THE

DAWN OF ANIMAL LIFE:

A LECTURE

DELIVERED IN

THE CITY HALL, GLASGOW,

March 2nd 1875;

UNDER THE AUSPICES OF

The Glasgow Science Lectures Association.

BY

PROFESSOR W. C. WILLIAMSON, F.R.S.,

THE OWENS COLLEGE, MANCHESTER.

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THE DAWN OF ANIMAL LIFE.

I AM not quite sure that the title of the lecture may not in some degree mislead you. It speaks of the dawn of life. At the first glance you might suppose that I was going to take you back into those mysterious ages, about which our excellent friend, Sir William Thomson, gave us a few hints of his own at Edinburgh, when life in any form first made its appearance upon earth. But that is not the subject which we are going to study; though were we to do so, I will venture to say that it would yield to no other in importance and interest.

I want rather to lead you to that particular part of our inquiry which has reference to objects that we see living under our own eyes, whose life-history we can trace, and yet which are entirely different from the things with which we are more usually familiar; they constitute the one pole of life of which man, the summit of all organisation, constitutes the opposite and highest pole.

You cannot have paid any attention to your own individual condition without feeling alive to the fact that your physical frame is an exceedingly complicated one. You know you have a number of organs, and a number of functions are performed by these organs. You have, in fact, a separate organ for every function, and every separate organ has a function of its own, that cannot be interchanged with the function of any other organ. In social life you may get your friend to do your work for a day or a week; but when you ask the eye to do the work of the mouth, the tongue the work of the nose, or the nose the work of the ear, you know that such an interchange is impossible.

But when we go to the opposite pole of animal life, what do we find? Have we there the same complex structure, or the same division of duty? Do we find separate parts, which can be distinguished under the microscope, and in which we can trace this corresponding division of functions? I propose to give you the answer to this question to-night; and I think I shall be able to shew you, before we have finished our evening's work, that the lowest animals are the very opposite of man in the points to which I have referred; that there is none of this difference of organisation—none of this speciality of parts—none of this isolation—this separation of organs for the fulfilment of particular work; but that every part of the animal can do equally well what any other part of the animal can do.

We scientific men are frequently accused of using hard words. I venture to admit the charge, and justify it in a very simple and intelligible way, by proving that there is another black as black as our own. I will ask you to take up any ladies' crotchet-book, and if Sir William Thomson or any of our learned friends on the platform behind me can tell you, unless they receive special feminine instruction, the meaning of the marvellous symbols in the book, I will give them credit for possessing even more genius than I already do. What do I mean by this? I mean there are certain special ideas which have to be represented by certain figures, letters, or words; these symbols, when employed in the crotchet-book, are designed to shew you to lift up your needle here and put it through there. Technical movements must be performed in order to produce the wonderful crotchet patterns, and there are particular symbols made to represent these different movements. A lady learns to understand the symbols the moment she sees them, and conceives it natural anybody else should do the same; but when she comes to botanical or zoological terms, she thinks there is something wrong in the invention of all the hard names, though they are as necessary to science as her own technical terms are to needlework.

But I promise you to use as few such as possible, and this I shall be better able to do because the objects about which I have to speak are limited in number.

Let me tell you in the first place what you must do. Go to some water-tub that may be standing near your house, scoop up a little fluid from the inner surface of the cask, and in all probability you will find that the water there contains more minute jelly-like objects than elsewhere. Or take a similar drop of water from an old neglected flower-pot that has been standing in the rain for weeks. If these fail, get a drop of water from the bottom of some pond. If you examine it under the microscope, you are sure to find in it some little spots, as if drops of diluted gum had been introduced into the water. What are these gum-like substances? I will tell you, and in doing so use the first of my big words. Fortunately this word is one you all know something about. It is one that some five or six years ago almost seemed to frighten England from its propriety. I mean the word protoplasm. You all, I daresay, remember my friend Professor Huxley's celebrated Essay on Protoplasm. Now, I am going to talk to you to-night almost exclusively about this Protoplasm in one form or another. This same little drop of jelly is neither more nor less than a speck of protoplasm. But what is protoplasm? The very name signifies that it is the primary raw material out of which other things are organised. You have blood circulating in your veins. If you examine a drop of it under the microscope you will find it filled with little red granules; red corpuscles, as they are called. Each one of these is essentially a little granule of protoplasm; if you examine that blood a little further, you find moving amongst these red particles a few white and somewhat larger ones. Note these latter particles well, and you will see that they are very similar things to my little drops of gum or jelly that you find in the water. Not only so, but you will see that these two things agree in one important point—viz., they frequently change their shape. Now they are round, now oval, and indeed now pushing out little projections from their margins. These atoms of protoplasm in the blood differ extremely little in their essential features from the simplest form of animal life with which we are acquainted. What is the condition of this earliest form ?

In fig. 1 you have one of the smallest forms of this little animalcule, called the Protamœba, the first and earliest form of the Amœba, which latter, in plain English, is called the Proteus animalcule, because, like the mythic Proteus of old, it is perpetually changing its shape. Like the white globule in our blood, it is round now, oval five minutes hence, and in ten minutes more it may become altogether different.

What does he do when about to feed? There is near him a little tempting morsel, and he contrives to come into contact with it. He does not bite it, because he has no teeth. He does not take it into his mouth, for he has no mouth. He does the next best thing. He just edges himself up to it, and having done that, he contrives to imbed the morsel in his body. There is no aperture into his body, and whichever side he brings into contact with the food is equally efficient. He contrives to bury the particle in his substance, and so long as it is there he is extracting some amount of nourishment from it, after which he ejects it. It is a simple sort of proceeding, but efficient for the accomplishment of its end.

How does he multiply himself? By a process equally simple—viz., he splits himself in two. A simpler process than that you cannot find. When you were children, and wanted to share your cake with a younger brother, you divided it in two; but mark the difference between the Protamœba and the cake. When you divided the cake, you had only the two halves left. There was no increase of growth in each half of the cake to reward your virtue. But when the Protamœbæ have divided, simple as they are in structure, they contrive to extract some nutriment out of the water, so that in a short time each of the two halves becomes as big as the original creature was. This little act, performed by the simplest and most lowly of all animal organisations, shews that in them there resides that all-important power which we call vitality, and the possession of which, as I think, I shall be able to prove to you before I have done, distinguishes the organic from the inorganic world, and demonstrates the *existence* of life.

