much patient labor to characterize those that are truly species and those that are varieties only.

EXPLANATION OF PLATE 11.

Fig. 1. *Lymnaxa megasoma* Say. Lake Champlain to Michigan.
" 2. " *appressa* Say. Northern States to Pacific.

Figs. 7, 8, 9, 10, 11, 12. *Lymnaxa elodes* Say. Northern United States.

Fig. 13. *Lymnaxa desidiosa* Say. New England to Kansas.


Fig. 20. *Physa ampullacea* Gould. Oregon.
" 23. " *gyrina* Say. Northern United States; figured from original specimen.

Fig. 24. *Physa elongata* Say. Northern United States.

WHAT IS BATHYBIUS?

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

During each successive year the Protozoa prove to be of increasing importance to the physiologist. In no other class of matured animals can the protoplasm, of which we have recently heard so much, be studied to such advantage. Constituting the lowest known manifestation of both animal and vegetable life, it seems to bring us very near to the boundary between the organic and the inorganic worlds. It exhibits the simplest phenomena of life under the least complex of conditions; hence it has recently been appealed to by one of the most philosophical of living zoologist as capable of
throwing light upon the most recondite of biological problems. Without accepting all, or even the chief of the conclusions at which Professor Huxley has arrived from his study of protoplasm, he must be deemed right in the importance which he assigns to it. Whether seen as the gelatinous sarcode of the Protozoa, occupying the base of the animal kingdom, or as the yolk-material out of which the embryo of the highest vertebrate is formed; whether we observe its plastic mass in the primordial germ of a Protococcus or of a Volvox, or as it appears in the leaf-bud of an oak, it everywhere brings before us the first stage in acts of organization in which it is the chief, if not the only actor. Nevertheless, I am unable to see that our study of protoplasm has brought us nearer than before to a knowledge of the origin of that mysterious force which converts inorganic into organized material. There yet remains to be bridged over that unfathomed gulf which separates death from life—the most complex effects of inorganic forces from the simplest of vital phenomena. We can trace the action and development of protoplasm through successive generations of organisms; but, like the spot where the rainbow touches the ground, its mysterious origin recedes as we advance, and a weary chase leaves us no nearer our object than when we commenced its pursuit. We increase our information respecting the conditions of its existence, but not of its origin; and I believe that from the nature of the problem this ignorance will continue.

We are asked, wherein does the so-called vital force differ from other physical forces? Oxygen and hydrogen combine to form water; if you admit vitality, why not require a principle of aequosity to explain this combination and its resultant phenomena? "What better philosophical status," asks Professor Huxley, "has vitality than aequosity?" I reply, we require the admission of no new force to explain the combination of gases in the formation of water. The phenomena occur in accordance with known laws of affinity.
The synthetical experiment is but one of a vast series of similar experiments, in each of which we can combine separate elements with absolute certainty that the resultants will be identical with, and fulfil all the functions of, the same products when formed in nature's laboratory. But the case is different when we turn to living organisms. We may know the proportions of oxygen, hydrogen, carbon, and nitrogen, existing in any form of protoplasm, and we may even succeed in forcing those elements into an artificial combination having the same proportions, but in no single instance have we been able to endow such a combination with the powers of life. The resultant is not protoplasm. It does not live. It performs none of the vital functions. "Certain conditions" are wanting, and, so far as experiment has hitherto gone, the laboratory has proved unable to supply those conditions. Some "force" is required which is not under the control of the ablest physicist, and which differs in kind as well as in degree from those with whose operations he is familiar. We infer this, because all the functions of the resultant of nature's organic synthesis are different from those of all artificial products. It is this lacking force which we indicate under the name of vital; and so long as experimental philosophers fail to make their artificial combinations do what it does, I claim to be as philosophical, and to be acting in as truly a scientific spirit, when I recognize its existence as when I speak of a magnetic force or of a force of gravitation.

Professor Huxley asks, "What justification is there, then, for the assumption of the existence in the living matter of a something which has no representative or correlation in the not living matter which gave rise to it?" Surely the question, thus put, involves a fallacy. Professor Huxley admits that to produce the results referred to the introduction of a new element is needed. The not living matter requires the aid and instrumentality of matter that is living, and it is precisely this necessity which leads me to conclude that the
living matter does contain something wanting to the "not living matter."

The living organism increases, multiplies, and reproduces itself through a power that is inherent, whereas a crystal can only do so through powers external to itself; whatever it may be, the vital power is always derived; no known combination of inorganic elements or dead forces could have created it. Except in a few obscure cases, too ill-understood to be made the basis of a grave argument, protoplasm can always be traced, directly or indirectly, to some pre-existing form of protoplasm. We nowhere discover any power which, without the intervention of some already living agent, can convert inorganic matter into living matter. If we could even trace back the history of protoplasm, until we reached one of Mr. Darwin's primæval germs, our philosophy would still leave the first of these living azotized combinations unaccounted for. Since, then, scientific experience affords no proof that life is nothing more than a function of material combinations, acted upon by physical forces, we are justified in the recognition of a vital principle, emanating primarily from a living Creator, but which, once created, appears capable of self-perpetuation to the end of time.

