ON BEAUTY, DESIGN, AND PURPOSE IN THE FORAMINIFERA.[1]

IN the dawn of history the Tartars in their flight before the victorious army of Ladislaus, King of Transylvania, scattered money as they fled, trusting to the apparently already established instincts of the Teuton soldiers that their pursuit would be thereby arrested. But King Ladislaus prayed that this money might be turned into stones, and his prayer was immediately granted. Hence the Nummulites. This, at any rate, is the account given of the matter in the sixteenth century by the learned Clusius,[2] and it is probably the first mention of the Foraminifera in print. The equally learned Strabo, however, had recorded that the Egyptian Nummulites were the petrified remains of beans left behind them by the builders of the Pyramids,[3] in spite of the explicit statement of Herodotus that the Egyptians never grew or ate beans in any form.[4] This Nummulite, which rightfully claims to be the earliest recorded Foraminifer, is also the highest and most complex of its order, and it was based upon his study of this family that Dr. Carpenter in 1885 claimed for the Foraminifera that they are the most highly specialised and structurally developed of the Protozoa.[5] "They stand at the summit of a long branch of the whole tree of life,"[6] and have with perhaps the single exception of the Globigerinidæ, played a more important part in the building up of vast tracts of the earth's surface than any other organism. The Nummulitic Limestones (Fig. 1) stretch in a broad band, in many places several thousands of feet in thickness, across Europe and Northern Africa, and through Asia by the Himalayas to China, the matrix, containing the perfect fossils, being a rock formed of their comminuted remains. The deposit is characteristic of the Eocene period; but the Nummulites have now died out, being represented to-day in the tropics by a single living species, *N. cummingii*.

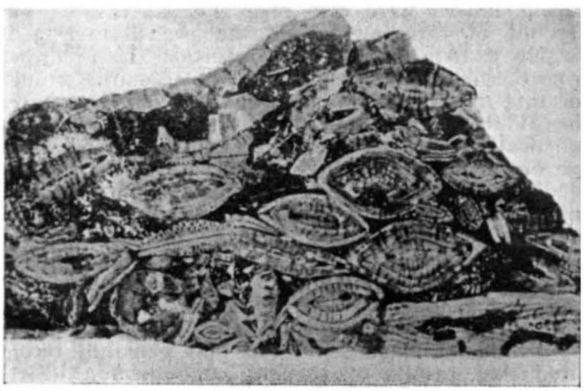

FIG. 1.—Section of Nummulitic Limestone.

Coeval with the Nummulites, and closely approximating to them in importance as world-builders, is the genus Alveolina, which is found in the same beds, either gradually replacing them, or sometimes taking their place with startling suddenness in the strata. Off the extreme point of Selsey Bill, in Sussex, the locally named "Mixon reef" rises at the summit of the Eocene deposits, composed almost entirely of fossil shells of *A. boscii* (Fig. 2), indistinguishable from the living shells of the species which abound to-day in the shallow water and littoral sands of Australian and other tropical shores.[7]

With all respect, however, to the recent utterances of its most noteworthy protagonist,[8] the Nummulite is a mere parvenu compared with the species *Spirillina groomii*, discovered in the Cambrian rocks of Malvern by Chapman,[9] and rediscovered by Arthur Earland and myself alive in the shallow waters of the west of Ireland,[10] which probably represents the earliest specific form of life to be found living at the present day. Even the conservative little Lingula shell has become slightly modified since its earliest ancestors wallowed in Cambrian mud a hundred million years ago.[11]

I have alluded to the Globigerinæ, which are to-day forming a geological deposit of unknown thickness over 48 millions of square miles in the modern oceans.[12] Agassiz has observed that "no lithological distinction of any value has been established between the chalk proper and the calcareous mud of the Atlantic,"[13] and it has been estimated that the time occupied by the deposit of the English chalk, arguing by the rate at which the Atlantic ooze is formed (which is about one foot in a century), must have been 150,000 years.[14]