Let me now take you a step farther. Fig. 2 is a little fellow similar to the one already described. Observe that he differs in having a little speck, *a*, in his interior which looks as if it meant little, but it means a great deal. We have here made an advance in the complexness of organisation. We have put our foot on the first rung of the

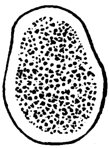


Fig. 1.
Protamœba.

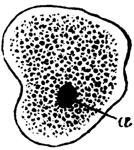


Fig. 2.
a. Nucleus.

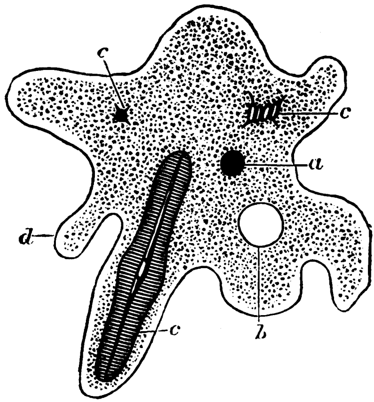


Fig. 3.—Amœba.
a. Nucleus. *b*. Contractile Vesicle. *c*. Vegetable objects upon which the Animal is Feeding. *d*. Pseudopodian Extensions of the Protoplasm.

ladder which will gradually lead us up to that summit which man occupies. Here is an organ of which we do not know the exact nature, but which we trace in an infinite variety of shapes both in animal and vegetable life. It has important functions of some kind or other to perform, otherwise it would not be so widely diffused. This little object is called the nucleus.

Let us now advance from the Protamœba to the Amœba itself. Fig. 3 represents one of the varied forms that it assumes. We have here, at *a*, a nucleus, like that in fig. 2. We find also at *b* a little transparent spot, and as that is always present we may be sure we have here an additional organ. This transparent spot expands for a few minutes, is filled with a colourless fluid, and then probably bursts; at all events it disappears. It is a Contractile Vesicle; but what its function is we do not know. We do know that when it has contracted in the way I have described, it re-appears in the same spot, and in this way goes on expanding and contracting almost as regularly as your heart contracts and expands, but with very much longer intervals. Possibly it concentrates some nutritive essence, and every time it contracts or bursts, diffuses this essence through the system. I will not vouch for the correctness of this explanation, but here is undoubtedly a second organ, indicating an important advance in the complexness of the organisation. So far as nourishment is concerned, we find no change. The letters *c, c, c,* indicate objects which we know to be plants, upon which the creature is feeding. It has buried them in its substance, and is extracting nourishment out of them.

Thus we see that, though we have made this amount of progress in the development of the organism, we have not really attained to anything materially new in the physical or physiological history of the animal. It multiplies in the same way as the Protamœba, dividing into two; or sometimes poking out a little bit of an arm, as at *d,* it pinches off a bit of its tip, which floats away, and starts life as a new independent creature. At the same time, notwithstanding these successive subdivisions, the creature itself grows, maintaining its original size, and undergoes its usual variations of form.

Such is the history of the Amœba or Proteus animalcule—a history simple, it is true, but which gives us a clue to a very large number of other histories very much more complicated. At the first glance you may be disposed to say, What is the use of studying a little object like this? The same question might be applied to the minute forms of vegetable life, upon which I have no time to enter. If we had time to study all these minute plants, it would not be unprofitably spent, as they exhibit similar phenomena, demonstrating how universal are the laws upon which nature is built up, and by which she acts.

Such studies *are* of real use, because they throw a light even upon the constitution of man.

We must now turn to one of the most mysterious objects with which I am acquainted; one to which our attention was originally directed—as our attention is frequently directed—by the friend, whose name I was delighted to hear you cheer so heartily a few moments ago—I mean Professor Huxley. Examining some of the sediments brought up from the deep sea, and with which I shall have something to do in a few minutes, he discovered that the mud so brought up had a slimy character about it. He found that when portions of it were put into water in a fresh state, a sticky substance diffused itself in the water but with a definite outline, just as if you had dropped thick gum into the water, and the two refused to mix. He noticed the fact that imbedded in this gum-like substance there were numerous minute, organised points, which he called Coccoliths. He came to the conclusion, which I have no doubt was strictly correct, that this gum-like material, to which he gave the name of Bathybius, was an animal substance very similar to that of the Amœba, or Proteus animalcule, but with this difference, that whilst the Proteus animal was capable of being put under the microscope, being an almost invisible speck, the Bathybius substance extended for hundreds and perhaps for thousands of miles along the sea-bottom. Wherever certain materials formed the sea-bed, there you had this Bathybius. Whether we may speak of it as one animal, or an almost world-wide aggregation of minute animal points, I cannot say; but I agree with Professor Huxley in regarding this Bathybius as a condition of animal life in its very lowest form.

Dr. Dawson, of the Macgill College, Montreal, Dr. Carpenter, and two or three others, have investigated the earliest form of animal life yet found in a fossil state; this peculiar structure, called the Eozoon, has built up calcareous masses at the bottom of the sea on a very gigantic scale. These masses seemed to the above observers—and I think they are correct—to be the products of an animal having had a very wide diffusion, the nature of which has been something like that of the Amœba. Now, it gives a strong probability to these views, that we have at the bottom of the Atlantic and Indian Oceans, and in various parts of the Pacific, at the present day, also on a very gigantic scale, a similar animal substance to that which Dr. Carpenter and others believe to have existed in ages gone by, and which constructed the calcareous Eozoon.

I will next direct your attention to some other curious forms. If you take up a little sand from favourable localities on the sea-shore, you will find that it frequently contains large numbers of exquisite, minute shells. Hooke, a celebrated microscopist in the days of Charles II., noticed the existence of these shells in sea-sand. From that time to the present, they have, at intervals, been made the objects of special study. They have at different times been put into all sorts of classes, and no wonder, since being so exquisitely beautiful and symmetrical, it is difficult to suppose they ever could have been formed by animals so low in the scale of organisation as the creatures that really did form them. They are now known by the name of Foraminifera, and the majority of them are so small as to be like dust. Unless the vision is aided by the microscope or the magnifying glass, you would not suppose them to be organised objects. They are so exquisite in texture and outline, and so variable in form, that Nasmyth, the engineer, always insisted that one little group which I keep in a microscopic slide, should be called "The School of Design." He said it contained more ideas for patterns and designs than he ever saw within so small an area. In most of these shells there are numerous chambers. Sometimes, as in fig. 4, these chambers are arranged in a straight line; in other cases they zigzag backwards and forwards, right and left alternately, as in fig. 5; and in others again they are spiral, as in figs. 6 and 7. These chambers represent so many successive growths. The shells, in many instances, are

Fig. 4. Nodosaria.

