From the equivalences $2C = 4H$ and $3C = 2O$
it follows that $C = 2H$
and $O = 3H$,
while from a similar examination of liquids containing chlorine he deduces $Cl = 7H$.

These equivalences enable him to write down what may be called the hydrogen equivalent, with respect to the value of the number N, of any compound of the four elements in question, *i.e.* the number of hydrogen atoms, which, if they existed as a molecule in the free state, would constitute a substance for which the value of N at the boiling-point would be the same as for the original substance. Thus, selecting a few substances whose hydrogen equivalents are tolerably evenly distributed over the range that he has examined, he obtains the following table:—

	H	N
CH_4O	$= H_9$ ...	59·8
C_2H_6O	$= H_{13}$ ...	38·4
C_3H_8O	$= H_{17}$ ...	29·0
$C_3H_6O_2$	$= H_{18}$ ...	27·0
$C_4H_8O_2$	$= H_{22}$ ...	20·4
C_8H_{10}	$= H_{26}$ ...	16·1
C_9H_{12}	$= H_{30}$ ...	13·1
C_8H_{18}	$= H_{34}$ ...	10·5
$C_8H_{16}O_2$	$= H_{38}$ ...	8·7
$C_{10}H_{22}$	$= H_{42}$ ...	7·7

From these observations as data, a curve is easily drawn of which the ordinates are proportional to the number of atoms in the hydrogen equivalent and the abscissæ to the corresponding value of N; and it is remarkable that the curve so drawn is of equable curvature, and corresponds equally well, not only to the selected data from which it is plotted, but also to all the other observed values of N, so that by transforming the molecular formula of any liquid into its hydrogen equivalent we can at once find, by reference to the curve, the value of N for the substance, and, by multiplying this by $\frac{\text{mol. weight}}{1000}$, we obtain the surface-tension at the boiling-point.

There are only three liquids for which Prof. Schiff notices that the value of N, as calculated from the curve, differs markedly from the observed value. These are—

Amylene (C_5H_{10}), for which	N (obsd.) = 22,	and N (calcd.) = 23·4
Diallyl (C_6H_{10}) ,,	,, = 18·4	,, = 20·5
Ethylene-chloride ($C_2H_4Cl_2$) ,,	= 24·6	,, = 20·5

In the first case the disagreement is explained by the presence of impurity; in the second, impurity is very possibly the cause; while in the third it is possible that the equation $Cl = H_7$ is not applicable to substances in whose formula more than a single carbon atom is represented, a point which the author hopes to clear up by further investigation. We observe, however, that to these disagreements should be added the case of ethyl-isobutyrate $C_6H_{12}O_2$), for which N as given by the curve is 13·1, while the observed value was 12·3, a deviation of 7·5 per cent. On this the author makes no remark.

We will venture here to call attention also to a slight error that pervades all Prof. Schiff's results. We refer to the manner in which he corrects for the meniscus. The importance of this correction is in these measures very considerable, since the total elevation observed is always less than 10 mm. and sometimes less than 5 mm., and the correction is sometimes as much as 2 per cent. of the whole. Prof. Schiff, rejecting as insufficiently accurate Laplace's correction, which is based on the assumption that the surface of the meniscus may be regarded as that of a hemisphere of the same radius as the tube, and which consists therefore in adding to the observed height one-third of this radius, prefers to measure the height of the meniscus directly and to take as the correction one-third of the arithmetical mean between the observed height and the radius of the tube. In doing this he assumes that the surface may be regarded as that of a sphere of radius very appreciably greater than that of the tube, and gives a diagram in which it is so represented; but if this assumption or representation were correct, the laws of capillary tubes would be very different from what they are; moreover, according to theory, the form of the meniscus, and therefore the correction, must always be the same for liquids with the same capillary elevation; but Prof. Schiff's correction, based on the direct measurement of the meniscus, varies very considerably for elevations that are almost identical, which shows that the measures of the meniscus are not to be relied on: thus in the case of ethyl-toluol (para) (C_9H_2) the elevation is ·603 cm., and the correction ·013 cm., while for isobutyl-formiate ($C_5H_{10}O_2$) the elevation is ·599 cm., but the correction ·008 c.m., and in many cases one of two liquids which must theoretically have the greater correction has in point of fact the smaller. In order to see how far the empirical correction was at fault, we have selected one of Prof. Schiff's measures in which the elevation has about its mean value, and have calculated for comparison the correction of Hagen and Desains, which is based on the very approximately accurate assumption that the meniscus may be regarded as an oblate spheroid, and which is said to have been verified (? in the case of water) for tubes whose diameter attained as much as 4·6 mm. The following is the result:—

			mm.
Propyl Formiate:	observed elevation	=	6·45
,, ,,	Laplace's correction	=	– 0·1046
,, ,,	Hagen and Desains' correction	=	– 0·102
,, ,,	Schiff's correction	=	– 0·07

