It was with great satisfaction that he had to announce that some very interesting communications would be made, for the first of which they would be indebted to Professor Phillips, who would now proceed with his communication.

Professor PHILLIPS, of St. Mary's Lodge, York, then read his paper

ON THE REMAINS OF MICROSCOPIC ANIMALS IN THE ROCKS OF YORKSHIRE. BY JOHN PHILLIPS, ESQ., F.R.S., F.G.S.

There is nothing more certainly proved, more generally known, or more important in Geological reasoning, than the fact that a very considerable portion of the stratified masses of the globe is composed of the remains of organized beings. Changed vegetables have yielded our coal—changed Zoophyta compose the entire mass of some limestones—shells contribute to augment the thickness of almost all the strata which rest upon the Gneiss and Mica schist groups.

It is also known, that, in very many instances, plants and Zoophyta occur in a fossil state, on the very spots where they were attached in life; that they did actually grow and perish where now we find their remains. Shells in like manner appear with all the marks of being entombed on or near to the very localities where their molluscous tenants respired and fed; the valves of oysters are yet attached to the rock, stone, or old shell on which the young ova fixed themselves; lithodomous Conchifers yet occupy the very holes which they have bored; Cardiacea and Veneridæ yet display their valves, as closed by the muscles in life, or partially opened by the decay of these muscles, or separated by the decay of the ligament, or finally broken and worn by the agitation of the water in which they died.

It follows, from investigations of this kind, that in the same physical area of the earth's surface, but at successive

times, different races of plants and animals lived, whose specific forms changed with those successive times, and being preserved to us, are characteristic or indicative of these times.

It also follows that the chemical processes which are necessarily coincident with the phenomena of life,—the decomposition of the carbonic acid of the atmosphere by respiration of plants,—the decomposition of sea water by marine plants and marine animals,—the secretion of solid carbonate of lime and pure silica in the substance of shells, corals, and sponges, must have continued through times and under conditions equal to produce the amount of those effects which Geology has measured and made known.

These things are generally known and admitted; but it is possible by scrutinizing more minutely the texture of rocks, to extend the data and fortify the reasoning. Our *admiration* of the degree in which the hard parts of animals have contributed to augment the so-called mineral masses of the globe will indeed rise to *astonishment*, if we call to our aid the magical power of the achromatic microscope, and investigate with it the ultimate constitution of the limestones, flints, sands, and clays, in which the unassisted eye sees nothing but a mere aggregate of earthy particles.

We may effect this in at least four ways;—1st, by cutting stones into thin slices, so that they become transparent; 2ndly, by incineration; 3rdly, by pulverizing and washing softer substances, such as chalk; and 4thly, by distilling chemically some parts of a rock, and leaving others for examination in a finely divided state.

This investigation has drawn forth a crowd of observers, of whom Ehrenberg is the chief. It results from their inquiries, that in the *superficial deposits* of Geology, which are scarcely counted among the old stratified masses, but belong to comparatively recent periods, vast numbers of

minute organisms occur, so that whole lakes have been filled up by them, and deposits, composed of little else than the remains of infusorial animalcula, have been measured to as much as 14 feet in thickness.*

Further, that in the genuine *Tertiary Strata*, as, for example, the Eocene Sands of Grignon, the proportion of minute Foraminifera, which is mixed with the common sand, is enormous.†

Again, that in secondary strata, especially in the *chalk*, minute Foraminifera and minute Infusoria abound, so that whole beds appear to consist of little else, especially in the South of England and in the North of Germany.‡

It has been also ascertained, that in the secondary strata below the chalk, particularly in the Oölites of Yorkshire and Stonesfield, many of the Foraminifera occur; and it is a result of my own researches, that in the mountain limestone they are not rare, and that the limestone of South Devon and the silurian limestones contain traces of this widely diffused class of Microzoa.

I will now briefly notice, commencing with the Mountain Limestone, the most frequent of the minute organized bodies, which are revealed by the microscope, in those parts of the calcareous deposits of Yorkshire, which, to the unassisted eye, appear to be devoid of organization.

Of this rock it will be sufficient to notice two varieties, the oölitic and the compact. In the former it is common to find, in the centre of the grains or ova, minute Foraminifera, bits of coral, small joints of Encrinites, and small Goniatites.

In the compact rock we find precisely the same things, as Foraminifera, small Milleporidæ, minute Cyathophylla, minute Calamoporæ, Crinoidal joints, and Goniatites. They

* Ehrenberg. † D'Orbigny, &c. ‡ Ehrenberg. Reade. Mantell.