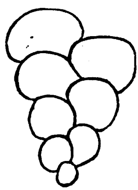


Fig. 5. Textillaria.

perforated with numerous holes, as in fig. 6. The name of Foraminifera has been given to these objects because of these little holes. What do these perforations mean? I will tell you. The shells are made up of lime, which the creatures obtain from the sea in which they live. The

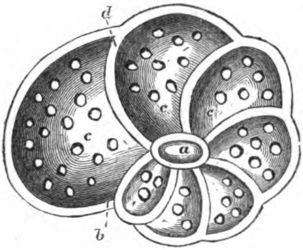


Fig. 6.—Young shell of *Discorbina Turbo*, shewing the foraminated walls of the chambers.

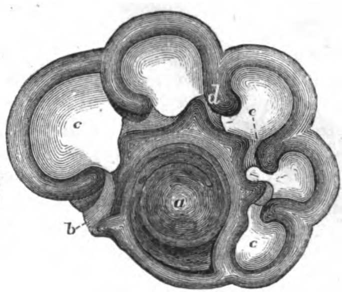


Fig. 7.—Young shell of *Peneroplis planatus*, with a non-foraminated shell. *a*. Primary segment. *b*. Aperture. *c*. Series of segments. *d*. Septa separating the successively added segments. *e*. Canals connecting the different segments, and once forming the orifice, like *b*, when each segment was in turn the outermost one. The same letters of reference apply to Fig. 6.

animals that tenant these shells are objects very like the Proteus animal. Fig. 8 represents one of these creatures with the animal inside. Notice streaming from its shell numerous delicate threads, which often blend together. Now, these threads are prolongations of the animal protoplasm exactly similar to those of the Amœba. They are much finer and more delicate, but in other respects are the same thing. These threads are called Pseudopodia, which means false feet; but they do more than act as feet, for they evidently collect from the sea the nourishment upon which the creatures subsist. When the shell has become too small to hold the growing protoplasm, a new joint or segment is formed at the end of those already existing. The new ones grow out of the old ones like buds. Their arrangement is endlessly diversified.

The point that I next wish particularly to impress upon you is, that these shells have played, and are still playing a very important part in the physical history of the globe. It was remarked by Dr. Buckland thirty years ago, that these microscopic creatures, or similar ones, have played a far more important part than elephants, lions, or tigers, in the history of the globe. I will now prove to you that they have done so.

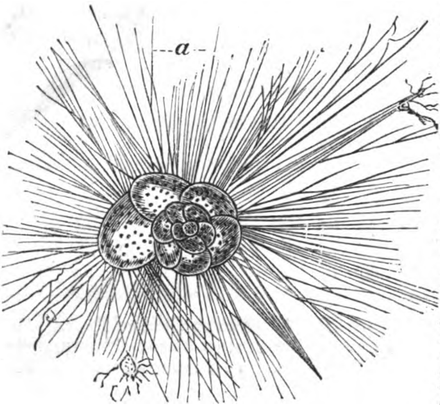


Fig. 8.—The same shell as fig. 6 with the soft animal projecting its numerous pseudopodia, *a*, through the foramina in the shell-wall.

Fig. 9 represents a round Foraminifer, consisting of a single joint with a little aperture serving as a mouth. This is the Orbulina. We find it in mud dredged up from our own North Sea,

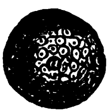


Fig. 9.—Orbulina in its common condition. *a*. Oral aperture.

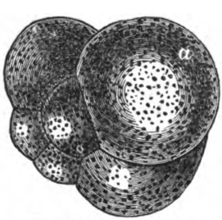


Fig. 10.—Upper surface of shell of *Globigerina bulloides* as usually found. *a*. The newest segment.

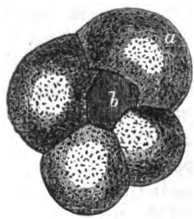


Fig. 11.—Under surface of fig. 10. *a*. The newest segment. *b*. The oral aperture.

between the Scotch coast and the Shetland isles. It early became plain to me that this little animal was a deep-sea form. I always found it associated with the shell, figs. 10 and 11, and which is so minute that it looks, when you view a lot of it with the naked eye, like the finest dust. A breath will suffice to blow it out of the box in which I keep it. This latter shell is the little object which has been the chief agent in modifying the crust of the globe.

When Ehrenberg, the great Prussian microscopist, was pursuing his investigations, and shewing the power of his genius by working with tools for which you would not give twenty shillings (it was not the tools, but the eye he contrived to put behind them that did the work) amongst other things he put under the microscope a little bit of powdered chalk. He found, to his perfect astonishment, and the astonishment of all of us, that the white Chalk, which runs in an almost unbroken line of elevated Downs from Flamborough Head to Dover and Beachy-head, and other points on the south-east coast of England, and which is generally about 500 feet in thickness—is neither more nor less than a vast accumulation of these minute shells. Not only so, but many of the shells of which that chalk consists are either the identical species represented by figs. 10, 11, or a variety of it, very slightly modified. The forms I am now describing to you are found at various localities, from the North Pole to the South Pole, and from the Red Sea to the middle of the Pacific Ocean. These shells underlie the deep sea, not universally, but in detached masses of vast extent. It is difficult to realise that the mass of chalk which, after having undergone a variety of chemical changes and been subjected to immense pressure, reducing its volume, could ever have been produced by such minute agents.

When the bed of the Atlantic was surveyed, preparatory to carrying out those great works with which your distinguished townsman, Sir William Thomson, was so intimately associated, it was found that a great part of the bed upon which the electric wire was to be laid consisted of these shells. We know now that a great part of the sea bottom between us and America consists of such shells, with a few minute, siliceous objects mixed with them, and which combination in all probability constitutes a mass hundreds of feet in thickness. We have no means of ascertaining its exact depth, but it is permeated through and through with Huxley's Bathybius. It is in virtue of this peculiar foraminiferous accumulation, forming a soft bed for the reception of the cable, that the success of Anglo-American telegraphy is largely due.