If, having recognized the importance of the study of protoplasm amongst the lower animals, we commence its pursuit, we soon discover the difficulties which surround it, especially when we discover the apparent inadequacy of the causes to the effects produced. We see a granular jelly evolving endlessly varied forms of grace and beauty; at one time using silica as its raw material, at another carbonate of lime. Here it glues together grains of sand, there it develops a new sand-like compound, the very nature of which has yet to be discovered. In one form it produces the horny network of a sponge — in another the ethereal tracery of an Euplectella. The colors of its products are almost as varied as their material forms. We seek the cause of all this rich diversity — but seek in vain. We see the almost
motionless granular jelly investing the objects of beauty which it has constructed, but it affords us no indication of the secret of its wondrous power.

We hail every new fact tending to throw light upon a history which is as obscure as it is marvellous. Hence the importance attached to Professor Huxley's discovery of the vast masses of submarine protoplasm, to which he has given the name of *Bathybius*. When, in 1857, Capt. Dayman, of H.M.S. Cyclops, returned from his exploration of the bed of the Atlantic, some of his specimens of "soundings" were placed in the hands of Professor Huxley for examination. The explorers had already noticed the singular stickiness of the mud brought up by the lead, and Professor Huxley soon found that this viscid condition arose from the diffusion through it of abundance of sarcode or protoplasm of a protozoic nature. The mud, like much of what constitutes the bed of the Atlantic, consisted of chiefly accumulated shells of *Globbigerna bulloides*—themselves the skeletons of a protozoic sarcode. The Bathybius occurred in minute patches of gelatinous protoplasm, usually of irregular shape, but occasionally assuming roundish forms. It consisted of a transparent jelly containing innumerable, very minute, granules, many of which Professor Huxley found to be equally soluble in dilute acetic acid and in strong solutions of the caustic alkalies; but, in addition, there occurred some remarkable bodies to which great interest is attached. In the first instance Professor Huxley noticed, adherent to the protoplasm, and occasionally embedded in it, numerous minute rounded bodies, soluble in acids, and to which he gave the name of *Coccoliths*. Still later, in addition to these Coccoliths, Dr. Wallich discovered, associated with the Bathybius, some larger spherical bodies of more complex organizations which he designated *Coccospheres*. Yet more recently Professor Huxley has reëxamined his specimens under higher powers, and found his Coccoliths were of two classes—to which he now gives the respective names of *Discolithus* and *Cyatho-
WHAT IS BATHYBIUS?

lithus. The Discolithi he describes as "oval discoidal bodies, with a thick strongly refracting rim, and a thinner central portion, the greater part of which is occupied by a slightly opaque, as it were, cloud-patch. The contour of this patch corresponds with that of the inner edge of the rim, from which it is separated by a transparent zone. In general the Discoliths are slightly convex on one side, slightly concave on the other, and the rim is raised into a prominent ridge on the more convex side."* These objects usually range from 1 to 3/4 of an inch in their longest diameter.

The Cyatholiths are like minute shirt-studs. They are stated to have "an oval contour, convex upon one face, and flat or concave upon the other. Left to themselves, they lie upon one or other of these faces, and in that aspect appear to be composed of two concentric zones surrounding a central corpuscule." "A lateral view of any of these bodies shows that it is by no means the concentrically laminated concretion it at first appears to be, but that it has a very singular and, so far as I know, unique structure. Supposing it to rest upon its lower surface, it consists of a lower plate, shaped like a deep saucer or watchglass; of an upper plate, which is sometimes flat, sometimes more or less watchglass-shaped; of the oval, thick-walled, flattened corpuscule, which connects the centres of these two plates; and of an intermediate substance, which is closely connected with the under surface of the upper plate, or more or less fills up the interval between the two plates, and often has a coarsely granular margin. The upper plate always has a less diameter than the lower, and is not wider than the intermediate substance.†" These Cyatholithi are further stated to vary in size from 3/4 to 1/2 of an inch in diameter. The Cocco-spheres are described by the same distinguished observer as

†Ibid. p. 207.
"of two types — the one compact and the other loose in texture. The largest of the former type which I have met with measured about 1\(\frac{1}{3}\) inches in diameter. They are hollow, irregularly flattened spheroids, with a thick transparent wall, which sometimes appears laminated. In this wall a number of oval bodies, very much like the 'corpuscules' of the Cyatholiths, are set, and each of these answers to one of the flattened facets of the spheroidal wall. The corpuscles, which are about 1\(\frac{1}{3}\) inches long, are placed at tolerably equal distances, and each is surrounded by a contour-line of corresponding form.” “Coccospheres of the compact type of 1\(\frac{1}{3}\) inches in diameter occur under two forms, being sometimes mere reductions of that just described, while, in other cases, the corpuscles are round, and not more than half to a third as big, though their number does not seem to be greater. In still smaller Coccospheres, the corpuscles and the contour-lines become less distinct and more minute, until, in the smallest which I have observed, and which is only 1\(\frac{4}{5}\) inches in diameter, they are hardly visible."

