold of atoms of matter, and must also be able to relax their hold of each other, and of atoms of matter.

From the fact that heat, pressure, electricity, etc., leave one body and pass to another, we conclude that the variable component is quite separate and distinct from atoms of matter.

But we further find that a charge of heat, pressure, etc., can be divided up as when, for example, a heated mass of some solid or liquid is dissipated in vapour by the atoms or molecules taking each a charge of heat to itself, and then moving off in separate paths and vanishing. And we conclude, therefore, that the variable component which thus divides itself up and distributes itself in separate charges amongst myriads of minute atoms or molecules of matter, must itself exist in a finely divided form in the shape of corpuscles comparable with atoms of matter in fineness.

And if the variable component exists in a finely divided form in the shape of corpuscles, then these corpuscles must have the power of laying hold of atoms of matter, and also of laying hold of each other, and likewise the power of relaxing their hold upon atoms of matter, and upon each other; since the parts of the variable component are able, as we have seen above, to lay hold of atoms of matter and of each other, and are able also to relax their hold upon atoms of matter, and upon each other.

But now we find that matter exists in two principal states, viz., the solid state and the gaseous state, both of which are more or less permanent states, and that these two states differ by the fact that in the solid state the variable component has a strongly marked tendency to draw the atoms or molecules together, while in the gaseous state it has an equally well marked tendency to drive the atoms apart.

The reality of the difference between the two states is shown by the fact that the atoms or molecules can be made to pass from one state to the other by applying, if they are in the gaseous state, something which tends to bring the atoms together, viz., pressure, and taking off something which tends to drive the atoms apart, viz., heat, in order to bring the mass into the solid state; or, if they are in the solid state, by doing exactly the reverse, viz., adding heat and taking off pressure, in order to bring them into the gaseous state.

And since there are these two permanent states which differ so markedly, we are driven to conclude that the variable component is made up of two kinds of corpuscles which differ permanently from each other in that the corpuscles of one kind tend to attract or draw atoms together, while those of the other kind tend to repel the atoms, or drive them apart. The fact that there are both critical temperatures and critical pressures; the fact that in many cases it is not sufficient merely to apply pressure in order to bring a substance from the gaseous into the solid state, but necessary at the same time to take off heat by cooling the substance; and likewise the fact that it is not sufficient merely to cool the substance, but necessary also to apply pressure in order to bring it from the gaseous into the solid state, all force upon us the conclusion that two kinds of corpuscles exist, and are in actual conflict. In the course of this conflict either can oust the other from its position about atoms of matter if it receives sufficient reinforcements, and it is therefore necessary not only to reinforce one of them, but also to provide a way of escape for the other, in order that the one reinforced may predominate, so far as to be able to change the state of the atoms.

The same conclusion is forced upon us by the *third law of motion*, that action and reaction are equal and opposite, since we recognise in action the advance of a reinforcement of corpuscles of one kind; and in reaction the retreat of an equal number of corpuscles of the opposite kind, tending to bring about a change exactly opposite to that which the advancing corpuscles tend to bring about.

The fact that there is such a conflict over the possession of atoms of matter, forces upon us the conclusion that corpuscles of both kinds have so strong a tendency to lay hold of atoms of matter that they will not relinquish their hold upon them, except under compulsion.

And we are driven to conclude that the tendency to lay hold of atoms of matter must be stronger in the corpuscles than the tendency to lay hold of each other, which leads them to accumulate in charges of heat, etc., because they are prepared to abandon the associated form, in order, as we have seen, to distribute themselves about atoms of matter.

The *third law of motion* further leads us to conclude that corpuscles are constant in volume, though variable in form, so that they can neither be compressed nor expanded, but must contract in a lateral direction if they extend in a longitudinal or *vice versâ* ; or, in other words, they must thin out if they lengthen, or shorten up if they thicken themselves.

If they were not constant in volume, they would be compressed sometimes instead of being dislodged by the advance of corpuscles of the opposite kind, and then action and reaction would not be equal and opposite.

For the same reason we are driven to conclude that all corpuscles are of the same volume.

We have thus arrived at the following conclusions in regard to the corpuscles, of which the variable component which holds atoms together in masses, and at the same time keeps them apart, is made up, as we have seen above, viz.:—

1. Corpuscles are of constant volume which is the same for all corpuscles—but variable in form, so that they can extend longitudinally by contracting laterally, or thicken themselves laterally by contracting longitudinally.

2. Corpuscles can lay hold of atoms of matter, and can also lay hold of each other, but have a stronger tendency to lay hold of atoms of matter than to lay hold of each other, so that they will separate from each other in order to lay hold of atoms of matter.

3. Corpuscles can, on compulsion, relax their hold upon atoms of matter to which they have attached themselves, and can voluntarily relax their hold upon other corpuscles to which they have attached themselves.

4. Corpuscles can carry atoms along with them in the direction in which they are moving by laying hold of them, or of other corpuscles directly attached to them, provided that they are not restrained by the efforts of other corpuscles tending to carry the atoms in the opposite direction.

5. Corpuscles are of two kinds, which differ from each other by reason of the fact that corpuscles of one kind tend to carry atoms in the opposite direction to that in which corpuscles of the other kind tend to carry them.

We have, therefore, now made out to some extent the properties of the corpuscle.

Having arrived at the properties of the corpuscle, the question now arises whether we can arrive at a form for the corpuscle in the same way as we were able to arrive at a form for the atom from its properties.

It is plainly useless to look amongst lifeless bodies for a form for the corpuscle with its activities and its power of laying hold of atoms and bearing them off, and its power of laying hold of other corpuscles.

We can find a form for the inert atom amongst lifeless masses. But for a form for the active, mobile corpuscle, we must plainly go to animate matter. We shall then have no difficulty in finding a suitable form amongst the lowliest forms of life.

In fact, we can get in one of the Protozoa, viz., the Amœba, or rather in the amœboid, swarm-cell of the Mycetozoa exactly the form we require.

We may meet an objection of the physicist to the employment of a living form for this purpose, by taking Haeckel's view. Haeckel, in complete agreement with von Nageli, says: "We thus arrive at the extremely important conviction that *all natural bodies* which are known to us are *equally animated;* that the distinction which has been made between animate and inanimate bodies does not exist. When a stone is thrown into the air, and falls to earth, according to definite laws, or, when in a solution of salt a crystal is formed, the phenomenon is neither more nor less a mechanical manifestation of life than the growth and flowering of plants, than the propagation of animals."—"History of Creation," translation revised by E. Ray Lankester, Vol. I., p. 23.

With this view, all objection to the course we are taking in using a living form to represent the active mobile principle in matter, and an inanimate form to represent the inert constant principle, disappears.

But Professor Butschli has supplied us with an argument in favour of the course we are taking, in using an Amœba to illustrate the form of the corpuscles of the variable components of matter, which meets more completely the possible objections of the physicist—inasmuch, as following Professor Quincke, he has shown that artificial Amœbæ can be obtained with drops of an emulsion, formed by rubbing up some salt soluble in water with rancid olive oil, so as to form a paste.—*Nature*, Vol. XLVIII., p. 594.

And thus he has shown that the Amœba, to some extent at all events, brings the physical and the physiological together.

Now, we learn that the Amœba proper is a minute, unicellular organism, consisting of a naked, structureless mass of slime, possessing the power of extending itself in any direction, either by assuming an elongated form so that the entire body is extended in some particular direction, or by extruding from its surface a number of thread-like processes, called pseudopodia, which can be used as prehensile organs to lay hold of the substances on which it feeds, or of the surfaces over which it desires to creep.

The Amœba can revert at any time from an elongated form into a compact spheroidal or discoidal form, and can at any time withdraw its pseudopodia and absorb them into the contents of its body.

The unicellular Amœba, with its power of extending itself in any direction by assuming an elongated form, and of drawing itself backwards or forwards by reverting to a compact form after laying hold of some object behind it or in front of it, and with its power of throwing out prehensile pseudopodia in any direction, and of withdrawing and re-absorbing them into its substance, affords almost exactly the form we require for the fluid corpuscle ; for it gives us a minute, structureless mass, able to lay hold of masses of matter by its pseudopodia, and able also by elongating itself bodily, to drive loose masses of matter apart, and by reverting from the elongated to the compact form to draw them together, provided always that they are small enough to be moved, as atoms of course are.

The Amœba proper does not, it is true, possess the power of coalescing to form masses, as it is necessary our corpuscles should be able to do in order to explain how bodies are charged with electricity, heat, etc.

But we find from De Bary, that though the Amœba does not possess the power of aggregating into masses, yet that the power of aggregating is possessed by Guttulina Protea, which is "really a naked Amœba."—"Comparative Morphology and Biology of the Fungi Mycetozoa and Bacteria," translated by H. E. F. Garnsey, p. 443 ; and moreover, that through the same Guttulina, the Amœba is directly connected, first with the Acrasieæ and then through the Acrasieæ with the Myxomycetes, the swarm-cells of which coalesce to form plasmodia. And we know from Mr. Arthur Lister's experiments with the plasmodia of one of the Myxomycetes, Badhamia Utricularis, referred to by Dr. Burdon Sanderson in his opening address to the British Association in 1893, that plasmodia, though mere expansions of "labile living material" quite structureless, are susceptible of allurement so as to be able to advance towards and envelop the object which allures them.—*Nature,* No. 1,246, Vol. XLVIII., p. 471.

In the case of Badhamia Utricularis, Mr. Lister finds that its plasmodia can be allured in this way by a pulp formed by mixing water with scrapings from the hymeneal surface of Stereum Hirsutum, a fungus on which Badhamia Utricularis feeds.—" Annals of Botany," No. 5, June, 1888.

From De Bary we learn that " the amœboid movement of the swarm-cells are continued in plasmodia. . . . . The microscope reveals a constant change of outline in all the branches, sometimes in the form of a single undulating movement, sometimes of an unceasing protrusion and withdrawal of small pointed tentacle-like processes or pseudopodia. Some of these pseudopodia or single flat projections of the main branches swell into a knob at the free extremity and presently grow into larger branches, while in another part, branches diminish in size and gradually sink back into the main stem. Here two branches grow out towards each other till they touch one another, and then coalesce and anastomose; there a branch becomes constricted at some point and divides into two. By these processes a plasmodium may separate into several parts, and several plasmodia may be united into one. But according to my own and Cienkowski's observations, union never takes place between plasmodia of different species."—" Comparative Morphology and Biology," translated by Garnsey, p. 425.

While Mr. Arthur Lister tells us that " there is no doubt that the young plasmodia exercise a distinct attracting influence on the swarm-cells in their neighbourhood."—"A Monograph of the Mycetozoa," p. 5.

Also, that "the movements in the interior of the swarm-cell are extended into a system of circulation in the plasmodium which spreads in a network of veins with a few principal channels."—*Ibid.*, p. 7.

In an Amœba, therefore, when modified so as to have the form of a swarm-cell of the Mycetozoa, we have a form which will answer all our requirements, and enable us to get a complete grasp of the form of the corpuscle of the variable component of matter with which we have to work. We must, however, carefully avoid straining the analogy too far.

The Amœba, or rather the amœboid, swarm-cell of the Mycetozoa, furnishes us with an example of a labile mass in the shape of a plasmodium, which is able at any time to assume either a quiescent compact pool form, or an active extended stream form, and able also to lay hold of, envelop, and transport small portions of matter; and at the same time is built up entirely of an aggregation of corpuscles in the form of minute, structureless, slimy masses of protoplasm. It shows us, also, how all that is necessary for the building up of such labile masses is that the minute masses of slime should be endowed with the power of changing their form, by throwing out from any or all parts of their surfaces a multitude of fine, thread-like processes, in the shape of pseudopodia, by which contiguous bodies may lay hold of each other, and also by extending themselves bodily in any direction in a single process, or perhaps in two or three processes, in which the minute masses pass from a compact into an elongated form, and thus come together; provided always that along with the power of extending themselves in this way the minute masses must have the power of reverting to a compact form by retracting the processes, whether large or small, after they have laid hold of each other by their pseudopodia, so as thus to draw together.

And our ordinary experience enables us to follow the various operations, for we know from the "sutures" which unite the bony plates of the skull, that joints can be made between two contiguous surfaces which have a multitude of minute processes thrown out from them, simply by letting the processes get interlocked and entangled with each other. Such a joint can be tightened up at any time by thickening the interlocked processes, until a tight fit is made, and loosened by thinning out the interlocked processes, until they come apart. In joints of the suture type we have then a ready way of explaining how corpuscles endowed with the power of throwing out a multitude of fine, thread-like processes from any or all parts of their surfaces, and again retracting and absorbing them, can unite so as to form a single mass, or again separate in part, or altogether from such a mass.

Again, we know that small, solid masses can be caught and held by twining thread about them, or about projections upon them, and therefore can easily understand how corpuscles endowed with the power of throwing out fine, thread-like processes from their surfaces, and again retracting them, can lay hold of small masses of solid matter, by twining their thread-like processes about them, or inserting the ends of their processes into pits or minute depressions upon them; and can relax their hold upon them in part or altogether by retracting these processes.

Then our ordinary experience in marshalling processions teaches us that a mass made up of corpuscles able to disengage themselves from it on one side, or on all sides, and able to extend themselves outwards from the mass, can readily pass from a compact form into an extended procession or stream form. Because it is plain that if one of the corpuscles on the surface of the mass, after disengaging itself on all sides but one from the corpuscles about it, assumes an elongated form, and extends itself outwards from the mass, and its example is followed in succession by each of the corpuscles below it in the mass, the result will be to form a procession, since the corpuscles below the surface, as they successively extend, will push forward those above the surface, and thus form a procession of corpuscles attached end to end, advancing continuously outwards from the mass, and ultimately forming a stream of corpuscles pouring out from the mass. The corpuscles in front will be pressed forward by those behind, and will carry with them in their advance any movable masses of matter of which they may lay hold.

A stream thus formed will cease to flow outwards, and commence to flow back if the corpuscles which set it in motion cease to extend themselves outwards, and commence to revert from the elongated into a compact form.

In this way then we get an actual example of a labile material, capable of advancing in streams upon masses of matter, and laying hold of such masses and transporting them, if movable, by its streams, and collecting them in its pools. We also get in it a material which is able to bind minute masses of matter together or drive them apart, because it is plain that one of these corpuscles, if it lays hold of two or more movable masses of matter by twining its thread-like processes about them, can drive the masses apart by elongating itself, or draw them together by reverting from an elongated to a compact form, and then flattening itself out between them.

Corpuscles, therefore, of the Amœba type, or rather of the amœboid swarm-cell type, furnish us with a binding material in the form of a fluid or labile material, which is able to lay hold of minute masses of matter and transport them by its streams, and either collect them in its pools and bind them together, or separate them and disperse them.

With it we are able to point to something which is actually able to do all that we conclude has to be done, in order to bring atoms of the form shown in the preceding chapter together, and make up with them the molecules, masses and structures, with which our universe is furnished, or in order to separate atoms one from another so as to dissociate molecules and vaporise masses.

And with it, too, we are able to show that in coming to the conclusion that atoms are built up into molecules, molecules into masses, and masses into the bodies which compose the planetary and solar systems of the universe, by the operations of a fluid material which tends in one form to collect them and bind them together, and in another to separate them and drive them apart, we are arguing from phenomena and not feigning hypotheses.

The swarm-cell then enables us to obtain an idea of the nature of the activities which the fluid corpuscle must possess in order to form atoms into molecules, masses, and planetary and solar systems. But at the same time it must be remembered that it does not give us even the faintest idea of the intensity of the activities possessed by the fluid corpuscle.

The activities of the fluid corpuscle, which acts in gravitation with far higher rapidity than that of lightning, are the same indeed in kind as those of the sluggish amœboid swarm-cell, but totally different in degree.

The activities, too, of the water molecule, when, in a drop of water flattened out in a film between two sheets of clean glass, it binds the two sheets of glass together in a very well-known experiment, or when, in the form of water of crystallisation, it binds solid molecules together in one of the many marvellously beautiful crystal forms which it is able to build, are the same in kind as those of the Amœba, when it lays hold, by means of its pseudopodia, of some surface over which it creeps, but totally different in degree.

The Mycetozoon swarm-cell then enables us to get a possible form for the fluid corpuscle, and enables us to show that our conclusions as to the constitution of matter are in accordance with phenomena, provided that we use it properly.

It gives us, in fact, the intense activities of the fluid corpuscle, which pass all our powers of comprehension, in a diluted and weakened form, in which we can follow their operations.

Used rightly, the illustration will be of the greatest service to us, but if misused and misapplied, it may, of course, lead us into all manner of absurdities.

With this caution, then, we will proceed with our task, which in accordance with Newton's directions is, "not only to unfold the mechanism of the world" but to work on and up through life to the great First Cause by arguing from phenomena and deducing cause from effect. And we have succeeded in finding a fluid corpuscle which will not only carry us across the border line between physics and physiology, but also over the whole course Newton has bidden us take.

Let us pause then, and make quite sure that we have clear and exact ideas about the fluid corpuscle which is to carry us, before proceeding further. We will put our conclusions, therefore, into the form of a few simple definitions and propositions based upon phenomena, following, as closely as we can, the plan adopted by Clerk Maxwell in his paper on "Faraday's Lines of Force." In this way we shall be able to give precision to our conclusions, and shall be able from time to time to amplify, correct, and strengthen them by reference to phenomena.

DEFINITIONS.

Definition I.

The corpuscle is a minute indivisible mass of labile material perfectly uniform in composition throughout, and of constant volume, which is the same for all corpuscles, but of variable form, owing to the influence of certain tendencies, which excite in corpuscles corresponding activities, and differentiate them into classes distinguished one from another by the strength of their tendencies.

Definition II.

The tendencies to which the corpuscle is subject are of two kinds, which are so far irresistible that the corpuscle will obey them, or the stronger of them if unable to obey both at the same time, whenever it is free.

(*a*) A tendency to laỳ hold of corpuscles of the same kind as itself impressed upon all corpuscles in the same strength.

(*b*) A stronger tendency to lay hold of atoms of matter not impressed upon all corpuscles, and not in equal strength on all those upon which it is impressed, but so that those in one part of space have the tendency in greater strength than those in another part of space, while at the same time the whole of the corpuscles in any one of such parts of space taken separately, have the tendency in exactly the same strength one as another.

Definition III.

Corpuscles differ from each other only by the strength of the tendency to lay hold of atoms of matter being greater in some kinds than in others, or being altogether absent.

Definition IV.

Corpuscles of the same kind have the tendency to lay hold of atoms of matter of the same uniform strength one as another, or resemble each other by being without a tendency to lay hold of atoms of matter.

Definition V.

The corpuscle has activities of two kinds, viz.:—

(*a*) A power of extending itself in any direction by elongating itself in that direction, while contracting itself in the transverse direction.

(*b*) A power of drawing itself together, and assuming a compact or quiescent form.

Definition VI.

The corpuscle has two ways of extending itself under Definition V. (*a*), viz.:—

(*a*) By elongating its body as a whole or in part in one or two processes.

(*b*) By extruding from the whole or from any part of the surface of its body a multitude of fine hair-like processes or pseudopodia.

DEFINITION VII.

The corpuscle has three ways of drawing itself together under Definition V. (*b*), viz. :—

(*a*) By drawing itself together into a compact or spheroidal form.

(*b*) By flattening itself out in a discoidal form.

(*c*) By retracting and absorbing its pseudopodia.

DEFINITION VIII.

Two corpuscles are said to be united when in close contact with each other, while at the same time, pseudopodia extruded from both of the contiguous surfaces are interlocked, so as to form a joint of the "suture" type, by which the bony plates of the skull are united by the interlocking of processes.

DEFINITION IX.

A corpuscle is said to be attached to an atom of matter when its pseudopodia are inserted into the pits on the surface of the atom.

DEFINITION X.

A pool is a collection—not of vast extent—of corpuscles of one and the same kind, all united together, and all, or at all events the greater number of them, in the compact form, (Definition VII., *a*) ; and has two forms, viz. :—

(a) The free pool, in which the corpuscles are united together in the absence of atoms of matter.

(b) The bound pool, in which the corpuscles have all of them a tendency to lay hold of atoms of matter and are attached, either directly or indirectly, to an atom

of matter, being spread in a layer over its surface or heaped in layers upon atoms so attached, and all united together.

Definition XI.

An *abyss* is a free pool of vast extent.

Definition XII.

An envelope is a collection of bound pools, some of which consist of corpuscles of one kind and others of corpuscles of another kind, distributed over the surface of an atom.

Definition XIII.

A domain is a collection of vast extent of bound pools, composed of corpuscles of one and the same kind, and of the atoms of matter to which the corpuscles are bound.

Definition XIV.

A stream is a procession of corpuscles in motion, consisting of a row of corpuscles of the same kind united at their ends to each other, wherein the greater number are in the extended form (Definition VI., *a*), or of any number of such rows arranged side by side. The motion of the procession is due to the action of some or of all of the corpuscles in the procession in extending themselves (Definition IV., *a*) in the direction in which the procession as a whole is advancing, or in that in which some part is advancing, if owing to the occurrence of bends the whole of the procession is not advancing in one direction.

Definition XV.