We have recently obtained some very important information about these little objects from the "Challenger." A variety of investigations have been carried on, and different conclusions arrived at by different individuals, as to where these shells live. Some, like Mr. Gwyn Jeffreys, insisted that they live near the surface of the water, and that the deposits are merely accumulations of dead shells which have sunk to the bottom. Others contend that they live at the sea bottom and die there—that being their home. But the very last information we have had from the "Challenger" has thrown a wonderful light, not only upon the position in which at least some of these creatures live, but upon the extraordinary appearance they present when living.

It appears that when these creatures are living at the surface, both the Globigerina and the Orbulina are armed with innumerable delicate, flexible, calcareous spines, as represented in figs. 12, 13. When the animals perish these spines fall off, and the shells descend to the bottom of the ocean. Such spiny investments probably characterise the younger states of the animal.

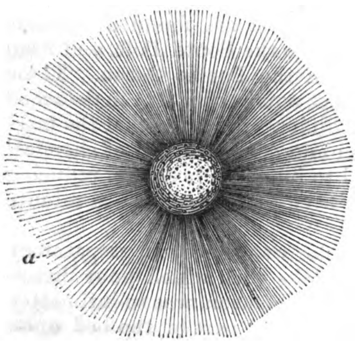


Fig. 12.—Orbulina as living at the surface of the sea. *a*. Calcareous spines projecting from the shell.

We advance now to another group of objects. When, in the days of

Hooke, of whom I have already spoken, attention began to be directed to the microscope, it was found that if a little vegetable matter was allowed to stand for a few days in water—in other words, to form what the druggists call an infusion—minute living objects appeared in it. Finding these objects in such infusions, and not being aware that they were to be found elsewhere, naturalists gave them the name of Infusoria. These became the special study of Ehrenberg; but he mixed up with this common group an enormous number of objects that were really plants. He was a magnificent observer, and had a wonderful genius for classification; but, unfortunately, he was not a physiologist; consequently he gave to these vegetable forms eyes, stomachs, teeth, and a whole host of other organs, which it is not usual for plants to have. About one-half of the things called Infusoria proved to be animals, but the other half turned out to be plants. His labour, however, was not thrown away. Investigations which were pursued into the history of these creatures demonstrated that they were closely allied to the Amœba, but with a decided advance in organisation. The animal consists of a mass of protoplasm, but in the interior we have a nucleus (figs. 14, *a*, to 16, *a*), a contracting vesicle (figs. 14, *b*, to 16, *b*); in addition to these organs we find, in the first place, that each animalcule is clothed with an external skin, which the

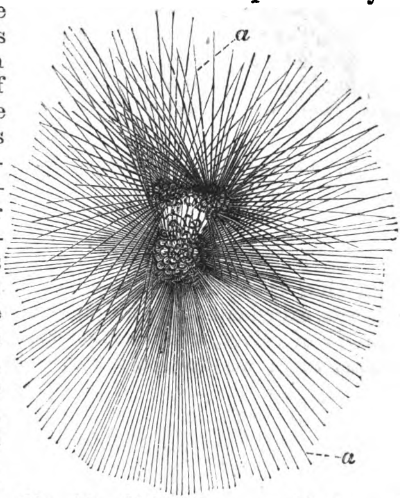
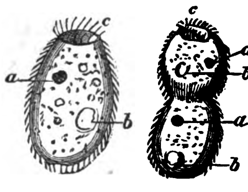
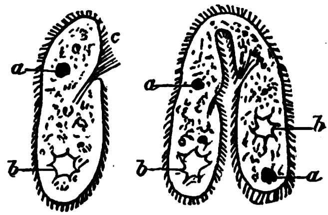


Fig. 13.—Globigerina. *a*. Clusters of spines projecting from each segment of the shell.

Amœba does not usually possess. Not only so, but we find that, in one part or another, there is a mouth—that is, an opening—where the skin is inverted into the interior of the animal for a very short distance like a tube, and that this is the inlet through which the food enters.



Figs. 14 and 14*.—A flask-shaped infusorial animal. *a.* Nucleus. *b.* Contractile vesicle. 14* is preparing to undergo fission transversely.



Figs. 15 and 16.—Paramecium. *a.* Nucleus. *b.* Contractile vesicle. *c.* Mouth. Fig. 16. is undergoing fission longitudinally.

The skin is furnished with innumerable minute moving threads, called cilia, resembling the vertical threads forming the *pile* of velvet, which are everlastingly at work, yet what moves them we do not know. But these ciliary movements acting in a variety of ways enable the animal to swim, which is their ordinary function.

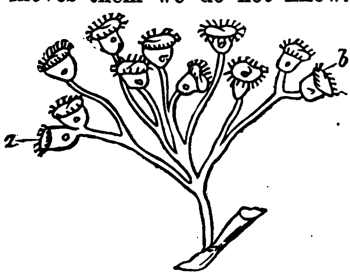


Fig. 17.—Carchesium. A flexible branched infusorian animal. *a.* An animalcule beginning to subdivide. *b.* Another, in which subdivision has reached the flexible peduncle.

Fig. 17 represents a fixed cluster of similar objects growing like a tree; a condition produced by a process of fission which allies these creatures to the Amœba. They multiply by splitting themselves into two, the process being effected in varying directions, and with different degrees of completeness. Sometimes the division will be lengthways, as the animal represented in fig. 15 is separating into two lateral halves in fig. 16; but sometimes they take a fancy to split in the opposite direction, as fig. 14 is doing in fig. 14*. In the Infusoria generally this splitting is done effectually; but fig. 17 is a creature which has done the splitting ineffectually. One individual of this cluster originally attached itself to a fixed object, and then elongated the footstalk by which it so attached itself. It then split into two, as just described, the divisions extending into the footstalk, but not reaching its base. Similar processes were repeated again and again, as at *a* and *b*, until the organism attained to the tree-like form represented in fig. 17.

Here you have something like what I daresay you people in Glasgow understand very well, viz., practical co-operation. To a certain extent independent, each animalcule obtains its own food, but they are all acting in harmony, nourishing the common structure of which they form mutually dependent parts. I take it something like that is the true mission of human society. No one can do without the other, any more than these animals are independent of each other. In social life we recognise that the rich are necessary to the poor, and the poor are necessary to the rich. Each have their own appropriate work to do in the world. The young require the experience of the old, and the old frequently require the energy and active force of the young. All are mutually dependent upon each other; and though it is perfectly true of any one, that society can do without us, yet, viewed as a whole, we are mutually dependent one upon another.