Corrected value (Schiff) 6·38; (Hagen and Desains), 6·348 mm.

It will thus be seen that an error of about ½ per cent. in the value of the surface-tension has entered into the result on this occasion, and that more has been lost than gained by substituting the empirical correction for that of Laplace; in some cases the error will be rather greater.

The importance in molecular physics of the step which Prof. Schiff has taken cannot easily be overrated. If it were only that he had found that isomeric substances have the same surface-tension at the boiling-point, that alone would have been a fact of great importance in reference to the interpretation of what we are accustomed to call the internal vapour-tension in a liquid; but in the system of absolute atomic equivalences with respect to surface-tension, and the knowledge of the manner in which the surface-tension varies with variations of the atomic equivalent, he has given to the physicist now for the first time most important data for correlating the surface-tension with the molecular actions existing expectively in the mass of the liquid and in the vapour above it.

A. M. W.

RESEARCHES ON THE ORIGIN AND LIFE-HISTORIES OF THE LEAST AND LOWEST LIVING THINGS[1]

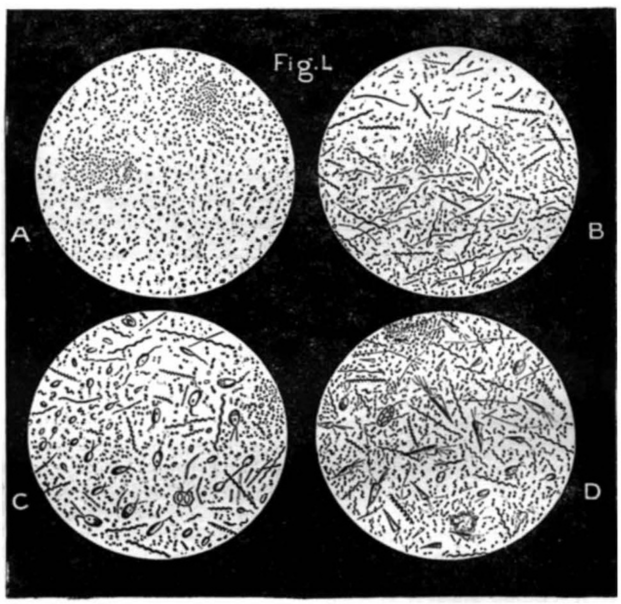
TO all who have familiarised themselves, even cursorily, with modern scientific knowledge, it is well known that the mind encounters the *infinite* in the contemplation of minute, as well as in the study of vast natural phenomena. The farthest limit we have reached, with the most gigantic standard of measurement we could well employ, in gauging the greatness of the universe, only leaves us with an overwhelming consciousness of the awful greatness—the abyss of the infinite—that lies beyond, and which our minds can never measure. The indefinite has a limit somewhere; but it is not the indefinite, it is the measureless, the infinite, that vast extension forces upon our minds. In like manner, the immeasurable in minuteness is an inevitable mental sequence from the facts and phenomena revealed to us by a study of the *minute* in nature. The practical divisibility of matter disclosed by modern physics may well arrest and astonish us. But biology, the science which investigates the phenomena of all living things, is in this matter no whit behind. The most universally diffused organism in nature, the least in size with which we are definitely acquainted, is so small that fifty millions of them could lie together in the one-hundredth of an inch square. Yet these definite living things have the power of locomotion, of ingestion, of assimilation, of excretion, and of enormous multiplication, and the material of which the inconceivably minute living speck is made, is a highly complex chemical compound. We dare not attempt a conception of the minuteness of the ultimate atoms that compose the several simple elements that thus mysteriously combine to form the complex substance and properties of this least and lowliest living thing. But if we could even measure these, as a mental necessity, we are urged indefinitely on to a minuteness without conceivable limit, in effect, a minuteness that is beyond all finite measure or conception. So that, as modern physics and optics have enabled us not to conceive merely, but to actually realise, the vastness of spatial extension, side by side