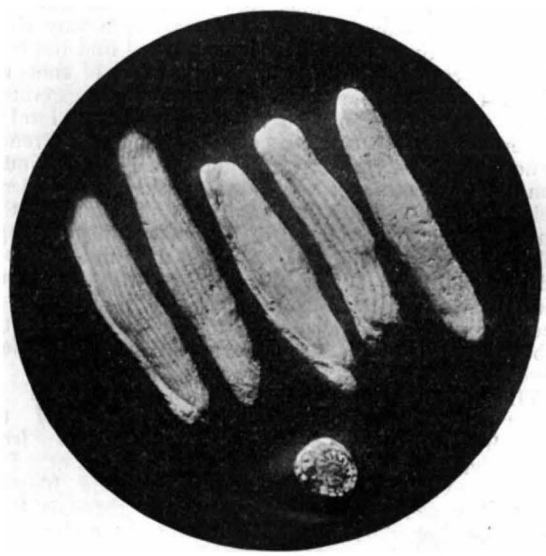

FIG. 2.—*Alveolina boscii*, Defrance.

As Maury has picturesquely said, "The sea, like the snow-cloud, with its flakes in a calm, is always letting fall upon its bed showers of microscopic shells."[15] These are some of the Foraminifera that

1 From a discourse delivered at the Royal Institution on Friday, May 21, by Mr. Edward Heron-Allen.
2 "Caroli Clusii et aliorum epistolae," Ep. xxxvii. Paris (c. 1550).
3 Strabo, "Geographica," bk. xvii., cap. i., 34.
4 Herodotus, "Euterpe," ii., 37.
5 W. B. Carpenter, "On the Structure of Orbitolites." Journ. Quekett Micr. Club, ser. 2, vol. ii., p. 102.
6 P. Chalmers Mitchell, Art. "Evolution" in "Encycl. Britannica," 11th ed., vol. x., p. 35. 1910.
7 E. Heron-Allen and A. Earland, "The Foraminifera in their rôle as World-Builders." Journ. Quekett Micr. Club, ser. 2, vol. xi., pp. 9-11, 1913.
8 R. Kirkpatrick, "The Nummulosphere." London, 1913, etc.
9 F. Chapman, "Foraminifera from an Upper Cambrian Horizon of the Malverns." Q. Journ. Geol. Soc., p. 257. 1900.
10 E. Heron-Allen and A. Earland, "The Foraminifera of the Clare Island District." Proc. R. Irish Acad., vol. xxxi. (Clare Island Survey part 64), p. 107, pl. ix., figs. 2, 3. 1913.
11 Cf. E. Heron-Allen, "Selsey Bill." London, 1911, p. 24.
12 Sir J. Murray, "The Ocean," p. 207. London, 1913.
13 A. Agassiz, "Three Cruises of the *Blake*," vol. i., p. 150. London 1888.
14 A. J. Jukes-Brown, "Handbook of Physical Geology," p. 130. London, 1884. The rate of deposition varies slightly according to depth. See Murray, *op. cit.*, p. 224.
15 M. F. Maury, "The Physical Geography of the Sea," 15th ed., p. 322. London, 1874. Cf. H. N. Moseley, "Notes of a Naturalist on the *Challenger*," p. 582. London, 1879. "The dead Pelagic animals must fall as a constant rain of food upon the habitation of their deep-sea dependants."

may be washed out of any ordinary lump of Upper Chalk. In many localities on a smaller scale the Foraminifera may be seen occupied in this process of world-building. The shore of Dog's Bay, in Connemara, is composed of sands in which no grain of sand has a place. As far as the eye can see, and as deep as man can dig, preserving any measure of self-respect, the littoral deposit consists of pure Foraminifera extending far above high water-, and far below low water-marks. In a lesser degree the same thing may be seen a little to the north, just south of Emlagh Point, while anyone who has taken the trouble to examine the grit shed in disconcerting quantities by a new Mediterranean sponge must realise what masses of Foraminifera make up the bulk of the shallow water sands in those latitudes.