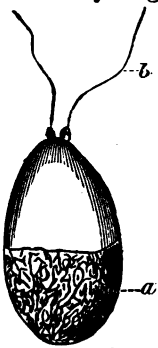


Fig. 18.—Cercomonad. *a*. Granular portion. *b*. Cilia.

I will now call your attention to some objects of which the history has been worked out by two gentlemen at Liverpool —Dr. Drysdale and the Rev. Mr. Dallinger. They have devoted their energies to the investigation of a very minute species of Infusoria, fig. 18, which was furnished with two large and very peculiar cilia, *b*, at one end. They noticed that when these animals multiplied they divided after the old fashion of protoplasmic structures. The protoplasm enclosed within the outer skin divided into two, these again became four, and so the divisions went on, until the bag was full, when the outer skin burst, and the enclosed objects were liberated; each of these liberated objects soon became like the parent from which they sprang.

But these observers noticed another mode of reproduction in the creatures. The lower half of each Infusorian consists of a granular substance, *a*, very different from the upper part. They found that the skin enclosing this granular part burst, and all these little granules were set free. Each of the granules soon became a new animal like the parent one.

If I had time to dwell upon the matter, I could shew you that the Amœba, the Foraminifera, and the Sponges pass through similar conditions. I wish you to note in your memory the fact, that as we descend from larger forms to forms only the one-eleven-hundredth of an inch in length, we trace precisely the same conditions of growth, of life, and of multiplication. You will see the importance of this in its bearing upon another question I will bring before you in a few minutes.

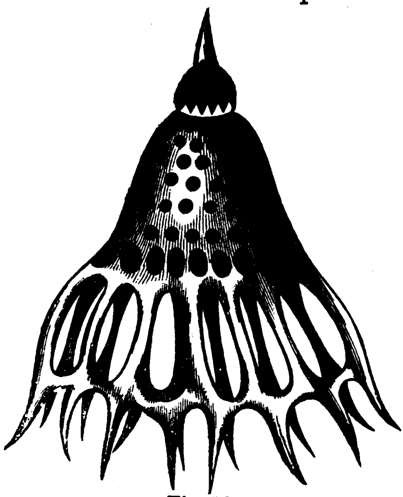


Fig. 19.
Siliceous skeleton of a Polycystinean.

I will now call your attention to these curious objects from the deep sea called Polycystineæ, because they have many cysts or cavities in them. They are siliceous, or made of something very like flint. These siliceous skeletons when living are covered with a sarcode or protoplasmic substance. Figs. 19 and 20 represent two elaborate skeletons of these Polycystineæ deprived of their sarcode. They are objects belonging to the same group, and having the same low organisation as those already described.

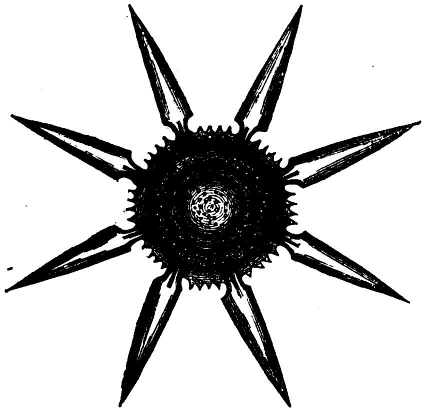


Fig. 20.
Siliceous skeleton of a Polycystinean.

We will pass from them to the Sponges. If time permitted I could shew you that the history of Sponges is quite as interesting as that of any of the other animals we are acquainted with. You are all familiar with the sponge of commerce—that elastic horny substance. When that Sponge was growing in the sea it was covered with slime. It is washed before it comes into your hands; if it were not, you would find it had a slimy, repulsive, nasty feeling, like that you experience when you lift up a snail. Now, this Sponge, with its horny skeleton, has a very curious history. If you notice closely you will find little punctures scattered all over its surface. When the sarcode or flesh invests it, these little pores absorb water. You will observe that at some points there are large apertures. Very generally these larger apertures form the summits of conical projections like the craters of miniature volcanoes. The water absorbed by the smaller openings passes out at the large ones.

Fig. 21 is a diagram, copied from one of Professor Huxley's, and which will illustrate what I mean. The black tint represents the substance of the Sponge, the skeleton, and the sarcode or protoplasm included. The arrows indicate the direction in which the water flows through these canals, and then emerges through the larger volcano-like apertures (fig. 21, *a*). It has long been a perplexing question how the water is forced through, but it lately has been discovered how this is done. It is found that some of the canals expand into little chambers, *c*, which are lined with cilia, or little appendages like those which enable the Infusoria to move. These are in constant action. The interior of the

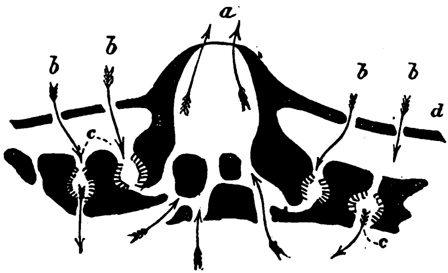


Fig. 21.—Diagrammatic representation of a section of a Sponge.
a. Exhalant aperture. *b b.* Inhalant apertures. *c.* Ciliated chambers. *d.* Surface tissue.

human mouth, as well as the interior of the bronchial tube and lungs, are lined with these cilia, which are constantly moving in such a peculiar way that the movement appears to be always in one direction. Their action resembles that of a field of corn when a breeze is blowing over it. We see wave after wave going from one side to the other, but we know very well that although the heads of corn appear to be travelling in that direction, the corn does not go, but that this appearance is caused by the sudden bending down of the corn in one direction, and the slower restoration of it to its old position. The quick movement strikes the eyes, but the slow movement is not noticed. Something of the same kind exists in these cilia. The consequence is that in the Sponge these little cilia keep up a movement in one direction, just as those in the interior of the lungs keep up a movement from within towards the throat. But for this movement we should be in danger of choking. The action causes an outward flow of mucus, and brings it up through the windpipe towards the throat where, by a vigorous cough, we can throw it out. Just in the same way the cilia of the Sponge produce currents in the sea water, which is drawn into the Sponge at the points *b*, *b*, and is being expelled again at the larger aperture *a*.

I have now shewn you the life-history of the Sponge, so far as mere nutrition is concerned. But Sponges will die like other folks, and their place has to be refilled; before shewing you how this is done, let me describe some other features of their internal structure.