[1] By Rev. W. H. Dallinger, LL.D., F.R.S., F.L.S., Pres. R. M. S.

with subtle tenuity and extreme divisibility of matter, so the labour, enthusiasm, and perseverance of thirty years, stimulated by the insight of a rare and master mind, and aided by lenses of steadily advancing perfection, has enabled the student of life-forms not simply to become possessed of an inconceivably broader, deeper, and truer knowledge of the great world of visible life, of which he himself is a factor; but also to open up and penetrate into a world of minute living things so ultimately little that we cannot adequately conceive them, which are, nevertheless, perfect in their adaptations and wonderful in their histories. These organisms, whilst they are the least, are also the lowliest in Nature, and are to our present capacity totally devoid of what is known as organic structure, even when scrutinised with our most powerful and perfect lenses. Now these organisms lie on the very verge and margin of the vast area of what we know as living. They possess the essential properties of life, but in their most initial state. And their numberless billions, springing every moment into existence wherever putrescence appeared, led to the question, "How do they originate?" Do they spring up *de novo* from the highest point on the area of *not-life*, which they touch? Are they, in short, the direct product of some yet uncorrelated force in nature, changing the dead, the unorganised, the not-living into definite forms of life? Now this is a profound question, and that it is a difficult one there can be no doubt. But that it is a question for our laboratories is certain. And after careful and prolonged experiment and research the legitimate question to be asked is, Do we find that in our laboratories and in the observed processes of Nature now, that the not-living can be, without the intervention of living things, changed into that which lives?

To that question the vast majority of practical biologists answer without hesitancy, *No*, we have no facts to justify such a conclusion. Prof. Huxley shall represent them. He says, "The properties of living matter distinguish it absolutely from all other kinds of things," and, he continues, "the present state of our knowledge furnishes us with no link between the living and the not-living." Now let us carefully remember that the great doctrine of Charles Darwin has furnished biology with a magnificent generalisation: one indeed which stands upon so broad a basis that great masses of detail and many needful interlocking facts are, of necessity, relegated to the quiet workers of the present, and the earnest labourers of the years to come. But it is a doctrine which cannot be shaken. The constant and universal action of variation, the struggle for existence, and the "survival of the fittest," few who are competent to grasp will have the temerity to doubt. And to many, that which lies within it as a doctrine, and forms the fibre of its fabric, is the existence of a continuity, an unbroken stream of unity running from the base to the apex of the entire organic series. The plant and the animal, the lowliest organised and the most complex, the minutest and the largest, are related to each other so as to constitute one majestic organic whole. Now to this splendid continuity practical biology presents no adverse fact. All our most recent and most accurate knowledge confirms it. But *the* question is, Does this continuity terminate now in the living series, and is there then a break—a sharp, clear discontinuity, and beyond, another realm immeasurably less endowed, known as the realm of not-life? or, Does what has been taken for the clear-cut boundary of the vital area, when more deeply searched, reveal the presence of a force at present unknown, which changes not-living into the living, and thus makes all nature an unbroken sequence and a continuous whole? That this is a great question, a question involving large issues, will be seen by all who have familiarised themselves with the thought and fact of our times. But we must treat it purely as a question of science; it is not a question of *how* life *first* appeared upon the earth, it is only a question of whether there is any natural force *now* at work building not-living matter into living forms. Nor have we to determine whether or not, in the indefinite past, the not-vital elements on the earth, at some point of their highest activity, were endowed with, or became possessed of, the properties of life.