A film is a collection of corpuscles of one and the same kind in the flattened form (Definition VII., *b*), united together at their edges so as to form a thin sheet, or several thin sheets superimposed one upon another, provided that the number thus superimposed is not sufficient to make the whole other than a thin sheet, *i.e.*, a sheet in which the thickness is very small compared with the length or breadth.

Definition XVI.

An atom is a minute indivisible mass of solid material perfectly uniform in composition throughout, absolutely unalterable either in size or form, or in any other way, and quite inert of itself, though movable under the activities of any corpuscle or corpuscles which has or have attached itself or themselves to it directly, or to other corpuscles attached to it and is or are in motion, provided that the motion of the atom is not resisted by other corpuscles with a stronger hold of it, or restrained in other ways.

The entire surface of the atom is pitted all over with minute depressions.

Definition XVII.

The non-valent or inactive atom is perfectly spherical in form, except where its surface is pitted by minute depressions, and is of one or other of certain sizes.

Definition XVIII.

The valent atom has the form of a sphere with flat places, in the shape of flat-lipped craters, on its surface, varying in number from one to four, according to the valency of the atom, so that the monovalent atom has one flat place, the divalent two, the trivalent three, and the tetravalent four.

The flat places are formed in two ways, viz., in the metalloid atom by cutting down the surface so as to make depressed flat places in the form of depressed flat-lipped craters on its surface; and in the metal atom by building up the surface so as to make elevated flat places in the form of elevated flat-lipped craters on its surface.

There are many different kinds both of metal and metalloid atoms, distinguished from each other by differences either of form in respect of the number of flat-lipped craters each has, or of size. But all atoms of the same kind are exactly alike in form and size and in all other respects.

Definition XIX.

Two atoms are said to be chemically combined when they are in close contact, so that a flat-lipped crater on the one is resting upon a flat-lipped crater on the other, and at the same time the atoms are bound together by corpuscles which, while firmly seated in a crater on one of the atoms, have a grip also upon a crater on the other.

Definition XX.

A molecule consists of two or more atoms united together in chemical combination.

Definition XXI.

Two molecules are said to cohere when one of the atoms in one of them is caught between two or more atoms in the other, or when more than one of its atoms are so caught; and being caught, afterwards held by the side grip of the corpuscles on the surfaces in contact.

LAWS OF MOTION.

Law I.

A corpuscle extending itself under a tendency (Definition II., *a*) to attach itself to another corpuscle of the same kind as itself; or under a tendency (Definition II., *b*) to attach itself to an atom of matter, will extend itself in the direction of the nearest corpuscle or atom, with a preference for the direction in which corpuscles of that kind, or atoms of matter are most densely packed together, if it has to choose between two or more corpuscles or atoms equally close to it.

Law II.

A stream of corpuscles moving under a tendency (Definition II., *b*) to attach itself to an atom of matter, will move straight upon the atom, unless it is restrained.

Law III.

A stream of corpuscles moving under the tendency referred to in Definition II. (*b*), in order to attach itself to several atoms of matter will, if unrestrained, move straight upon the nearest atom, with a preference for the direction in which atoms are most densely packed together, in case the choice lies between two or more atoms equally close to it.

POSTULATES.

Postulate I.

Any corpuscle which, while elongated in either of the ways specified in Definition VI. (*a*), or while in the compact form specified in Definition VII. (*a*), has attached itself to an atom of matter (Definition IX.), or intertwined its pseudopodia with those of another corpuscle can, if unrestrained, move bodily towards that atom or corpuscle first, by retracting its pseudopodia (Definition VI., *c*), while still retaining its hold upon the atom or corpuscle; and secondly, by assuming a compact form (Definition VII., *a*) if it is elongated, or assuming a film form (Definition VII., *b*) if it is in the compact form; and can, if unrestrained, thus move bodily over the surface of a bound pool of corpuscles of the same kind as itself, by intertwining its pseudopodia with those of corpuscles in advance, and then drawing itself forward if by so moving it can get nearer to the surface of the atom.

Postulate II.

Any corpuscle which, while attached on one side directly to an atom of matter, or indirectly by being united to another corpuscle of the same kind which is itself directly attached, and while elongated in either of the ways specified in Definition VI., or while in the compact form specified in Definition VII. (*a*), has attached itself to another atom, can, if unrestrained, draw the two atoms together; first, by retracting its pseudopodia (Definition VII., *c*), and afterwards by resuming a compact form (Definition VII., *a*) if it is in an elongated form; or by assuming the film form (Definition VII., *b*), if it is in the compact form.

POSTULATE III.

Any two corpuscles of the same kind which are within reach of each other and unrestrained, will lay hold of each other by throwing out pseudopodia and intertwining them, and then, after drawing together, unite (Definition VIII.). And any two corpuscles which are united can separate by retracting their pseudopodia if impelled by the tendency to lay hold of atoms of matter (Definition II., *b*) or forcibly displaced.

POSTULATE IV.

Any corpuscle having a tendency to attach itself to atoms of matter (Definition II., *b*), and having an atom or atoms of matter within its reach and being unrestrained, will extend itself towards and attach itself to that atom, or to the nearest atom if there are several of them; or, if other corpuscles of the same kind have previously attached themselves to the atom, so as to enclose it completely, will unite (Definition VIII.) with one of them, selecting the corpuscle which at the time is nearest to the surface of the atom.

POSTULATE V.

Any corpuscle having a tendency to attach itself to atoms of matter (Definition II., *b*), and being in a free pool of corpuscles of the same kind as itself, and being unrestrained, will, in the presence of an atom or atoms of matter anywhere outside the pool, extend itself in the direction of the nearest atom, pressing upon and urging forward in the direction of the nearest atom any corpuscles of the same kind as itself which may be in front of it.

POSTULATE VI.

Any corpuscle having a tendency to attach itself to atoms of matter (Definition II., *b*), and being in a bound pool of corpuscles of the same kind as itself, but not directly attached (Definition IX.) to any atom of matter will, if it finds itself nearer to another atom than it is to the one to which the bound pool is attached, overflow towards the nearest atom by extending itself and pressing upon other corpuscles of the same kind as itself, if any are in front of it, so as to urge them forward in the direction of the atom.

POSTULATE VII.

Any corpuscle which has the tendency to lay hold of atoms of matter (Definition II., *b*) in a strong form, can dislodge any corpuscle which has the same tendency in a weaker form from its position upon the surface of an atom of matter, by thrusting it on one side; and can displace any such corpuscle from its path when it is extending itself towards (Definition VI., *a*) or moving in the stream form (Definition XIV.) upon any atom of matter.

Postulate VIII.

Any corpuscle which while having the tendency to lay hold of atoms of matter (Definition II., *b*) in a strong form lays hold of an atom of matter, either directly by attaching itself to the atom, or indirectly by uniting itself to another corpuscle attached directly or indirectly to the atom, will, under circumstances such that if no corpuscles of any other kind were present, it would be able to move the atom, be able to move it against all the efforts of a single corpuscle which has the tendency to lay hold of atoms of matter in a weaker form to restrain it.

But a single corpuscle with the tendency in a strong form may be overpowered by the combined efforts of several corpuscles with the tendency in a weaker form; and similarly the combined efforts of several corpuscles with the tendency in a strong form may be overpowered by the combined efforts of a greater number of corpuscles with the tendency in a weaker form.

Postulate IX.

An abyss of fluid corpuscles which have no tendency to lay hold of atoms of matter, can have the tendency to lay hold of atoms impressed upon the whole or upon any given part of it in any strength, and at any time if required.

PROPOSITIONS.

Proposition I.

Corpuscles of the same kind will collect together and form a free pool in the absence of atoms of matter unless restrained.

For under Definition II. (*a*), corpuscles have a tendency to lay hold of other corpuscles of the same kind as themselves.

And under Postulate III., every corpuscle will unite with all corpuscles within its reach under the terms of the Proposition, either directly or indirectly through other corpuscles directly united to them, and connecting it and them.

But after a corpuscle has united with other corpuscles its powers of reaching will be extended; because they will be supplemented by those of all the corpuscles united to it, which will have the same tendency as itself to reach out to other corpuscles in the neighbourhood.

Hence, if other corpuscles are contiguous to the group, additions will be made to it from time to time, as one by one they are reached and united to the group.

Thus, therefore, the group will grow into a pool. Other groups and other pools will be formed in the same way if the corpuscles are thickly distributed. In course of time the pools will reach out to and unite with one another; and

Page 137, line 11, for the words "will resolve itself into a stream," etc., read "will resolve itself if unrestrained into a stream," etc.

this will go on until finally all are merged in one large free pool.

Scholium. If the corpuscles are so thinly distributed that corpuscles, or groups, or pools, are unable to reach each other, owing to the intervals between corpuscles, groups, or pools, being too large to be traversed, the case will be one of restraint by the greatness of the intervals.

Proposition II.

Any free pool consisting of corpuscles endowed with a tendency to attach themselves to atoms of matter will resolve itself into a stream in the presence of atoms of matter anywhere outside the pool.

For the tendency in corpuscles to attach themselves to atoms of matter (Definition II., *b*) is stronger than the tendency to lay hold of each other (Definition II., *a*), and under Postulate V. all the corpuscles in the pool will, under the conditions of the Proposition, extend themselves in the direction of the atoms, those below the surface nearest to the atoms pressing upon those above them, and urging them forward in the direction of the atoms.

The surface of the pool opposite to the atoms will, therefore, begin to advance in the direction of the atoms by the extension of the corpuscles in the surface nearest to the atoms, and by their upheaval under the pressure of the corpuscles below them.

The corpuscles, however, are of constant volume (Definition I.), and therefore, when extending in any direction, must contract transversely, *i.e.*, must contract in a plane at right angles to that in which they extend.

At the same time, the corpuscles, though abandoning the pool form, and advancing in the direction of atoms of matter under the influence of the irresistible tendency to lay hold of atoms of matter (Definition II., *b*) which impels them, are still subject to the tendency (Definition II., *a*) to lay hold of their fellow corpuscles.

Thus, in advancing upon the atoms of matter and contracting transversely, they will not in contracting draw away from each other and proceed independently in separate rows, but the rows will keep their hold upon each other, and draw together at the same time as they contract in extending, so that the front of the advancing stream will be contracted, and be very small in comparison with the surface of the pool from which it issues.

And thus the widely-extended pool, formed of layers of compact corpuscles disposed side by side, will pass into a contracted stream formed of rows of extended corpuscles, perhaps thread-like in their tenuity, stretching out side by side far into space in their advance upon the alluring atoms.

Corollary I.—If the entire surface of the pool is not free to advance owing to some obstruction which leaves only a narrow opening for the stream, it will issue under increased pressure; because the corpuscles at the opening will be urged forward, not only by the corpuscles immediately below them in the pool, but also by all which can go straight to the atoms of matter by passing through the opening and are thus included in a cone, with apex at the opening and base at the bottom of the pool, *i.e.*, at the surface opposite to that in which the opening exists.

Owing to the occurrence of the obstruction, the nearest atom for all the corpuscles in the cone lies in the direction of the opening, since all others are cut off by the obstruction; and, therefore, all the corpuscles included in the cone will extend in the direction of the opening; and as soon as the corpuscles in this cone begin to contract laterally, and extend towards the opening, the surrounding corpuscles will move into the cone. If the atoms are too far off to allure the corpuscles the case may be taken to be one of restraint.

Corollary II.—If the atoms are irregularly distributed in space so as to lie in patches opposite different parts of the surface of the pool it will resolve itself into a number of streams.

This follows from the fact that under Law I., the corpuscles extend themselves towards the nearest atoms.

Proposition III.

A stream of corpuscles on reaching an atom of matter will form a bound pool about it, if unrestrained.

For under Postulate IV., any corpuscle which is within reach of an atom of matter, will attach itself to it in the manner shown in Definition IX., if unrestrained.

Hence the leading corpuscles in a stream which reaches an atom will attach themselves to the atom forthwith, so as to cover its entire surface; and the corpuscles which follow them being restrained from attaching themselves to the atom directly by the covering of corpuscles already attached to it, will heap themselves upon the covering corpuscles in order to get as near to the atom as possible, and at the same time will unite with the corpuscles on which they have heaped themselves (Postulate III.), thus forming a bound pool about the atom, consisting of concentric layers of atoms in the form of spherical or imperfectly spherical shells.

Since atoms are spherical or imperfectly spherical in form according as they have valency or no valency (Definitions XVII. and XVIII.) it follows that layers of corpuscles evenly spread over them will be spherical or imperfectly spherical shells.

Proposition IV.

A stream of corpuscles on reaching a region of space in which atoms are distributed, will form a chain of bound pools.

For under Law III., the stream will make always for the nearest atom, and on reaching it will, under the last Proposition, form a bound pool about it.

The bound pool formed about the first atom will, as it grows, in course of time become so deep that its surface will be nearer to some other atom than it is to the surface of the atom on which it is heaped.

Page 140, line 19, for the words "will form a chain of bound pools" read "will form a chain of bound pools if unrestrained."

When this occurs the pool will overflow (Postulate VI.) to this atom, and form a bound pool about it, until this pool in its turn becomes so deep that an overflow takes place to a third atom, and afterwards from the third to a fourth. And so on.

Thus the stream will flow from atom to atom, always making for the nearest atom, and always advancing by making bound pools upon the atoms, and overflowing from each in turn to another atom, and thus forming a chain of pools, linking atom to atom.

If, however, the stream is large, it plainly may have many atoms equally near to different parts of the head of the stream at the same time, and thus may form a series of chains of pools instead of a single chain.

Proposition V.

Any stream of corpuscles of one kind which forms a chain of pools will not flow continuously in a straight line after forming the first pool in any region of space where the atoms have been irregularly distributed.

For the stream makes always for the nearest atom (Law III.).

Unless, therefore, the atoms are so distributed in space that the nearest atom lies always straight ahead of the course the stream is following, the stream cannot flow continuously in a straight line. And it is evident that the nearest atom cannot lie always straight ahead, unless some of the atoms have previously been arranged in a straight row, at equal intervals, and thus distributed uniformly.

It follows, therefore, that in a region of space where atoms are irregularly distributed, the nearest atom will not lie ordinarily straight ahead of the course the stream has previously been following, but will lie sometimes to one side and sometimes to another of that course.

Thus the stream will meander so that its course may be divided up into lengths, each consisting of an irregular spiral.

Proposition VI.

Any stream which consists of several rows of corpuscles will if unrestrained form a fluid tube, or a portion of a fluid tube, when flowing over a chain of pools; or will form a series of such tubes, or portions of tubes, if it flows over several chains of pools.

Since the corpuscles move under the tendency to attach themselves to atoms of matter (Definition II., *b*), it is plain that a corpuscle which enters a bound pool will not leave that pool, and move on to another, unless it is at the time nearer to the atom in the second pool than it is to the atom in the first. And this plainly can only be the case when the first pool is deeper than the second.

In order, then, that the corpuscles may flow over the surfaces of the pools in one of these chains of pools, the pools must be so formed that the corpuscles, as they flow from one pool to another, will continually approach nearer and nearer to an atom of matter. Thus, there must be a steady slope, as it were, on the surfaces of the pools in one of these chains, just as there must be a slope on the surface of a river in order that water may flow freely in the river.

In order that there may be the necessary slope, it is plain that the pools must be so formed that a corpuscle will find itself nearer to the atom in each succeeding pool than it was in the one before it; and also in each separate pool will find itself nearer to the atom in the lower part of the pool than it was in the upper, and continually getting nearer as it descends the surface of the pool. In order, therefore, that the corpuscles may find themselves nearer to the atoms on the surface of each succeeding pool, it is plain that the pools must diminish in depth, so that the second pool may be shallower than the first, the third shallower than the second, the fourth shallower than the third, and so on, in a regular gradation of depth, from the first pool onwards.

And, also, there must be a regular gradation of depth in each pool, such that the depth at the front part of a pool may be greater than the depth at the middle, and the depth at the middle greater than the depth at the back; and again, the depth at the back of a pool must be greater than the depth at the front of the next pool beyond it in the chain.

The form of the pool must, therefore, approximate to that of a bird's egg, with its pointed end towards the beginning of the chain; so placed, in fact, that the corpuscles enter the pool at the pointed end, and leave it at the blunt end.

A chain of egg-shaped pools held together, and at the same time kept apart by a stream of fluid corpuscles flowing in a sheet over their surfaces, will therefore at first resemble a string of bird's eggs, with their pointed ends all turned upwards, and a regular gradation in size, such that the biggest egg is at the top of the string, which represents the beginning of the chain of pools, and the second egg is the next largest, and the third the next in point of size, and so on.

The pools, however, though having some resemblance to bird's eggs, will be much shorter and blunter than eggs usually are, so that the difference between the pointed and blunt ends will be very slight.

From their resemblance to a string of bird's eggs, we can picture to ourselves the general appearance of one of these chains of pools.

But in the last Proposition we have seen that a stream flowing by one of these chains of pools tumbles over from pool to pool in a series of cascades.

And we know also that, whenever a stream consisting of several rows of corpuscles flowing side by side is flowing over a chain of pools, the rows of corpuscles will distribute themselves over the surfaces of the pools under the tendency to attach themselves to atoms of matter (Definition II., *b*), which compels them to get as close as possible to atoms of matter.

If, then, the number of rows of corpuscles in the stream is sufficient when they are spread over the surfaces of the pools to form a fluid sheet covering the entire surfaces of the pools in one of these chains of egg-shaped pools, it is plain that a cross-section of the curved fluid sheet which spreads out over the surfaces of the egg-shaped pools will be a closed curve. The fluid sheet will, therefore, form a fluid tube, with an enlargement opposite each atom, and a constriction between each pair of atoms.

It is plain also, that if the rows of corpuscles in the stream are not sufficiently numerous to cover the entire surfaces of the pools with a fluid sheet, and thus to form a complete fluid tube, they will still form a portion or portions of a fluid tube, which can be made into a complete fluid tube by increasing sufficiently the number of rows of corpuscles in the stream.

Corollary.—The egg-shaped type of pool will, however, plainly disappear, or be considerably modified, if the atoms drift along down the fluid tubes, and thereby bring the pools closer together. The chain of pools will then approximate to a cylindrical form, with more or less well marked constrictions or corrugations between each pair of atoms, and with a slightly tapering or conical shape to give enough slope for the corpuscles to flow over it.

And a sheet of the fluid made up of rows of corpuscles flowing side by side over the surface of a slightly conical chain of pools of this kind will form a fluid tube slightly conical and nearly cylindrical in form.

We shall see in the next Proposition that atoms will drift along down the fluid tubes, and be collected together. This, therefore, is the ordinary form of the fluid tube.

Proposition VII.

Fluid tubes formed of rows of corpuscles of one kind flowing side by side in a sheet over the surfaces of bound pools, which are composed of corpuscles of the same kind as the corpuscles in the tubes, will carry the bound pools along with them, together with the atoms immersed in the pools, if not restrained.

For the corpuscles in a tube which is flowing over the surface of a bound pool, have a strong tendency to lay hold of the atom of matter (Definition II., *b*) immersed in the bound pool, and will thus have a tendency to heap themselves about the atom by intertwining their pseudopodia with those of the corpuscles on the surface of the pool (Proposition III.), provided that the corpuscles in the pool are of the same kind as themselves.

Hence, the corpuscles in the tube will lag momentarily at each pool, and tend to drag the pool along with them as they flow on, by attaching themselves momentarily to the corpuscles on the surface of the pool.

Hence, the corpuscles in a tube which is flowing over the surfaces of the pools, in a chain of pools composed of corpuscles of the same kind as themselves, will tend to drag the pools and the atoms immersed in the pools along with them. Thus, the first atom in the chain will be carried towards the second; the second towards the third; the third towards the fourth, and so on.

And as the atoms thus drift down the streams towards each other, the surface level of the pools will fall by the overflowing (Postulate VI.) of the pools when the atoms come closer together; because the depth of a pool, and thus the level of the surface of the pool, depends upon the distance which divides the atom, upon which the pool is formed from the next nearest atom, in such a way that when the distance is great the pool is deep, and when it is small the pool is shallow.

That this is so, will be plain from the way in which the pools are formed, viz., by the continuous heaping up of corpuscles upon the surface of an atom, until the surface rises so high that an overflow takes place, because the surface is nearer to the next atom than to the one on which the pool is formed (Postulate VI.).

Thus the pools tend to become of one uniform depth by the indrift of the atoms, until they are all brought to a uniform distance from one another.

Hence the streams tend to collect atoms together.

Proposition VIII.

A corpuscle seated in a crater upon an atom will have a firmer hold of the atom than any corpuscle of the same kind seated elsewhere upon the atom can have.

For not only has a corpuscle seated in a crater its body wedged tightly into the crater so that its hold cannot be dislodged by any shearing strain, but also it has, by inserting its pseudopodia into the pits on the sides of the crater, a side grip of the atom by its hold on the sides of the crater in addition to the end grip which all corpuscles have.

With such a grip on the sides of a crater, it will manifestly be a much more difficult matter to detach the corpuscle than it would be if it were simply seated upon the atom with an end hold only of the atom.

Proposition IX.