Such, then, shortly is the occurrence of the Foraminifera, which, leaving on one side the doubtful record of *Strombus lapidus* by Gesner in 1565,[16] which Prof. Rupert Jones identified as a Vaginulina,[17] make their first appearance in the Micrographia of Hooke in 1665[18] as "Figures observed in small sand." He figures one of them, which is clearly the common shore form *Rotalia beccarii*. In 1702 Prof. Plimmer's "Immortal Beadle,"[19] Antony van Leeuwenhoek, in a letter to the Royal Society,[20] figured the equally common and related form *Polystomella striato-punctata* "from out of the stomach of a shrimp," in which happy hunting-ground Reade recorded the presence of Foraminifera more than 150 years later.[21] There can be no doubt that they play an important part in determining the movements of many of our most important food fishes.[22]

Since the day of Leeuwenhoek the Foraminifera have continually engaged the attention of zoologists. Before Linnæus we have the works of Plancus,[23] Ledermüller,[24] and others, but between the time of Linnæus and the early years of the last century the era of monographs began; Walker and Boys in England,[25] Fichtel and Moll in Germany,[26] Lamarck in France,[27] Soldani in Italy,[28] have left behind them specialist works upon the Foraminifera which still form (sometimes to our serious embarrassment) the foundations of our study.

The recent period may be said to have commenced in 1819, when the father of Alcide d'Orbigny wrote to the geologist Fleuriau de Bellevue that his son was studying "microscopic cephalopods" from the shore sands at Esnandes, near their native town, La Rochelle.[29] After this, captains of ships and travelling naturalists supplied young d'Orbigny with a mass of material from all parts of the world, resulting in the publication of his Tableau Méthodique,[30] in which a vast number of species both recent and fossil were recorded. His records from Madagascar in particular are of supreme interest for us, for we have recently examined a series of dredgings from Kerimba, on the adjacent African coast,[31] in which we have rediscovered most, if not all, of his Madagascan species. He recorded in particular the species *Pavonina flabelliformis* (Fig. 3), which after 1826 was entirely lost sight of for half a century, when it was rediscovered in Madagascan sand by Brady.[32] It is quite one of the most beautiful of the Foraminifera, whether viewed as an opaque object or by transmitted light.

The true nature of the Foraminifera was not, however, understood until Dujardin in 1835[33] separated them from the Cephalopods, among which they had been grouped on account of certain superficial characteristics, and their extensile bodies. From this time onward the literature of the Foraminifera has expanded into a vast body of memoirs and monographs in every European language.[34]

The Foraminifera are to be found in all parts of the world and under all conditions, on the shore, in deep-sea soundings and dredgings, and floating at all depths of the ocean, whence they are taken in tow nets, and they divide roughly into two great classes, the Calcareous, which secrete from the surrounding waters a delicate and beautiful shell of carbonate of lime, and the Arenaceous, which build their shells out of sand-grains, sponge-spicules, and other fortuitous materials, often affording remarkable indications of phenomena of purpose and intelligence to which I shall presently refer. A single species, *Carterina spiculotesta*, builds its shell of fusiform calcareous spicules, secreted by the animal itself by a process which is at present entirely obscure. A remarkable feature of the organism is that whereas the resulting spicules on the upper surface follow the convolutions of the chambers, on the under side they are turned inwards so as to converge towards the central umbilicus.

FIG. 3.—*Pavonina flabelliformis*, d'Orbigny.

The distinction between the calcareous and arenaceous shells is purely artificial, isomorphs existing between the three great classes, the hyaline (or perforate), the porcellanous (or imperforate), and the sandy (or arenaceous). A typical isomorphism is represented by the three genera Cornuspira, which is porcellanous, Ammodiscus, which is arenaceous, and Spirillina, which is hyaline.