On that subject there is no doubt. The elements that compose protoplasm—the physical basis of all living things—are the familiar elements of the world without life. The mystery of life is not in the elements that compose the vital stuff. We know them all, we know their properties. The mystery consists *solely* in *how* these elements can be so combined as *to acquire* the transcendent properties of life. Moreover, to the investigator it is not a question of *by what means* matter dead—without the shimmer of a vital quality—became either slowly or suddenly possessed of the properties of life. Enough for us to know that whatever the power that wrought the change, that power was competent, as the issue proves. But that which calm and patient research has to determine is whether matter demonstrably *not living* can be, without the aid of organisms already living, endowed with the properties of life. Judged of hastily, and apart from the facts, it may appear to some minds that an origin of life from not-life, by sheer physical law, would be a great philosophical gain; an indefinitely strong support of the doctrine of evolution. If this were so, and, indeed, so far as it is believed to be so, it would speak and does speak volumes in favour of the spirit of science pervading our age. For although the vast majority of biologists in Europe and America accept the doctrine of evolution, they are almost unanimous in their refusal to accept as in any sense competent the reputed evidence of "spontaneous generation"; which demonstrates, at least, that what is sought by our leaders in science is not the mere support of hypotheses, cherished though they may be: but the truth, the uncoloured truth, from nature. But it must be remembered that the present existence of what has been called "spontaneous generation," the origin of life *de novo* to-day, by physical law, is by no means required by the doctrine of evolution. Prof. Huxley, for example, says, "If all living beings have been evolved from pre-existing forms of life, it is enough that a single particle of protoplasm should *once* have



appeared upon the globe, as the result of no matter what agency; any further independent formation of protoplasm would be sheer waste." And why? we may ask. Because one of the most marvellous and unique properties of protoplasm, and the living forms built out of it, *is the power* to multiply indefinitely and for ever! What need, then, of spontaneous generation? It is certainly true that evidence has been adduced purporting to support, if not establish, the origin in dead matter of the least and lowest forms of life. But it evinces no prejudice to say that it is inefficient. For a moment study the facts. The organisms which were used to test the point at issue were those known as *Septic*. The vast majority of these are inexpressibly minute. The smallest of them, indeed, is so small that, as I have said, fifty millions of them, if laid in order, would only fill the one-hundredth part of a cubic inch. Many are relatively larger, but all are supremely minute. Now, these organisms are universally present in enormous numbers, and ever rapidly increasing in all moist putrefactions over the surface of the globe.

Take an illustration prepared for the purpose and taken direct from nature. A vessel of pure drinking water was taken during the month of July at a temperature of 65° F., and into it was dropped a few shreds of fish muscle and brain. It was left uncovered for twelve hours; at the end of that time a small blunt rod was inserted in the now somewhat opalescent water, and a minute drop taken out and properly placed on the microscope, and, with a lens just competent to reveal the minutest objects, examined. The field of view presented is seen in Fig. 1, A. But—with the exception of the dense masses which are known as zooglœa or bacteria, fused together in living glue—the whole field was teeming with action. Each minute organism gyrating in its own path, and darting at every visible point. The same fluid was now left for sixteen hours, and once more a minute drop was taken and examined with the same lens as before. The field presented to the eye is depicted in Fig. 1, B, where it is visible that whilst the original organism persists yet a new organism has arisen in and invaded the fluid. It is a relatively long and beautiful spiral form, and now the movement in the field is entrancing. The original organism darts with its vigour and grace, and rebounds in all directions. But the spiral forms revolving on their axes glide like a flight of swallows over the ample area of their little sea. Ten hours more elapsed and, without change of circumstances, another drop was taken from the now palpably putrescent fluid. The result of examination is given in Fig. 1, C, where it will be seen that the first organism is still abundant, the spiral organism is still present and active, but a new and oval form, not a bacterium, but a *monad*, has appeared. And now the intensity of action and beauty of movement throughout the field utterly defy description, gyrating, darting, spinning, wheeling, rebounding with the swiftness of the grayling and the beauty of the bird. Finally, at the end of another eight to sixteen hours, a final "dip" was taken from the fluid, and under the same lens it presented as a field what is seen in Fig. 1, D, where the largest of the putrefactive organisms has appeared and has even more intense and more varied movements than the others. Now the question before us is, "How did these organisms arise?" The water was pure; they were not discoverable in the fresh muscle of fish. Yet in a dozen hours the vessel of water is peopled with hosts of individual forms which no mathematics could number! How did they arise? from universally diffused eggs? or from the direct physical change of dead matter into living forms? Twelve years ago the life-histories of these forms were unknown. We did not know biologically how they developed. And yet with this great deficiency it was considered by some that their mode of origin could be determined by heat experiments on the adult forms. Roughly the method was this. It was assumed that nothing vital could resist the boiling point of water. Fluids, then, containing full-grown organisms in enormous multitudes, chiefly bacteria, were placed in flasks, and boiled for from five to ten minutes. While they were boiling the necks of the flasks were hermetically closed; and the flask was allowed to remain unopened for various periods. The reasoning was: "Boiling has killed all forms of vitality *in* the flask; by the hermetical sealing nothing living can gain subsequent access to the fluid; therefore, if living organisms do appear when the flask is opened, they must have arisen in the dead matter *de novo* by spontaneous generation, but if they do never so arise the probability is that they originate in spores or eggs."