Any two atoms which have corpuscles seated in the craters on their surfaces will, if they drift near to each other in such a way that a crater in the one comes exactly opposite to a crater in the other, and at the same time the craters come so close together that the corpuscles seated in the two craters can lay hold of each other, be afterwards firmly united together and form a molecule or connected pair of atoms, which will move and behave as if it were a single atom provided that the corpuscles are unrestrained.

For a corpuscle with its strong tendency to lay hold of atoms of matter (Definition II., *b*) will plainly not have that tendency fully satisfied so long as it is attached on one side only to an atom, but will seek to get itself between two atoms flattened out between them to its fullest extent in the film form (Definition VII., *b*), with a firm hold of both atoms.

Hence, any corpuscle which when seated in a crater on an atom like a coral polyp in its coral cell finds another atom within its reach will throw out pseudopodia (Definition VI., *b*) and lay hold of the atom (Postulate IV.), or of the pseudopodia of some corpuscle upon the atom (Postulate III.). But under the conditions of the problem there are two corpuscles thus situated.

Hence, the two corpuscles thus situated will each lay hold of the other's pseudopodia, and having thus laid hold of each other will draw the two atoms on which they are seated together by respectively retracting their pseudopodia, each seeking under tendency (Definition II., *b*) to attach itself to the atom held by the other, while still keeping hold of its own atom.

And if when the two atoms come close together, each of the two corpuscles protrudes itself half out of its own crater so as to make room for the other corpuscle, and at the same time takes possession of half of the other's crater, the two atoms will be firmly bound together as two blocks of stone are bound together by a dowel.

The two atoms when drawn in this way close together, will have their flat-lipped craters fitting tightly down one upon the other, and thus the atoms will have no tendency to roll upon each other. Hence, the corpuscles will hold them much more firmly than they could do if the rounded portions of their surfaces were in contact.

Proposition X.

Any two molecules which have an atom on the one wedged in between or interlocked with two or more atoms on the other, with strong corpuscles between the interlocked surfaces of the atoms, will cohere, or be held more firmly by the strong corpuscles between them than any two other molecules of the same kind which are uninterlocked and unconnected by strong corpuscles seated in craters can be, provided that the strong corpuscles are not restrained.

For it is evident that strong corpuscles hold interlocked atoms of molecules at an advantage, since with pseudopodia inserted into the pits on the side surfaces of the atoms they will have a side grip of the interlocked atoms, in addition to the end grip, which is all the hold they have of uninterlocked atoms.

And it is plain from the results of an ordinary experience that a side grip which can only be detached by forcing the pseudopodia out of the pits by a shearing action gives a much firmer hold against a blow or a strain tending to pull the molecules directly apart than an end grip which can be detached by merely pulling the pseudopodia straight out of the pits. It is plain, therefore, that the interlocked molecules will be held together more firmly against any action tending to pull the molecules directly apart than uninterlocked atoms which are not held together by corpuscles seated in craters can be; while the interlocked molecules are at the same time secured against shearing strains tending to separate the molecules by making them slide one upon another, partly by the interlocking of the atoms and partly by the side grip which the strong corpuscles have upon the interlocked atoms; whereas uninterlocked molecules, which are held together only by the end grip of the strong corpuscles between them, plainly have very slight protection against such strains. Hence interlocked molecules with strong corpuscles between the surfaces of the interlocked atoms will be held more firmly together by the strong corpuscles between them than molecules which are uninterlocked, and, at the same time, unconnected by corpuscles seated in craters can be; and thus interlocked molecules will cohere.

Proposition XI.

Two bodies consisting of many myriads of molecules of different kinds united by cohesion, which touch each other otherwise than lightly while moving side by side in the same direction and with the same velocity through space, will cohere if both are rotating on their respective axes in the same direction, at the same speed, and in a plane at right angles to the general direction in which they are moving through space, provided that they are not disintegrated by the collision and not restrained.

Since the bodies are moving through space with the same velocity and in the same direction, neither of them can ever overtake the other so as to strike it end on.

The bodies, therefore, cannot touch anywhere except at their sides or edges when their paths converge.

And since they are rotating in the same plane and in the same direction, they will touch each other under circumstances very similar to those under which two toothed wheels touch each other if put directly into gearing, while both are driven at the same speed and in the same direction. We know that under such circumstances the two toothed wheels will either break each other or stop each other by the interlocking of their teeth.

And so, too, the molecules in the two bodies will interlock at the point of contact; and amongst myriads of molecules thus interlocking some pairs will necessarily interlock so that an atom in one of the molecules will get wedged, more or less tightly in between two or more atoms, in the other: since the molecules are of different kinds; and therefore will have atoms of different sizes; and also gaps of different sizes between the atoms on their surfaces.

But by Proposition X., molecules which interlock so that an atom in one molecule gets wedged between two or more atoms in the other molecule, afterwards cohere. Hence the two bodies will cohere under the conditions of the problem by the coherence of some of their atoms at the point of contact.

Corollary.—If one of the bodies is much smaller than the other, it will be unable to stop the rotation of the larger body, and will, therefore, be carried round by the larger body after cohering with it, so that the two will afterwards rotate as one mass.

Proposition XII.

Two bodies consisting of many myriads of molecules of different kinds united by cohesion, which touch each other while moving side by side in the same direction and with the same velocity through space, will not cohere if they are rotating on their respective axes in opposite directions, at the same speed and in a plane at right angles to the general direction in which they are moving through space.

The bodies touch under the same conditions as the two bodies in the last Proposition, except that they are rotating in opposite directions instead of in the same direction.

The two bodies will touch, therefore, under circumstances very similar to those under which two toothed wheels touch when put directly into gearing at a time when both are being driven at the same speed in opposite directions.

We know that under such circumstances the teeth of the two toothed wheels will meet and move on together without interlocking or interfering with each other's movements.

And so, too, the molecules at the points of contact in the two bodies will meet without interlocking, and thus without any coherence amongst the molecules of which they are built up.

And as there will be no cohesion between the molecules in the two bodies, so there will be no cohesion between the bodies themselves. The bodies will, therefore, continue to rotate independently.

Proposition XIII.

Any straight or approximately straight row of corpuscles of one and the same kind having its two ends attached each to a separate atom of matter will—if the corpuscles are in the elongated form (Definition VI., *a*) and joined end to end so as to be arranged lengthwise in the row, or are in the compact form (Definition VII., *a*)—draw the two atoms nearer together, unless it is restrained.

For the corpuscles in the row being all of them under the influence of the tendency to lay hold of atoms of matter (Definition II., *b*) will seek to get as close as possible to atoms of matter. And it is evident that the corpuscles in the row, whether they are in the elongated form (Definition VI., *a*) or in the compact form (Definition VII., *a*) can all of them get much closer to the two atoms to which the row is attached by assuming the film form, and thereby flattening themselves out transversely, and shortening the row longitudinally than they would be if they remained either in the elongated or in the compact form.

Hence a row of atoms in the elongated or in the compact form, when between two atoms of matter, with a hold upon each, will behave just as a single corpuscle under the same circumstances will behave, viz., will draw the two atoms together by assuming the film form if unrestrained (Postulate II.).

Page 155, line 18, for the words "if they are unrestrained" read "if the corpuscles are unrestrained and are all of one kind."

Proposition XIV.

If in any spherical body in which the atoms are all of one kind, the atoms are disposed in the form of a series of concentric spherical shells, each one atom in depth, so that the number of atoms per square unit is the same in each shell; and that the atoms are equally spaced in each shell; and so that each atom is connected with the atoms contiguous to it in the same shell by approximately straight rows of corpuscles spreading out over the shell, all of equal length, and all containing the same number of corpuscles in the compact form, all of them of equal length measured in the direction of the row, and, therefore, also of equal thickness; then the atoms will be impelled towards the centre of the sphere with an attraction inversely proportional to their respective distances from the centre by the action of the rows of corpuscles in drawing the atoms together, if they are unrestrained.

The atoms throughout each of the spherical shells are each connected with other atoms contiguous to it in the same shell by approximately straight rows of corpuscles, all of one kind and all in the compact form, spreading out over the shell.

Hence, under Proposition XIII., the atoms in each shell will be drawn together by the rows of corpuscles as they endeavour to flatten themselves out in the film form (Definition VII., *b*) between the atoms.

Since the corpuscles are all of exactly the same strength, (Definition II., *b*); and since throughout each shell there are exactly the same number of corpuscles in each of the rows which connect the atoms; and the rows are all of exactly the same length; and the corpuscles in all the rows are all in exactly the same condition and of exactly the same form and length: Therefore, throughout each shell the rows of corpuscles which connect the atoms together will be all exactly alike, and subject to exactly the same conditions, and will, therefore, all behave in the same way.

Hence, throughout each of the shells the atoms will all be drawn together to the same extent, and in the same way under the action of the rows of corpuscles, as the corpuscles endeavour to flatten themselves out in the film form between the atoms (Proposition XIII.) while spreading out over the shell.

Each of the shells, therefore, will contract uniformly as the atoms of which it is composed are drawn uniformly together by the contraction of the rows of corpuscles between them, and will press all the shells inside it inwards towards the centre of the sphere.

Each of the contracting shells besides pressing the other shells inside it inwards towards the centre of the sphere, will also draw the shells outside it inwards towards the centre of the shell, because the corpuscles on the outer surface of the contracting shell will be united to the corpuscles contiguous to them in the inner surface of the next shell outside, under the tendency to lay hold of other corpuscles which actuates all corpuscles (Definition II., *a*).

The outcome of all the pressures and tensions arising from the contraction of the shells, will plainly be an attraction at the surface of the spherical mass or outermost shell of the mass inwards towards the centre of the mass.

In order to investigate the effect of the tensions and pressures upon different portions of the interior of the mass, we may locate them by assuming that the action of the corpuscles in drawing the atoms together, takes effect only over the central portion of the body, the diameter of which $= d$ units; owing to the corpuscles in the remainder being restrained, and that the shells outside this central portion simply receive and transmit from one to another undiminished, the tension at the surface of the central portion tending to draw it inwards.

Let the tension per square unit of surface at the surface of the central portion $= t$.

Then since the diameter of the central portion $= d$ units, the total surface area of the central portion will be $= d^2 \times 3{\cdot}1415$ square units.

Hence the total tension at the surface of the central portion will be $= t\, d^2 \times 3{\cdot}1415$.

And the tension upon each of the shells outside the central portion $\because = t\, d^2 \times 3{\cdot}1415$, since it is transmitted from one to another undiminished.

But the surface area of the outer shell which has a diameter of $2\, d$ units $= 4\, d^2 \times 3{\cdot}1415$ square units.

And the surface area of the outer shell which has a diameter of 3 d units $= 9\, d^2 \times 3{\cdot}1415$ square units.

And that of the outer shell with diameter 4 d units $= 16\, d^2 \times 3{\cdot}1415$ square units.

Hence the tension per square unit on the shell with diameter $2\, d = \frac{t}{4}$, that on the shell with diameter $3\, d = \frac{t}{9}$, that on the shell with diameter $4\, d = \frac{t}{16}$. And so on.

But the distance of the surface of the central portion with diameter d from the centre of the spherical mass $= \frac{d}{2} = r$.

And the distance of the shell with diameter 2 d from the centre of the spherical mass $= \frac{2d}{2} = 2\, r$. That of the shell with diameter $\frac{3d}{2} = 3\, r$. That of the shell with diameter $\frac{4d}{2} = 4\, r$.

Hence the shell at distance $2\, r$ has a tension per square unit $= \frac{t}{4}$; the shell at distance $3\, r$ has a tension per square unit $= \frac{t}{9}$; the shell at distance $4\, r$ a tension per square unit $= \frac{t}{16}$.

Therefore, the tension per square unit at each of the outer films is inversely proportional to the square of the distance of the shell from the centre of the spherical mass.

But the number of atoms per square unit in all the shells is alike, according to the terms of the proposition.

Therefore, also, the tension on each atom outside the central portion drawing the atom in towards the centre of the spherical mass is inversely proportional to the square of its distance from the centre of the mass.

But now let us assume that the corpuscles in the inner central portion of the body, with diameter $= d$, cease to draw the atoms together, and that those in the films outside this central portion commence to draw the atoms together and to contract the shells; then there will be a thick spherical shell, with internal diameter $= d$, composed of a number of these concentric shells, all of which are contracting and putting pressure upon the inner central portion, which has ceased to contract.

Let the resulting pressure on the surface of the central portion per square unit of surface $= p$. And suppose that the shells in the inner portion transmit the pressure undiminished from one to another. Then the total pressure on each of the shells in the inner portion will be $= p\,d^2 \times 3{\cdot}1415$.

But the area of the shell with diameter $= \frac{d}{2}$ units will be $= \frac{d^2}{4} \times 3{\cdot}1415$. Therefore, the pressure per square unit in this shell will be $= 4p$.

Similarly, the pressure on the shell with diameter $= \frac{d}{3}$ will be $= 9p$, and the pressure on the shell with diameter $= \frac{d}{4}$ will be $16p$, and so on.

But the distance from the centre of the spherical mass of the shell with diameter $= \frac{d}{2}$ will be $= \frac{d}{4} = \frac{r}{2}$. That of the shell with diameter $= \frac{d}{3}$ will be $= \frac{r}{3}$. And that of the shell with diameter $= \frac{d}{4}$ will be $= \frac{r}{4}$, and so on.

Hence, the shell whose surface is at half distance has a pressure per square unit four times as large as that of the shell at full distance; and the shell at one-third distance has a pressure nine times as large; and the shell at one-fourth distance a pressure sixteen times as large as that of the shell whose surface is at the full distance from the centre of the spherical mass.

Hence the pressure per square unit on the inner shells will be inversely proportional to the squares of their respective distances.

And since the number of atoms per square unit is the same in all films, it follows that the pressure on each atom in the inner central portion, with diameter $= d$ units, will be inversely proportional to the squares of their distances. And this proof will also hold, whatever be the diameter of the contracting portion.

By taking, therefore, the first or innermost shell and letting it alone contract, and then taking the first and second shells together and letting them alone contract, and so on, it can, in this way, be shown that each of the shells except the first is drawn inwards towards the centre of the sphere by a tension inversely proportional to the square of the distance by the contraction of all the shells inside it. Likewise it can, by commencing with the outermost shell, be shown in the same way, that each of the shells except the outermost is pressed inwards towards the centre of the sphere by a pressure inversely proportional to the square of the distance by the contraction of all the shells outside it.

And thus, it can be shown generally, that the atoms in all shells throughout the mass are subjected to an attraction inversely proportional to the squares of their respective distances from the centre of the mass.

Corollary I.—It is plain that the same reasoning will apply if molecules are substituted for atoms, and thus that in a similar mass made up of molecules instead of atoms, the molecules would be subjected to an attraction inversely proportional to the squares of their respective distances.

Corollary II.—Since the outer shell in the spherical mass is drawn inwards by an attraction inversely proportional to the square of its distance from the centre of the mass, it is plain that any mass or body attached to the outer shell, and therefore to the outside of the spherical mass, would also be attracted by a force inversely proportional to the square of its distance from the centre of the mass.

And if the second body be also a spherical mass, similar in all respects to the first spherical mass, or differs from it only in the number of concentric shells disposed about its centre, and therefore only in the length of its diameter; then it is plain that the first spherical mass will also be drawn towards the centre of the second spherical mass by an attraction inversely proportional to the square of the distance of its surface from the centre of that mass.

It is thus plain that the two masses will mutually attract each other by an attraction inversely proportional to the square of the distance which separates the surface of each from its own centre.

Corollary III.—If the atoms in the concentric shells are unequally distributed the shells will not contract uniformly, but the amount of contraction will be greater in the portions in which atoms are closely packed together than in the portions in which atoms are thinly distributed; because it is the presence of the atoms which makes the corpuscles active, and therefore there will be greater activity where the number of atoms is large than where the number is small.

Corollary IV.—If a portion of one or more of the shells in the spherical body is displaced by the intrusion of a dense mass, while the atoms in the remainder of the spherical body are equally but thinly distributed throughout the shells, the result will be that in the shell or shells so disturbed the distribution of the atoms will be unequal. Corollary III. tells us that there will be more contraction and greater pressure inwards upon the other shells inside the mass at the point where the dense mass has penetrated, than elsewhere in the spherical mass.

If, therefore, the difference of density between the intruding dense mass and the shells is sufficiently great, the dense mass will sink into the spherical mass by displacing portions of the shells below it.

Proposition XV.

If in an abyss (Definition XI.) composed of corpuscles having no tendency to lay hold of atoms of matter a large part is impressed with the tendency to lay hold of atoms of matter in equal strength throughout, while encompassing an irregular heap of atoms of matter which have no bound pools of corpuscles attached to them, the corpuscles in the portion of the abyss so impressed with the tendency to lay hold of atoms of matter will form with the atoms a domain (Definition XIII.), if unrestrained.

All corpuscles contiguous to the atoms of matter in the heap will, on being impressed with the tendency to lay hold of the atoms, attach themselves to the nearest atoms (Postulate IV.).

There will then be an outside coating of corpuscles attached to atoms of matter, and, consequently having no tendency to move in any direction, surrounded by a great mass of corpuscles pressing in upon the heap from all sides.

The heap being irregular will be unequally pressed, and will therefore be disintegrated under the unequal pressure, having nothing to keep it together except the hold of the corpuscles occupying the interstices between the atoms, which, being spherical or imperfectly spherical in shape, will touch each other only at their flat places or at a few points, and thus necessarily have interstices.

The atoms which separate out will have bound pools formed upon their surfaces by the nearest corpuscles under Postulate IV.

The disintegrating action will go on until the whole of the atoms have had bound pools formed upon their surfaces by the corpuscles, and are thus disseminated through the mass of corpuscles, each with a bound pool of corpuscles about it; and thus a domain will be formed (Definition XIII.).

Proposition XVI.

If, when an abyss (Definition XI.) composed of corpuscles with no tendency to lay hold of atoms encompasses a domain (Definition XIII.) containing the entire stock of atoms of matter in existence in the universe, disseminated throughout a vast mass of corpuscles having the tendency to lay hold of atoms of matter in a weak form, and when space is filled quite full, without interstices, with corpuscles and atoms, a great part of the abyss, including the portion which encompasses the domain, has a tendency to lay hold of atoms of matter (Definition II., *b*) impressed upon it in a strong form, an invasion of the domain by the strong corpuscles will take place, resulting in the establishment of a system of fine streams of strong corpuscles pouring into the domain upon the atoms of matter side by side, with a similar system of streams of weak corpuscles dislodged and driven out, provided that the strong corpuscles are unrestrained.

In Proposition II., Corollary II., it is shown that when atoms of matter are irregularly distributed in space in the neighbourhood of a free pool of corpuscles endowed with the tendency to lay hold of atoms of matter, a number of streams will issue from the surface of the pool, and flow in the different directions in which the atoms are distributed.

In the present case we have a pool of strong corpuscles of vast extent, enclosing a domain in which a vast number of atoms of matter are distributed singly throughout the domain, each in a bound pool of weak corpuscles.

Under Postulate VII., strong corpuscles can displace weak corpuscles which intervene between themselves and atoms of matter, and are also able to dislodge them from any atom to which they have attached themselves.

Hence, the strong corpuscles will pour into the domain of weak corpuscles in streams which will make straight for the atoms.

Since, however, space is by the terms of the Proposition filled quite full without interstices by the corpuscles and the atoms together, it follows that each of the strong corpuscles which enters the domain of the weak corpuscles will have to dislodge one of the weak corpuscles from that domain in order to obtain an entrance, and to effect an exchange of places with it.

Hence, the advance of the strong corpuscles as they pour into the domain will be broken up by the retreat of the weak corpuscles as they pour out of the domain to take the places vacated by the strong corpuscles on the outside of the domain.

The streams of the strong corpuscles will, therefore, consist each of a single row of strong corpuscles flowing into the domain side by side, with a similar stream of weak corpuscles flowing in the opposite direction with the same velocity out of the domain.

CHAPTER V.

ANTAGONISM.

"*The universality of Antagonism has not received the attention it seems to me to deserve from the fact of the element of force, or rather of the conquering force being mainly attended to, and too little note taken of the element of resistance unless the latter vanquishes the force, and then it becomes, popularly speaking, the force, and the former force, the resistance.* . . . .

"*Heraclitus, quoted by Professor Huxley, said, War is the father and king of all things.* . . . ."—Sir William R. Grove, lecture on "Antagonism," delivered at the Royal Institution, 20th April, 1888.—*Nature*, Vol. XXXVII., p. 618.

So far we have followed Newton's directions. He says emphatically, "as in mathematics, so in natural philosophy, the investigation of difficult things by the method of analysis ought ever to precede the method of composition."—"Opticks," 3rd edition, p. 380.

We have, so to speak, pulled down the universe, and taken it to pieces by a process of analysis. And we have now the materials from it all sorted, and stacked, and ready for use in rebuilding the universe by a method of synthesis.

The materials, as we have seen in the preceding chapter, are in the shape of inert solid atoms to furnish, as it were, minute bricks for our structures, and minute fluid corpuscles to furnish a binding material—the mortar, as it were—to hold the atoms together in our structures.

We have every reason to believe that a fluid will answer well as a binding material from the marvellous way in which water, in the form of *water of crystallisation,* binds molecules together to form crystals of many kinds which, as we learn from chemistry, "fall to powder when this chemically combined water is driven off by heat."—Roscoe & Schorlemmer, "Treatise on Chemistry," Part I., p. 244. New edition.