First, observe that, in addition to the horny substance that forms the skeleton of the Sponge, we have spicula—little spines. Sometimes they are like pins with heads to them, and sometimes like needles. Sometimes the spikes are adorned with all sorts of fringes, constituting some of the most beautiful objects that you can purchase from dealers in microscopic curiosities. These spicula form additions to the skeleton. We find in one group that they consist of carbonate of lime. In such instances they are triradiate, like the three legs of the coat-of-arms of the Isle of Man. When three points radiate from a common centre you may be sure they are calcareous, but when they are like needles you may generally conclude that they are siliceous.

One new form of Sponge has been brought to us within the last few years, the first specimen of which is now in the British Museum. For this specimen £30 was paid. Then a few more came to England, and they were sold at prices ranging from ten to fifteen guineas. One day a friend of mine connected with the custom-house in London, was at the custom-house, when another of the officers said to him, "Come here and I will shew you something that will astonish you." He pointed to one box in which there were hundreds of these costly objects, then to a second which contained a similar number. Nobody could find out whose they were, or to whom they were consigned; nor, up to the present day, has it been discovered, so far as I know, where they went to. Now and then an odd one came out, and was sold for ten guineas; now, however, they are to be bought for a few shillings each. The Euplectella, as this Sponge is called, is the loveliest object ever produced either by nature or art, and in saying that I am aware I am saying a very strong thing. It is sometimes called the Venus's Flower-basket, and is composed of delicate threads of silica, like spun glass, arranged in regular geometric patterns. It is almost incredible that so exquisite a design could be produced by a mass of jelly-like substance similar to the Amœba, and which is not one bit more highly organised than I have shewn that animal to be.

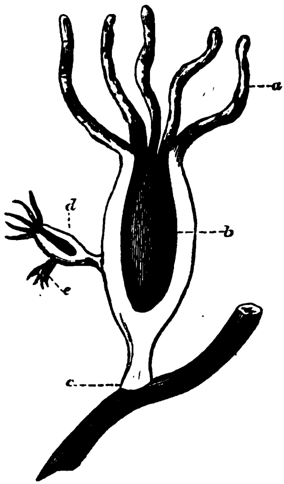
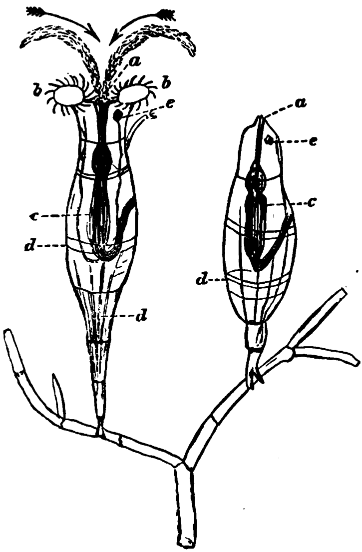


Fig. 22.—Diagrammatic representation of a section of a Hydra. *a*. Tentacles. *b*. Digestive cavity. *c*. Foot attached to a plant. *d*. A young offshoot. *e*. A similar offshoot of the third generation.

What gives that mass of jelly the power of constructing these elaborate skeletons, arranged in such geometric forms? It is the wonderful force which we recognise under the name of *Life*. When men tell me that by bringing together certain combinations of inorganic elements, they can produce gelatine and albumen, and various other animal substances with which we are familiar—seeking to make me believe they have taken the first step in producing life, I challenge them to produce anything like what I have just described. I do not deny they may succeed in getting something like albumen or gelatine, but it is essentially *dead*—it possesses none of the powers of living protoplasm.

We may next go to the Hydra, the fresh-water Polype found in the ponds of our own neighbourhood. There is a decided break between the animals I have just been describing and this Polype. Fig. 22 exhibits a much more elaborate construction than we have hitherto seen. We find arms, called tentacles, at *a*, a true stomach or digestive cavity at *b*, and a foot at *c*, by which the object attaches itself to fixed bodies. Not only so, but there are sprouts growing out of its side which are chips of the old block. These offshoots grow precisely as the bud grows from the side of a young tree. You sow the seed of the oak, and know that in due season it will spring up as a single shoot with a couple of leaves. Watch its development, and you will see that leaf forms after leaf; by and by the stem begins to throw out buds from its side, forming a branching structure. These buds are produced in a perfectly intelligible way. If I had time, I could demonstrate that the process of their formation is very much the same as that by which the branch *d*, of the Hydra has been formed. The latter shoots out from the side of the parent animal like the vegetable bud; not only so; this second generation is often seen throwing out a third one, *e*. When the organism reaches this stage, the young growths usually become detached, and pursue life on their own account. By and by similar buds form both on them and on the parent animal, repeating the same history as before. These fresh-water Polypes exhibit a life-history which gives us the clue to that of numerous animals which we find on the sea shore. You are familiar with the corallines—the northern representatives of the corals found abundantly in tropical seas. These corallines are flexible, horny, and branch very elaborately. But when we examine their mode of growth we find it to be just like that of the Hydra, with this difference—in the Hydra, the young branches become detached from the parent stem; the coralline animals, being encased in a horny coat of mail, are unable to detach their young shoots; hence they go on branching until they develop into complicated structures, often sustaining thousands and tens of thousands of Polypes upon a single stem.

Associated in the same infusions with the Infusoria about which I have been speaking, we often find another extraordinary group of creatures. Figs. 23 and 24 represent the most common of these Rotifera, as they are termed, in two states. Fig. 24 exhibits him in a somewhat quiet condition, anchored by his toes, as they are sometimes termed, to a twig of an aquatic plant. When he chooses he can extend his snout, *a*, and throw out two round wheels, as at fig. 23, *b*. When we watch the action of these wheels, it is difficult to resist the conclusion that they are spinning round and round. But they are not. Round the edge of each of these circular discs there is a circle of cilia. When these cilia are in extremely quick and active motion, they give to the two discs an appearance of revolving in opposite directions, whereas, in fact, they are merely creating currents in the water which move in the directions indicated by the two arrows.



Figs. 23 and 24.—Two animals of *Rotifer vulgaris* adherent to a plant. 23 has his ciliated discs, *b*, *b*, fully expanded and in action. *a*. Mouth. *c*. Stomach. *d*. Longitudinal and circular muscular bands. *e*. Brain. In fig. 24 the discs have been drawn back into the anterior part of the body.

These currents are really two whirlpools which meet in the middle, and convey such particles as the water contains straight to the animal's mouth. Thus his food is brought to his very door. All he has to do, when he sees a tempting morsel, is to make a snap at it, or if it is not tempting, he lets it go by.