One of the most beautiful and delicate of the arenacea is *Reophax scottii*, which is built entirely of minute flakes of mica cemented together at the edges.

Polymorphina regina is a very handsome representa-

16 C. Gesner, "De omni rerum fossilium genere, gemmis," etc. (Last sect., p. 165). Tiguri, 1565.
17 T. Rupert Jones, Q. Journ. Geol. Soc., pl. xxxiv., fig. 5, *Vaginulina laevigata*. 1884.
18 R. Hooke, "Micrographia," p. 80. pl. v., fig. x. London, 1665.
19 H. G. Plimmer, *Bedellus immortalis* (Presidential Address), J. R. Micr. Soc., p. 121. 1913.
20 A. van Leeuwenhoek, "Sevende verfolg der Brieven," p. 196, pl. opp., p. 191, fig. 7. Delft, 1702.
21 J. B. Reade, Trans. Micr. Soc., vol. ii, pp. 20–24. London, 1849.
22 F. Pearcey, "On the Movements and Food of the Herring," Proc. Roy. Phys. Soc., Edinburgh, vol. viii, p. 389. 1885.
23 Janus Plancus, "De conchis minus notis liber." Venice, 1739. 2nd ed., Rome. 1760.
24 M. F. Ledermüller, "Mikroskopische Gemuths- und Augen-Ergötzung." Bayreuth, 1760–61.
25 Walker and Boys, "Testacea minuta rariora." London, 1784.
26 Fichtel and Moll, "Testacea microscopica." Vienna, 1798.
27 J. B. de Lamarck, "Système des Animaux sans Vertèbres." Paris, 1801.
28 A. Soldani, "Testaceographia." Senis, 1789–98.
29 C. d'Orbigny, Journal de Physique, vol. lxxxviii., p. 187. Paris, 1819.
30 A. d'Orbigny, "Tableau Méthodique de la Classe des Rhizopodes," Ann. Sci. Nat., vol. vii., pp. 245–314. Paris, 1826.

31 E. Heron-Allen and A. Earland, "The Foraminifera of the Kerimba Archipelago," Trans. Zool. Soc. (Lond.), pt. i., vol. xx. (1914), p. 363; pt. ii. (1915). (In the press.)
32 H. B. Brady, *Challenger* Reports, vol. ix., "Foraminifera," p. 375, pl. xlv., figs. 17–21. 1884.
33 F. Dujardin, "Observations nouvelles sur les pretendus Céphalopodes Microscopiques," Bull. Soc. Sci. Nat. France, No. 3, p. 36. 1835.
34 C. D. Sherborn, "A Bibliography of the Foraminifera." London, 1888.

tive of a genus which is frequently found attached to sand grains and shells by fistulose processes (Fig. 4).

The Globigerinæ, to which we have already alluded, are often merely stages in the life-history of *Orbulina universa*, which we may break open and find in it the earlier Globigerina.

Pulvinulina is represented by *P. pauperata* (Fig. 5).

The object and significance of this variety of beautiful forms are entirely obscure, but have engaged the attention of many biologists both in the Foraminifera and in the Radiolaria.[35] It must be remembered that a Foraminifer, like a Radiolarian, is a unicellular

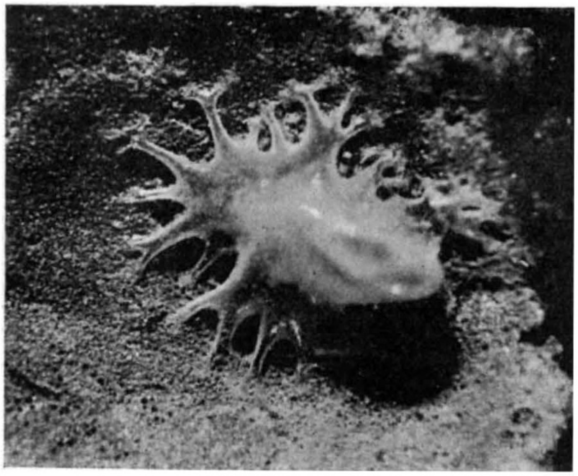

FIG. 4.—*Polymorphina rotundata*, d'Orbigny, fistulose and adherent.

animal consisting solely of a microscopic globule of undifferentiated protoplasm, vivified by a nucleus the functions of which are little understood, but which are essential to the existence of the animal.