We are sure, therefore, that we have a reliable binding material in our fluid corpuscles.

However, we want the fluid corpuscles to do something more besides acting as a binding material. We want the fluid corpuscles in the stream form to carry the atoms, and in the pool form to bring them together so that they may fall into their places in the structures we have to build.

And we have every reason to believe that our fluid corpuscles will be able to do these also for us from the way in which streams of water transport particles of sand and silt.

On looking closer at our materials we find that the atoms are all squared on one or more sides, so as to fit accurately together in one or more positions, and are thus ready shaped for building purposes. At the same time we find that they are of two kinds, which differ from each other in regard to their squared faces, one kind, shown in Fig. 1, p. 80, having depressed faces formed by cutting down the surface of a sphere so as to make a short atom, and the other kind having raised faces formed by building up the surface of a sphere so as to make pear-shaped or elongated atoms, as shown in Fig. 2. Each of these kinds of atoms is divided into four classes, which differ from each other only in the number of squared faces upon the atom, the maximum number being four. Again, each of these classes is sub-divided into a limited number of sizes which differ from each other in respect of the length of the diameter of the sphere, from which the atom is derived by a process of cutting down or building up as the case may be.

All atoms which, being of the same size, belong to the same class and to the same kind, are precisely alike in every respect, but at the same time differ from all other atoms of every other size or kind or class, and when collected in a mass form what is called an elementary substance.

Fluid corpuscles are of constant volume, which is the same for all, but are variable in form and are constantly changing, either partially or entirely from one to another of four principal forms, viz., a compact or pool form (Definiton VII., *a*); a flattened or film form (Definition VII., *b*); an elongated or stream form (Definition VI., *a*), in which they are able to extend themselves in the direction of any other corpuscle or of any atom of matter; and lastly, the hirsute form (Definition VI., *b*), in which they throw out, from their surfaces, pseudopodia able by intertwining to lay hold of atoms of matter and of other corpuscles.

A fluid corpuscle has thus, as pointed out in the preceding chapter, a general resemblance in form to an Amœba.

We are not, however, to suppose that it resembles an Amœba in any other way except in its form and in its tendencies.

For the Amœba is composed of molecules of matter, as well as of corpuscles of both kinds; and with a heavy load of large molecules is very sluggish, and slow in its movements; while the corpuscle, so long as it is unattached to an atom, is unclogged by any load of atoms, and at the same time is in its substance more subtle than the rarest medium we can obtain in a vacuum tube or otherwise, and is, therefore, exceedingly active, far surpassing in fact, in the celerity of its movements, anything which comes under our observation.

But besides resembling an Amœba in form, a corpuscle resembles it also in being subject to allurement.

The Amœba, or rather the amœboid, swarm-cell is in the pool or plasmodium form susceptible of allurement in the presence of its food supplies; while the corpuscle in the pool form is susceptible of allurement in the presence of atoms of matter. This susceptibility to allurement arises from the fact that corpuscles are endowed not only with the ability to extend themselves in the direction of other corpuscles, or of atoms of matter, and to attach themselves either to other corpuscles, or to atoms; but also with a strong tendency (Definition II., *a*) to lay hold of each other, while they are at the same time susceptible of a still stronger tendency (Definition II., *b*) to lay hold of atoms of matter which will impel them to separate from each other, in order to attach themselves to atoms of matter, and will not be satisfied until each corpuscle is ensconced between two atoms of matter, with a direct hold upon both, and has flattened itself out in the film form (Definition VII., *b*) to the fullest extent between them. At the same time the tendency to lay hold of matter (Definition II., *b*) may be acquired in different degrees of strength, and so that a corpuscle with a strong tendency will be so strongly allured by the presence of atoms of matter as to be able to displace and thrust aside a corpuscle with a weaker tendency.

Our intention is to take the materials thus obtained by analysis, and to show by the method of synthesis that they are sufficient for rebuilding the universe in its original form, so as thereby "to unfold the mechanism of the world," and explain the phenomena of life, which are, as pointed out at p. 124, steps which Newton requires us to take in solving his problem.

We have in the preceding chapter plain directions for the use of the materials in the form of a few simple Propositions. And we know from Proposition XV., on p. 162, that if a sufficient quantity of corpuscles are impressed with the tendency to lay hold of atoms of matter (Definition II., *b*), a universe of some kind will be built up, provided that a sufficient stock of atoms is available.

The universe so built up would, however, be built up by competition amongst the corpuscles for the best places about the atoms of matter, in which much would depend upon the start.

But it would be a totally different universe from the one we have to build. There would be in it no strife, no storms, no dissociation, no disintegration, no dislodgment, but a quiet distribution of the atoms throughout the abyss of corpuscles just as molecules of salt or sugar are quietly distributed throughout a glass of water when a lump of salt or sugar is thrown into it, and after a time all change and motion cease.

The universe which we require is a universe such as ours. It has, therefore, to be built up in the face of strenuous resistance at every step and stage, and when up has to be maintained against ceaseless efforts to wreck it and break it up by which on one side or another masses are from time to time disintegrated, solids melted, liquids vaporised, and molecules dissociated, and thus, the work of building for the time undone.

We have, therefore, to import into the building of the universe the element of antagonism, so as to exhibit the work of construction, and the introduction of order and law going on in the midst of destructive agencies tending to bring back disorder and lawlessness. And we plainly have it in our power to do this, because the different portions of an abyss of corpuscles, under Postulate IX., can acquire the tendency to lay hold of atoms of matter (Definition II., *b*) in different degrees of strength, at different times.

We can thus take the case in which one portion of an abyss of corpuscles acquires the tendency to lay hold of atoms of matter (Definition II., *b*) before the remaining corpuscles acquire the same tendency, and having acquired the tendency takes possession at once of the whole stock of atoms of matter in the universe, and forms with them under Proposition XV. a domain of the kind we have just been contemplating, in which the atoms are distributed throughout the pool of corpuscles, as salt or sugar molecules in a quantity of water; and can then plainly import the element of antagonism into it by letting the remaining corpuscles acquire the tendency to lay hold of atoms of matter (Definition II., *b*) in a stronger form than that in which it was acquired by the corpuscles which have taken possession of the atoms. For the weak corpuscles will then hold the whole stock of atoms in their possession, and, therefore, the strong corpuscles will have no way of satisfying their strong tendency to lay hold of atoms except by invading the domain of the weak corpuscles, and dislodging them from their position about the atoms of matter.

And if then the abyss of force corpuscles is so vast and the stock of atoms of matter so large that between them they are able to fill space quite full, without interstices, we shall have precisely the same case as that dealt with in Proposition XVI.

For we shall have an abyss of strong corpuscles which have just acquired the tendency to lay hold of atoms of matter (Definition II., *b*) encompassing a domain of weak corpuscles which hold possession of the entire stock of atoms of matter in the universe, and have distributed them throughout the domain, just as sugar or salt molecules are distributed throughout a quantity of water when a lump of sugar or salt is dissolved in it.

Proposition XVI. shows that under such circumstances the strong corpuscles will invade the domain of the weak corpuscles by a system of streams in which each stream will consist of a single row of strong corpuscles making straight for the nearest atom of matter, and having a similar stream of the weak corpuscles which are dislodged from their own domain and driven out by its intrusion flowing side by side with it in the opposite direction, and thus out into the place vacated by itself on the outside of the domain.

The streams will flow side by side in opposite directions, the one flowing in and the other out, much in the same way as a jet issues when an orifice is made in a closed air-tight vessel full of water. We know that under such circumstances the water will not flow out of the closed vessel unless a stream of air flows in to take its place, and that two streams will, in reality, flow side by side, the one out of the vessel and the other in.

In this way we get antagonism developed in the strongest possible form, inasmuch as the strong corpuscles can effect nothing without overcoming the resistance of the weak corpuscles and dislodging a number of them; so that every action effected by a stream of strong corpuscles flowing in will be attended by a reaction in the shape of an equal and opposite stream of weak corpuscles flowing out.

By the aid of our Propositions, we can follow the operations of the invading streams of strong corpuscles.

They will advance with difficulty indeed, and will be delayed and hindered, but will not be stopped, since, under Postulate VI., strong corpuscles can displace from their path and dislodge any and all of the weak corpuscles which come in their way.

The strong corpuscles will therefore advance as directly and certainly as if no weak corpuscles were present. In fact, the only difference at first will be that they will advance more slowly than they would do if no weak corpuscles were present. Later on, indeed, we shall find the strong corpuscles repulsed at various points, though on the whole successful, and then complications will arise with which we shall have to deal. For the present, however, we have a perfectly simple case.

The strong corpuscles then being unrestrained will advance in streams upon the atoms of matter in the way shown in Proposition II.; will take possession of the atoms by forming, first, bound pools about them, as shown in Proposition III., and then chains of pools with them in the way shown in Proposition IV.; will flow from atom to atom over the surfaces of the chains of pools in the form of fluid tubes or portions of fluid tubes in the manner shown in Proposition VI.; will transport the atoms by these fluid tubes or portions of fluid tubes, as shown in Proposition VII.; will link atoms together in chemical combination so as to form molecules in the manner shown in Proposition IX.; will unite molecules together by cohesion, and form them into masses and bodies in the manner shown in Proposition X.; will connect bodies together to form lunar and solar systems in the manner shown in Proposition XI.; and lastly, will draw the bodies in the solar and lunar systems, and the molecules in bodies together by a process of gravitation, or gravity in the manner shown in Propositions XIII. and XIV.

Thus the strong corpuscles will advance triumphantly. Nevertheless, they will not be able to carry on their operations with the same ease and freedom as they would if the weak corpuscles were not present, or being present could be at once thrust aside, but they will be hampered, resisted, and retarded at every step and stage. We must, therefore, now turn our attention for a time to the resistance they encounter from the weak corpuscles.

In the first place then, the continuity of the advance of the strong corpuscles will, as shown in Proposition XVI., be broken up by the retreat of the weak corpuscles which are dislodged and driven out of their own domain, so that there will be a stream of weak corpuscles flowing out of the domain side by side with each stream of strong corpuscles which flows in.

Then, too, each fluid tube developed in the manner shown in Proposition VI., will consist in part, only, of a curved sheet of strong corpuscles flowing into the domain of the weak corpuscles, over the surface of the pools in the chains of pools which are formed as shown in Proposition IV., and in part also of a precisely similar sheet of weak corpuscles flowing in the opposite direction out of the domain. Hence the tubes will tend to carry the atoms by which they flow in opposite directions.

The portion of the tube which is made up of strong corpuscles flowing into the domain will tend to carry the atom into the domain of the weak corpuscles, and the portion made up of weak corpuscles flowing out of the domain will tend to carry the atoms in the opposite direction out of the domain. The strong corpuscles will, however, prevail (Postulate VIII.), because they have a stronger hold upon the atoms. And, therefore, the atoms will drift down the streams of strong corpuscles, and slip through the streams of weak corpuscles as a ship slips through a current in the ocean when running before a stiff breeze or air current in the opposite direction. The ship is, however, retarded by the ocean current, although it slips through it, and so also will the atom be retarded, although it slips through the current of weak corpuscles.

Then, too, the streams and tubes, or parts of tubes, of weak corpuscles will tend to dissociate molecules, break up masses, and separate bodies which have been collected in lunar and solar systems, and though their efforts will be futile so long as there are streams or tubes, or parts of tubes, of strong corpuscles of equal volume flowing alongside of them in the opposite direction, the case will be very different if the streams of strong corpuscles are not in sufficient volume to keep the streams of weak corpuscles in check.

And if gravitation occurs in the manner explained in Propositions XIII. and XIV., viz., by molecules or bodies being drawn together by the longitudinal contraction and lateral expansion of rows of corpuscles between them, all tending to flatten themselves out so as to get as close as possible to the atom under the tendency to lay hold of atoms of matter (Definition II., *b*), there will plainly be an outflow of weak corpuscles dislodged from the interior of the body or system, and driven out as the molecules or bodies are drawn closer together For the hold of the strong corpuscles is increased by the action of the strong corpuscles in flattening themselves out and thus spreading out over a larger portion of the surface of each atom; and this cannot be without a dislodgment of weak corpuscles.

And this outflow of weak corpuscles will not be attended with any corresponding inflow of strong corpuscles.

With this explanation of gravitation, therefore, there should be an outflow of weak corpuscles towards the outside of bodies, and also of lunar and solar systems; and this outflow, being unrestrained by any corresponding inflow of strong corpuscles, will tend to expand and melt solids, vaporise liquids, dissociate molecules, and generally to give rise to all the phenomena of heat which ordinarily come under our observation.

In this way then we can get, as we shall now proceed to show a little more fully, a universe built up in the face of strenuous resistance by the action of strong corpuscles in invading the domain of the weak corpuscles, as shown in Proposition XVI. For the corpuscles move upon the atoms of matter disseminated throughout that domain, in streams. The streams, on reaching the nearest atoms, take possession of them by heaping themselves upon the atoms, and thus forming pools about them in the manner shown in Proposition

III.; much in the same way, in fact, as water vapour in the air forms pools in the shape of rain, or mist drops about particles of dust or soot as nuclei.

The pools of strong corpuscles being fed by the streams, continue to grow until in each case the surface rises so high as to be nearer some other atom than the one on which the pool is formed. An overflow then takes place, as shown in Proposition IV., on to the second atom, and a pool is formed about it, which, in its turn, overflows to a third atom. Thus the streams flow from atom to atom, forming a pool about each atom which they reach and then overflowing from this pool to the next nearest atom, and so on, making always for the nearest atom and forming chains of pools connecting atom to atom as shown in Proposition III. and IV.

The streams flowing from pool to pool by these chains of pools will flow in sheets over the surfaces of the minute pools, in the manner set forth in Proposition VI., as a river flows in a sheet over the surfaces of the pools which are formed when weirs are built along its course.

But the pools in these minute chains of pools are, as shown in Proposition VI., at first approximately egg-shaped, though afterwards, when they close up, becoming approximately cylindrical. Hence the streams will flow in curved sheets over the surfaces of these minute pools. And these curved sheets will form, as shown in Proposition VI., fluid tubes or portions of tubes with liquid cores containing atoms of matter as nuclei.

And when fluid tubes or portions of fluid tubes have been developed they will begin, as shown in Proposition VII., to carry the pools over which they flow, and the atoms immersed in the pools along with them.

And thus we shall have an endless number of processions of minute atoms drifting side by side down minute fluid tubes or portions of tubes. And if the tubes were perfectly straight and perfectly parallel to one another, we should get nothing more so long as the flow continued.

But the chains of pools are formed by the progress of the streams in passing from atom to atom always by way of the nearest atom. And if then atoms are irregularly distributed in space, it is plain, as shown in Proposition V., that streams which flow from atom to atom, always by way of the nearest atom, will not run straight, but will meander from side to side according as the nearest atom lies, to this side or to that of the direction they have previously been following. In fact, we shall get a number of irregularly spiral reaches with paths in some cases crossing and recrossing those of other streams.

And we can easily arrange, under Postulate IX., to start the invasion before atoms have been uniformly distributed throughout the domain of the weak corpuscles, and can, therefore, arrange the invasion so that the fluid tubes which result from it shall not run in straight lines parallel to each other, but shall follow irregularly spiral paths, crossing and recrossing each other in many cases.

The atoms in the processions of atoms which drift along down these spiral tubes, or parts of tubes, crossing and recrossing each other's paths irregularly, will necessarily come into collision sometimes, and will sometimes collide so that craters in the colliding atoms come opposite to each other and allow the corpuscles in the craters an opportunity of locking the atoms together in the manner shown in Proposition IX., so as to form molecules by chemical combination. In this way then we shall get our building operations started, and shall get atoms built up into molecules by chemical combination. But the irregularities in the spiral tubes will tend to work out as the atoms drift along; and their paths to approximate more and more to an average path.

And the average path will manifestly be a spiral, either with a right-handed or a left-handed twist.

Consequently we shall have in course of time space traversed by processions of atoms and molecules which are drifting along approximately spiral paths, some with a right-handed and some with a left-handed twist, and in many cases crossing or intersecting each other's paths, and thus necessarily coming sometimes into collision with each other.

Molecules which get their atoms interlocked during collision, so that the strong corpuscles between the interlocked atoms are able to bind the molecules together into a mass by the process of cohesion in the way shown in Proposition X., will necessarily have their tubes twisted up together as strings would be twisted up under similar circumstances into a cord.

But Propositions XI. and XII. tell us that it is only molecules twisting in the same direction which will get interlocked so as to cohere, and thus that there will be a selective action in operation under which masses will be built up of molecules all twisting in the same direction; so that the masses themselves will rotate each on its axis as it drifts along in the same direction as the molecules of which it is built up were twisting before they were united by cohesion. Each of these masses drifts along down a current formed by twisting up the tubes of the molecules of which the mass is built up, until together they form a spiral current, with the tubes of the molecules at the centre of the mass serving for a core, about which the tubes of the other molecules are twisted one after another as they are taken on somewhat after the manner in which casing strands are twisted about a submarine cable.

In this way we get the second stage in our building operations started, viz., the stage of cohesion.

And after a time we shall have space traversed by a number of bodies, each of which is drifting down a spiral current with a right-handed or a left-handed twist, according as the body is built up of molecules with a right-handed or with a left-handed twist, the direction of the twist in the spiral current being the same as that of the spiral tubes of which the current is built up.

When the number of bodies built up by cohesion becomes large, collisions will necessarily occur sometimes amongst them since their paths in many cases intersect each other.

And amongst many encounters some will necessarily take place under circumstances such as will be attended with an interlocking of the molecules in the colliding bodies, and the consequent cohesion of the bodies in the manner shown in Proposition XI. But Proposition XII. tells us that union will only take place between bodies which are twisting in the same direction.

By the union of bodies in this way nebulous masses will be formed.

When a small body unites with a large one of the same density as itself, the large body will naturally carry the small one round with it in the same way as it carries round portions of the same size in its own structure, and we shall have the beginning of a lunar or solar system. In such a system the spiral current of the small body will be twisted up about the spiral current of the large body as a core.

In this way we reach the third stage in structure building, viz., the development of lunar and solar systems—the solar system following in the ordinary course as soon as a sufficiently large number of lunar systems have been developed to bring about the occurrence of collisions amongst lunar systems with sufficient frequency to get a number of lunar systems united to a great central body, which is sufficiently large to carry them all round with it as it rotates.

If the central body is sufficiently large to carry a number of lunar systems round with it as it rotates on its axis in drifting down its own spiral current, it will twist up their currents about its own just as they would be twisted up under the same circumstances into a rope, if each were a separate strand or string.

In the nebulous form the whole solar system will rotate as one mass, though each lunar system in it has its own separate current, and drifts through space down the great loops formed in that current by the process of twisting it up round the main current to which it is subjected, and drifting down these loops retains its position as an integral portion of the rotating mass.

But gravitation will be at work in some cases upon these nebulous masses, in the manner shown in Proposition XIV., as soon as they are formed.

And under gravitation, in the form of gravity, the molecules in each of the bodies of which the nebulous mass is made up will be drawn towards the centre of the body, and thus each of the bodies will begin to contract.

Under Corollary II. of Proposition XIV., each of the contracting bodies will draw towards itself all the bodies to which it is united.

If then we call the great central body the sun, and call the large central body of one of the lunar systems attached to the sun, Jupiter, we shall have the sun pulling Jupiter towards its own centre, and Jupiter pulling the sun towards its own centre, and the mutual action of the two bodies resulting in the shortening of the distance which separates their centres from each other by a longitudinal contraction in the rows of corpuscles which connect the two centres together. There will also be a similar action between the planets and each of their respective satellites.

In this way we get an illustration of one of Newton's views in regard to gravitation, viz., the view enunciated in the following remark, "and though the mutual actions of two planets may be distinguished and considered as two, by which each attracts the other; yet as these actions are intermediate, they do not make two but one operation between two terms. Two bodies may be mutually attracted each to the other by the contraction of a cord interposed."—"Newton's System of the World," 2nd edition, p. 38.

But the contraction of each of these bodies under the action of gravity and of the nebulous mass as a whole under the action of gravitation, will lead to the dislodgment on a large scale of weak corpuscles, which will flow from the inside to the outside of each body, and from the inside to the outside of each nebulous mass. And in addition to this, each of the operations of chemical combination and cohesion will be attended by a dislodgment and outflow of weak corpuscles.

And there will be, as pointed out at p. 177, no corresponding inflow of strong corpuscles to counteract the action of the outflowing weak corpuscles in dissociating atoms in unstable molecules, and separating molecules in gaseous masses, and upheaving them, and whirling them aloft in great outrushes of vapour, and thus giving rise to the phenomena associated with heat.

We shall thus have a manifestation of heat phenomena in connection with an outflow of weak corpuscles, which will take place at each of the stages of structure building, viz., chemical combination, cohesion, and the formation of lunar and solar systems; but a manifestation on a much grander scale in connection with gravitation.