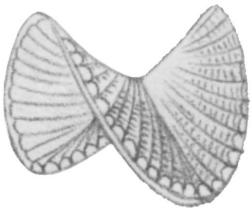

FIG 8

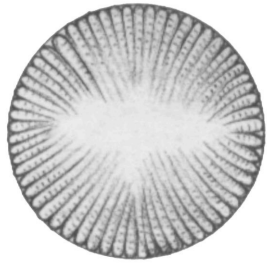

FIG 9

FIG 7

FIG 6

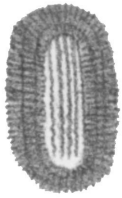

FIG 5

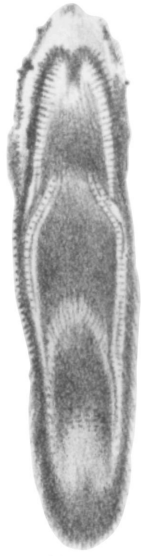

FIG 3

FIG 4

FIG 1

FIG 2

J F MASSER LITH LEEDS

are by no means equally diffused. In the brown clouded marbles of Beetham Fell, they are so very plentiful as to crowd the field of the microscope. Similar characters belong to the white Mountain Limestones of Russia.*

Amongst these fossils I distinguish a beautiful concamerated shell, most probably a Foraminifer, with a large opening in each septum, on the interior edge. Formerly I saw in the possession of Mr. John E. Bowman a specimen of this kind, visible to the naked eye, and named it Endothyra Bowmanni. (*See Fig.* 1.) The volutions are swollen externally between the septa.

Another common form of Foraminifera is represented in section in *Fig.* 2.

Beside these, are many minute spiral shells of Gasteropoda.

In the Magnesian Limestone, as yet, I have been comparatively unsuccessful. The compact parts of the rock seem to consist of earthy grains, imbedded in a cement of crystalline carbonate of lime; and this is a very general character of the so-called earthy limestones. Similar characters belong to the Magnesian (Permian) Limestone of Russia.

The Nodular Lias beds of Yorkshire I have not yet examined. The blue Lias of the South of England is in some beds rich in portions of Crinoidea, but in others almost devoid of organization. Small Conchifera appear in the sections, but I have not observed Foraminifera. There are in this stone some singular patches, (green, by transmitted light,) which I am as yet unable to resolve.

The whole Lias of the vicinity of Bath is a mass of minute granulation, cemented by a carbonate of lime. There are many little concentric textures, with a dark centre.

* I am indebted to Sir R. I. Murchison for specimens of the Palæozoic Limestones of Russia. They have furnished many interesting facts under the microscope.

Some beds of the Oölite of Yorkshire are remarkably rich in minute organization. Abstracting the consideration of the oviform grains, which in this rock are somewhat different from the ova in the Bath Oölite, we find minute spines of Echini, bits of shell, and plenty of small Foraminifera. These latter are in fact numerous, and generally of the form of Textilaria. Within a circle of 1-40th of an inch in diameter, we frequently find three of these beautiful shells, the lamina which discloses them being less than 1-200th of an inch thick. This would give, in one cubic inch, 960,000 individuals, or one million wanting 40,000. I have seen but few Rotaliæ in this Oölite.

Fig. 3 represents a beautiful section of one of the discoid or Nautiloid Foraminifera, parallel to, but not quite through, the axis; the enclosing calcareous paste is there. The transverse fibres, of which the shell consists, are visible.

Fig. 4 is a minute spiral shell of a Gasteropod, (Turbo), enclosed in a thin calcareous paste.

Fig. 5. A portion of a species of Cidaris, enclosed in an oval grain, which is formed of concentric sheaths of radiating fibres.

Fig. 6. A finger joint of an Encrinite, enclosed in a grain of opaque granular calcareous paste, in which neither concentric sheaths nor radiating fibres are distinct.

The Oölitic grains are separately suspended, so to speak, in a connected mass of clear crystallized carbonate of lime; and this circumstance is almost universally recognised in the Oölites of the North of England. The Oölite of Ketton, in Northamptonshire, is, in this respect, very different, being mostly an aggregation of round grains in contact.

In the chalk of Yorkshire occur, but far less frequently than in that of Kent and Germany, minute Foraminifera, especially of the genera Rotalia and Textilaria. I have rarely found in it the spicula of sponges, or the minute coralloidal bodies which are mentioned elsewhere.