This protoplasm is extended in the form of fine filaments which intermingle freely with one another, called pseudopodia, and their mechanical functions are locomotion and the capture of food. I have made a series of photographs of a fine Gromia which emerged from the mud in one of my tanks, climbed up the glass until it encountered a sea-weed stem, up which it crawled, and finally drew itself off on to the glass again by means of its pseudopodia. It then got lost,

FIG 5. *Pulvinulina pauperata*, Parker and Jones.

but on punching a hole in a piece of black paper which was then gummed on to the glass and a strong beam of light directed through it, it came back into the circle of light, apparently indicating that these creatures are sensitive to light.

The other important function is the capture of food, which is caught outside the shell and usually drawn into it, as in this case of *Miliolina durrandii*, which has ingested a smaller Foraminifer and a diatom.[36]

It is a most significant, and at present unexplainable, fact that these minute protoplasmic globules secrete such varied materials for the formation of their shells from the surrounding medium as carbonate of lime, silica, and even sulphate of strontium, but the nature and character of their protoplasmic bodies which perform this function defies analysis or definition in the present state of our knowledge.

Their life-cycles have been carefully studied by Lister,[37] Schaudinn,[38] Winter,[39] and others, and the fact has been established that most, if not all, Foraminifera exhibit the phenomenon called dimorphism (that is to say, they start with a large or a small central chamber), and that the small-chambered (or microspheric) individuals reproduce themselves by means of amœbulæ expelled from the shells producing the megalospheric young, whilst the large-chambered (or megalospheric) individuals discharge flagellispores which conjugate with the flagellispores of other individuals and producing microspheric young, recommence or continue the life-cycle.

Within the last few months, owing to the initiative and manipulative skill of Mr. J. E. Barnard, a new and very striking method of investigation has been developed which not only reveals the internal structure of Foraminifera without the need of cutting sections, and so destroying the specimens, but may have far-reaching results when applied to the study of the living protoplasmic bodies. This is the application of the X-rays to the shells, the results of which operation are highly interesting and significant.[40] Here is a very thick and opaque species, *Biloculina bulloides*. The application of the X-rays reveals the internal arrangement of the chambers clearly. Here again is the coarse tropical calcareous form *Operculina complanata*, the whole of the interior septation of which is perfectly shown by the skiagraph. The process is especially valuable in connection with the arenaceous forms. Here is one of the most rugose species, and one which is exceedingly difficult to sectionise, owing to the sand-grains imbedded in the calcareous cement of which it is formed, *Cyclammina cancellata*. The skiagraph not only reveals its intricate labyrinthic interior, but here, as in the other species, reveals the fact that the individual is of the megalospheric stage of the life-cycle. The method is invaluable for the determination of doubtful species. The two species, *Jaculella obtusa* and *Botellina labyrinthica*, are externally very difficult to distinguish, but the skiagraph reveals the simple tubular cavity of the former as contrasted with the labyrinthic interior of the latter, and so determines the identity of the organisms.

You may rightly ask yourselves in what, beyond the beauty of the shells, consists the interest and value of the elaborate and concentrated study to which the Foraminifera have been subjected. Their value is both scientific and economic. They are the largest of the unicellular organisms—which are the closest to the beginnings of life—and if ever the structure and nature of protoplasm are to be determined, it will be, in my opinion, by the study of the Foraminifera that this conclusion will be arrived at. Economically they form the food of worms, starfishes, and many of the lower invertebrata, which in turn feed the food-fishes of the world.