Now it must be observed concerning this method of inquiry that it could never be final: it is incompetent by deficiency. Its results could never be exhaustive until the life-histories of the organisms involved were known. And further: although it is a legitimate method of research for partial results, and was of necessity employed, yet it requires precise and accurate manipulation. A thousand possible errors surround it. It can only yield scientific results in the hands of a master in physical experiment. And we find that when it has secured the requisite skill, as in the hands of Prof. Tyndall, for example, the result has been the irresistible deduction that living things have never been seen to originate in not-living matter. Then the ground is cleared for the strictly biological inquiry, How do they originate? To answer that question we must study the life-histories of the minutest forms with the same continuity and thoroughness with which we study the development of a crayfish or a butterfly. The difficulty in the way of this is the extreme minuteness of the organisms. We require powerful and perfect lenses for the work. Happily during the last fifteen years the improvement in the structure of the most powerful lenses has been great indeed. Prior to this time there were English lenses that amplified enormously. But an enlargement of the image of an object avails nothing, if there be no concurrent disclosure of detail. Little is gained by expanding the image of an object from the ten-thousandth of an inch to an inch, if there be not an equivalent revelation of hidden details. It is in this revealing quality, which I shall call *magnification* as distinct from *amplification*, that our recent lenses so brilliantly excel. It is not easy to convey to those unfamiliar with objects of extreme minuteness a correct idea of what this power is. But at the risk of extreme simplicity, and to make the higher reaches of my subject intelligible to all, I would fain make this plain.

But to do so I must begin with familiar objects, objects used solely to convey good relative ideas of minute dimension. I begin with small objects with the actual size of which you are familiar. All of us have taken a naked-eye view of the sting of the wasp or honey-bee; we have a due conception of its size. This is the scabbard or sheath, which the naked eye sees.[1] Within this are two blades, terminating in barbed points. The point of the scabbard more highly magnified is presented, showing the inclosed barbs. One of the barbs, looked at on the barbed edge, is also seen. Now these two barbed stings are tubes, with an opening in the end of the barb. Each is connected with the tube of the sac C. This is a reservoir of poison, and D is the gland by which it is secreted. Now I present this to you, not for its own sake, but simply for the comparison, a comparison which struck the earliest microscopists. Here is the scabbard carefully rendered. One of the stings is protruded below its point, as in the act of stinging: the other is free to show its form. Now the actual length of this scabbard in nature was the *one-thirtieth* of an inch. I have taken the point C of a fine cambric sewing needle, and broken it off to slightly less than the one-thirtieth of an inch, and magnified it as the sting is magnified. Now here we obtain an instance of what I mean by magnification. The needle-point is not merely bigger, unsuspected details start into view. The sting is not simply enlarged, but all its structure is revealed. Nor can we fail to note that the *finish* of art differs from that of Nature. The homogeneous gloss of the needle disappears under the fierce scrutiny of the lens, and its delicate point becomes furrowed and riven. But Nature's finish reveals no flaw, it remains perfect to the last.

We may readily amplify this. The butterflies and moths of our native lands we all know; most of us have seen their minute eggs. Many are quite visible to the unaided eye; others are extremely minute. A gives the egg of the Small White Butterfly,[2] B that of the Small Tortoiseshell, C that of the Waved Umber Moth, D that of the Thorn Moth, E that of the Shark Moth, at F we have the delicate egg of the Small Emerald Butterfly, and at G an American Skipper, and finally at H the egg of a moth known as Mania Maura. In all this you see a delicacy of symmetry, structure and carving, not accessible to the eye, but clearly unfolded. We may, from our general knowledge, form a correct notion of the average relation in size existing between butterflies and their eggs; so that we can compare. Now there is a group of extremely minute insect-like forms that are the parasites of birds. Many of them are just plainly visible to the naked eye, others are too minute to be clearly seen, and others yet again wholly elude the unaided sight. The e Epizoa generally lodge themselves in various parts of the plumage of birds; and almost every group of birds becomes the host of some specific or varietal form with distinct adaptations. There is here seen a parasite that secretes itself in the inner feathers of the peacock, this is a form that attacks the jay, and here is one that secretes itself beneath the plumage of the partridge.