"The Coccospheres of the loose type of structure run from the same minuteness up to nearly double the size of the largest of the compact type, viz., 1\(\frac{1}{3}\) inches in diameter. The largest (of which I have seen only one specimen) is obviously made up of bodies resembling Cyatholiths of the largest size in all particulars except the absence of the granular zone, of which there is no trace. I could not clearly ascertain how they were held together, but a slight pressure suffices

*Fig. 101 is a "sketch of a mature eight-chambered Textularian shell, each segment of which is studded with Coccoliths. The specimen referred to was obtained along with numerous others, from a depth of 1913 fathoms (upwards of two miles) between the Coasts of Greenland and Labrador." Dr. Wallich from whom we quote, believes "that the Coccospheres are the parents of the Coccoliths." See his article "On the Vital Functions of the Deep-sea Protozoa," Monthly Microscopic Journal, No. 1, Jan., 1839, 8vo, London. — Eds. Nat.
to separate them."* The relations subsisting between these Coccospheres on the one hand, and the Cyatholiths on the other, are very obscure; but Professor Huxley deems it probable that some close affinity does exist; but whether the Coccospheres have been formed from a coalescence of Cyatholiths, whether the Cyatholiths have resulted from the breaking up of the Coccospheres, or whether the Coccospheres are altogether independent structures, yet remains to be decided. There appears, however, no reason to doubt that Coccoliths, Coccospheres and Cyatholiths, equally belong to Bathybius, as the skeleton of a sponge, or the shell of a Foraminifer belong to their respective protoplasmic sarcodes.

Since Professor Huxley completed the observations to which I have referred, Dr. Carpenter and Professor Wyville Thompson have conducted a very important series of deep-sea dredgings off the north coasts of Scotland, and in the neighborhood of the Faroe Islands. In Capt. Dayman's dredging operations the viscid mud was found between the fifteenth and forty-fifth degrees of W. longitude. Those of Drs. Carpenter and Thompson were carried on much further eastward; but in the latter instance the same deposit was found over a range of at least two hundred miles, throughout which the dredge came up from time to time filled with Globigerina-mud and saturated with Bathybius, with its associated Coccoliths and Coccospheres. The Globigerina deposit exists in a similar manner in many and distant parts of the ocean, in both hemispheres; and it is more than probable that when the remote localities are subjected to the same examination as our northern seas have recently undergone, Bathybius will be found in them also. Its low organization renders it probable that it will be found to be like its companion Globigerina, a thorough cosmopolite. On this point Dr. Carpenter suggests that the range of these objects is regulated by temperature rather than by locality. It was

already known that many deep-sea localities existed, in which the Globigerina-mud did not occur; and it had even been suggested that its range was limited to that of the warm Gulf-stream. Dr. Carpenter confirms this general conclusion, and points out that its prevalence is connected with a bottom temperature of 45°, which in our northern latitudes can only be attributed to the Gulf-stream.

Bathybius yet requires to be considered in two other important relationships—the one geological and the other zoological.

Chalk, examined microscopically, has long been known to abound in minute ovate organisms, known as crystalloids, associated with the Globigerinæ and Textillaræ, of which chalk mainly consists. I recognized the organic origin of these bodies in 1847, and figured (Fig. 102) one of them very imperfectly, viewed as an opaque object, in my memoir "On some of the Microscopic Objects found in the Mud of Levant;"* but, ignorant of Coccoliths, I concluded that they belonged to some minute form of Oolina or Lagena. More recently Mr. Sorby has subjected these bodies to a much more careful examination, and both he and Dr. Wallich have identified them with Professor Huxley’s Coccoliths. It now appears that both Coccoliths, Cyatholiths and Coccospheres, occur fossilized in the chalk, establishing, in a remarkable manner, the close resemblance of the conditions under which the chalk-beds were formed and those existing along the tract of the Gulf-stream at the present day. Dr. Carpenter goes even further than this, and regards it as "highly probably that the deposit of Globigerina-mud has been going on over some part or other of the North Atlantic sea-bed, from the Cretaceous epoch to the present time (as there is much reason to think that it did elsewhere in anterior geological periods), this mud being not merely a chalk formation, but a continuation of the chalk formation;  