The result will be that atoms dissociated from unstable molecules, and molecules detached from solid masses, will be upheaved, and thoroughly shaken up together. And this will go on until at last, under the numerous collisions which occur during the process of shaking up, atoms will get so firmly seated and bound together by chemical combination, in the way explained in Proposition IX., as to form stable molecules which can no longer be dissociated by heat, except at very high temperatures; and molecules get interlocked so firmly as to cohere in the way explained in Proposition X., in masses which will become liquid or solid, and resist under ordinary circumstances the further action of heat upon them.

The bodies of which the nebulous masses are made up will thus begin to contract and grow dense under the combined action of gravity, cohesion, and chemical combination upon them.

Thus, each nebulous mass will begin to break up into a number of dense bodies, connected together by a rare medium. The bodies will grow denser and denser, and the medium connecting them together will grow rarer and rarer until at last it becomes so rare that the dense bodies will break loose so far as to begin to rotate once more in the same way as each was rotating before it joined the nebulous mass, owing to the twist in the current down which it drifts.

While the planets are thus rotating each in a period of its own, dependent upon the sharpness of the twist in its spiral tubes, they will continue to revolve round the great central body in the same direction as they rotate, being held by the rare medium which connects them with the central body.

But though they will continue to revolve about the great central body they will not revolve in the same time as the great central body rotates, as they did when they formed an integral part of a great rotating nebulous mass, but will slip to a large extent from the hold of the great central body, owing to the rareness of the medium which connects them with the central body. And the outermost bodies will slip more than the inner, because they are held less firmly than the inner bodies. And since the outermost bodies slip more than the inner bodies, their periods of revolution will be longer than those of the inner bodies, and generally, the period of revolution will increase with the distance.

We have now a universe built up and maintained in the face of strenuous resistance with all the phenomena of chemical combination, cohesion, gravitation, and condensation from the gaseous into the liquid, and from the liquid into the solid state, which indicate activity in building present, side by side with the phenomena of dissociation, heat, and conversion from solid into liquid, and from liquid into gas, by which the work of structure building is for a time arrested in its progress and undone, now on this side and now on that —and thus a universe such as the one in which we dwell, amongst ceaseless change and motion.

And in this universe we have a host of mighty suns drifting side by side through space, each down a vast current of fluid corpuscles steadily flowing into the heart of the domain into which these suns are drifting ; and each with a company of planets and lunar system revolving round it in a plane, at right angles to the direction in which the sun advances.

We have now, therefore, the mechanism of the world unfolded before us.

But before proceeding further it is necessary to look a little more closely into the chemical stage in structure building which we have rapidly passed in review.

In the next chapter we shall therefore go further into this stage, so as to get clearer ideas in regard to it.

CHAPTER VI.

FROM A CHEMICAL POINT OF VIEW.

"*But though in the course of ages catastrophes have occurred, and may yet occur in the heavens, though ancient systems may be dissolved, and new systems evolvèd out of their ruins, the molecules of which these systems are built—the foundation stones of the material universe—remain unbroken and unworn. They continue this day as they were created—perfect in number and measure and weight.*" — J. Clerk Maxwell, "Scientific Papers," edited by Niven, Vol. II., p. 377.

THE first point to notice in looking at the explanation put forward in the preceding chapters, is the fact that under it all valent atoms are derived from pre-existing spherical atoms without valency.

The explanation, in fact, has at its foundation inactive elements with perfectly spherical non-valent atoms.

The atoms of these inactive elements are said to have no valency, in the sense that they cannot form stable molecules with atoms of another kind, as the atoms of all active elements are able to do, without meaning to convey the idea that they are absolutely unable to form associations with other atoms under any circumstances whatever.

We know that round shot can be built up into piles if the bottom course is confined in some way and prevented from spreading.

And so, too, we can see how it may be possible to pile up the spherical atoms of these inactive elements into liquid or solid masses, by confining them in tubes, and then subjecting them to great pressure as in the case of Argon, which becomes liquid, but only under a pressure of 50 atmospheres, as shown by Dr. Olczewski, in his paper on "The Liquefaction and Solidification of Argon," which was read before the Royal Society on the 31st January, 1895.

We know also that a sphere, though it cannot lodge on a convex surface, can yet lodge on a concave surface, or in a hollow, and can sit quite securely in a cup-shaped seat which fits it, provided that it is not shaken too violently.

We can see, therefore, that it may be quite possible for the spherical atoms of these inactive elements to lodge amongst the atoms of some of the complex molecules, which can be built up with carbon and with other substances, and in that way enter into combination. And we can understand how, with suitable arrangements, it may even be possible to get the atoms of inactive elements, when they are confined in a tube, to lodge upon the craters on the atoms of some of the elements, so as to form for a time unstable molecules, which will, however, break up if they are allowed any freedom.

The inactive elements, therefore, which our conclusions contemplate have perfectly spherical atoms, which cannot under ordinary circumstances form stable molecules with atoms of another kind in the same way as the valent atoms of the active elements do, but may be able to combine under extraordinary circumstances. And such substances as these we find Argon and Helium, from the published accounts of their behaviour, to be. For we find that Argon and Helium are elements of no valency with spherical atoms, and being so, afford proof that elements of no valency with spherical atoms are in existence, and thus also afford confirmation of the correctness of the conclusions set forth in "Force as an Entity," in regard to the existence of elements of that particular kind.

This then, as far as we are concerned, is the great fact which Argon and Helium show. Let us, therefore, look into this point.

In this connection we may refer once more to the remarks in regard to the sphericity of the Argon atom, which were made by Professor Rücker, as President of the Physical Society, when the paper by Lord Rayleigh and Professor Ramsay, on "Argon: a New Constituent of the Atmosphere," was read before the Royal Society on the 31st January, 1894.

We have seen in the extract from these remarks at p. 57, that on that occasion Professor Rücker in the course of his remarks showed from the ratio of the specific heats of Argon, that it is necessary that the Argon atom should be regarded as spherical.

In the case of Helium, we find in a paper by Professor Ramsay, Dr. Collie, and Mr. Travers, which was read before the Chemical Society on the 20th June, 1895, the following statement in reference to the results of certain experiments to determine the wave length of sound with a sample of Helium, viz., "the ratio of the specific heats of Helium, calculated from these numbers as before is 1·652, a sufficiently close approximation to the theoretical number 1·66. In the case of Argon the purest specimen obtained gave for the ratio 1·659."—*Nature*, 1st August, 1895, p. 333.

Argon and Helium therefore agree in showing, by the ratios of their specific heats, that elements of no valency have spherical atoms.

We know that Argon means an inactive thing; and that Argon has been so named by its discoverers on account of its inactivity.

We are aware at the same time that Mr. Berthelot has succeeded in getting Argon to combine with a condensed compound of benzene, and are prepared to find that other combinations of a like kind can be effected; but since we perceive that it is only under extraordinary circumstances that such combinations can be effected, they in no way alter our estimate of the inactivity of Argon judged by our standard.

In fact, Argon in showing itself able to form associations to the extent our conclusions would show spherical atoms to be capable of doing, and at the same time extremely reluctant to form combinations in the ordinary way, except perhaps with highly complex molecules, manifests itself to be an inactive element of the very kind we require.

But it may, as already pointed out, do more for us even than showing generally that inactive elements exist, for if it turns out to be homogeneous and not a mixture, it will, seeing that it is of atomic weight 40, prove to be the inactive element of atomic weight 37 to 40 from which the third metal and second metalloid series are derived, and which, moreover, was tabulated at p. 64 of "Force as an Entity" four years before Argon was actually discovered.

So, also, if Helium turns out to be homogeneous it will, seeing that its atomic weight according to the latest determination is about 4·4, prove, as already pointed out, to be the inactive element of atomic weight 5, from which the first metal series is derived, as explained at p. 88, and chronicled in the *Chemical News*, of the 22nd March, 1895, before the discovery of Helium was announced.

If, therefore, Argon and Helium prove to be homogeneous, they will be not only the fulfilment of a prediction in "Force as an Entity" that inactive elements are in existence, but in addition the fulfilment of a prediction that inactive elements of atomic weight 40 and of atomic weight 5 are in existence.

We recur to these facts again in order to point out that Argon and Helium may very well turn out to be homogeneous, even though we have strong grounds for believing in the existence of other inactive elements besides the two of atomic weights 5 and 37 respectively, and notably of one of atomic weight 20, which we might reasonably suppose to be as abundant as any, seeing that from it are derived the first of the metalloid and the second of the metal series, which include some of the most widely distributed of the elements.

For it may quite well happen that the inactive element of atomic weight 20 is too volatile to be found in the atmosphere at the surface of our earth, and that the others of atomic weight 60, 80, 105 and 130, and upwards, are too sparsely distributed to be found in sufficient quantities for recognition in our earth's atmosphere.

The fact pointed out by Mr. Crookes in his paper "On the Spectra of Argon," read before the Royal Society on the 31st January, 1895, that there are two modifications of Argon, one a red glowing and the other a blue glowing gas, can perhaps be accounted for by the results obtained by Faraday in his experiments with gold films. Faraday, after remarking upon "the greening effect of pressure which is general to gold," goes on to make the following remarks: "I think I am justified by my experiments in stating that fine gold particles . . . . can in one state transmit light of a *blue-grey* colour, or can by heat be made to transmit light of a *ruby* colour, or can by pressure from either of the former states be made to transmit light of a *green* colour; all these changes being due to modification of the gold, as gold."—"Experimental Researches in Chemistry," p. 403.

From these experiments we learn that changes of temperature and pressure are competent to give rise to modifications of colour. And, indeed, the same fact is shown by mercuric iodide $Hg\ I_2$, as is well known.

We conclude, therefore, that it is quite possible that the red and the blue modifications of Argon may be modifications of Argon, as Argon, produced simply by changes of temperature and pressure, and not by a mixture of two elements, one glowing red, and the other glowing blue. The probability that the two modifications are due simply to differences of temperature and pressure is increased by the fact recorded by Mr. Crookes in the above paper, "That the change from red to blue is chiefly dependent on the strength and heat of the spark; partly also on the degree of exhaustion."—*Chemical News*, Vol. LXXI., No. 1,836, p. 59.

It may well be, therefore, that Argon and Helium are both homogeneous gases.

In any case, whether they are homogeneous or not, they are profoundly interesting to us, as representing the fulfilment of a prediction more or less completely; but far more because they form part, as we believe, of the raw material from which the manufactured material in our universe, viz., the valent atoms of the active elements, has been prepared; and also furnish with their freedom from cohesion and subjection to gravitation a material for filling interstellar space.

We have seen that the non-valent spherical atoms of the inactive elements have been made valent by two processes, by which they are either fashioned as metalloid elements by a process of cutting down the surface of the sphere at one or more places, and making at each of these places a flat-lipped crater in a depression, or as metal elements, by building up the surface of the sphere at one or more places, so as to form at each of these places a flat-lipped elevated crater of the volcano type.

We have seen also that valent atoms of these types pitted all over with minute depressions afford a secure lodgment for fluid corpuscles, which seize and heap themselves upon them in the pool form, as water collects about dust particles and forms raindrops; or as on a vast scale it collects in lakes, and seas, and oceans, on the surface of our earth.

We have seen also how valent atoms thus begirt with pools of fluid corpuscles of two kinds, one a weak kind, and the other a strong which is gradually dislodging the weak kind and getting the atoms into its possession, have at the same time fluid corpuscles seated in their craters with a grip on the sides of the craters, which gives them a firmer hold of the atom than corpuscles seated outside the craters can have, so that the corpuscles in these craters are, in fact, seated much in the same way as coral polyps are seated in coral cells.

We have further seen that whenever two atoms with corpuscles seated in their respective craters come within reach of each other, so that the corpuscles in one or other of their craters are able to reach out far enough to lay hold of each other by their extended pseudopodia, the two atoms are gripped and drawn together by the efforts of the strong corpuscles to spread themselves out in the film form between them.

We have seen that atoms which are drawn together in this way by the longitudinal contraction and lateral expansion of strong corpuscles seated in their craters, with a firmer hold upon their surfaces than corpuscles seated outside of their craters can have, will necessarily be brought together in such a way that crater will sit upon crater; since they will rock and roll upon their rounded surfaces in all other positions until they come into that position; and then they will cease to roll, and remain quietly seated with their flat-lipped craters in contact with each other, and with the corpuscles in those craters gripping them and binding them closely together, and so forming them into a molecule.

We can see that molecules formed in this way will be stable, because their atoms are held together by strong corpuscles which, being securely seated in craters, with a grip on the sides of the craters, have a firmer hold of the atoms than other corpuscles which lay hold of them in any other part can have. Hence their atoms cannot be drawn apart by other corpuscles, and can only be separated by violent collisions with other molecules or bodies, or by violence in some other way.

We can see that chemical union in this form, brought about as it is by the action of strong corpuscles in drawing atoms together, must necessarily be accompanied by the dislodgment of a portion of the weak corpuscles which keep the atoms apart; and that the dislodged corpuscles will flow out, seeking to attach themselves to other atoms of matter. In this way, an outflow of weak corpuscles will be set up in the opposite direction to the inflow of strong corpuscles, by which the atoms are brought together, and thus an outflow of repulsive force in the form of heat, tending to separate the atoms of any molecules or the molecules of any masses which lie in its way.

Thus we see that chemical union of this kind is necessarily accompanied by the disengagement of heat; and therefore the resulting compound will be exothermic.

The outburst of heat, disengaged in this way, may be so fierce as to be able to overcome the cohesion of the molecules in some solid mass by which it passes, and, by bringing the loosened molecules in contact with molecules of some other kind, be able to give rise to the formation of an endothermic compound, which could not take place without heat to separate the molecules.

We know from Definition I. of Newton's "Principia," that the quantity of matter in a body is proportional to the weight of the body. And we have strong grounds for concluding that all atoms are constituted of the same material, which is of uniform composition in all. We find, for instance, that all metalloids are made valent in one and the same way, *viz.*, by taking off one portion weighing not less than 1, and not more than 3·5 from a spherical atom for each atom taken on; also that most of the metals are made valent in one and the same way, viz., by adding one portion weighing not less than 1, and not more than 4 to a spherical atom for each atom taken on; and, at the same time, that the four metalloid series and four of the metal series have, as shown at p. 88, a common origin in four inactive elements with spherical atoms, so that the portions taken off one set of spherical atoms in making metalloid elements, are simply transferred to another set of spherical atoms, in order to make metal elements.

Since the process by which valency is conferred upon the metalloids is the same for all and the result the same, we are justified in concluding that the material operated upon is the same in every case. And since also the process by which valency is conferred upon the metals is the same in most cases, and the result the same, we are justified in concluding that the material operated upon is the same in most cases.

And having determined thus that all the metalloids are composed of one and the same material, and that most of the metals which come under our cognisance are composed of one and the same material, we further arrive at the conclusion that all the metalloids and most of the metals which come under our cognisance are composed of one and the same material; since we find that four of the metal series have a common origin with and thus are composed of the same material as the four metalloid series; and if the atoms of four of the metal series are of the same material as the atoms of the metalloids, then the atoms of the remainder of the metal elements which come under our cognisance must in most cases be of the same material also, because, as we have seen above, the atoms of most of the metals are composed of the same material.

And if the atoms of the elements are in any cases composed of the same material uniform in composition throughout, then in such cases we plainly can calculate the relative sizes of the atoms of the inactive elements from which the active elements are derived, with our view that the atoms of these inactive elements are spherical in form and of known weight. For by taking the unit of weight to be a measure of the unit of mass, that is to say, of the quantity of matter in a mass of unit length, breadth, and depth, or in other words, in a cubic unit of mass, we can ascertain from the numerical values of the weights the number of units of mass in each atom, and thus the contents of the atom; and from the contents, the number of units of length in its diameter from the rule that the contents of a sphere $= \frac{\pi}{6} d^3$.

Proceeding in this way, we find that the atom of the inactive element of atomic weight 5, from which the first metal series is derived, has a diameter approximately 2·12 units in length;

That the atom of the inactive element of atomic weight approximately 20, from which the second metal and first metalloid series are derived, has a diameter approximately 3·37 units in length;

That the atom of the inactive element of atomic weight approximately 40, from which the third metal and second metalloid series are derived, has a diameter approximately 4·24 units in length;

That the atom of the inactive element of atomic weight approximately 60, from which the fourth metal series is derived, has a diameter approximately 4·86 units in length;

That the atom of the inactive element of atomic weight approximately 80, from which the fifth metal and third metalloid series are derived, has a diameter approximately 5·345 units in length;

That the atom of the inactive element of atomic weight approximately 105, from which the sixth metal series is derived, has a diameter approximately 5·86 units in length;

And lastly, that the atom of the inactive element of atomic weight approximately 130, from which the seventh metal and fourth metalloid series are derived, has a diameter approximately 6·29 units in length.

Thus it appears that the diameter of the atom of the inactive element, from which the seventh metal series and the fourth metalloid series are derived, is nearly three times as large as that of the atom of the inactive element from which the first metal series is derived, and not much short of being twice as large as the atom of the inactive element from which the second metal and first metalloid series are derived.

And now, then, we are introduced for the first time to atoms which differ in size. Hitherto we have been dealing with atoms which differed in form, but we can easily see how difference in size can modify very greatly the characteristic properties of atoms. The connection between difference in size and difference in weight will be obvious to us at once from our ordinary every-day experience of the difference in weight between small pieces and large pieces, when the large pieces and the small pieces are of the same material. We can, therefore, have no possible difficulty in understanding the simple explanation that atoms are all of precisely the same material one as another, but differ in weight, because some are small and others large in comparison with each other, though the largest of them is exceedingly minute when compared even with the smallest object we can discern with a microscope.

Hence, difference in size gives us a complete explanation of difference in weight.

But we know that other things being equal, small bodies are more easily moved than large, and thus we shall be fully prepared to find a close connection subsisting between difference in size and difference in mobility. We shall understand, therefore, at once the beautiful example which the halogens present of the effect of size in modifying mobility.

The halogens form a group composed of the four monovalent members of the four metalloid series, viz., Fluorine, Chlorine, Bromine, and Iodine; and thus all have atoms of the same form—that of a sphere with one crater, which gives a diatomic molecule in the shape of a dumb-bell, with the handle or middle bar removed.

Thus the atoms of all have the same form, and differ only in size so far that iodine has, as we have seen above, an atom nearly twice as large as the atom of fluorine, half as large again as the chlorine atom, and larger by one-fifth than the bromine atom.

They therefore present us with a beautifully clear case in which difference of size comes in as the only modifying feature.

And we find difference in size bringing about a marked difference in mobility. For we have fluorine, with the smallest atom of all, existing in the form of a mobile gas; chlorine, with atoms, coming next in point of size to those of fluorine, existing as a dense gas, which can be liquefied with comparative ease; bromine, with atoms, standing next in point of size to those of chlorine, existing as a liquid; and lastly, iodine, with the largest atom of all, existing as a solid.

Thus we have in the halogens a regular gradation in size, side by side with a regular gradation in mobility; and thus a very clear and beautiful example of the effect of increase of size in bringing about diminished mobility.

We can readily understand also how size comes in in connection with Diffusion.

For we know that a number of spheres can never be made to fit closely together, and that the intervals between a number of large spheres will be larger than the intervals between a number of small spheres, and even large enough in some cases to allow very small spheres to pass bodily in between them.

We can easily understand, therefore, that a mass made up of a mixture of spheres of different sizes, connected together by fluid corpuscles, which have a tighter hold upon the atoms when the intervals between them are small, than when they are large, will be more compact and coherent when the atoms are mixed up together, so that the intervals between them are as small as possible, than they will be if the large atoms are by themselves on one side, and the small atoms by themselves on another side.

Hence we can easily perceive that if under conditions such as those obtaining at the surfaces of gravitating bodies, the gases in the atmospheres about these bodies are being constantly upheaved by the outflow of heat, and brought down again by the action of gravitation, the molecules of the gases in the atmospheres of gravitating bodies will be brought by constant agitation to form a perfect mixture, in which large and small will be so blended together that the intervals between the atoms will be as small as possible. In short, the whole mass will be brought into a condition of maximum stability by a process of diffusion in which the mixed mass will lose mobility.

We can easily see also how size may have much to do with Periodicity. In fact, we have in valency eight kinds of forms, viz., four metalloid and four metal forms, repeated over and over again; and it is from our point of view entirely due to the fact that the non-valent atoms operated upon are of at least a dozen different sizes, that the number of kinds of valent atoms are not restricted to the eight kinds of forms with which valency deals. As it is we have, in the case of the metalloids, the four forms in which valency deals repeated on non-valent atoms of four different sizes, and thus sixteen, or rather, fourteen different metalloid atoms turned out; for two are wanting. And in the case of the metals, we have the four forms with which valency deals repeated over and over again on the seven non-valent atoms specified on p. 90, in addition to at least five or six others which we have not dealt with for want of space, and thus some fifty or more different kinds of atoms turned out.

Hence, we have in effect the forms with which valency deals repeated over and over again on four different scales in the case of the metalloid; and in the case of the metal atoms, on at least a dozen different scales corresponding to the different sizes of non-valent atoms in existence.

Viewed in this way, we perceive that periodicity is due simply and solely to difference of size in the non-valent atoms, from which the valent atoms are derived.

But size must manifestly have a marked effect upon cohesion as well as in chemical combination and periodicity, if our explanation of cohesion is correct.