Now these minute creatures also deposit eggs. They are placed with wonderful instinct in the part of the plumage and the part of the feather which will most conserve their safety; and they are either glued or fixed by their shape or by their spine in the position in which they shall be hatched. I show here a group of the eggs of these minute creatures. I need not call your attention to their beauty; it is palpable. But I am fain to show you that, subtle and refined as that beauty is, it is clearly brought out. The flower-like beauty of the egg of the peacock's parasite, the delicate symmetry and subtle carving of the others simply entrance an observer. Note then that it is not merely *enlarged* specks of form that we are beholding, but such true magnifications of the objects as bring out all their subtlest details. And it is *this* quality that must characterise our most powerful lenses. I am almost compelled to note in passing that the *beauty* of these delicate and minute objects must not be considered *an end*—a purpose—in Nature. It is not so. The form is what it is because it *must be* so to serve the end for which the egg is formed. There is not a superfluous spine,

[1] A magnified image of the bee's sting was projected on the screen.
[2] A series of the eggs of butterflies were then shown, as were the objects successively referred to but not here reproduced.

not a useless petal in the floral egg, not an unneeded line of chasing in the decorated shell. It is shaped beautifully because its shape is needed. In short, it is Nature's method; the identification of beauty and use. But to resume. We may at this point continue our illustrations of the analytical power of moderate lenses by a beautiful instance. We are indebted to Albert Michael of the Linnean Society of England for a masterly treatise on a group of Acari, or *Mites*, known as the *Oribatidæ*. Many of these he has discovered. The one before you is a full grown Nymph, of what is known as a *palmicinctum*. It is deeply interesting as a form; but for us its interest is that it is minute, being only a millimetre in length. But it repeatedly casts the dorsal skin of the abdomen. Each skin is bordered by a row of exquisite scales; and then successive rows of these scales persist, forming a protection to the entire organism. Mark then that we not only reveal the general form of the Nymph, but the lens reveals the true structure of the scales, not enlargement merely, but detail. The egg of the organism, still more magnified, is also seen.

To vary our examples and still progress. We all know the appearance and structure of chalk. The minute Foraminifera have, by their accumulated tests, mainly built up its enormous masses. But there is another chalk known as Barbadoes earth; it is siliceous, and is ultimately composed of minute and beautiful skeletons such as those which, enormously magnified, you now see. These were the glassy envelopes which protected the living speck that dwelt within and built it. They are the minutest of the Radiolaria, which peopled in inconceivable multitudes the Tertiary oceans; and, as they died, their minute skeletons fell down in a continuous rain upon the ocean bed, and became cemented into solid rock, which geologic action has brought to the surface in Barbadoes, and many other parts of the earth. If a piece of this earth, the size of a bean, be boiled in dilute acid and washed, it will fall into powder, the ultimate grains of which are such forms as these which you see. The one before you is an instance of exquisite refinement of detail. The form from which the drawing of the magnified image was made was extremely small—a mere white speck in the strongest light upon a black ground. But you observe it is not a speck of form merely enlarged. It is not merely beauty of outline made bigger. But there is—as in the delicate group you now see—a perfect opening up of otherwise absolutely invisible details. We may strengthen this evidence in favour of the analytical power of our higher lenses, by one more *familiar* example, and then advance to the most striking illustration of this power which our most perfect and powerful lenses can afford. I fear that it may be taking too much for granted to assume that every one in an audience like this has seen a human flea! Most, however, will have a dim recollection or suggestive instinct as to its size in nature. Nothing striking is revealed by this amount of magnification excepting the existence of breathing pores, or spiracles along the scale armour of its body. But there is a trace of structure in the terminal ring of the exoskeleton which we cannot clearly define, and of which we may desire to know more. This can be done only by the use of far higher powers.