When I hear of a man making £100,000 honestly, I consider there is usually something more in this than mere chance. I do not much believe in luck in this world. What is termed such, is often the union of a good head, selfdenial, and industry. It is the combination of these qualities that raises one man above another. The qualities may not be of the highest intellectual order, but they are qualities worth having, provided they are honestly used. Such a man sets *his* wheels to work, and produces currents which converge at one point—his pocket. If there are any of the class of operatives present, let me remind them that the study of nature ever teaches us the necessity for mutual dependence. Remember that whilst our wealthy friend is setting these streams in motion, and they are flowing legitimately to the fixed point I have indicated, every one of them is passing your mouths, and each operative who aids in producing these currents takes his snap at the good things which they convey. He gets his share; and if he is sober and diligent, and exhibits the same qualities as his master does, he will not only rise higher and higher in the social scale, but sooner or later may be a master himself, when we may hope the streams will meet in *his* pocket.

These Rotifera have a digestive system, *c*, longitudinal and circular muscular bands, *d*, and a true brain, *e*. The bodies of these animals are so transparent that we can see everything going on within them.

The study of these Rotifera is an extremely interesting one, since there are some curious points in their history. Dr. Carpenter tried an experiment, which has also been tried by others. He froze a number of these objects in a watch glass; on thawing them again he found that whilst some had perished several were still living. He then froze the living ones a second time, when a few more were killed. A third freezing destroyed them all. These Rotifera are common in the spouts and gutters on the tops of houses. Sometimes these gutters are filled with water, when the animals are lively; but in the heat of the summer season they are often dried up, when the Rotifera are reduced to particles of mere dust. Some time ago the Rev. Lord Sydney Godolphin Osborne, the well known S. G. O. of *The Times*, sent me some Rotiferous dust in a pill-box. He had had it in his possession for months; but when I put a little of it into water, in less than five minutes the animals which it contained were all in full action. I first saw little specs of jelly, which in a few minutes expanded into perfect Rotifera. They had been in the dormant state in which I received them for months; but when they fairly got into the water they put their wheels to work, and looked as if they were uncommonly hungry. It was quite amusing to see how readily they took to their work of feeding. I kept some of the dry dust in my possession for seven or eight months, and at the end of that time, when a little drop of water was brought in contact with them, they were as active and vigorous as ever. Here are creatures of high organisation, yet so endowed with peculiar qualities, that whether, on the one hand, we freeze them, or on the other dry them up, they still live.

This subject of vital endurance leads us to the consideration of an allied, though different problem. You are all, probably, aware that within the last few years an old question has again come to the front and attracted the attention of both the wise and the unwise, the learned and the unlearned. I mean that of spontaneous generation.

Our forefathers two centuries ago knew little of the inner secrets of nature. They supposed that frogs and other highly organised creatures were brought into existence by spontaneous generation—meaning by that that they were formed in some mysterious way, out of dead, inorganic, slimy earth, without the previous intervention of living creatures. When investigation proved that these higher animals had not been formed in this way, men applied the same hypothesis to other creatures of a lower order. Throughout the history of this subject the advocates of this doctrine have always retreated from position to position, from the known to the unknown—in the same way that witches, races of pigmies, and anthropophagi with heads under their shoulders, were always described as existing in remote places about which little was known.

The progress of zoological knowledge having shewn that none of the higher creatures were produced by spontaneous generation, the Infusoria, of whose life-history very little was known until within the last twenty years, were confidently referred to as illustrations of the doctrine; but later investigations have shewn that none of the higher forms of these minute creatures are exceptions to the general rule that life alone produces life; and consequently the supporters of the doctrine are now compelled to fall back upon the lower Infusorial types—creatures which are so minute that the study of their life-history becomes in the greatest degree difficult, and the results of that study obscure and doubtful. Let it be distinctly remembered that wherever we have been able clearly to ascertain how their reproduction was effected, it has proved to be in the strictest accordance with that of creatures of higher organisations than themselves.

Dr. Bastian, of London, the modern advocate of the disputed doctrine, makes certain infusions, and he finds that certain minute objects appear in them, which he declares to have been produced by spontaneous generation. He heated the fluids in which these things are developed, raising them to such a temperature as, in his opinion, must necessarily kill all the germs of life. The experiments, we are assured by him, were conducted under such precautions that no such germs could re-enter the infusions from the surrounding air. Yet these infusions still exhibited, in a short time, minute forms of animal and vegetable life. On the other hand, a very distinguished naturalist in Paris, M. Pasteur, declares that if such experiments are properly conducted so that the heat is equally diffused, every germ being actually killed, and no new germs admitted, this result will not be obtained. It is necessary for you to understand that the air is literally filled with such germs; you inhale them with every breath you take; whether or not they produce disease, as some suppose them to do, I will not venture to say.

In these cases the question resolves itself into one of accuracy of observation. My friends, Dr. Roberts, of Manchester, Professor Huxley, and others, have gone over the same ground as Dr. Bastian has done, and their conclusions are more in accordance with those of Pasteur than of Bastian. They say that when the observations are properly carried on, and care is taken to exclude life from the bottles, no germs re-appear.

I venture to affirm that in cases of this kind one positive observation is worth a hundred negative ones. If Dr. Bastian tells me he has taken all needful precautions, and yet he invariably gets these germs, I venture to ask whether it is not possible there has been some undetected loophole through which the germs may have entered the infusions. But, on the other hand, when I find that a man like Dr. Roberts conducts experiments again and again, and obtains positive results, the opposite of those obtained by Dr. Bastian, and this too, after his infusions have been kept for months, I say, one such observation is worth a hundred negative ones.

Within the last few weeks some important observations, bearing upon this subject, have been made by the Rev. W. H. Dallinger and Dr. Drysdale. Owing to some remarkable peculiarities in the aspect of the minute Infusorian which was the subject of their study, they were enabled to follow its life-history with considerable success. This result was obtained through persevering observations, during the continuance of which the two observers successively relieved each other at the microscope. Fig. 18 represents a common form of the Monad, as the minute Infusorian in question is called. They found that it multiplied through various modes of mechanical subdivision, or fission, as in the animals described in an earlier part of this lecture; but the portion of its history which bears in the most important manner upon the question of spontaneous generation is connected with the peculiar structure of the posterior half of the body of each Monad. As shewn at fig. 18, *a*, this portion of the organism consists of a more granular form of protoplasm than its opposite extremity. Under special circumstances the skin enclosing the granular part becomes ruptured and the granules are liberated. The observers found that each of these liberated granules developed into a perfect Monad in the course of a few hours.