so that we may be said to be still living in the cretaceous epoch."*

With the earlier part of the preceding paragraph I partly agree, but from its concluding sentence I must dissent. Chalk chiefly consists of an accumulation of Globigerina cretacea, associated in almost equal proportions with a minute Textillaria and with Coccoliths. The fossil Globigerina is probably but a mere variety of the recent G. bulloides; hence so far as it is concerned, ancient and modern deposits may have been continuous. But in none of the modern Globigerina beds which I have examined have I found anything resembling the fossil Cretaceous Textillaria, the disappearance of which requires to be accounted for. What I believe to be the same species occurs abundantly, amongst other modern types of Foraminifera, in the recent sandy deposit underlying Boston in Lincolnshire, but I never succeeded in discovering it living in the sea. From some unknown cause it has disappeared. On the other hand, our modern deposits abound in Diatoms and Radiolariae, of which no trace appears in the true Cretaceous beds. That in the depth of the Atlantic Cretaceous and modern deposits may be conformably and continuously superimposed is not impossible, but conformable continuity of series does not constitute identity of age or of formation. In the Speeton clay of the Yorkshire coast we have, in the same blue deposit, a transition from the Oolites to the Cretaceous beds. The deposits have continued to accumulate without physical change from the one age to the other, but the formations to which the upper and lower portions of this clay belong are distinct, and represent distinct epochs. Dr. Carpenter is disposed to conclude that the higher forms of the Atlantic and Cretaceous fauna will prove to be nearly identical; but I doubt this, and we must not repeat the blunder of Ehrenberg, in the case of the tertiary beds of the Mediterranean coasts, which he regarded as Cretaceous, because he found

that they abounded in Cretaceous types of Foraminiferans, overlooking the wide differences presented by the higher organizations of the two formations. So in the instance under consideration. Owing to the low vitality of the Protozoa, some of them have survived the changes which time has wrought in the higher groups of animals. The recent Globigerinae and Bathybius are probably descendants from those which lived during the Cretaceous period, but their companions are not the same. The abundant Textillariae are replaced by Diatoms and Radiolariae. Instead of Marsupites we have the Rhizocorinus. The Ananchytes and Galerites are represented by Cidarites and Spatangi; amongst star-fishes Tosia (Goniaster) has given place to Ophiocoma. For the chambered Cephalopods we have the modern cuttlefishes, whilst the Saurians and Ganoid fishes of the Cretaceous age have left no descendants in these Atlantic depths, their places being taken, in all probability, by the more familiar and much more useful codfish.

The zoological affinities of Bathybius are not very difficult to understand, though the young student is apt to become bewildered by the growing number of classifications of the Protozoa that are being offered for his acceptance, and the multitude of new terms with which, in consequence of these new classifications, our journals have become loaded. The last of these arrangements is that of Häckel, who has separated the Protozoa, under the name of Protista, equally from plants on the one hand and from animals on the other. He regards them as the common starting-point from which, in accordance with Darwinian ideas, both plants and animals have derived their origin. Without necessarily accepting this creation of a third organic kingdom, we may beneficially recognize Häckel's division of the Amœban section of the Protozoa into two groups, viz.: the Monera and the Protoplasta; the former comprehending those Amœbæ which exhibit an uniform granular sarcode without any trace of or differentiation into
special organs, and the latter including those types in which we have such special structures in the form of contractile vesicles, nuclei, or other differentiated appendages. So far as the structure of the sarcode is concerned, Bathybius is apparently a true Monera, and such its discoverer considers it to be. At the same time, the existence in connection with it of Coccoliths and Cyatholiths indicates the necessity for separating it from Haeckel’s other Monera, which have no such special appendages. But the time has not arrived for determining the absolute relations of these objects. New types, as Haeckel himself admits, are being discovered, rendering modifications of his groups necessary. Meanwhile there can be no question that Bathybius is the lowest of those known Protozoa, which, like the Foraminifera, secrete calcareous elements. Remembering the extent to which the sarcode is diffused through the mud of the Atlantic, there appears much that is suggestive and important in the observation of Dr. Carpenter, that, had its power of secreting a calcareous framework been somewhat increased, so that instead of detached structures in the form of Coccoliths, etc., it had produced a continuous calcareous mass, it would have given us a living prototype of the Laurentian Eozoon. The discovery of this widely and continuously diffused Bathybius strongly sustains Dr. Carpenter in his conviction of the animal origin of that primæval structure.—*Popular Science Review*, October, 1869.

---

**REVIEWS.**

**RESULTS OF DEEP SEA DREDGING BETWEEN CUBA AND FLORIDA.**—Mr. A. Agassiz makes a “Preliminary Report on Echini and Starfishes Dredged in Deep Water.” Part 1st is devoted to descriptions of new genera and