To effect this, we must carefully cut off this delicate structure, and so prepare it that we may employ upon it the first of a series of our highest powers. The result of that examination is given here.[1] You see that the whole organ has a distinct form and border, and that its carefully carved surface gives origin to wheel-like areolæ which form the bases of delicate hairs. The function of this organ is really unknown. It is known from its position as the *pygidium*; and from the extreme sensitiveness of the hairs to the slightest aërial movement may be a tactile organ warning of the approach of enemies, the eyes have no power to see. But we have not yet reached the ultimate accessible structure of this organ. If we place a portion of the surface under one of the finest of our most powerful lenses, this will be the result.[2] Now, without discussing the real optical or anatomical value of this result as it stands, what I desire to remind you of is (1) the natural size of the flea; (2) the increase of knowledge gained by its general enlargement; (3) the relation in size between the flea and its pygidium; and (4) the manner in which our lenses reveal its structure, not merely amplify its form. Now with these simple and yet needful preliminaries you will be able to follow me in a careful study of the least, the very lowliest and smallest, of all living things. It lies on the very verge of our present powers of optical aid, and what we know concerning it will convince you that we are prepared with competent skill to attack the problem of the life-histories of the smallest living forms. The group to which the subject of our present study belongs is the Bacteria. They are primarily staff-like organisms of extreme minuteness, but may be straight, or bent, or curved, or spiral, or twisted rods. This entire projection is drawn on glass, with *camera lucida*, each object being magnified 2000 diams., that is to say, four millions of times in area. Yet the entire drawing is made upon an area of not quite three inches in diameter and afterwards projected here. The objects therefore are all equally magnified, and their relative sizes may be seen. The giant of the series is known as *Spirillum volutans*; and you will see that the representative species given become less and less in size until we reach the smallest of all the definite forms and known to science as *Bacterium termo*.

Now within given limits this organism varies in size, but if a fair average be taken its size is such that 50,000,000 laid in order would only fill the one-hundredth of a cubic inch. Now the majority of these forms *move* with rapidity and grace in the fluids they inhabit. But how? by what means? By looking at the largest form of this group you will see that it is provided with two delicate fibres, one at each end. Ehrenberg and others strongly suspected their existence, and we were enabled, with more perfect lenses, to *demonstrate* their presence some twelve years ago. They are actually the swimming organs of this Spirillum. The fluid is lashed rhythmically by these fibres, and a spiral movement of the utmost grace results. Then do the intermediate forms that move also possess these flagella? and does this least form in nature, viz. *Bacterium termo*, accomplish its bounding and rebounding movements in the same way? Yes! by a series of resolute efforts, in using a new battery of lenses—the finest that at that time had ever been put into the hands of man—I was enabled to show in succession that each motile form of Bacterium up to *B. lineola* accomplished its movements by fibres or flagella; and that in the act of self-division, constantly taking place, a new fibre was drawn out for each half before separation.

(*To be continued.*)

[1] The pygidium of the flea, very highly magnified, was here shown.

[2] An illustration of the pygidium structure seen with 1/35th immersion was given

THE PERIPATETIC METHOD OF INSTRUCTION IN SCIENCE AND ITS DEVELOPMENT[1]

THE object of this paper is to plead for the introduction of science as a part of the system of ordinary education in all public elementary schools, and to describe the method by which alone, in the opinion of the writer, it is possible that this should be accomplished. There is a general consensus of opinion that a far larger place than has hitherto been allowed in England should be assigned to science in our national system of education, as well as in our grammar-schools and Universities; but no strong conviction yet exists that a certain amount of strict and definite scientific training should be given to all the scholars in our public elementary schools as soon as they are prepared to receive it, which is practically found to be after they have passed the fourth standard. The extent of this claim for the introduction of science as a part of the ordinary curriculum of a public elementary school must be noted, in order that the worth and importance of the proposed method for securing thoroughly effective teaching may be understood.

The provision of special scholarships for those who possess exceptional intellectual power—admirable and necessary as this is—does not meet the broad claim I make. To furnish stages in the ladder by which a lad of mark, endowed with "five talents," may climb from the elementary school to the science college, is only to offer to the children of the poor opportunities to which they are justly entitled by virtue of the fact that genius, like truth, can neither be bought or sold, and is bestowed upon men entirely apart from any considerations connected with social rank and circumstances. But scholars of average ability, those who have no special endowments qualifying them for exceptional careers, ought not to be kept in ignorance of the fixed laws and the majestic marvels of the world in which they will have to labour, or to be deprived of the practical guidance, the intellectual interests, and the protection against coarse and degrading tastes, which scientific training is capable of bestowing upon

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