It will be remembered that cohesion, according to our explanation, is brought about by the interlocking of atoms in contiguous molecules, which occurs when projecting atoms in one set of molecules get caught in the intervals between the atoms in another set, and being caught, are afterwards bound together by the fluid corpuscles between the surfaces of the atoms thus brought into close contact.

The fluid corpuscles between the surfaces of atoms thus interlocked, get a side grip upon the surfaces which gives them an advantage over corpuscles which hold with an end grip; and thus have an advantage very much of the same kind, but less in degree than the advantage which fluid corpuscles, seated in craters, with a grip upon the sides of the craters have.

We can readily understand how large atoms, either projecting far out from the atoms on which they are seated, or else having large intervals between the atoms which are seated upon them, will facilitate by their size the operations of cohesion.

Thus we can perceive that size must necessarily have a marked effect in bringing about cohesion of a kind which depends upon the interlocking of molecules.

And, indeed, we have already had at p. 202, a good example of the effect of size in bringing about cohesion in the group of halogens, consisting of four monovalent metalloid elements with atoms which differ from each other only in size.

We have seen there how iodine, which has the largest atom of the four, is a solid; how bromine with the next largest atom is a liquid; and how chlorine and fluorine, with the smallest atoms, are gases.

If necessary, any number of examples of phenomena pointing in the same direction could be given.

Instead, however, of multiplying examples to prove a point which is admirably illustrated by the behaviour of the halogens, it may perhaps be better to take in hand one or two anomalous cases which create difficulties in connection with this explanation.

The first of these is the fact that the gas hydrogen, when it combines with the gas oxygen, forms either water H_2O, or hydrogen peroxide HO or H_2O_2, both of which are liquids, instead of forming gaseous compounds, as it does when combining with the other elements, with one or two exceptions.

With our conclusions in regard to the form of the hydrogen atom, viz., that it represents a portion of the chips in the form of spherical segments detached from the spherical non-valent atoms of the inactive elements in making the valent atoms of the metalloid elements, we have no difficulty in understanding how hydrogen makes gaseous compounds even with heavy solid metalloids, such as iodine and antimony;

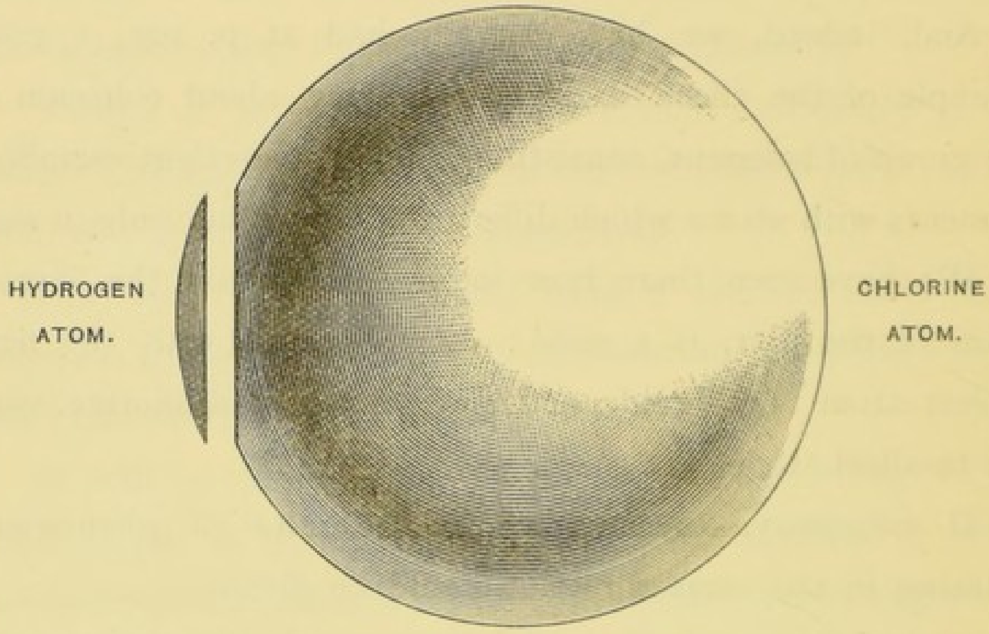

FIG. 3.

GASEOUS MOLECULE OF HYDROCHLORIC ACID, HCl,

Enormously enlarged, showing the hydrogen atom, with flat side turned inwards towards the chlorine atom.

for the hydrogen atoms simply replace the spherical segments detached in giving valency to the atoms of iodine and antimony, and thus restore the atoms of these elements in the way shown in Fig. 3, very nearly to their original spherical form, with which they are necessarily gases, as there is nothing to interlock in spherical atoms.

But with this view the water molecule, consisting as it does of two hydrogen atoms combined with a single oxygen atom, ought undoubtedly to be gaseous, for the two hydrogen atoms ought to replace the two spherical segments detached from the oxygen atom in the process of giving it divalency by making two flat places for depressed craters upon its surface. Consequently, the water molecule ought to be almost perfectly spherical in form, and therefore of necessity gaseous if our view of the form of the atom is correct.

The existence therefore of the water molecule in the form of a liquid, and not in that of a gas, creates a formidable difficulty in connection with our explanation of the form of the atom and of the nature of cohesion.

One thing, however, is quite certain, and that is, that the behaviour of hydrogen in forming liquid compounds with oxygen, and its next door neighbour fluorine, is quite anomalous; inasmuch as hydrogen generally forms gaseous compounds with the metalloids, and thus behaves exactly in the way it should behave if our estimate of its form is correct.

In view, then, of the undoubted fact that the behaviour of hydrogen when combining with oxygen to form liquid compounds is anomalous, it seems possible that when oxygen and hydrogen combine it is only the oxygen molecules which are broken up, and that the hydrogen molecules remain intact.

Hence, in water we shall have chains of molecules made up of oxygen atoms alternating with hydrogen molecules, or in other words the water molecule will consist of a single oxygen atom with a hydrogen atom seated on each of its craters, with its flat face turned outwards as in Fig. 4, instead of inwards as in Fig. 3.

With this explanation it is necessary to conclude that the fluid corpuscles in the craters of the oxygen atom are able to overlap the edges of the small hydrogen atoms, and

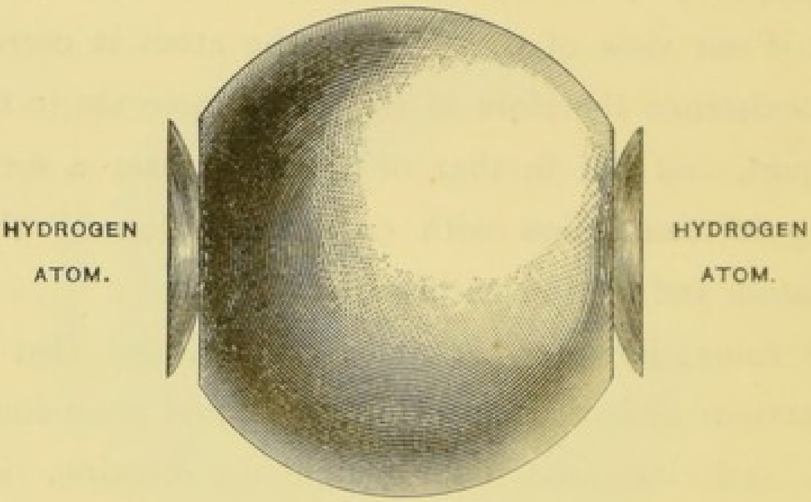

FIG. 4.

LIQUID MOLECULE OF WATER, H_2O,

Enormously enlarged, showing the two hydrogen atoms, with flat sides turned outwards away from the oxygen atom.

thus get a firmer grip of them than would be possible by holding on merely to their rounded surfaces.

Chemists are quite familiar in the case of oxygen with the idea of a chain-like union of atoms. There is, therefore, nothing unreasonable in the conclusion that a chain-like arrangement prevails amongst water molecules. In the case of water molecules of the form shown in Fig. 4, we may conclude that the chains of molecules will be very long, and being very long will naturally cling together for the same reason that elongated metal molecules cling together; and thus that it is in reality the length of the associated molecules which gives the mass its cohesion.

There is another case which creates a difficulty besides the case of water, viz., the occurrence of carbon disulphide CS_2, as a liquid and not as a solid.

In carbon disulphide we have a case in which the liquid state is reached by a loss of cohesion, inasmuch as carbon and sulphur, which combine to form carbon disulphide, are both solids; and thus, in it, we have a converse case to that of water H_2O, in which the liquid state is reached by a gain of cohesion, inasmuch as hydrogen and oxygen, which combine to form water, are both gases.

To explain the occurrence of carbon disulphide in the liquid state, we have recourse again to the chain of atoms which helped us in the case of the water molecule.

We can easily see why sulphur should form chains of atoms, because it is the divalent member of the second metalloid series, and thus differs from oxygen, which is the divalent member of the first metalloid series, only in having atoms of a larger size.

The form of the divalent atom, with two craters on opposite sides of the atom, manifestly favours the formation of a chain-like arrangement of the atoms.

The conclusion, therefore, is natural that sulphur owes its solidity to the adoption of a chain-like arrangement amongst its atoms, and thus, in fact, to immobility due to size, because its chains of molecules hang together.

The conclusion is also natural that carbon disulphide owes its liquidity to the fact of the chain-like arrangement of the sulphur molecules being broken up by combination with small carbon atoms.

According to this explanation, carbon, in combining with sulphur, plays exactly the opposite part to that played by hydrogen in combining with oxygen to form water (H_2O) molecules, inasmuch as hydrogen brings about the formation of a chain-like arrangement of molecules which did not previously exist, and thus converts a gaseous mass made up of a number of separate molecules into a liquid mass of associated molecules; while carbon, in combining with sulphur to form carbon disulphide (CS_2) molecules, puts an end to a chain-like arrangement of atoms previously existing amongst sulphur molecules, and, by severing the mass up into a number of separate molecules, converts it from a solid into a liquid mass.

It may be added that the conclusion that solid sulphur is arranged in chain-like rows of atoms is strongly supported by the well-known fact that the vapour density of sulphur shows that at a temperature of 500° C. its molecules are hexatomic, and that these chain-like molecules, consisting each of six atoms, are not dissociated completely into molecules of two atoms each until a temperature of 1000° C. is reached. It is, therefore, reasonable to conclude that in the solid state the chains of atoms are much longer than they are in the vapour at 500° C. Thus the correctness of our explanation is confirmed in a remarkable manner.

Hence it is plain that increase of size operates in the direction of increasing cohesion in the case of metalloid atoms which have depressed craters approximately uniform in size on surfaces otherwise perfectly spherical. But it is also plain that increase of size may operate in the opposite direction and diminish cohesion instead of increasing it in the case of metal atoms which have elevated craters approximately uniform in weight, and, therefore, also approximately uniform in size on surfaces otherwise perfectly spherical; because elevated craters which are all of one size will necessarily form much more marked features on small atoms than on large, since a small atom studded with projections of the same size as the projections on a large atom will relatively have a much more irregular surface than the large atom.

Hence small metal atoms may get interlocked with each other and cohere owing to the irregularity of their surfaces, in spite of smallness of size; while large ones may escape.

Accordingly, we find that the metal elements with small atoms, viz., lithium of atomic weight 7; beryllium of atomic weight 9; and boron of atomic weight 11; are all markedly solid, and thus form a remarkable contrast to the smallest of the metalloid atoms which are all gases, except the tetravalent carbon which, owing, as we may reasonably conclude, to the fact of its having four craters on the surface of an atom of weight 12, is too angular to be gaseous. And also we find mercury of atomic weight 200·5 as a liquid.

We can readily understand, with our explanation, the part that heat plays in chemical changes, since it represents as we have seen the action of an outflow of weak corpuscles, and thus "a mode of motion" tending to carry atoms, molecules, masses, and bodies, in the opposite direction to that in which the strong corpuscles tend to carry them; so that whereas the strong corpuscles endeavour to bind atoms together in molecules, the outflow of weak corpuscles, in the shape of heat, tends to force the atoms apart and break up molecules; and whereas the strong corpuscles tend to bind molecules together by cohesion when they have become interlocked by their atoms, the outflow of the weak corpuscles in the shape of heat tends to shake them apart by continued upheavals and finally projects them into space and scatters them.

Thus the function of heat is to loosen, dissociate, and scatter.

But by loosening and scattering, heat may plainly play an important part in chemical combination, both by setting atoms free and thus enabling them to make fresh combinations, and by relegating them to new situations in which they will come in contact with atoms of other kinds. For this reason heat is necessary in many reactions.

Since it is the presence of weak corpuscles which separates atoms, molecules, masses and bodies, from one another, it is plain that the weak corpuscles must be dislodged whenever atoms, molecules, masses or bodies are brought closer together. The outflow takes the form of heat when it is not brought about by a corresponding inflow of strong corpuscles.

Heat will, therefore, always be disengaged when atoms are brought close together in chemical combination, or molecules brought together by cohesion or gravitation. But the heat so disengaged may pass at once into the molecules of masses in which chemical combination is taking place, and be absorbed in dissociating the molecules, or melting or vaporizing the masses, and thus none of it be actually evolved.

In fact, the amount disengaged may be altogether insufficient to effect the amount of dissociation, or vaporization, which some reactions require, and it may be necessary then to supply additional heat from some other source. So that in place of obtaining a supply of heat from a process of this kind, heat may have to be supplied to enable it to go on.

CHAPTER VII.

LIFE.

"*This is what we call the 'levelling up' policy, and it has been expounded with great clearness by Professor von Nägeli. . . . . He can draw no line across the chain of being, and say that sensation and consciousness do not extend below that line. He cannot doubt that every molecule possesses something related, though distantly, to sensation.*"—James Clerk Maxwell, "Scientific Papers," edited by W. D. Niven, Vol. II., p. 761.

We have now got a universe built up of valent atoms of matter by the orderly operations of the strong fluid corpuscles which have collected the atoms, and fashioned with them great lunar and solar systems, and set them drifting in shoals through space.

The mighty orbs in these systems are in different stages of construction; some are solid, some liquid, some gaseous or nebulous. Some are hard and cold, some glowing with intense heat, some just beginning to grow warm, but all represent first of all fortresses built and held in an enemy's country, to cover further operations.

That is the aspect in which we have viewed their construction in previous chapters. We have now to consider them in another aspect, as parts of a great machinery for collecting matter.

We have seen in Chapter III. that the atoms of which matter is made up have, when valent, two principal forms, the pear shaped or elongated metal form, and the metalloid form in the shape of a chipped sphere.

We have seen also that the metal atoms with their elongated form, are easily laid hold of by the fluid corpuscles, and built up into solid masses. Indeed, so easily are the metallic atoms laid hold of that the whole of them, comprising some fifty or more different kinds, with the single exception of mercury, occur only in the solid state, at the ordinary temperature and pressure of our atmosphere.

The case is different, however, with the more nearly spherical metalloid atoms. These are laid hold of in some cases with much more difficulty by the strong fluid corpuscles. And accordingly we find that out of the fourteen metalloid elements known to us four are gases, and two of them, viz., oxygen and nitrogen gases, so permanent, that until the last few years all attempts on the part of the chemist to reduce them to the liquid state were futile.

And in addition to the metallic and metalloid atoms, there is the singular hydrogen atom, the smallest of all known atoms.

And besides all these, there are likewise perfectly spherical atoms without valency, from which the valent atoms are derived by a process of cutting down or building up, and of which the present representatives are Argon and Helium.

We thus learn that there are certainly several valent elements, viz., hydrogen, nitrogen, and oxygen, and in addition to them, the compound carbon dioxide CO_2, with all of which the strong fluid corpuscles find much difficulty in building.

At the same time we find that the permanent gases actually known to us exist in enormous quantities, especially in the envelopes of our earth, since the water in the oceans and seas which cover so large a portion of the earth's surface is a compound of hydrogen and oxygen gases, and the atmosphere which covers the whole is a mixture of oxygen and nitrogen. And seeing then that they are found in such enormous quantities on the very outside of our earth, it is not unreasonable to suppose that there are enormous quantities of them still free in space; of course, in a very highly rarefied condition.

Now in our solar and lunar systems we plainly have a most powerful apparatus for collecting attenuated gases. For photographs of flying bullets fully demonstrate the fact that a wave of compressed air is formed in front of a bullet flying at a speed of about 1,300 feet or upwards, as Professor Mach and, after him, Professor C. V. Boys have shown.—See *Nature,* Vol. XLVII., p. 420.

But if a rifle bullet, travelling at a speed of 1,300 feet per second is able to compress the air in front of it, it is reasonable to suppose that our earth which, according to astronomers, is travelling at a speed of nineteen miles per second at least, and therefore some sixty times as fast as a bullet, will produce compression amongst the gases, if there are any, in space, however attenuated they may be.

And since laboratory experiments show that it is by compression that gases are condensed, we are arguing from phenomena and not feigning hypotheses in assuming that in our earth, and in the other planets and heavenly bodies which are moving through space at the tremendous speeds which astronomical observations assign to them, we have an arrangement capable of condensing any gaseous matter which has escaped condensation, and collecting it in atmospheres.

And if individual planets and other heavenly bodies, as they fly through space, can condense and store up attenuated gases, then it is plain that in a system of such bodies such as is our solar system, which consists of a great central sun drifting through space, under a proper motion, with an attendant company of planets and lunar systems spread out all round it in a plane at right angles to the path by which it advances, under its proper motion, we have a vast machine for collecting gaseous and other matter from space. In this machine, the planets and lunar systems, with mountain chains piled high upon their surfaces, are like great wrinkled fists stretched out to enormous distances on all sides, and whirled round and round so as to clutch all loose masses and gaseous atoms which come in their way. And in the myriads of such systems with which space is strewn we have, as shown by phenomena, an efficient arrangement for sweeping space clear, and gathering up all matter that has escaped condensation.

In this connection we may point out that Helmholtz has made the following remark—"The earth and the planets have for millions of years been sweeping together the loose masses in space."—"Popular Lectures on Scientific Subjects," 2nd series, translated by Atkinson, p. 169.

We thus learn that in our solar system, with its company of planets whirring round the great sun as it drifts through space, we have a machine for sweeping up all loose matter whether in the gaseous or solid state, which had previously escaped the operations of the strong fluid corpuscles.

And we gather also from the fact that our own atmosphere is a mixture of gases, that gaseous matter when swept up is collected in the first instance in the atmospheres of the planets. But the atmosphere of a planet, vast as it appears to us, is exceedingly small in comparison with the immense extent of space swept by the planet even in a single year in its journey of many millions of miles round the sun.

Hence, if a planet meets with any considerable quantity of gaseous matter in space, the storage room in its atmosphere will very soon be filled up, and then it will become useless as a part of a machine for collecting gaseous matter. For it will simply drop all that it gathers after its storage room has been quite filled up.

A planet, therefore, will soon become clogged and useless as a working part of a machine for sweeping up gaseous matter if it is not provided with some means of packing up and stowing away gaseous matter, after such matter has been collected in its atmosphere.

It requires, therefore, to be provided with machinery for constantly packing up and stowing away portions of the gaseous matter in its atmosphere, so as to make room for all the gaseous matter it picks up in its journey through space.

Now we find that machinery of the very kind required is provided in plant life of all kinds, from the lowly herb carpeting the surface of the ground up to the mighty tree towering up some hundreds of feet into space from points of vantage on mountain sides.

We have likened the planet to a great fist thrust out into space, and clutching all loose matter which comes in its way, but we may liken the leaf to an open hand held out by a great arm or limb, as we sometimes aptly call the tree branch, in order to seize the gaseous matter of the atmosphere.

And very tight is the grip of the leaf when once it gets firm hold of the matter it wants; for gaseous molecules of carbon dioxide CO_2, and vapour molecules of water H_2O are not released until they have been squeezed together into solid starch molecules $(C_6H_{10}O_5)n$, and with all the excess of oxygen atoms squeezed quite out of them are ready for use in the further building operations which the tree conducts. For a mighty builder, is, a giant tree. Moreover, there are some points about its building operations which concern us very closely.

The first point about the structures, which the tree along with all other forms of plant life builds, is the fact that they are built up almost entirely of atoms obtained from gases in the atmosphere—in fact they are built up almost entirely of the starch molecules moulded by the leaves, with the addition of water and of a small proportion of molecules of several salts obtained by the roots from the earth, and of some other atoms obtained from the gases in the atmosphere.

The next point to notice about the structures built by the tree, is the fact that they are built in the very way in which all our structures so far have been built, inasmuch as they are built by the action of a fluid which carries the materials by its streams, and brings them together in pools. The fluid in question is water in the form of sap, circulating in the tree and bearing with it starch and other molecules in solution; the pools are the cells in which protoplasm, albumen, and other composite molecules are elaborated when the necessary materials are brought in by streams of sap.

And the last point to notice about the structures built by plant life is the fact that many of them are extremely complex and cannot be built up by any of the processes by which inorganic compounds are obtained, though organic compounds of a less complex kind can be prepared. Indeed, so complex are the molecules of some substances, such as protoplasm, albumen, and many others, that chemists have not as yet been able to make out their precise composition.