The Yorkshire chalk is not so well suited for microscopic examination as that of the South of England, nor are the flints which abound in it so rich in organization as those of Kent and Wiltshire. They appear, however, to contain, though in less abundance, the same minute organizations. Flint, with a peculiar cloudy, mottled, textural arrangement, which Mr. Bowerbank refers to sponge, contains imbedded in its substance several kinds of minute structures, of which the so-called Xanthidia are the most remarkable. In general, I find in the chalk and flint a quantity of organization, continually increasing in proportion to the clearness and perfection of the microscope. Not a small part of the mere powder-grains are single cells of the Rotalia and Textilaria. (See *Fig.* 7 for the outline of a Rotalia.)*

Among the numerous lacustrine deposits on the coast of Yorkshire, of which 16 years ago I published the descriptions, one has often since attracted my attention, from the great probability of its containing Infusorial animalcula. I allude to the peculiar white and brown cretaceous marly deposits, a quarter of a mile north of Bridlington. I have often examined this marly substance, but my instrumental means, till within a few years, were inadequate to the research. The Rev. W. V. Harcourt found it to contain a certain proportion of silica. I have repeated this experiment, and find among the siliceous grains left by the action of dilute acid, a considerable number of Loricated Infusoria, chiefly of the genera Navicula, Cocconema, Bacillaria, and Eunotia. I have also been fortunate enough to discover a new species of the rare genus Campilodiscus in this marl; and as occurrences of this kind are not frequent in England, and as no fossil Infusoria have been

* Dr. Mantell has found in the substance of flint not only the shells but the animal substance of Rotaliæ.

as yet even mentioned in Yorkshire, I have drawn up a short catalogue of the contents of the deposit, as far as I have yet traced them.

In the Bridlington Deposit occur :—

Foraminifera...	1. Rotalia.....	Probably derived by watery action from the adjoining chalk.
	2. Textilaria...	
Infusoria.		
Pyxidicula ?		
Gaillonella varians		Also at Bann, Ireland.
Navicula phœnicenteron.		„ „
„ inequalis		„ „
„ viridis.....		„ „
„ gibba		„ „
„ indeterminate		At Berlin.
Cocconema lanceolata		At San Fiora.
Bacillaria vulgaris		„
Campilodiscus zonalis *.....		„
Eunotia diadema.....		„
„ serra		At San Fiora and in Hanover.
Synedra ulna		Also in the Polierschiefer.

Fig. 8 represents the Campilodiscus zonalis, found fully inflected, as some of the specimens of Campilodiscus clypeus occur at Egra. *Fig.* 9 shows its expanded discoid aspect, when the inflection is slight, but easily made evident by a proper management of the microscope. The radii (if they may be so called) are symmetrical to two axes, which may be compared to the equator and a central meridian, in the common projection of the sphere, the seeming radii being slightly comparable to the terminal parts of the arcs of latitude in this projection. In very favourable lights, concentric striations may be detected crossing these ribs, and there is some appearance of punctation on the outer edge. In other cases, the ribs seem nearly smooth or delicately punctated. This may arise from the different character

* See *Figs.* 8 and 9.

of the two discoid faces. These specimens are rare, even in fragments.

The Infusorial remains are by no means equally diffused through the marl. On some occasions I have sought whole days in vain for any interesting forms, but sometimes a small fragment of marl has yielded me a good supply. They are, however, never so plentiful as in many of the localities in Italy, Germany, Hanover, Sweden, and North America. The deposits of San Fiora, in Tuscany, and Hanover, seem to yield nearly all the species of Bridlington; and in *Charlesworth's Magazine* for 1839, and in a drawing in the possession of Dr. Mantell, many of the same Infusoria are noticed from Bann, in the county of Down, in Ireland.

As it thus appears from all the investigations, that there are two tribes in particular which have left their minute remains in such abundance, through a large series of rocks, as to have been rather boldly regarded as the real constituent molecules of them, I shall add a short summary of their more remarkable natural characters, as determined by examination of living and fossil specimens.

1. The Foraminifera consist of an external shell and internal soft animal, which fills it. The shell is concamerated, or, to speak more correctly, is composed of several cells, arranged in a series either discoid or spiral, or aggregated; the cells communicating by large openings, all filled by connected tubes of the animal substance, and (usually) perforated on the free surfaces by many small holes, which give passage to fine ciliæ, or pseudopodia, like the ciliæ of bryozoa.