These facts shew us that the process of Fission occurs amongst these very minute forms, which are not more than $\frac{1}{1100}$ of an inch in length, just as in the Sponges, and in the larger Infusoria. Remember that we are now considering creatures so minute that fifty years ago it was almost beyond the powers of existing microscopes to make any trustworthy study of them possible. The lens of the microscope used was 1·50th of an inch focal length, while few persons are in the habit of using lenses of higher power than the 1·8th or the 1·12th of an inch in searching out the hidden secrets of nature. Yet, on applying this power of 1·50th of an inch to these minute objects, we find the same laws of organisation and reproduction prevailing amongst them as exist amongst the more conspicuous of these early forms of animal life.

These gentlemen exposed the above animals on seven occasions to a dry temperature of 121° centigrade, which is considerably above the boiling point of water, and found that it killed all the parent and mature animals, but in two instances it did not kill the granular germs. They found the latter still living, and watched their development into the well-known mature forms. They thus obtained the proof, supposing that these experiments were accurate, of what we long before believed to be true, viz., that the temperature which killed the parents left the germs possessed of life.

That this was the true explanation was shewn to be probable by their next experiment. They raised the temperature *of the fluid* in which the animals lived to 66° C., and found that this sufficed to kill all the adults, whilst the germs survived even after that temperature had been raised to 127° C.

If I were asked to believe that a man walked through the streets of Glasgow with his head under his arm, I should obviously want a very strong amount of evidence before I believed the statement, and so would you. So it is with any alleged facts that run counter to the known history of protoplasm; we demand unusually strong evidence before we accept such allegations. We have seen what protoplasm does on a large scale in the larger animals, and as we trace it downwards amongst the minuter forms of life, we see that in its nourishment, its growth, and its multiplication it exhibits certain phenomena that have a common existence in all organisms from man down to these lowest Monads. The little atoms of protoplasm contained in the human blood multiply by subdivision in the same way as the protoplasm does amongst these creatures. The Protoplasms which fill the cells of all animal bodies, as well as those universally diffused throughout the vegetation of the world, are multiplied in the same way by successive fissions as in those I have described to you. We thus see that when we trace the highest vegetable organisms down to their simplest states, we find precisely similar phenomena to be of universal occurrence.

Hence we have every reason to suppose, judging from analogy, that if we succeed in effectively studying forms yet more minute than those with whose life-history we are already acquainted, we shall find the same processes still in action. When Newton and the older astronomers turned their telescopes to the stars, they knew nothing of the remote systems which modern astronomers have succeeded in discovering. Newton shewed us how the nearer planets and the remoter stars obeyed the same law of gravitation. Have our modern astronomers, as they discovered yet remoter planets and newer nebulæ, found the law of gravitation reversed? No; they see the same mysterious force regulating the movements of the most distant as well as the nearest suns. They find everywhere in the heavens unity in the forces of nature; in like manner when we have traced these vital processes down amongst these minute atoms, and found no material change in their nature, we are fairly justified in assuming that as we trace them yet lower, we shall discover a similar continuity of known vital actions. If this be true, we are landed in a position which makes me utterly fearless in relation to the investigations of science. I know I have nothing to do here with questions of theology. But in admitting the possible correctness of some scientific doctrines which to you may appear to have dangerous tendencies, do not imagine from my making such admissions that I am *a priori* hostile to that Christian faith which I cherish in common with most of yourselves. It may be true that my remote ancestor was a monkey. I do not care if he was; he has done me no harm, and may have handed down to me some vigorous activity of body, the result of his woodland life. Neither do I care if evolution proves to be true—if every living organic thing that now appears in nature once emanated from one solitary germ of life. I do not fear, because, instead of such a theory enabling us to dispense with the God of nature, the recognition of a creative Power is as necessary to explain the origin of that one primary germ, as to explain the existence of the world itself. If it be true, as I have been teaching you, that no life appears, except as the product of pre-existing life, it is equally true that there has been an unbroken continuity of life from the beginning down to the present time.

I believe that the philosophy of the evolutionists embodies a vast amount of truth, and that their inevitable recognition of the fact that organic life had a beginning upon the earth, and had not existed throughout eternity, is not the least important of the conclusions involved in that philosophy. The high-priests of the evolutionist school tell us that organic life is now a much more complex thing than it once was, and that the more complicated organisms have been gradually evolved out of others that were less complex. We are thus led back to a point of time when the first germ of life dawned upon the earth; this is important, because we have not the same proofs that the *inorganic* universe had such a beginning. Those who argue in favour of the eternity of matter are not so easily answered as are those who contend for the eternity of life and organisation. But if there was a time when so important an element of the world's being as life was non-existent, and yet another time when it began to exist, it becomes somewhat probable that the inorganic world had a beginning likewise. Be that as it may, the truth of which I am speaking accords, as far as it goes, with the first of our great scriptural beliefs—viz., that there was an origin and a Creator of all things.

The advocates of spontaneous generation may however admit this much. They may contend that they only connect creation with its Creator at an earlier stage of His work, and that He who endowed the first germ with its marvellous functions displayed a yet mightier power when He endowed the dust of the earth with similar potentialities. This is doubtless true; but I contend that we yet lack all proof that dead, inorganic matter can be converted into living matter, save through the agency of pre-existing life; and it is my firm conviction that no such proof will ever be obtained. The chemist may so combine atoms as to obtain products like *dead* albumen and similar animal substances, but he has hitherto failed to endow them with life. They cannot imbibe nourishment from without, multiply by dividing and subdividing, ever growing as they do so; in a word, they lack *vitality*.

If any who now listen to me think that I am lowering their grand conception of a Deity by thus possibly reducing part of His creative work to the production of a solitary germ, I confess I cannot agree with them. If such a germ contained within itself the potentiality of development into the entire living creation, I confess I cannot conceive of a higher manifestation of creative power than is involved in its production. The being who originated such a germ must at least correspond with our feeble conceptions of Him whom we reverently call God. If so, I think we cannot avoid going a step further, and exclaiming with one of England's noblest intellects—

> "If there's a Power above us,
> And that there is, all nature cries aloud
> Through all her works, He must delight
> In virtue."