We thus learn three things in regard to the structures built by plant life, viz., first, that they are built mainly out of the gases in the atmosphere; secondly, that they are built up in the same way as other structures in the universe; and thirdly, that they cannot be built up by any other process.

Plant life, therefore, represents a machinery for removing gaseous matter from the atmosphere, and packing it up and stowing it away, and thus making room for more gaseous matter to be taken in. And thus it represents also an advanced stage in the conflict between strong and weak corpuscles over the possession of atoms of matter, in which chemical combination, cohesion, and lunar and solar system building are the previous stages, and organised resistance has broken down, and scattered bands only have to be dealt with.

It will, therefore, naturally occur to us to inquire how it is able to build such substances.

It clearly represents an invasion of strong corpuscles, for it dislodges weak corpuscles, and builds in the face of the resistance of these corpuscles. But we notice that it always obtains the materials with which it builds from composite molecules. It takes, as we have seen, the composite carbon dioxide molecule CO_2, and strips off the two oxygen atoms from the carbon atom, and it takes the composite water molecule H_2O, and strips the two hydrogen atoms off the oxygen atom, and then it builds up with the carbon and hydrogen atoms so obtained, molecules of starch $(C_6H_{10}O_5)n$, and afterwards the complex protoplasm molecule, which is so complex that no chemist has hitherto been able to determine its precise composition.

Now in stripping off the two oxygen atoms from a carbon dioxide molecule, and the two hydrogen atoms from a pure water molecule, both of which are operations of considerable difficulty, life has to dislodge the hold of the strong corpuscles which bind the oxygen atoms to the carbon atom in the carbon dioxide molecule, and the hydrogen atoms to the oxygen atom in the water molecule.

And in order that it may do this, and at the same time be able to build as it does, molecules such as those of albumen and protoplasm, which are more complex by far than any built by strong corpuscles by chemical combination, it must plainly have a stronger tendency to lay hold of atoms even than strong corpuscles have.

Hence, we require for the advent of plant life to have a portion of the corpuscles which are still outside the domain of the weak fluid, impressed with a tendency to lay hold of matter (Definition II. *b*), in a stronger form even than that in which the strong corpuscles have acquired it. We shall, then, have three kinds of fluid corpuscles, viz., weak, strong, and stronger.

The stronger corpuscles, though comparatively few in number, will, under the stronger tendency to lay hold of atoms which they have acquired, be able to dislodge, and thus make their way in the stream form through all the other corpuscles, whether of the weak or of the strong kind, which intervene between themselves and the nearest atoms of matter.

The streams of the stronger corpuscles will, under their stronger tendency to lay hold of atoms of matter, make (Law III.) for the bodies in which matter has been collected by the strong corpuscles, and laying hold (Postulate

VII.) of the molecules which come first in their way, viz., the water-vapour molecules (H_2O), and the carbon dioxide molecules (CO_2), in the atmospheres of those bodies will build up with them separate bodies on their own account in the shape of trees, shrubs, herbs, etc., which the strong corpuscles themselves are unable to build. In this way the stronger corpuscles reinforce the strong corpuscles in the particular direction where help is required. And the strong corpuscles give way to them and allow them to break up the carbon dioxide and water molecules which they had previously formed, in order that the stronger corpuscles may build the complex living forms which the situation requires.

Thus plant life, like chemical combination, cohesion, and gravitation, is a stage in the conflict with the weak corpuscles over the possession of atoms of matter, and like the other stages, results in the building of structures in the shape of separate bodies, each of which is a mixed pool, consisting partly of the stronger corpuscles and partly of weak corpuscles. Very different, indeed, are the structures built by plant life from those built by chemical combination and cohesion, and quite separate therefrom, though growing upon and rooted in them, but still built on the same orderly plan as those, with cells and bodies, or collections of cells corresponding to the molecules and masses or bodies in the other structures.

No breach of continuity so far is discernible.

The machinery of plant life, like that of the solar systems which it supplements, would soon, however, get clogged and useless if left to itself.

For giant trees, though each forms a great reservoir for storing up hydrogen and carbon, and each sheds annually, when in full vigour, a great mass of material elaborated from the gases of the atmosphere, in the shape of leaves, flowers, and fruit, to be stored up in the earth, will not go on growing for ever; but, after they reach a certain size, gradually lose their vitality, and in the end cease to grow altogether.

They are, then, great pools filled up with carbon, hydrogen, oxygen, nitrogen, and other atoms drawn from the atmosphere, and packed up and stowed away, but, nevertheless, pools which can take no more and which are worse than useless as machines for collecting matter, since they take up room required for growing trees.

If cut down and broken up, the hard portions will mingle with the soil of the earth, and add their quota to the great stock of hydrocarbons mixed with the soil. But standing when dead they represent clogged machinery.

And if there were no agency but plant life at work on the earth, the whole surface of the earth would, in course of time, become covered with dead trees, herbs, and grasses, with branches and stalks matted closely together, and defying wind and storm to bring them down, in the absence of insects to cut into them, or fungus or bacillus to set up decay; unless, indeed, the whole mass took fire, and was consumed. In that event, however, the gases collected so sedulously by plant life would once more be set free in the atmosphere, and all the work of plant life undone.

In fact, the whole sweeping machinery of plant life and planet would again become clogged and useless.

Some agency is required, therefore, to gather in the stores collected from the atmosphere, and packed up by plant life; and to distribute the material over the earth in a form in which it can mingle with the soil.

And we find that the necessary agency is provided in animal life, if we include in that term all forms from bacillus up to elephant, which are unable to manufacture albumen or starch from the gases of the atmosphere, and are obliged to obtain their supplies from plant life.

Now plant life, as we have seen, takes forcible possession of the composite molecules, viz., carbon dioxide CO_2, water H_2O, etc., which are built up by chemical combination, and uses them to elaborate complex molecules of starch, albumen, protoplasm, cellulose, etc. So, too, we find that animal life in its turn takes forcible possession of the starch, sugar, albumen, and other molecules elaborated by plant life, and either utilizes them in the preparation of complex molecules of gelatine, fibrine, globulin, keratin, etc., or strews them over the surface of the ground, after breaking up the masses in which they are collected.

Again, plant life seizes, as we have seen, its supplies of carbon dioxide and water, etc., by branches spreading out into leaves, which take in gaseous matter from the atmosphere, and by roots covered with root-hairs, which take up water from the soil; and with it roots and branches are attached to a trunk or stem.

So, too, we find that animal life is provided with root-like or branch-like limbs by which to reach and seize its supplies, and also with modified limbs in the shape of jaws for cutting or breaking up its supplies of food. And these limbs are attached to a trunk or body.

Again, plant life utilizes only a portion of the supplies of carbon dioxide, water, etc., which it seizes, and liberates the remainder in the form of free oxygen, to combine with volatile hydrogen, which is too mobile to remain in an atmosphere such as that of our earth except in combination.

So, too, animal life utilises only a portion of the vegetable matter which it seizes, viz., the soft parts, and rejects the hard parts. At the same time, the hard parts are broken up in order to get at the soft, and either strewn at once over the soil, or taken along with the soft into a sac or body cavity where they are mixed up with water and digestive juices, which dissolve out the soft parts while leaving the hard unaltered.

The liquid portion of the contents of the sac is then absorbed into the frame of the animal, while the solid portion, in a broken and macerated condition, is extruded in a form in which it can readily mingle with the soil.

Thus animal life, by cutting up the hard parts to get at the soft, is distinctly an agency for gathering in the stores of materials collected by plant life from the atmosphere of planets, and putting these stores away in the earth.

Again, we have seen at p. 222, that plant life, inasmuch as it takes forcible possession of the composite molecules built up by the strong corpuscles by the process of chemical combination, and builds with them exceedingly complex molecules of kinds which cannot be built up by any known process in chemistry, requires for its development fluid corpuscles which have acquired the tendency to lay hold of atoms of matter (Definition II., *b*), in a form stronger than that in which it has been acquired by the strong corpuscles, but otherwise similar in all respects both to strong corpuscles and to weak corpuscles. And that, therefore, we require to have three kinds of corpuscles, viz., weak corpuscles, strong corpuscles, and stronger corpuscles, differentiated from each other solely by differences in the strength of the tendency to lay hold of atoms of matter (Definition II., *b*), possessed by all, but found in the weakest form in the weak corpuscles, in a strong form in the strong corpuscles, and in a stronger form in the stronger corpuscles. Then, too, we have seen that the order in point of strength must also be the order in point of time, viz., the weakest first and the strongest last ; and that the weak corpuscles must be the first to acquire the tendency to lay hold of atoms of matter, otherwise they would not get possession of matter at all. Then the strong corpuscles must be the next to acquire the tendency, so that they may invade the domain in which the weak corpuscles hold atoms of matter in their possession, and collect the atoms, step by step, in planetary and solar systems, which sweep up loose atoms and masses of matter as they drift along down the invading streams of strong fluid corpuscles, constantly pouring into the domain of the weak fluid. While the stronger corpuscles must acquire the tendency last of all, because their part is to supplement the action of the moons and planets as instruments for sweeping up loose atoms.

But now we have another agency, viz., the agency of animal life capable in its turn of forcibly dispossessing plant life of the complex molecules of albumen, protoplasm, cellulose, etc., which it builds up, and utilising the materials so obtained in the construction of other complex molecules, such as gelatine, fibrine, globulin, keratin, etc., which plant life is unable to build.

Hence we require for animal life corpuscles of another kind, with the tendency to lay hold of atoms of matter (Definition II., *b*) in the strongest form; and therefore now four kinds of corpuscles, viz., weak, strong, stronger and strongest, corpuscles differentiated from each other solely by the tendency to lay hold of atoms of matter.

A portion of space still smaller even than that required for the corpuscles of plant life will, however, suffice for those of animal life, since the amount of building which it does is exceedingly small in comparison with the amount done by the strong corpuscles, or even with that done by plant life. But though its streams are few in number, they will be flowing under the tendency to lay hold of atoms of matter in the strongest form, and thus will easily dislodge all other corpuscles in their path, and be able to make straight for the great bodies in which atoms of matter are collected (Law II.); and if they find any bodies which have been built up by plant life on the outside of these great bodies, will be able forcibly to take possession of them, and convert them to their own uses.

Thus, animal life represents a further stage in the progress of the invasion of the domain of the weak fluid by corpuscles of the strong kinds.

CHAPTER VIII.

CONTROLLING AGENCIES.

"*And these things being rightly dispatched, does it not appear from phenomena that there is a Being incorporeal, living, intelligent, omnipresent, who in infinite space as it were in His sensory, sees the things themselves intimately, and thoroughly perceives them, and comprehends them?*"—Newton, "Opticks," 3rd edition, p. 345.

WITH herbivorous animal life, the series of building operations conducted by the fluid corpuscles come to an end.

In the course of these operations the valent atoms of matter are, as we have seen, first built up into molecules by chemical affinity; then molecules are built up into masses, and finally into the heavenly bodies by cohesion; and then heavenly bodies are built up into lunar and solar systems by gravitation.

We have seen also that the solar systems thus built up constitute each with its company of lunar systems revolving round a central sun at right angles to the course along which that sun is drifting a vast machinery for sweeping up loose atoms, molecules, and masses, which have escaped the operations of chemical affinity, cohesion, or gravitation. We have seen, too, that in connection with the sweeping machinery thus provided by the solar systems, plant life comes in, and taking in hand the matter swept up builds with the gaseous molecules on which cohesion can get no hold exceedingly complex albuminous molecules, thereby bringing the gaseous molecules within reach of cohesion, by which they are fashioned into plant cells and plant bodies; and thus that plant life supplements the operations of the sweeping machinery provided by the solar systems. Lastly, we have seen that like as plant life comes in to supplement the sweeping operations of the solar systems, so herbivorous animal life comes in to supplement the building operations of plant life by gathering in the materials which plant life collects, and thus completing the work.

But though the building operations of the fluid corpuscles end with herbivorous animal life, yet the activities of life by no means end with it ; for we have carnivorous animal life exceedingly active upon our earth, and withal, playing—if we include under the term all flesh-eating things from bacillus up to mammal—a most conspicuous part. We have therefore, now, to make an attempt to ascertain what part carnivorous life in reality plays.

It is manifest at once that carnivorous life plays no subordinate part, but, in fact, dominates the whole of life. That this is so is clear, for the giant elephant and mighty rhinoceros, which can hold their own against any of the carnivora in single combat—whether the assailant be lordly lion or crafty tiger—yet succumb to the attacks of the microbe hosts, when weakened by an improper diet, by exposure, by injuries, or by old age.

In fact, it very soon becomes clear that the part carnivorous life has to play is that of enforcing against herbivorous life the provisions of the stern law of "the survival of the fittest" by destroying the weakly, the sick, the wounded, the aged, and the unwary; also that of keeping herbivorous life within proper bounds by destroying all forms found straying into tracts where they are at a disadvantage, either from their coats being of the wrong colour or being too thin to afford adequate protection, or from their limbs being badly shaped for the work they have to do, or from their bodies being unfitted to assimilate the food supplies available for them, or from any other cause by which they are enfeebled and prevented from escaping from or resisting their foes, or eluding observation.

In short, we find carnivorous life to be a controlling agency, charged with the duty of keeping the machinery of herbivorous life in full working order.

It is necessary, however, in taking this view of carnivorous life, to separate the nobler forms which kill for themselves and to which alone this view applies, from the ignoble forms, which feed on carrion and are mere scavengers, playing a part subordinate to that played by the nobler forms.

With carnivorous life in its nobler forms, from the pathogenic bacillus with its poisonous secretions up to the tiger and the lion with their formidable teeth and claws, we pass from work to control.

And for it we need a supply of corpuscles with the tendency to annex in a stronger form than that in which it is present in other corpuscles; so that being completely masters of the situation they may be able to advance in the direction of the heavenly bodies in which atoms of matter are more condensed than they are elsewhere, and taking forcible possession of such animal bodies as come within their reach on the surfaces of the heavenly bodies, convert the matter within them to their own purposes.

Thus carnivorous life in its nobler form will perform its function of control by annexing and converting to its own use the matter in such of the forms of herbivorous life as come within its reach; and these will naturally be the less active and the less wary forms.

Hence the aged, the sickly, the maimed, the deformed, and generally the feeble and the sluggish, will be weeded out by it, and utilised in building up the forms which it affects. We are able in this way to arrive at a controlling agency without any breach of continuity, and from it can pass at once to another form of control, viz., that exercised by man.

Man is both herbivorous and carnivorous, but possesses no organs for elaborating poisonous secretions within his body for employment in the destruction of his foes, or in the capture of his prey, such as are possessed by the lowlier forms of carnivorous life. Neither has he teeth nor claws suitable for disabling his foes, such as the higher forms of carnivorous life have. And yet this feeble creature, man, with weak limbs, weak jaws, weak powers of digestion, compelled to light fires in order to cook his food and warm his ill-clad body, has absolute control not only over herbivorous life, but over carnivorous life also, by means of the weapons which he fashions with such skill and cunning that no living thing can cope with him.

Here, then, we have control exercised not by superior bodily strength, or superior offensive bodily powers, but by superior knowledge by superior consciousness.

To arrive at man's true position we must analyse the tendency to lay hold of matter by which all fluid corpuscles in our universe are actuated to a greater or less extent, according as the tendency is relatively strong or weak in them.

And when we proceed to analyse this tendency we perceive at once that it must have two components, viz., consciousness and desire.

It is perfectly plain from our ordinary experience that there can be no tendency to lay hold of matter unless there is first a consciousness of the presence of matter, and secondly, a desire to lay hold of it. And it is manifest that in all the ordinary forms of life activity is mainly due to desire; and it is in the intensity or fierceness of desire that one form excels another, and carnivorous life has the advantage over herbivorous life.

In man, however, it is consciousness which predominates, and it is in consciousness and not in the fierceness of desire that he excels. It is, in fact, to consciousness of his own needs, and of his own weakness, that man's activity is due principally, and to a less extent to desire.

Hence we perceive that man is on a totally different footing from other forms of life, inasmuch as it is desire which lends them their strength, while man's strength lies in his consciousness.

Therefore, human life represents control by intensified consciousness, just as carnivorous life represents control by intensified desire.

But manifestly intensified consciousness will not have the tendency to annex in the same strength as intensified desire. It will know the whereabouts of matter better but will not be able to displace intervening corpuscles, and advance upon it with irresistible strength, in the same way as intensified desire can do. Intensified consciousness will thus be at a disadvantage in any contest with intensified desire over the possession of matter. In fact, in such a contest it cannot possibly win, except by turning its superior knowledge to account, to attack intensified desire under conditions in which for want of sufficient knowledge it cannot employ its superior strength to full advantage, or by turning it to account to provide itself with weapons which make up by the mechanical advantage supplied by sharp edges and points, for the physical disadvantage under which it labours from want of strength.

For the development of human life, therefore, a supply of fluid corpuscles is needed with desire of the same strength as in the fluid corpuscles by which herbivorous life is developed, but with consciousness greater by a long way than the consciousness existing in corpuscles of any other form.

Under such circumstances man would commence his career as an animal of the herbivorous kind with an intensified consciousness, but otherwise not differing from herbivorous animals generally, because his consciousness would not come into play at the outset.

This is manifestly in accordance with all that we can learn in regard to the development of man from his frame and from his habits. His rounded jaws and the wide palms of his hands plainly proclaim that he began life as a fruit-eating animal ; and his bare skin tells of a steamy tropical climate such as is to be found in river valleys in tropical regions now.

In such regions, the buffalo loses the coat of hair which it has during the first few months of its life ; and the elephant is hairless, in marked contrast with its hairy relative whose remains are occasionally found embedded in ice in Arctic regions. The rhinoceros, too, and the hippopotamus, are hairless.

In such company man's naked body would be quite in keeping with the rest.

But man, with his consciousness, was not contented with his lot, but took to making experiments probably in every direction, but certainly in his food. In the course of his experiments he discovered that he was able to assimilate and digest cooked food of kinds which he could not digest in the raw state. He could thus, by his own act, fit himself to live on food which by nature he was unfitted to eat, and could by habit acquire a liking for many kinds of cooked food.

The animal is under the closest restrictions as to its eating, being instructed by its likings and dislikes as to what it should eat and what it should avoid, and prevented by a death penalty enforced against it by sickness or death by poison from transgressing the command not to eat impressed upon it by its dislikes. It is, as we have seen, mainly by eating that the animal performs the part allotted to it in the universe, of tending plant life and harvesting the stores which plant life collects, if it is herbivorous, or if it is carnivorous, of tending herbivorous life and keeping it under due control. And each form has a certain range of diet allotted to it which it cannot transgress without being poisoned so far, at all events, as to be made sick or to be enfeebled and thus prevented from escaping its foes, if not actually killed outright.

And since one form eats with avidity what is rank poison to another, we see that each has its allotted range, and is prevented from interfering with others. Thus, the whole of life gets a due amount of care and attention.

Man, as we have seen, has, like the rest, a range assigned to him as an animal of the herbivorous kind, and a very restricted range, confined in fact to the fruits, nuts, succulent shoots and roots, which he is able to eat without cooking. But as an eater of cooked food with tastes acquired by habit for flesh, and grain, and roots of many kinds, he has a world-wide range, attained, however, by rebelling against a plain command not to eat impressed upon him as an animal, and involving transgression of the bounds assigned to him.

Man then has, from an animal point of view, rebellion printed on his forehead in the boldest of characters. And it is manifest that the penalty of rebellion has at least in part been visited upon him. Take for example the fact that man cannot trust his appetite to guide him aught in the matter of eating and drinking.

The wild animal follows its own fancy in the matter of eating, and finds that its appetite and its likings and dislikes guide it aright.

But man, with his acquired tastes, has constantly to exercise self-restraint in the matter of eating or drinking, and can in no wise trust his inclinations to guide him aright. The result of following his appetite will be suffering from indigestion, or sickness, or perhaps the development of a confirmed habit of indulgence, ending too often in a drunkard's death. In fact, a man's own desires will lure him to destruction unless resisted—will, if given the rein, drag him down irresistibly to destruction.

Here, then, is a marvellous spectacle! Here we see man at war with himself, obliged to resist and restrain himself. Here we have man his own enemy, as the saying goes. Here the spectacle is that of a man drinking himself to death, rushing open-eyed to destruction.

The wild animal has to be on its guard against enemies outside, but is at peace with itself, and can trust itself implicitly. While man has the foe within, and is at war with himself.

Here, truly, is a notable difference, and it comes of rebellion. It comes in fact from having acquired tastes which grow upon a man instead of natural instincts.

Look, too, at all the misery from cold, from insufficient clothing and want of proper shelter; from grinding poverty, and from overwork, or from unhealthy work, to which a great part of mankind is subjected.

This misery is the penalty of rebellion, brought on man by his own act in overstepping the bounds assigned to him, and bringing himself under unnatural conditions. It comes of man's transgression.

We have seen some of the effects upon himself of man's rebellion; let us look now at some of the effects of that rebellion upon Nature.

Look then, in Eastern lands, at the bare, baked hills and scorched plains, which once were covered with noble forests, but now are dry and desolate, because man's imperious need of fuel for cooking his food and fashioning weapons and implements, and of timber to provide shelter for himself against wet and cold, has cleared away their forests. The result of clearing away all the forests is to drive the rain clouds aloft, so that they sail over these heated tracts high up, instead of coming low down into the cool shade and dropping their refreshing loads amongst trees stretching out their limbs to detain them, as would have been the case if the forests had not been cleared away.