I come now to the concluding and most important section of my discourse, which concerns itself with the phenomena of purpose and intelligence which I have

[35] Cf. F. Gamble in Ray Lankester, "A Treatise on Zoology," pt. i., fasc. 1, pp. 130, 131. 1900.

[36] E. Heron-Allen, "Contributions towards the Study of the Bionomics of the Foraminifera," Phil. Trans. Roy. Soc. (Lond.) 1915.

[37] J. J. Lister, "Contributions to the Life-History of the Foraminifera," Phil. Trans. Roy. Soc. (Lond.), vol. clxxxvi. B, pp. 401–453. 1895.

[38] F. Schaudinn, "Die Fortpflanzung der Foraminiferen," Wiegmann's Archiv. für Naturgeschichte, Jahrg. xlix., pp. 428–454.

[39] F. Winter, "Zur Kenntniss der Thalamophoren," Archiv für Protistenkunde, vol. vii. 1907.

[40] J. E. Barnard, "X-Rays in Relation to Microscopy," Journ. R. Micr. Soc., p. 1. London, 1915.

claimed to be exhibited by some of the Foraminifera in the construction of their shells, a claim which has been, and is, denied by several very distinguished zoologists, and admitted, with some reservations, by others no less distinguished.[41] There are limits to what is known, but I refuse to admit that there are limits to what is knowable. As Prof. MacBride has justly observed: "To put forward an unknown entity as the cause of phenomena which we cannot unravel is not to explain, but in reality to give up the attempt at explanation."[42]

The method in which the arenaceous Foraminifera collect and adjust the materials from which they build their marvellous shells is obscure, and though a light begins to dawn upon the process it would take too long to go into the matter on this occasion. Surface tension no doubt plays an important part in the operation, but surface tension will not account for the mysterious fact that certain species, such as, to take a single instance especially, *Haplophragmium agglutinans,* incorporate into their shells fragments of heavy gem minerals such as magnetite, garnet, and topaz, which are not by reason of their specific gravity to be found in the same sand-strata as the relatively light quartz-grains which are mainly used in the construction of the shell. The common *Verneuilina polystropha* of our shores exhibits this phenomenon also to a remarkable degree. It is, however, the intelligence (and I use this word with a full sense of the responsibility which I incur in using it) displayed in the manipulation of the material which compels the attention of the biologist. We are all familiar with the beautifully built tubes of the Caddis worm, and some of the marine worms build tubes of no less remarkable ingenuity, as, for instance, Amphictene, and one local variety of this worm constructs its tube as neatly as a bricklayer building a wall out of fragments of sponge-spicules of a carefully selected size. But these are Metazoa, higher animals, endowed with organs and senses. The Foraminifera, I must repeat for emphasis, are unicellular creatures without any differentiated organs or even structure of any kind whatever.

Take the common arenaceous form, *Psammosphaera fusca,* which builds itself into a roughly agglutinated house of sand grains. There is no selection here. There is none in the variety *P. testacea,* which uses only the shells of dead and living Foraminifera—it uses them because it has nothing else to use; but *P. parva* (Fig. 6), finding itself by its small size and free habit liable to suffocation in the ooze on which it lives, builds its house round a catamaran spar formed of a long sponge-spicule, which buoys it up upon the mud surface. Another species, *P. rustica,* builds in the spaces of a tent-pole arrangement of such spicules —several individuals frequently combining to form a mutually supporting mass. This creature fills in the triangular spaces between the main tent-poles with broken spicules of successively graduated lengths, and when it arrives at an awkward terminal space finds and incorporates a truncated triaxial sponge-spicule to fill in the angle.