The ovary, digestive canal, &c., are known to take a direction through several cells; no nervous system has yet been seen; no vascular circulation is known; no special organs for respiration; and in general, though the shell is polythalamous, the animal is not a Cephalopod,

but Acephalous, and of the Zoophytic type. The shell is *calcareous.*

Animals of this kind seem to have had little or no locomotion, beyond what belongs to the ova of many invertebrata. The ciliæ probably produced currents in the water, as the ciliæ of the Sertularidæ do.

The recent Nonionina and Rotalia have been fully described by Ehrenberg *(Taylor's Scientific Memoirs.)* The specimens which he examined were from Cuxhaven.

Rotalia is a spiral and discoid form, composed of six or more nearly globular cells, the last being largest.

Textilaria is spiral or plaited round an axis, and resembles often a small spiral Gasteropod.

Nearly all the Infusorial fossils belong to the peculiar group of forms which the Botanist claims as jointed algæ, or disjointed algæ; and the Zoologist regards as self-moving self-dividing animals, having (in some) digestive cavities within the body, and (in some) external vibratile ciliæ. They are found associated (jointed algæ), or detached (disjointed algæ). They are all externally covered by a *siliceous shield* or shell, by the forms and structures of which the genera and species are determined.

It appears from the researches of Ehrenberg, that the species found at Bridlington are nearly all now living at this present day. It is somewhat difficult to assure ourselves of this perfect identity, in respect of such microcosms; but observers agree in the statement that no clear or certain mark of distinction appears between the fossil and recent specimens of the Navicula, which have been named as under:—

Navicula phœnicenteron.
„ inæqualis.
„ viridis.
„ gibba.
„ scalprum.
Bacillaria vulgaris.

This conclusion of the identity with living types of many of the Infusorial forms, which occur in tertiary and supra-tertiary deposits, is in harmony with researches into other tribes of fossil animals. But, in extending our view to older strata, some difference arises in this respect. It is well known that at the most, only one or two species of the fossil shells which occur in the chalk are identical with recent shells; and there is no other tribe of the animal kingdom, except the microscopic races, which yield even one such analogue, in the chalk or strata below. But of the microscopic Infusoria, Ehrenberg mentions three living species which occur in the flint, viz. :—

Peridinium pyrophorum.
Xanthidium ramosum.
„ hirsutum.

And three others, which occur in the white chalk, viz. :—

Fragilaria rhabdosōma.
„ striolata.
Gaillonella aurichalcea.

He also enumerates in the white chalk of England, Denmark, and Sicily, nine species of Foraminifera, which are also living in the sea, viz. :—

1. Globigerina bulloides.
2. „ helicina.
3. Rosalina globularis.
4. Rotalia ocellata.
5. „ globulosa.
6. „ perforata.
7. „ turgida.
8. Textilaria aciculata.
9. „ globulosa.

If we reflect on the *number* of the fossil forms here referred to living types, the great skill and patience of the observer, and the support which he has received to a certain extent from other naturalists, we shall be disposed

to accept the conclusion of M. Ehrenberg as probable. It is, moreover, confirmed by the facts already alluded to, of one or two species of recent shells, (Terebratula caput serpentis and T. vitrea,) which are regarded by eminent naturalists as undistinguishable from the T. striatula and T. subundata of the chalk.

We must, therefore, admit, in respect of the living species of these microscopic Foraminifera and Infusoria, an earlier date among the stratified rocks than belongs to nearly every other living type; an interesting conclusion, on which M. Ehrenberg has founded a series of propositions, which are valuable, but less novel than some authors suppose. For it is not only perfectly well established in Geology, that each group of life has its own laws of distribution in the earth, which can only be known by observation, but further, that the Geological range through which fossil species occur is greater in the invertebral than in the vertebral tribes; greater in the Mollusca than in the Crustacea; and greater in the Zoophyta, to which these fossil Foraminifera, and some at least of the Infusoria, belong, than in any other grade of animal life.

In accordance with this view, we find in the Mountain Limestone, Zoophyta and Mollusca, which are referrible to existing genera, with Fishes of extinct genera, but no Reptiles; in the chalk, Reptiles of extinct genera, with Zoophyta and Shells, of which one or two belong even to living species; and in the marls of Bielbeck, in Yorkshire, thirteen forms of Shells, belonging to species now living, with the extinct Elephant, Rhinoceros, and Lion.

The subject to which I have called your attention to-day is one which it is difficult to guard from the rash hands of cosmogonists, who see in every new Geological discovery only an advanced post of science, which they, if auxiliaries, would unwisely push beyond the point of security; if enemies, would as unwisely attack with their whole dis-