These bare, mute, desolate, brown hills, once green, once gay with brightly coloured flowers, once resonant with song and call and chatter of merry birds, and teeming with eager life, have they not partaken of man's transgression?

These plains, sand-strewn and buried under the dry *debris* from hillsides which have lost at man's hand their protective forest covering, and are now exposed to frost and blast and torrent; these plains, now deserted by the perennial streams which once were fed by springs amongst the forest-clad slopes, but now are represented chiefly by desolating floods which at rare intervals sweep down when a storm-cloud bursts amongst the bare hills; these barren desert plains, once watered well and covered with an unbroken stretch of forest tangled with cane and creeper, have they not suffered from man's transgression?

Then think for a moment of the privation and suffering inflicted on bird and beast by man's clearances and drainage works. These clearances for food crops change the whole face of a country, and leave no proper shelter in inclement weather, and no feeding ground for many of the birds and beasts which cannot find a subsistence in cornfields.

The bird and the animal suffer from exposure in inclement weather when their forest homes have been cleared away; and from privation when their feeding grounds are drained, and the trees and bushes which furnished their food supplies are cut down. In fact, the clearances which bring food in plenty, and comfort to man bring want and suffering to the beast and bird whose homes are invaded and food supplies cut off. They retreat before the invader, but to regions where the struggle is harder, and ever increases in stringency as they go back and back; and in the end they perish when a hard winter comes, or a season of prolonged drought, or when further retreat is impracticable.

Shelterless, famished, exterminated, the wild beast and bird in many cases drink to the dregs the cup of suffering and death, which is the penalty of man's transgression.

We have thus learnt that man has thrown up the part of a denizen in warm sheltered river valleys, or in hot moist climates which he was as an animal fitted by nature to play, and taken upon himself a role of a cosmopolitan character. In order to play the new part which he has taken upon himself in open rebellion, he has transgressed the bounds assigned to him, and occupied regions where he is unfitted by nature to live. Being unable to live naturally in these, for him, inhospitable regions, he has had to supply his wants unnaturally at the expense of other forms of life which have consequently had their operations to a great extent disorganised by him.

We have seen that man burns up the trees in order to warm himself, or cook his food, or make weapons. In doing this he takes the great stores of carbon, hydrogen, and nitrogen, which have been collected from the gases in the atmosphere by plant life, and again returns them to the atmosphere, and thus undoes the work of the past.

The work of the past is thus undone, and then, too, the work of the present is hampered and hindered in many ways by the clearances which man makes in the forests on the hills to supply himself with fuel and timber, and in the forests on the plains in order to build towns or to make room for his grain crops.

Man, however, has not contented himself with burning up the stores of material collected by plant life on the surface of the earth in the shape of forests, but having got rid of most of the forests has now gone down below the surface of the earth, and is disinterring the stores collected ages ago by plant life, and laid up in coal seams, and is busily engaged in burning them up too.

Man is, therefore, as an animal a complete anomaly. Instead of forwarding as other forms of life do the work of collecting from the atmosphere, and storing up in the earth matter which would otherwise escape the building operations of the strong corpuscles, man takes the stores of matter built up by plant life, and dissipates them in order to obtain heat for cooking his food or warming himself, or for his other unnatural wants; unnatural, that is to say from an animal point of view. And in addition to this he largely disorganises the work of life in the present and brings it sometimes almost to a standstill in some localities.

What useful purpose then does man serve upon the earth?

The answer to this can hardly be other than that he serves no useful purpose as an animal. This is plain speaking. But if we would understand the situation we must not blind ourselves to obvious facts.

Man then is a controlling agency which has taken control upon itself, and thus in transgression. The work he does as an animal is that of a rebel, work of disorganisation, work of undoing, mainly though of course not entirely.

But the penalty for rebellion is death. There can be no mistaking that fact in view of the elaborate machinery provided for giving effect to that penalty, and of the dreadful array of poisons, of fangs, and of claws provided for exacting it.

In man's case, however, the full penalty has manifestly not been exacted. For instead of being cut off, mankind is increasing and multiplying, and overspreading the earth. And at the present rate the whole face of the earth will shortly be cleared of its forests and occupied, and the coal seams all dug out and burnt up.

Indeed, before the world is older by many centuries man will have quite undone the past work of plant life in collecting matter from the gases of the atmosphere, packing it up in solid form and stowing it away in the earth; and also will have hampered greatly future work in the same direction.

How can we reconcile such a state of affairs, which represents the triumph of the weak corpuscles in their work of opposition and resistance over the strong, with the fact that elsewhere the weak corpuscles are being driven out except at some points where they retreat in such strength as to be able to overpower for a time the advance of the strong corpuscles in some particular direction?

There is one point to notice in connection with this state of affairs, and that is the fact that all races of mankind are not increasing. In fact, it is practically the Aryan family only, and the European branch of that family, which is rapidly increasing. Other races are dwindling, or at best holding their own.

And there is also one other point to notice, and that is the fact that the races which are increasing or holding their own are distinguished by having, deeply ingrained in their nature, a love of knowledge.

Thus, the race which is increasing with such rapidity, viz., the European branch of the Aryan family, is distinguished above all others by the eager search for knowledge which it prosecutes.

And we note also that the Hindoo and the Chinaman are both diligent students of ancient lore, though they have lost the faculty of making fresh acquisitions of knowledge.

We find, moreover, that the same conditions obtained in the past, and that nations increased when they were in earnest in the search for knowledge, and dwindled away when they grew wealthy, self-indulgent, and careless about the pursuit of knowledge.

There are notable instances of this in the cases of Egypt, Babylon, Phenicia, Greece, and Rome, and we may also include the Arabs. These all at one time were eager in the pursuit of knowledge, and then increased and spread, but afterwards grew careless and dwindled away.

We find, too, that by the labours of these successive races a vast amount of knowledge has been stored up.

We gather, then, that man has some other part to play than that of an animal, and in fact that the real work of man is to collect and store up knowledge, just as the other forms of life collect between them from the atmosphere matter which otherwise would escape the operations of cohesion, and then pack it up in the solid form and finally stow it away upon the earth.

And we find that man, or at all events one branch of mankind, and that the branch which is increasing and spreading with great rapidity, is now actively engaged in collecting and storing up knowledge. At the same time, we find that this branch of mankind is collecting and storing up knowledge by dissipating the stores of material collected by plant life in the past, *i.e.*, by burning up in its locomotives, steamships, and machines, the coal which plant life stored up.

Indeed, so rapidly is this branch of mankind spreading, and so actively is it engaged in dissipating the stores of material collected by plant life, that ere many more centuries are over it will, if unchecked, have cleared, as we have just been showing, the face of the earth of its forests, and occupied it with its fields, and burnt up the whole stock of coal stored up in the earth.

We are compelled to conclude, therefore, that the work which man does in storing up knowledge is of more importance than the work done by all the other forms of life put together, seeing that man's work is done by undoing the work of the other forms of life.

But if this view is correct, it follows of necessity that the conflict between strong and weak corpuscles, which has resulted in the building up of this universe of ours, must have other issues than that of getting possession of matter to which the building of our universe is due.

For man does not help forward the building of the universe, but instead employs himself in pulling down a part of the building.

In this connection we may notice that man in acquiring knowledge has to encounter strenuous opposition not only from enemies outside, but also from enemies within himself. The animal has enemies outside, but man, as we have seen already, has a foe within constantly urging him to use his knowledge for his own destruction, by enjoying himself to excess, and giving himself up to intemperance, gluttony, or debauchery. And he has to maintain a ceaseless watch against influences of this kind, otherwise he will give way as thousands of weak souls do, and, losing all power of self-restraint, rush headlong to a drunkard's end.

On the other hand, he has also within himself other influences constantly urging him to deny himself, and live a sober, temperate life. The most powerful of these is the voice of conscience, as we call it.

Hence, man with his store of knowledge is the battle-ground of two opposite sets of influences, the one drawing him over to the side of law and order, and striving to utilise him in building up a family and a nation, and the other impelling him to the side of disorder and anarchy, and seeking to get him to destroy himself, or to destroy others, and break up family life or national life.

The battle over man is, in fact, the same in kind as that over the atom.

The atom, as we have seen in the three preceding chapters, is the battle-ground of two sets of corpuscles, and is laid hold of by one set of corpuscles and built up in an orderly and regular way into molecules and masses in the face of strenuous resistance and opposition from another set of corpuscles, which often succeed in breaking up molecules and masses after they have been built up. And so it is, as we have just seen, with man. He is drawn towards the side of law and order by one set of influences, and built up into families and societies; and at the same time urged by another set to give himself up to disorderly courses and to lawlessness and excess, and employed to break up families and societies.

We are not to conclude, however, that the end and object of the conflict in the case of man is the building up or breaking down of families and societies. For manifestly the case is not so.

The conflict is over the individual man. The family and society are simply means of getting and keeping the individual man. It is so with the atom. The conflict is over the individual atom. The molecule and the mass are merely means of keeping the atom when brought in.

Thus it is apparent that the conflict over man is the same in kind as the conflict over the atom.

The difference in the two cases lies not in the nature of the conflict, but in the issue.

The issue of the conflict over the atom is here present before us in a vast collection of atoms brought in and arranged in a regular and orderly way, in a universe in which law and order are supreme though their rule is not unresisted. The issue of the conflict over man is not here.

Man, as we have seen, is on the wrong side in the conflict over the atom. He is a scattering agency, and not a gathering agency. There could be no object in building him up into families and societies, and thus strengthening his hands, if the issues in his case were here. He would simply be strengthened for the work of undoing.

So far, then, as we have been able to make out, man gathers nothing but knowledge. He is a gathering agency in respect of knowledge, though a scattering agency in respect of matter. But now comes this point. Being possessed of a store of knowledge, man is not like the atom, wholly inert and unconcerned in regard to the conflict which goes on over him, but fully alive to the situation.

When he yields to the influence of the gathering agencies drawing him to the side of law and order, he does so consciously, and deliberately disregards the allurements of the scattering agencies urging him to the side of disorder and excess.

And so also when he yields to the allurements of the scattering agencies and takes to disorderly courses, he does so consciously, and deliberately stifles the appeals of the gathering agencies. Man, therefore, by virtue of the possession of knowledge, makes choice of the side he will take in the conflict, and deliberately ranges himself on the side of the gathering agencies, or of the scattering agencies.

In thus making choice of sides, the thing which is gathered or scattered by the exercise of that choice is the man himself —his entire self. His entire self is ranged on the side of law and order, or on that of disorder. And with himself he brings over all the store of weak corpuscles, as well as of strong corpuscles, of which he is built up. He cannot alter the tendencies of these corpuscles so as to make weak into strong, or strong into weak; but he can alter their consciousness by impressing his personality upon them, so as to make them consciously take the side of law and order, or the side of disorder.

In the conflict over the atoms it is dominion over matter which is at stake. In the conflict over man it is dominion over the corpuscles which is at stake.

Man then, as we conclude, gathers corpuscles or scatters them.

The issues of the conflict over man are, therefore, not here.

Now we have seen, in the preceding chapters, that the result of the conflict over the atoms of matter is that the weak corpuscles are being steadily dislodged from their position about the atoms of matter, and driven out to occupy the portion of space vacated by the invading hosts of strong corpuscles.

The conflict is, therefore, one which cannot go on for ever, but must one day come to an end.

However vast may be the domain in the occupation of the weak corpuscles, they must in the end be driven out.

There will then be a complete separation between the weak corpuscles and the strong.

The strong corpuscles will be in full possession of the whole stock of atoms of matter in one region of space, and the weak corpuscles, with the exception of those brought over by man to the side of the strong corpuscles, will occupy another region of space apart from matter altogether.

There will be an end then to this universe of ours, which is, as we have seen, the result of the conflict over the possession of atoms of matter, and not the object of the conflict.

What form the new universe will take we cannot, of course, tell.

We can well believe, however, that there will be no strife there.

And yet that there will be no stagnation. For there are degrees of strength among the strong corpuscles, and they work harmoniously together, giving way to each other.

Moreover, there will be the weak corpuscles brought over to the side of the strong by man, and able to take a part among the strong, owing to the possession of larger consciousness. They will be able to do this just as a weak man is able to take a controlling part here in this world by virtue of his larger share of consciousness, and in spite of physical weakness. The work of each man will be there then gathered in with the strong if he has gathered, or cast out with the weak if he has scattered.

We have no reason to doubt that atoms of matter will be there in that new universe.

Since nothing can in any way wear them, we conclude that they will remain unaltered.

We have thus reached the end of the great conflict over the possession of matter. We have seen the effects of the conflict in the building up of this universe of ours in the face of strenuous opposition and resistance, and strenuous efforts to break it down, which have succeeded, indeed, from time to time in rending it deeply, and in disfiguring it; but otherwise have been unavailing.

The result is before us in the shape of a beautiful universe disfigured by ugly rents and scars, but complete.

Having thus seen the effects of the strife, we must now endeavour to make out the cause of the conflict.

Obviously, this is not a mere case of machinery on a vast scale working against friction.

Machinery there is, no doubt, in abundance working on a vast scale, as we have pointed out, but it is working for no industrial purpose. It consists rather of machines for collecting the spoils of war.

And then manifestly it is not automatic machinery, for it needs constant attention, as we have seen, to prevent it from getting clogged, and needs constant superintendence.

It may, however, be objected that machinery can be kept automatically from getting clogged, and can be controlled automatically by a governor.

And such an objection might perhaps have some validity, were it not for the fact which we have just been noticing that in the case of this machinery control has been violently usurped by man, who has put much of the machinery out of gear; and, besides, is busily engaged in converting the present out-turn to his own ends, and fast dissipating the stores of past ages.

Man has been enabled to do this by reason of the fact that the conflict is a very real one, and not in any way a one-sided affair, but a deadly struggle for mastery between two sides, of which one, indeed, is being overpowered, dislodged, and driven out, but still at various points is able for a time to offer successful resistance.

Man, with his large stock of knowledge, is able to understand the different phases of the struggle, and to turn them to account for his own purposes.

In this way he is able to utilise the temporary advantages which the weak corpuscles obtain in their retreat at various points, by diverting the issues from them in some particular direction, and thus concentrating them so as to produce the effects he desires.

He needs, as we have seen, a supply of heat in order to cook his food, warm his body, and smelt metals for fashioning arms and implements. And so he turns to the work of plant life, and operates upon the stores of timber and coal collected by it. These stores are, as we have seen, the most difficult to collect, and therefore necessarily the easiest to disperse. Man takes them in hand, and first heaps them together, and then starts the work of dissociation amongst the complex and therefore easily dissociated molecules, of which they are made up.

He commences with the most combustible materials, and through them is able to attack the denser materials, thus using his consciousness to concentrate the energies of the weak corpuscles upon the weakest points in the work of the strong corpuscles. In this way he is able to undo the work of the strong corpuscles, and throw it back a whole stage.

But here we have design coming in, and all trace of automatic working gone.

We have, in fact, man exploited to do the work of rebellion.

In him we perceive that the conflict of the universe is not a collision between machines, but a struggle between two Personages over the possession of matter. We conclude that one of these Persons is Supreme, and being supreme is carrying out His will in regard to matter by collecting the atoms through the agency of strong corpuscles, bringing them in and disposing them in an orderly and regular way in molecules, masses, and bodies, great and small, built up in beautiful forms.

We conclude that the other is being dislodged and driven out from his position through the agency of the weak corpuscles about the atoms of matter, but is offering through the weak corpuscles the most strenuous resistance, and in his retreat does his utmost to undo and mar the work of the Supreme Power; and succeeds, indeed, in disfiguring and defacing it, and marring its beauty and harmony, and even for a time in undoing it at various points, but is unable permanently to stop it.

It is in connection with this resistance and opposition that man's consciousness has been utilised in order to undo the work of the Supreme Power in collecting matter out of the gases in the atmosphere.

But man, though a rebel in respect of his animal nature, has not been given over by the Supreme Power. This is perfectly plain from the conflict which goes on in him, and from the terrible fascination which impels a man downward to self-destruction, when he has been given over, as evidenced so manifestly in the drunkard's death.

In this connection we may turn to the phenomena on record, which tell us that God so loved the world that He sent His Son into the world to take man's nature and substance upon Him, in order to help man in this fight, and to suffer on behalf of mankind the penalty of death which, as we have seen, mankind had incurred by rebellion.

We find that this record agrees with other records of phenomena.

The phenomena of Evolution tell us that it is by the advantageous variation of the individual that advantage is obtained in the struggle for the natural life, and that new species arise.

And it is in complete accordance with this that men should obtain advantage in the struggle for the higher life by the coming of One who had more of the Divine Nature. That such a One should give rise to a new species of men, possessing more of the Divine Consciousness, is in complete accordance, we assert, with the teaching of evolution.

Moreover, we perceive that the remedy of eating in obedience prescribed by that Divine One for the ills from which mankind suffers is a remedy which suits the case exactly, inasmuch as these ills have come, as we have seen, from eating in disobedience. And, further, we find that mankind has escaped in some wonderful way the penalty of death which, as we have seen, it had incurred by rebellion.

But it has been asserted that the drama is on too vast a scale for such an insignificant part of the universe as this earth of ours.

And no doubt the results so far attained have not been commensurate with the effort put forth. There can be no doubt that mankind, notwithstanding the fact that this astounding drama has been enacted, is not, with the exception of a small minority, actively working on the side of the Supreme Righteousness; but is for the most part only passively accepting the reign of law and order under the restraints of society, and to a large extent is actively engaged in opposing that reign.

In studying such facts as these, we must look at the Potentiality, as well as at the Actuality of the case.

Looking, then, at the Potentiality, we recognise the fact that man is able by the Divine Consciousness to subdue the evil in him, and bring his whole body into subjection to the Power of Good, following the example of that Divine One who took man's nature, and subdued the evil in it, and having so subdued it made it possible for man to subdue it likewise.

And it is plain that the result of bringing the whole body into subjection in that way is to bring the weak corpuscles of which in part that body is constituted over to the side of the Supreme Righteousness by impressing the Divine Consciousness upon them; even as it is likewise plain that the result of bringing the whole body into subjection to evil is to carry the strong corpuscles by which that body is built up over to the evil side, by impressing upon them an evil consciousness.

By bringing the weak corpuscles over to the side of good man is able, we conclude, to do more for the cause of good by far than he does as an animal for the cause of evil, by scattering the molecules collected by plant life. There is, therefore, in man a great potentiality.

The actuality is indeed small. In fact, mankind on the whole are taking over strong corpuscles to the side of evil, instead of bringing weak corpuscles over to the side of good.

The results, therefore, have not justified so far the enactment of the great drama to which we have referred. And yet mankind has not been given over—very plainly not.

There is one possible explanation of the situation, and that is that a day is coming when the whole of mankind will be actively and consciously engaged on the side of good, and will then atone for all the evil they have done by scattering the atoms, and taking over corpuscles to the side of evil.

And we find that there is a recorded promise of such a day; of a day when "the earth shall be full of the knowledge of the Lord as the waters cover the sea."—Isaiah xi., 9.

Here is a complete explanation of the situation, and a justification for the enactment of the great drama.

This, then, in a strengthened and extended form, is the case put in "Force as an Entity."

But now Argon has come to substantiate it by showing us in conjunction with the series formed by the valent elements that there are in this universe raw materials unsuited for building purposes, as well as the shaped materials—the valent elements of which the universe is built—suited exactly for building purposes by being squared on one or more sides, so that they may be properly bedded in the structures in which they are used.

In this way Argon, by showing us that the materials for building a universe require shaping, shows us that our universe had a Maker, and shows us one of the quarries as it were from which the materials for our universe were obtained.

In this way Argon represents the realisation of Newton's views, that "God in the beginning formed matter in solid . . . . particles of such sizes and figures . . . . as most conduced to the end for which He formed them."

It tells us, too, that Sir John Herschel and Clerk Maxwell were right in holding the molecule to have "the essential character of a manufactured article."

It tells us, too, that our fathers who walked by faith did not walk in darkness groping blindly, but very certainly discerned the right way, and kept to it.

We who follow them enjoy greater advantages, but have the same path to tread.

Argon and Helium, then, have risen like stars upon the horizon to give us fuller light, and to show us the way out of the desert of Agnosticism, and out of the bogs of Atheism.

We will finish up now with the concluding portion of Clerk Maxwell's remarks in regard to the molecule, which we have already quoted in part. He says: "The molecules . . . . the foundation stones of the material universe remain unbroken and unworn. They continue this day as they were created—perfect in number, and measure, and weight; and from the ineffaceable characters impressed upon them we may learn that our aspirations after accuracy in measurement, truth in statement, and justice in action, which we reckon amongst our noblest attributes as men, are ours because they are essential constituents of the image of Him who in the beginning created, not only the heavens and the earth, but the materials of which heaven and earth consist."—"Scientific Papers," edited by Niven, Vol. II., p. 377.

We would merely wish to substitute atoms for molecules in that statement.

W. B. Whittingham & Co., Ltd., Printers, 91, Gracechurch Street, London.

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