It is when we come to the devices employed by the Foraminifera for their protection from living foes, or the forces of nature, that their purposive intelligence becomes the most phenomenal. Many of the larger and doubtless more succulent forms are peculiarly liable to attack from parasitic worms—an elaborate study of which has been made by Prof. Rhumbler.[43] A striking instance of this occurs in the case of *Crithionina pisum,* which has a softly agglutinated shell, which is often found (as in one of the specimens exhibited) bored by worms. Certain individuals have arrived at protecting themselves with a *chevaux de frise* of sponge-spicules, and these we never find, so far as our experience goes, suffering from these attacks. *Haliphysema ramulosa* is another easily attacked species, and it protects its aperture with a similar defensive apparatus. The same protective investment is assumed by *Hyperammina ramosa,* a species which ramifies in a most remarkable manner, so much so that Earland once constructed for me a Christmas greeting slide out of its many vagariant forms. (The "selection" in this case is rather that of Earland than of the Rhizopod.)

The genus Marsipella, of which the most familiar form is *M. cylindrica,* is built up of sponge-spicules set parallel to its axis, and is excessively friable, perfect specimens being very seldom found. It consists of a simple tube affording an easy prey to parasitic worms. It has consequently learnt to protect itself with a crown of spines, which keep out these intruders. But some individuals, to which we have given the specific name *M. spiralis,* have made the same discovery as did the prehistoric genius who invented string. They increase their power of resistance to shock by twisting their spicules into a left-handed spiral, by which means their power of resistance is enormously increased.[44]

But probably the zenith of purpose and intelligence is reached by the genus Technitella, a genus named by Canon Norman—the Little Workman—with good cause. The most familiar species, *T. legumen,* builds its shell apparently of sponge-spicules set parallel to its axis. The accidental smashing of a specimen, however, revealed to us the fact that only the outer layer of spicules is thus disposed. The inner layer is set at right angles to the outer, thus producing the nearest approach to the woof and warp of a textile fabric possible in so rigid a material as sponge-spicules. This is clearly seen in a highly magnified fragment of a broken shell. The genus reaches its highest development of purposive selection, however, in our species *T. thompsoni,* which, out of the vast and heterogeneous mass of material at its disposition, selects only the anchor-plates of a particular kind of Echinoderm, which it cements together at their edges with an invisible cement, and thus constructs what is certainly one of the most decorative, and certainly the most highly perforated shell in existence.[45]

FIG. 6.—*Psammosphaera parva,* Flint.

In the presence of the phenomena which I have exhibited before you this evening there are zoologists who aver that there is no such thing as purpose or intelligence to be postulated as a motive for the behaviour, not only of the Protozoa, but even of much higher orders of animal life. Jules Fabre, who has by consent assumed the purple among the historio-

[41] E. Heron-Allen, "On Purpose and Intelligence in the Foraminifera," Proc. Zool. Soc., p. 1069. London, 1914.
[42] E. W. MacBride, in NATURE, vol. xciv, p. 304, November 19, 1914.
[43] L. Rhumbler, "Beiträge zur Kenntniss der Rhizopoden," Zeitschr. Wiss. Zool., vol. lvii., p. 580. 1894.
[44] E. Heron-Allen and A. Earland, "On some New Astrorhizidæ and their Shell Structure," Journ. R. Micr. Soc., p. 382. 1912.
[45] E. Heron-Allen and A. Earland, "On a New Species of Technitella from the North Sea," Journ. Quekett Micr. Club, ser. 2, vol. x., p. 403. 1909.

graphers of the insect world, denies intelligence even to the Digger Wasps, and to the Termites of Ceylon—at the end of all his amazing observations he says, "*Ils ne savent rien de rien.*" I prefer to go back exactly half a century to when Philip Henry Gosse, F.R.S., than whom no keener observer of marine organisms ever lived, said, "The more I study the lower animals, the more firmly am I persuaded of the existence in them of psychical faculties, such as consciousness, intelligence, and choice, and *that* even in those forms in which as yet no nervous centres have been detected."[46] A distinguished critic, Dr. Chalmers Mitchell, tells me that I might as well claim intelligence and purpose for such plants as the Tragopogons, the seeds of which are fitted with a parachute, which enables them to travel to new pastures. I almost wonder that I am not accused of agreement with the whimsical suggestion of Samuel Butler, who looked forward to the day when we should see little engines playing about the doors of the engine sheds, whilst the parent engine smoked peacefully inside. I refuse to admit that the seed parallel has any bearing upon the case. I am dealing with the utilisation of independent materials collected by the Foraminifera for a specific purpose. In the case of the seeds it is a development of a useful integral part and a consequent "survival of the fittest"—but if a bean in the kitchen-garden were to attach to itself the parachute of a Tragopogon and fly over the wall when in danger of its life at the hands of the cook, *that* would be an exercise of purpose and intelligence comparable with the phenomena which I have exhibited this evening.

An evolutionary cycle is *ex-hypothesi* continuous, and I refuse to allow a consistent evolutionist to postulate a discontinuity in his evolutionary cycle—he cannot at some unknown point introduce into his bioplasm an outside and novel influence to which he gives the name of "Intelligence." I claim that every living organism living an independent existence of its own is endowed with the measure of *intelligence* requisite to its individual needs.

We must accumulate facts, we must assimilate phenomena, we must strive after a comprehension of motive forces. To quote Prof. MacBride once more: "The use of hypotheses which assist in binding together the facts observed in the behaviour of living things, and in elucidating the laws which govern them . . . may be regarded as neither vitalistic nor mechanistic, but as plain common-sense applications of the indicative method. In this way only it seems to me we shall ever make progress with 'explanations' of the phenomena of life, for all 'explanation' in the last resort consists merely in putting together similar things."[47]

But to arrive at a conclusion we must study the life-history of these lowly organisms, which, as Prof. Verworn has said, seem to be especially provided for the biologists, since of all living creatures they are nearest to the origin of life. We must not merely collect and classify them like postage stamps. The study of the Foraminifera has been grievously afflicted with a tendency to lie upon a platform between two points, on one of which sits the invalided Man of Science who, forbidden by his doctor to work, has bought a pound of the comfit known to our youthful taste as "Hundreds and thousands," and who employs his time sorting out the red, the white, and the blue, setting aside as new species those globules which have been damaged in the process of manufacture—and on the other of which sits the Grammarian, whose sole regret upon his deathbed was that he had not devoted the whole of his life to the dative case.

[46] P. H. Gosse, "A Year at the Shore," p. 247. London, 1865.
[47] E. W. MacBride, in NATURE, vol. xciv., p. 304, November 19, 1914.

GEOGRAPHY OF BRITISH FISHERIES.

IN a paper entitled "Geography of British Fisheries," published in the *Geographical Journal* for June, Prof. J. Stanley Gardiner discusses the deep-sea fishing industry, trawling, and drifting, which has an annual value of upwards of fifteen million pounds. The main points of the paper are here summarised.

There are about 3000 first-class fishing vessels, of which the trawlers work from the White Sea to the Moroccan coast, wherever depths of fewer than 200

FIG. 1.—Aberdeen Fish Wharf.

fathoms are found. Off Spain, Portugal, and Morocco their existence depends on the limit of territorial waters not being increased beyond three miles. What Prof. Gardiner is more especially concerned with are the habits of the fishes, their growth and reproduction, in so far as they are affected by the physical conditions of the waters in which they live. It is this correlation of habits with physical conditions that is essentially the geography of living animals. Not only have the adult fish to be considered, but also their eggs, their larval stages, and the eggs, young, and adults of all the lower animals and plants on which they feed.

Currents merit particular attention, for the eggs and (or) young of practically all our food fishes are passively distributed by their agencies. Currents are best ascertained by regular observations on the temperature and salinity of the fishing waters, which are divided into oceanic and coastal zones, the former with relatively uniform conditions, the latter subject to great seasonal changes. A further division is into Atlantic and Arctic regions, our edible fish all belonging to the former, and following its waters in the summer as they push back the Arctic ice. There is, however, considered to be an intermingling of boreal